Reexamination of Duration and Schedule of Short-Period Traffic Counts in Canada

by

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ABSTRACT

REEXAMINATION OF DURATION AND SCHEDULE
OF SHORT-PERIOD TRAFFIC COUNTS IN CANADA

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This thesis analyses the accuracy and cost-effectiveness of short-period manual traffic counts. Alberta's primary highway system is investigated for the purpose of this study. The most important feature of the analysis is that it takes into account the nature of the road sites surveyed. The roads in the system under investigation are classified into four types: (a) commuter sites; (b) non-recreational low volume sites; (c) rural long distance sites; and (d) recreational sites.

The accuracy of short-period counts is expressed in terms of a deviation either side of the estimated volume, which defines limits of the interval in which the actual volume is most likely to be. In the tests of this study, a relative measure of deviation, namely the coefficient of variation, is used in order to compare the variation in several sets of data for the counts of different durations and schedules.

The analysis carried out in this thesis illustrates clearly that the most important considerations for rationalization of short-period manual counts are: (a) the type of road site being surveyed;

and (b) the hour-to-hour traffic variations within the same day. The month of year, the day of week, and the duration of counts are other significant factors which must be considered in order to devise the most efficient way of short-period counts.

The findings of this research provide a better understanding of the factors that affect the accuracy of estimating traffic volumes. It is hoped that with this better understanding, agencies will be able to design and schedule more cost effective short-period traffic counting programs without any loss in accuracy, since many other provincial highway agencies have available to them the same type of data as used in this analysis.

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INTRODUCTION

Several traffic counting programs are undertaken by roadway agencies to obtain values of average annual daily traffic (AADT) and other traffic data for their road networks. The most commonly used programs are: (a) continuous counting by permanent traffic counters (PTCs); (b) seasonal counting by portable counters, where counts are taken few times a year for periods from 48 hours to 2 weeks in length; and (c) short-period counting, where manual traffic counts are undertaken for less than a day. The PTCs provide actual temporal distribution of traffic movement and the true values of AADT. The seasonal and short-period counts furnish only sample information and, therefore, need appropriate factoring to yield the estimates of AADT values.

In addition to the estimates of AADT, the short-period counting programs provide such important data as vehicle classification and turning movements, which are frequently required for planning and design of roads for both safety and economy purposes. The proposed study is concerned with the short-period manual counting programs.

All the provincial transportation agencies in Canada undertake short-period traffic counting programs on an annual basis. Most of such traffic counting is carried out by employing

students during Spring and Summer seasons, including the months of May, June, July and August. The number of students hired for this purpose varies from province to province and is generally in the range of 10 to 20 students for the entire period.

Although it is true that the short-period manual counting is undertaken for a period of less than a day, there is a considerable difference in the actual durations and schedules adopted by the different provinces. For example: (i) Le Ministère des Transports in Quebec generally carries out 12-hour (07:00h-19:00h) and 8-hour (07:00h-11:00h and 15:00h-19:00h) schedules; (ii) Alberta Transportation uses 12-hour (07:00h-19:00h) and 9-hour (08:00h-17:00h) schedules; and (iii) Ontario's Ministry of Transportation and Communications (MTC) employs 8-hour (07:00h-11:00h and 14:00h-18:00h) schedules.

There are two important aspects which should be considered in relation to the short-period manual counting programs. One is that the quality of data used in transportation studies is a crucial factor affecting the reliability of the results. The other is that because collecting data is expensive, especially when considerable overtime wages are involved in 9-hour or 12-hour counting, the method of collection should be as cost-effective as possible.

During these times of budgetary constraints, some authorities feel that the improvement in accuracy, in extending a traffic count at a spot location beyong six hours, may be small.

But very little scientific work has been done towards any systematic comparison between the 12-hour traffic surveys and the shorter surveys in the context of the provincial or rural roads in Canada. The main objectives of this study are: (a) to analyse the accuracy and cost-effectiveness of the existing programs, such as 12-hour, 9-hour and 8-hour counts as compared to shorter manual traffic counts; (b) to study the influence of road type and traffic volume on the accuracy of different short-period surveys; and (c) to specify appropriate schedules of the shorter counts if they are reasonable in terms of the accuracy of the results.

Chapter 2

STUDY BACKGROUND AND APPROACH

Estimation of AADT from Short-Period Counts

The usual method of estimating AADT from sample counts is that advocated by the U.S. Bureau of Public Roads in its Guide for Traffic Volume Counting Manual (BPR, 1965). In general, the BPR method involves: (a) grouping together the PTC sites into similar patterns of monthly traffic variation; (b) determining average expansion factors for each group; (c) assigning road sections that do not have PTCs to one of these groups; and (d) applying the appropriate average expansion factor to sample counts to produce an estimate of AADT.

A commonly used form of mathematical relationship for estimating AADT from sample counts of less than 24 hours, is in which the count is expanded first to 24-hour volume using an hourly expansion factor (H), second to average daily volume by using a daily expansion factor (D), and, third, to the annual flow using a seasonal expansion factor (S). This formula may be expressed as:

(1) Estimated AADT = short-period volume count x H x D x S

As indicated earlier, the values of average expansion factors for different groups of roads are computed from the PTC data. These factors are defined as:

(2) $$\text{Hourly factor (H)} = \frac{\text{Average volume for 24-hour period}}{\text{Average volume for particular duration of the count}}$$

(3) $$\text{Daily factor (D)} = \frac{\text{Average total volume for week}/7}{\text{Average volume for particular day}}$$

(4) $$\text{Seasonal factor (S)} = \frac{\text{Total yearly volume}/12}{\text{Total volume for particular month}}$$

These expansion factors are normally plotted or tabulated as shown in Table 1.

Table 1

Typical Hourly, Daily, and Seasonal Factors for Obtaining the Annual Average Daily Traffic (AADT)

HOURLY VARIATION OF TRAFFIC VOLUME ON A STATE HIGHWAY SYSTEM

Hour	Per Cent of Total 24 Hour Volume	Hour	Per Cent of total 24-Hour Volume
6:00– 7.00 A.M.	2.53	6:00– 7 00 P.M	6 12
7.00– 8 00 A.M.	3 69	7.00– 8.00 P.M.	5 72
8 00– 9.00 A.M.	4 42	8:00– 9 00 P.M	4.74
9 00–10:00 A.M.	5.34	9:00–10 00 P.M.	3.85
10:00–11:00 A.M.	5.73	10:00–11 00 P.M	3 18
11.00–12.00 A.M.	5.42	11.00–12 00 Midnight	2.61
12.00– 1:00 P.M.	5.34	12.00– 1:00 A.M.	1.89
1:00– 2:00 P.M	6.18	1.00– 2:00 A.M.	1 32
2 00–3:00 P.M	6 56	2:00– 3.00 A.M.	0 90
3:00– 4.00 P.M.	6 88	3:00– 4:00 A.M	0.76
4.00– 5 00 P.M.	7.71	4:00– 5 00 A.M.	0 76
5:00– 6:00 P.M.	7.30	5:00– 6 00 A.M.	1.05

Example An 8-hour count (7.00–11:00 A.M. and 2 00–6.00 P.M.) constitutes 47 6 per cent (factor 2 09) of total 24 hour volume. Average 24-hour count = 8-hour count (7 00–11:00 A.M. and 2.00–6:00 P.M.) × 2 09.

DAILY VARIATION OF TRAFFIC VOLUME ON A STATE HIGHWAY SYSTEM

Day	Per Cent of Total Weekly Volume	Per Cent of Average Day	Weekly Factor
Sunday	18.10	126.73	0 789
Monday	13 32	93.25	1.072
Tuesday	12 75	89.14	1 121
Wednesday	12.89	90 22	1.108
Thursday	13.00	91 04	1 096
Friday	14.06	98.44	1 015
Saturday	15 88	111.18	0.899

Example To convert a Tuesday count to average day for week, multiply by 1.121.

SEASONAL VARIATION BY MONTHS

Month	Per Cent of Average Month	Monthly Factor	Month	Per Cent of Average Month	Monthly Factor
January	82.24	1 215	July	109.51	0.913
February	83 94	1.191	August	113 38	0.882
March	90.89	1.100	September	113.10	0 884
April	100 79	0 992	October	107.46	0.931
May	105.29	0 949	November	97.38	1.026
June	108.89	0 918	December	87.13	1.114

(Source: *Traffic Engineering Handbook*, 3rd ed., ITE, 1965)

Example To convert a count in May to average month for year, multiply by 0 949.

In this thesis, a slight variation from the commonly used equation (1) for estimating AADT from short-period counts will be applied. First, the sample counts of shorter duration than 24 hours, taken on a particular day in a given month, is expanded to an average 24-hour daily volume using a weekly expansion factor (WF) for a given month, and then to the annual average flow using a monthly expansion factor (MF) for a given year. This relationship may be expressed as:

(5) $$\text{Estimated AADT} = \text{Short-period volume count} \times \text{WF} \times \text{MF}$$

where

(6) $$\text{Weekly Factor (WF)} = \frac{\text{Average 24-hour volume for a given day and month}}{\text{Average short-period count for a given day and month}}$$

(7) $$\text{Monthly Factor (MF)} = \frac{\text{Annual average daily traffic volume (AADT)}}{\text{Average 24-hour volume for a given day and month}}$$

Tables 2 and 3 give an example of the weekly and monthly expansion factors from a permanent traffic counter at site C09 (commuter).

Table 2

Weekly Factor for a 12HR (7-19) Volume Count at Site C09 (Commuter) on a Wednesday in May for 1978, 1979 and 1980

YEAR	DATE	12HR-VOL.	24HR-VOL.
1978	3	7058	8985
1978	10	6862	9066
1978	17	6824	8811
1978	24	6899	8784
1978	31	6682	8491
1979	2	7122	8992
1979	9	7484	9423
1979	16	7207	9203
1979	23	7032	9174
1979	30	7410	9394
1980	7	7624	9806
1980	14	7851	10150
1980	21	7809	10042
1980	28	8012	10244
	AVERAGE:	7277	9326

$$\text{12HR Weekly Factor} = \frac{\text{AV.24HR-VOL}}{\text{AV.12HR-VOL}} = \frac{9326}{7277} = 1.282$$

Table 3

Monthly Factor for a Volume Count
at Site C09 (Commuter) in May for the Year 1978

DAY OF WEEK	AVERAGE 24HR-VOLUME	AADT	MONTHLY FACTOR
Sunday	6725	8296	1.234
Monday	8318	8296	0.997
Tuesday	8574	8296	0.968
Wednesday	8868	8296	0.935
Thursday	9441	8296	0.879
Friday	10158	8296	0.817
Saturday	8220	8296	1.009

Errors of AADT Estimates

There are four sources of error in estimating AADT at a point using Equation 1:

1. The hourly factor at a counting site generally will not be exactly equal to the group mean;

2. the daily factor at the counting site will differ from the average daily factor for the group;

3. the seasonal factor at the site will not be exactly the same as the mean group seasonal factor; and

4. the road section on which a count is taken may have been assigned to a wrong PTC or road group. This error is assumed to be negligible (Bodle, 1966).

The magnitudes of error due to the hourly factor is generally expected to be a function of the duration and schedule of a particular short survey. However, any variation in the duration and schedule of a short-period count will not affect the errors due to the daily factor and the seasonal factor.

In the past, there have been studies to determine the effect of the duration of sample counts on the accuracy of resulting AADT estimates. The results of one such study concerning the so-called "coverage counts" (or seasonal traffic

counts) were published by Petroff and Blensly (1954). Commenting on Figure 1, which is adopted from the U.S. study, the authors state:

> "The observation of the data presented in Figure 1 which is of utmost practical significance is that traffic counts of 24-hour duration on weekdays have a coefficient of variation of 10 percent or less when compared with the mean volume for a weekday in a given month of stations having the mean volume of about 500 vehicles per day or more. This applies usually to all months except the winter months in some states..... Counts of 48-hour duration improve the accuracy by 20 to 25 percent, thus raising the confidence limit from 68 percent to about 75 percent for one standard deviation of 10 percent, also extending the range of volumes down to about 300 vehicles per day.
>
> This translated into everyday language means that two-thirds to three-fourths, depending on the length of the count, of all coverage or blanket counts may be expected to have an error of about 10 percent or less when compared with the true mean weekday volume of the month during which they were taken when volumes are 300 to 500 vehicles per day or more."

The above observations are for sample counts of one day or longer duration in rural areas. Very limited amount of work has been reported in literature concerning the errors of shorter duration counts.

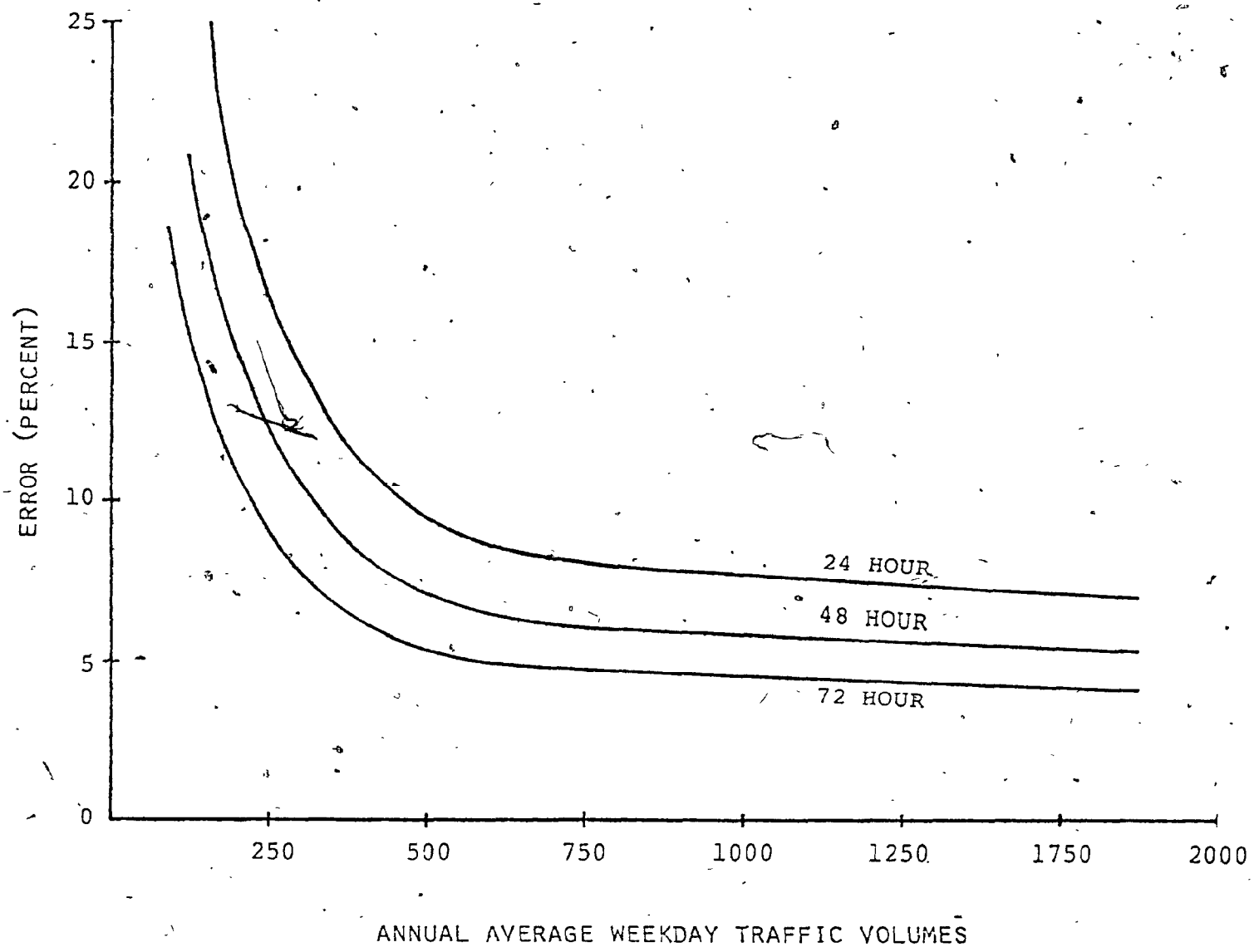

FIGURE 1 - Variation of weekday traffic volumes. Source: Petroff and Blensly (1954)

A study conducted by local Government Operational Research Unit (1978) for the Department of Transport in Britain showed that a "reasonably accurate estimate" of AADT can usually be based on a single 16-hour count. Another British study (Phillips, 1980) on short-period counting reported that:

> "A six-hour count in the afternoon (1300h-1900h or 1400h-2000h) on a weekday in late spring or early autumn will provide a reasonable estimate of the annual flow....
>
> If a more accurate estimate of annual flow is required it would be better to repeat the six-hour count later in the same month rather than increase the length of counting to 16 hours. The expected accuracy from two six-hour counts is similar to that from a single 16-hour count, even though four hours less counting is undertaken."

The principal focus of this thesis is to analyse the errors associated with the existing manual counting programs as used in Alberta, Ontario and Quebec, and to investigate the potential increases in the errors if shorter counts (e.g. 6-hour and 4-hour programs) are adopted by the provincial authorities.

Statistical Accuracy of Short-Period Counts

The accuracy of short-period counts can be expressed in terms of a deviation either side of the estimated 24-hour volume, which defines limits of the interval in which the actual 24-hour volume is most likely to lie. In the tests of this study, it was necessary to use a relative measure of deviation in order to compare the variation in several sets of data for counts of different durations. The coefficient of variation was used for this purpose. For a particular short-period count at a given roadway site, the coefficient of variation (CV) was defined as:[1]

$$(8) \qquad CV = \frac{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})^2}}{\bar{X}} = \frac{\text{standard deviation}}{\bar{X}}$$

where

X_i = ith volume count (percent) at the site of a given schedule,

n = total number of volume counts (percent) taken at the site, and

$\bar{X}$ = the average value of the n volume counts (percent).

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[1] Volume counts (percent) is defined as

$$\frac{\text{short period count}}{\text{daily volume}} \times 100$$

The coefficient of variation CV, as defined in Equation 8, is the standard deviation expressed as a fraction (or percentage) of the mean value $\bar{X}$. A low value of CV, which is associated with less dispersion of individual volume date about their mean, reflects a high accuracy in estimating the actual traffic volumes. Table 4 gives an example of the coefficient of variation CV for site C09 (commuter).

Table 4

Coefficient of Variation CV of Volume Count (Percent)
on a Wednesday in May for 1978, 1979 and 1980
Commuter Site - C09

YEAR	DATE	9HR VOL. (8-17h)	12HR VOL. (7-19h)	24HR VOL. (0-24h)	9HR Vol:Count (Percent) (9HR/24HR)	12HR Vol.Count (Percent) (12HR/24HR)
1978	3	5210	7058	8985	58.0	78.6
1978	10	4978	6862	9066	54.9	75.7
1978	17	5014	6824	8811	56.9	77.4
1978	24	5143	6899	8784	58.5	78.5
1978	31	4996	6682	8491	58.8	78.7
1979	2	5223	7122	8992	58.0	79.2
1979	9	5534	7484	9423	58.7	79.4
1979	16	5248	7207	9203	57.0	78.3
1979	23	5081	7032	9174	55.3	76.7
1979	30	5337	7410	9394	56.5	78.9
1980	7	5543	7624	9806	56.5	77.7
1980	14	5836	7851	10150	57.5	77.3
1980	21	5692	7809	10042	56.7	77.8
1980	28	5868	8012	10244	57.3	78.2
				AVERAGE:	57.2	78.0
				STD:	1.2	1.0
				CV:	0.021	0.013

The two error terms that were important from the point of view of this study were defined as following:

(9) (a) $$ET = \frac{(\overline{AADT} - AADT)}{AADT} \times 100$$

where ET = total percent error in the estimated value of annual average daily traffic from a specific week day in a given month;

$\overline{AADT}$ = the estimated value of the flow; and

AADT = actual value of the flow; and

(10) (b) $$R.M.S.(ET) = \sqrt{\frac{\sum_{j=1}^{n} ET_j^2}{n}}$$

where R.M.S.(ET) = the root mean square of a set of ET from a specific week day in a given month

ET_j = jth total percent error at the site of a given schedule

n = total number of possible ET taken at the site of a given month

Table 5 gives an example of these two error terms for site C09 (commuter).

Table 5

ET and R.M.S.(ET) at Site CO9 (Commuter) on a Wednesday in May for a 12HR (7-19h) Counting Schedule in 1978, 1979 and 1980

YEAR	DATE	12HR VOL.	WEEKLY FACTOR	MONTHLY FACTOR	ESTIMATED AADT	ACTUAL AADT	ET
1978	3	7058	1.282	0.935	8460	8296	2.0
1978	10	6862	1.282	0.935	8225	8296	0.8
1978	17	6824	1.282	0.935	8180	8296	1.4
1978	24	6899	1.282	0.935	8270	8296	0.3
1978	31	6682	1.282	0.935	8010	8296	3.4
1979	2	7122	1.282	0.950	8674	8809	1.5
1979	9	7484	1.282	0.950	9115	8809	3.5
1979	16	7207	1.282	0.950	8778	8809	0.3
1979	23	7032	1.282	0.950	8567	8809	2.8
1979	30	7410	1.282	0.950	9025	8809	2.5
1980	7	7624	1.282	0.926	9051	9319	2.9
1980	14	7851	1.282	0.926	9320	9319	0.0
1980	21	7809	1.282	0.926	9271	9319	0.5
1980	28	8012	1.282	0.926	9512	9319	2.1
						R.M.S.(ET):	2.1

Study Data

Since the PTCs, when grouped, are considered to represent the population of the group, their statistical measures of variation (such as standard deviation and coefficient of variation) are also the measures of the errors at the short-period counting sites - the latter being also samples taken out of the same population.

For the purpose of this study, Alberta's PTC data were analysed. The PTC information for the years 1978, 1979 and 1980 were included in the study. Considering the reliability of the available Alberta's PTC data for those years, a total of 41 PTCs were selected to be used in this investigation.

Because the short-period manual traffic counting in Alberta and other provinces is carried out mainly in the Spring and Summer seasons, only the months of May, June, July and August were chosen for the analysis. Computations for the coefficient of variation were carried out by each day of the week for different counting schedules. The holidays, such as Victoria Day and Canada Day, were eliminated from the analysis. A number of certain other days, that displayed very unusual volume and pattern of traffic (such as due to reconstruction of a facility), were also excluded from the study. Otherwise, it was assumed that the hourly traffic variations at study sites did not change significantly from 1978 to 1980.

Classification of Road Sites

One of the most important causes of variability in the traffic flows and the errors of AADT estimates is the nature of the road sites surveyed. Actually, it is believed that the difference between sites can be so large as to overwhelm other causes of variability in predictions. On the basis of two recent studies[2] (Sharma and Werner, 1981; Sharma, 1981) on Alberta highways, the study sites were classified into four broad types according to their temporal variations in traffic flows and other such characteristics as trip purpose and trip-length distribution. These types are:

1. Commuter sites, e.g., the PTC site of C09 located on Highway 3 East of Lethbridge;
2. non-recreational low volume (rural) sites, e.g., the PTC site C147 located on Highway 35 North of Grimshaw;
3. rural long distance sites, e.g., the PTC site of C18 located on Trans-Canada Highway West of Medicine Hat; and
4. recreational sites, e.g., the PTC site of C114 located on Yellowhead Highway East of Jasper National Park.

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[2] Appendix A gives the computer program for the recent study by Sharma and Werner on an improved method of grouping provincewide permanent traffic counters, using a clustering technique called hierarchical grouping.

Trip purpose information for the typical examples of these classes, i.e., sites C09, C147, C18 and C114 are summarized in Table 6. Seasonal variation in traffic flows at these typical sites is portrayed in Figure 2.

Table 6. Seasonal traffic variation and estimated trip-purpose characteristics of some typical road sites in Alberta.

Road Sites	Road Class	Trip-Purpose, % (Summer Weekdays)	
		Social-Recreational	Work-Business
C09	Commuter	17	83
C147	Non-recreational low volume	22	78
C18	Rural long distance	63	37
C114	Recreational	75	25

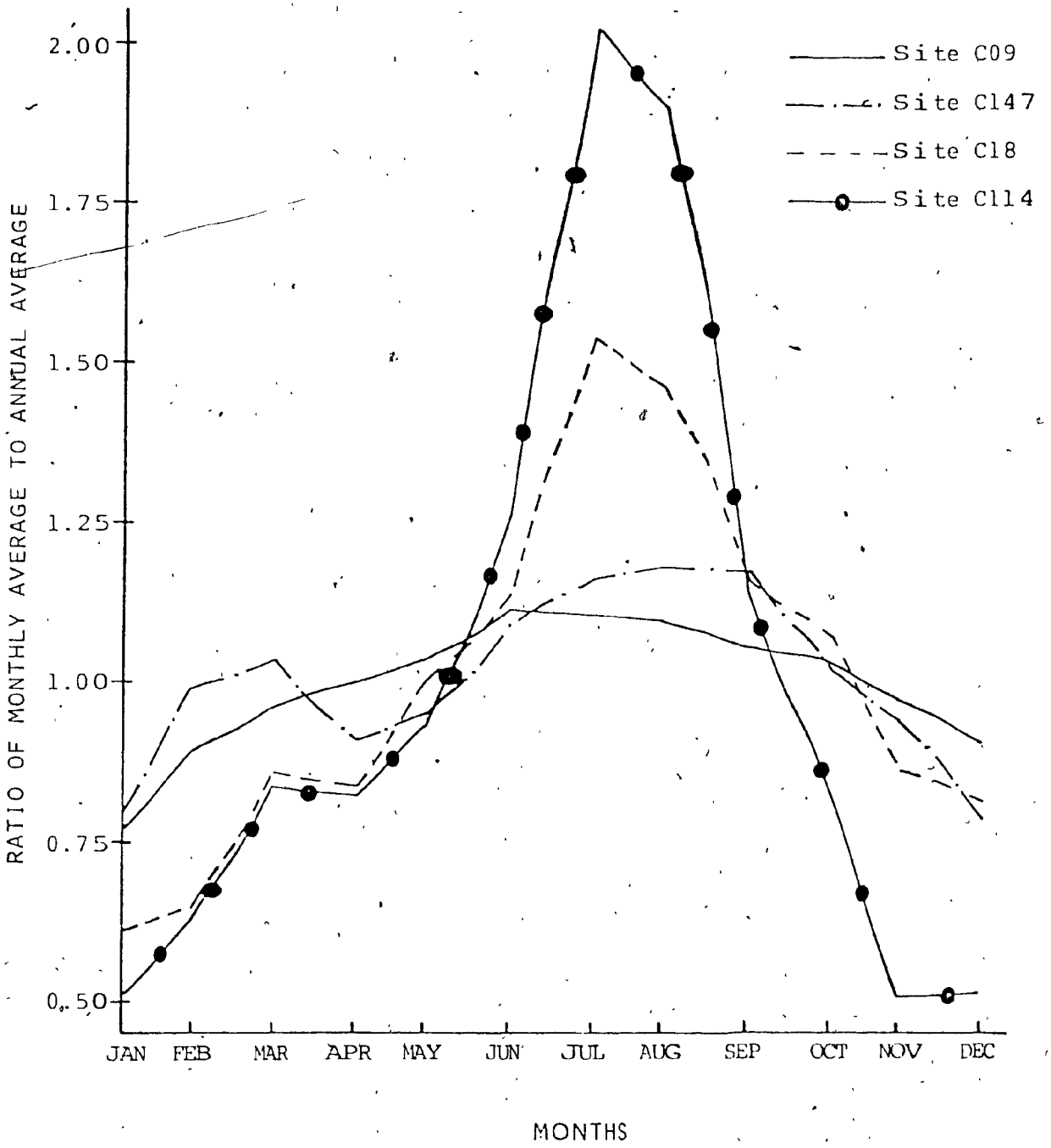

FIGURE 2 - Seasonal variation in traffic flows at some typical road sites in Alberta.

Selection of Study Schedules

Other important considerations in manual traffic surveys are the duration and schedule of counting. For a particular day, the best short-period will be that which: (a) has the most stable relationship with the annual flow; and (b) contains the most representative and important levels (e.g., evening peak) of traffic that occur in the course of the day.

Sample schedules in this study were selected mainly from the considerations of: (a) the current practice in Canada; and (b) the variability in the volumes of different duration counts in the day. According to (a), three schedules were chosen. These are:

(1) 12-h(07:00h-19:00h)

(2) 9-h(08:00h-17:00h)

(3) 8-h(07:00h-11:00h and 14:00h-18:00h)

The coefficients of variation for continuous counts of 8-hour and shorter duration were investigated for all classes of roads,[3] such as shown in Figure 3 for the rural long distance road site of C18. It became apparent that,

[3] Appendix C gives the stability of weekday volume counts for the months of May, June, July, August in 1978, 1979 and 1980; sites C09, C147, C18 and C114.

Appendix D gives the stability of daily volume counts for the months of May and July in 1978, 1979 and 1980; sites C09 and C18.

for the best results, shorter manual counts would have to be carried out with their mid-points at 15:00h or 16:00h in the afternoon. However, for the purpose of detailed discussion and comparisons, some other schedules were also selected in this study. Assuming that all manual counts would be conducted between 07:00h and 19:00h, the following schedules were chosen in addition to the existing three schedules:

(1) 6-h(a.m.) (07:00h-13:00h)

(2) 6-h(p.m.) (13:00h-19:00h)

(3) 4-h(a.m.) (07:00h-11:00h)

(4) 4-h(p.m.) (14:00h-18:00h)

(5) 2-h(p.m.) (16:00h-18:00h)

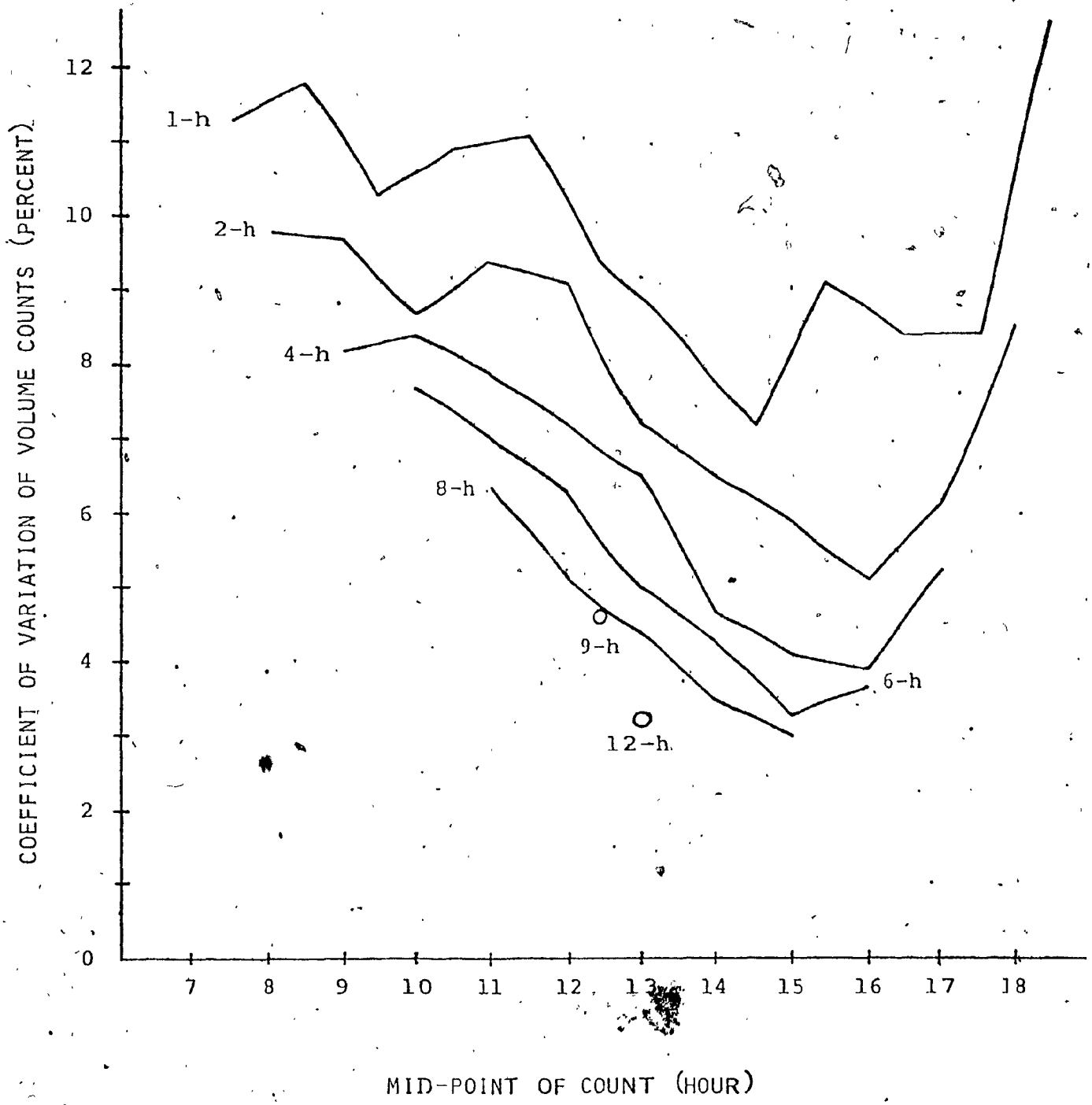

FIGURE 3 - Stability of weekday volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; rural long distance site - C18.

Chapter 3

RESULTS AND DISCUSSION

Tables 7 to 10 in Appendix B contain the computed values of coefficients of variation (CV) of volume count (Percent) at the typical road sites for the selected schedules of short-period counting. The tabulations are made for each day of the week for the months of May, June, July and August. Figures 4 to 7 are drawn using the data from Tables 7 to 10, respectively, but for the sake of simplicity of presentation and discussion the values of CV are averaged for the weekdays and the results for May and July are plotted in these figures. Please note that the results for the months of June and August are omitted because of their close similarity to the results of May and July, respectively.

Examination of Figures 4 to 7 reveals several important facts which are common to each type of road site. One observation is that the coefficient of variation for a 12-h schedule is smaller than other schedules. Therefore, the 12-h schedule can be expected to provide most accurate estimates of traffic statistics.[4] Another striking observation from these figures

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[4] Appendix E contains the plotted values of R.M.S.(ET) for the estimated values of AADT at the typical road sites (C9, C147, C18, C114) for the months of May to August for the years 1978, 1979 and 1980.

is that Alberta's 9-h short-period schedule produces higher values of CV as compared to the 6-h(p.m.) schedule in a great majority of cases. Actually, the results, such as shown in these figures, indicate that many times even the 4-h(p.m.) schedule can provide as good an estimate of volume as does the 9-h schedule. It may also be noted from the values of CV that the 8-h schedule yields better results than the 9-h schedule. The results for the 8-h schedule are generally similar to that of the 6-h(p.m.) schedule.

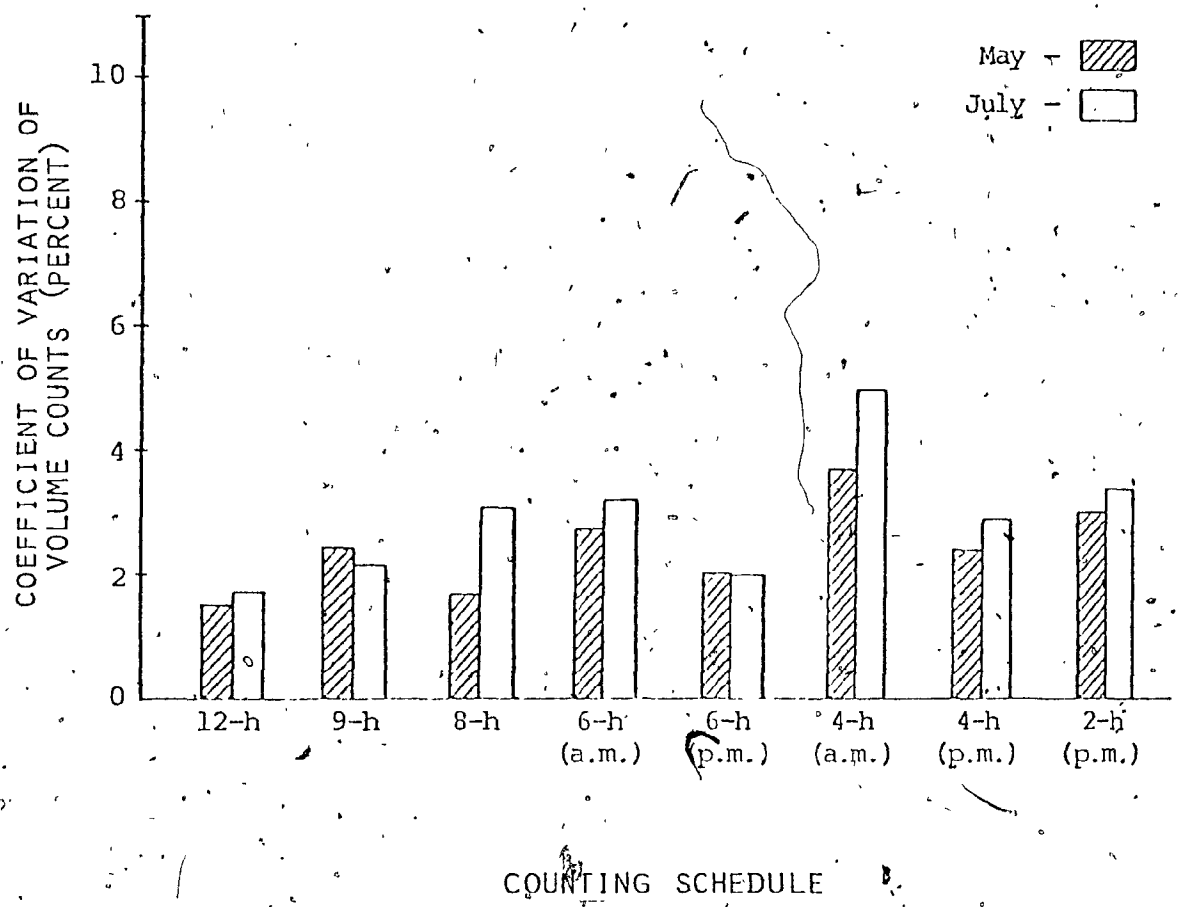

FIGURE 4 - Coefficients of variation of volume counts (Percent). Data: weekdays of May and July in 1978, 1979, and 1980; commuter site - C09.

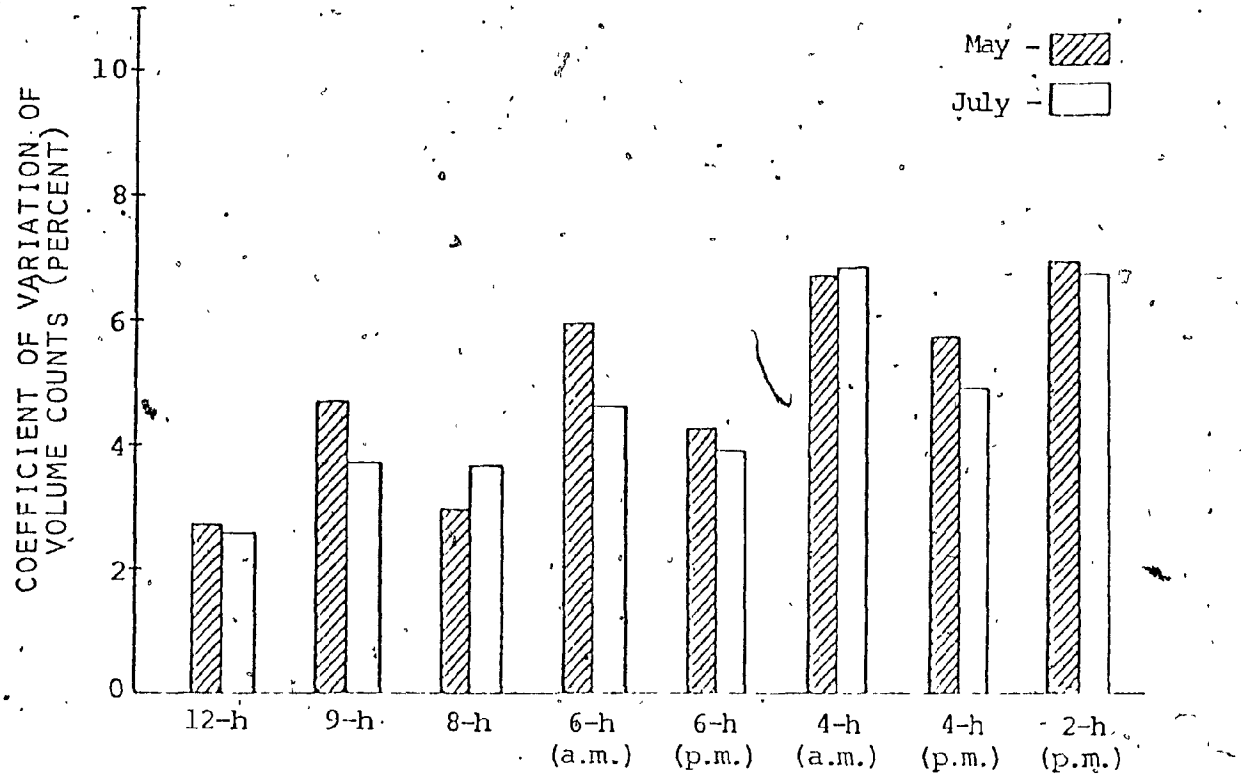

FIGURE 5 - Coefficients of variation of volume counts (Percent). Data: weekdays of May and July in 1978, 1979, and 1980; non-recreational, low volume site - C147.

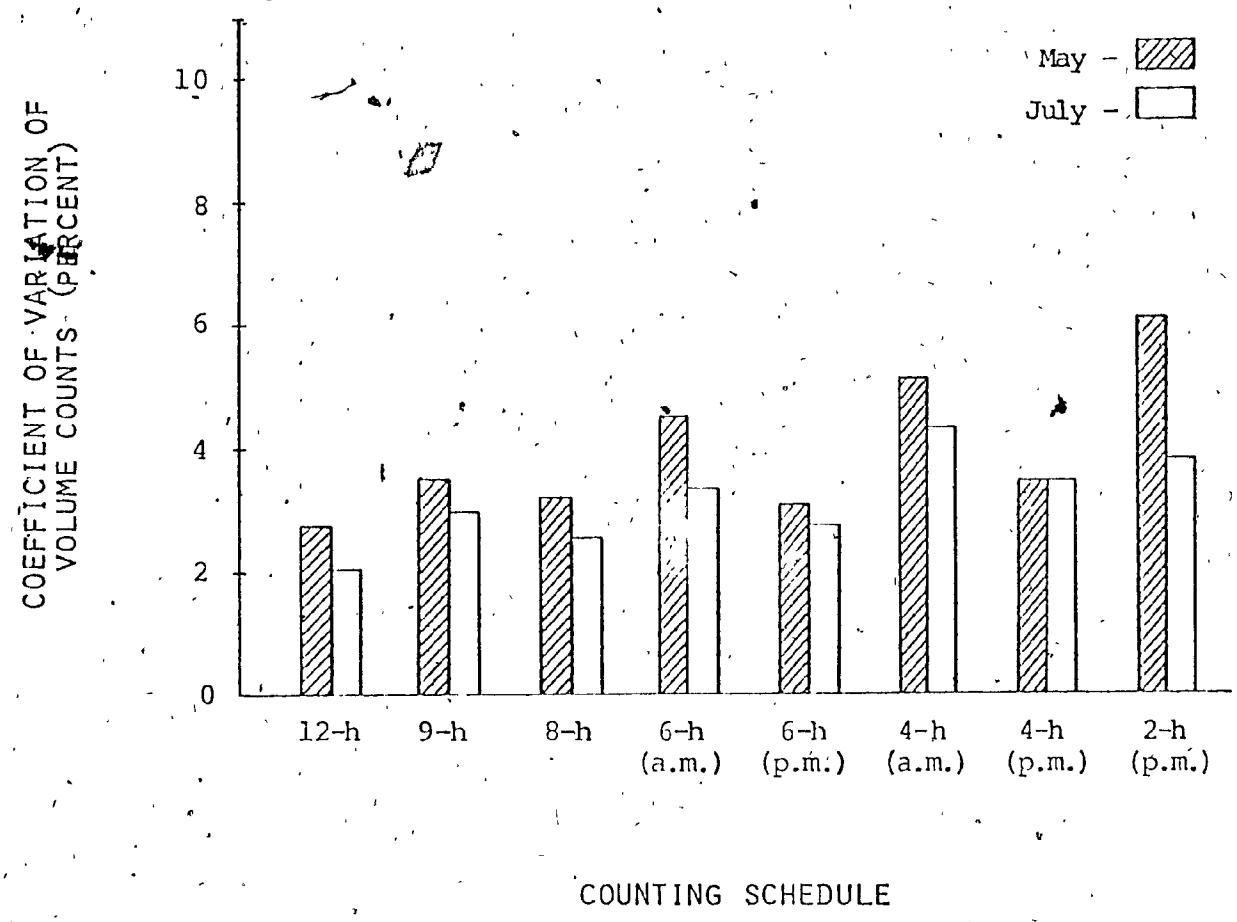

FIGURE 6 - Coefficients of variation of volume counts (Percent). Data: weekdays of May and July in 1978, 1979, and 1980; rural long distance site - C18.

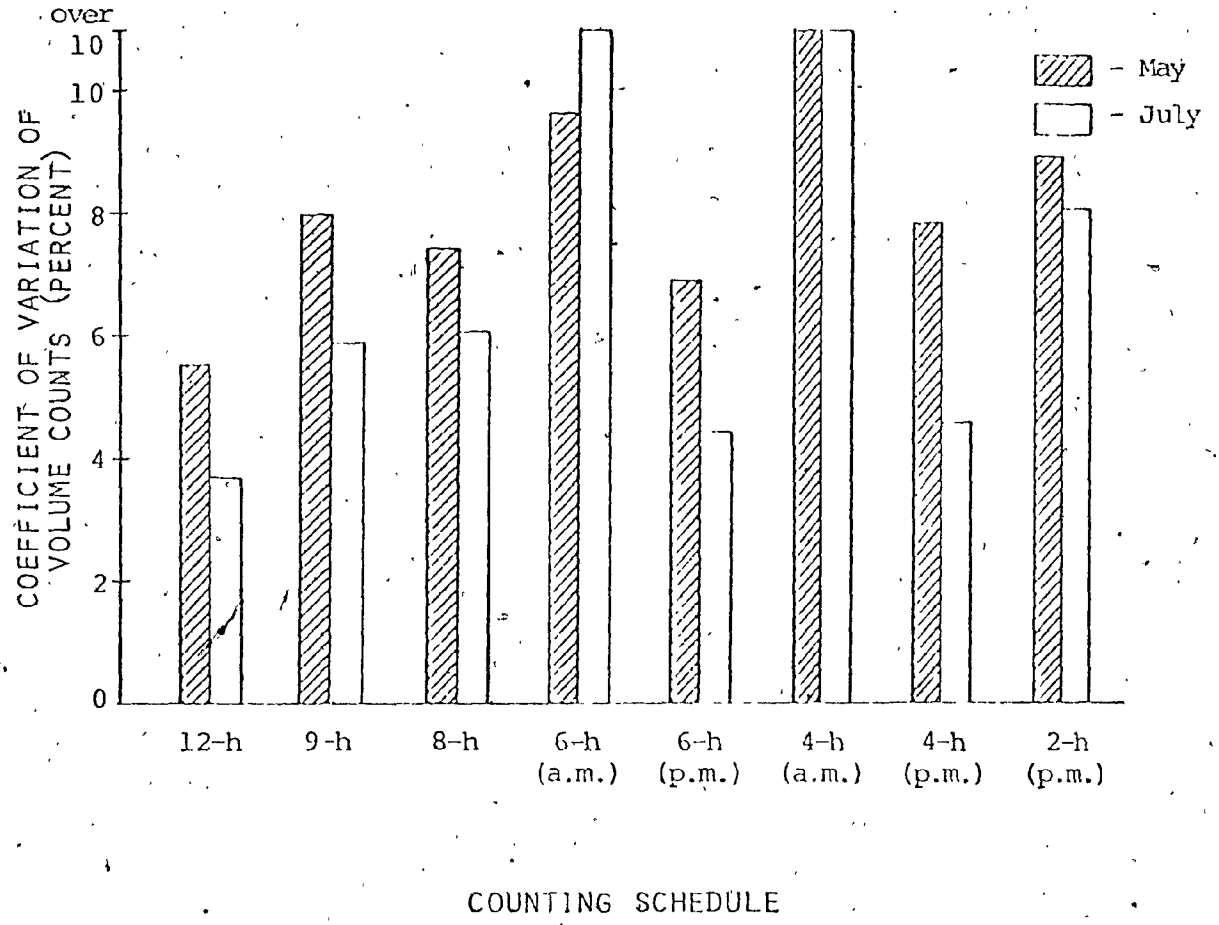

FIGURE 7 - Coefficients of variation of volume counts (Percent). Data: weekdays of May and July in 1978, 1979, and 1980; recreational site - C114.

Figures 4 to 7 also indicate clearly that the morning hours are not very appropriate for short-period counting. For example, the values of CV for the 6-h(a.m.) and 4-h(a.m.) are considerably higher than the values for 6-h(p.m.) and 4-h(p.m.), respectively. In fact, it should be noted that a short-period count of two to four hours in the late afternoon will provide the same accuracy of data as a 6-hour count in the morning.

Prior to examining the effect of road sites on the accuracy of short-period counts, let us consider the influence of traffic volume (or AADT) on the expected values of CV. Figure 8 presents the average values of CV as a function of AADT. Smooth hand-fitted curves in the figure are drawn from the scatter of CV statistics for all 41 study sites for the weekdays of May to August period. The X-axis in the figure is the average AADT for 1978, 1979 and 1980 - the years for which PTC data is analysed in this investigation.

These curves clearly indicate that the errors in estimated volumes are expected to be less for the road carrying large volumes of traffic. However it can also be noticed that, beyond a certain critical range of AADT, the errors are not likely to decrease significantly with further increase in traffic volume. For example, this critical range of AADT from Figure 8 is: (a) 2,000 for the 12-h schedule; (b) 3,000 for the 6-h(p.m.) schedule; (c) 3,500 for the 4-h(p.m.) schedule; and (d) 4,000 for the 2-h(p.m.) schedule.

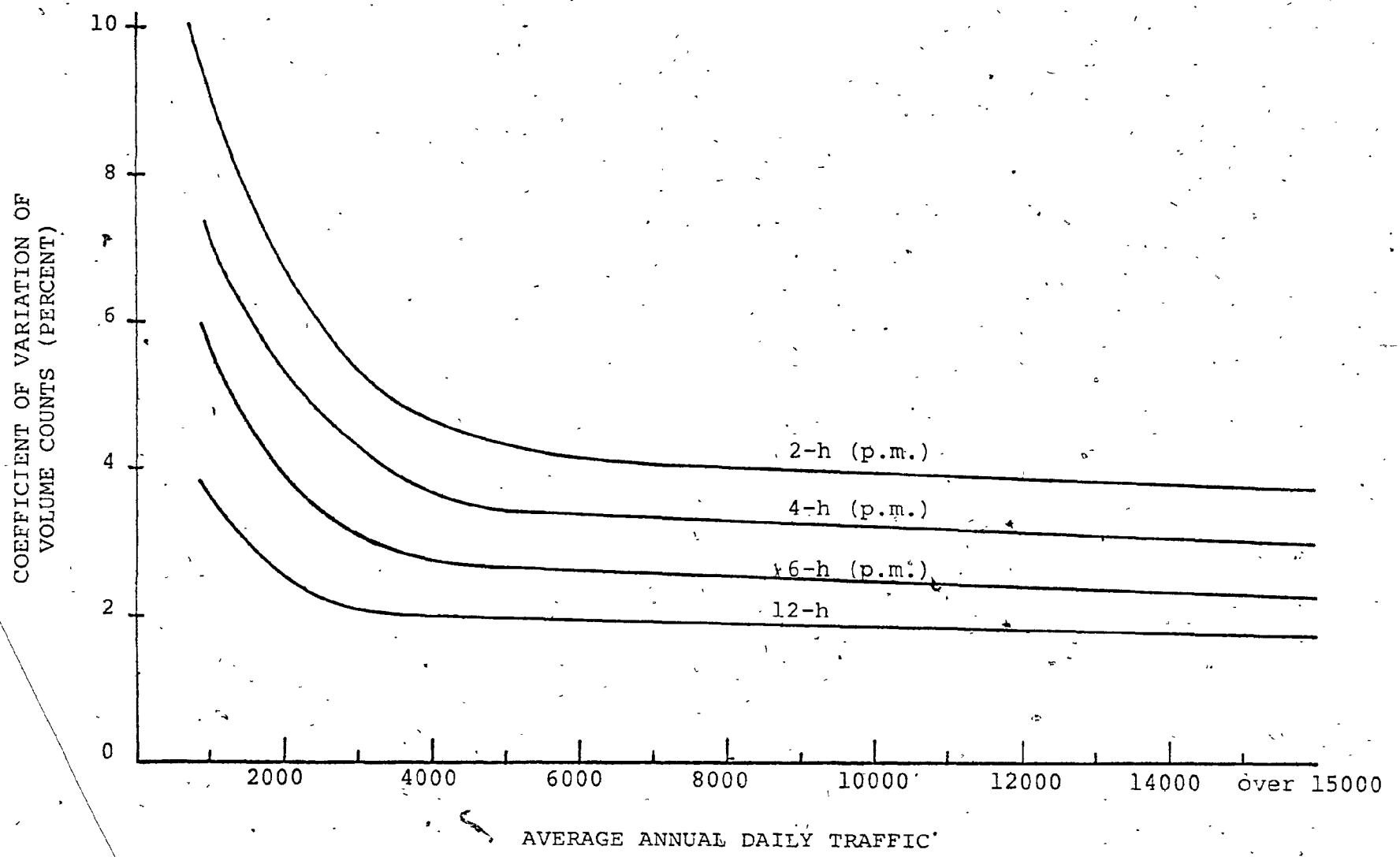

FIGURE 8.- Coefficients of variation of volume counts (Percent). Data: weekdays of May, June, July and August in 1978, 1979 and 1980; averages of all study sites.

There is one important factor in relation to the effect of road sites on the accuracy of counts. It is that, in general, different classes of road sites carry different amount of traffic volume. For example, commuter sites located near large population centres are likely to carry much heavier traffic volumes as compared to other road sites which, by their nature, serve primarily such specific purposes as "long distance" farm-to-market, or highly recreational trips. The average AADT values for the four typical road sites of this analysis are:

(1) 8,800 for C09 - commuter site;

(2) 1,180 for C147 - non-recreational low volume site;

(3) 3,500 for C18 - rural long distance site; and

(4) 2,055 for C114 - recreational site.

The effect of road types on estimated errors of counting can be deduced by referring back to Figures 4 to 7. It is evident that the values of CV or the errors of estimation are functions of the location of short-period count. As generally expected, the lowest errors are observed in the case of commuter site C09 and the highest in the case of recreational site C114. The values of CV in those figures also suggest that the 2-h(p.m.) schedule at a commuter site, or the 4-h(p.m.) schedule at a rural long distance site, or the 6-h(p.m.) schedule at a non-recreational low volume site, are all likely to produce the same accuracy as would the 12-h(p.m.) schedule at a recreational site.

Even though the volume of traffic, particularly when AADT is less than 2,000, may have some effect on the accuracy of counts (Figure 8), it is believed that the difference in the accuracy of counts at various sites is due primarily to the trip-purpose characteristics (as shown in Table 1). The work-business trips are considered to be less variable from day to day as compared to the social-recreational trips. A good example in this respect is to compare the results for C147 low-volume rural site, and C114 recreational site. Even though site C147 has a lower value of AADT, its results are more accurate as compared to C114. This difference can be attributed to the trip-purpose characteristics. The social-recreational components of trip purpose for C147 and C114 during the Summer weekdays are 22% and 75%, respectively.

A formal analysis of variance pertaining to the effects of days, months, and their possible interactions with different road types was not carried out in this study. However, the study results such as included in Tables 7 to 10 and Figures 4 to 7 seem to indicate that: (a) there is no effect of weekdays on the accuracy of counts; and (b) the months have some interaction with the nature of the sites surveyed. It is apparent that site C18 (rural long distance) and site C114 (recreational) are expected to produce most accurate estimates during the months of July (and August) when the tourist-recreational travel is at peak levels in Alberta. In contrast, the other two sites seem to provide better results during May (and June) when the work-business trips are still at their normal levels.

Chapter 4

CONCLUSIONS TO RECOMMENDATIONS

The analysis carried out in this paper illustrates clearly that the most important considerations for rationalization of short-period manual counts are: (a) type of road site being surveyed; and (b) the hour-to-hour traffic variations within the same day. The month of year, the day of week, and the duration of counts are other significant factors which must be considered in order to design the most efficient schedules of short-period counts. The following specific conclusions are drawn from this investigation of 41 PTC sites in the province of Alberta:

1. For the counts of eight hours or less on weekdays, a period with mid-point at 15:00h or 16:00h is expected to provide the most accurate volume estimates for each class of road. An additional advantage of including this period is that peak-hour turning movements and vehicle classification can still be observed because such counting period generally includes the evening peak of traffic volume.

2. The accuracy of short-period counts is a function of the nature of road sites surveyed. The highest accuracy is expected for commuter sites and the lowest in the case of highly recreational sites. In fact, the

values of coefficient of variation, computed for the study sites of this investigation, indicate that the 2-h(p.m.) schedule at a commuter site or the 4-h(p.m.) schedule at a rural long distance site or the 6-h(p.m.) schedule at a non-recreational low volume site, are all likely to produce the same accuracy as would the 12-h(p.m.) schedule at a recreational site.

3. There seems to be some interaction between the type of road surveyed and the month of counting. For example, recreational roads produce more reliable traffic estimates in the months of July and August when the tourist-recreational travel is at peak levels. In contrast, commuter sites provide better information during May and June.

4. The 9-h schedule, as currently used in Alberta, produces less accurate volume estimates as compared to the 6-h(p.m.) schedule in a great majority of cases. Actually, the results indicate that, many times, even the 4-h(p.m.) schedule can provide as good estimates of volume as does the 9-h schedule. The accuracy of 8-h schedule, as used in Ontario, is generally similar to the 6-h(p.m.) schedule.

5. The traditional 12-h surveys yield the most accurate estimates of 24-h volume. The differences in the accuracy of 12-h schedule and carefully selected 6-h(p.m.)

schedule are: (i) 0 to 1 percent at commuter and long distance rural sites; and (ii) 1 to 2 percent for non-recreational low volume sites and recreational sites. However, since the overtime wage rules in Canada increase the personnel cost of 12-h count to nearly three times that of a shorter six-hour count, the traditional 12-h surveys are less cost-effective than the 6-h(p.m.) surveys. Actually, in many cases, even the 4-h(p.m.) schedules could be considered reasonably accurate and cost-effective.

6. Another conclusion of this study is the effect of AADT on the accuracy of short-period counts. In general, the errors in volume are expected to be less for the roads carrying large volumes of traffic. But, beyond certain critical range of AADT, the errors are not likely to decrease significantly with further increase in traffic volume. For example, this critical range of AADT appears to be: (a) 2,000 for the 12-h survey, (b) 3,000 for the 6-h(p.m.) survey, and (c) 4,000 for the 2-h(p.m.) survey.

Further work is suggested to investigate the accuracy and cost-effectiveness of the schedules, involving two short counts (such as 6-hour, 4-hour and 2-hour surveys) which are taken during two different months as compared to a single count of 12-hour duration.

Even though Alberta's primary highway system was investigated, it is recommended that many other provincial highway agencies could benefit from using the findings of this research which provide a better understanding of the factors that affect the accuracy of estimating traffic volumes. It is hoped that with this better understanding agencies will be able to design and schedule more cost effective short-period traffic counting programs without any loss in accuracy.

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APPENDIX A

PROGRAM HGROUP

```
      PROGRAM HGROUP (INPUT,OUTPUT)
C     DESCRIPTION OF PARAMETERS AND INPUT DATA.
C     NV - NUMBER OF VARIABLES (E.G., 12 MONTHLY TRAFFIC FACTORS)
C     NS - NUMBER OF COUNTERS TO BE GROUPED
C     KP - LEVEL OF GROUPING TO BEGIN GROUP-MEMBERSHIP
C          PRINTING (SUGGESTION, KP = NS-1)
C     KC - ALPHAMERIC COUNTER-CODE
C      D - DATA MATRIX CONTAINING NV VARIABLES (IN COLUMNS)
C          FOR EACH OF THE NS COUNTERS (IN ROWS)
C
      DIMENSION D(150,150), KC(150), KG(150), W(150), LC(150)
      READ 5, NV, NS, KP
    5 FORMAT (3I5)
      DO 10 I = 1,NS
   10 READ 15, KC(I),(D(I,J),J=1,NV)
   15 FORMAT (A4,3X,12F6.3)
C     CONVERT DATA MATRIX TO INITIAL MATRIX OF ERROR POTENTIALS
      DO 30 I = 1,NS
      DO 20 J = 1,NV
   20 W(J) = D(I,J)
      DO 30 J = I,NS
      D(I,J) = 0.0
      DO 25 K = 1,NV
   25 D(I,J) = D(I,J) + (D(J,K) - W(K))**2
   30 D(I,J) = D(I,J) / 2.0
      DO 35 I = 1,NS
      DO 35 J = I,NS
   35 D(J,I) = 0.0
      NG = NS
C     INITIALIZE GROUP-MEMBERSHIP AND GROUP-IN VECTORS.
      DO 40 I = 1,NS
      KG(I) = I
   40 W(I) = 1.0
C     LOCATE OPTIMAL COMBINATION.  IF MORE THAN 2 GROUPS REMAIN.
   45 NG = NG - 1
      IF (NG .EQ. 1) GO TO 95
      X = 10.0**10
      DO 55 I = 1,NS
      IF (KG(I) .NE. I) GO TO 55
      DO 50 J = I,NS
      IF (I .EQ. J .OR. KG(J) .NE. J) GO TO 50
      DX = D(I,J) - D(I,I) - D(J,J)
      IF (DX .GE. X) GO TO 50
      X = DX
      L = I
      M = J
   50 CONTINUE
   55 CONTINUE
      NL = W(L)
      NM = W(M)
      PRINT 60, NG, L, NL, M, NM, X
```

```
   60 FORMAT (// I4, 25H GROUPS AFTER COMBINING G, I3,
     1 4H (N=, I3,7H) AND G, I3, 4H (N=, I3, 10H). ERROR =, F10.4//)
C     MODIFY GROUP-MEMBERSHIP AND GROUP-IN VECTORS, AND ERROR POTENTIALS.
      WS = W(L) + W(M)
      X = D(L,M) * WS
      Y = D(L,L) * W(L) + D(M,M) * W(M)
      D(L,L) = D(L,M)
      DO 65 I = 1,NS
      IF (KG(I) .EG. M) KG(I) = L
   65 CONTINUE
      DO 75 I = 1,NS
      IF (I .EQ. L .OR. KG(I) .NE. I) GO TO 75
      IF (I .GT. L) GO TO 70
      D(I,L) = (D(I,L) * (W(I) + W(L)) + D(I,M) * (W(I) + W(M))
     1 + X - Y - D(I,I) * W(I)) / (W(I) + WS)
      GO TO 75
   70 D(L,I) = (D(L,I) * (W(L) + W(I)) + (D(M,I) + D(I,M))
     1 * (W(M) + W(I)) + X - Y - D(I,I) * W(I)) / (W(I) + WS)
   75 CONTINUE
      W(L) = WS
      IF (NG .GT. KP) GO TO 45
C     PRINT GROUP MEMBERS OF ALL OBJECTS, IF OPTIONED.
      DO 90 I = 1,NS
      IF (KG(I) .NE. I) GO TO 90
      L = 0
      DO 80 J = I,NS
      IF (KG(J) .NE. I) GO TO 80
      L = L + 1
      LC(L) = KC(J)
   80 CONTINUE
      PRINT 85,I,L,(LC(J),J=1,L)
   85 FORMAT (2H G, I3, 4H (N=, I3, 2H) , 15A7 / (14X, 15A7))
   90 CONTINUE
      GO TO 45
   95 STOP
      END
```

APPENDIX B

Table 7. Coefficient of variation of volume counts (Percent) recorded at PTC site C09 (commuter) for the selected schedules of short period counting

Month	Counting Schedule	Coefficient of Variation of volume counts (Percent) (cv), %						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat
May	12-h	2.7	1.4	1.3	1.3	1.4	2.2	2.0
	9-h	3.0	2.1	2.5	2.0	2.4	3.1	2.2
	8-h	2.8	1.7	2.0	1.8	1.7	2.1	3.6
	6-h(a.m.)	7.2	2.6	2.9	2.6	2.0	3.7	4.8
	6-h(p.m.)	2.7	1.7	2.3	2.0	2.1	2.1	2.9
	4-h(a.m.)	9.6	3.3	4.3	4.4	2.8	3.5	8.3
	4-h(p.m.)	2.8	2.1	2.4	2.1	2.8	2.6	3.0
	2-h(p.m.)	3.6	2.5	4.3	3.4	2.5	2.3	3.8
June	12-h	2.6	0.9	1.2	1.9	1.6	1.4	1.2
	9-h	3.0	1.8	1.7	2.4	2.1	1.7	1.8
	8-h	3.0	3.0	1.7	2.9	1.9	2.4	2.0
	6-h(a.m.)	6.9	2.6	2.0	2.3	2.0	2.5	4.2
	6-h(p.m.)	1.8	2.2	2.4	2.1	2.0	1.5	3.1
	4-h(a.m.)	10.9	6.3	2.8	3.6	3.0	3.7	6.6
	4-h(p.m.)	2.4	2.0	2.7	3.1	2.1	2.2	3.8
	2-h(p.m.)	2.3	3.7	2.4	2.8	4.0	4.0	3.7
July	12-h	2.9	1.1	1.2	2.1	2.1	2.3	4.1
	9-h	2.7	1.4	1.3	3.1	2.5	2.5	5.1
	8-h	3.2	3.5	2.1	3.6	2.9	3.3	5.2
	6-h(a.m.)	6.0	3.0	3.6	3.5	3.3	2.6	9.1
	6-h(p.m.)	2.4	1.4	1.8	2.2	1.9	2.8	3.3
	4-h(a.m.)	7.9	6.3	5.1	4.8	5.0	3.7	13.4
	4-h(p.m.)	3.4	2.3	2.1	3.8	2.6	3.6	3.9
	2-h(p.m.)	4.4	2.6	3.2	2.9	3.8	4.4	4.0
August	12-h	4.2	1.5	1.1	1.4	1.8	1.7	2.7
	9-h	4.2	2.2	2.1	1.4	2.1	2.0	3.1
	8-h	4.8	2.5	2.0	3.1	2.7	2.9	3.0
	6-h(a.m.)	11.9	2.7	2.3	3.1	4.1	3.8	3.8
	6-h(p.m.)	3.9	2.1	1.2	1.9	1.7	1.7	3.7
	4-h(a.m.)	17.6	3.0	3.5	5.7	5.9	5.2	6.5
	4-h(p.m.)	5.2	3.5	2.4	2.9	2.6	2.7	3.7
	2-h(p.m.)	6.0	3.5	4.2	3.8	3.8	4.9	5.0

Table 8. Coefficient of variation of volume counts (Percent) recorded at PTC site C147 (non-recreational low volume) for the selected schedules of short period counting

Month	Counting Schedule	Coefficient of Variation of volume counts (Percent) (cv), %						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat
May	12-h	2.5	2.5	2.2	1.8	3.6	3.4	3.0
	9-h	6.5	5.6	3.2	3.4	5.9	5.2	4.3
	8-h	7.3	1.8	2.8	1.5	4.5	4.1	4.9
	6-h(a.m.)	14.8	9.5	4.6	4.9	6.8	4.0	7.7
	6-h(p.m.)	5.2	4.0	4.8	4.1	3.3	5.1	4.2
	4-h(a.m.)	23.8	8.3	6.5	6.3	7.2	5.1	14.1
	4-h(p.m.)	10.7	4.4	5.5	5.7	6.6	6.7	7.1
	2-h(p.m.)	11.5	9.2	6.6	8.9	8.4	6.6	10.8
June	12-h	6.8	2.1	3.0	3.1	2.5	3.1	3.4
	9-h	7.9	1.9	2.4	5.4	5.6	5.3	3.7
	8-h	6.5	4.6	2.8	2.4	3.9	4.3	5.3
	6-h(a.m.)	19.8	5.8	5.1	8.7	6.6	7.8	10.4
	6-h(p.m.)	6.6	4.6	4.1	5.5	2.2	3.8	7.0
	4-h(a.m.)	19.6	11.2	5.8	9.2	5.7	10.2	18.4
	4-h(p.m.)	7.5	4.5	4.5	5.1	4.5	5.8	8.0
	2-h(p.m.)	9.4	8.7	4.8	3.7	10.0	12.3	11.6
July	12-h	4.3	2.7	3.2	2.5	2.4	2.0	3.2
	9-h	6.7	4.4	4.5	3.6	3.6	2.4	3.7
	8-h	6.3	5.4	4.1	2.9	2.7	3.0	4.6
	6-h(a.m.)	11.6	6.6	5.2	3.8	3.3	4.1	5.4
	6-h(p.m.)	4.4	3.3	4.3	3.3	3.7	5.0	4.4
	4-h(a.m.)	14.9	10.8	6.6	4.9	4.6	7.3	10.1
	4-h(p.m.)	4.6	5.6	5.7	3.7	3.6	6.0	6.0
	2-h(p.m.)	5.1	8.8	6.0	6.2	8.6	3.8	8.7
August	12-h	4.3	2.9	4.6	2.0	2.6	3.4	3.4
	9-h	5.1	1.8	6.0	1.8	4.2	3.7	3.8
	8-h	5.8	4.3	7.6	3.3	4.5	5.5	5.6
	6-h(a.m.)	8.9	6.7	5.9	6.1	7.3	6.4	8.2
	6-h(p.m.)	6.0	2.8	7.7	3.3	3.4	3.8	3.5
	4-h(a.m.)	14.3	10.2	7.7	8.9	11.1	9.4	12.0
	4-h(p.m.)	7.2	2.6	10.3	4.9	5.3	5.0	5.4
	2-h(p.m.)	11.6	6.8	11.3	5.6	6.2	6.4	9.0

Table 9. Coefficient of variation of volume counts (Percent) recorded at PTC site C18 (rural long distance) for the selected schedules of short period counting

Month	Counting Schedule	Coefficient of Variation of volume counts (Percent) (cv), %						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat
May	12-h	2.7	2.8	2.2	2.5	3.0	3.4	2.7
	9-h	4.1	2.3	3.6	3.5	4.0	4.0	3.7
	8-h	3.1	2.9	2.5	3.0	3.5	4.2	3.2
	6-h(a.m.)	11.7	3.3	3.3	2.8	5.1	8.4	5.3
	6-h(p.m.)	6.8	3.0	2.7	3.5	3.0	3.2	5.0
	4-h(a.m.)	15.4	4.2	3.8	2.8	5.2	9.7	8.3
	4-h(p.m.)	7.0	3.2	3.1	3.9	4.1	3.0	6.6
	2-h(p.m.)	8.5	7.0	5.3	7.3	6.7	4.3	8.7
June	12-h	2.5	2.0	1.5	1.7	2.0	2.6	2.2
	9-h	2.9	2.5	1.9	2.4	2.8	2.8	2.9
	8-h	2.7	2.2	2.6	2.0	2.4	4.0	2.7
	6-h(a.m.)	6.0	2.9	3.1	1.8	3.5	3.6	2.1
	6-h(p.m.)	2.4	2.8	2.5	2.5	2.6	2.6	3.8
	4-h(a.m.)	5.9	3.2	4.0	2.8	4.4	4.4	3.0
	4-h(p.m.)	3.2	3.6	3.4	2.0	2.3	4.8	3.9
	2-h(p.m.)	4.1	3.7	3.9	4.2	3.7	6.4	5.6
July	12-h	2.2	2.0	2.0	1.9	2.5	1.8	2.2
	9-h	3.2	3.0	3.3	2.7	3.6	2.3	2.6
	8-h	2.0	2.6	2.2	2.3	2.6	3.1	2.4
	6-h(a.m.)	2.5	3.1	3.3	2.5	3.9	3.5	3.6
	6-h(p.m.)	3.6	1.7	3.5	2.9	3.1	2.6	3.9
	4-h(a.m.)	5.5	3.2	4.8	3.5	4.6	5.2	5.5
	4-h(p.m.)	4.1	3.1	4.2	3.2	3.2	3.6	4.0
	2-h(p.m.)	5.6	3.5	4.5	3.2	3.9	3.9	3.4
August	12-h	2.7	1.4	2.1	2.3	1.4	2.8	2.6
	9-h	3.6	2.2	2.5	3.3	2.6	3.2	2.8
	8-h	3.2	1.8	2.8	2.5	2.1	3.4	3.3
	6-h(a.m.)	8.6	2.2	2.7	2.3	2.8	4.9	5.1
	6-h(p.m.)	3.7	2.7	3.0	3.8	3.2	3.0	4.4
	4-h(a.m.)	11.7	3.8	4.4	4.4	4.5	6.0	7.2
	4-h(p.m.)	4.4	4.1	3.8	4.2	4.4	4.0	4.7
	2-h(p.m.)	4.8	5.1	5.3	4.3	5.7	6.5	5.2

Table 10. Coefficient of variation of volume counts (Percent) recorded at PTC site C114 (recreational) for the selected schedules of short period counting

Month	Counting Schedule	Coefficient of Variation of volume counts (Percent) (cv), %						
		Sun	Mon	Tue	Wed	Thu	Fri	Sat
May	12-h	7.6	6.1	6.0	5.6	3.9	6.2	7.1
	9-h	13.0	8.8	8.9	8.0	5.7	8.6	11.2
	8-h	9.3	7.9	8.3	7.5	6.9	6.6	9.7
	6-h(a.m.)	23.6	11.2	9.1	7.4	7.4	13.0	12.1
	6-h(p.m.)	9.3	7.8	5.7	6.8	5.7	8.7	8.8
	4-h(a.m.)	37.5	21.0	16.5	11.7	14.0	17.9	21.0
	4-h(p.m.)	10.8	8.0	6.5	8.6	6.7	9.5	10.9
	2-h(p.m.)	14.2	8.9	9.5	10.8	6.8	8.8	11.7
June	12-h	3.3	2.3	2.6	3.0	3.8	6.2	4.0
	9-h	5.7	2.5	3.6	3.8	4.6	8.8	6.5
	8-h	2.7	1.7	3.5	1.9	4.5	6.4	3.1
	6-h(a.m.)	5.7	4.9	5.4	4.1	4.4	9.8	8.9
	6-h(p.m.)	3.1	4.6	3.3	4.4	4.7	5.5	2.0
	4-h(a.m.)	3.9	5.2	7.0	7.9	4.2	11.2	8.3
	4-h(p.m.)	3.6	4.6	1.8	3.5	5.0	4.5	2.4
	2-h(p.m.)	6.9	7.5	1.4	2.7	4.8	2.4	5.3
July	12-h	4.1	2.6	4.0	3.2	2.7	5.9	2.7
	9-h	5.7	4.9	5.8	6.1	4.1	8.6	4.1
	8-h	7.0	5.6	5.9	5.5	5.0	8.6	5.9
	6-h(a.m.)	12.8	15.2	12.3	12.3	8.5	18.4	10.9
	6-h(p.m.)	4.5	6.1	3.7	4.4	4.4	3.6	4.3
	4-h(a.m.)	25.9	29.8	19.0	19.7	18.0	27.7	19.8
	4-h(p.m.)	5.3	5.7	4.6	4.0	4.5	4.2	3.9
	2-h(p.m.)	7.8	9.5	7.4	7.9	6.3	9.5	7.1
August	12-h	6.6	4.7	5.2	4.7	5.0	6.7	4.8
	9-h	9.5	7.1	7.8	6.4	7.2	8.8	6.4
	8-h	8.8	8.1	7.8	7.5	7.7	9.1	7.7
	6-h(a.m.)	16.8	15.3	15.5	13.5	11.8	14.7	10.9
	6-h(p.m.)	4.0	4.1	3.3	4.0	3.4	3.4	4.3
	4-h(a.m.)	28.5	27.5	25.9	24.4	20.2	22.4	18.8
	4-h(p.m.)	5.1	5.1	3.5	4.1	4.2	4.5	4.7
	2-h(p.m.)	8.4	8.7	7.0	9.4	2.5	3.3	6.5

APPENDIX C

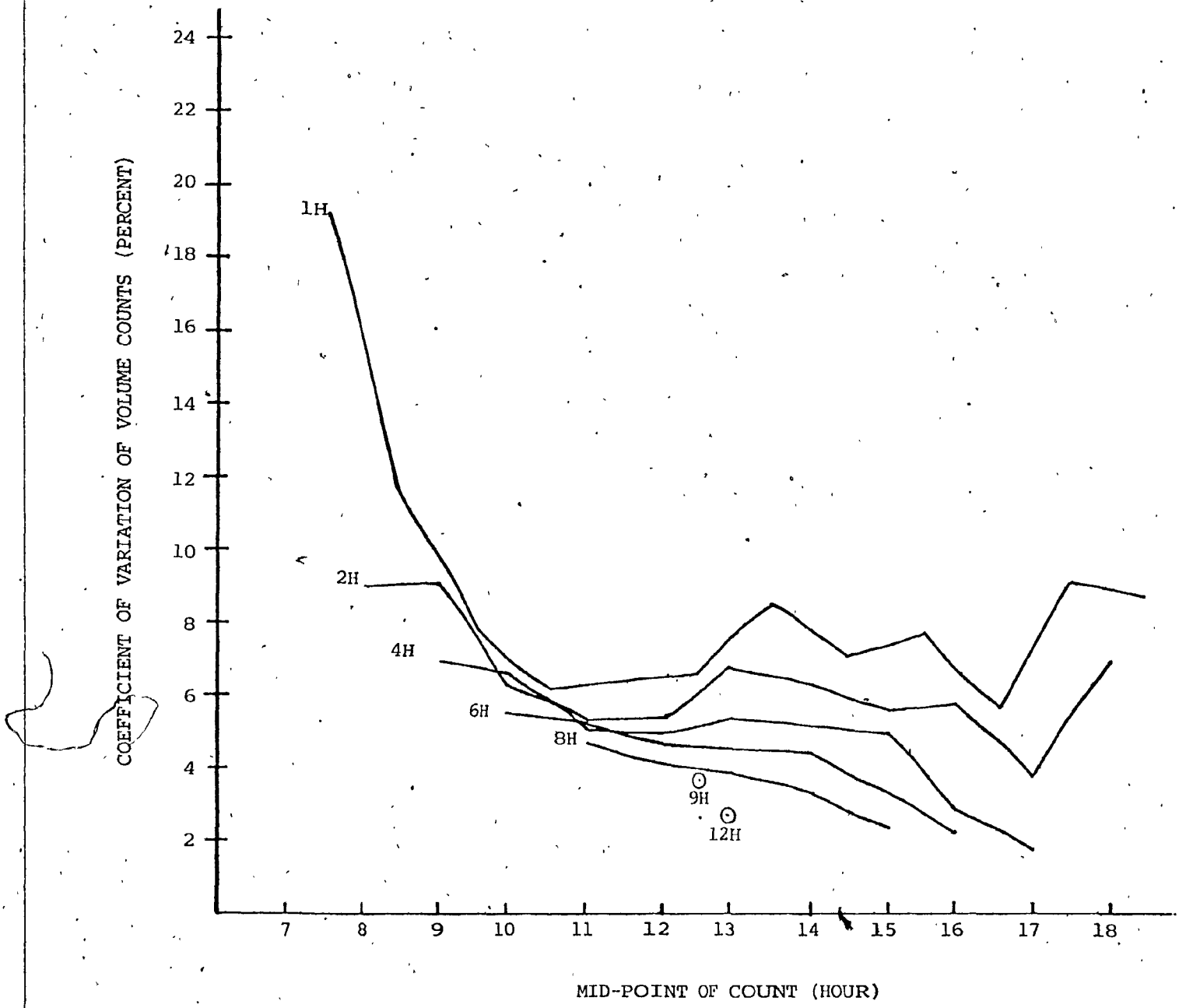

FIGURE 9 - Stability of weekday volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; commuter site - C09.

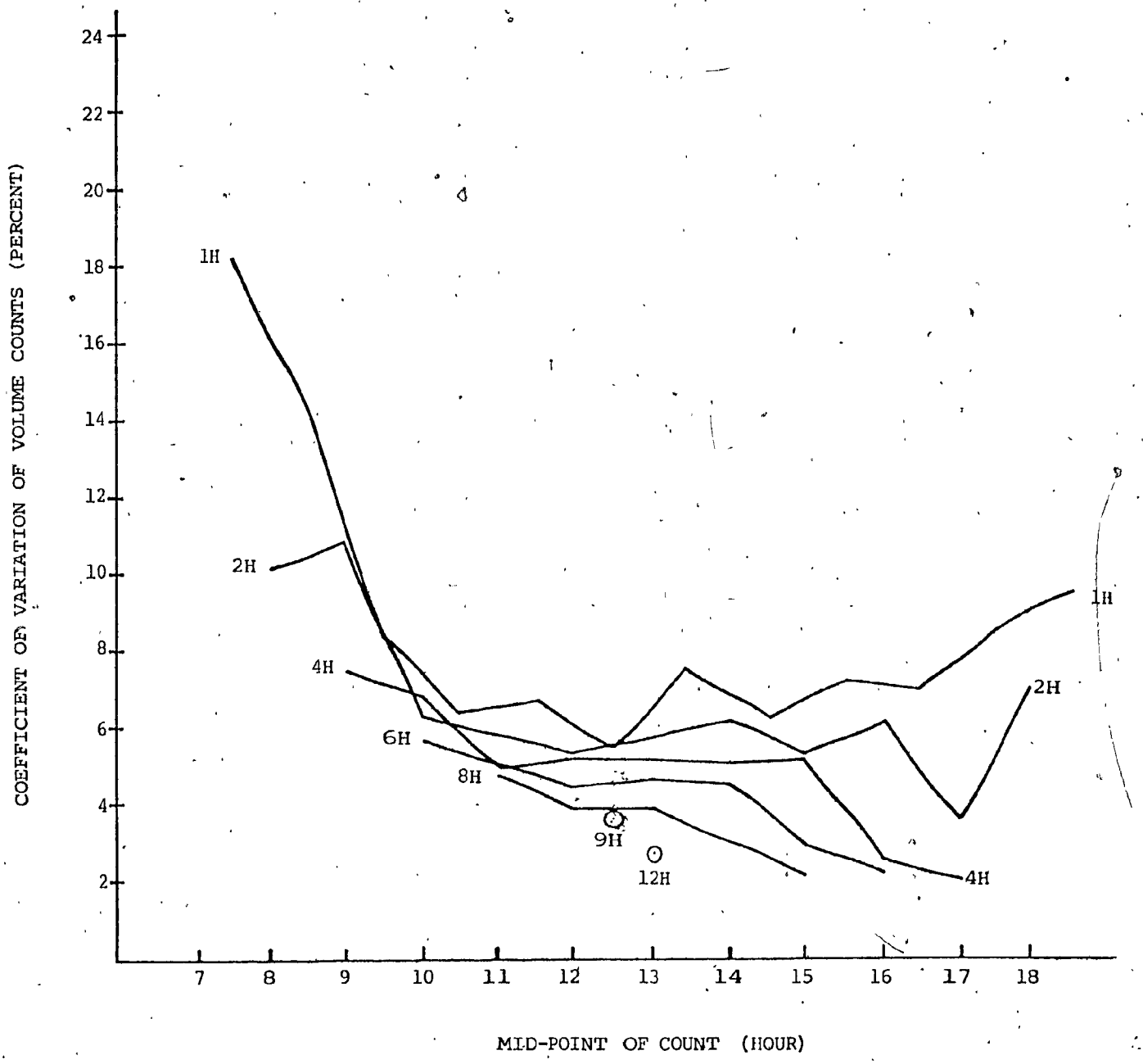

FIGURE 10 - Stability of weekday volume counts (Percent). Data: the month of June in 1978, 1979 and 1980; commuter site - C09.

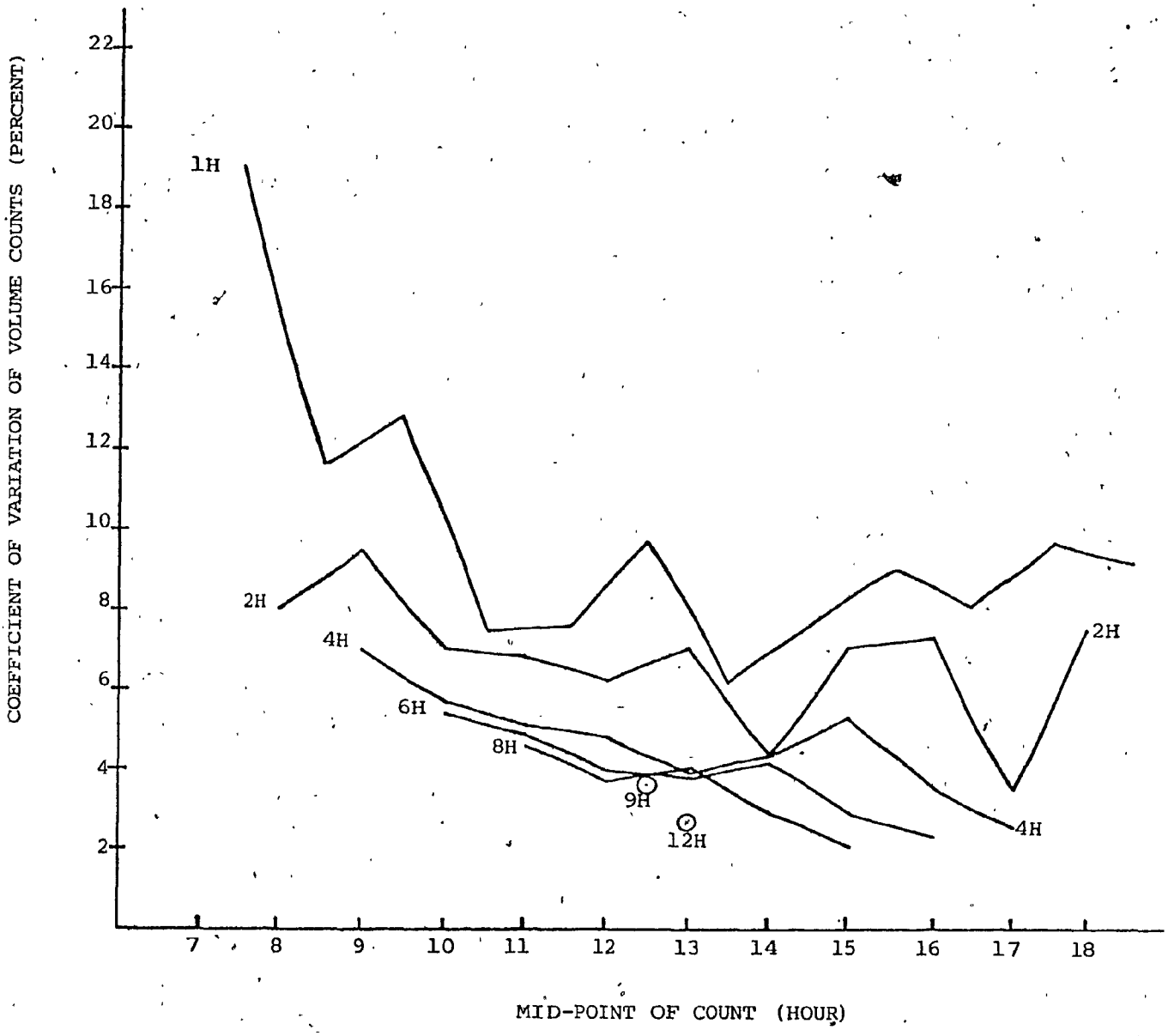

FIGURE 11 - Stability of weekday volume counts (Percent). Data: the month of July in 1978, 1979 and 1980; commuter site - C09.

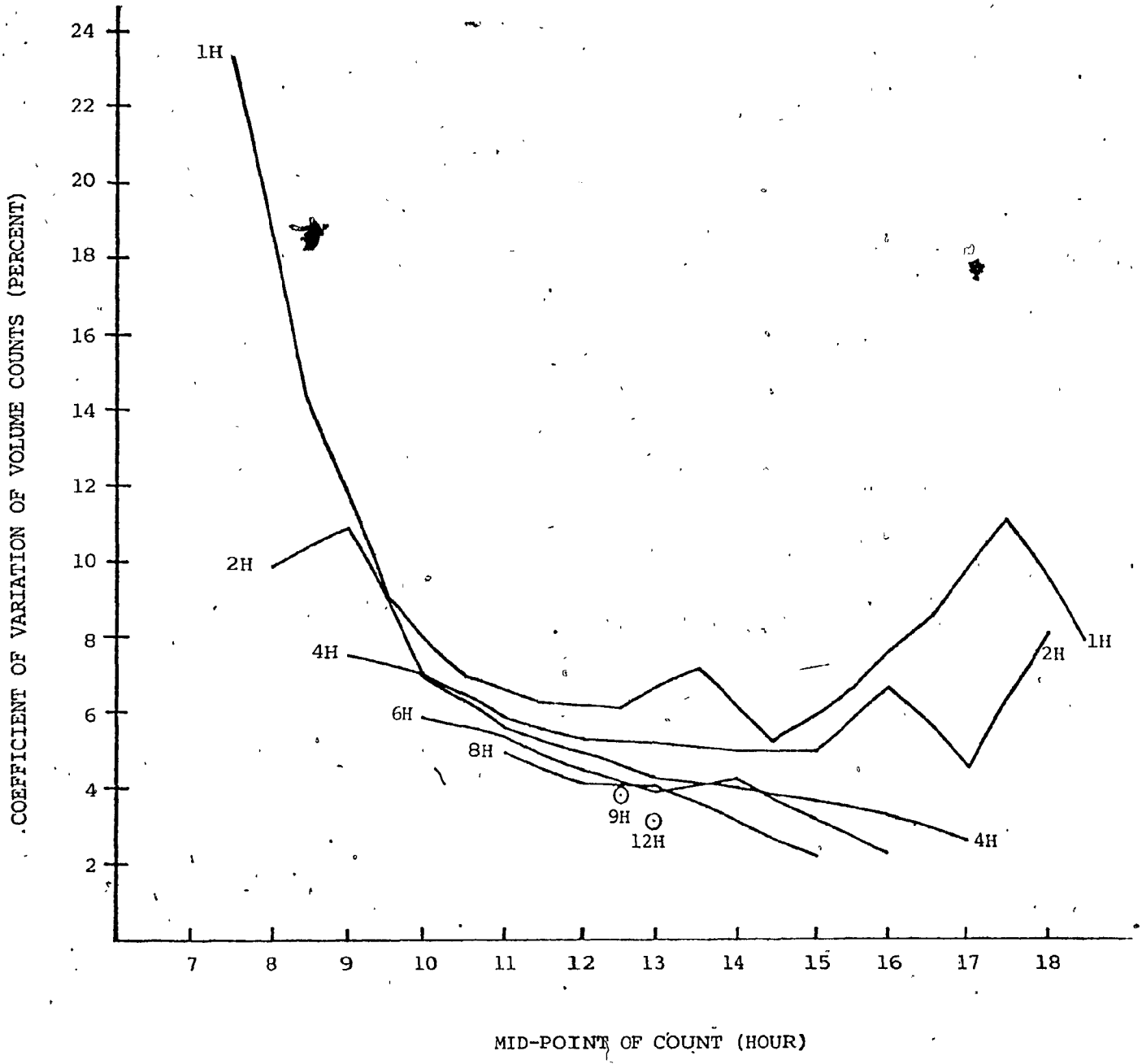

FIGURE 12 - Stability of weekday volume counts (Percent). Data: the month of August in 1978, 1979 and 1980; commuter site - CO9.

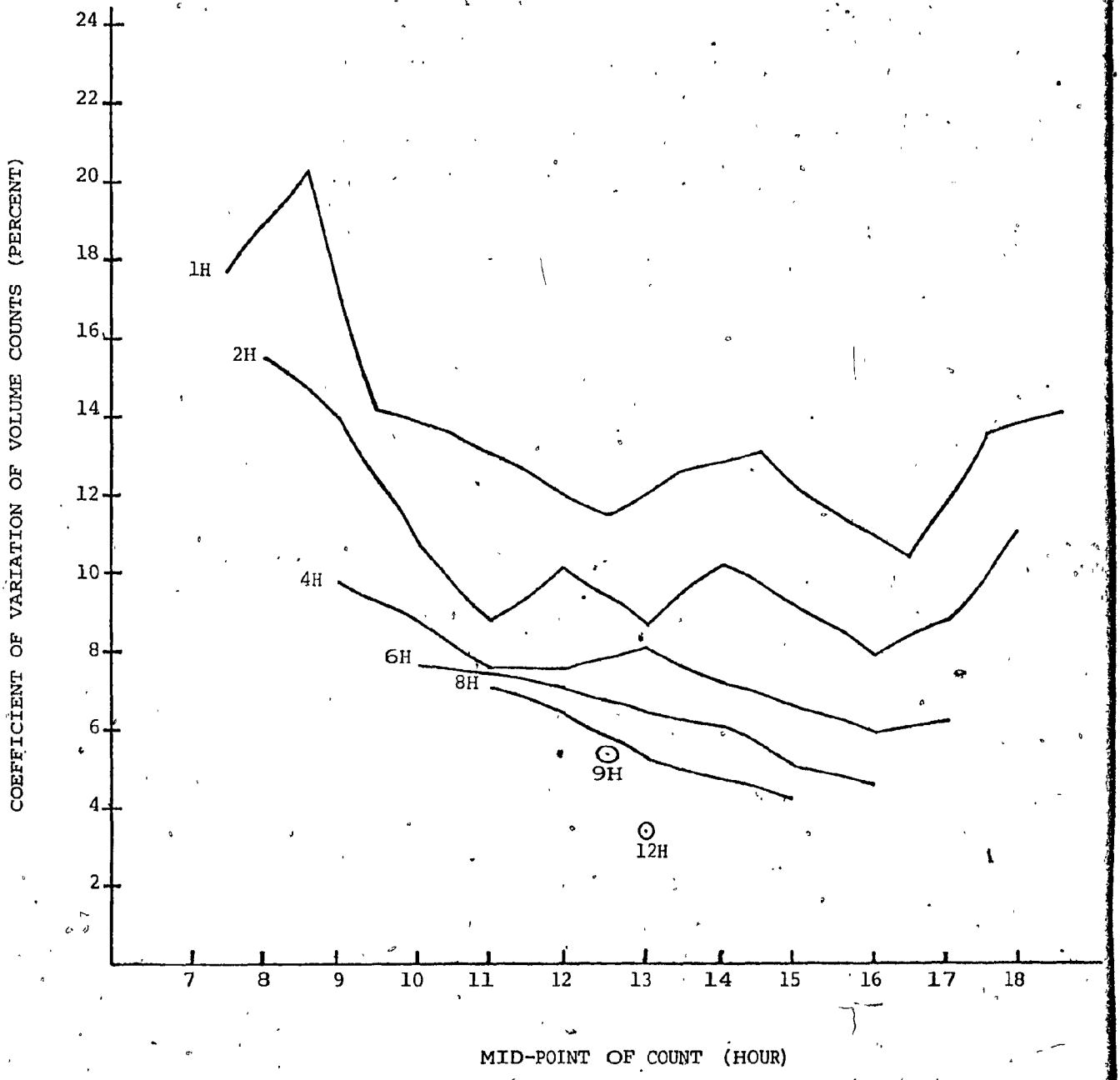

FIGURE 13 - Stability of weekday volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; non-recreational low volume (rural) site - C147.

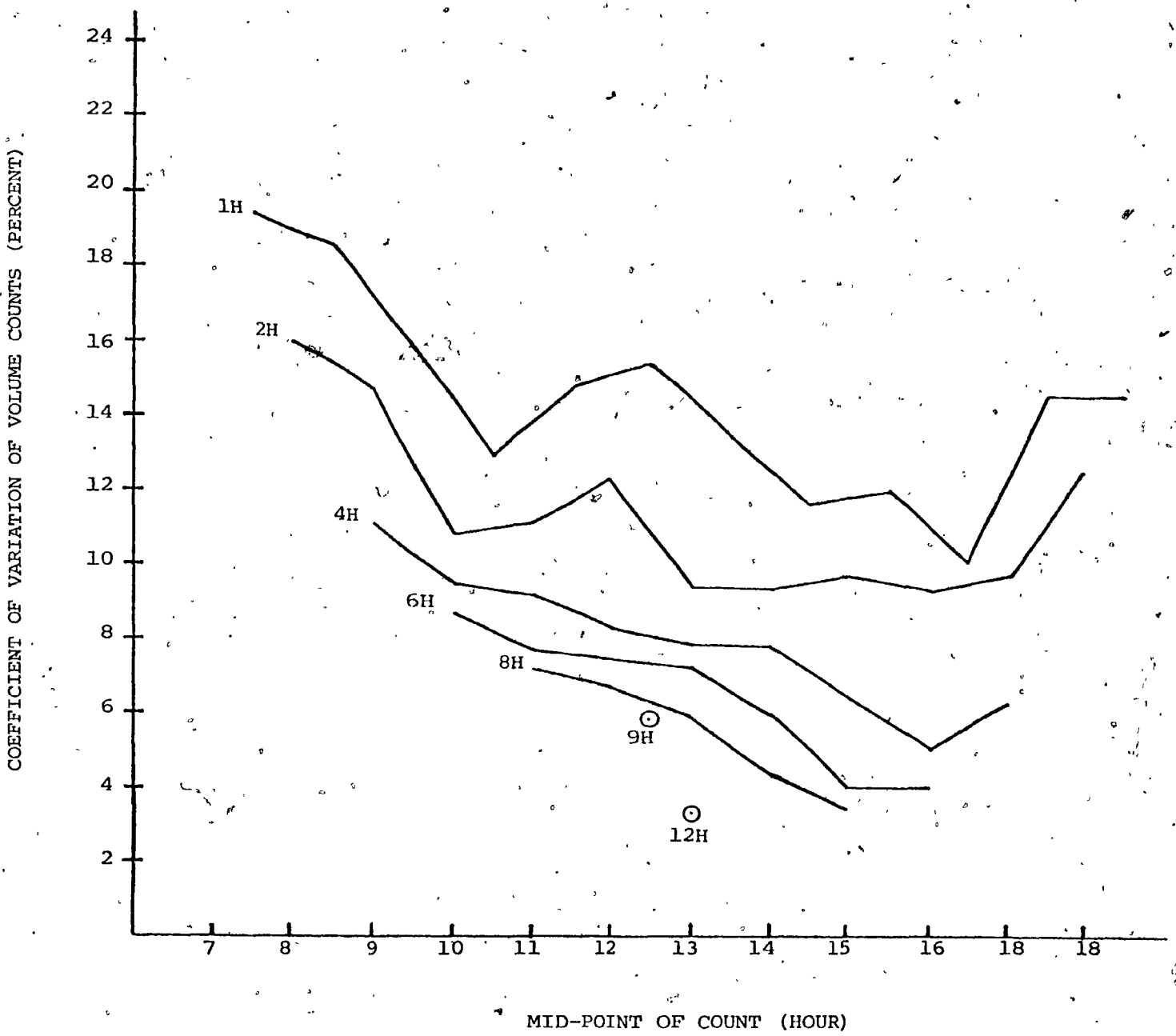

FIGURE 14 - Stability of weekday volume counts (Percent). Data: the month of June in 1978, 1979 and 1980; non-recreational low volume (rural) site - C147.

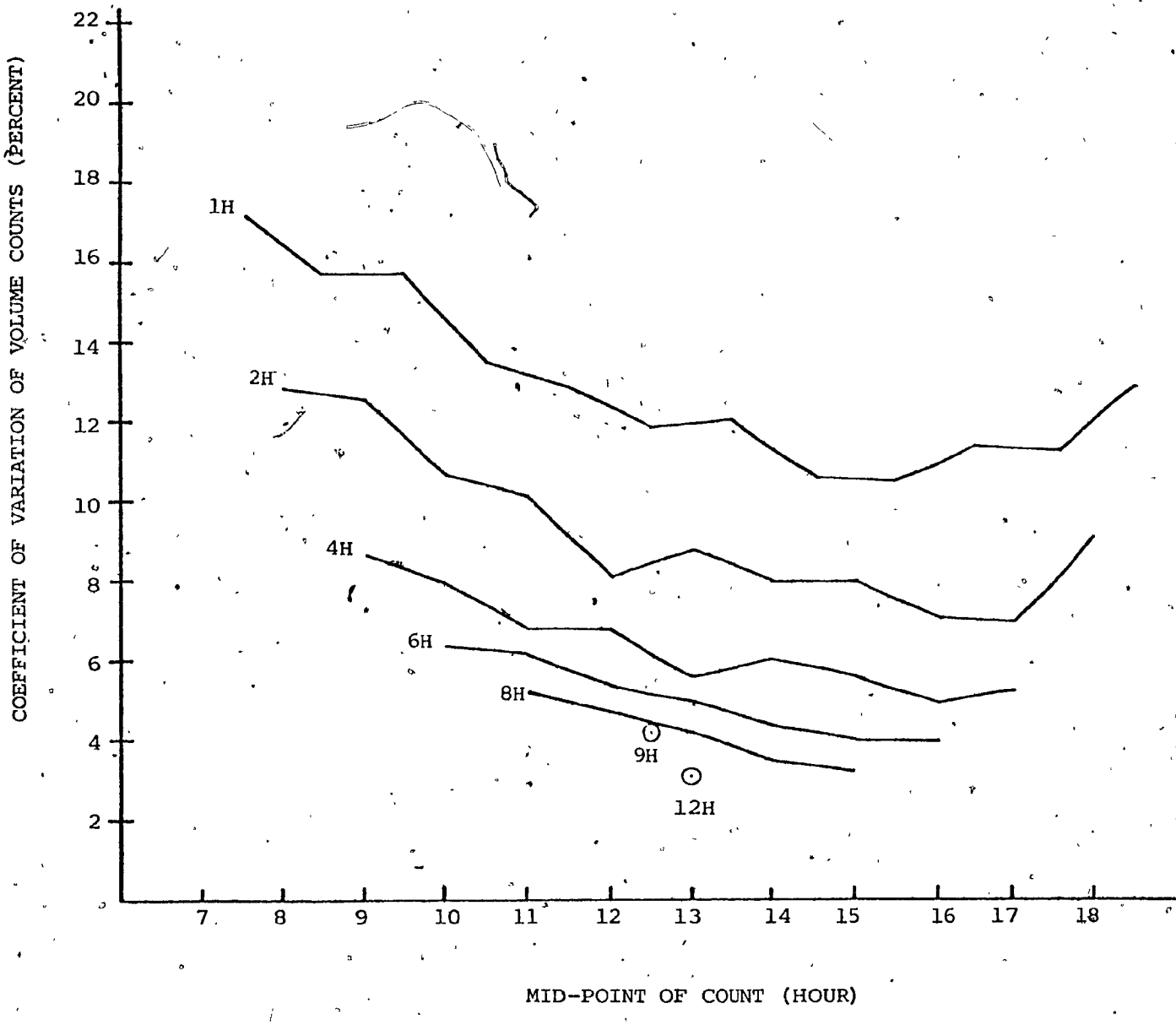

FIGURE 15 - Stability of weekday volume counts (Percent). Data: the month of July in 1978, 1979 and 1980; non-recreational low volume (rural) site - C147.

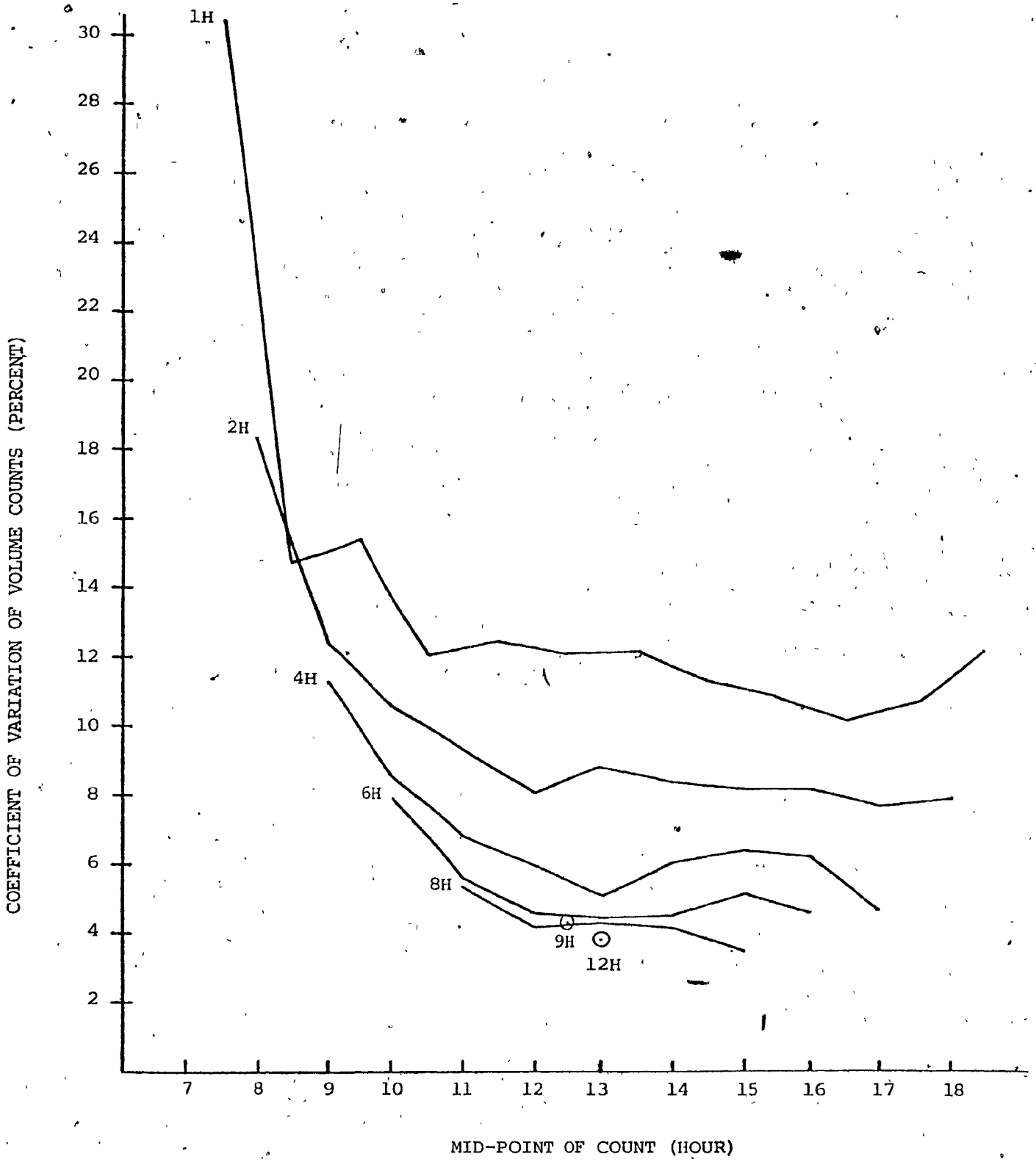

FIGURE 16 - Stability of weekday volume counts (Percent). Data: the month of August in 1978, 1979 and 1980; non-recreational low volume (rural) site - C147

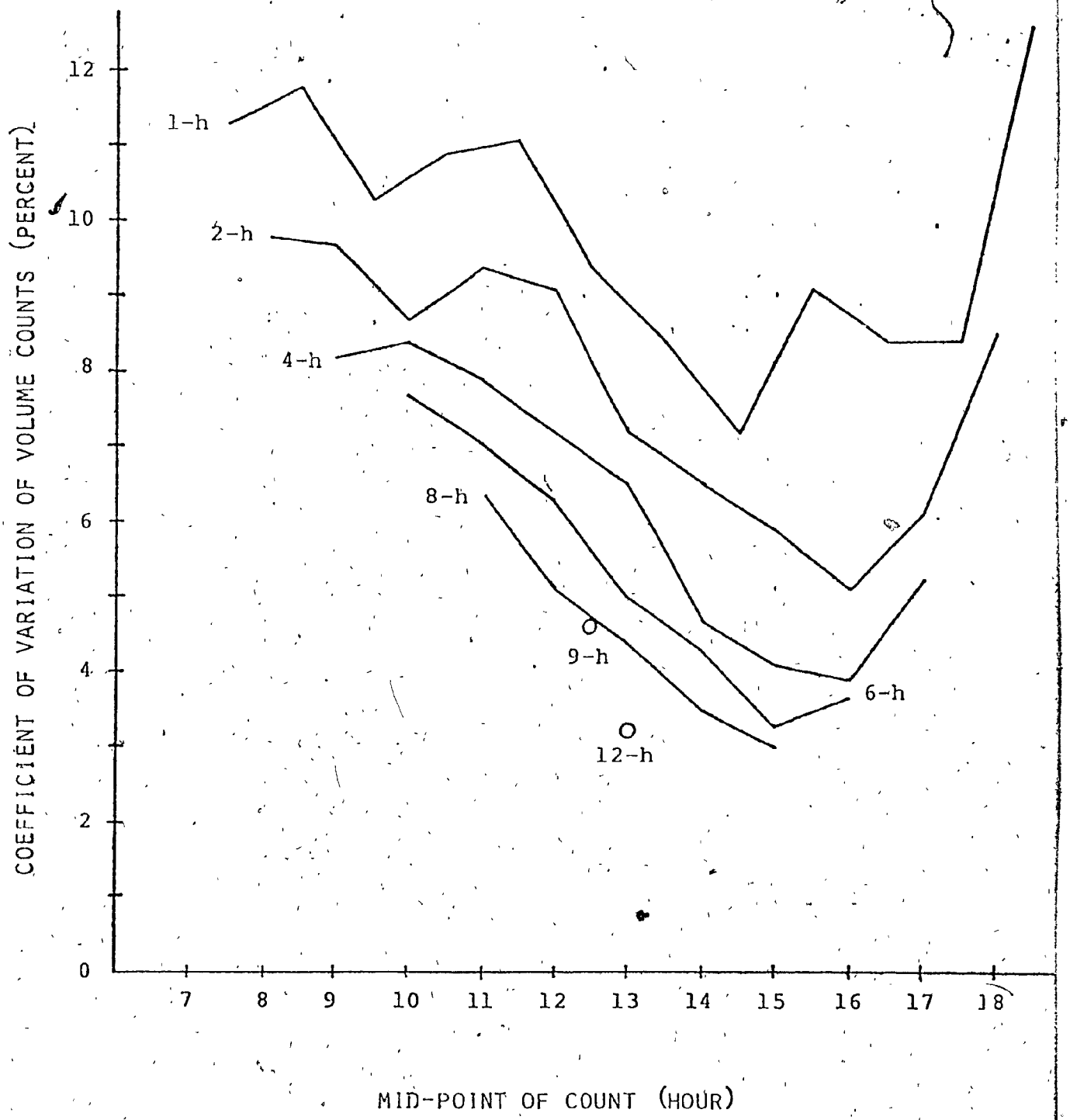

FIGURE 17- Stability of weekday volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; rural long distance site - C18.

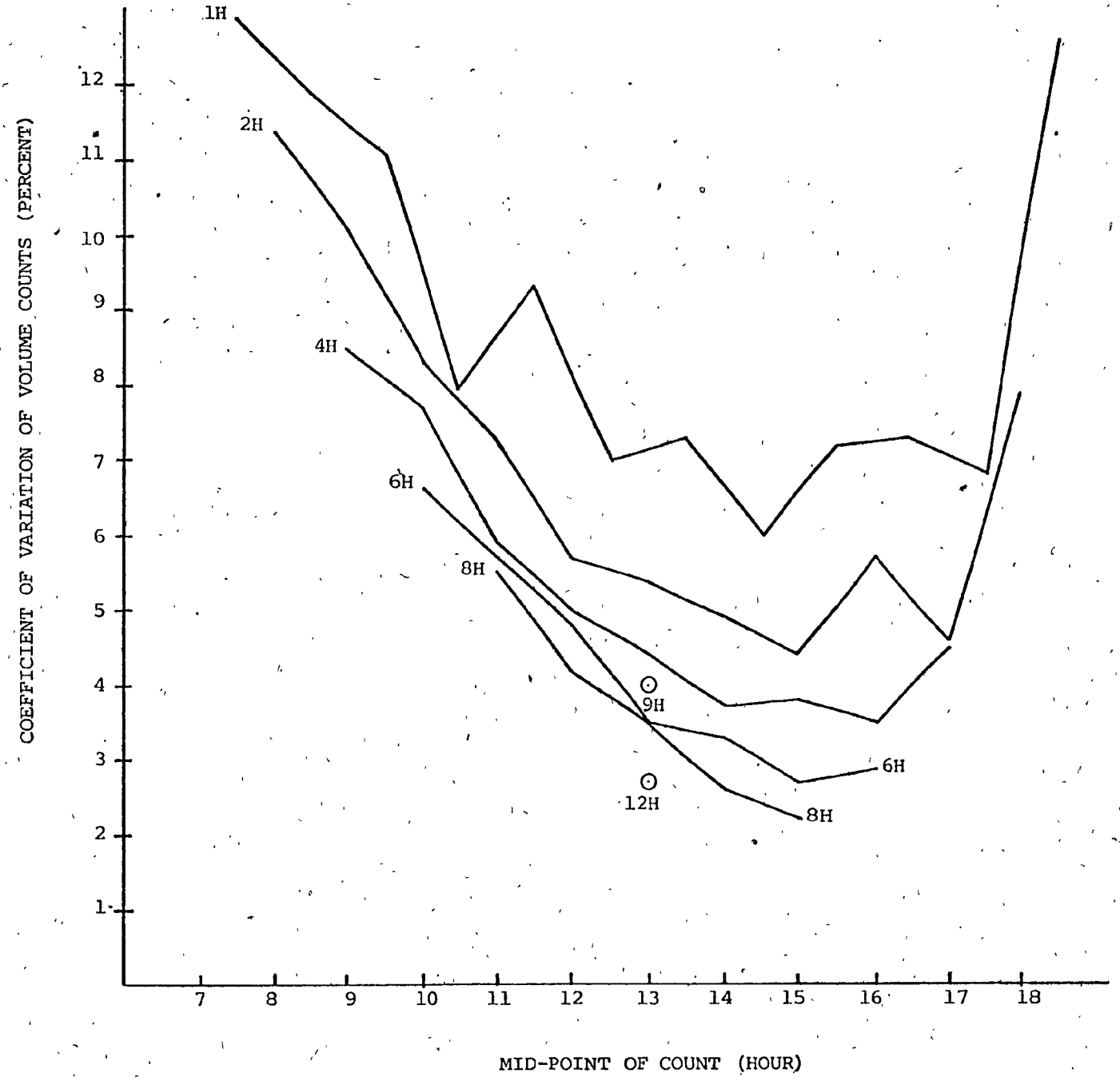

FIGURE 18 - Stability of weekday volume counts (Percent). Data: the month of June in 1978, 1979 and 1980; rural long distance site - C18.

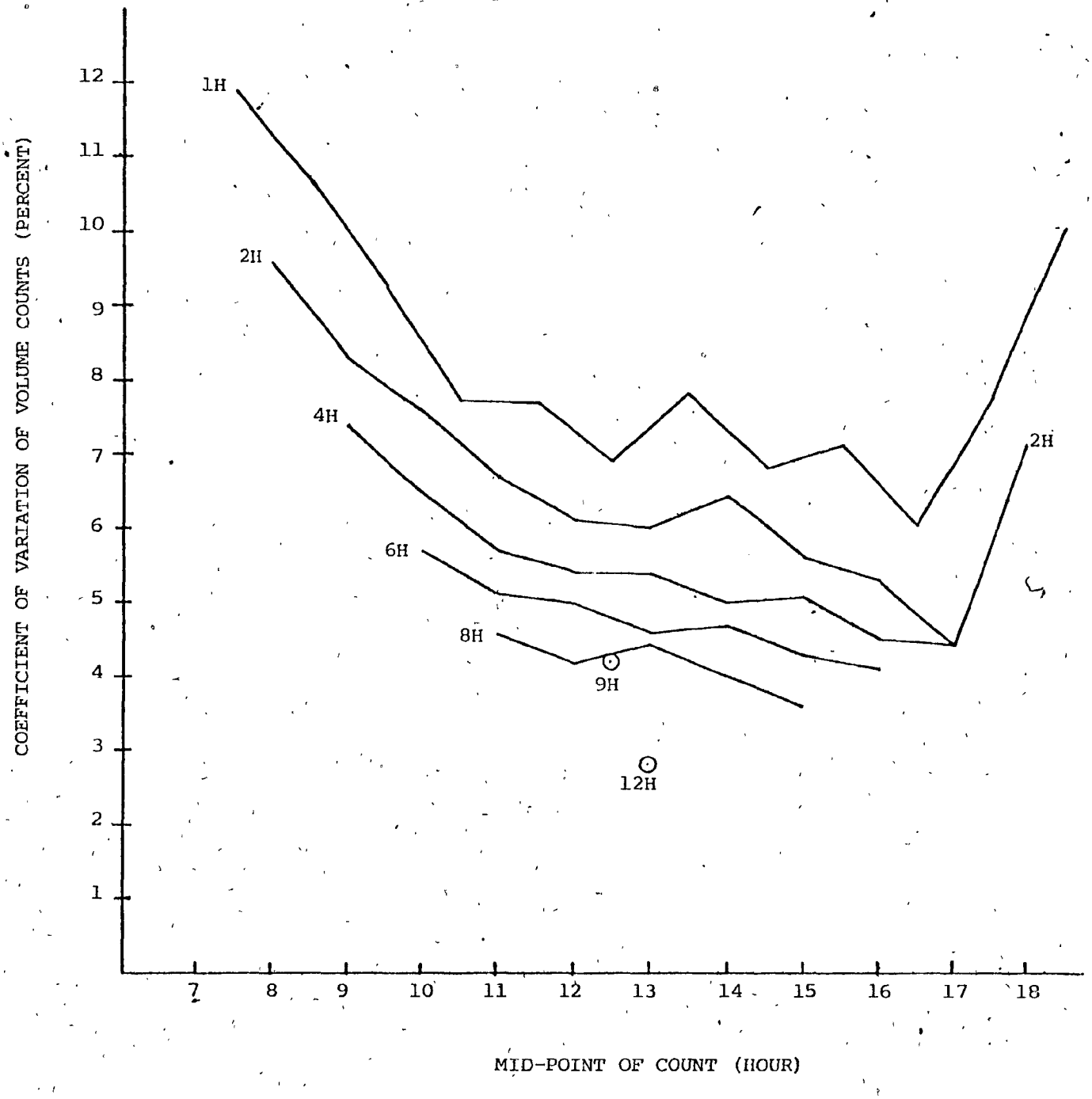

FIGURE 19 - Stability of weekday volume counts (Percent). Data: the month of July in 1978, 1979 and 1980; rural long distance site - C18.

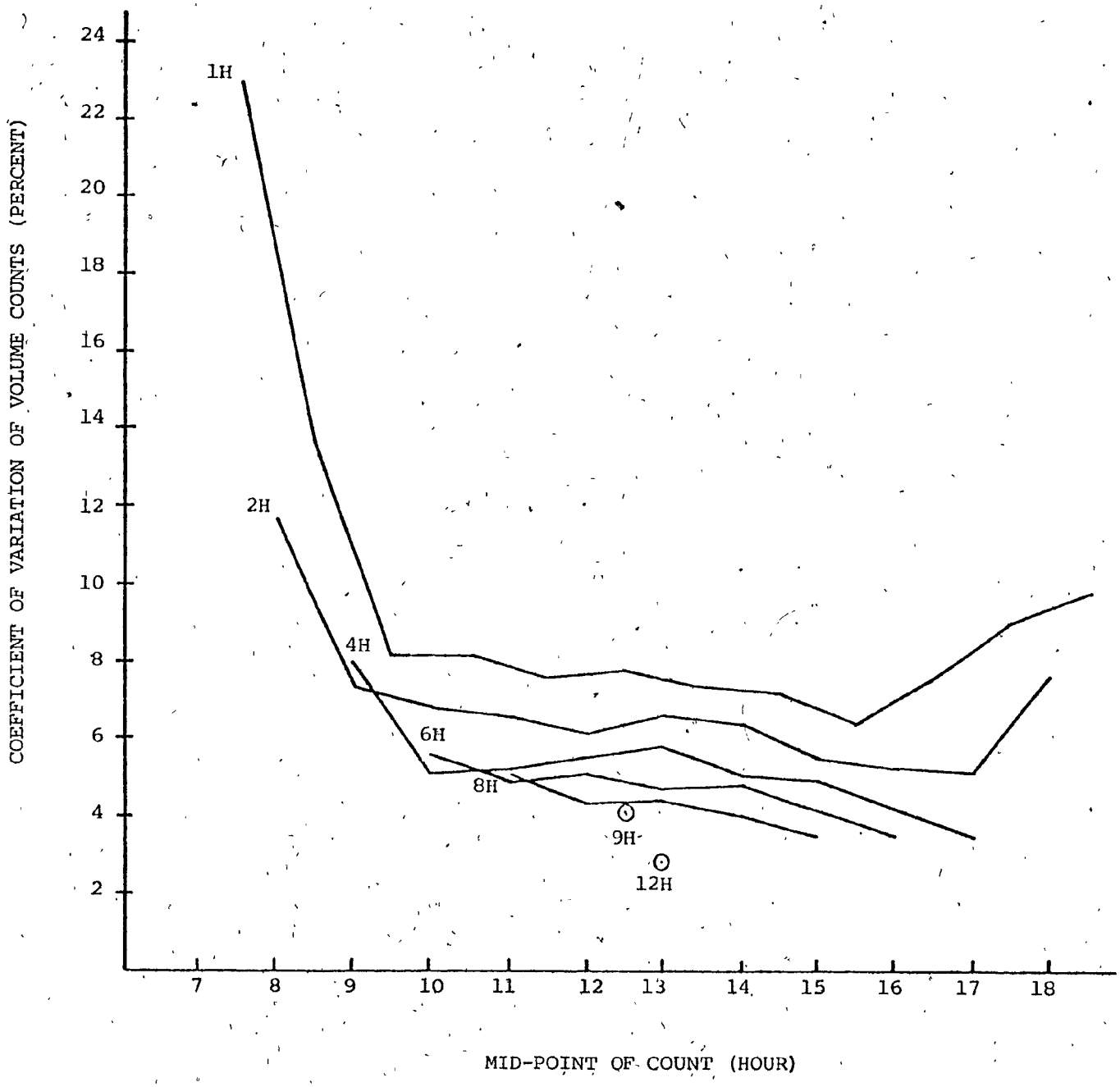

FIGURE 20 - Stability of weekday volume counts (Percent). Data: the month of August in 1978, 1979 and 1980; rural long distance site - C18.

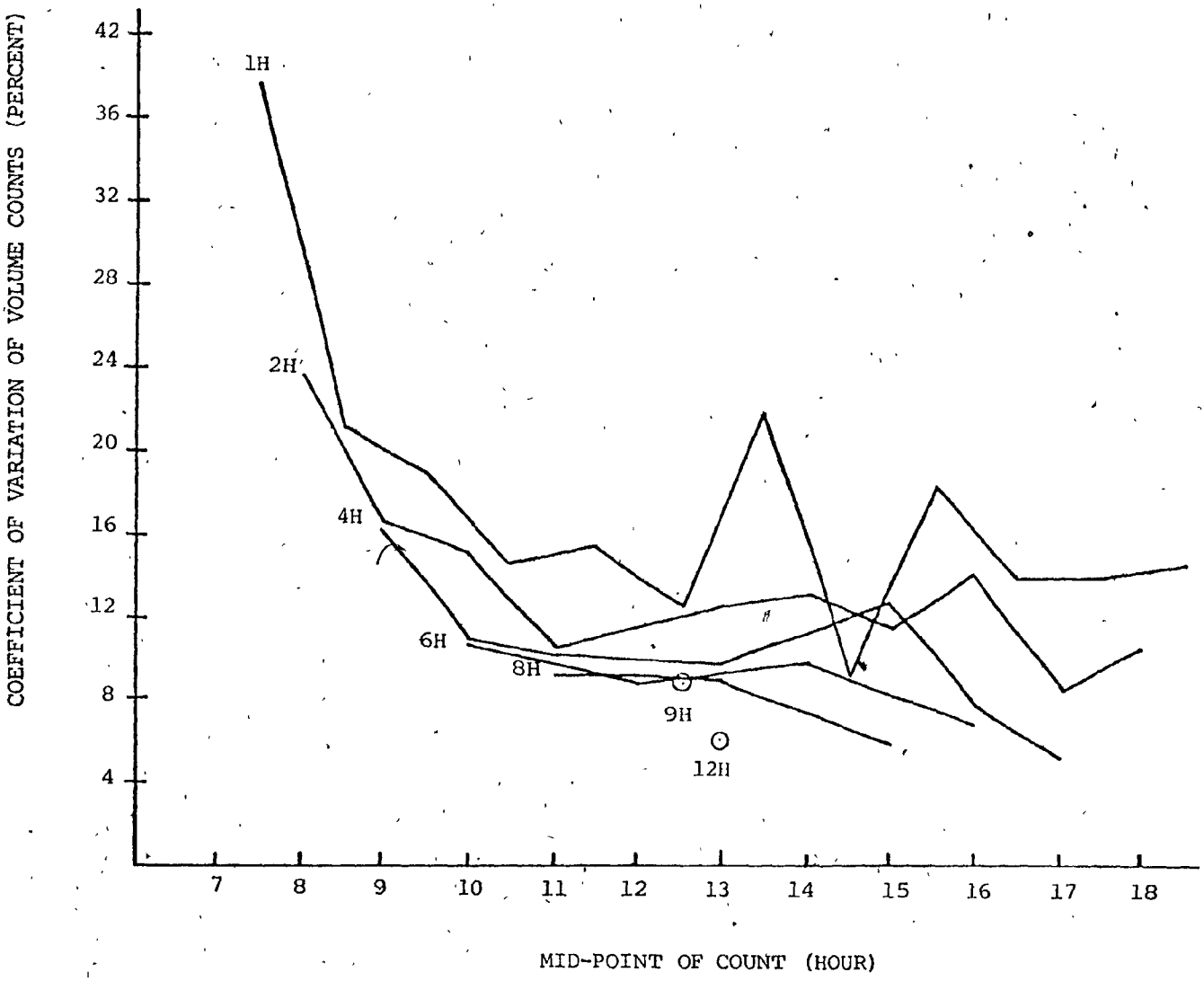

FIGURE 21 - Stability of weekday volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; recreational site - C114.

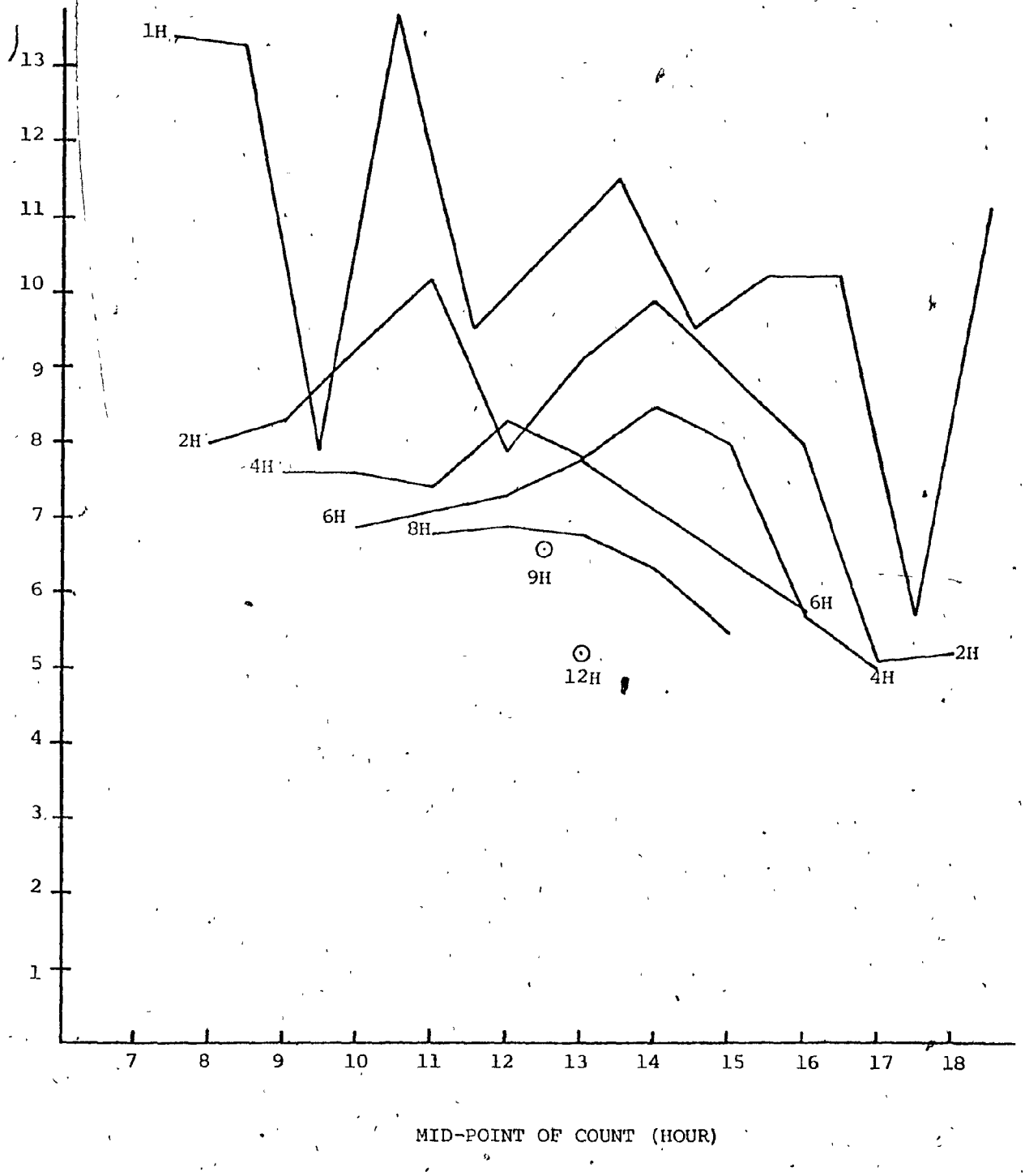

FIGURE 22 - Stability of weekday volume counts (Percent). Data: the month of June in 1978, 1979 and 1980; recreational site C114.

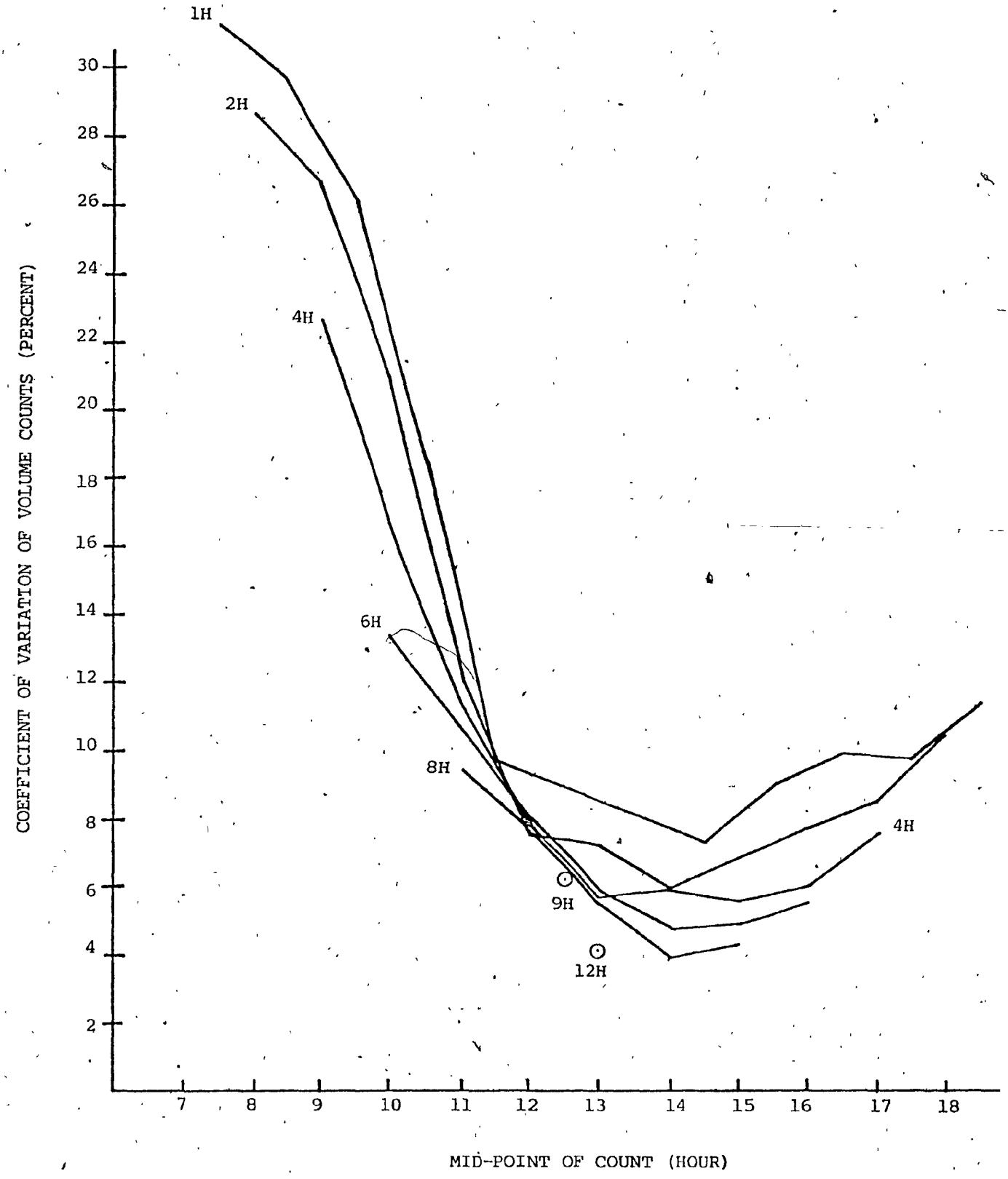

FIGURE 23 - Stability of weekday volume counts (Percent). Data: the month of July 1978, 1979 and 1980; recreational site C114.

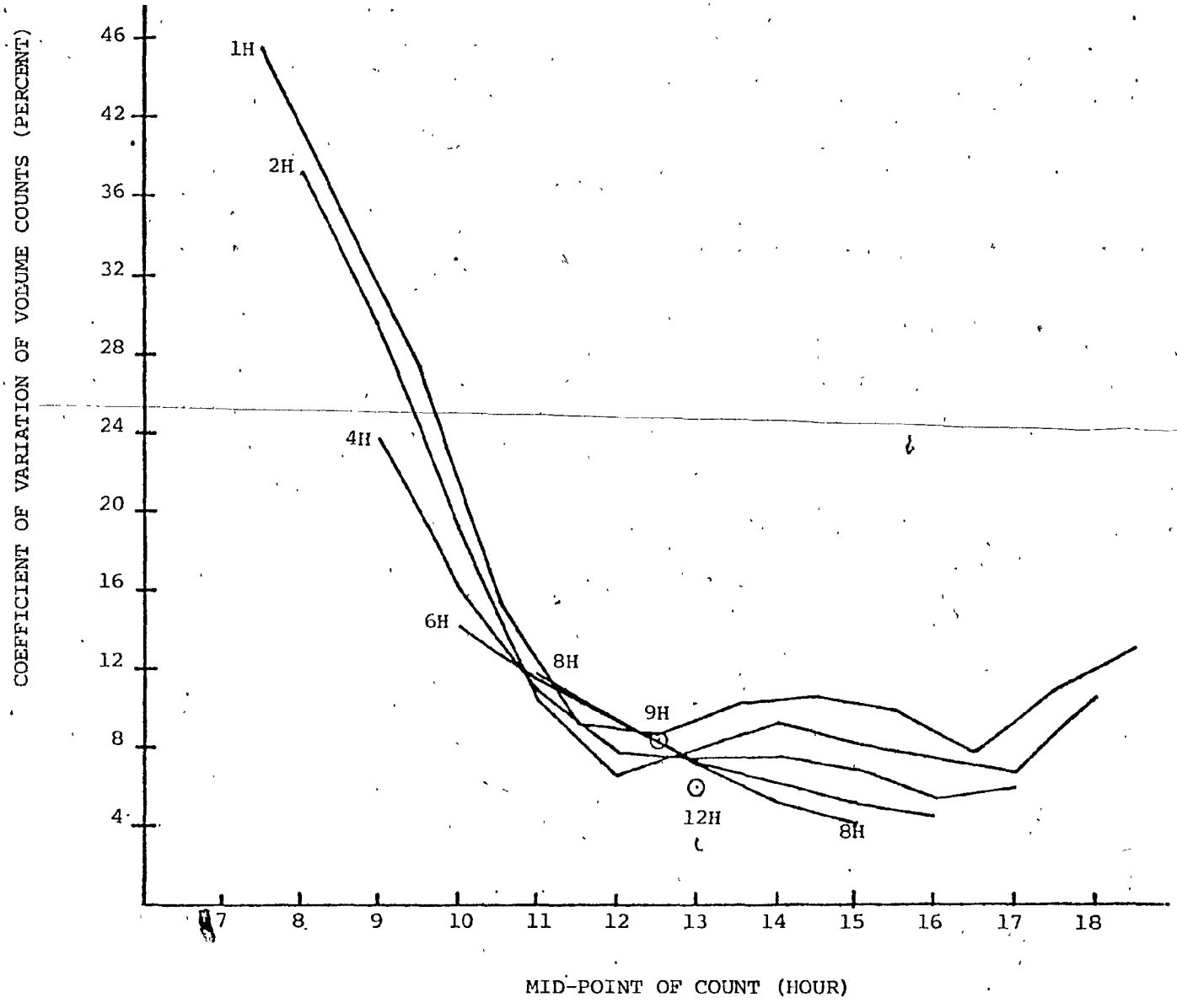

FIGURE 24 - Stability of weekday volume counts (Percent). Data: the month of August 1978, 1979 and 1980; recreational site C114.

APPENDIX D

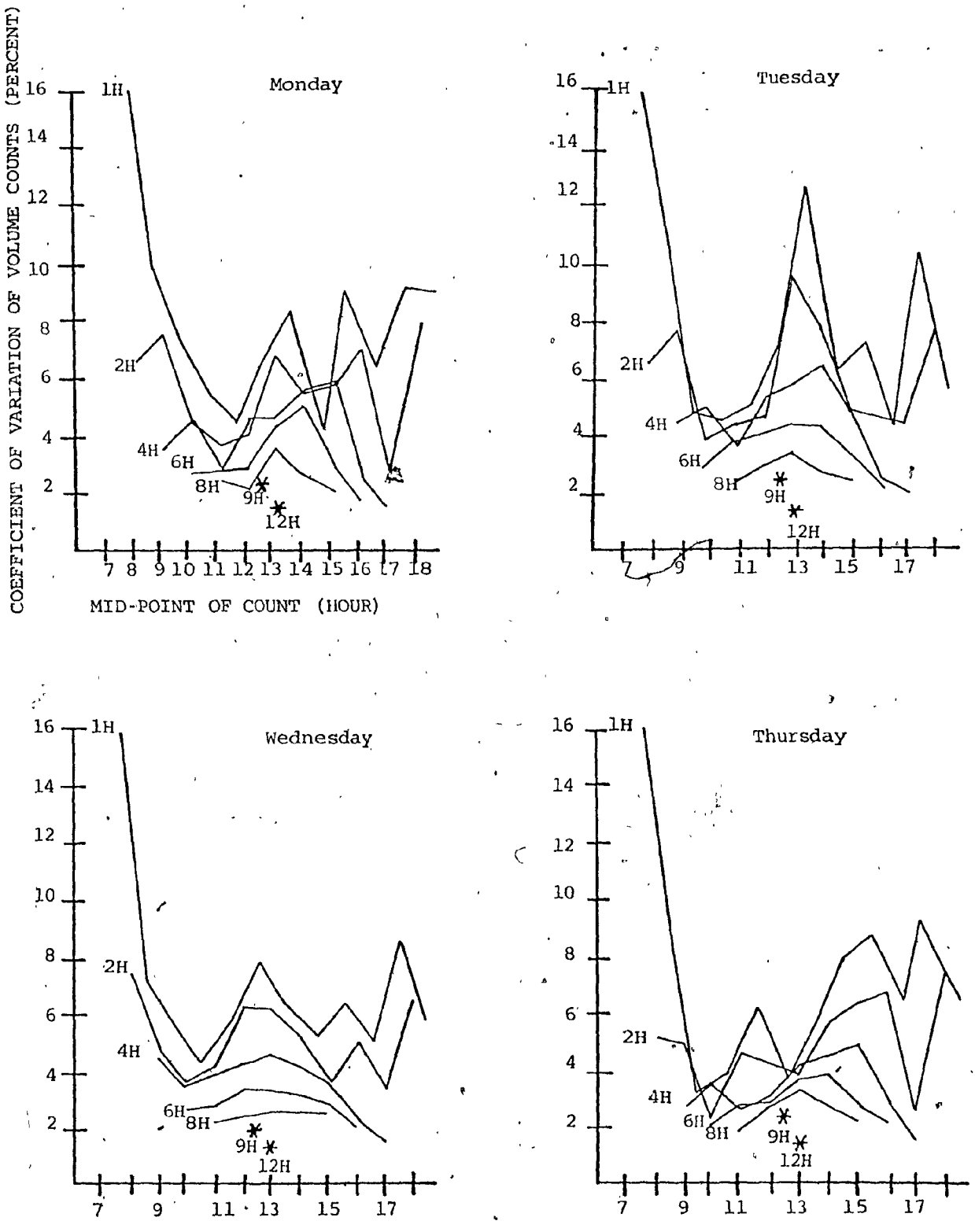

FIGURE 25 - Stability of daily volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; commuter site - C09.

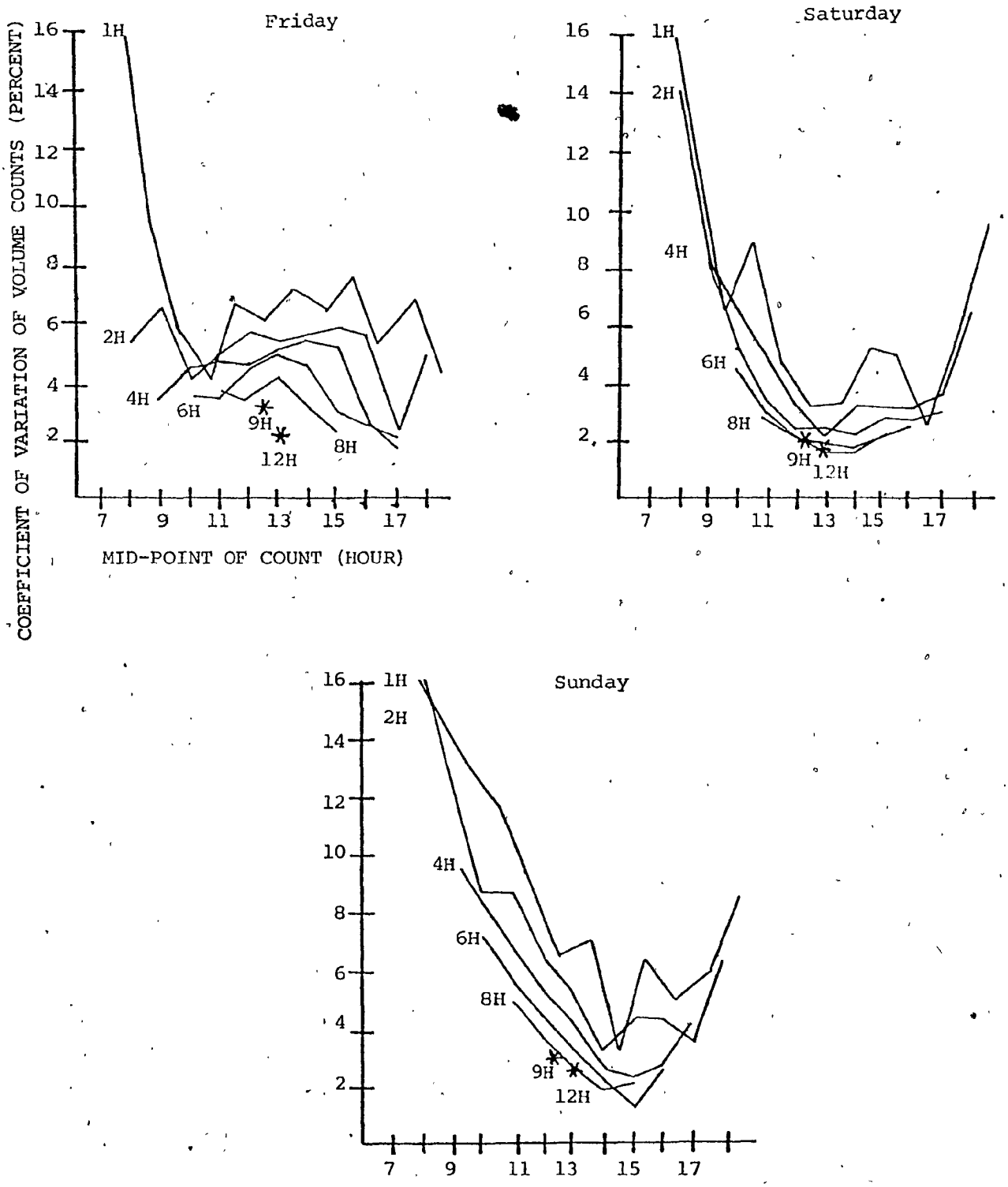

FIGURE 26 - Stability of daily volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; commuter site - C09.

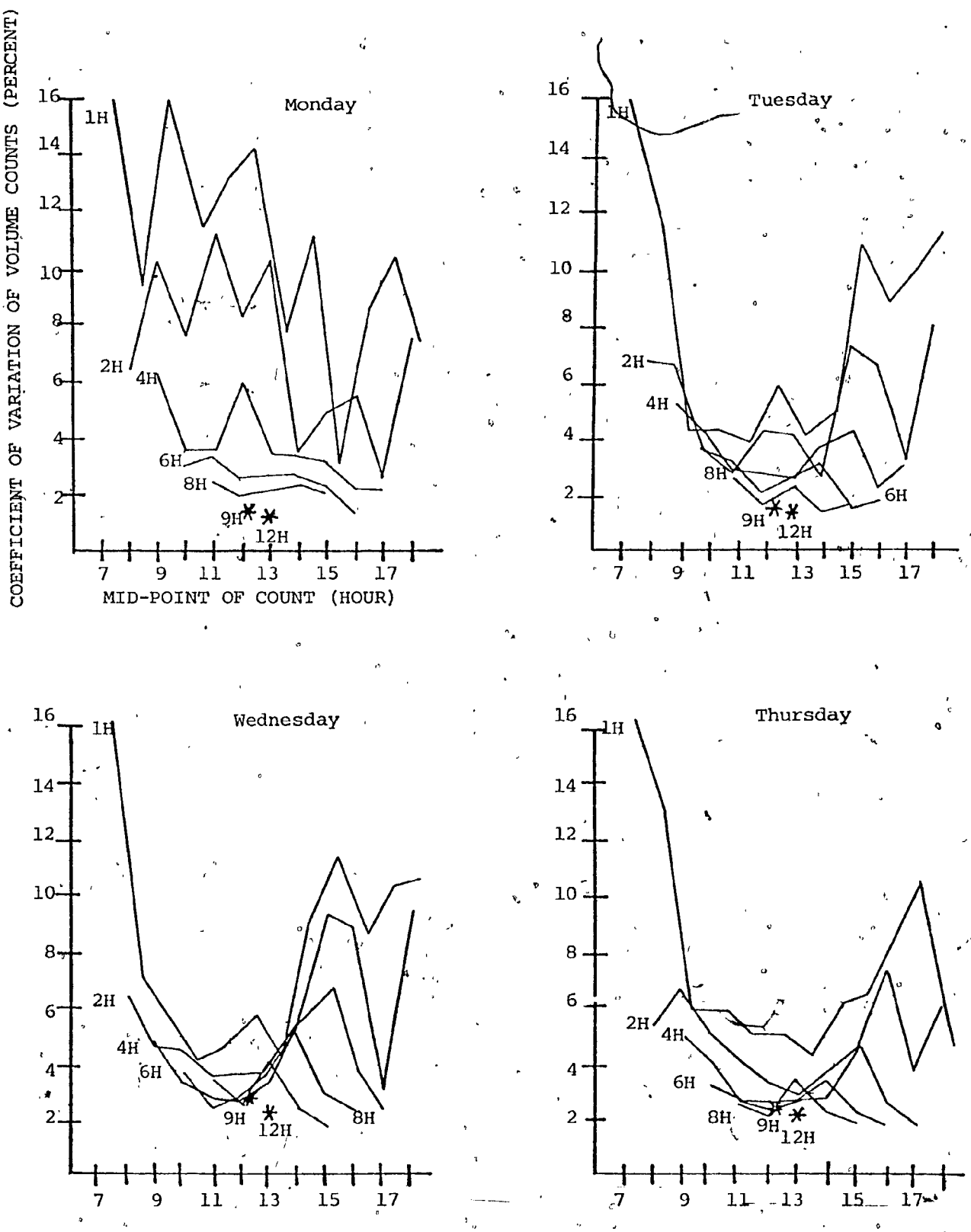

FIGURE 27 - Stability of daily volume counts (Percent). Data: the month of July in 1978, 1979 and 1980; commuter site - C09.

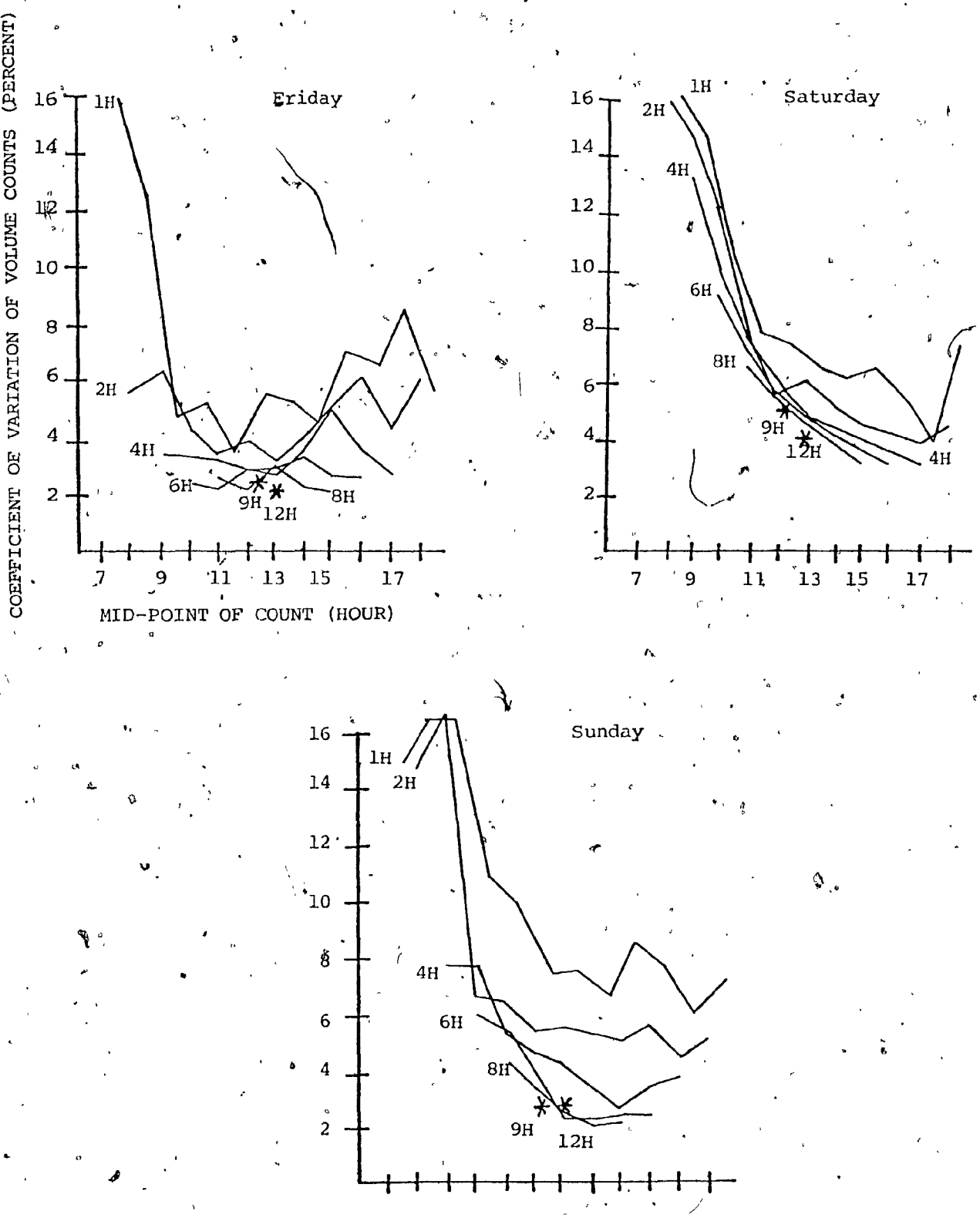

FIGURE 28 - Stability of daily volume counts (Percent). Data: the month of July in 1978, 1979 and 1980; commuter site - C09

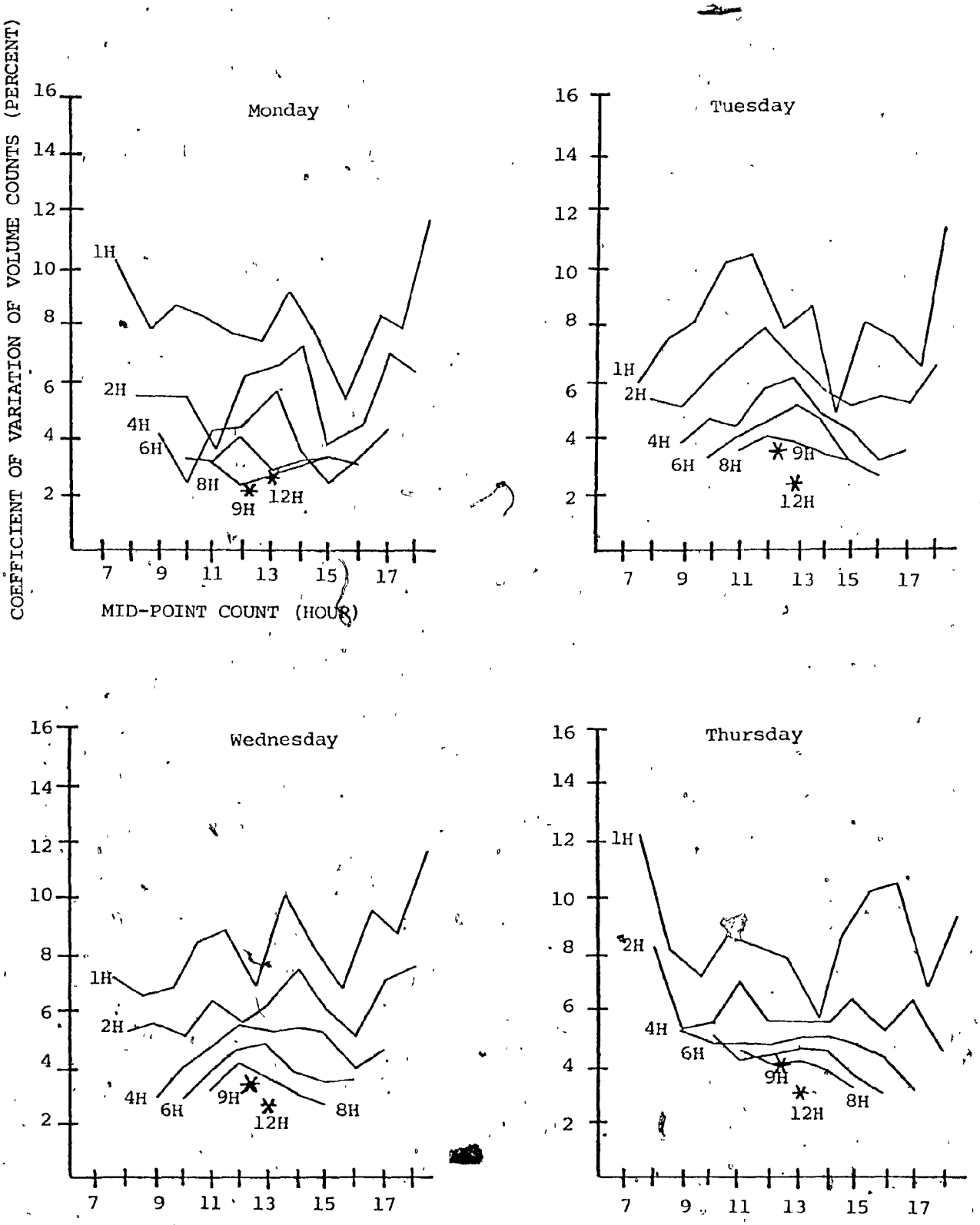

FIGURE 29 - Stability of daily volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; rural long distance site - C18.

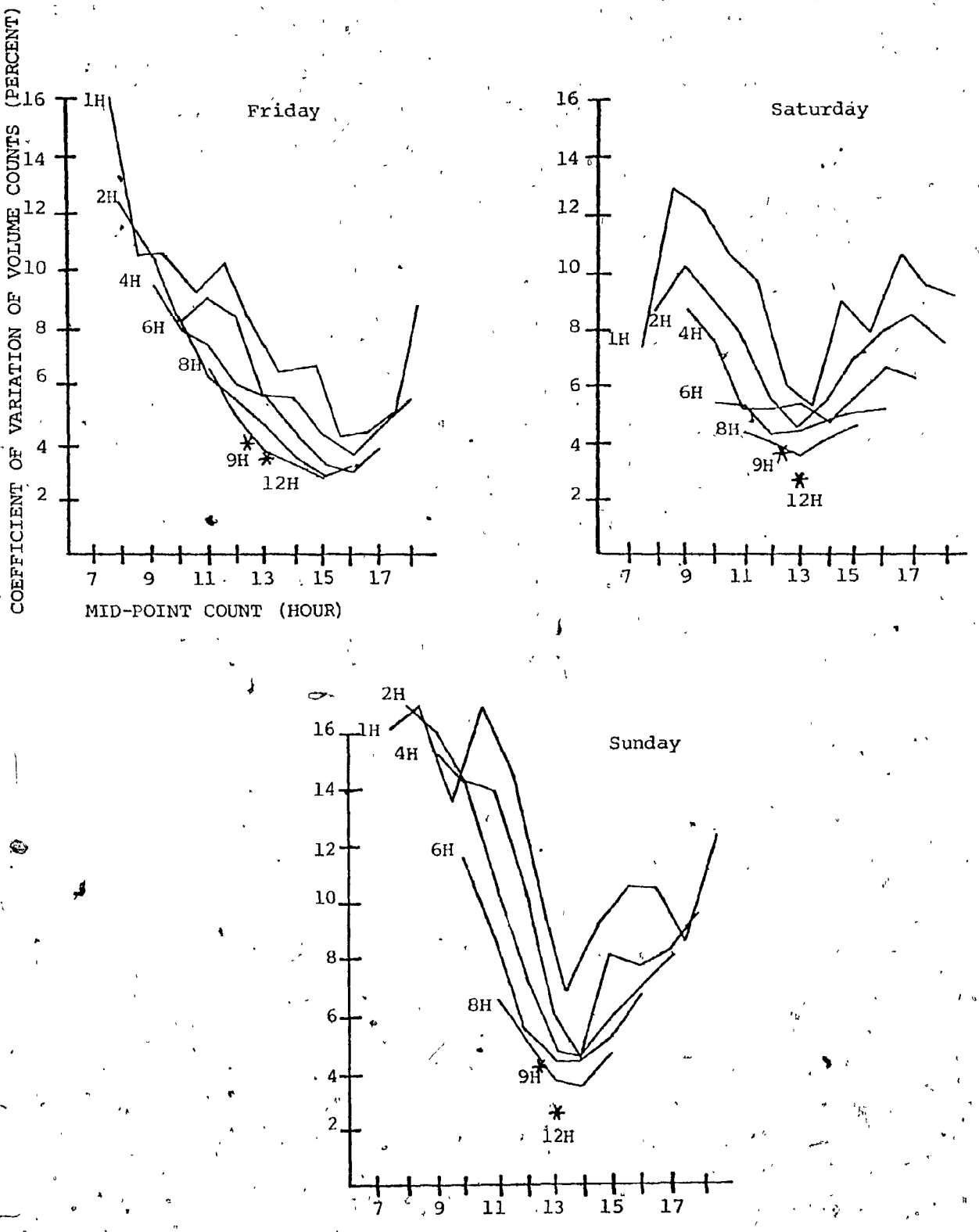

FIGURE 30 - Stability of daily volume counts (Percent). Data: the month of May in 1978, 1979 and 1980; rural long distance site - C18.

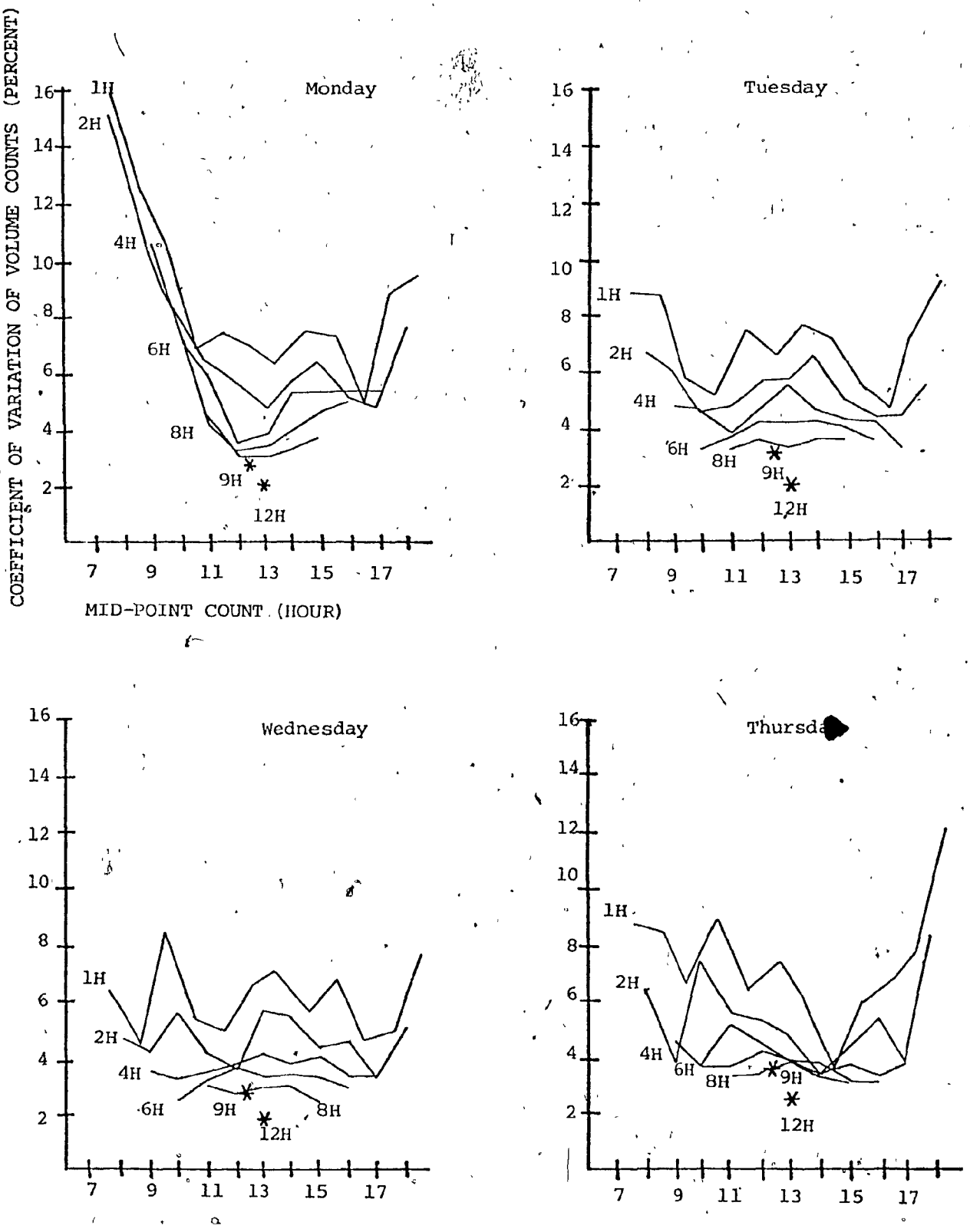

FIGURE 31 - Stability of daily volume counts (Percent). Data: the month of July in 1978, 1979 and 1980; rural long distance site - C18.

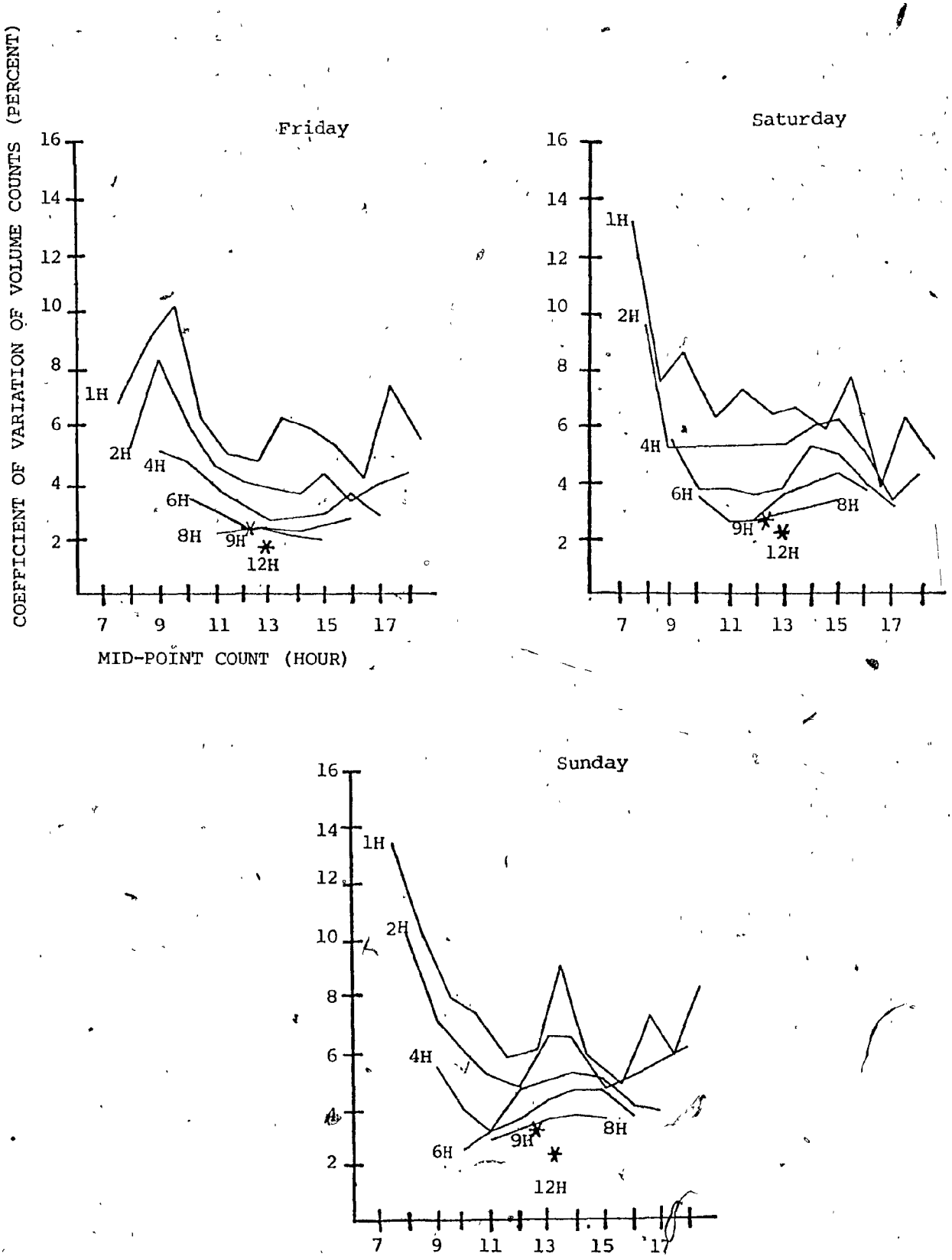

FIGURE 32 - Stability of daily volume counts (Percent). Data: the month of July in 1978, 1979 and 1980; rural long distance site - C18.

APPENDIX E

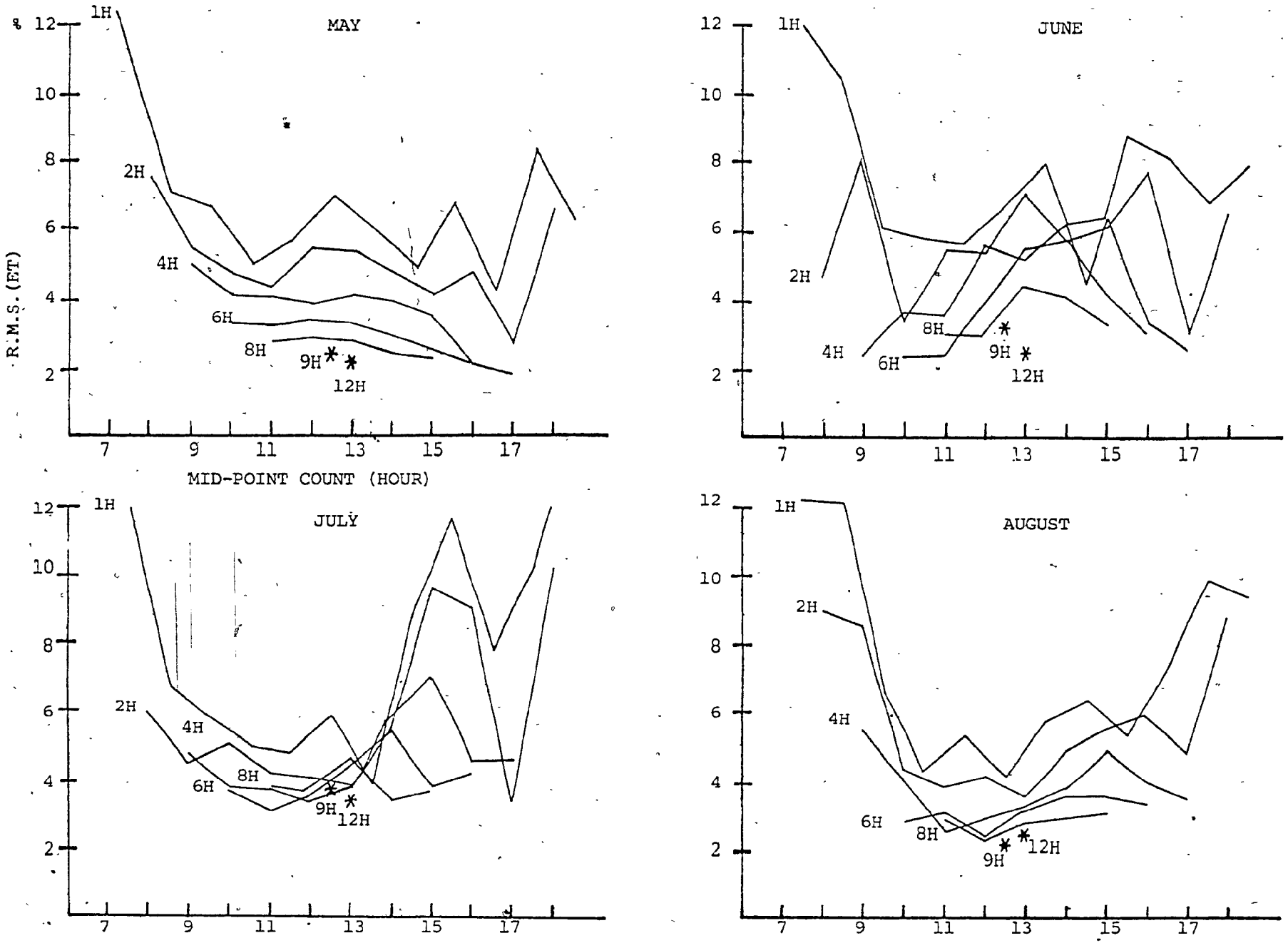

FIGURE 33 - Stability of R.M.S.(ET) for the estimated values of AADT.
Data: Wednesday in 1978, 1979 and 1980; commuter site - C09.

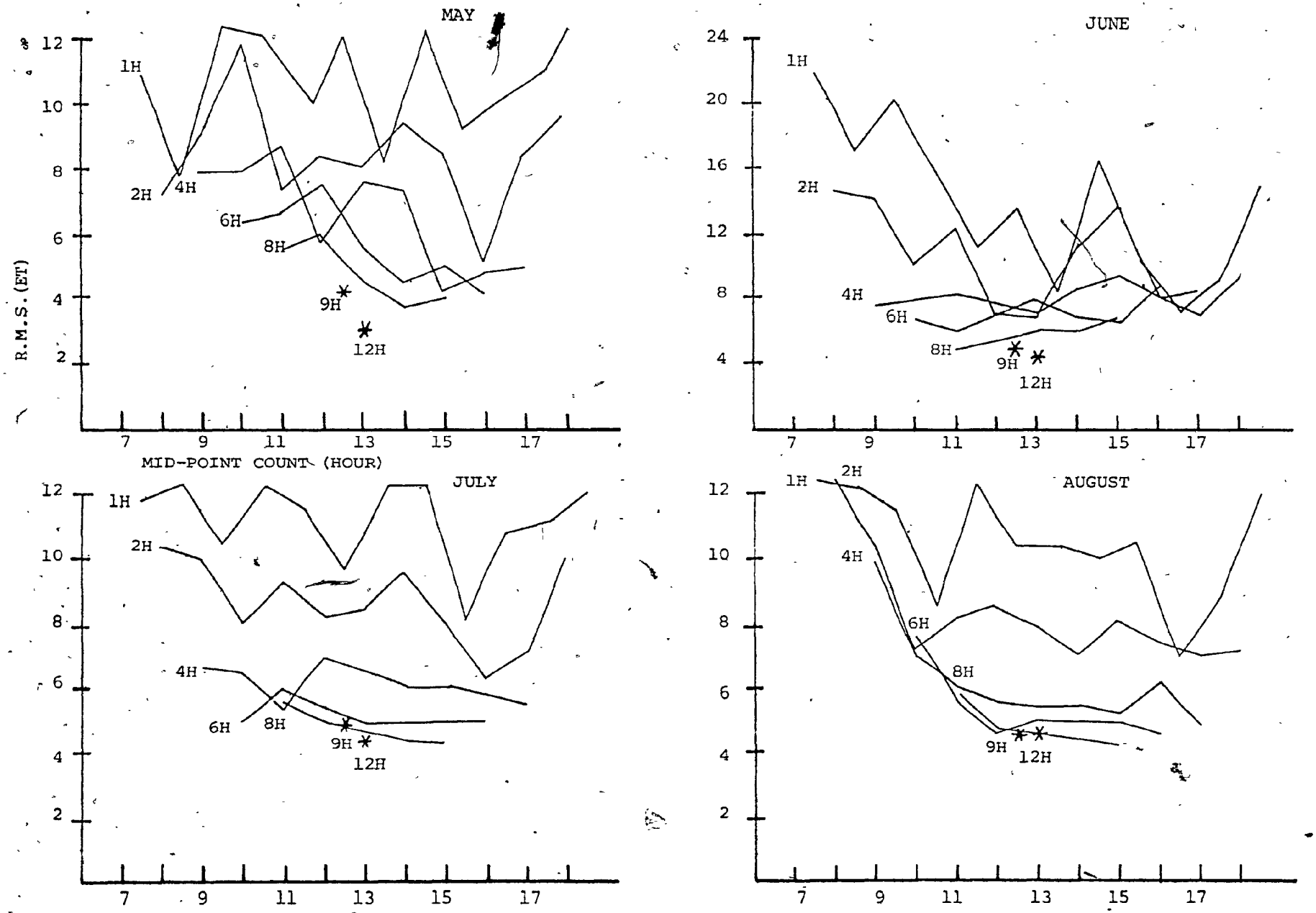

FIGURE 34 - Stability of R.M.S.(ET) for the estimated values of AADT.
Data: Wednesday in 1978, 1979 and 1980; non-recreational low volume (rural) site - C147.

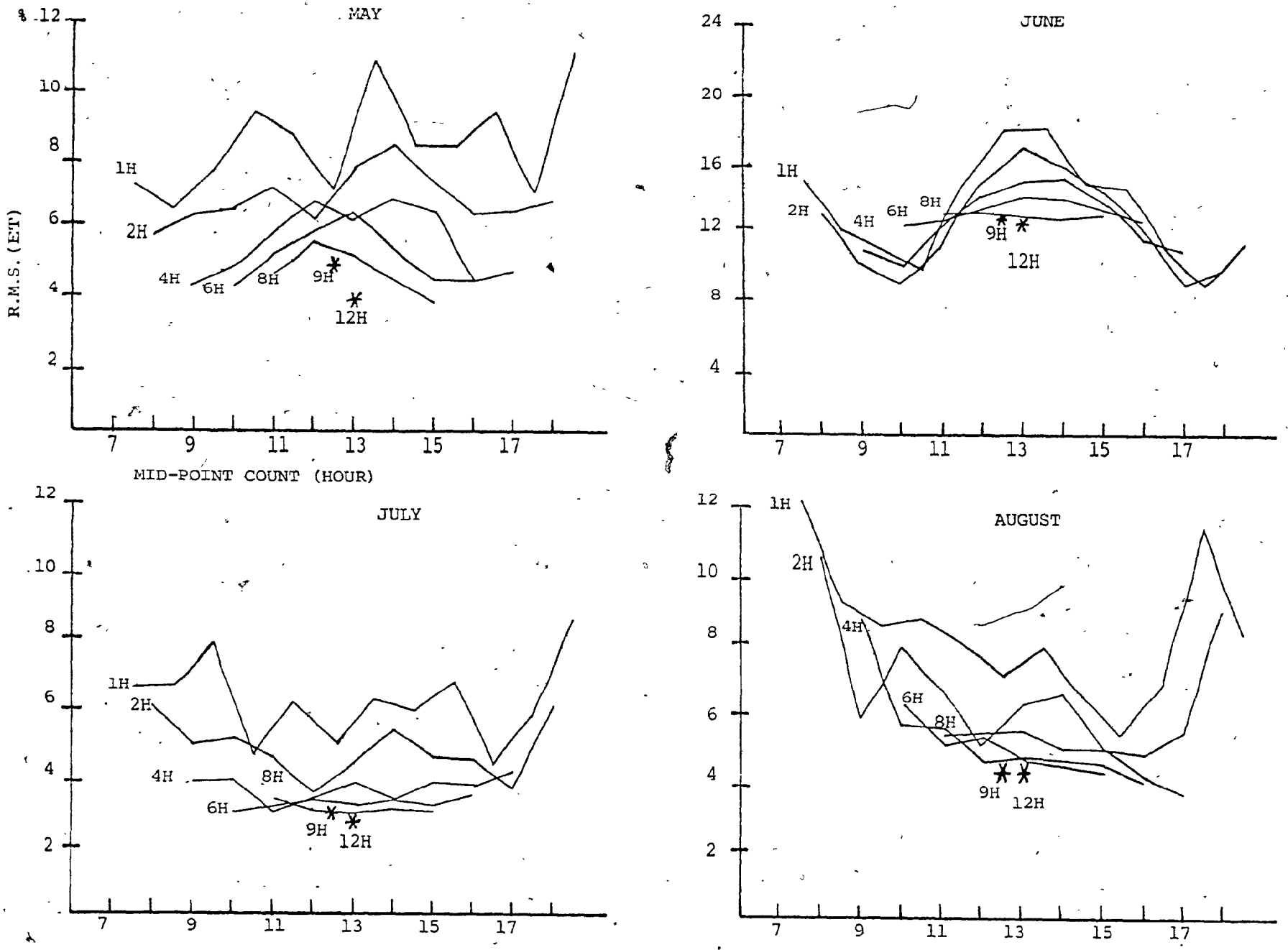

FIGURE 35 - Stability of R.M.S.(ET) for the estimated values of AADT.
Data: Wednesday in 1978, 1979 and 1980; rural long distance site - C18.

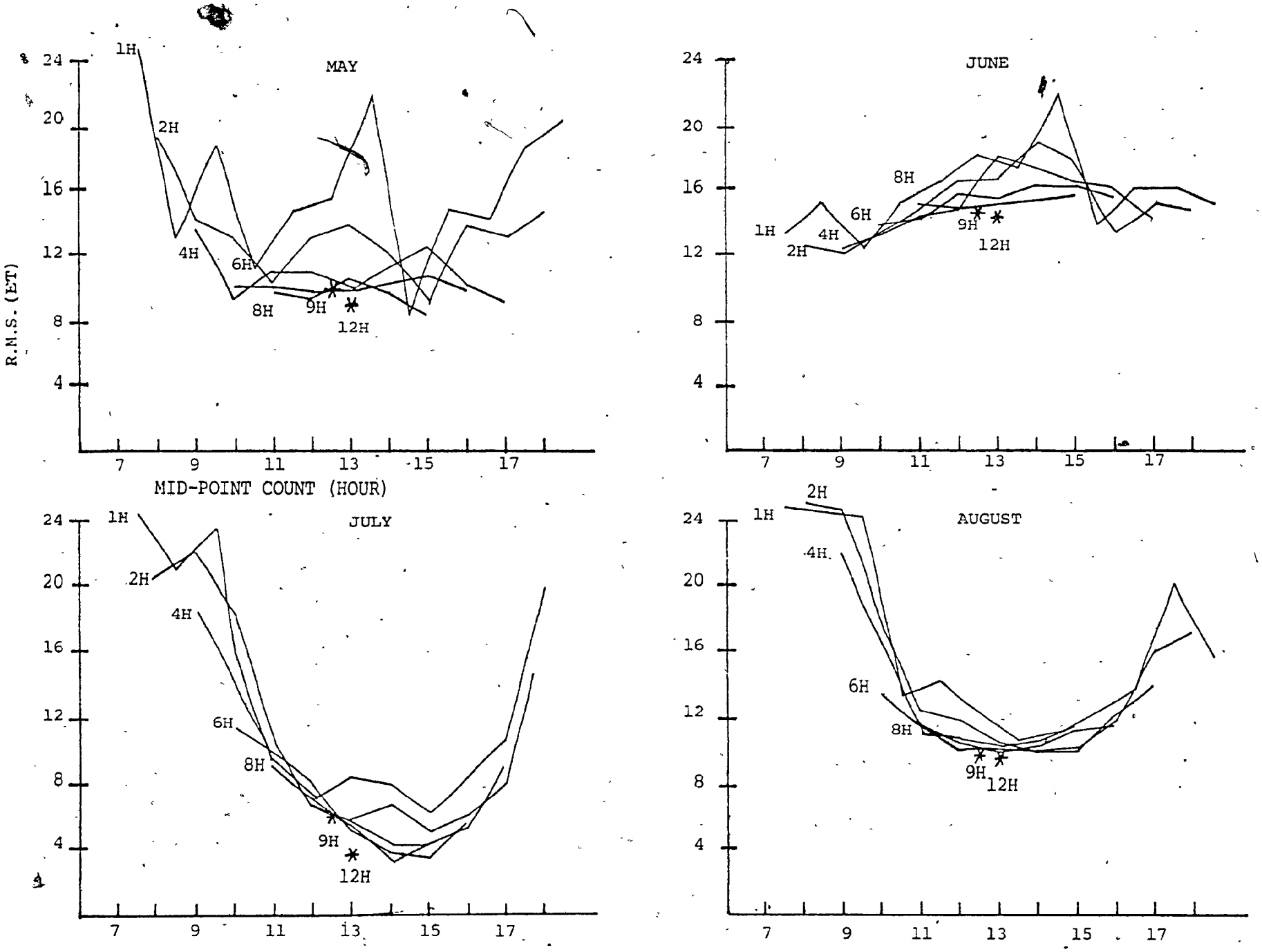

FIGURE 36 - Stability of R.M.S.(ET) for the estimated values of AADT.
Data: Wednesday in 1978, 1979 and 1980; recreational site - C114