1997 WORK ZONE SPEED STUDY

EXECUTIVE SUMMARY

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16. Abstract

The primary purpose of this study was to evaluate the effect of posted speed limits in work zones on motorist speeds. Several other factors were also studied: day-to-day basis: type of lane closure/separation, presence and absence of workers, and the number of lanes open to travel. Sites for this study were chosen to explicitly minimize the contribution of congestion.

While it is difficult to accurately identify and separate the effects all factors that influence motorists' speeds at any point in time, it is known from this study that, for the sites studied, lower speeds were observed when lower speed limits were posted. Equally clear is the fact that although lower speeds were observed, they are significantly higher than the posted limits and disproportionately higher (in work zones) than they are otherwise at these same sites. That is, the differences between observed speeds and posted limits are greater when work zones are present than when they are not. Finally, there was a very strong effect due to the number of open lanes noted—one as large or larger than any effect of the speed limit *per se*.

With respect to the effectiveness of the posted limits, it is important to note that different limits are almost always associated with different types of lane closure/separations and configurations. The strong relationship between speed and the number of open lanes is not unexpected, but it seems clear that there is a dilemma to be confronted between the conflicting objectives of slowing motorists through work zones and minimizing delay. Limiting the number of lanes available will generally result in lower speeds but motorist delay will clearly increase, and opening more lanes will invariably result in higher speeds, apparently independent of the posted limit.

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Executive Summary

Introduction and Problem Statement

The 1997 work zone speed study was undertaken to assess the effects of different posted speed limits in work zones. The sites used for the study were restricted to selected limited-access highways (freeways) in Michigan. The project consisted of collecting and analyzing vehicle speed data during and after the work zones were active at the selected sites. The data collection period began in July and continued until late November, 1997.

As a general rule, during the 1997 construction season, there were three different speed limits which were used on Michigan freeways: **60 mph** for sites where more extensive, non-maintenance projects were being done and workers were not present; **50 mph** for sites where more extensive, non-maintenance projects were being done and workers generally were present; and **45 mph** for sites where maintenance work was being done. These limits (except for maintenance sites) were generally higher than they had been in the past. It should be noted that there were exceptions to these limits and their use (e.g., some sites might be posted at 50 mph although workers were not present at a specific point in time). Moreover, some work sites warranted higher or lower limits because of the nature of the geometry of the work zone site or other reasons. The vast majority of sites had a 70 mph limit when there were no work zones present. It should also be noted that when sites were posted at 50 mph, the speed limit was "stepped down" in 10 mph increments.

In addition to the effects of the posted speed limits themselves, analyses were also done to assess the contributions of other variables to the observed speeds. For example, do motorists adjust their speeds only in reaction to the posted limits, because workers are present, because of the number of open travel lanes, or, most likely, some combination of these and/or other factors.

Site Selection

Within the context of the project, there were two different issues to be addressed: motorist response to the generally lower (45 mph) limits that are used in conjunction with maintenance work which is typically accomplished in relatively short time frames and with very temporary lane closures/separations (e.g., using cones); and motorist response to the differential (60 or 50 mph) limits imposed at longer-duration work zones when work activities (within a marked zone) may or may not be occurring at a given point in time.

Most of the site identification was done opportunistically by taking "tours" of selected geographical areas to identify active work sites, consulting the Michigan American Automobile Association (AAA) web site, and through interaction with various MDOT personnel. At sites, traffic volumes had to be low enough so that congestion did not seriously limit vehicle speeds (i.e., free-flow conditions were desired). Overall, 35 sites were used although not all analyses incorporated data from all sites.

Data Collection

Vehicle speed data were collected using videotape equipment and reduced using the Autoscope® system. In addition to the speed data, information about the site was also gathered and included: weather conditions, presence and location of workers, speed limit that was in effect, type of work being done, presence of police, and so forth. Data about the non-construction conditions (e.g., normal speed limit) were also collected. Vehicle speed data were generally collected during non-rush hour conditions so that congestion and vehicle-to-vehicle interactions had a minimum effect on the speed data collected—i.e., it was desired to have information regarding the free-flow speeds of vehicles, effectively isolating the effects of the speed limits themselves.

Approach to Data Analysis

The fundamental objective of the data analysis was to determine the effects of work zone speed limits on the speeds of motorists who went through those zones. The initial analysis, reported in ***Work Zone Speed Study (Draft Final Report)***, was concerned with relatively simple determinations of average speeds "during" and "after" the work zones were in place on a site-by-site basis. In that report, the statistical analysis that was done was kept fairly simple (e.g., calculation and some comparison of mean speeds). It was clear, however, that there were variations in average speeds that were likely due to factors other than the posted speed limit—e.g., the number of lanes open to traffic. Thus, additional work, involving more detailed statistical analysis, was done and reported in the ***1997 Work Zone Speed Study***. Considerably more detail on the results at each site and the statistical analyses can be found in the two reports just cited. The most important results are summarized here.

Initial Data Analysis and Results

The initial results included the following:

In most instances, average speeds observed at the different sites when work zones are not present are higher than the posted speed limits (for these sites, this is typically 70 mph).

In virtually all instances, the speeds observed when work zones are present exceed the posted limits. This is independent of the posted limit.

Average speeds observed when the work zone limit was 60 mph were generally higher than those observed when lower limits (45 or 50) were posted.

Although only a few work zones were observed where the limit was stepped down from 70 to 50 mph, the average speeds observed in these zones were somewhat lower than those when the work zone limit was 60 mph and somewhat higher than those where it was 45 mph.

The average speeds observed when the work zone limit was 45 mph were generally the lowest.

Speeds were generally lower when workers were present versus when they were not.

Speeds were generally lower when only one traffic lane was available.

These results seem to support the notion that speed limits do have some effect on controlling motorist speeds as lower limits are seemingly associated with lower speeds. **But**, at the same time, at many of the sites surveyed there were also generally clear reasons why motorists should be traveling more slowly (e.g., a limited number of lanes). Results at some sites seem to indicate that motorists will travel at speeds they consider to be reasonable independent of the posted limit.

Supplementary Analysis and Results

The supplementary analysis was done to try and separate the effects of these different variables. In addition to the speed limits in effect, the factors that were evaluated included the number of lanes open during and after construction, whether workers were present or not, the worker location (relative to where the data were collected), and the type of lane closure/separation (e.g., barrier wall, drums). An overall analysis (looking at all variables/factors at once) that considered type of lane closure/separation (barrier walls, cones, or drums), whether workers were present or not, the number of lanes open to traffic (1, 2, or 3), and the speed limit (45, 50, or 60 mph) in effect showed that they all had statistically significant effects (.05 or better) on the average speed.

The effects of different variables were also investigated on a one-by-one basis. The statistical tests that were done included t-tests and oneway ANOVAs. All differences that are noted are "statistically significant" (unless otherwise indicated) at a significance of .05 or smaller.

Are speeds in construction zones generally higher than posted limits?

For all sites when the posted speed limit in the work zone was 60 mph, the mean speed was 65.9 mph; for a posted limit of 50 mph, the mean was 61.1 mph; and for a posted limit of 45 mph, the mean was 53.5 mph (table 1). Moreover, when all groups are considered at once (i.e., the average speed in 60 mph zones is compared with average speeds in 50 and 45 mph zones), all means are different. This implies that lower speed limits will result in statistically lower speeds, although the speeds are still in excess of those limits. It should be noted that these mean speeds are independent of the consideration of other factors—e.g., type of lane closure/separation will vary. For all sites after the work zone is removed, the average speed was 72.3 mph, versus a posted limit of 70 mph.

Table 1. Average speeds and posted limits

	during work			after work
posted limit	60 mph	50 mph	45 mph	70 mph
average speed	65.9	61.1	53.5	72.3

Does the number of open lanes make a difference in motorist speeds?

Not taking into account the actual posted limit or other variables, the number of open lanes appears to make a difference in speed: 55.3 mph for 1-lane zones (two normal lanes restricted to one); 65.0 for 2-lane zones (three normal lanes restricted to two); and 69.0 mph for 3-lane zones (normally 3-lane sections, no lane reductions).

The same sort of analysis was done with consideration of the difference in posted limits (see table 2). First, for a posted speed of 60 mph, a similar trend was noted: with one lane open, the mean speed was 58.8 mph; with two lanes open, it was 65.1 mph; and with three lanes open it was 69.0 mph. (Other variables were not controlled—e.g., workers may or may not have been present.) When the posted speed was 50 mph (stepped down from 70 to 60 to 50), the results were: 58.0 mph with one lane open; and 64.1 mph with two lanes open. ***The similarity between the observed speeds with one lane (58.8 vs. 58.0) and two lanes (65.1 vs. 64.1) open, regardless of the posted limit implies that motorists may well be responding more to the geometry than the posted limit***—especially since the speed with one lane open is actually lower than the posted limit in the one instance.

An analysis was also done looking at all instances when the number of open lanes was limited to one, reduced from two. In this instance, there were sites with posted limits of 60, 50, and 45 mph. The ANOVA indicated that there were differences in the mean speeds (58.8, 58.0, and 53.5 mph, respectively) based on posted limit. However, the difference between the first two categories (posted limits of 60 and 50 mph) was **not** significant. It should also be noted that the 45 mph sites were more likely to only have cone lane closures/separations and workers were more likely to be present.

Table 2. Average speeds and number of open lanes

	posted speed limits during construction			
lane reduction	all sites	70 to 60	70 to 60 to 50	70 to 45
2 to 1	55.3	58.8	58.0	53.5
3 to 2	65.0	65.1	64.1	----
3 to 3	69.0	69.0	----	----

Taken collectively, these results indicate that the number of open lanes does have an effect on the motorist speeds through construction zones and, that while lower posted limits may have an effect on lowering the speeds, the lane effect may well be larger.

Does the presence of workers make a difference in motorist speeds?

The effects of the presence of workers was examined but proved somewhat more difficult to isolate than expected—there were not many instances when a clear comparison of worker presence versus not were available for a wide range of conditions or at the same site.

With a speed reduction of 70 to 60 mph and a lane reduction of two to one, a comparison of speeds with and without workers present (in this instance within ¼ of a mile of the data collection

site) was made which showed that the average speeds were 59.7 mph when workers were present and 56.3 mph when they weren't. Differences when the lane reductions were three to two and no lane reduction with workers present at various locations within the work zone (as measured from the data collection point) are shown in table 3. These results appear to show that worker presence does not always make a difference in motorist speeds.

Table 3. Average speeds and worker presence

		posted work zone speed limits	
lane reduction	worker presence	60 mph	45 mph
2 to 1	not present	59.7	54.6[3]
	under bridge	---	52.2[3]
	within ¼ mile	56.3	51.1
	within ½ mile	---	56.1[3]
	within 2 miles	---	59.6
	moving	---	55.3[3]
3 to 2	not present	65.0[1]	---
	under bridge	64.8[1]	---
	within ¼ mile	65.3[1]	---
	moving	65.2[1]	---
3 to 3	not present	69.6	---
	within ¼ mile	65.4[2]	---
	within ½ mile	73.2	---
	within 1 mile	67.2[2]	---

[1] differences not significant
[2] difference between ¼ and 1 mile not significant
[3] difference between no workers, under, ½ mile, and moving not significant

There were also a few instances where some comparisons of workers present vs. not present could be made at the same site. The first site is a special case where there was never any lane closure (although barrels and other signs regarding the work zone were alongside the road for all data collection) and the posted speed limit was always 55 mph (I-496 in Lansing). The average speed when workers were present (within ¼ mile of the data collection site) was 63.1 mph versus 60.6 mph when they were not—the workers' presence had no significant effect in reducing speeds. Another site where a similar comparison was made was a relatively high-speed location on I-96 near Kensington Road where three lanes were maintained and the work was in the median with protection/separation of workers and traffic provided by a barrier wall (there was a minor lane shift and narrowing of the lanes). When workers were not present, the average speed was 71.0 mph compared to 67.2 during another period when workers were present within one mile of the location. The final site was a result of happenstance—although the intent was to collect data when there was no work zone present, data were actually collected when workers were present immediately under the bridge where the data collection equipment was installed. The unique characteristic was that there was no advance warning of the workers being present and there was no lane closure—the motorists would encounter the work zone unexpectedly. These observations were compared with "after" data when no workers were present at all. The average speed when workers were present was 59.8 mph compared with 68.2 mph afterwards.

Does the type of lane closure/separation make a difference?

There were three different types of lane closures/separations examined: cones, barrels/drums, and concrete barrier walls. In general, the cones were used for short-term closures and the barrier walls used for longer-term sites. Drums, on the other hand, seemed to be used in a broader range of situations.

The first analysis addressed specifically to the lane closure/separation issue was a comparison of all sites regardless of speed limit, worker presence, and number of open lanes. As would be expected intuitively, lower speeds were associated with less formidable closures/separations: barrier walls, 67.4 mph; barrels, 61.5 mph; and cones, 53.7 mph. Similar comparisons were also undertaken for different posted speed limits and number of open lanes (table 4).

Table 4. Average speeds and type of lane closure/separation

			60 mph			50 mph		45 mph
type of lane closure/ separation	all sites[1]	lane reduction independent of lanes[2]	3 to 3	3 to 2	2 to 1	3 to 2	2 to 1	2 to 1[4]
barrier walls	67.4	67.9	69.0	65.2[3]	---	---	---	56.9
barrels/drums	61.5	63.8	---	65.0[3]	58.8	64.1	58.0	52.5[5]
cones	53.7	---	---	---	---	---	---	53.7[5]

[1] independent of posted speed limit, open lanes
[2] independent of number of open lanes
[3] not significantly different
[4] all 45 mph sites were reduced to one lane
[5] not significantly different

There is no difference noted between speeds at sites with barrier walls versus those with barrels/drums when the speed limit is 60 mph and there are two lanes open. On the other hand, at sites where there is only one operating lane and a 45 mph speed limit, there are differences between speeds at sites with barrier walls and those with barrels/drums or cones. However, there is no difference between the latter two types of closures/separations at those sites (i.e., the average speed of 52.5 mph for barrels/drums is not significantly different from the average speed of 53.7 mph for cones). Overall, it would appear that motorists' speeds are likely to be higher when barrier walls are present than not, although the difference is lessened when more than one lane is open. The differences noted between barrels/drums and cones when all sites are considered (in the left-most column of numbers) is attributable to the number of lanes that are open more than the difference in the device since all "cone sites" had only one lane open while some of the situations for the other two "treatments" were 2- or even 3-lane sites. Considering barrel/drum closure/separation, the table allows comparison between the average speeds with two lanes open and both 60 and 50 mph speed limits in effect—the difference is less than one mph (65 vs. 64.1). Likewise, the average speeds are also shown with only one lane open with both 60 and 50 mph speed limits—again, the difference is less than one mph (58.0 vs. 58.8). The number of

open lanes seems to have a greater effect than the type of closure/separation although motorist speeds when barrier walls are present are always higher than the when they are not.

Summary of Results, Discussion, and Conclusions

Overall speeds in work zones

Notwithstanding differences in observed speeds in work zones which may be due to a combination of factors including the presence/absence of workers, the type of lane closure/separation, and the number of open lanes, it is clear that speeds in construction zones are generally higher than the posted limits when the traffic is relatively free-flowing (i.e., not slowed by congestion or some incident). At a posted speed limit of 60 mph, the average observed speed is almost 65.9 mph; at 50 mph, the observed average is 61.1 mph; and at a posted limit of 45 mph, the observed speed is 53.5 mph. By the same token, the average speeds observed ***after*** the work zone is removed are also greater than the posted limit, 72.3 mph for a 70 mph limit.

So, when motorists are asked to slow from their nominal speed of 70 to 60 mph, or 10 mph, they respond with an actual reduction of ~6 mph (they slow from an average of ~72 to an average of ~66); when asked to slow from 70 (to 60) to 50, or 20 mph, they slow ~11 mph; and, finally, when asked to slow from 70 to 45 (in one step), or 25 mph, they decrease ~19 mph. While motorists respond to work zones by slowing down, they do not slow down to the posted speed. Indeed, their speeds through work zones are disproportionately greater than they are when the work zones are not present (i.e., they exceed the work zone speed limits by a greater increment than the normal speed limit). Moreover, the greatest speed reduction, which occurs in 45 mph zones, may well be a result of the number of open lanes.

The effect of the number of open lanes in work zones

A large portion of the speed reduction in work zones appears to be due to the number of open lanes. Overall, 3-lane work zones (no lane closures) experienced the highest speeds, 69.0 mph, versus 2-lane zones (one lane reduced) at 65.0 mph and 1-lane zones at 55.3 mph. However, the lane effect was most noticeable when sites with the same number of open lanes but different posted limits were compared: for two open lanes, average speeds for 60 mph and 50 mph limits were, respectively, 65.1 and 64.1 mph; with only one open lane, the average speeds ranged from 53.5 mph (45 mph limit) to 58.0 mph (50 mph limit) to 58.8 mph (60 mph limit). That is, with a 60 mph posted limit, 1-, 2-, and 3-lane sections experienced average speeds of 58.8, 65.1, and 69.0 mph; with a 50 mph limit, 1- and 2-lane sections experienced average speeds of 58.0 and 64.1, respectively. Moving from one open lane to two resulted in an average speed increase of just over 6 mph, regardless of whether the limit is 50 or 60 mph. Having a third lane open resulted in another 4 mph increase.

While the results associated with the number of lanes are not particularly surprising at one level—it would be expected that even in uncongested conditions restricting traffic to one lane would result in speed decreases—the fact that the lane configuration may be as important as the posted limit is somewhat unexpected. It seems clear that an attempt to keep capacity as high as possible

during construction (maximize the number of open lanes) will likely result in higher speeds through the construction zones—at least in uncongested situations.

The effect of workers being present

If the apparent magnitude of the effects of the number of lanes was a little surprising, the lack of equally clear effects due to the presence of workers was as well. In some instances, the presence of workers appeared to contribute to a decrease in motorist speeds and in some instances it did not—the results were inconsistent.

Interestingly, at three atypical sites, worker presence generally seemed to have the effect of decreasing motorist speeds. Most striking was one case where the workers were present under the bridge from which data were being collected—no signs for the work zone were present and there was no lane closure, the "unannounced" workers were working at the roadside. In this instance, a speed reduction of 8.4 mph was realized (compared to the average speed at the site when no workers or work zone traffic control devices were present).

The effect of type of lane closure/separation

In general, the analysis that was done indicated that the three types of lane closure/separation studied—barrier walls, barrels/drums, and cones—were associated with different average speeds, 67.4, 61.5, and 53.7 mph, respectively. However, the results also showed that there was a distinct relationship between the use of the three devices and lane configuration. For the sites studied, barrier walls were used when two or three lanes were open (60 mph limits), barrels/drums were used for in situations where one or two lanes were open (speed limits of 60, 50, and 45 mph), and cones were used *only* when the speed limit was 45 mph and only one lane was available. Moreover, it was noted that for barrels/drums the observed speeds were the same when the number of lanes available was the same, independent of differences in the posted speed limit. Thus, the effect of type of lane closure/separation is obscured to some degree by the situations in which they are used. However, the effect does not seem to be great based on the data available here.

Conclusions

The primary purpose of this study was to evaluate the effect of posted speed limits in work zones on motorist speeds. Several other factors were also hypothesized to have an effect on motorist speeds in work zones on a day-to-day basis: type of lane closure/separation, presence/absence of workers, and the number of lanes open to travel through the zone. Sites for this study were chosen to explicitly minimize the contribution of congestion given that assessing motorist reaction to posted speed limits was the principal objective.

While it is difficult to accurately separate the effects of the various factors that influence the speeds of motorists in work zones or to identify **all** of the relevant factors at any point in time, it is known from this study that, for the sites studied, lower speeds were observed when lower speed limits were posted. Equally clear is the fact that although lower speeds were observed, they are

significantly higher than the posted limits and disproportionately higher (in work zones) than they are otherwise at these same sites. That is, the differences between observed speeds and posted limits are greater when work zones are present than when they are not. Finally, there was a very strong effect due to the number of open lanes noted—one as large or larger than any effect of the speed limit *per se*.

With respect to the effectiveness of the posted limits themselves, it is important to note that different limits are almost always associated with different types of lane closure/separations and lane configurations. The strong relationship between motorist speed and the number of available lanes is not unexpected, but it seems clear that there is a dilemma to be confronted between the conflicting objectives of slowing motorists through work zones and minimizing delay. Limiting the number of lanes available will generally result in lower speeds but motorist delay will clearly increase, and opening more lanes will invariably result in higher speeds, apparently independent of the posted limit.

If compliance with posted limits is desirable, it seems clear from this study that something more than the standard speed limit signs will have to be used in work zones. Options would include enhanced signs and/or increased enforcement.

1997 WORK ZONE SPEED STUDY

DRAFT FINAL REPORT

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15. Supplementary Notes

16. Abstract

This study was directed to the evaluation of the effects of different posted speed limits in work zones on freeways (normal speed limit = 70 mph) in lower Michigan in uncongested conditions. The speed limits were 60 mph, 50 mph (stepped down in 10 mph increments from 70 mph), and 45 mph. It was found that while increasingly lower posted limits resulted in lower motorist speeds, but that the observed average speeds were always higher than the posted limits. The difference between average speeds and posted limits in work zones was greater than the difference between average and posted speeds at the same sites when work zones were not present. The effects of other factors (number of open lanes, type of lane closure/separation, worker presence/absence) were also investigated, and it was found that the number of open lanes is a major contributor to motorist speed—e.g., at posted limits of 60 and 50 mph, the observed average speeds were the same when the number of open lanes was the same, independent of the posted limits.

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DRAFT FINAL REPORT

INTRODUCTION

The 1997 work zone speed study was undertaken in order to assess the effects of different posted speed limits in work zones. The sites used for the study were restricted to selected limited-access highways (freeways) in Michigan. The project consisted of collecting and analyzing vehicle speed data during and after the work zones were active at the selected sites. (A limited number of "before" data were also collected.) The data collection period began in July and continued until late November 1997.

With respect to speed limits in work zones, Michigan has recently (1996) changed the posted limits. As a general rule, during the 1997 construction season, there were three different speed limits which were used on Michigan freeways: **60 mph** for sites where more extensive, non-maintenance projects were being done and workers **were not** present; **50 mph** for sites where more extensive, non-maintenance projects were being done and workers generally **were** present; and **45 mph** for sites where maintenance work was being done. These limits (except for maintenance sites) were generally higher than they had been in the past. The changes were made in response to motorist complaints of excessively low limits and to minimize user delays. In addition, it was suspected that compliance with the new limits would be improved, consistent with the widely-held conventional engineering wisdom that most motorists will travel at a speed that is appropriate for conditions which are encountered on a roadway. That is, motorists will be more likely to obey limits which are perceived as being "reasonable." It should be noted that there were exceptions to these limits and their use (e.g., some sites might be posted at 50 mph although workers were not present at a specific point in time). Moreover, some work sites warranted higher or lower limits because of the nature of the geometry of the work zone site or other reasons. The vast majority of sites had a 70 mph limit when there were no work zones present. It should also be noted that when sites were posted at 50 mph, the speed limit was "stepped down" in 10 mph increments—i.e., 70 to 60 to 50 mph (rather than 70 to 50 mph directly).

In addition to the effects of the posted speed limits themselves, analyses were also done to assess the contributions of other variables to the observed speeds. For example, do motorists adjust their speeds only in reaction to the posted limits, because workers are present, because of the number of open travel lanes, or, most likely, some combination of these and/or other factors.

SITE SELECTION

Within the context of the project, there were two different issues to be addressed: motorist response to the generally lower (45 mph) limits that are used in conjunction with maintenance work which is typically accomplished in relatively short time frames and with very temporary lane closures/separations (e.g., using cones); and motorist response to the differential (60 or 50 mph) limits imposed at longer-duration work zones when work activities (within a marked zone) may or may not be occurring at a given point in time. In general, the lane closures/separations that

accompany the latter work will be more substantial—e.g., concrete barrier wall. The idea behind the differential limits is that, geometry permitting, there may not be sufficient reason to restrict motorists to the lower speeds when there are no work activities underway.

Initially, it was intended to identify sites in conjunction with Michigan Department of Transportation (MDOT) personnel. For maintenance sites, this became quite difficult given that the scheduling of work in the field was subject to daily variation. Given the short duration of the work typically done at maintenance sites, in several instances data collection teams were sent to sites where work had been done the day before, work was being done the following day, or the site was inappropriate. In addition, information received about different longer-term sites was sometimes inconsistent. Given these problems, most of the site identification was done opportunistically:

several "tours" were taken of selected geographical areas in order to identify sites and data collection opportunities and to determine the status of known work zones;

the Michigan American Automobile Association (AAA) web site was monitored to identify sites, work in progress, and when work was done at sites where "during" data had been collected;

data collection teams "roamed" in selected geographic areas and, when an appropriate site was identified, the team would collect "during" data (and then return later for "after" data);

MDOT personnel were contacted to determine maintenance and construction locations and scheduled activities; and

other interested parties were used as resources (e.g., attendees at an MDOT-sponsored work zone task force meeting).

The site selection procedure was not highly scientific in nature—for example, no attempt was made to determine a statistically appropriate number of 45 mph sites in advance of the project. Rather, the selection procedure was, as noted, opportunistic. The project team attempted to identify as many sites as quickly as possible and proceed with data collection. At about the mid-point of the data collection period, the numbers of various types of sites where data had been collected were determined and a "correction" was made—i.e., it was determined that a sufficient number of 45 mph (maintenance) sites had been identified and the emphasis shifted to non-maintenance sites.

The above notwithstanding, there were some general criteria for site selection:

an overpass on which the data collection equipment could be installed had to be present (see the discussion of data collection which follows in a later section);

sites had to be on limited-access highways (i.e., interstate-type highways);

traffic volumes had to be low enough so that congestion did not seriously limit vehicle speeds (i.e., free-flow conditions were desired);

travel time from East Lansing had to be less than about two hours (to enable the data collection team to travel to the site, set up for and collect data, and return within a day); and

sites had to be safe for the data collection team (e.g., an overpass had to have "space" for the data collection team to be protected from passing traffic).

The final count on the different types of sites that were included in the study is: 70→60, 15; 70→60→50, 4; 70→50, 1; 70→45, 12; 70→70, 1; and 55→55, 2.

DATA COLLECTION

Vehicle speed data were collected using the Autoscope® system which requires that videotapes of traffic be made from an overhead vantage point. The basic procedure for data collection was as follows:

a standard video camera was installed on a tripod on an overpass over the selected roadway segment (site);

calibration "marks" were spray-painted on the outside of the edgelines;

the camera was focused on the traffic as it approached and passed underneath the bridge (the useful field encompassed by the camera is several hundred feet of the overpass);

a "test" vehicle was driven through the site several times at a known speed for calibration purposes (after data collection activities early in the project showed some problems with variance in speedometer readings on the test vehicles, they were equipped with a radar unit for accurate assessment of its speed); and

passing traffic was videotaped for ~2-hour periods.

Vehicle speed data were collected for all lanes (in a given direction) that were open to traffic.

In addition to the vehicle speed data, information about the site was also gathered. These data included weather conditions, presence and location of workers, speed limit that was in effect, type of work being done, presence of police, and so forth. Data about the non-construction conditions (e.g., normal speed limit) were also collected. Vehicle speed data were generally collected during non-rush hour conditions so that congestion and vehicle-to-vehicle interactions had a minimum effect on the speed data collected—i.e., it was desired to have information regarding the free-flow speeds of vehicles, effectively isolating the effects of the speed limits themselves.

It should be noted that the Autoscope® system was used because it was the easiest and quickest system to deploy in the field at a given site (setting up a videocamera and spray-painting reference

points outside of the lanes versus installing pneumatic tubes or other sensing devices **in** the travel lanes at a site and setting up other vehicle monitoring equipment). Using Autoscope®, the only exposure to the mainline traffic that data collectors had was when the reference points were spray-painted on the shoulders. Moreover, use of this system did not require any coordination with anyone beyond the project team.

Because of the "opportunistic" approach to site identification and the relatively late start in the construction season (July), very few locations actually had "before" data collected.

DATA REDUCTION

The Autoscope® system basically consists of vehicle presence recognition and a time-over-distance speed calculation for each vehicle. The data reduction requires an initial calibration based on the known speeds of "test" vehicles that traverse the site and the field-marked calibration points that appear on the tape. A drawback to the system is that, once calibrated, the reduction of data is done in real time—i.e., it takes two hours (plus calibration time) to process a 2-hour tape from the field.

The system produces a summary form which can be printed as a hard copy and/or saved as a computer file (which can then be manipulated) and shows the following for each lane or collectively (all lanes):

basic user-input site-descriptive information,
date,
time,
a user-supplied station identification,
average flow,
actual volume,
average speed,
the product of volume and speed,
vehicle count by (three) vehicle classes,
average time headway,
time occupancy (of "trap" area),
level of service (based on speed),
space mean speed,
space occupancy, and
density.

The volume, average speed, and several of the other output variables are based on a user-defined time increment. The time increment that was used in this project was five minutes. Thus, the average speed that was recorded was the average of all vehicles that were detected in a lane in a five-minute period. The data of primary interest here are the times and average speeds.

The forms were both printed in hard copy form and saved as a computer file. The computer files were subsequently converted to Excel® spreadsheets. The Excel® files were used to produce graphs showing the average speeds at each site.

APPROACH TO DATA ANALYSIS

The fundamental objective of the data analysis was to determine the effects of work zone speed limits on the speeds of motorists who went through those zones. The initial analysis, reported in ***Work Zone Speed Study (Draft Final Report)*** and dated 31 December 1997 (and referred to hereinafter as the ***Initial Report***), was concerned with providing relatively simple determinations of average speeds "during" and "after" the work zones were in place on a site-by-site basis. In that report, the statistical analysis that was done was kept fairly simple (e.g., calculation and some comparison of mean speeds). Based on the site-by-site analysis, some generalized conclusions were also offered. At the same time, it was clear that there were some variations in average speeds that were likely due to factors other than the posted speed limit—e.g., there might be differences in average speeds in 50 mph zones due to worker presence and the number of lanes of traffic that were maintained. It was also noted that there were some sites where conditions were so significantly different from other sites that they should be considered as "outliers" (e.g., one site where both during and after speed limits were the same) and excluded from the analysis. Finally, there were some sites where the data appeared to be flawed or compromised in some way.

In light of the initial findings and subsequent discussions with MDOT, additional analytical work was undertaken. This consisted of a comprehensive review of the data that were collected at each site and the conditions under which they were collected (in some cases adjustments were made and the field data were processed again), elimination of some flawed and/or compromised data, elimination of some sites, and more rigorous statistical analysis in general. The additional analysis consisted of before-after comparisons of mean speeds on a site-by-site basis, comparisons of mean speeds for all sites with different speed limits, and comparisons of mean speeds with explicit consideration of other factors such as number of open lanes using multivariate analysis of variance (ANOVA) and other techniques.

For the discussion of the results that follows, it is useful to understand the data that were available from the Autoscope® system and how they were initially analyzed. This is shown in some detail for one typical site. On the following page the tabular results (output) for one lane of traffic for a typical site ***during*** construction are shown. As noted above, the data range from basic descriptive information to the average speed for the vehicles observed in each time increment.

The graph that follows the table is based on both ***during*** (from the table) and ***after*** data (the latter are not shown). This graph shows a comprehensive overview of the speeds, aggregated over all open lanes in one direction, that were observed at the typical site:

general site identification information is shown at the top of the graph;

EB M-14@Dixboro Rd. During Construction
08/28/97

EB M-14@Dixboro Rd. (During) 08/28/97 11:40 AM-1:40 PM
157 Lane 2

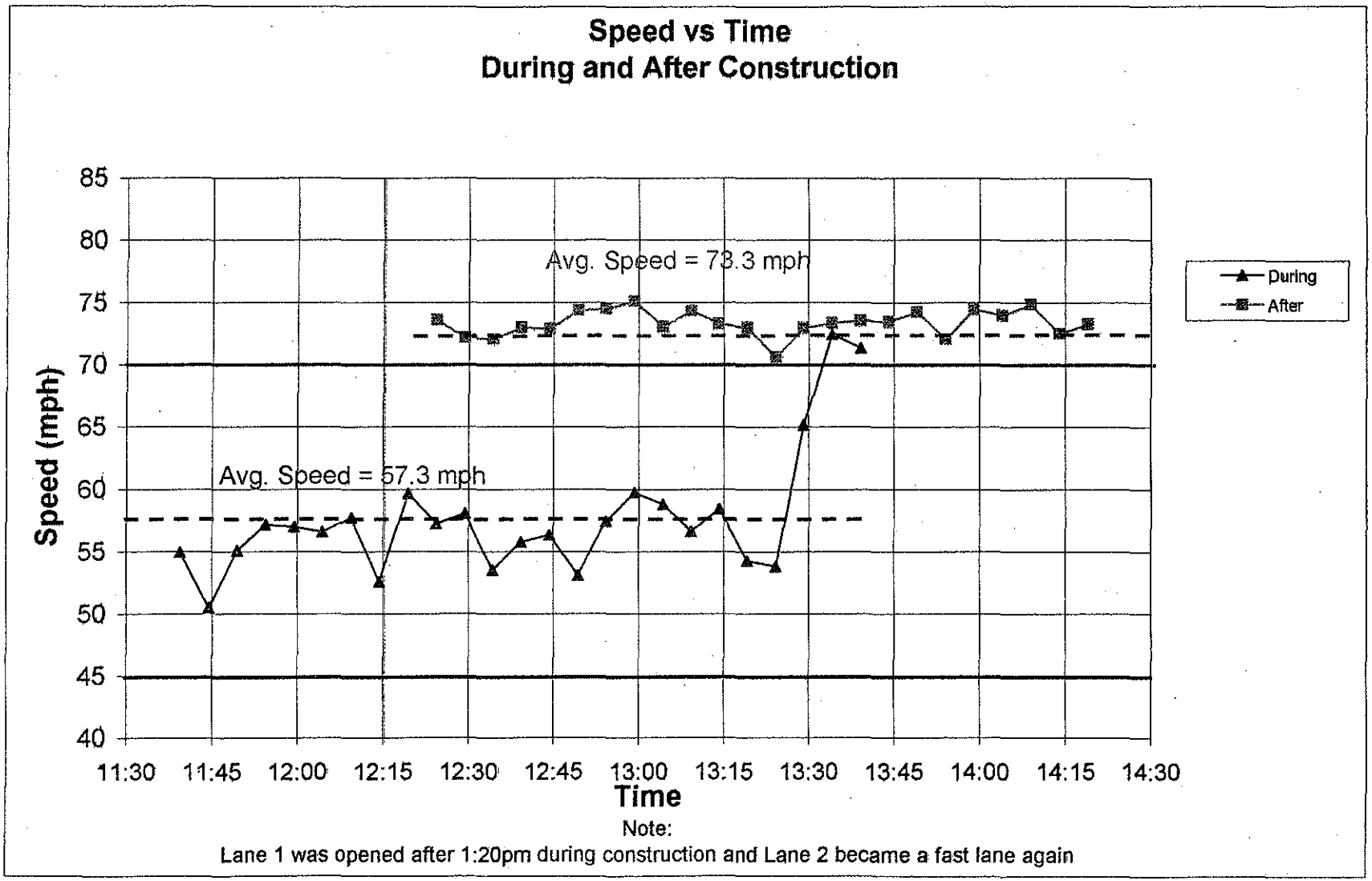
Lane 2

Data from: 8/28/97 11:40 AM
Data to: 8/28/97 1:40 PM

Date	Time	Station ID	Average Flow	Volume	Average Speed	Vol.*Spd	Class 1	Class 2	Class 3	Time Headway	Time Occupancy	LOS	Space Mean Speed	Space occupancy	Density
8/28/97	11:40 AM	157	252	21	54.93	1153.53	11	2	3	14.28	9.96	C	41.26	5.25	6.1
8/28/97	11:45 AM	157	1416	118	50.48	5956.64	80	16	16	2.53	0.09	D	41.52	0.35	34.09
8/28/97	11:50 AM	157	1284	107	55.04	5889.28	78	11	13	2.8	17.81	C	42.01	7.52	30.56
8/28/97	11:55 AM	157	1308	109	57.11	6224.99	80	4	13	2.75	16.74	B	32.35	7.32	40.42
8/28/97	12:00 PM	157	1692	141	56.95	8029.95	102	13	16	2.12	21.83	B	54.63	8.91	30.96
8/28/97	12:05 PM	157	1476	123	56.54	6954.42	77	12	24	2.43	22.94	B	55.63	10.22	26.52
8/28/97	12:10 PM	157	1560	130	57.68	7498.4	91	18	12	2.3	19.77	B	55.92	8.13	27.89
8/28/97	12:15 PM	157	1632	136	52.53	7144.08	91	15	16	2.2	24.17	D	34.15	11.18	47.77
8/28/97	12:20 PM	157	1308	109	59.6	6496.4	81	8	10	2.75	15.41	A	53.38	6.56	24.5
8/28/97	12:25 PM	157	1380	115	57.2	6578	79	12	15	2.6	18.31	B	36.97	7.63	37.32
8/28/97	12:30 PM	157	1368	114	58.02	6614.28	81	13	8	2.62	16.78	B	48.13	7.24	28.41
8/28/97	12:35 PM	157	1440	120	53.48	6417.6	86	13	17	2.5	20.28	D	52.3	8.45	27.52
8/28/97	12:40 PM	157	1632	136	55.75	7582	105	16	9	2.2	19.68	C	52.85	7.47	30.87
8/28/97	12:45 PM	157	1416	118	56.32	6645.76	81	12	17	2.53	19.76	C	52.41	8.52	27.01
8/28/97	12:50 PM	157	1608	134	53.06	7110.04	108	14	6	2.23	20.2	D	31.92	8.04	50.36
8/28/97	12:55 PM	157	1668	139	57.43	7982.77	98	17	18	2.15	23.25	B	53.45	9.25	31.19
8/28/97	1:00 PM	157	1164	97	59.71	5791.87	63	18	11	3.08	14.65	A	51.61	5.81	22.55
8/28/97	1:05 PM	157	1632	136	58.78	7994.08	91	25	10	2.2	20.64	B	34.38	8.08	47.45
8/28/97	1:10 PM	157	1620	135	56.61	7642.35	94	24	12	2.21	20.73	B	36.94	7.83	43.84
8/28/97	1:15 PM	157	1356	113	58.39	6598.07	79	25	6	2.65	17.03	B	54.76	6.19	24.76
8/28/97	1:20 PM	157	1620	135	54.22	7319.7	95	21	15	2.21	22.55	C	50.04	8.73	32.37
8/28/97	1:25 PM	157	1596	133	53.77	7151.41	93	27	8	2.25	21.32	C	49.55	8.08	32.2
8/28/97	1:30 PM	157	936	78	65.12	5079.36	56	15	0	3.84	10.3	A	63.56	3.94	14.72
8/28/97	1:35 PM	157	1020	85	72.42	6155.7	61	18	1	3.52	9.9	A	71.89	3.36	14.18
8/28/97	1:40 PM	157	1176	98	71.3	6987.4	63	23	6	3.05	12.76	A	49.9	4.5	23.56
Total				2880		164998.08									

Average Speed = 57.3 MPH

EB M-14@Dixboro Rd.
8/28/97 and 9/09/97



Note:
Lane 1 was opened after 1:20pm during construction and Lane 2 became a fast lane again

the normal/after (70 mph) and during (45 mph) work speed limits are shown with solid horizontal lines (green and red, respectively);

the overall average speeds both after (73.3 mph) and during (57.3 mph) work are shown with dotted horizontal lines (again green and red, respectively);

the variations in the average speeds over time are shown for both during and after are shown with jagged colored lines; and

explanatory notes are shown as necessary.

Each point in the plot represents the average speed of all vehicles in a 5-minute time increment (based on one line in the relevant table). Thus, it should be noted that the average speed calculations are based on a varying number of vehicles (i.e., the number that was actually observed during any 5-minute increment). Lane-by-lane and aggregated tables and graphs for all sites were presented in the ***Initial Report*** and are not provided again here. The site-by-site narrative summaries are, however, presented in appendix A. For the analysis that follows, an observation (unit of analysis) is, likewise, the 5-minute average speed.

DATA ANALYSIS AND RESULTS

In this section, the results of the initial analysis as reported in the ***Initial Report*** are reiterated and then the more comprehensive supplementary analysis and results are presented.

INITIAL RESULTS

The results summarized below and in the summary table (table 1) which follows were originally shown in the ***Initial Report*** and included the following:

In most instances, average speeds observed at the different sites when work zones **are not** present are higher than the posted speed limits (for these sites, this is typically 70 mph).

In almost all instances, the speeds observed when work zones **are** present exceed the posted limits. This is independent of the posted limit. For the sites with 60 mph work zone limits, the observed overall average speeds ranged from 56.1 to 74.4 mph. The sites where averages below 60 mph were noted both had only one lane available for traffic and one had workers present. For the sites where the limit was stepped down from 70 to 60 to 50 mph, the average speeds ranged from 57.3 to 64.0—the results were very mixed for these zones and presumably depended on the limit itself, worker presence, and lane availability. Finally, for the 45 mph zones, average speeds ranged from 46.3 to 69.0 mph although most ranged from the high 40s to upper 50s.

Average speeds observed when the work zone limit was 60 mph were generally higher than those observed when lower limits (45 or 50) were posted.

Table 1. Summary of Initial Results										
type of site and identification	work/ closure type[1]	worker presence	regular speed limit	average speeds		speed limit during	average speeds during			comments
				before	after		1	2	3	
70-60										
I-96 EB @ Dorr Road	long-term	no	70	--	--	60	65.9	--	--	2 lanes[2]
I-96 WB @ Dorr Road	long-term	yes	70	--	--	60	60.5	--	--	2 lanes[2]
I-96 EB @ Kensington Road	long-term	no,yes[4]	70	--	68.7	60	68.7	66.3	--	3 lanes[3,4]
I-96 WB @ Kensington Road	long-term	no,yes[4]	70	--	--	60	72.3	68.2	--	3 lanes[3,4]
I-96 EB @ Pleasant Valley Road	long-term	yes	70	--	74.7	60	74.4	--	--	3 lanes[3]
I-96 WB @ Chilson Road	long-term	yes	70	--	--	60	69.3	--	--	2 lanes[2]
US-10 WB @ Flajole Road	long-term	no	70	--	62.6	60	61.7	--	--	1 lane[12]
US-10 WB @ Bay City Road	long-term	no	70	--	66.9	60	56.5	--	--	1 lane[12]
US-10 WB @ W. River Road	long-term	no	70	--	--	60	60.6	--	--	1 lane
I-94 WB @ Hall Road	long-term	no	70	--	--	60	66.3	--	--	2 lanes[2]
I-69 WB @ exit 184	long-term	yes	70	--	71.5	60	56.1	--	--	1 lane
I-275 NB @ Cherry Hill	long-term	no	70	--	71.2	60	68.1	--	--	2 lanes[2]
I-275 NB @ Hannan Road	long-term	yes,no,no	70	--	71.6	60	65.4	65.5	64.0	2 lanes[2,5]
I-275 SB @ Hannan Road	long-term	no,no	70	--	67.4	60	63.9	60.5	--	2 lanes[2]
I-275 NB @ Ecourse Road	long-term	yes	70	--	72.5	60	--	64.7	--	2 lanes[2]
70-60-50										
I-96 EB @ Chilson Road	long-term	no	70	--	66.8	50	63.0	--	--	2 lanes[2,13]
US-10 WB @ M-18	long-term	yes	70	--	--	50	57.3	--	--	1 lane
I-94 EB @ Michigan Avenue	long-term	no	70	--	73.6	50	58.6	--	--	1 lane
I-275 NB @ Ecourse Road	long-term	yes	70	--	72.5	50	64.0	--	--	2 lanes[2,6],police
I-275 NB @ Joy Road	long-term	no	70	--	--	50	30.5	--	--	2 lanes[2,7,14]
70-50										
I-69 WB @ Miller Road	long-term	yes	70	--	64.8	50	53.9	--	--	1 lane
70-45										
I-96 EB @ Nicholson Road	maint	yes	70	--	74.8	45	52.0	--	--	1 lane
I-96 EB @ Exit 129	maint	yes	70	--	69.7	45	46.3	--	--	1 lane
I-96 WB @ Exit 133	maint	yes	70	--	73.8	45	69.0	--	--	2 lanes[2]
I-69 EB @ Lake Nepessing Road	maint	yes	70	--	70.0	45	57.3	--	--	1 lane
US-27 NB @ Base Line Road	long-term	yes	70	--	75.2	45	50.3	--	--	1 lane
US-27 SB @ Base Line Road	long-term	yes	70	--	--	45	48.8	--	--	1 lane

Table 1. Summary of Initial Results

type of site and identification	work/ closure type[1]	worker presence	regular speed limit	average speeds before	average speeds after	speed limit during	average speeds during 1	average speeds during 2	average speeds during 3	comments
US-127 NB @ Barnes Road	maint	yes	70	73.8	71.7	45	54.0	--	--	1 lane
US-127 NB @ Henry Road	maint	yes	70	--	76.0	45	56.7	--	--	1 lane
US-131 SB @ M-46	maint	yes	70	--	70.6	45	59.5	--	--	1 lane
US-23 SB @ Carpenter Road	long-term	yes	70	--	78.0	45	52.7	--	--	1 lane
US-23 NB @ Carpenter Road	long-term	no	70	--	72.0	45	54.5	--	--	1 lane
US-23 SB @ Geddes Road	maint	no	65	--	73.5	45	61.8	--	--	1 lane[9,14]
M-14 EB @ Dixboro Road	maint	yes	70	--	73.3	45	56.0	--	--	1 lane[9]
M-14 WB @ Dixboro Road	maint	yes	70	--	70.8	45	38.7	--	--	1 lane[9,14]
other										
I-69 WB @ Miller Road	maint	yes	70	--	64.8	70	--	60.3	--	2 lanes[8]
I-496 EB @ Washington	long-term[10]	yes	55	--	--	55	56.4	--	--	2 lanes[11]
I-496 WB @ Washington	long-term[10]	no,yes	55	--	--	55	59.5	61.8	--	2 lanes[11]

notes:
[1] long-term >2 weeks, maint <2 weeks
[2] lane reduction from 3 to 2 lanes, 2 lanes open
[3] no lane reduction, shoulder used as lane, 3 lanes open, work in median
[4] workers not present for "during 1," present for "during 2"
[5] workers present for "during 1," not present for "during 2" and "during 3"
[6] police present in area
[7] changeable message sign present
[8] for "during 2," both lanes open and no speed limit reduction; for supporting graph and tables, see I-69 @ Miller 70-50 materials
[9] closed lane was opened during data collection for "during" period—average speed is not representative of period when lane closed
[10] work was long-term but worker presence and lane closures were sporadic
[11] both regular lanes were open, work was on shoulder
[12] snow showers experienced during "after" period
[13] significant geometric changes in lane shift
[14] eliminated from much of analysis because of congestion effects on speed

Although only a few work zones were observed where the limit was stepped down from 70 to 60 to 50 mph, the average speeds observed in these zones were somewhat lower than those observed when the work zone limit was 60 mph and somewhat higher than those where the posted limit was 45 mph.

The average speeds observed when the work zone limit was 45 mph were generally the lowest.

Speeds were generally lower when workers were present versus when they were not.

Speeds were generally lower when only one traffic lane was available.

These results seem to support the notion that speed limits do have some effect on controlling motorist speeds as lower limits are seemingly associated with lower speeds. At the same time, for many of the sites surveyed there were also generally clear reasons **why** motorists should be traveling more slowly (e.g., a greater propensity for worker presence, less substantial lane closures/separations, and a limited number of available lanes). Results at some sites seem to indicate that motorists will travel at speeds they consider to be reasonable independent of the posted limit.

SUPPLEMENTARY ANALYSIS AND RESULTS

The initial results indicated that lower speed limits seemed to be associated with lower speeds in work zones. What was not so clear were the effects of other variables in achieving the lower operating speeds—e.g., do motorists slow down because of a 45 mph speed limit or because they were more likely to encounter (for the sites studied) workers in a 45 mph zone? The supplementary analysis was done to try and separate the effects of these different variables.

SPECIAL CONSIDERATION/ELIMINATION OF SITES

One of the first things that was done during the supplementary analysis was to review sites where the data appeared to be different from what would be expected (e.g., abnormally high or low) or where known site conditions made them different from others in their "speed limit group" (e.g., all sites where the speed limit was reduced in steps from 70 to 50 mph). Some such sites were eliminated from all further analysis while others were eliminated only from certain analyses done on groups of sites in the aggregate. A listing of the sites/data that were eliminated from some analyses and the rationales is provided in appendix B. Sites/data were eliminated for all or part of the analysis because of severe geometry (e.g., a tight lane shift), non-free-flow conditions, inappropriate signing, and unique site conditions (e.g., only one site had a 55 mph speed limit during and after construction). Many of the analyses reported below were done with and without the elimination of these sites/data. The elimination of some data/sites is mentioned in the following only when it made an important difference in the outcome of the analysis. The two forms of the data are referred to as "original" (no eliminations) and "modified" (some data/sites eliminated).

SUPPLEMENTARY ANALYSIS

In addition to the speed limits in effect, the factors that were evaluated included the number of lanes open during and after construction, whether workers were present or not, the worker location (relative to where the data were collected), and the type of lane closure/separation (e.g., barrier wall, drums). The type of construction being undertaken was also considered but it was decided that the classification scheme that had been developed might have been inconsistent. Moreover, it is argued that if motorists respond at all to different construction-related stimuli, they respond to the presence of workers, what the separation between the workers and travel lane(s) looks like, and the speed limit much more than they do the type of activity in which the worker is involved. The details of one typical test are shown and then other results are summarized without the statistical detail.

A series of multiple-way ANOVAs was run (using the Statistical Package for the Social Sciences [SPSS]—SPSS was used for all statistical analysis) to evaluate whether there was any statistical interaction between the different factors under consideration. The first analysis was run on all data collected **during** the times when the work zones were in place with the dependent variable being average speed. (This was done using the "modified" file.) Independent variables considered were: type of lane closure/separation (barrier walls, cones, or drums), whether workers were present or not, the number of lanes open to traffic (1, 2, or 3), and the speed limit (45, 50, or 60 mph) in effect. The analysis showed that closure/separation type, worker presence, open lanes, and speed limit all had significant effects (.05 or better) on the average speed. This is illustrated in table 2.

Table 2. Analysis of variance for average speeds during construction

dependent variable	independent	variables	sum of squares	df	mean square	F	signif
average speed	main effects	combined	41405	7	5915	311.8	.000
		closure type	21588	2	10794	568.9	.000
		worker presence	968	1	968	51.0	.000
		# open lanes	17039	2	8519	449.0	.000
		speed limit	1810	2	905	47.7	.000
	model		41405	7	5915	311.8	.000
	residual		25272	1332	19		
	total		66677	1339	50		

Subsequent analyses were done with the speed limit held constant—e.g., for a speed limit of 45 mph what are the effects of closure/separation type, worker presence, and the number of open lanes. With a speed limit of 45 mph there were no sites with more than one open lane in the

modified file, but separation type and worker presence were significant. With a speed limit of 50 mph, there were no sites with other than drum closures/separations and workers were always present so the only effect that was tested was the number of open lanes (one or two) which was significant. Finally, for a speed limit of 60 mph, worker presence, the number of open lanes, and type of separation were significant.

Two more ANOVAs were done with worker presence fixed to examine whether the other factors (type of lane closure/separation, number of open lanes, and posted speed limit) had significant effects. In both analyses (with and without workers present), all three factors were significant. This suggests that although the presence of workers has an effect on motorist speeds, the other factors have impact as well.

The effects of different variables were also investigated on a one-by-one basis. The results are shown in the following paragraphs which are headed by basic questions/hypotheses that were addressed. The statistical tests that were done included t-tests and oneway ANOVAs. All differences that are noted are "statistically significant" (unless otherwise indicated) at a significance of .05 or smaller. Unless otherwise noted, the analyses were undertaken on the modified file.

Are speeds in construction zones generally higher than posted limits?

For all sites when the posted speed limit in the work zone was 60 mph, the mean speed was 65.9 mph; for a posted limit of 50 mph, the mean was 61.1 mph; and for a posted limit of 45 mph, the mean was 53.5 mph. Moreover, when all groups are considered at once (i.e., the average speed in 60 mph zones is compared with average speeds in 50 and 45 mph zones), all means are different. This implies that lower speed limits will result in statistically lower speeds, although the speeds are still in excess of those limits. The mean speeds that are noted are independent of the consideration of other factors—e.g., type of lane closure/separation will vary, as will worker presence. For all sites **after** the work zone is removed, the average speed was 72.3 mph, versus a posted limit of 70 mph. (See table 3.)

Table 3. Average speeds and posted limits

	during work			after work
posted limit	60 mph	50 mph	45 mph	70 mph
average speed	65.9	61.1	53.5	72.3

Does the number of open lanes make a difference in motorist speeds?

Not taking into account the actual posted limit or other variables, the number of open lanes both when work zones are present and when they are not appears to make a difference in speed. When the work zone are not present ("after"), the difference is counterintuitive—i.e., the average speed for 2-lane sites was 73.0 mph versus 71.4 mph for 3-lane sites. The difference, while significant, is not very large and may be a function of site geometry or some other factor. The speeds when the work zone are present are as would be expected: 55.3 mph for 1-lane zones (two normal lanes restricted to one), 65.0 for 2-lane zones (three normal lanes restricted to two), and 69.0 mph

for 3-lane zones (normally 3-lane sections, no lane reductions). All differences are significant, both overall and pairwise. The largest difference, between ~55 mph for 1-lane sections and ~65 mph for 2-lane sections is as would be expected given that the two-lane sections afford significantly more maneuvering room and speed-restricting platoon formation is less likely.

The same sort of analysis was done considering the difference in posted limits. First, for a posted speed of 60 mph, a similar trend was noted: with one lane open, the mean speed was 58.8 mph; with two lanes open, it was 65.1 mph; and with three lanes open it was 69.0 mph. (Other variables were not controlled—e.g., workers may or may not have been present.) When the posted speed was 50 mph (stepped down 70→60→50), the results were: 58.0 mph with one lane open; and 64.1 mph with two lanes open. The similarity between the observed speeds with one lane (58.8 vs. 58.0) and two lanes (65.1 vs. 64.1) open, regardless of the posted limit implies that motorists may well be responding more to the geometry than the posted limit—especially since the speed with one lane open is actually lower than the posted limit in the one instance.

An analysis was also done looking at all instances when the number of open lanes was limited to one, reduced from two. In this instance, there were sites with posted limits of 60, 50, and 45 mph. The ANOVA indicated that there were differences in the mean speeds (58.8, 58.0, and 53.5 mph, respectively) based on posted limit. However, the difference between the first two categories (posted limits of 60 and 50 mph) was **not** significant. It should also be noted that the 45 mph sites were more likely to only have cone lane closures/separations and workers were more likely to be present. (See table 4 for a summary of results.)

When the number of open lanes was limited to two (reduced from three), a comparison could be made between sites with posted limits of 60 and 50 mph (stepped down 70→60→50). In this instance, average speeds were 65.1 and 64.1, respectively. While the average speed when the limit was 50 mph was somewhat lower, the difference was **not** significant (significance level = .082).

Table 4. Average speeds and number of open lanes

	posted speed limits during construction			
lane reduction	all sites	70→60	70→60→50	70→45
2→1	55.3	58.8	58.0	53.5
3→2	65.0	65.1	64.1	----
3→3	69.0	69.0	----	----

Taken collectively, these results indicate that the number of open lanes does have an effect on the motorist speeds through construction zones and, that while lower posted limits may have an effect on lowering the speeds, the lane effect may well be larger.

Does the presence of workers make a difference in motorist speeds?

The effects of the presence of workers was examined but proved somewhat more difficult to isolate than was expected—there were not many instances when a clear comparison of worker

presence versus not were available for a wide range of conditions or at the same site. At the same time, it seemed clear from the initial results as well as the more complex ANOVAs reported earlier that worker presence does make a difference in motorist speeds.

With a speed reduction of 70→60 mph and a lane reduction of two to one, a comparison of speeds with and without workers present (in this instance within ¼ of a mile of the data collection site) was made which showed that the average speeds were 59.7 mph when workers were present and 56.3 mph when they weren't. Differences when the lane reductions were three to two and no lane reduction with workers present at various locations within the work zone (as measured from the data collection point) are shown in the following table. These results (summarized in table 5) appear to show that worker presence does **not** always make a difference in motorist speeds.

Table 5. Average speeds and worker presence

		posted speed limits	
lane reduction	worker presence	60 mph	45 mph
2→1	not present	59.7	54.6[3]
	under bridge	---	52.2[3]
	within ¼ mile	56.3	51.1
	within ½ mile	---	56.1[3]
	within 2 miles	---	59.6
	moving	---	55.3[3]
3→2	not present	65.0[1]	---
	under bridge	64.8[1]	---
	within ¼ mile	65.3[1]	---
	moving	65.2[1]	---
3→3	not present	69.6	---
	within ¼ mile	65.4[2]	---
	within ½ mile	73.2	---
	within 1 mile	67.2[2]	---

[1] differences not significant
[2] difference between ¼ and 1 mile not significant
[3] difference between no workers, under, ½ mile, and moving not significant

There were also a few instances where some comparisons of workers present vs. not present could be made at the same site. The first site is a special case where there was never any lane closure (although barrels and other signs regarding the work zone were alongside the road for all data collection) and the posted speed limit was always 55 mph (I-496 in Lansing). The average speed when workers were present (within ¼ mile of the data collection site) was 63.1 mph versus 60.6 mph when they were not—the workers' presence had no significant effect in reducing speeds. Another site where a similar comparison was made was a relatively high-speed location on I-96 near Kensington Road where three lanes were maintained and the work was in the median with protection/separation of workers and traffic provided by a barrier wall (there was a minor lane shift and narrowing of the lanes). During the data collection periods when workers were not present, the average speed was 71.0 mph compared to 67.2 during another period when workers were present within one mile of the location. The final site was one that was a result of

happenstance—although the intent was to collect data when there was no work zone present data were actually collected when workers were present immediately under the bridge where the data collection equipment was installed. The unique characteristic was that there was no advance warning of the workers being present and there was no lane closure—the motorists would encounter the work zone fairly unexpectedly. These observations were compared with "after" data when no workers were present at all. The average speed when workers were present was 59.8 mph compared with 68.2 mph afterwards—this is probably the "purest" measurement of the effect that workers might have.

Does the type of lane closure/separation make a difference?

There were three different types of lane closures/separations encountered at the sites examined in 1997: cones, barrels/drums, and concrete barrier walls. In general, the cones were used for short-term closures and the barrier walls used for longer-term sites. Drums, on the other hand, seemed to be used in a broader range of situations. The multi-way ANOVAs reported earlier indicated that the type of lane closure/separation was associated with differences in motorist speeds.

The first analysis addressed specifically to the lane closure/separation issue was a comparison of all sites regardless of speed limit, worker presence, and number of open lanes. As would be expected intuitively, lower speeds were associated with less formidable closures/separations: barrier walls, 67.4 mph; barrels, 61.5 mph; and cones, 53.7 mph. Similar comparisons were also undertaken for different posted speed limits and number of open lanes. These results are summarized in table 6.

Table 6. Average speeds and type of lane closure/separation

			60 mph			50 mph		45 mph
type of lane closure/ separation	all sites[1]	lane reduction→ independent of lanes[2]	3→3	3→2	2→1	3→2	2→1	2→1[4]
barrier walls	67.4	67.9	69.0	65.2[3]	---	---	---	56.9
barrels/drums	61.5	63.8	---	65.0[3]	58.8	64.1	58.0	52.5[5]
cones	53.7	---	---	---	---	---	---	53.7[5]

[1] independent of posted speed limit, open lanes
[2] independent of number of open lanes
[3] not significantly different
[4] all 45 mph sites were reduced to one lane
[5] not significantly different

There is no difference noted between speeds at sites with barrier walls versus those with barrels/drums when the speed limit is 60 mph and there are two lanes open. On the other hand, at sites where there is only one operating lane and a 45 mph speed limit, there are differences between speeds at sites with barrier walls and those with barrels/drums or cones. However, there is no difference between the latter two types of closures/separations at those sites (i.e., the

average speed of 52.5 mph for barrels/drums is not significantly different from the average speed of 53.7 mph for cones). Overall, it would appear that motorists' speeds are likely to be higher when barrier walls are present than not, although the difference is lessened when more than one lane is open. The differences noted between barrels/drums and cones when all sites are considered (in the left-most column of numbers) is attributable to the number of lanes that are open more than the difference in the device since all "cone sites" had only one lane open while some of the situations for the other two "treatments" were 2- or even 3-lane sites. Considering for barrel/drum closure/separation, the table allows comparison between the average speeds with two lanes open and both 60 and 50 mph speed limits in effect—the difference is less than one mph (65 vs. 64.1). Likewise, the average speeds are also shown with only one lane open with both 60 and 50 mph speed limits—again, the difference is less than one mph (58.0 vs. 58.8). The number of open lanes seems to have a greater effect than the type of closure/separation although motorist speeds when barrier walls are present are always higher than the when they are not.

SUMMARY, DISCUSSION, AND CONCLUSIONS

The purpose of this study was to determine the effectiveness of various standard speed limits in work zones on freeway-type roadways in Michigan which had regular (non-construction) speed limits of 70 mph. The study was undertaken during the summer and fall of 1997. The speed limits that were studied included: **60 mph** for sites where more extensive, non-maintenance projects were being done and workers **were not** present; **50 mph** for sites where more extensive, non-maintenance projects were being done and workers generally **were** present; and **45 mph** for sites where maintenance work was being done. While most sites were posted with these limits according to the "rules" noted, there were some exceptions (e.g., 45 or 50 mph when geometry was very restrictive). Sites were located on interstate and US-numbered routes in Michigan and generally outside of metropolitan areas (this was to allow collection of data on "free-flow" traffic which was not slowed by congestion—i.e., motorists would be more likely responding to the posted speed limits and characteristics of the work zones and **less** the behavior of the vehicles in front of them as would be the case in a congested situation). A concerted attempt was made to separate the effects of the posted speed limits from those of other work zone characteristics (e.g., the presence or absence of workers, the number of lanes that were open).

Traffic data were collected at 35 sites in approximately 2-hour time blocks using a videocamera-based surveillance system and reduced using the Autoscope® system. The data available for analysis included average speeds for 5-minute periods, other traffic characteristics, and a variety of information about the work zones themselves (e.g., posted speed limit, type of work, type of lane closure/separation device, location of workers present).

Initial results from this project were reported in an earlier draft report and were "validated" and extended as part of the more extensive analysis that was undertaken and reported on here. As part of that analysis, some earlier field data were recalibrated and some data/sites were eliminated (or at least handled separately) because of irregularities, unique site conditions, or other reasons. This resulted in a modified data file which was used in the more recent analysis.

SUMMARY OF RESULTS AND DISCUSSION

The summary of results reported below is based on analysis primarily done on the modified data files.

OVERALL SPEEDS IN WORK ZONES

Notwithstanding differences in observed speeds in work zones which may be due to a combination of factors including the presence/absence of workers, the type of lane closure/separation, and the number of open lanes, it is clear that speeds in construction zones are generally higher than the posted limits when the traffic is relatively free-flowing (i.e., not slowed by congestion or some incident). At a posted speed limit of 60 mph, the average observed speed is almost 65.9 mph; at 50 mph, the observed average is 61.1 mph; and at a posted limit of 45 mph, the observed speed is 53.5 mph. By the same token, the average speeds observed ***after*** the work zone is removed are also greater than the posted limit, 72.3 mph for a 70 mph limit.

So, when motorists are asked to slow from their nominal speed of 70 to 60 mph, or 10 mph, they respond with an actual reduction of ~6 mph (they slow from an average of ~72 to an average of ~66); when asked to slow from 70 (to 60) to 50, or 20 mph, they slow ~11 mph; and, finally, when asked to slow from 70 to 45 (in one step), or 25 mph, they decrease ~19 mph. While motorists respond to work zones by slowing down, they do not slow down to the posted speed—indeed, their speeds through work zones are disproportionately greater than they are when the work zones are not present (i.e., they exceed the work zone speed limits by a greater increment than the normal speed limit). The greatest speed reduction, which occurs in 45 mph zones, may well be a result of the number of open lanes (see next section).

THE EFFECT OF THE NUMBER OF OPEN LANES IN WORK ZONES

A large portion of the speed reduction in work zones appears to be due to the number of open lanes. Overall, 3-lane work zones (no lane closures) experienced the highest speeds, 69.0 mph, versus 2-lane zones (one lane reduced) with an average speed of 65.0 mph and 1-lane zones at 55.3 mph. However, the lane effect was most noticeable when sites with the same number of open lanes but different posted limits were compared: for two open lanes, average speeds for 60 mph and 50 mph limits were, respectively, 65.1 and 64.1 mph; with only one open lane, the average speeds ranged from 53.5 mph (45 mph limit) to 58.0 mph (50 mph limit) to 58.8 mph (60 mph limit). Looked at these figures the other way around, with a 60 mph posted limit, 1-, 2-, and 3-lane sections experienced average speeds of 58.8, 65.1, and 69.0 mph; with a 50 mph limit, 1- and 2-lane sections experienced average speeds of 58.0 and 64.1, respectively. That is, moving from one open lane to two resulted in an average speed increase of just over 6 mph, regardless of whether the limit is 50 or 60 mph. Having a third lane open resulted in another 4 mph increase.

While the results associated with the number of lanes are not particularly surprising at one level—it would be expected that even in uncongested conditions restricting traffic to one lane would result in speed decreases—the fact that the lane configuration may be as important as the posted limit is somewhat unexpected. It seems reasonably clear that an attempt to keep capacity as high

as possible during construction (maximize the number of open lanes) will likely result in higher speeds through the construction zones—at least in uncongested situations.

THE EFFECT OF WORKERS BEING PRESENT

If the apparent magnitude of the effects of the number of lanes was a little surprising, the lack of equally clear effects due to the presence of workers was as well. In some instances, the presence of workers appeared to contribute to a decrease in motorist speeds and in some instances it did not—the results were inconsistent.

Interestingly, at three atypical sites, worker presence generally seemed to have the effect of decreasing motorist speeds. Most striking was one case where the workers were present under the bridge from which data were being collected—no signs for the work zone were present and there was no lane closure, the "unannounced" workers were working at the roadside. In this instance, a speed reduction of 8.4 mph was realized (compared to the average speed at the site when no workers or work zone traffic control devices were present).

THE EFFECT OF TYPE OF LANE CLOSURE/SEPARATION

In general, the analysis that was done indicated that the three types of lane closure/separation that were studied, barrier walls, barrels/drums, and cones, were associated with different average speeds, 67.4, 61.5, and 53.7 mph, respectively. It could be argued that motorists are willing to go faster through a work zone if they are separated from the work that is going on by a more substantial barrier, and that appeared to be the case.

However, the results that were presented also showed that there was a distinct relationship between the use of the three devices and lane configuration. For the sites studied, barrier walls were used when two or three lanes were open (and 60 mph posted limits), barrels/drums were used for in situations where one or two lanes were open (and speed limits of 60, 50, and 45 mph), and cones were used only when the speed limit was 45 mph and only one lane was available. Moreover, it was noted that for barrels/drums the observed speeds were the same when the number of lanes available was the same, independent of differences in the posted speed limit.

To some degree the effect of type of lane closure/separation is obscured by the situations in which they are used. However, the effect does not seem to be great based on the data available here.

LIMITATIONS OF THE STUDY

There are some limitations to the study and the methodology that should be mentioned. First, as noted, the sites were opportunistically selected and there was no control over when and where construction would be done or what types of traffic control devices would be used. Second, there was a significant range in the type of sites studied—from heavily-used commuter routes which were congested at some (non-data collection) times of day to rural sites with relatively low volumes. These "site" effects were not studied in any systematic way. Third, the data collection sites, while consistent from during to after, were not consistent with respect to placement within

the work zone or in relation to where workers, if present, were located. Finally, the experiment design was not a "full-factorial" design wherein there were sites included which covered all possible combinations of the independent variables. This limited some of the analyses that could be done (e.g., interaction effects in the ANOVAs could not be examined). It should also be noted that while average speeds are typically given throughout the report to the nearest 0.1 mph, that accuracy is most likely not really achieved by the equipment that was used.

These caveats notwithstanding, the data that were collected are thought to be reasonably representative of what went on at a fairly large number of freeway work sites throughout lower Michigan during the 1997 construction season. The general trends of the effects of posted speed limits in work zones and those of the other independent variables are reported with reasonable confidence.

CONCLUSIONS

The primary purpose of this study was to evaluate the effect of posted speed limits in work zones on motorist speeds. Several other factors were also hypothesized to have an effect on motorist speeds in work zones on a day-to-day basis: type of lane closure/separation, presence/absence of workers, and the number of lanes open to travel through the zone. Another factor which looms large is, obviously, congestion which results from lane and lane-width reductions—sites for this study were chosen to explicitly minimize the contribution of congestion given that assessing motorist reaction to posted speed limits was the principal objective.

While it is difficult to accurately separate the effects of the various factors that influence the speeds of motorists in work zones or to identify **all** of the relevant factors at any point in time, it is known from this study that, for the sites studied, lower speeds were observed when lower speed limits were posted. Equally clear is the fact that although lower speeds were observed, they are significantly higher than the posted limits and disproportionately higher (in work zones) than they are otherwise at these same sites. That is, the differences between observed speeds and posted limits are greater when work zones are present than when they are not.

With respect to the effectiveness of the posted limits themselves, it is important to note that different limits are almost always associated with different types of lane closure/separations and lane configurations. The relationship between speed and the number of available lanes is not unexpected, but it seems clear that there is a dilemma to be confronted between the conflicting objectives of slowing motorists through work zones and minimizing delay. Limiting the number of lanes available will generally result in lower speeds but motorist delay will clearly increase, and opening more lanes will invariably result in higher speeds, apparently independent of the posted limit.

If compliance with posted limits is desirable, it seems clear from this study that something more than the standard speed limit signs will have to be used in work zones. Options would include enhanced signs and/or increased enforcement.

APPENDIX A

SITE-BY-SITE RESULTS

SITE-BY-SITE RESULTS

The results that follow are organized on a site-by-site basis in the same order as tahe summary table (table 1) which was presented in the report and is reproduced on the following page for convenience. For each site, there is a standard format showing the characteristics of the work being done, the site itself, and the speed-related results. In addition to the "form," a single summary graph is presented for each site. All of the supporting results tables and more detailed graphs were in the ***Initial Report*** and are not provided again here.

Summary of Initial Results										
type of site and identification	work/ closure type[1]	worker presence	regular speed limit	average speeds		speed limit during	average speeds			comments
				before	after		during 1	during 2	during 3	
70-60										
I-96 EB @ Dorr Road	long-term	no	70	--	--	60	65.9	--	--	2 lanes[2]
I-96 WB @ Dorr Road	long-term	yes	70	--	--	60	60.5	--	--	2 lanes[2]
I-96 EB @ Kensington Road	long-term	no,yes[4]	70	--	68.7	60	68.7	66.3	--	3 lanes[3,4]
I-96 WB @ Kensington Road	long-term	no,yes[4]	70	--	--	60	72.3	68.2	--	3 lanes[3,4]
I-96 EB @ Pleasant Valley Road	long-term	yes	70	--	74.7	60	74.4	--	--	3 lanes[3]
I-96 WB @ Chilson Road	long-term	yes	70	--	--	60	69.3	--	--	2 lanes[2]
US-10 WB @ Flajole Road	long-term	no	70	--	62.6	60	61.7	--	--	1 lane[12]
US-10 WB @ Bay City Road	long-term	no	70	--	66.9	60	56.5	--	--	1 lane[12]
US-10 WB @ W. River Road	long-term	no	70	--	--	60	60.6	--	--	1 lane
I-94 WB @ Hall Road	long-term	no	70	--	--	60	66.3	--	--	2 lanes[2]
I-69 WB @ exit 184	long-term	yes	70	--	71.5	60	56.1	--	--	1 lane
I-275 NB @ Cherry Hill	long-term	no	70	--	71.2	60	68.1	--	--	2 lanes[2]
I-275 NB @ Hannan Road	long-term	yes,no,no	70	--	71.6	60	65.4	65.5	64.0	2 lanes[2,5]
I-275 SB @ Hannan Road	long-term	no,no	70	--	67.4	60	63.9	60.5	--	2 lanes[2]
I-275 NB @ Ecourse Road	long-term	yes	70	--	72.5	60	--	64.7	--	2 lanes[2]
70-60-50										
I-96 EB @ Chilson Road	long-term	no	70	--	66.8	50	63.0	--	--	2 lanes[2,13]
US-10 WB @ M-18	long-term	yes	70	--	--	50	57.3	--	--	1 lane
I-94 EB @ Michigan Avenue	long-term	no	70	--	73.6	50	58.6	--	--	1 lane
I-275 NB @ Ecourse Road	long-term	yes	70	--	72.5	50	64.0	--	--	2 lanes[2,6],police
I-275 NB @ Joy Road	long-term	no	70	--	--	50	30.5	--	--	2 lanes[2,7,14]
70-50										
I-69 WB @ Miller Road	long-term	yes	70	--	64.8	50	53.9	--	--	1 lane
70-45										
I-96 EB @ Nicholson Road	maint	yes	70	--	74.8	45	52.0	--	--	1 lane
I-96 EB @ Exit 129	maint	yes	70	--	69.7	45	46.3	--	--	1 lane
I-96 WB @ Exit 133	maint	yes	70	--	73.8	45	69.0	--	--	2 lanes[2]
I-69 EB @ Lake Nepessing Road	maint	yes	70	--	70.0	45	57.3	--	--	1 lane
US-27 NB @ Base Line Road	long-term	yes	70	--	75.2	45	50.3	--	--	1 lane
US-27 SB @ Base Line Road	long-term	yes	70	--	--	45	48.8	--	--	1 lane
US-127 NB @ Barnes Road	maint	yes	70	73.8	71.7	45	54.0	--	--	1 lane

Summary of Initial Results										
type of site and identification	work/ closure type[1]	worker presence	regular speed limit	average speeds		speed limit during	average speeds			comments
				before	after		during 1	during 2	during 3	
US-127 NB @ Henry Road	maint	yes	70	--	76.0	45	56.7	--	--	1 lane
US-131 SB @ M-46	maint	yes	70	--	70.6	45	59.5	--	--	1 lane
US-23 SB @ Carpenter Road	long-term	yes	70	--	78.0	45	52.7	--	--	1 lane
US-23 NB @ Carpenter Road	long-term	no	70	--	72.0	45	54.5	--	--	1 lane
US-23 SB @ Geddes Road	maint	no	65	--	73.5	45	61.8	--	--	1 lane[9,14]
M-14 EB @ Dixboro Road	maint	yes	70	--	73.3	45	56.0	--	--	1 lane[9]
M-14 WB @ Dixboro Road	maint	yes	70	--	70.8	45	38.7	--	--	1 lane[9,14]
other										
I-69 WB @ Miller Road	maint	yes	70	--	64.8	70	--	60.3	--	2 lanes[8]
I-496 EB @ Washington	long-term[10]	yes	55	--	--	55	56.4	--	--	2 lanes[11]
I-496 WB @ Washington	long-term[10]	no,yes	55	--	--	55	59.5	61.8	--	2 lanes[11]

notes:
[1] long-term >2 weeks, maint <2 weeks
[2] lane reduction from 3 to 2 lanes, 2 lanes open
[3] no lane reduction, shoulder used as lane, 3 lanes open, work in median
[4] workers not present for "during 1," present for "during 2"
[5] workers present for "during 1," not present for "during 2" and "during 3"
[6] police present in area
[7] changeable message sign present
[8] for "during 2," both lanes open and no speed limit reduction; for supporting graph and tables, see I-69 @ Miller 70-50 materials
[9] closed lane was opened during data collection for "during" period—average speed is not representative of period when lane closed
[10] work was long-term but worker presence and lane closures were sporadic
[11] both regular lanes were open, work was on shoulder
[12] snow showers experienced during "after" period
[13] significant geometric changes in lane shift
[14] eliminated from much of analysis because of congestion effects on speed

70→60 SITES

Generally, these sites were more longer-term with more substantial work being done over the course of the construction season. In most instances, lane closures were of a more permanent type—e.g., barrier walls adjacent to the lanes that remained open. More often than not, workers were not present when data were collected. There was no "before" data collection for any of these sites. For convenience purposes, each site begins a new page.

I-96 EB @ Dorr Road

Location: Howell, exit 142.
Direction: Eastbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

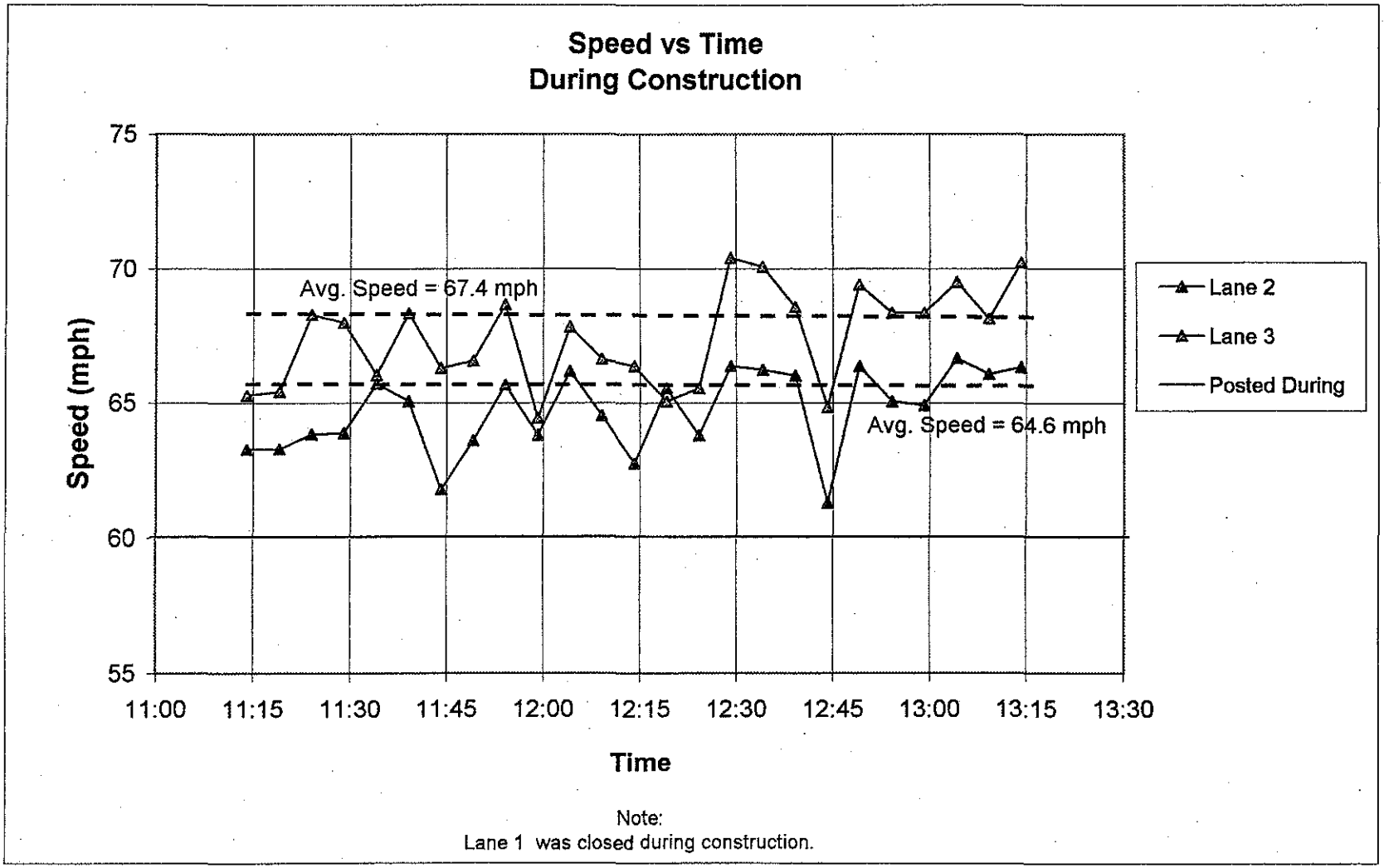
During Data Collection
Date and Time: Monday, 8/18/97, 11:05 AM-1:05 PM
Weather: Sunny
Speed Limit During Construction: 60
Type of Work Done: Resurfacing and rehabilitation of all lanes
Lane Closure(s): Slow lane closed, 2 open (on WB side)
Lane Shift: Yes (two lanes shifted toward WB traffic)
Type of Lane Closure: Barrier walls separated EB traffic from slow lane and WB traffic
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 65.9
Other Information: Slow lane was open only to traffic entering from entrance 141 and did not serve regular EB highway traffic

After Data Collection

None

Comments: Two lanes of traffic were constantly maintained and there was little direct interaction between the travel lanes and the construction activities.

EB I-96@Dorr Rd.
08/18/97



Note:
Lane 1 was closed during construction.

I-96 WB @ Dorr Road

Location: Howell, exit 142
Direction: Westbound
Number of Lanes Without Construction: 3 (lanes shared with EB traffic)
Regular Speed Limit: 70

Before Data Collection

None

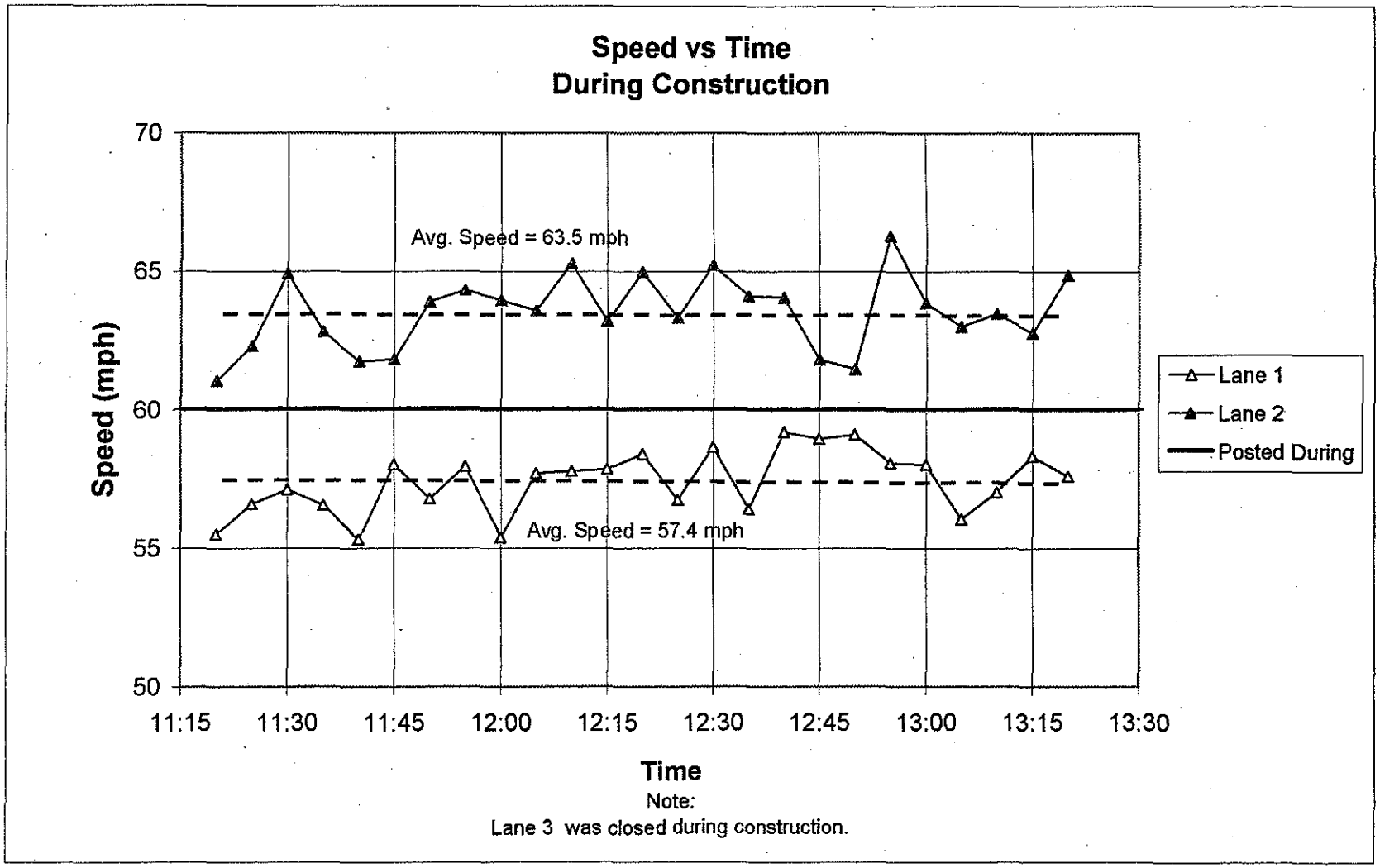
During Data Collection
Date and Time: Monday, 8/18/97, 11:20 AM-1:20 PM
Weather: Sunny
Speed Limit During Construction: 60
Type of Work Done: Resurfacing and rehabilitation of all lanes
Lane Closure(s): Passing lane closed, 2 open
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Barrier walls separate traffic from EB traffic
Special Traffic Control: No
Workers Present During Data Collection: Yes, very little interaction
Police Present During Data Collection: No
Average Speed: 60.5
Other Information: Right shoulder used as slow lane

After Data Collection

None

Comments: This site was similar to the eastbound site except for worker presence and the use of the shoulder as a travel lane. Either one or both of these characteristics could have contributed to the lower average speed.

WB I-96@Dorr Rd.
08/18/97



I-96 EB @ Kensington Road

Location: Brighton, exit 151
Direction: Eastbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

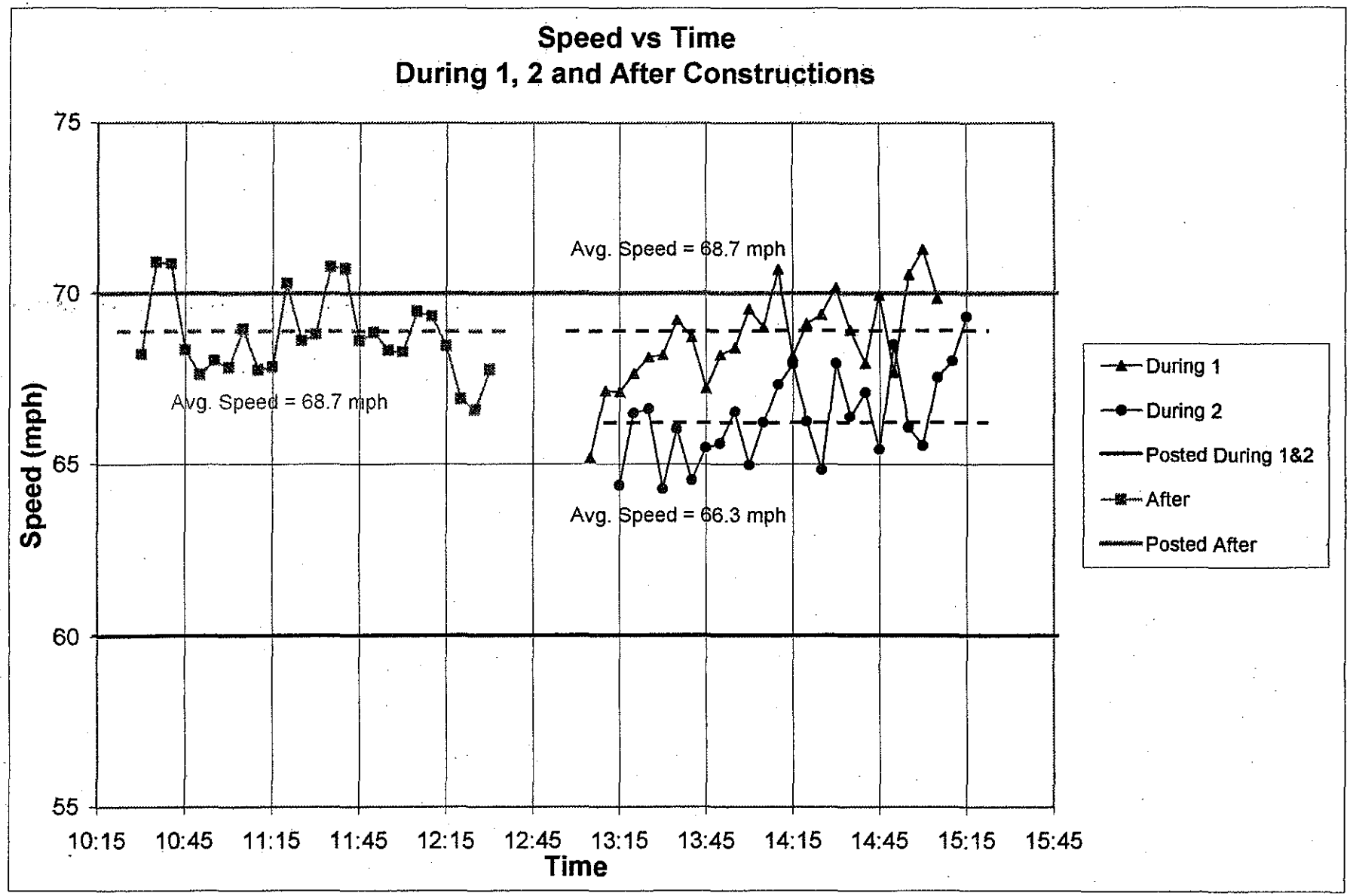
During Data Collection 1
Date and Time: Thursday, 7/17/97, 1:00 PM-3:00 PM
Weather: Cloudy
Speed Limit During Construction: 60
Type of Work Done: Median work
Lane Closure(s): Left lane closed, 3 open (narrowed lanes)
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Barrier walls separated traffic from left lane
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 68.7
Other Information: Right shoulder used as slow (3rd) lane, rumble strips on lane 1

During Data Collection 2 (conditions same as 1 except as noted)
Date and Time: Tuesday, 8/19/97, 1:10 PM-3:10 PM
Weather: Sunny
Workers Present During Data Collection: Yes, in median area (within ¼ mile upstream)
Average Speed: 66.3
Other Information: Right shoulder used as slow (3rd) lane

After Data Collection
Date and Time: Tuesday, 11/25/97, 10:30 AM-12:30 PM
Weather: Partly cloudy
Average Speed: 68.7

Comments: The "during" speeds are not that different from one another although when workers were present, the average was slightly lower. The similarity of the "after" average speed tends to support the inference that there was little speed reduction actually due to the construction activities. After data were, however, collected somewhat earlier in the day.

EB I-96@Kensington Rd.
7/17/97, 8/19/97 and 11/25/97



I-96 WB @ Kensington Road

Location: Brighton, exit 151
Direction: Westbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

During Data Collection 1
Date and Time: Thursday, 7/17/97, 1:10 PM-3:10 PM
Weather: Cloudy
Speed Limit During Construction: 60
Type of Work Done: Median work
Lane Closure(s): Left lane closed, 3 open lanes, narrowed
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Barrier walls separated traffic from left lane
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 72.3
Other Information: Right shoulder used as slow (3rd) lane, rumble strips in lane 1

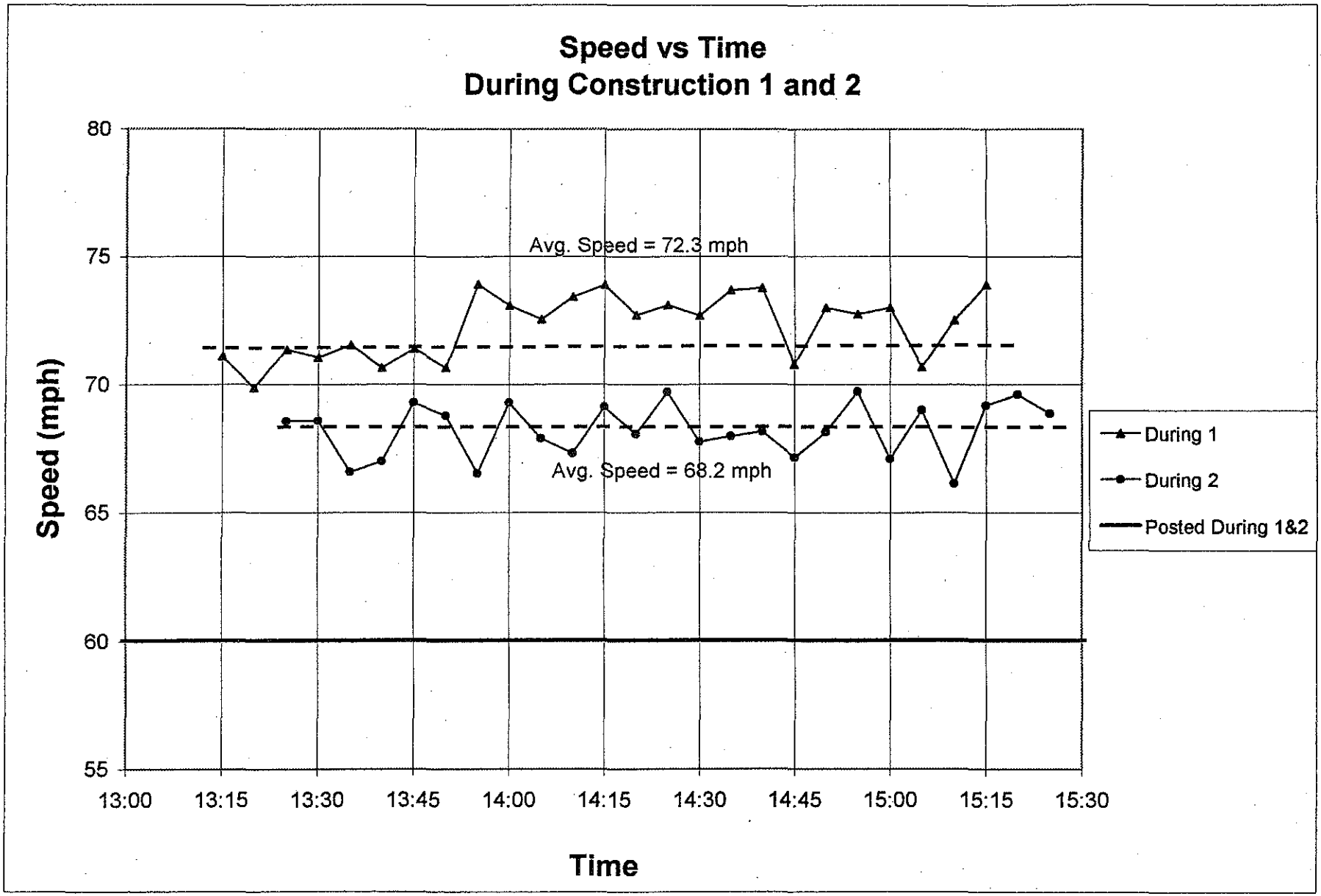
During Data Collection 2 (conditions same as 1 except as noted)
Date and Time: Tuesday, 8/19/97, 1:25 PM-3:25 PM
Weather: Sunny
Workers Present During Data Collection: Yes, in median area (within ¼ mile upstream)
Average Speed: 68.2

After Data Collection

None

Comments: Lower average speeds are again noted when workers are present although they are still quite high relative to the posted speed limit.

WB I-96@Kensington Rd.
7/17/97 and 8/19/97



I-96 EB @ Pleasant Valley Road

Location: Brighton, exit 150
Direction: Eastbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

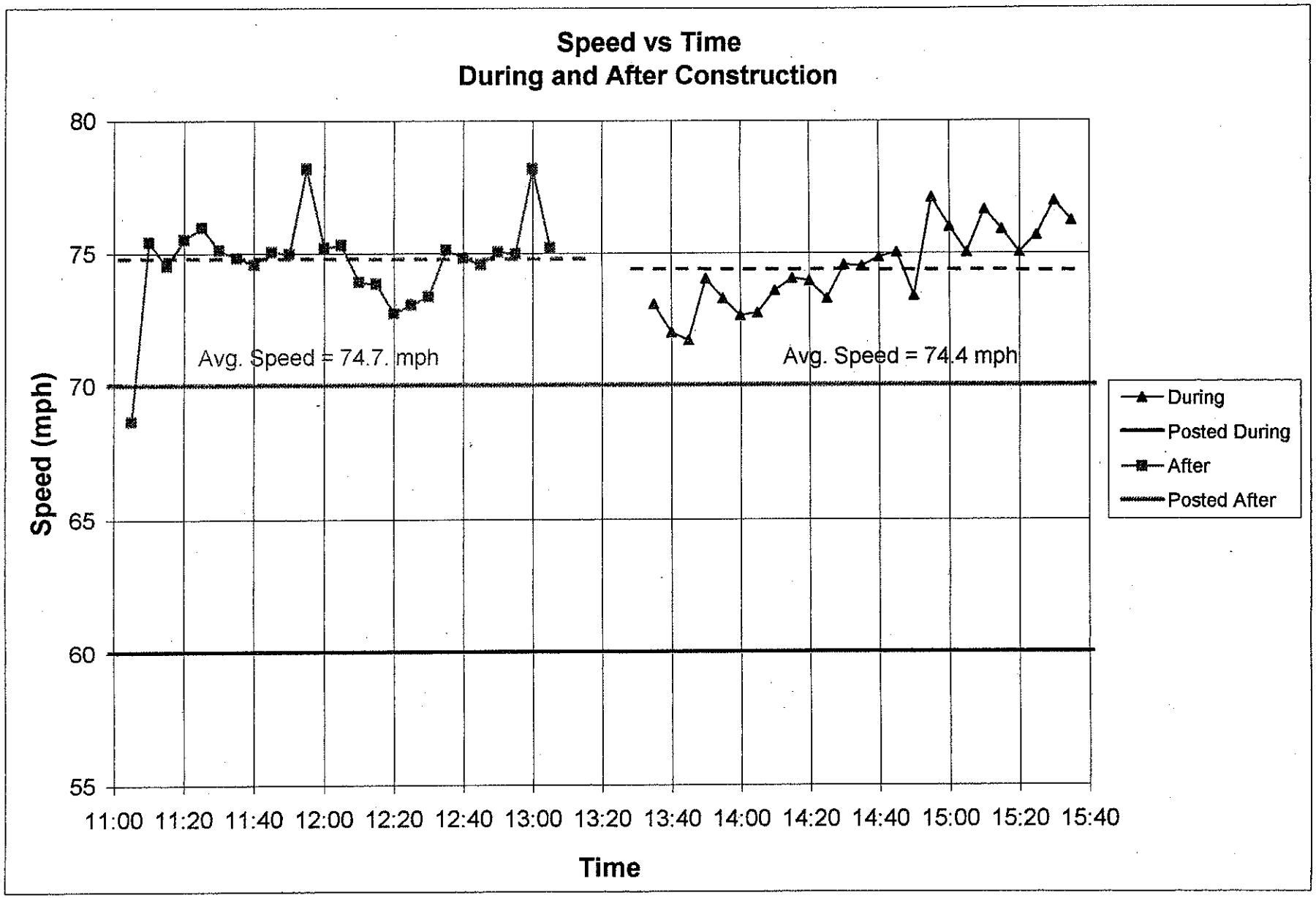
None

During Data Collection
Date and Time: Tuesday, 7/15/97, 1:30 PM-3:30 PM
Weather: Cloudy
Speed Limit During Construction: 60
Type of Work Done: Median work
Lane Closure(s): Left lane closed, 3open
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Barrier walls separated traffic from left lane
Special Traffic Control: No
Workers Present During Data Collection: Yes (in the median within ½ mile)
Police Present During Data Collection: No
Average Speed: 74.4
Other Information: Right shoulder used as slow (3rd) lane

After Data Collection
Date and Time: Tuesday, 11/25/97, 11:00 AM-1:00 PM
Weather: Partly cloudy
Average Speed: 74.7

Comments: Compared to similar sites (Kensington Road), the average speed was still quite high even though workers were present. The time of day was somewhat different however.

EB I-96@Pleasant Valley Rd.
7/15/97 and 11/25/97



I-96 WB @ Chilson Road

Location: Howell, exit 141
Direction: Westbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

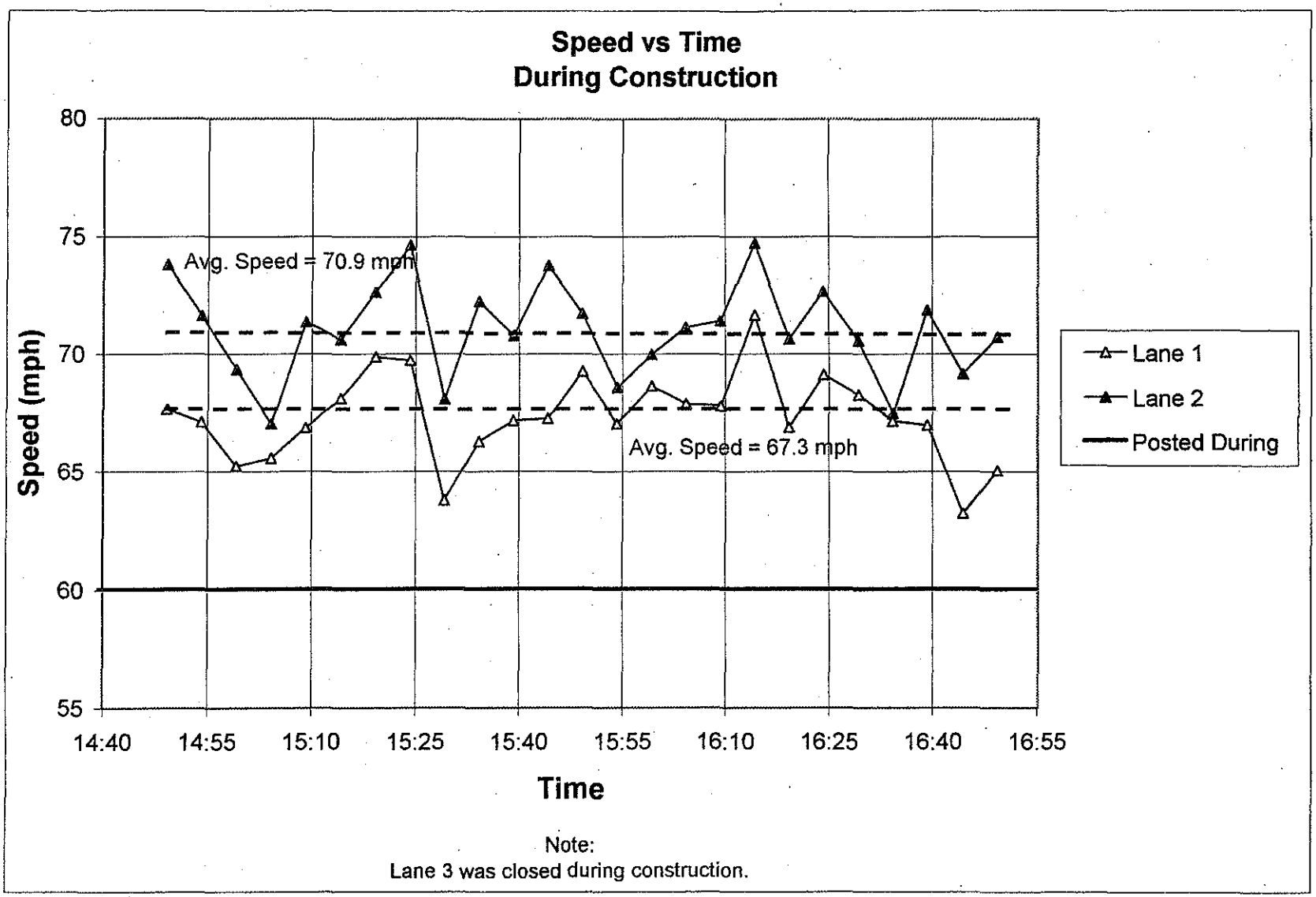
During Data Collection
Date and Time: Monday, 8/18/97, 2:50 PM-4:50 PM
Weather: Sunny
Speed Limit During Construction: 60
Type of Work Done: Resurfacing and rehabilitation of all EB lanes
Lane Closure(s): Passing lane closed, 2 open, lanes narrowed
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Barrier walls separated WB traffic from EB traffic
Special Traffic Control: No
Workers Present During Data Collection: Yes, little interaction, workers on other side
Police Present During Data Collection: No
Average Speed: 69.3
Other information: Right shoulder used as slow lane

After Data Collection

None

Comments: The average speeds observed at this site is reasonably consistent with those observed at other sites where workers were present.

WB I-96@Chilson Rd.
11/25/97



Note:
Lane 3 was closed during construction.

US-10 WB @ Flajole Road

Location: Midland
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

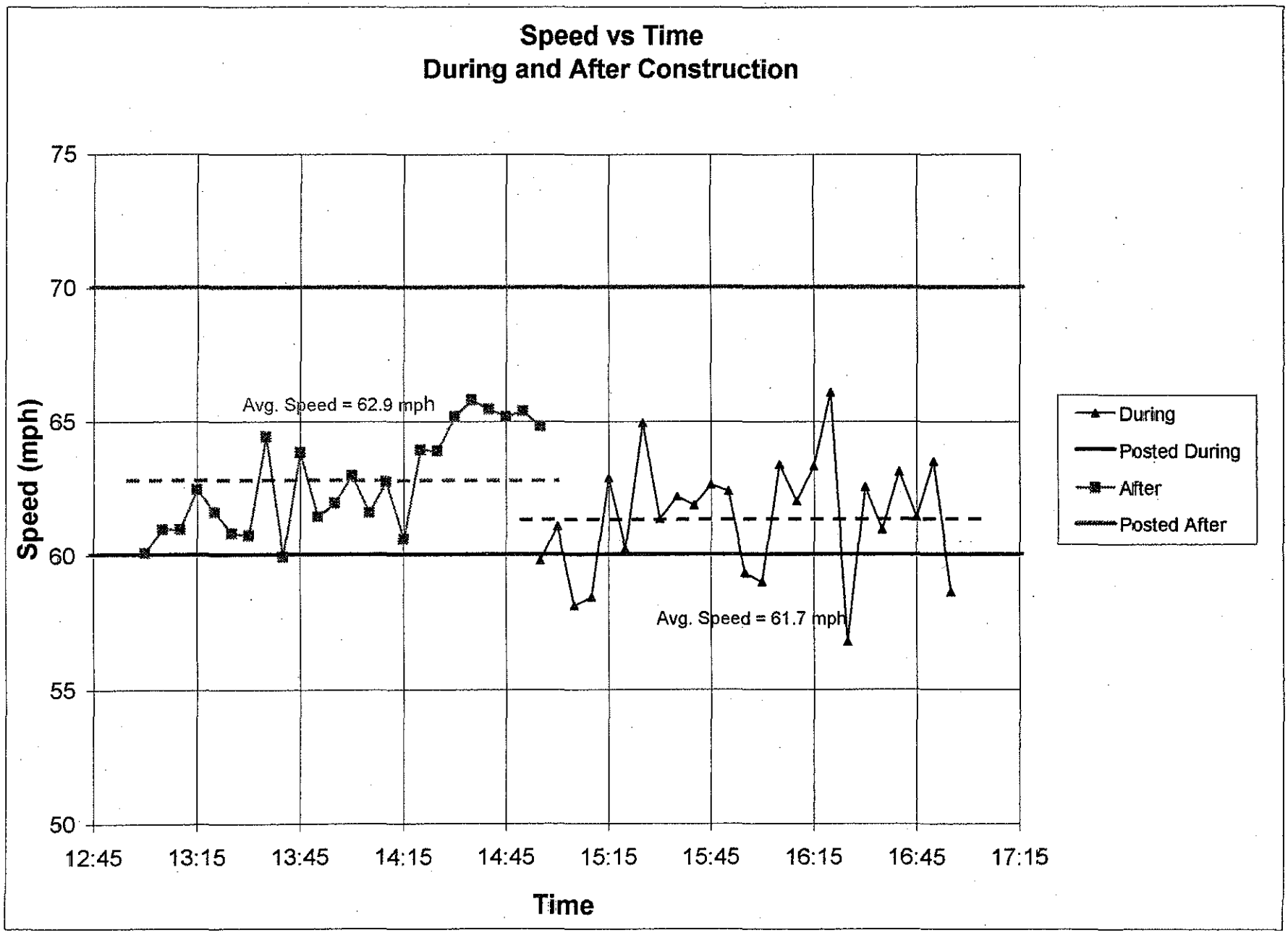
None

During Data Collection
Date and Time: Tuesday, 10/14/97, 2:55 PM-4:55 PM
Weather: Cloudy, windy
Speed Limit During Construction: 60
Type of Work Done: Bridge/deck repair
Lane Closure(s): Slow lane closed, only 1 lane open
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 61.7
Other Information: Site was located at the start of the construction zone

After Data Collection
Date and Time: Tuesday, 11/11/97, 1:00 PM-2:55 PM
Weather: Snow showers, windy
Average Speed: 62.6

Comments: The average speeds observed at this site are somewhat lower than those observed at the I-96 sites. This could be due to a variety of reasons including: lower volumes, different environment, proximity of construction activity (although no workers were present) and the nature of the lane closure (drums versus barriers), and the fact that only one lane was open. The only slightly higher "after" average speeds seem low for the site but may be partially due to weather conditions.

WB US-10@Flajole Rd.
10/14/97 and 11/11/97



US-10 WB @ Bay City Road

Location: Midland
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

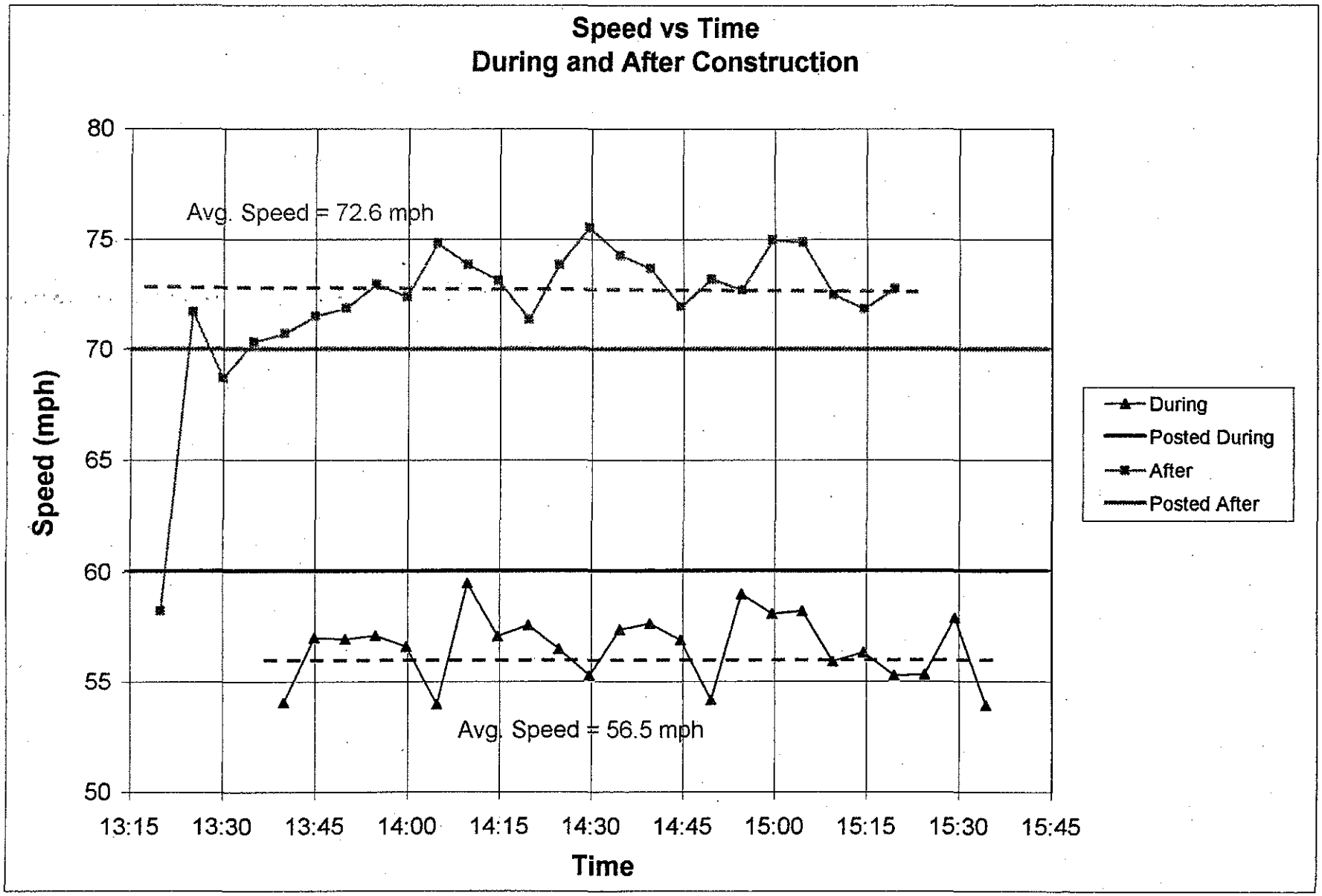
None

During Data Collection
Date and Time: Tuesday, 10/14/97, 1:35 PM-3:35 PM
Weather: Cloudy, windy
Speed Limit During Construction: 60
Type of Work Done: Bridge/deck repair
Lane Closure(s): Slow lane closed, only 1 open
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 56.5

After Data Collection
Date and Time: Tuesday, 11/11/97, 1:20 PM-3:20 PM
Weather: Snow showers, windy
Average Speed: 66.9

Comments: The lower speeds during the work period at this site are probably due, in part, to the fact that only one lane is open even though no workers were present. The average speeds both during and after the work are very near to what would be desired.

WB US-10@Bay City Rd.
10/14/97 and 11/11/97



US-10 WB @ W. River Road

Location: North of Midland
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

None

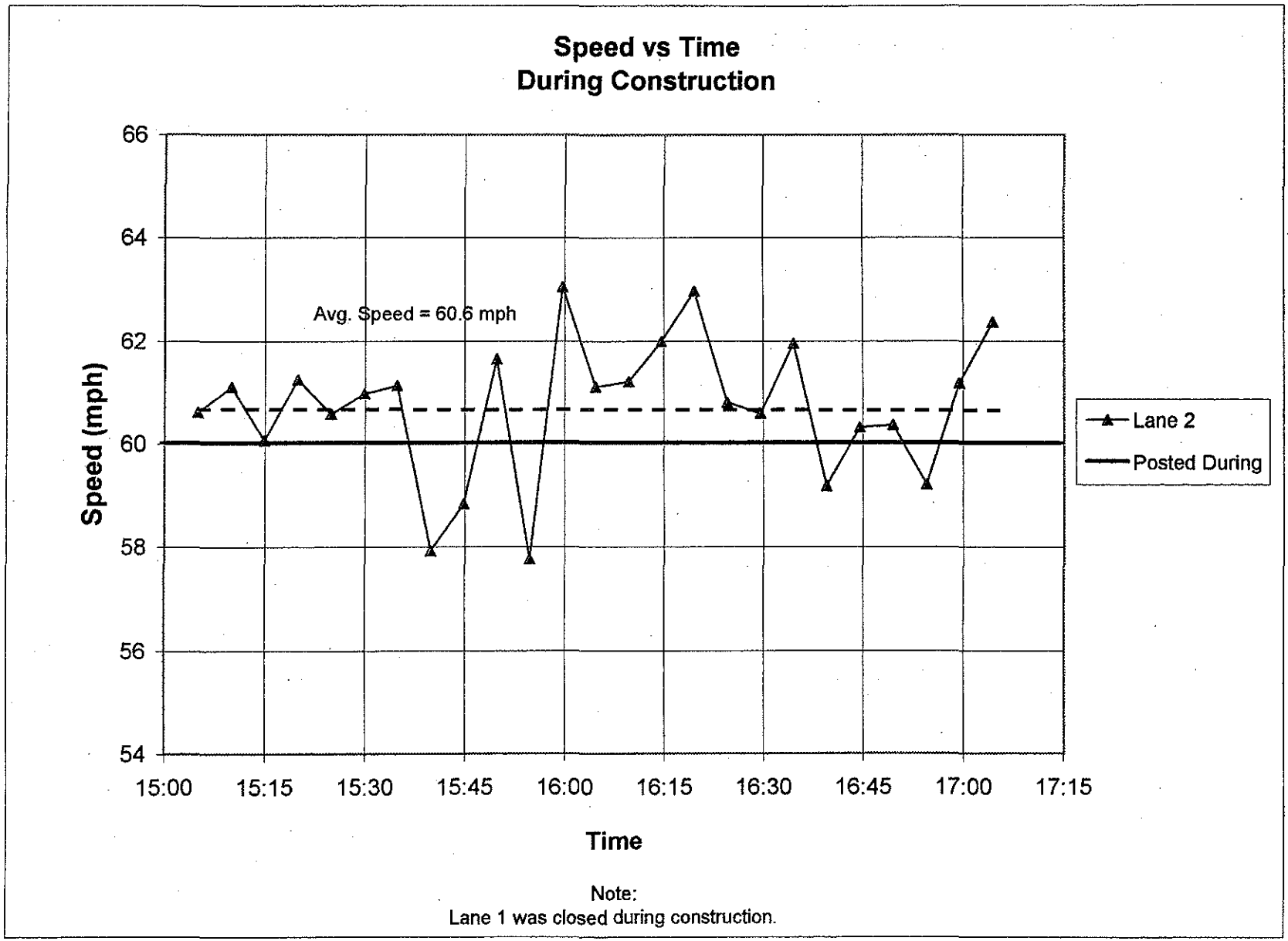
During Data Collection
Date and Time: Friday, 10/17/97, 3:00 PM-5:00 PM
Weather: Partially cloudy, windy
Speed Limit During Construction: 60
Type of Work Done: Joint repair of right lane
Lane Closure(s): Slow lane closed, only 1 lane open
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 60.6

After Data Collection

None

Comments: Again the low speeds "during" are most likely attributable to the fact that only one lane is open. The presence of the drums may also provide the allusion that workers are more likely to be present (even though they are not).

WB US-10@W. River Rd.
10/17/97



Note:
Lane 1 was closed during construction.

I-94 WB @ Hall Road

Location: South of Port Huron, exit 240
Direction: Westbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

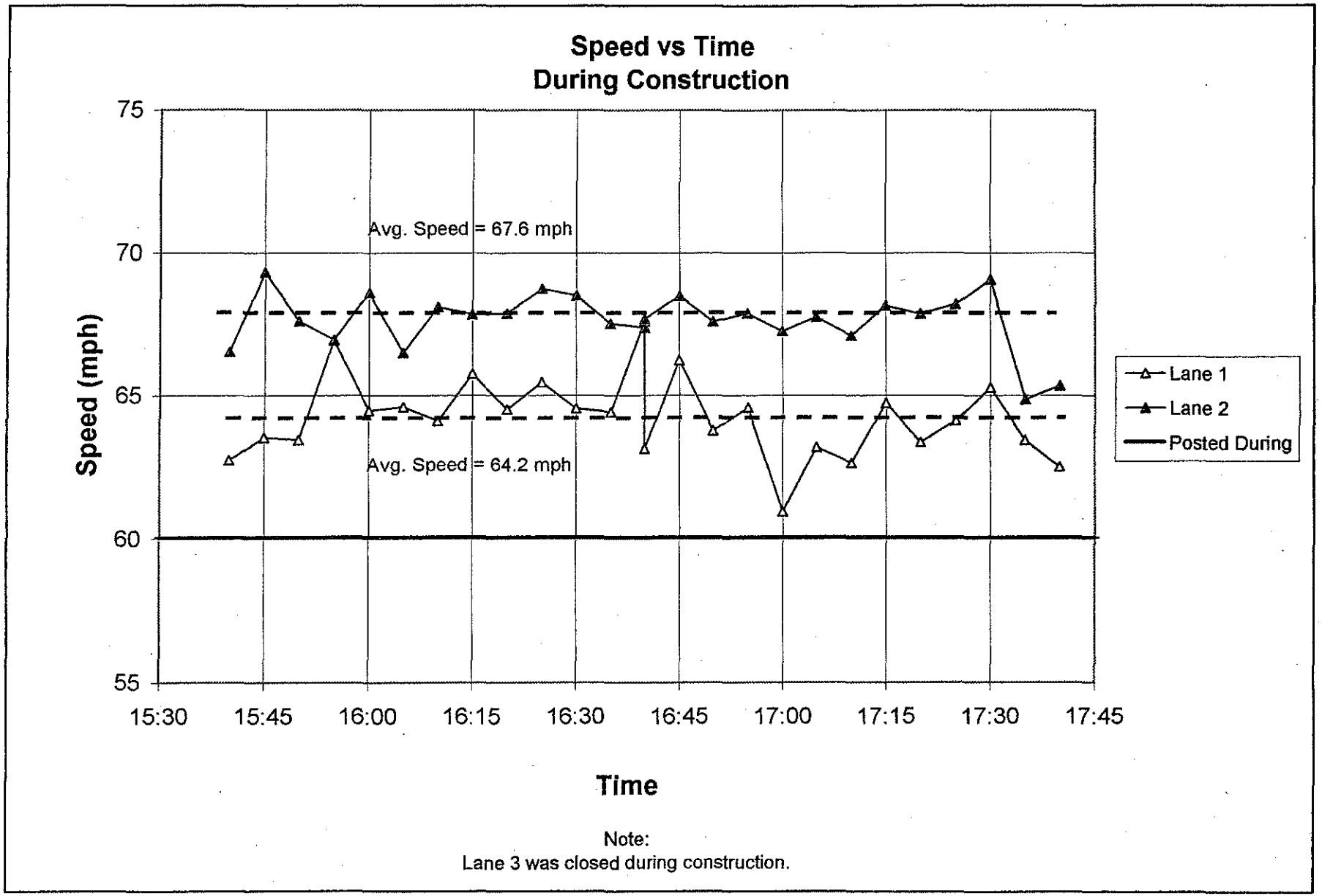
During Data Collection
Date and Time: Friday, 8/29/97, 3:40 PM-5:40 PM
Weather: Sunny
Speed Limit During Construction: 60
Type of Work Done: New bridge construction
Lane Closure(s): Passing lane closed, 2 lanes open
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 66.3
Other comments: The site was close to a new bridge construction site, approximately ¼ mile east of Hall Road.

After Data Collection

None

Comments: Average speeds during construction are again fairly high. This is probably most likely attributable to the fact that 2 lanes remain open to traffic.

WB I-94@Hall Rd
8/29/97



Note:
Lane 3 was closed during construction.

I-69 WB @ Exit 184

Location: West of Port Huron
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

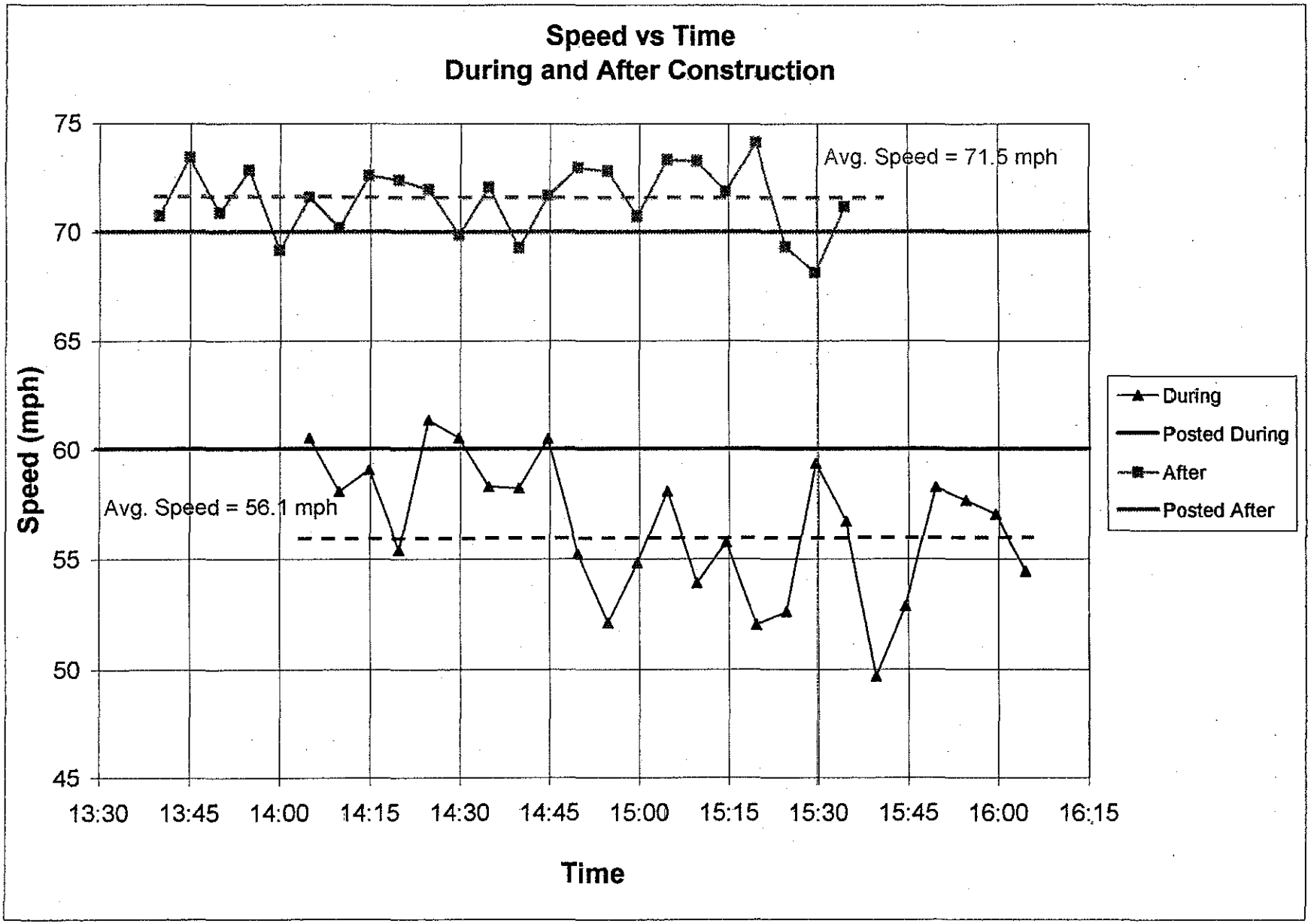
None

During Data Collection
Date and Time: Monday, 9/22/97, 2:00 PM-4:00 PM
Weather: Partly cloudy
Speed Limit During Construction: 60
Type of Work Done: Joint repair of right lane
Lane Closure(s): Slow lane closed, only one lane open
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, within ¼ mile
Police Present During Data Collection: No
Average Speed: 56.1

After Data Collection
Date and Time: Thursday, 10/30/97, 1:35 PM-3:35 PM
Weather: Partly sunny, windy
Average Speed: 71.5

Comments: The speeds are more or less as would be hoped for—with average speeds being relatively low when workers are present. The lower-than-posted average speeds during are presumably due to the fact that workers were present and that the lane closure was accomplished with cones only.

WB I-69@Exit 184
9/22/97 and 10/30/97



I-275 NB @ Cherry Hill Road

Location: Novi, near exit 25
Direction: Northbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

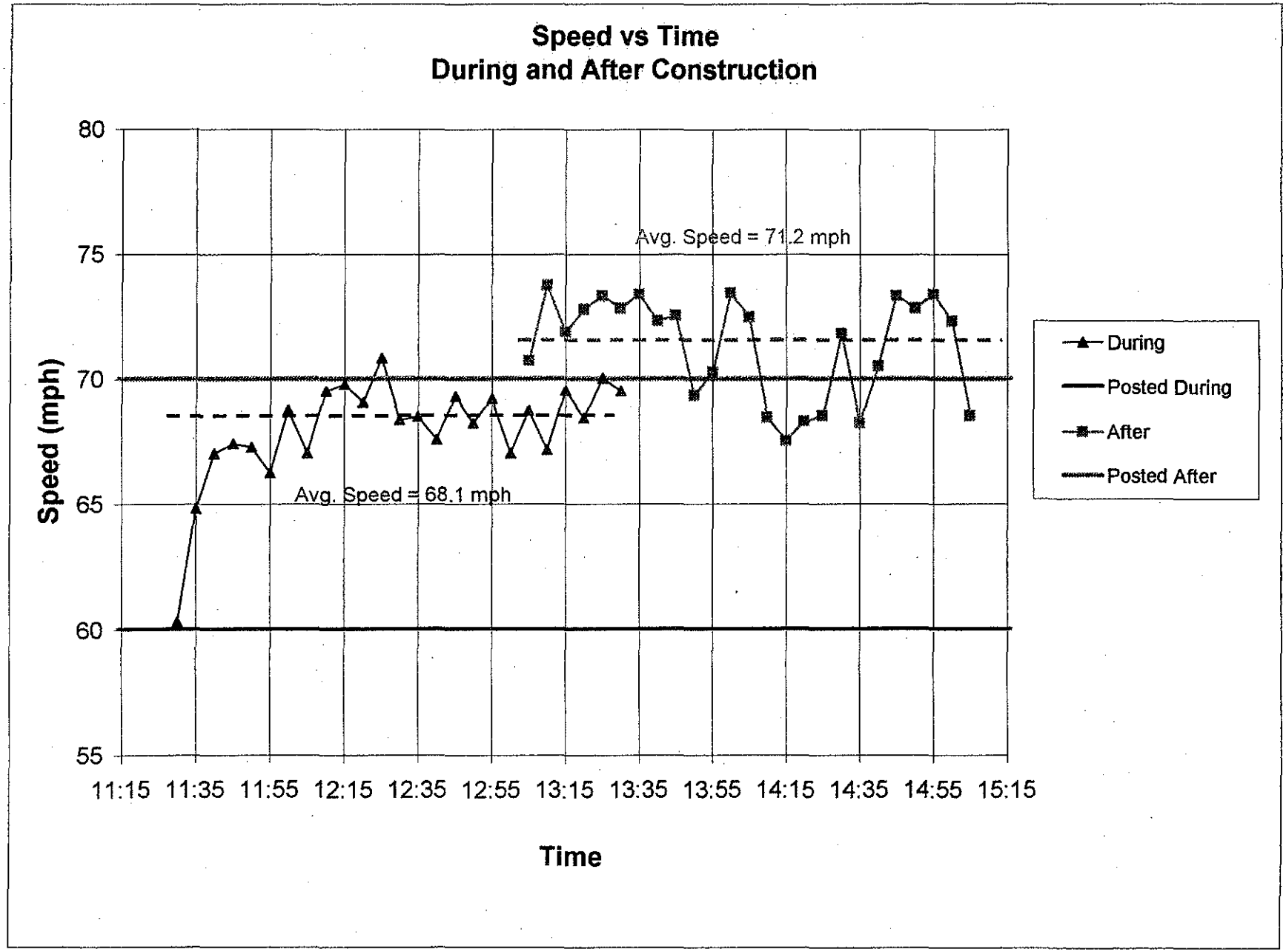
None

During Data Collection
Date and Time: Monday, 10/06/97, 11:30 AM-1:30 PM
Weather: Sunny
Speed Limit During Construction: 60
Type of Work Done: Rehabilitation of right and middle lanes, joint repair
Lane Closure(s): Slow lane and part of the middle lane closed although 2 lanes open to travel.
Lane Shift: Yes (toward left shoulder)
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 68.1
Other Information: Left shoulder used as lane

After Data Collection
Date and Time: Tuesday, 12/02/97, 1:00 PM-3:00 PM
Weather: Partially cloudy
Average Speed: 71.2

Comments: While the "after" speeds were near the speed limit, the "during" speeds were relatively high. This is presumably due to the fact that workers were not present and two lanes of traffic were being maintained.

NB I-275@Cherry Hill
10/06/97 and 12/02/97



I-275 NB @ Hannan Road

Location: Near Novi, north of I-94, exit 18
Direction: Northbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

During Data Collection 1
Date and Time: Thursday, 7/24/97, 10:45 AM-12:45 PM
Weather: Sunny
Speed Limit During Construction: 60
Type of Work Done: Rehabilitation and resurfacing of right and middle lanes
Lane Closure(s): Slow lane closed, 2 lanes maintained for traffic
Lane Shift: Yes (toward left shoulder)
Type of Lane Closure: Drums
Special Traffic Control: CMS used
Workers Present During Data Collection: Yes, within ¼ mile
Police Present During Data Collection: No
Average Speed: 65.4
Other Information: Left shoulder used as lane

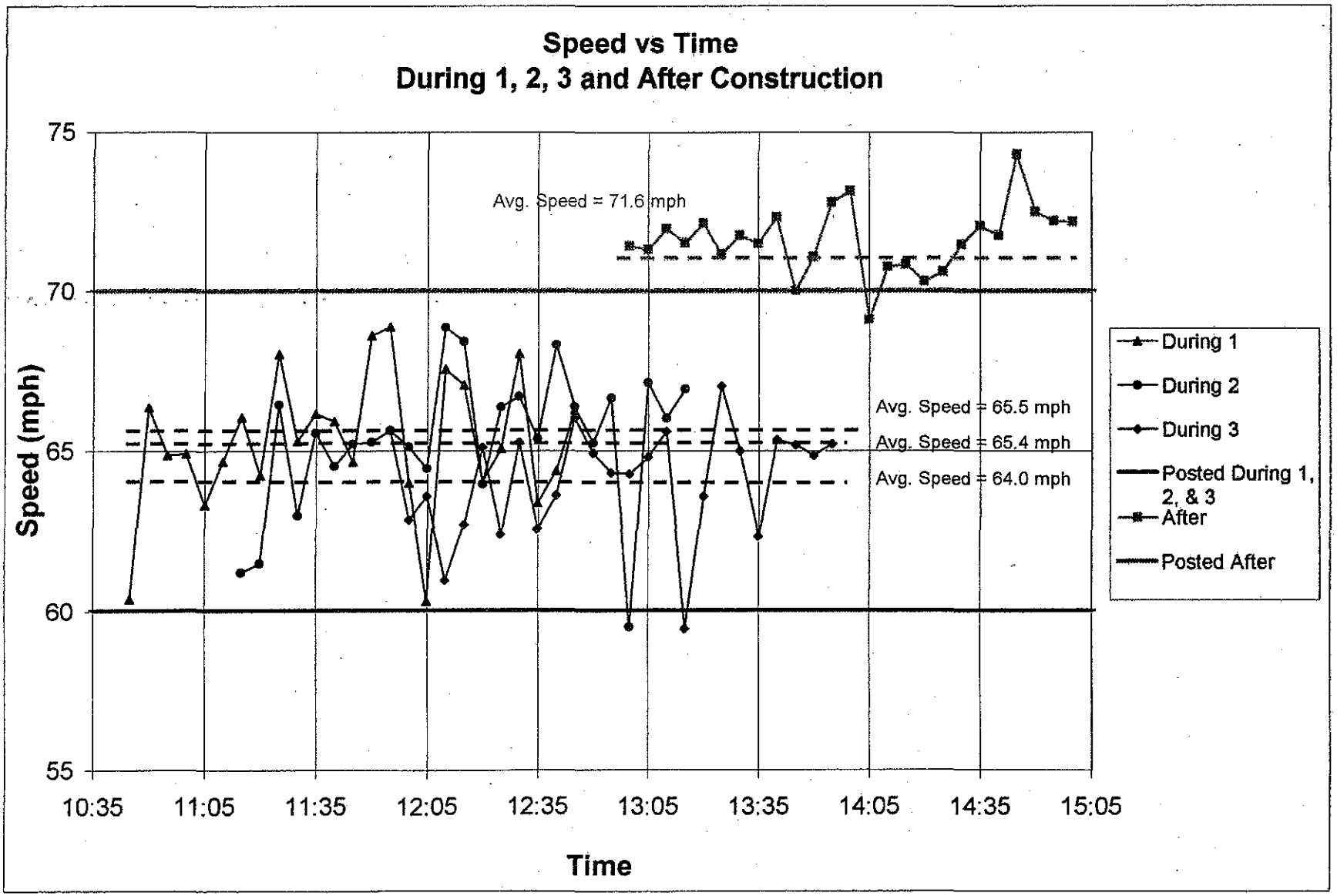
During Data Collection 2 (conditions same as 1 except as noted)
Date and Time: Thursday, 7/31/97, 12:10 PM-2:10 PM
Weather: Sunny
Workers Present During Data Collection: No
Average Speed: 65.5

During Data Collection 3 (conditions same a 1 except as noted)
Date and Time: Tuesday, 8/26/97, 12:00 PM-2:00 PM
Weather: Sunny
Workers Present During Data Collection: No
Average Speed: 64.0

After Data Collection
Date and Time: Friday, 10/10/97, 1:00 PM-3:00 PM
Weather: Sunny
Average Speed: 71.6

Comments: While speeds during work were lower than during the after period, the similarity of speeds with and without workers present was unexpected. Presumably the fact that two lanes of traffic were maintained contributed to the higher speeds "during."

NB I-275@Hannan Rd.
7/24/97, 7/31/97, 8/26/97 and 10/10/97



I-275 SB @ Hannan Road

Location: Near Novi, north of I-94, exit 18
Direction: Southbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

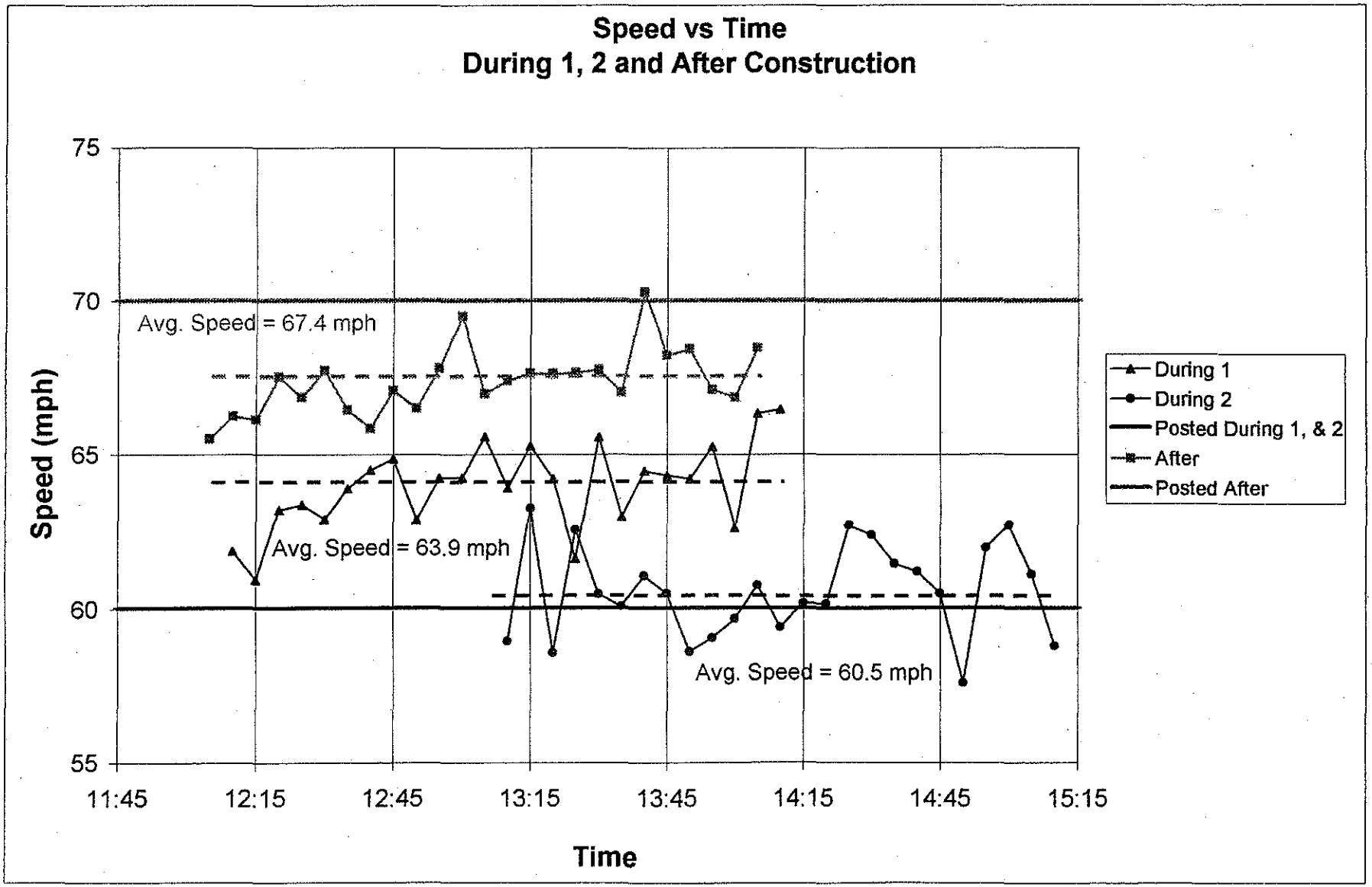
During Data Collection 1
Date and Time: Tuesday, 8/26/97, 12:05 PM-2:05 PM
Weather: Sunny
Speed Limit During Construction: 60
Type of Work Done: Rehabilitation and resurfacing of right lane, joint work
Lane Closure(s): Part of the slow and middle lanes closed, 2 lanes of traffic maintained
Lane Shift: Yes (toward left shoulder)
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 63.9
Other comments: Left shoulder used as lane

During Data Collection 2 (conditions same as 1 except as noted)
Date and Time: Friday, 10/10/97, 1:00 PM-3:00 PM
Weather: Sunny
Average Speed: 60.5
Other comments: Right shoulder used as lane

After Data Collection
Date and Time: Thursday, 11/06/97, 12:00 PM-2:00 PM
Weather: Cloudy, breezy
Average Speed: 67.4

Comments: The relatively low average speeds, especially during the second during period, with no workers present was unexpected based on results at other sites.

SB I-275@Hannan Rd.
8/26/97, 10/10/97 and 11/06/97



I-275 NB @ Ecorse Road

Location: Near Novi, north of I-94, exit 20
Direction: Northbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

During Data Collection 1

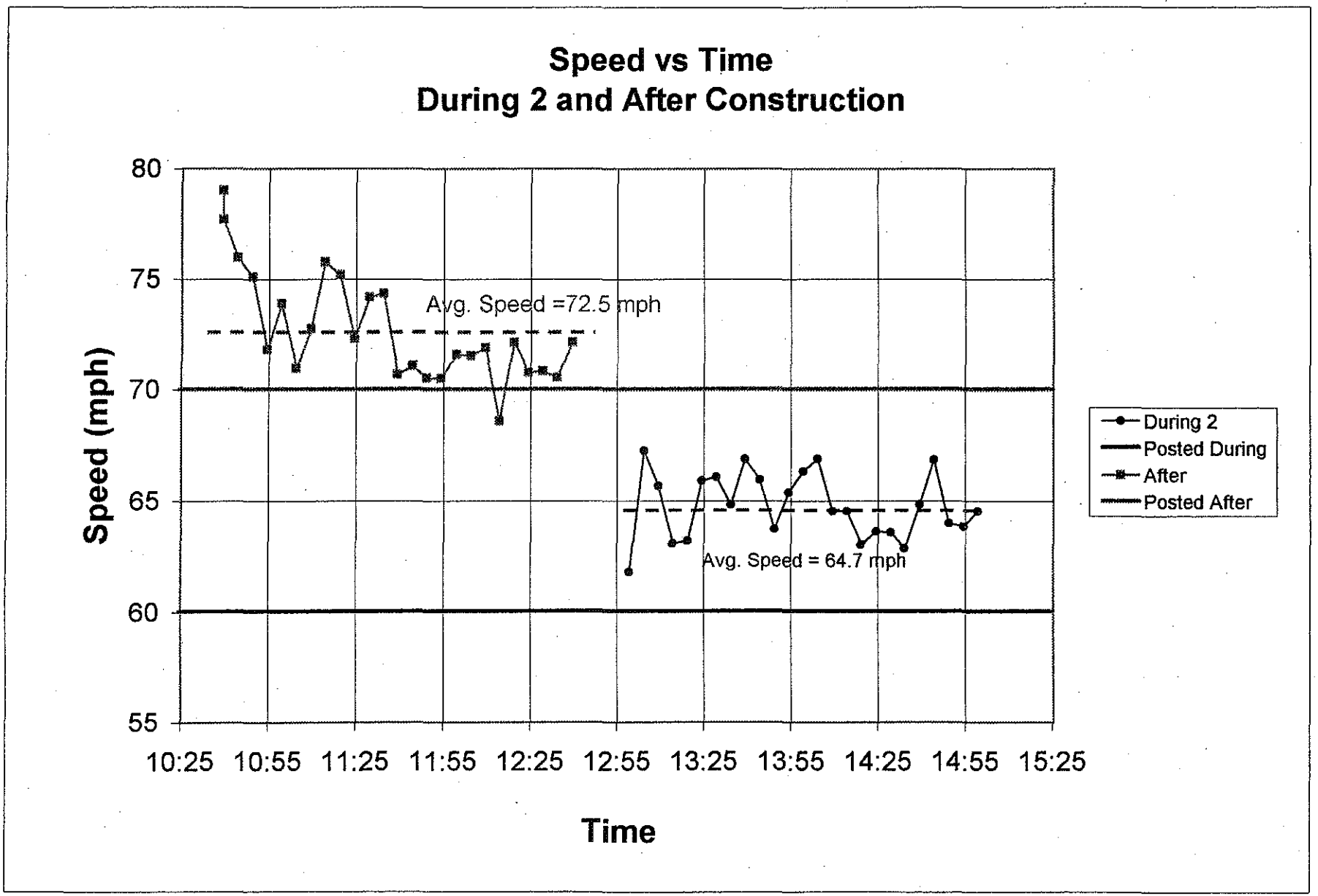
(see 70-60-50 sites)

During Data Collection 2
Date and Time: Tuesday, 8/26/97, 1:00 PM-3:00 PM
Weather: Sunny, breezy
Speed Limit During Construction: 60
Type of Work Done: Rehabilitation and resurfacing of median and passing lanes
Lane Closure(s): Median and passing lanes closed, 2 lanes maintained, narrow lanes
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, under bridge
Police Present During Data Collection: No
Average Speed: 64.7
Other comments: Right shoulder used as lane

After Data Collection
Date and Time: Tuesday, 11/25/97, 10:39 AM-12:39 PM
Weather: Partly sunny, breezy
Average Speed: 72.5

Comments: The average speeds observed during construction were on the high side relative to others when workers were present. In general, however, the I-275 sites resulted in somewhat higher speeds when workers were present. This might be due to the fact that 2 lanes were maintained or local conditions of some sort.

NB I-275@Ecorse Rd.
8/26/97 and 11/25/97



70→-60→50 SITES

The five sites where the "step-down" speed limits were used are those where it was anticipated to be those where workers were present and/or more exposed or where the geometry was more restrictive. Unfortunately, workers were only present at two of the five sites where data collection occurred.

I-96 EB @ Chilson Road

Location: Howell, exit 141
Direction: Eastbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

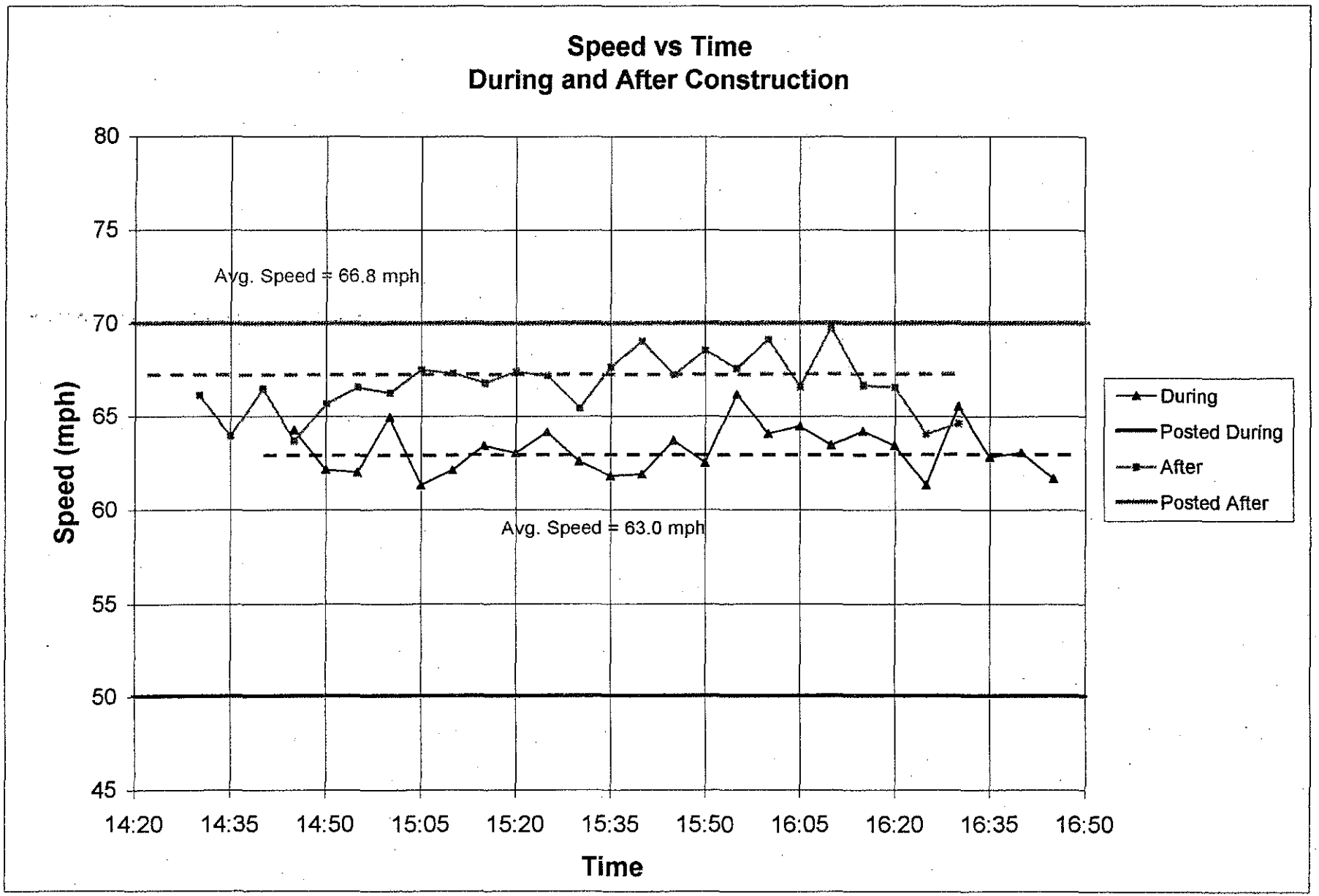
None

During Data Collection
Date and Time: Monday, 8/18/97 2:40 PM-4:40 PM
Weather: Sunny
Speed Limit During Construction: Reduced in steps from 70 to 60 to 50
Type of Work Done: Resurfacing and rehabilitation of right lane of all EB lanes, lanes shift to other side
Lane Closure(s): Slow lane closed, 2 lanes of traffic maintained
Lane Shift: Yes (toward WB traffic)
Type of Lane Closure: Barrier walls separated EB traffic from WB traffic and slow lane
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 63.0

After Data Collection
Date and Time: Tuesday, 11/25/97, 2:30 PM-4:30 PM
Weather: Partly cloudy
Average Speed: 66.8

Comments: The during speeds are similar to those observed at the sites where the speed limit was only stepped down to 60. It should be noted, however, that no workers were present during data collection. The average speeds observed during the after period seem somewhat low for this site.

EB I-96@Chilson Rd.
8/18/97 and 11/25/97



US-10 WB @ M-18

Location: North of Midland
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

None

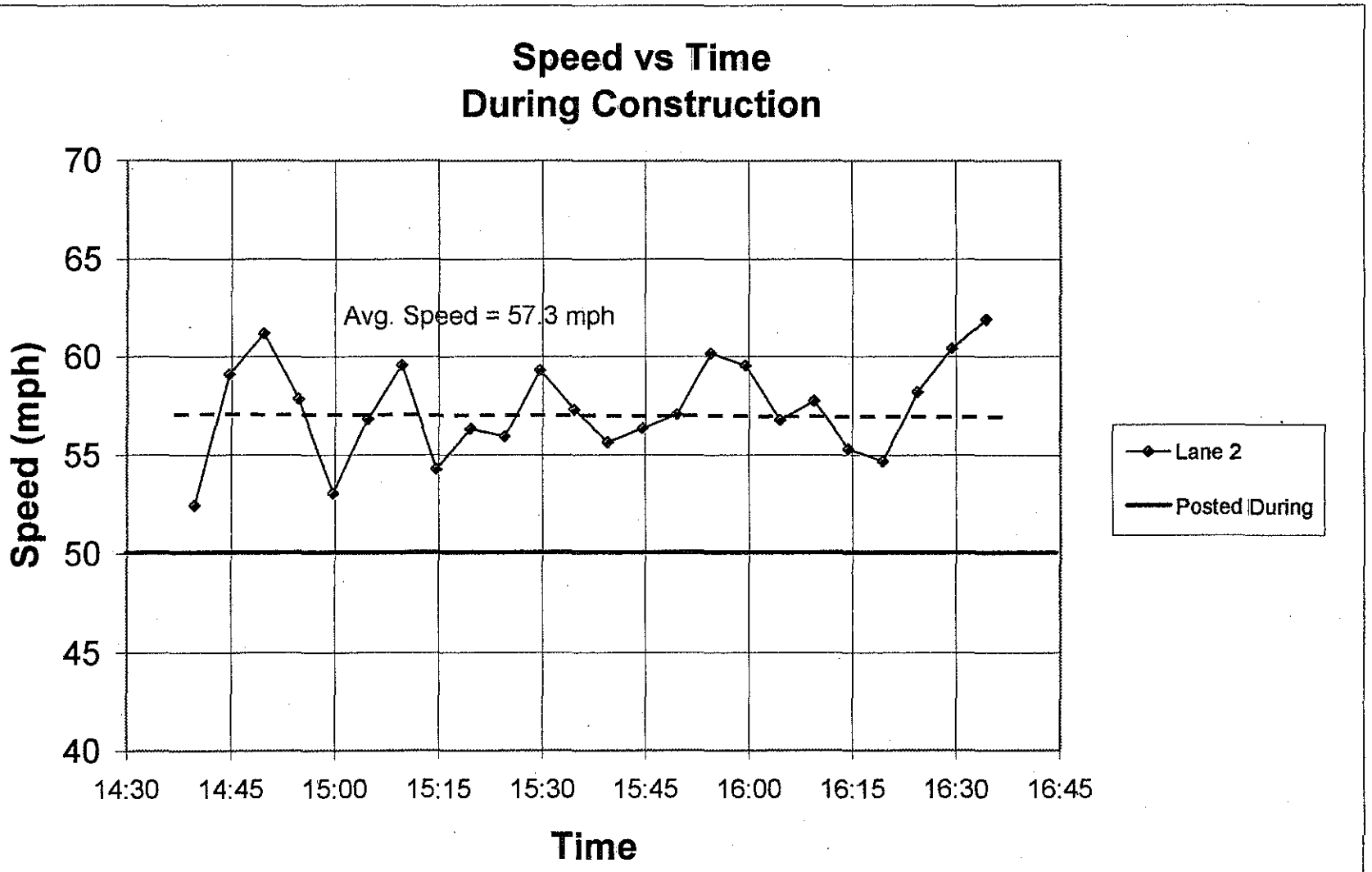
During Data Collection
Date and Time: Friday, 10/17/97, 2:40 PM-4:35 PM
Weather: Partly cloudy, windy
Speed Limit During Construction: Reduced in steps from 70 to 60 to 50
Type of Work Done: Joint repair of right lane
Lane Closure(s): Slow lane closed, 1 lane open to traffic
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes (½ mile upstream (east) of the bridge)
Police Present During Data Collection: No
Average Speed: 57.3
Other Information: Construction ends right after the bridge

After Data Collection

None

Comments: The speeds observed at this site were among the lowest in the first two categories. It should be noted, when comparing this site with others, that workers were present, only one lane was open, and only cones were used for the lane closure.

WB US-10@M18
10/17/97



Note:
Lane 1 was closed during construction.

I-94 EB @ Michigan Avenue

Location: West of Jackson, near exit 128
Direction: Eastbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

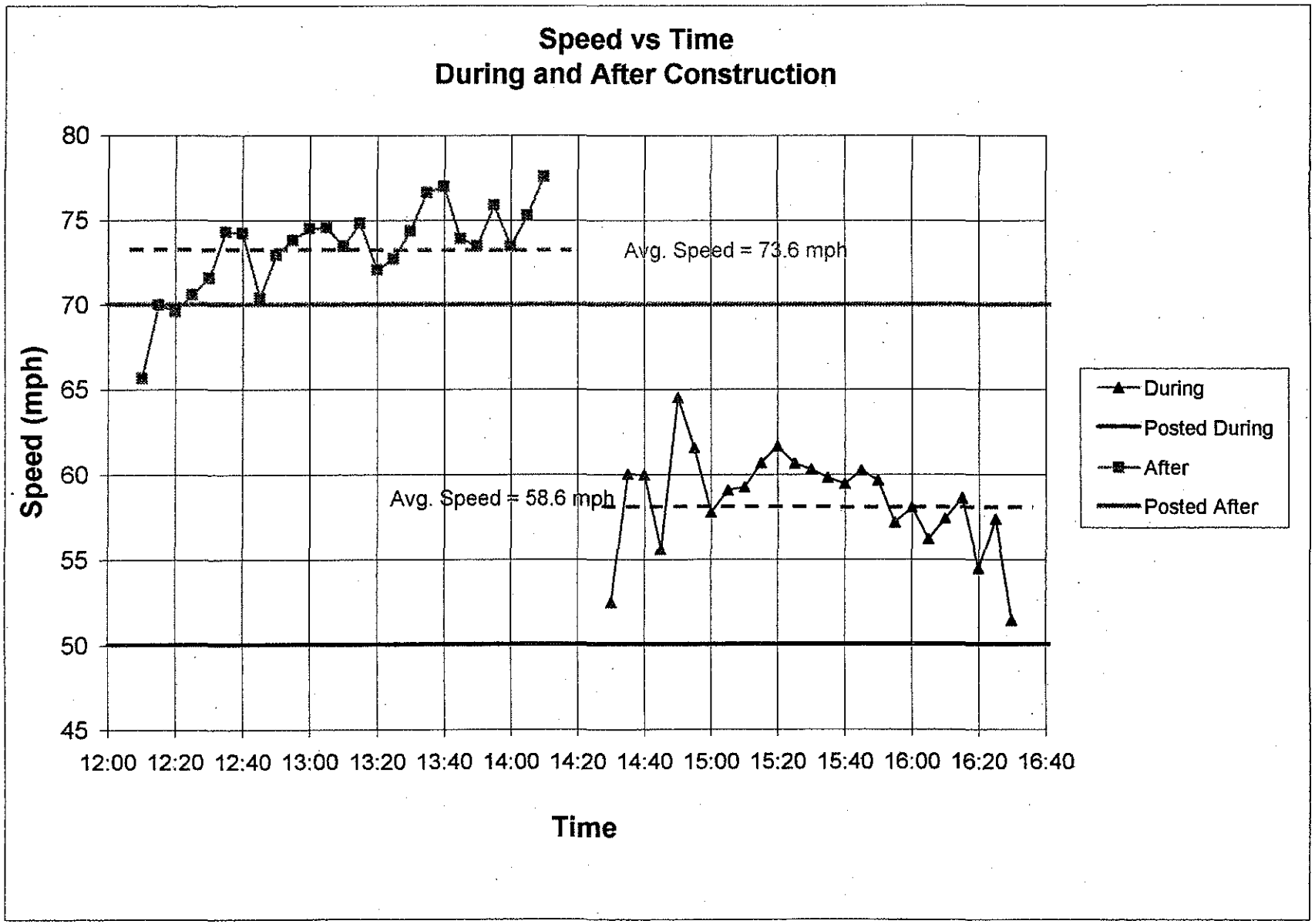
None

During Data Collection
Date and Time: Tuesday, 9/16/97, 2:30 PM-4:30 PM
Weather: Sunny
Speed Limit During Construction: Reduced in steps from 70 to 60 to 50
Type of Work Done: Resurfacing and rehabilitation of right lane
Lane Closure(s): Slow lane closed, only 1 lane open to traffic
Lane Shift: None
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 58.6

After Data Collection
Date and Time: Tuesday, 10/3/97, 12:10 PM-2:10 PM
Weather: Partly cloudy
Average Speed: 73.6
Other Information: Drums remained at the site, 5' from edge of passing lane

Comments: The "during" speeds observed at this site are comparable to those observed at the US-10 site just reviewed although there were NO workers present on I-94.

EB I-94@Michigan Ave.
9/16/97 and 10/03/97



I-275 NB @ Ecorse Road

Location: Near Novi, north of I-94, exit 20
Direction: Northbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

During Data Collection 1
Date and Time: Thursday, 7/24/97, 11:15 AM-1:15 PM
Weather: Sunny
Speed Limit During Construction: Reduced in steps from 70 to 60 to 50
Type of Work Done: Resurfacing and rehabilitation of right lane; joint repair.
Lane Closure(s): Slow lane closed, 2 lanes of traffic maintained, narrow lanes
Lane Shift: Yes (toward left shoulder)
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, under bridge
Police Present During Data Collection: Yes
Average Speed: 64.0
Other Information: Left shoulder used as lane

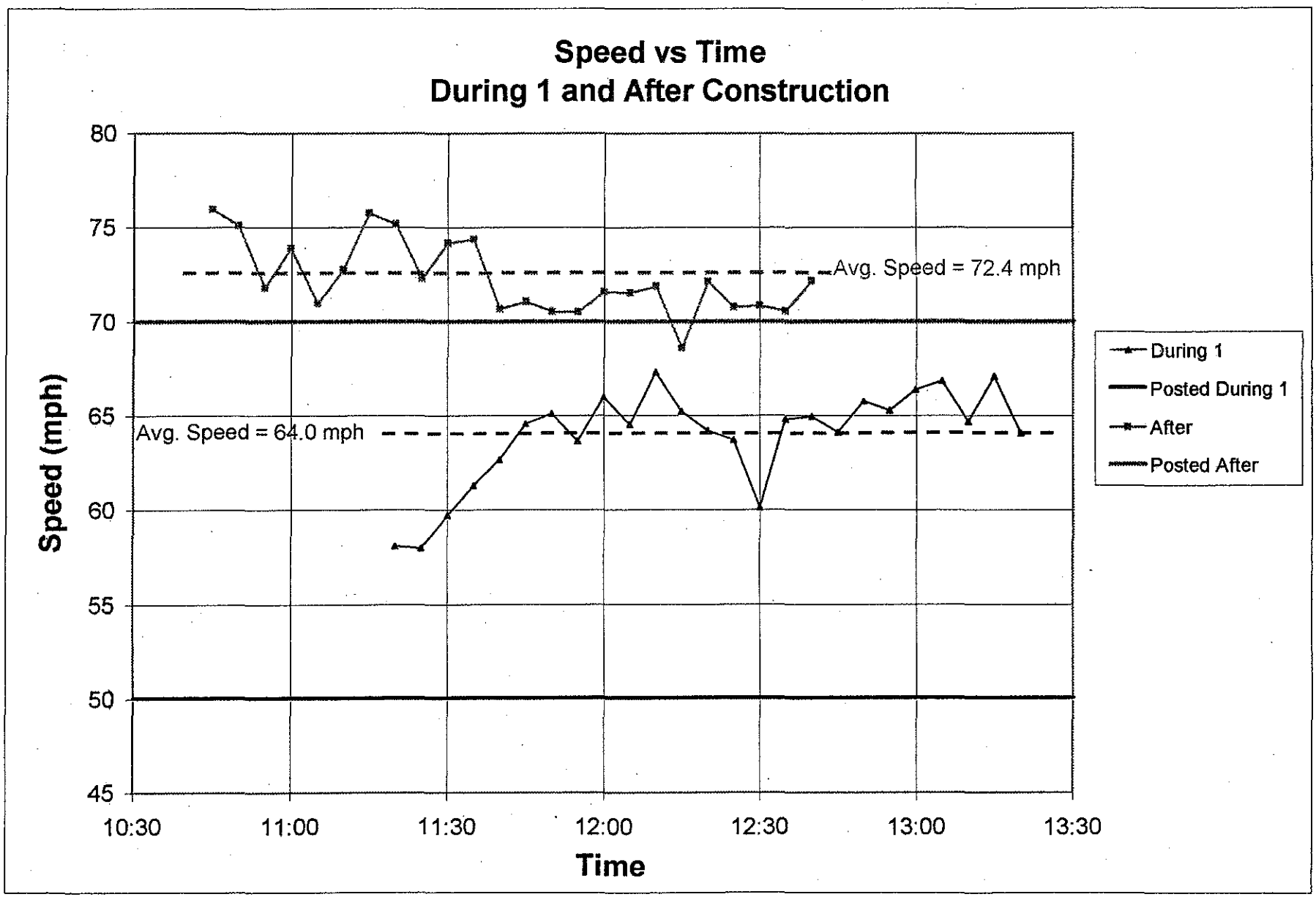
During Data Collection 2

(see 70-60 sites)

After Data Collection
Date and Time: Tuesday, 11/25/97, 10:39 AM-12:39 PM
Weather: Partly sunny, windy
Average Speed: 72.5

Comments: The average speeds after and during when the speed limit was reduced to 50 mph were almost identical to those noted earlier (at this same site) when the limit was reduced only to 60 mph. In both "after" instances, workers were present although police were present for the "during 1" phase.

NB I-275@Ecorse Rd.
7/24/97 and 11/25/97



I-275 NB @ Joy Road

Location: Novi, near exit 28
Direction: Northbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

None

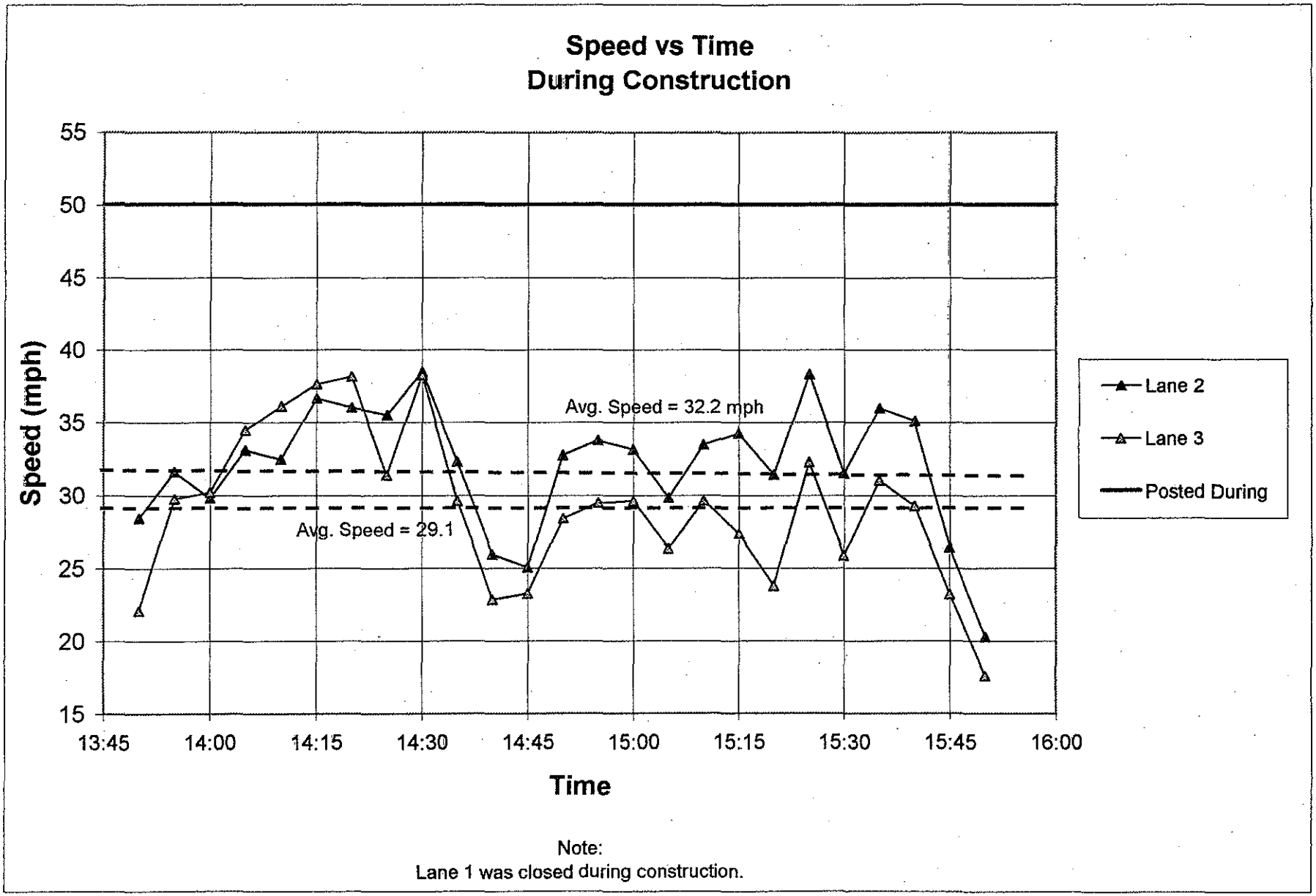
During Data Collection
Date and Time: Friday, 10/24/97, 1:40 PM-3:40 PM
Weather: Breezy, showers
Speed Limit During Construction: Reduced in steps from 70 to 60 to 50
Type of Work Done: Resurfacing and rehabilitation of right lane.
Lane Closure(s): Slow lane closed, 2 traffic lanes maintained
Lane Shift: Yes (toward left shoulder)
Type of Lane Closure: Cones
Special Traffic Control: CMS. Displayed Messages: "Speed Limit 50 mph," and. Give Workers a Brake"
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 30.5

After Data Collection

None

Comments: The extremely low (relatively speaking) speeds indicate that other factors were having some effect (e.g., congestion).

NB I-275@Joy Rd.
10/24/97



Note:
Lane 1 was closed during construction.

70→50 SITES

One "different" site was one where the speed limit was reduced directly from 70 to 50 mph without an intervening "step" at 60 mph.

I-69 WB @ Miller Road

Location: West of Port Huron, milepoint 179
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

None

During Data Collection 1
Date and Time: Tuesday, 7/22/97, 2:25 PM-4:25 PM
Weather: Sunny
Speed Limit During Construction: 50
Type of Work Done: Joint repair of right lane
Lane Closure(s): Slow lane closed, only 1 lane of traffic maintained
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, moving
Police Present During Data Collection: No
Average Speed: 53.9
Other Information: Construction started 2.5 miles east of the site

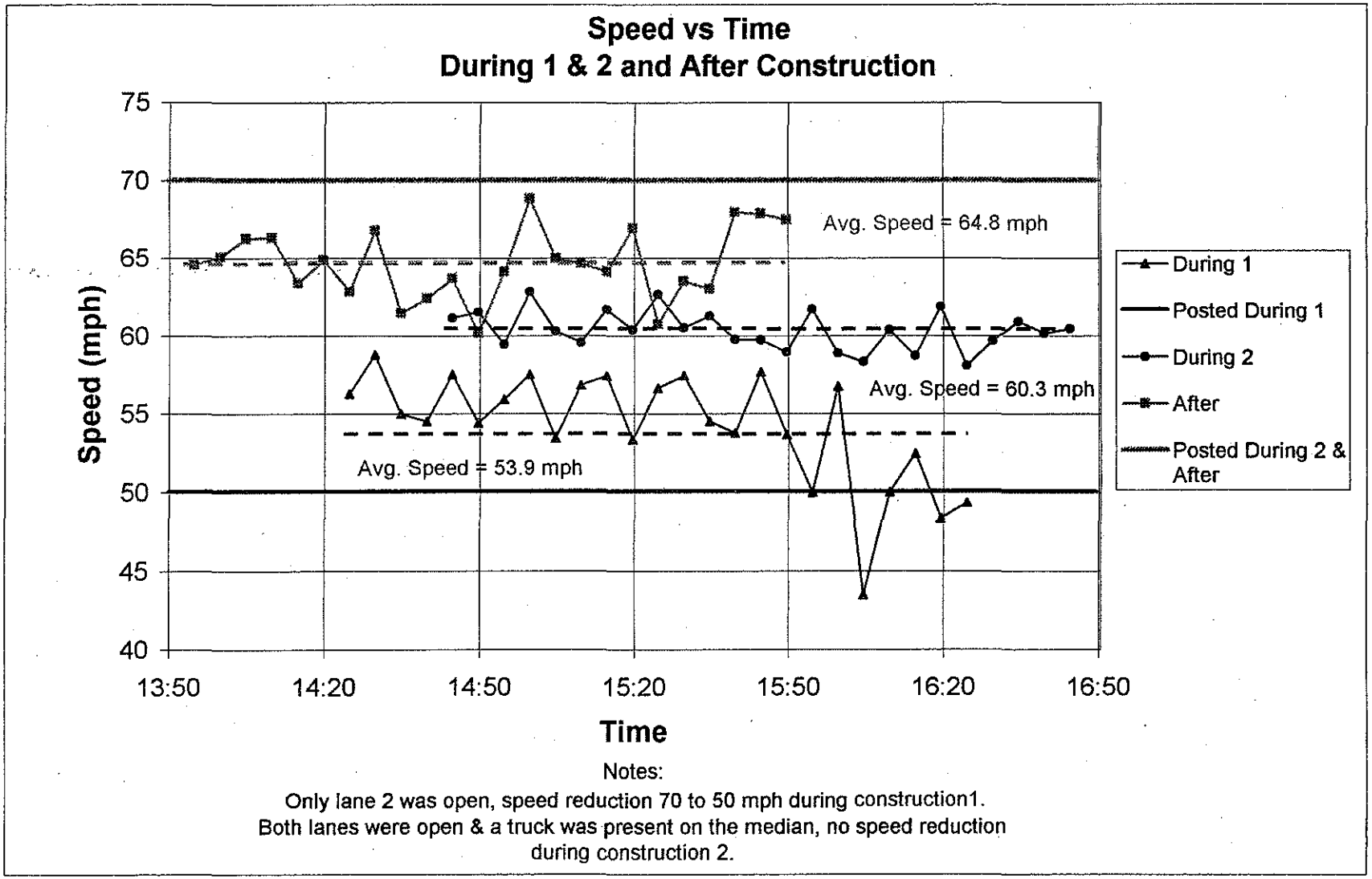
During Data Collection 2

See 70-70 site in the final section.

After Data Collection
Date and Time: Thursday, 10/30/97, 1:50 PM-3:50 PM
Weather: Partly sunny, windy
Average Speed: 64.8

Comments: The average speeds observed here and for the same site when there was work but no other "treatment" illustrate the relative effects of workers, treatment, and normal conditions. The average speeds are, respectively, 60.3, 53.9, and 64.8 mph.

WB I-69@Miller Rd.
7/22/97, 9/16/97 and 10/30/97



Notes:
Only lane 2 was open, speed reduction 70 to 50 mph during construction1.
Both lanes were open & a truck was present on the median, no speed reduction during construction 2.

70→45 SITES

These sites are generally "maintenance" sites which were marked at 45 mph. Most of the sites have work of very short duration (e.g., a day or two) and may change during the day. While there may be some motorist anticipation of the lane closures, it is much less than for the other types of sites discussed thus far. Given the short duration of these sites, workers were present for most of the "during" data collection.

I-96 EB @ Nicholson Road

Location: Near Fowlerville, close to exit 129
Direction: Eastbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

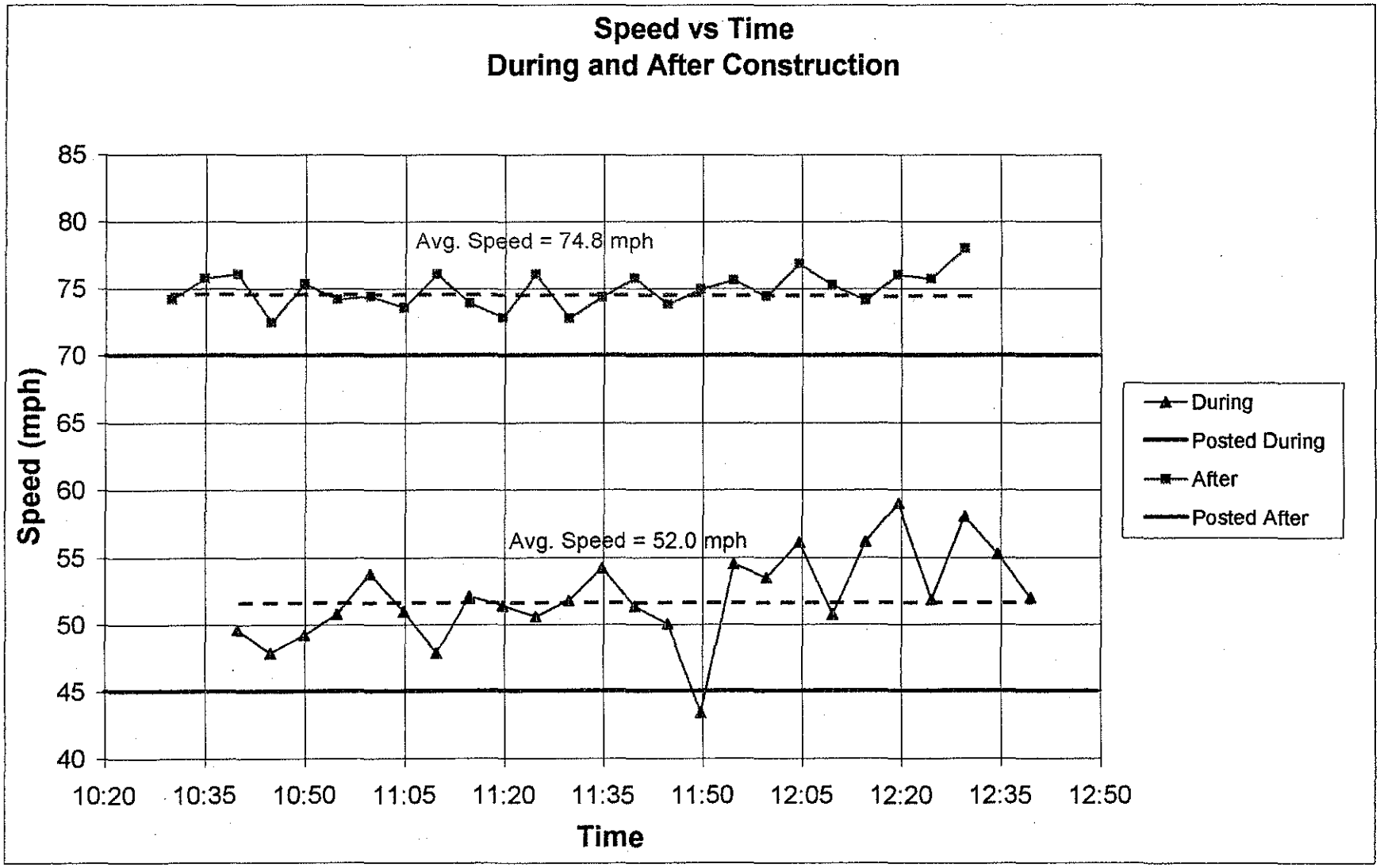
None

During Data Collection
Date and Time: Thursday, 8/14/97, 10:40 AM-12:40 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Joint repair and shoulder work
Lane Closure(s): Slow lane closed, 1 lane open
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: Yes, under bridge
Police Present During Data Collection: No
Average Speed: 52.0

After Data Collection
Date and Time: Wednesday, 8/27/97, 10:30 AM-12:30 PM
Weather: Sunny
Average Speed: 74.8

Comments: The average speeds observed at this site are somewhat lower than those observed at the longer-term sites thus far. Like other sites, the average speeds during the work period are higher than the posted limit.

EB I-96@Nicholson Rd.
8/14/97 and 8/27/97



I-96 EB @ Exit 129

Location: Near Fowlerville
Direction: Eastbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

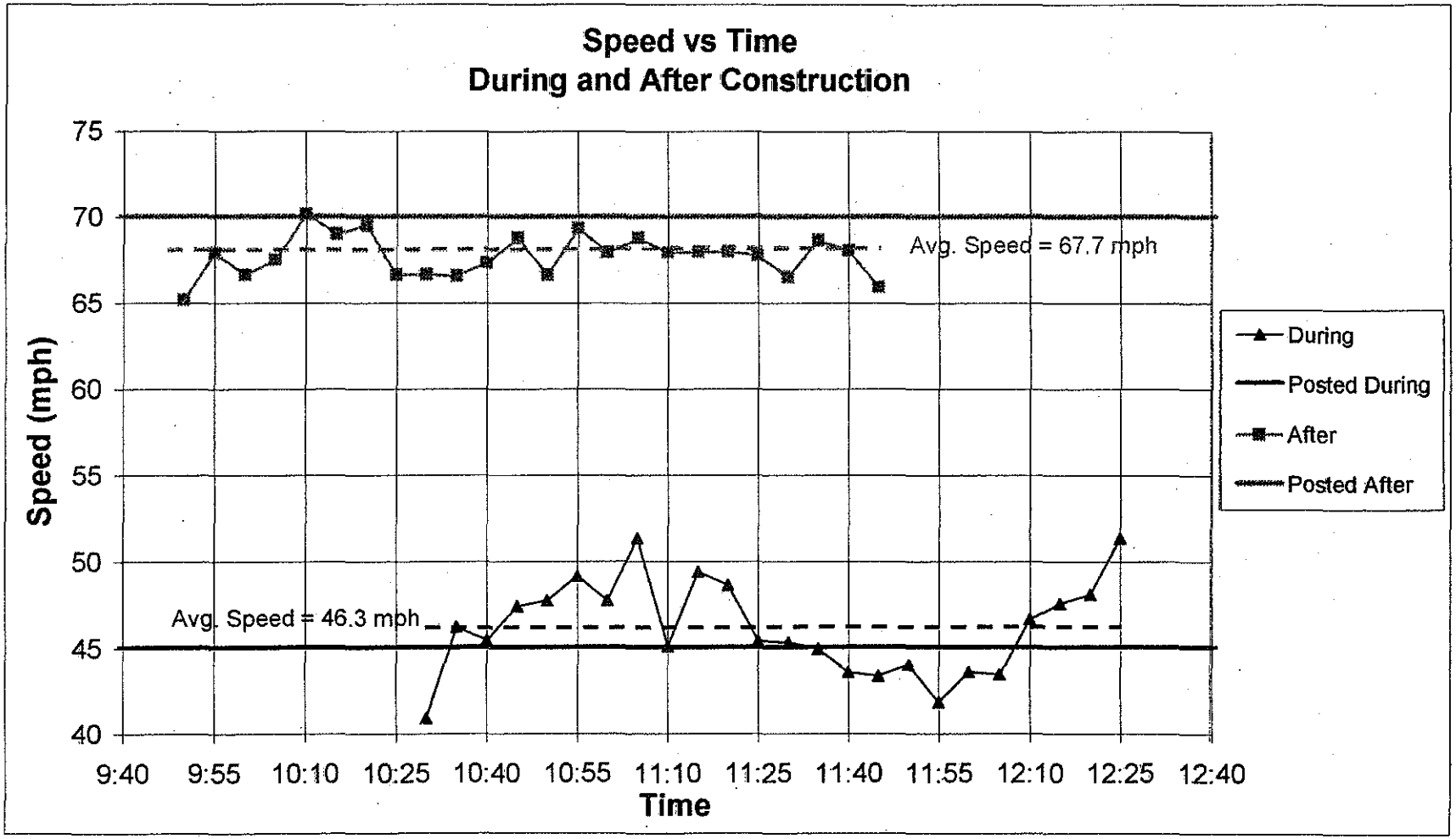
None

During Data Collection
Date and Time: Thursday, 9/04/97, 10:30 AM-12:30 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Joint and crack repair of left lane
Lane Closure(s): Passing lane closed, 1 lane open
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: Yes (under the bridge and 1 mile west of the site)
Police Present During Data Collection: No
Average Speed: 46.3

After Data Collection
Date and Time: Tuesday, 9/16/97, 9:45 AM-11:45 AM
Weather: Partly sunny
Average Speed: 69.1

Comments: Speeds at this site during the work period are even lower than the first site possibly due to the fact that at least two separate groups of workers have been encountered by the motorists.

EB I-96@Exit 129
9/04/97 and 9/16/97



I-96 WB @ Exit 133

Location: Near Flowlerville
Direction: Westbound
Number of Lanes Without Construction: 3
Regular Speed Limit: 70

Before Data Collection

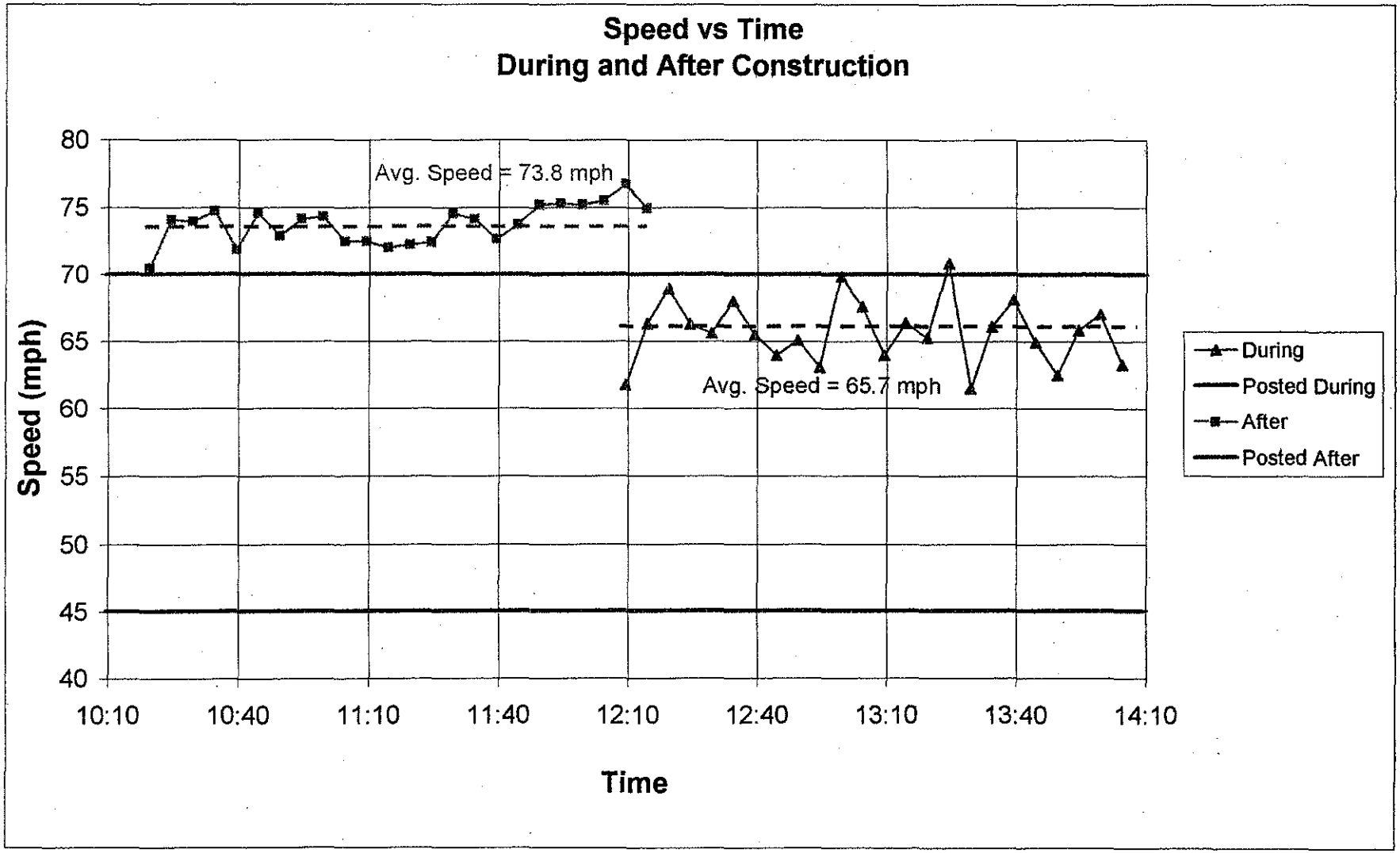
None

During Data Collection
Date and Time: Thursday, 9/04/97, 12:10 PM-2:10 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Joint and crack repair
Lane Closure(s): Slow lane closed, 2 lanes open to traffic
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: Yes (approximately 0.5 mile west of the site)
Police Present During Data Collection: No
Average Speed: 69.0
Other Information: The road was curved approximately 0.25 mile upstream of the site

After Data Collection
Date and Time: Tuesday, 9/16/97, 10:15 AM-12:15 PM
Weather: Partly sunny
Average Speed: 73.8

Comments: The average speeds during the work period are considerably higher for this period than they were at a nearby site (albeit in the other direction). The difference seems attributable, at least in part, to the fact that two lanes are open to traffic in this instance.

WB I-96@Exit133
9/04/97 and 9/16/97



I-69 EB @ Lake Nepessing Road

Location: Near Lapeer, exit 153
Direction: Eastbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

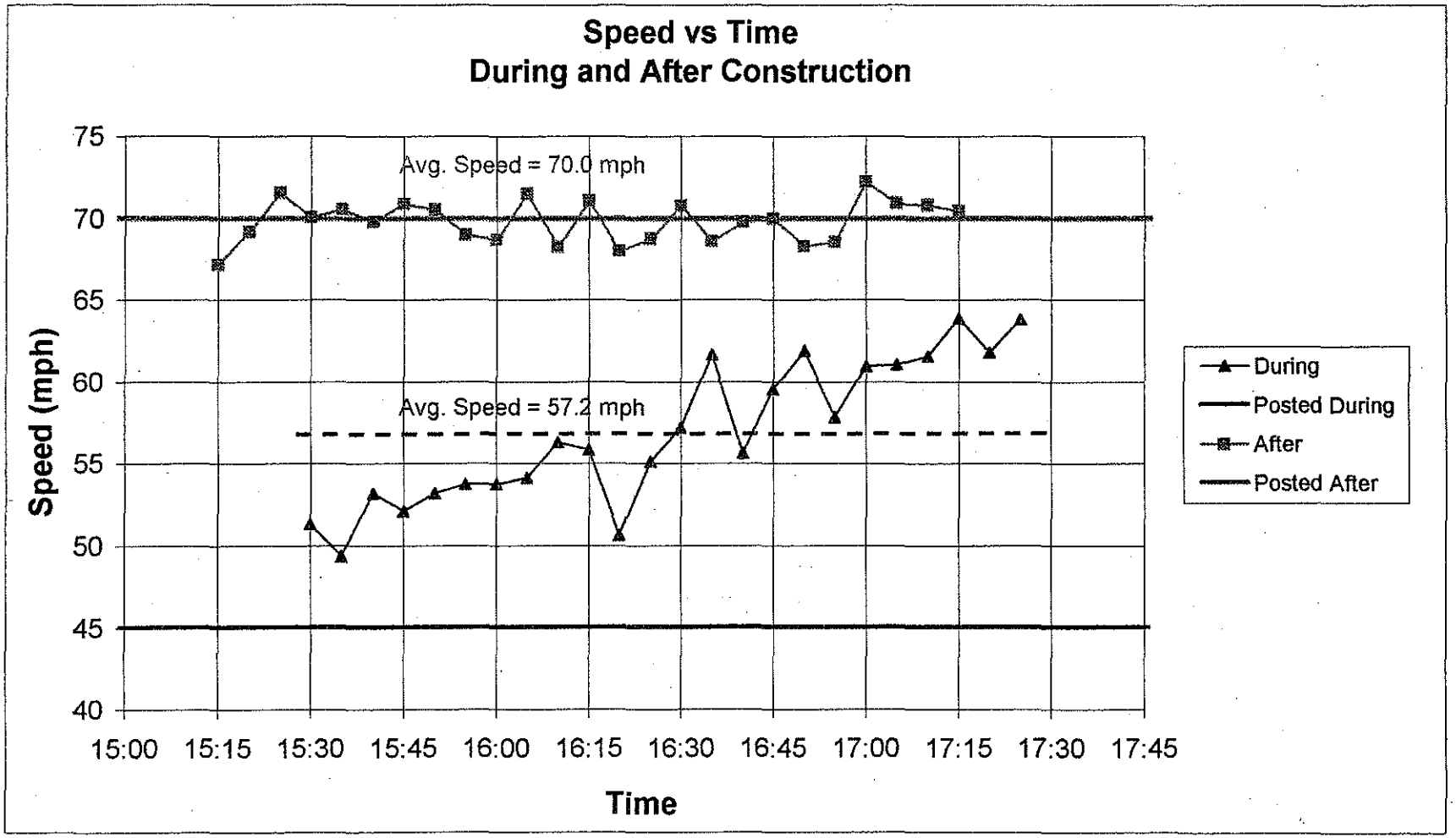
None

During Data Collection
Date and Time: Thursday, 8/28/97, 3:30 PM-5:25 PM
Weather: Cloudy
Speed Limit During Construction: 45
Type of Work Done: Joint repair and rehabilitation of left lane
Lane Closure(s): Passing lane closed, only 1 lane open to traffic (on shoulder)
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, within ¼ mile
Police Present During Data Collection: No
Average Speed: 57.3
Other Comments: Some drivers were observed to drive on the right shoulder

After Data Collection
Date and Time: Friday, 9/19/97, 3:15 PM-5:15 PM
Weather: Partly cloudy, showers, clear
Average Speed: 70.0

Comments: The average speed at this site is somewhat higher than the other 45 mph sites (save the last I-96 site which had two lanes open) and comparable to the other sites which only had one lane open to traffic and workers present, independent of the actual speed limit posted.

EB I-69@Lake Nepessing Rd.
8/28/97 and 9/19/97



US-27 NB @ Base Line Road

Location: St. Louis
Direction: Northbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

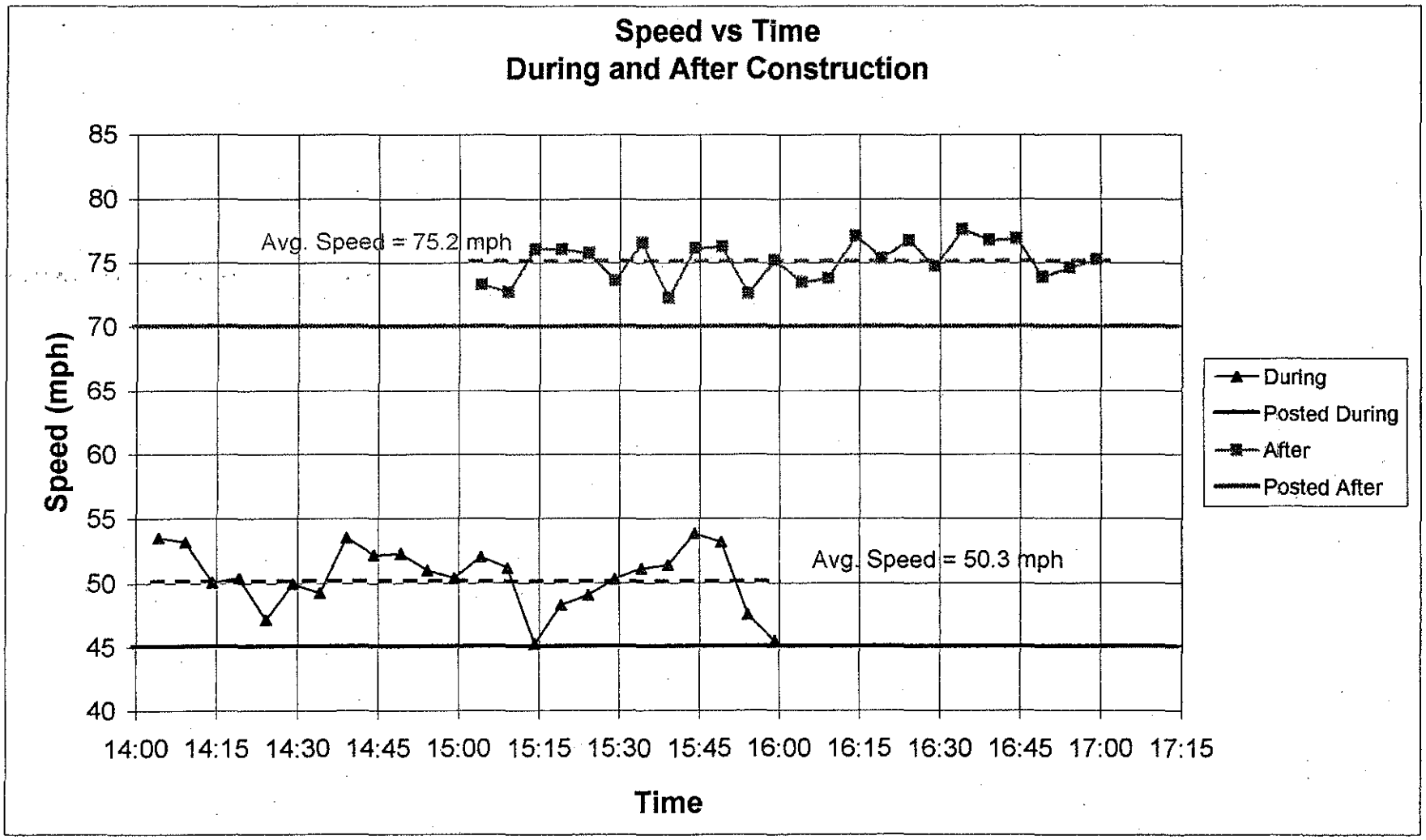
None

During Data Collection
Date and Time: Friday, 9/26/97, 2:00 PM-4:00 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Major rehabilitation/construction of passing lane
Lane Closure(s): Passing lane closed, 1 lane open to traffic
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, within ¼ mile
Police Present During Data Collection: No
Average Speed: 50.3
Other Information: Right shoulder used as lane

After Data Collection
Date and Time: Thursday, 11/06/97, 3:00 PM-5:00 PM
Weather: Cloudy
Average Speed: 75.2

Comments: While the after average speeds seem high, the during speeds are among the lowest observed. Again, there was only one lane open and the posted limit was 45 mph.

NB US-27@Base Line Rd.
9/26/97 and 11/06/97



US-27 SB @ Base Line Road

Location: St. Louis
Direction: Southbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

None

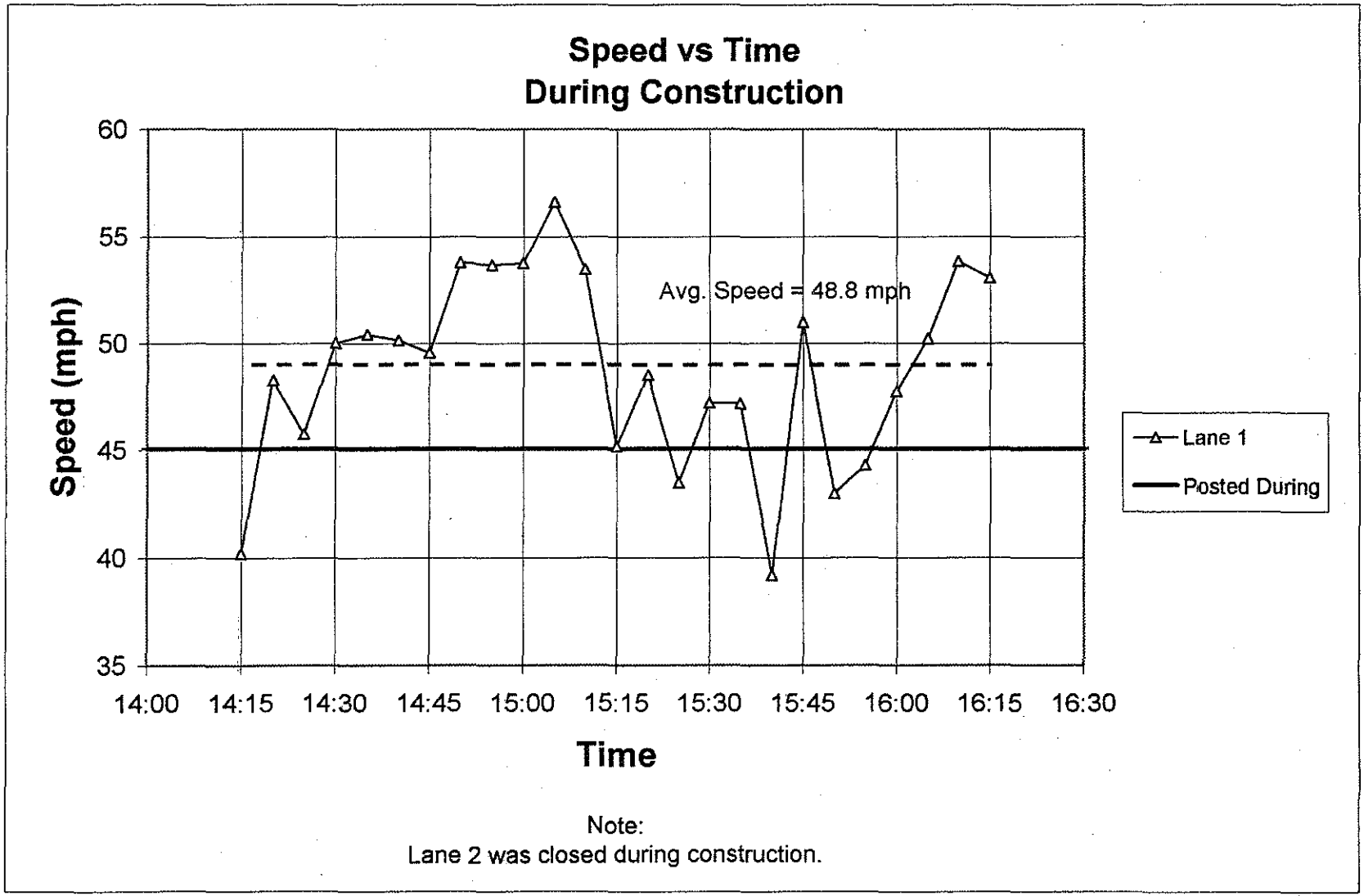
During Data Collection
Date and Time: Thursday, 9/26/97, 2:15 PM-4:15 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Major rehabilitation/construction of passing lane
Lane Closure(s): Passing lane closed, 1 lane open
Lane Shift: Yes (toward right shoulder)
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, within ¼ mile
Police Present During Data Collection: No
Average Speed: 48.8
Other Information: Right shoulder used as lane

After Data Collection

None

Comments: While there were no after data for comparison purposes, the average "during" speeds at this site are comparable to the other 70-45 sites where workers are present.

SB US-27@Base Line Rd.
09/26/97



Note:
Lane 2 was closed during construction.

US-127 NB @ Barnes Road

Location: Near Mason
Direction: Northbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

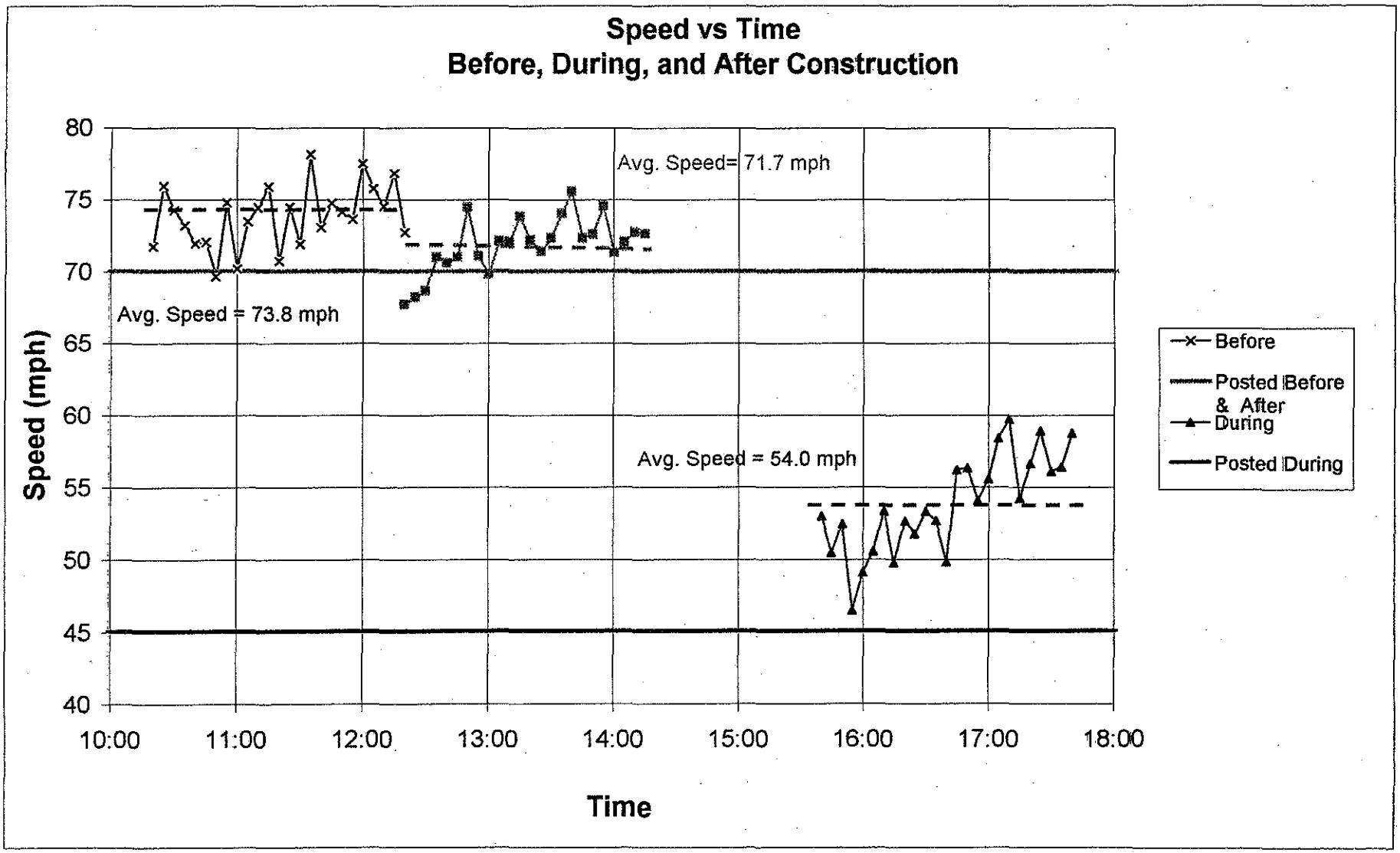
Before Data Collection
Date and Time: Wednesday, 7/16/97, 10:20 AM-12:20 PM
Weather: Sunny
Average Speed: 73.8
Other Information: Pavement condition was poor, with longitudinal and transverse joint and mid block cracks

During Data Collection
Date and Time: Monday, 7/28/97, 3:40 PM-5:40 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Rehabilitation and resurfacing of left lane
Lane Closure(s): Passing lane closed (approximately 2 miles from the bridge), 1 lane open
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: Yes, moving
Police Present During Data Collection: No
Average Speed: 54.0
Other Information: Although there was no lane shift, vehicles traveled on the right shoulder due to the presence of workers and construction equipment. Workers left the site at 4:45 PM

After Data Collection
Date and Time: Tuesday, 8/05/97, 12:20 PM-2:20 PM
Weather: Sunny, windy
Average Speed: 71.7

Comments: This is the only site with before and after data—the before and after speeds are reasonably similar. The "during" speeds are similar to other sites in this group.

NB US-127@Barnes Rd.
7/16/97, 7/28/97, and 8/05/97



US-127 NB @ Henry Road

Location: Near Jackson
Direction: Northbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

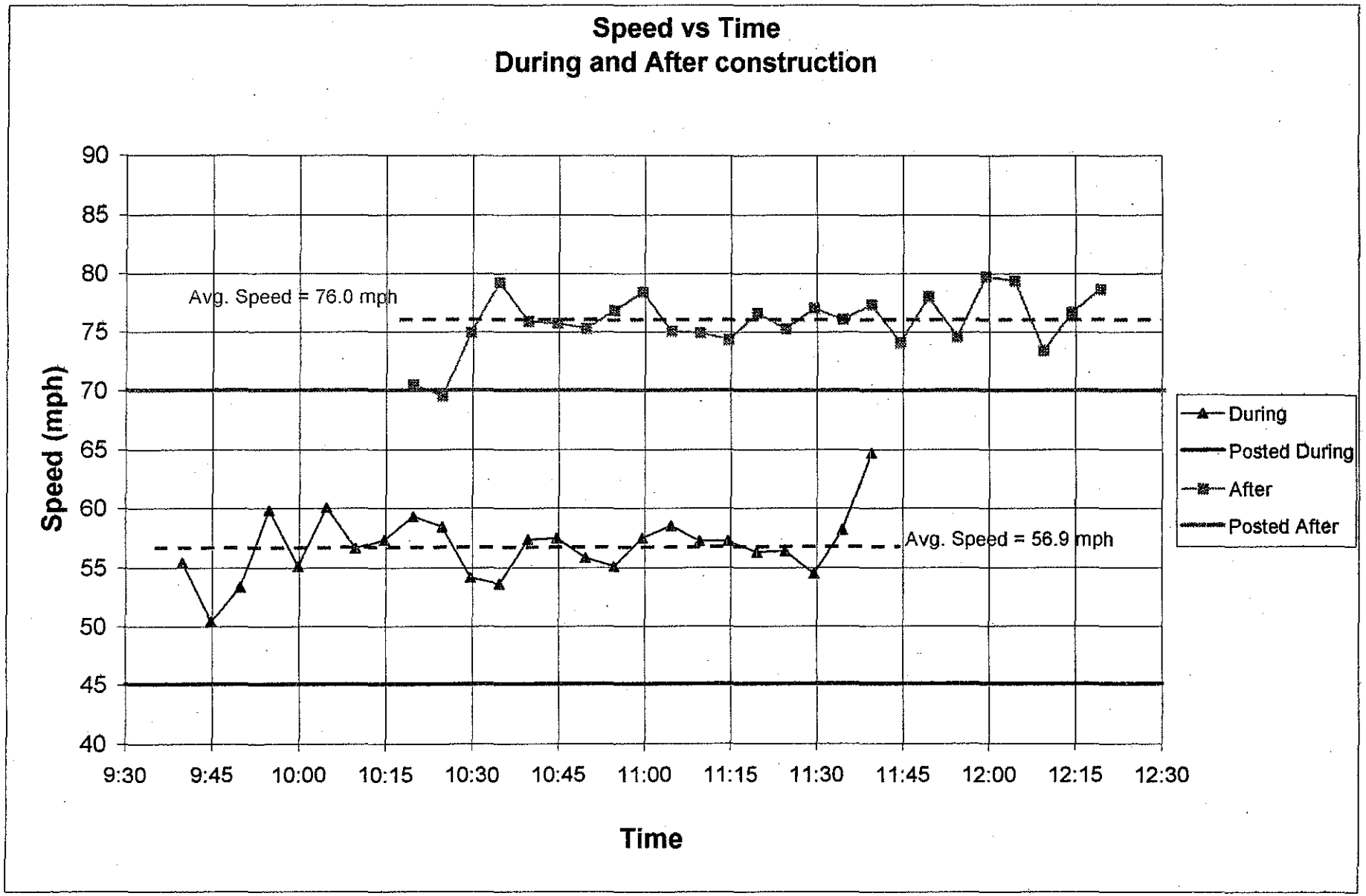
None

During Data Collection
Date and Time: Tuesday, 7/22/97, 9:40 AM-11:40 AM
Weather: Rain showers
Speed Limit During Construction: 45
Type of Work Done: Joint repair
Lane Closure(s): Slow lane closed, 1 lane open to traffic
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: Yes, moving
Police Present During Data Collection: No
Average Speed: 56.7
Other Information: Construction work and cones located just north of the bridge. At 11:15 AM cones were removed

After Data Collection
Date and Time: Friday, 8/01/97, 10:20 AM-12:20 PM
Weather: Cloudy
Average Speed: 76.0

Comments: While the "after" speeds seem abnormally high, the "during" speeds are fairly comparable to others in the category.

NB US-127 @Henry Rd.
7/22/97 and 8/01/97



US-131 SB @ M-46

Location: Kent, north of Grand Rapids
Direction: Southbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

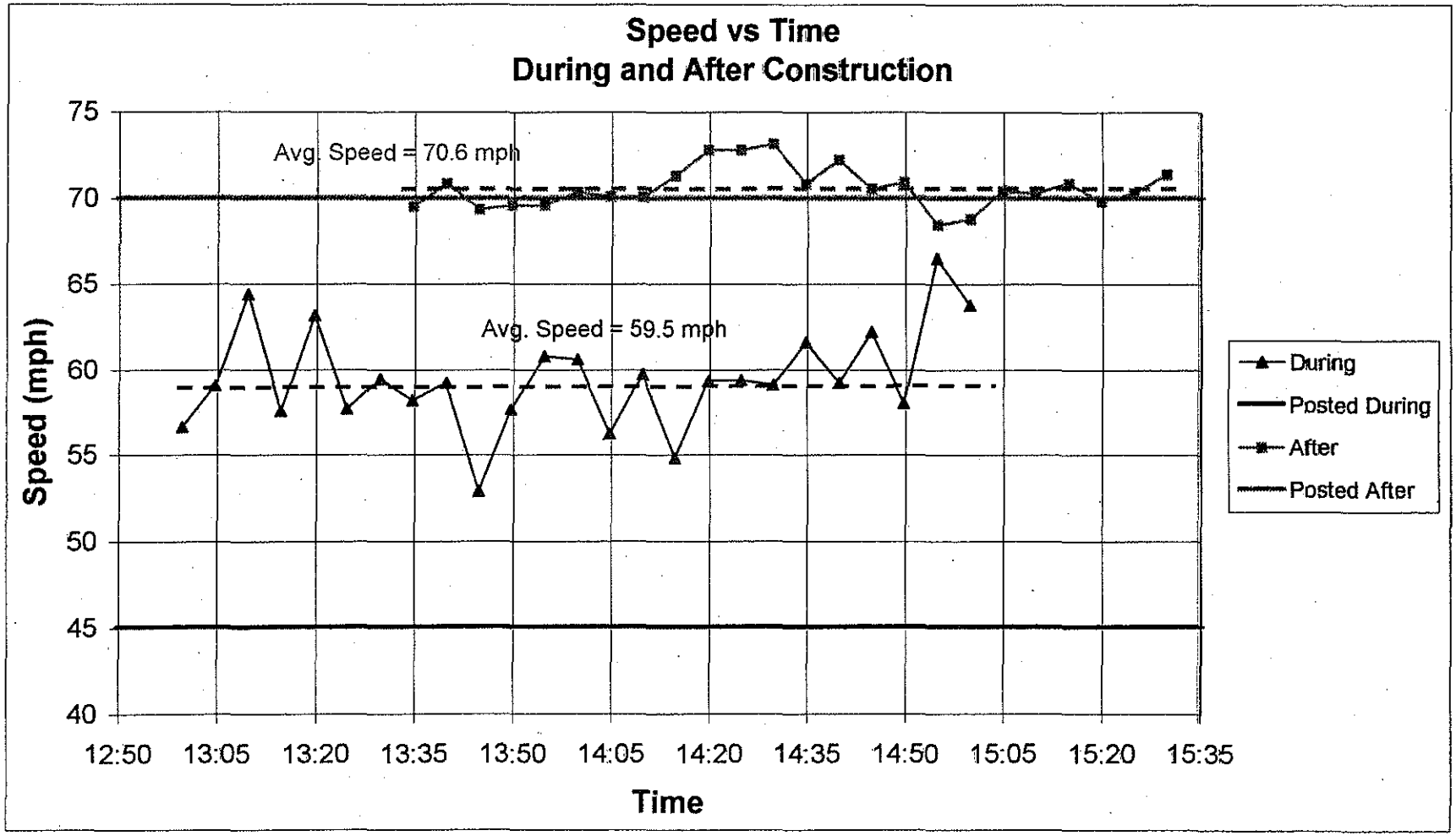
None

During Data Collection
Date and Time: Tuesday, 9/23/97, 1:00 PM-3:00 PM
Weather: Sunny, breezy
Speed Limit During Construction: 45
Type of Work Done: Joint and crack repair of passing lane
Lane Closure(s): Passing lane closed, 1 lane open
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: Yes (about 2 miles downstream of the site)
Police Present During Data Collection: No
Average Speed: 59.5

After Data Collection
Date and Time: Tuesday, 10/07/97, 1:30 PM-3:30 PM
Weather: Sunny
Average Speed: 70.6

Comments: The average speeds during the work noted here were among the highest for this category where only one lane was open.

SB US-131@M-46
9/23/97 and 10/07/97



US-23 SB @ Carpenter Road

Location: South of Ann Arbor, exit 27
Direction: Southbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

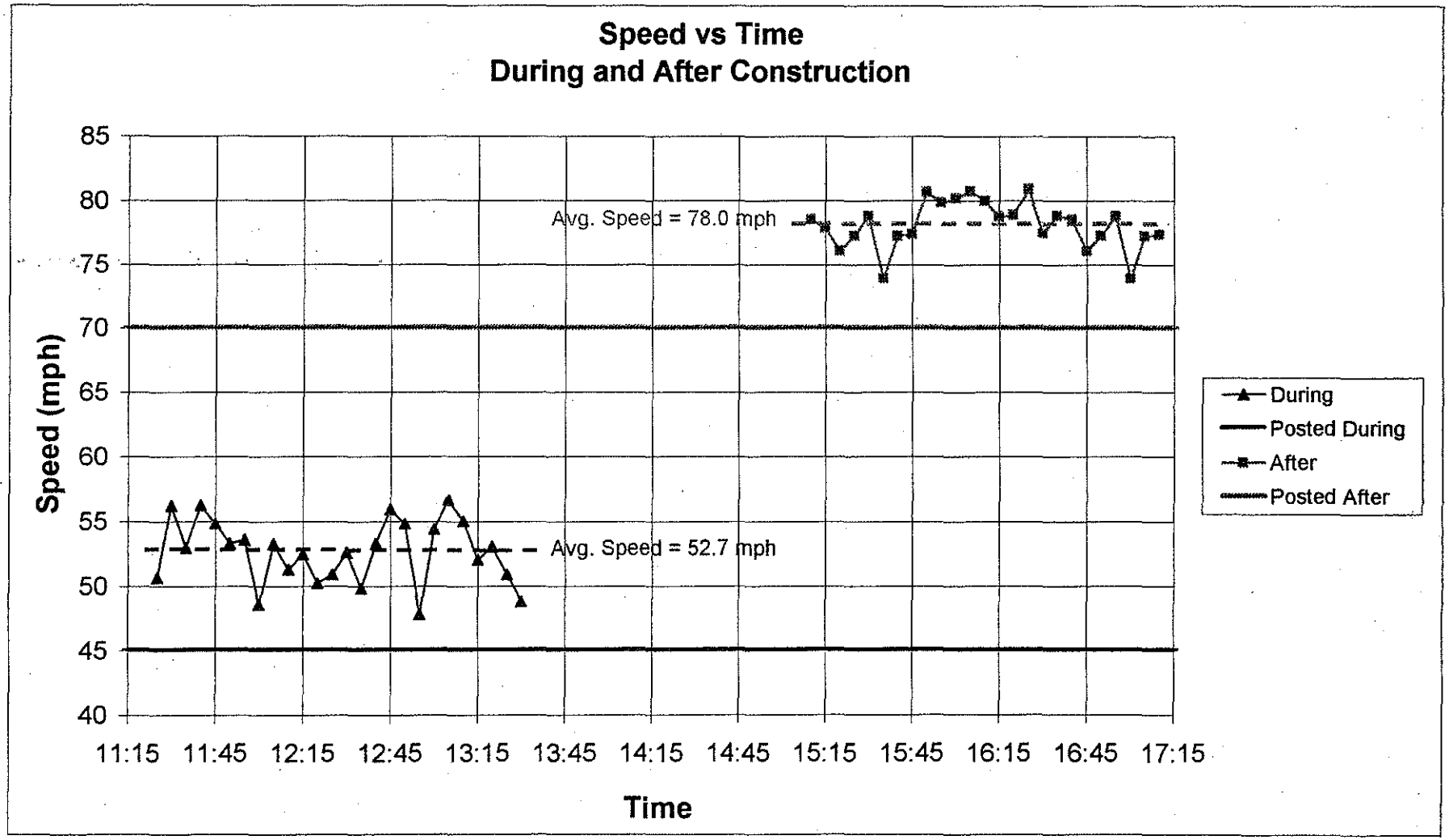
None

During Data Collection
Date and Time: Thursday, 9/18/97, 11:20 AM-1:20 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Shoulder work and barrier installation
Lane Closure(s): Slow lane closed, 1 lane open to traffic
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes (100 ft upstream of the site and 0.25 mile upstream of the bridge)
Police Present During Data Collection: No
Average Speed: 52.7

After Data Collection
Date and Time: Tuesday, 11/18/97, 3:10 PM-5:10 PM
Weather: Cloudy
Average Speed: 78.0

Comments: While the after speeds seem abnormally high, the during speeds are among the lowest for this category.

SB US-23@Carpenter Rd.
9/18/97 and 11/18/97



US-23 NB @ Carpenter Road

Location: South of Ann Arbor, exit 27
Direction: Northbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

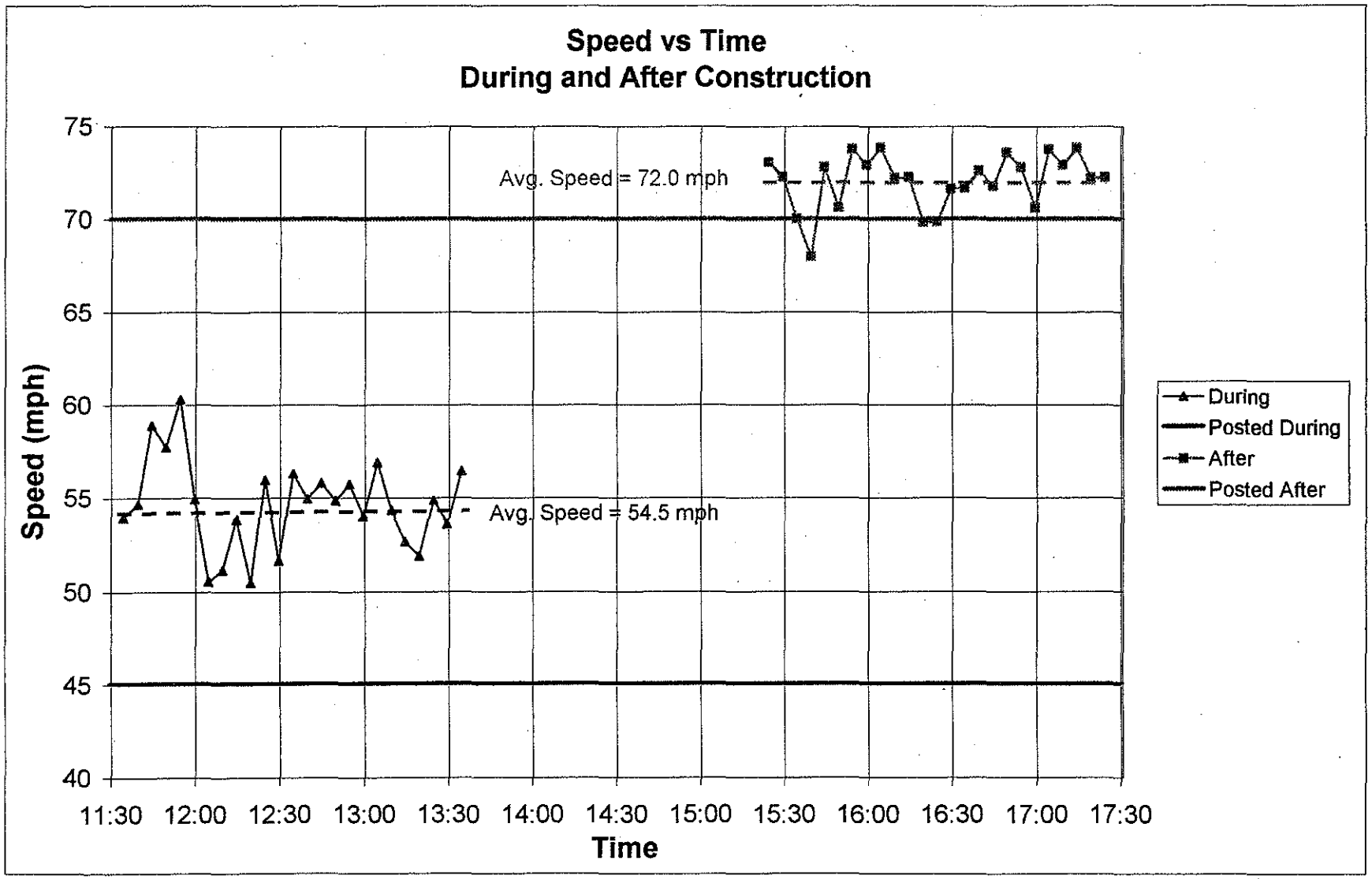
None

During Data Collection
Date and Time: Thursday, 9/18/97, 11:30 AM-1:30 PM
Weather: Sunny
Speed Limit During Construction: 45
Type of Work Done: Resurfacing and rehabilitation of lanes
Lane Closure(s): Slow lane closed, 1 lane of traffic maintained
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 54.5
Other Information: The road was curved approximately 150 ft upstream of the site

After Data Collection
Date and Time: Tuesday, 11/18/97, 3:20 PM-5:20 PM
Weather: Cloudy
Average Speed: 72.0

Comments: Although no workers were present the speeds observed during the work period were comparable to those at other sites when workers were present.

NB US-23@Carpenter Rd.
9/18/97 and 11/18/97



US-23 SB @ Geddes Road

Location: South of Ann Arbor, near exit 39
Direction: Southbound
Number of Lanes: Without Construction: 2
Regular Speed Limit: 65

Before Data Collection

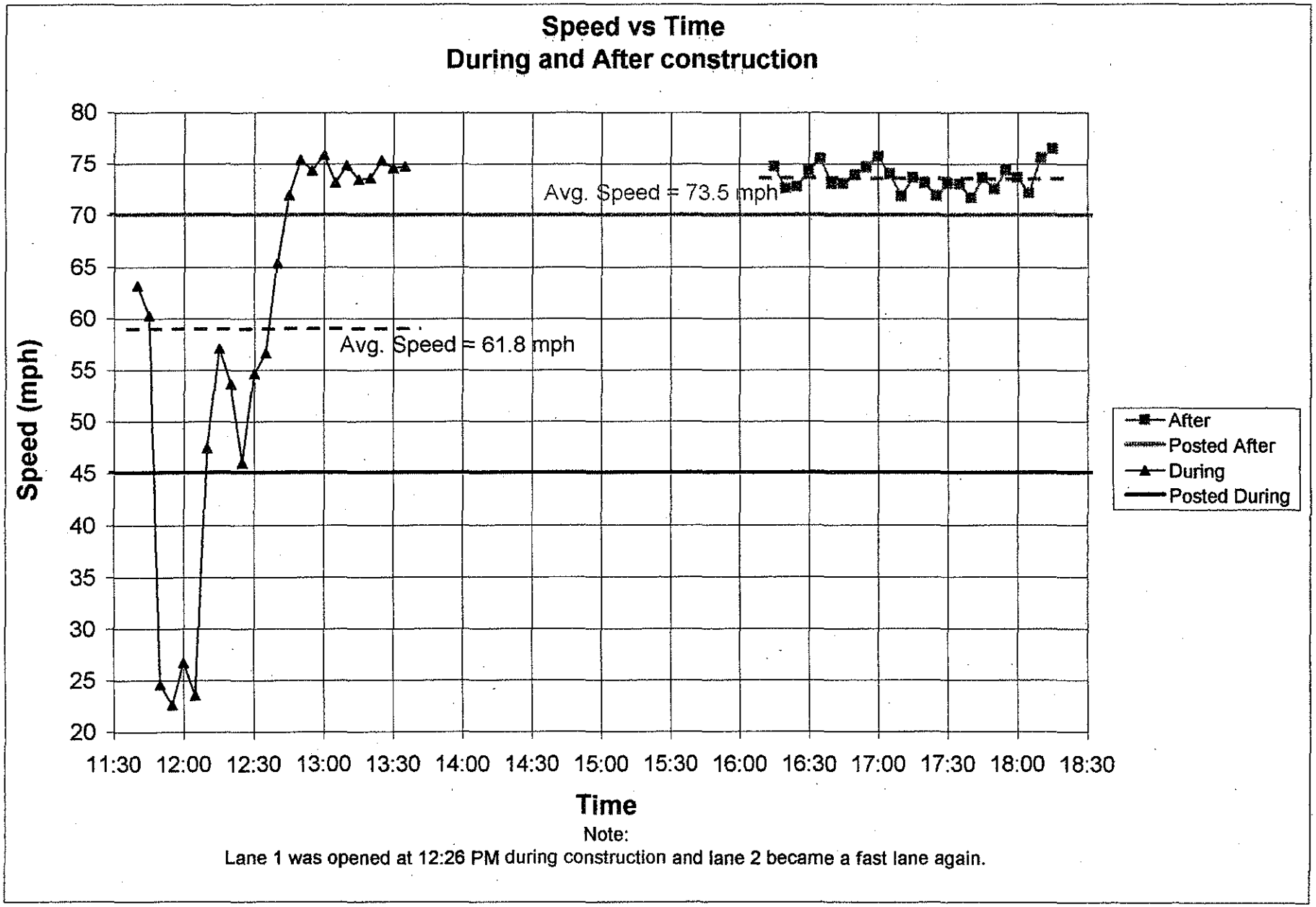
None

During Data Collection
Date and Time: Friday, 8/22/97, 11:40 AM-1:35 PM
Weather: Cloudy, breezy
Speed Limit During Construction: 45
Type of Work Done: Resurfacing and rehabilitation of right lane
Lane Closure(s): Slow lane closed (until 12:26 PM), 1 lane open to traffic
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: No (just stopped by to remove cones at 12:26 PM)
Police Present During Data Collection: No
Average Speed: 61.8
Other Information: The work was completed, but the right lane was still closed. There was a PDO accident approximately 0.5 mile upstream of the site. The site was congested from time to time. Deleted from at least some analyses.

After Data Collection
Date and Time: Thursday, 9/04/97, 4:15 PM-6:15 PM
Weather: Sunny
Average Speed: 73.5

Comments: The average speed during the work activity is somewhat misleading as the lane closure was removed about midway through the period.

SB US-23@Geddes Rd.
8/22/97 and 9/04/97



Note:
Lane 1 was opened at 12:26 PM during construction and lane 2 became a fast lane again.

M-14 EB @ Dixboro Road

Location: East of Ann Arbor
Direction: Eastbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

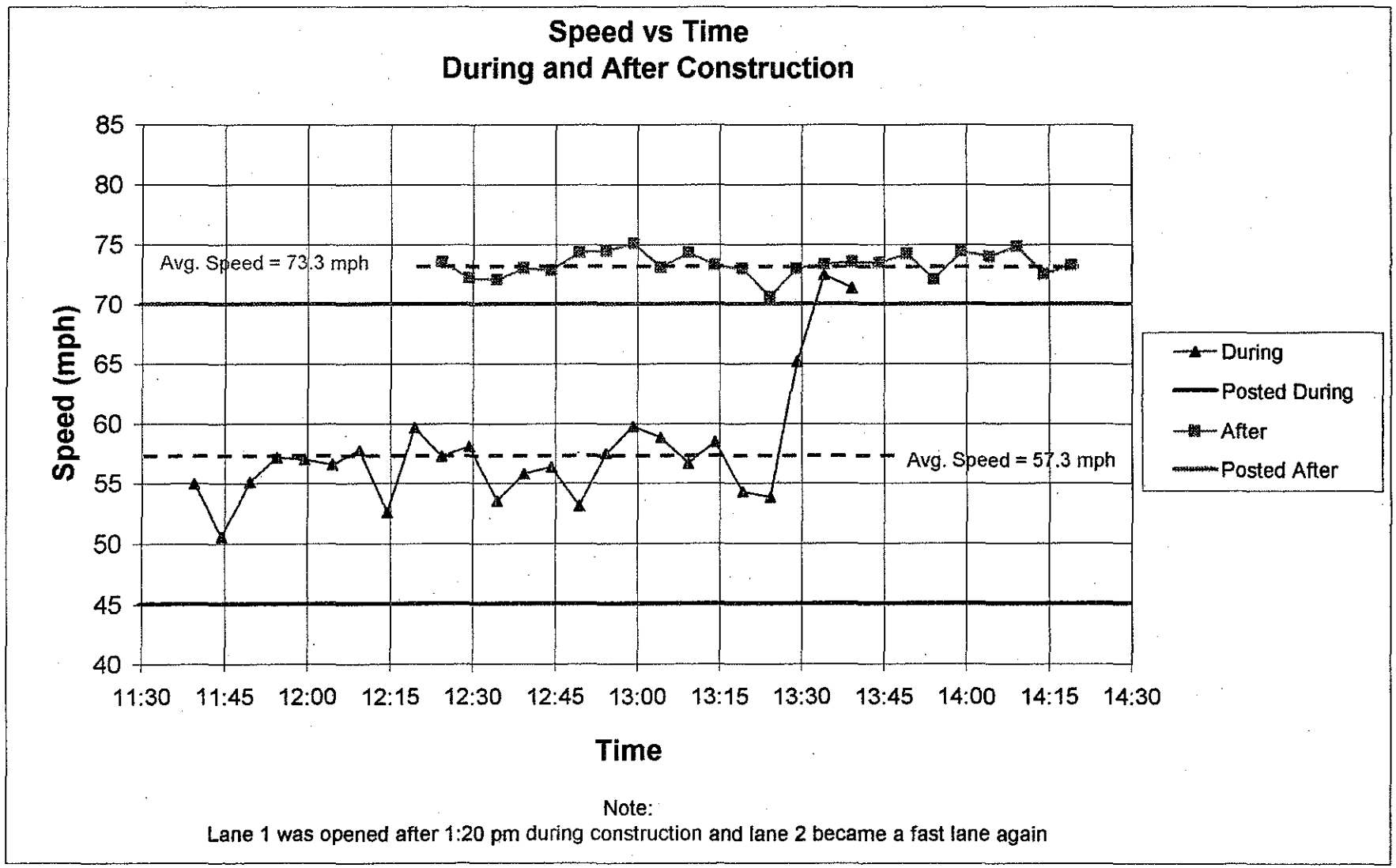
None

During Data Collection
Date and Time: Thursday, 8/28/97, 11:40 AM-1:40 PM
Weather: Partly cloudy
Speed Limit During Construction: 45
Type of Work Done: Shoulder work
Lane Closure(s): Slow lane closed (until 1:25 PM), 1 lane of traffic maintained
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes (approximately 0.5 mile west of the site)
Police Present During Data Collection: No
Average Speed: 56.0

After Data Collection
Date and Time: Tuesday, 9/09/97, 12:20 PM-2:20 PM
Weather: Showers
Average Speed: 73.3

Comments: Again, the average speeds observed during the work period may be slightly higher due to the fact that the lane closure was dismantled during the period and the lane was opened.

EB M-14@Dixboro Rd.
8/28/97 and 9/09/97



Note:
Lane 1 was opened after 1:20 pm during construction and lane 2 became a fast lane again

M-14 WB @ Dixboro Road

Location: East of Ann Arbor
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

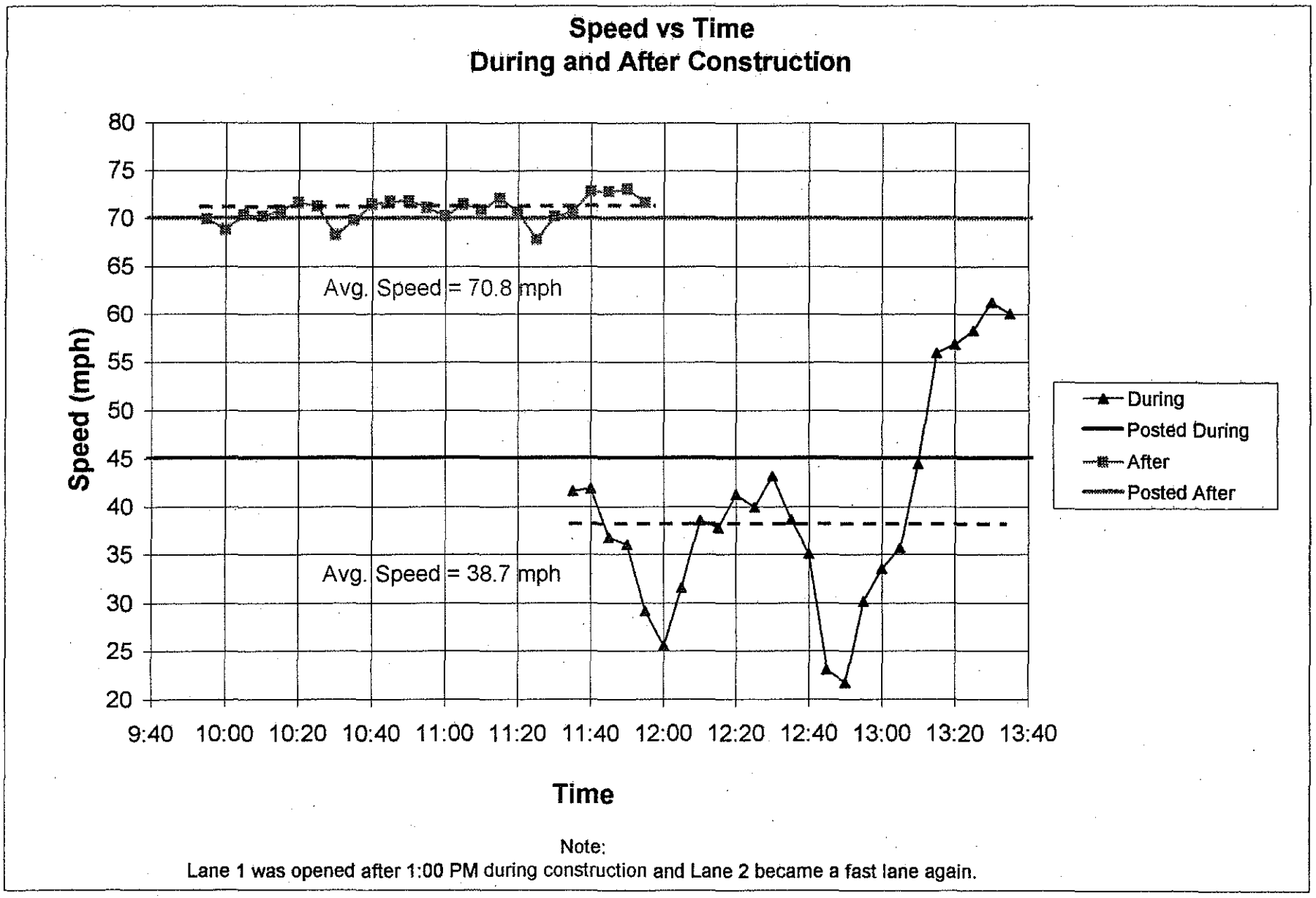
None

During Data Collection
Date and Time: Thursday, 8/28/97, 11:30 AM-1:30 PM
Weather: Partially cloudy
Speed Limit During Construction: 45
Type of Work Done: Shoulder work
Lane Closure(s): Slow lane closed (until 1:00 PM)
Lane Shift: No
Type of Lane Closure: Cones
Special Traffic Control: No
Workers Present During Data Collection: Yes (approximately 0.5 mile west of the site)
Police Present During Data Collection: No
Average Speed: 38.7

After Data Collection
Date and Time: Tuesday, 12/02/97, 9:53 AM-11:53 AM
Weather: Cloudy
Average Speed: 70.8

Comments: There were congested conditions during the during data collection.

WB M-14@Dixboro Rd.
8/28/97 and 12/2/97



Note:
Lane 1 was opened after 1:00 PM during construction and Lane 2 became a fast lane again.

OTHER SITES

There were several other "odd" sites where data were collected. These included one site where the posted speed limit both during and after (and before) was 55 mph as well as one where there was no speed limit reduction whatsoever although work was being done.

70→70: I-69 WB @ Miller Road

Location: West of Port Huron, milepoint 179
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 70

Before Data Collection

None

During Data Collection 1

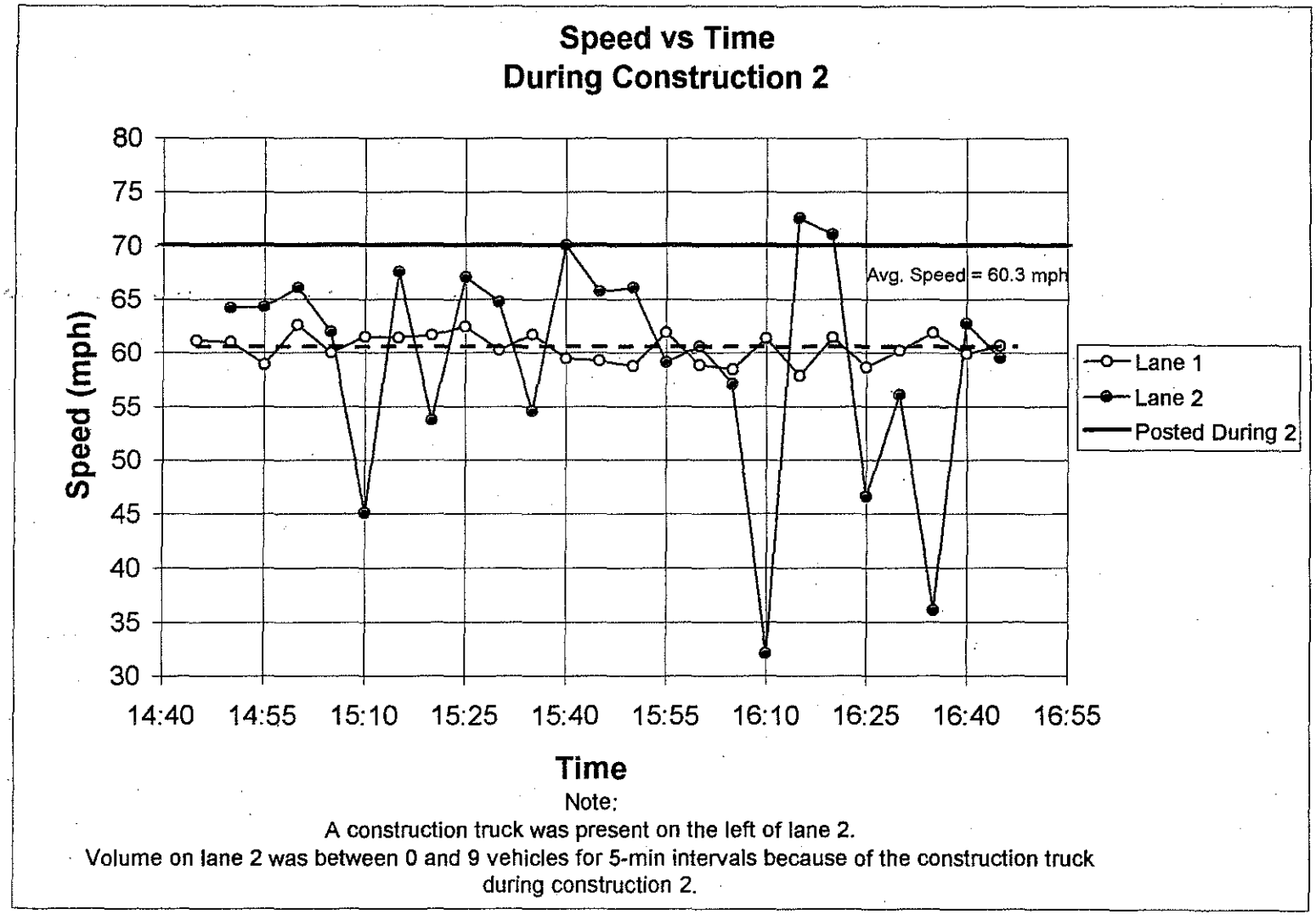
See 70-60-50 sites.

During Data Collection 2
Date and Time: Tuesday, 9/16/97, 2:45 PM-4:45 PM
Weather: Partly cloudy
Speed Limit During Construction: 70
Type of Work Done: Bridge repair
Lane Closure(s): No
Lane Shift: No
Type of Lane Closure: None
Special Traffic Control: No
Workers Present During Data Collection: Yes (under the bridge)
Police Present During Data Collection: No
Average Speed: 60.3
Other Information: Construction truck present on the left shoulder, 100' east of bridge

After Data Collection
Date and Time: Thursday, 10/30/97, 1:50 PM-3:50 PM
Weather: Partly sunny, windy
Average Speed: 64.8

Comments: Although the data collection for this condition was unplanned, it is interesting to note that this site illustrates the effect of the presence of workers without any lane closures or special speed limits.

WB I-69@ Miller Rd.
9/16/97



Note:
A construction truck was present on the left of lane 2.
Volume on lane 2 was between 0 and 9 vehicles for 5-min intervals because of the construction truck during construction 2.

55→55: I-496 EB @ Washington

Location: Lansing, exit 6
Direction: Eastbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 55

Before Data Collection

None

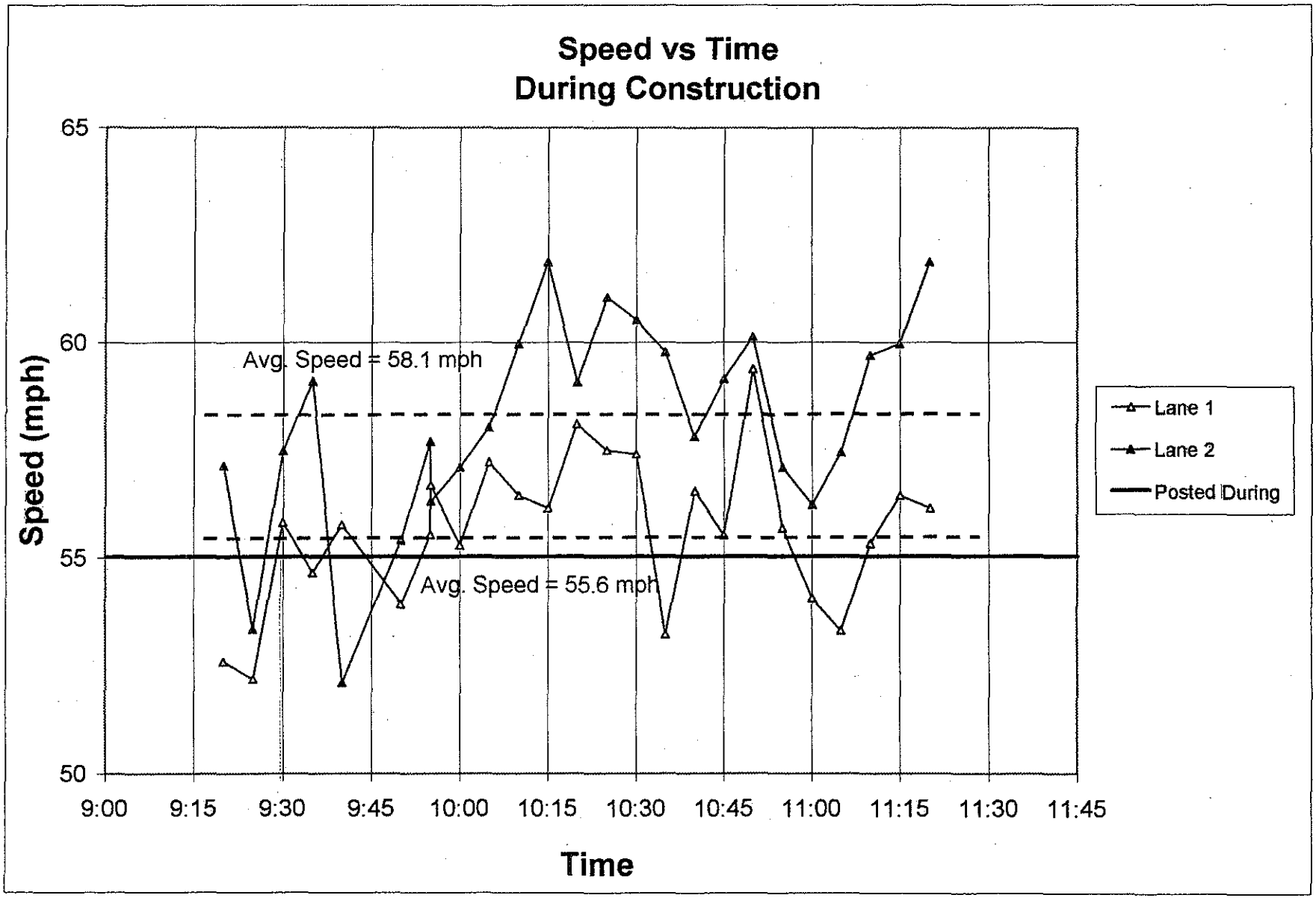
During Data Collection
Date and Time: Wednesday, 8/20/97, 9:20 AM-11:20 AM
Weather: Showers
Speed Limit During Construction: 55
Type of Work Done: Shoulder work and barrier installation
Lane Closure(s): None, left shoulder closed
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: Yes, moving
Police Present During Data Collection: No
Average Speed: 56.4

After Data Collection

None

Comments: This site was urban in character and had a 55 mph speed limit posted. This limit was maintained even work was being done.

EB I-496@Washington St.
8/20/97



55→55: I-496 WB @ Washington

Location: Lansing, exit 6
Direction: Westbound
Number of Lanes Without Construction: 2
Regular Speed Limit: 55

Before Data Collection

None

During Data Collection 1
Date and Time: Friday, 8/08/97, 10:05 AM-12:05 PM
Weather: Sunny
Speed Limit During Construction: 55
Type of Work Done: Shoulder work and barrier installation
Lane Closure(s): No lanes closed, shoulders closed
Lane Shift: No
Type of Lane Closure: Drums
Special Traffic Control: No
Workers Present During Data Collection: No
Police Present During Data Collection: No
Average Speed: 59.5

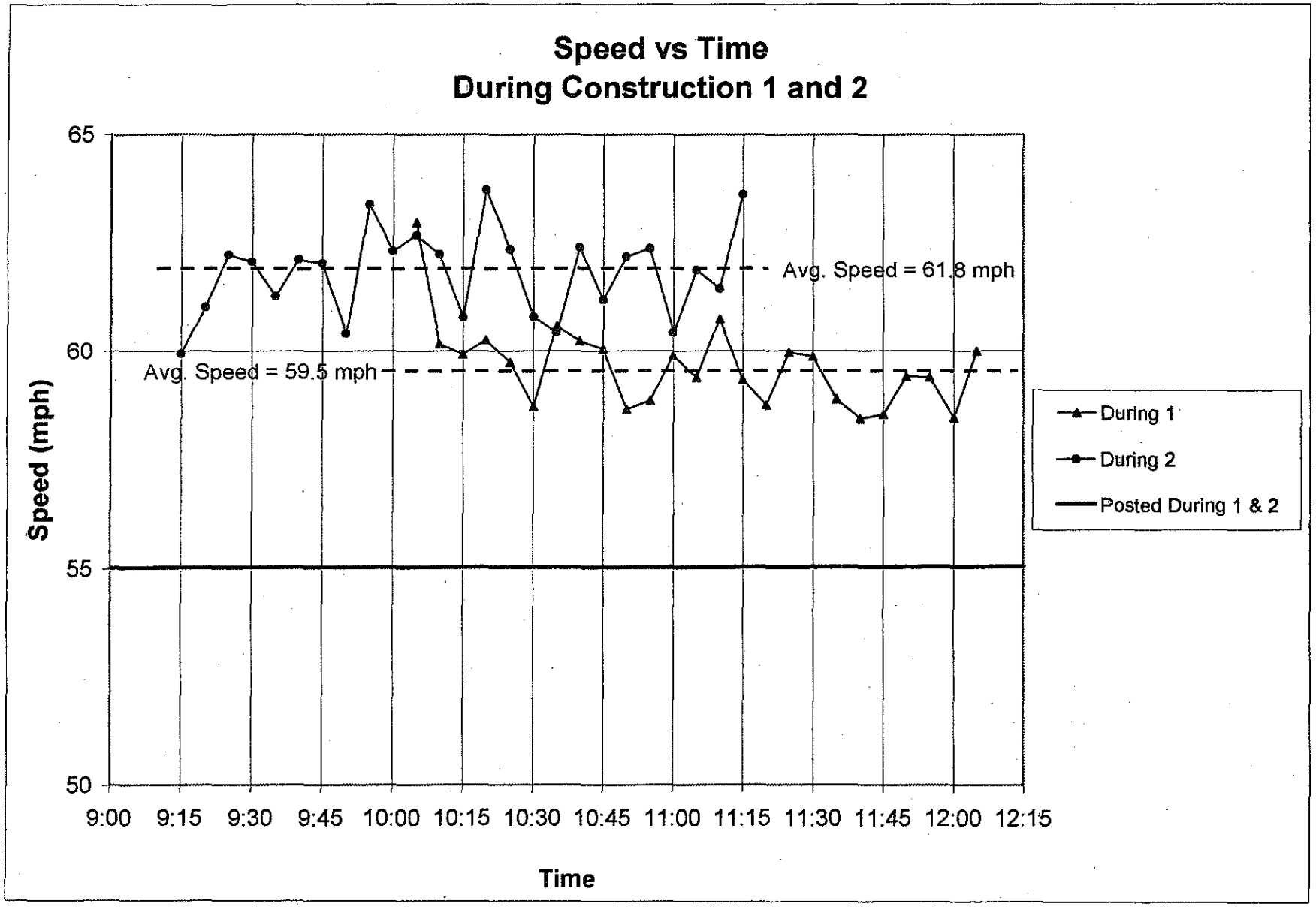
During Data Collection 2 (conditions same as 1 except as noted)
Date and Time: Wednesday, 8/20/97, 9:15 AM-11:15 AM
Weather: Rainy
Average Speed: 61.8
Workers Present During Data Collection: Yes, within ¼ mile

After Data Collection

None

Comments: The average speeds observed during the work period at this site were somewhat higher than similar sites.

WB I-496@Washington St.
8/8/97 and 8/20/97



APPENDIX B

SPECIAL SITE CONSIDERATIONS

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During the initial analysis, several sites were noted as being different from others. For the supplemental analysis, these sites were typically eliminated when those differences might make a difference (although analyses were typically done with and without these sites present). In most instances, some during and after analysis was still done for these sites. A list of the sites follows.

EB 1-96 at Chilson Road

This site was a 70-60-50 site during construction. However, the 50 mph limit was apparently due to a sharp (abrupt) lane shift that was present in this zone and not worker presence. This appeared to be the only site where the 50 mph limit was evoked because of geometry.

WB 1-69 at Miller Road

This was the **only** that went from 70 to 50 mph without an intermediate step of 60.

WB I-69 at Miller Road

During another period at the I-69/Miller Road site, there was no speed reduction at all although there were workers present immediately under the bridge used for data collection. This is the only site of its kind.

EB and WB I-496 at Washington Avenue

This was one of the few sites in a very urbanized area (downtown Lansing). It also had no speed reduction during construction (the normal limit of 55 mph was maintained), no lane reduction, and involved some shoulder and guardrail work. After conditions also had barrels present.

EB I-96 at Exit 133

This site was the only 70-45mph site that had a reduction of three lanes to two with a 70-45 mph speed reduction.

SB US-23 at Geddes Road

The "after" speed limit is 65 mph—it is the only site with this speed limit. The "during" data did not reflect "free flow" conditions.

NB US-127 at Barnes Road

This is the only site that had "before" data. These data at this site were not used.

WB US-10 at Flajole and Bay City Roads (2 sites)

These were the only sites where "after" speeds were collected during snow showers.

WB M-14 at Dixboro Road

During data were not indicative of "free flow."

WB I-96 at Pleasant Valley Road

There were no workers and no lane reductions for this 70-60 site and speeds appeared to be abnormally high (the average speed was calculated in excess of 75 mph)—an error of some sort was expected in either the collection or reduction of the data.

NB I-275 at Joy Road

The during data were not indicative of "free flow" conditions.