RD 88-036

MEASURING PEDESTRIAN VOLUMES AND CONFLICTS

VOLUME I. PEDESTRIAN VOLUME SAMPLING

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FINAL REPORT

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16. Abstract

This final report presents the findings, conclusions, and recommendations of the study conducted to develop a model to predict pedestrian volumes using small sampling schemes. This research produced four pedestrian volume prediction models (i.e., 1-, 2-, 3-, and 4-hour models) using 5-, 10-, 15-, and 30-minute volume counts. These volume counts best predicted the hour and multihour volumes when sampled at the midpoint of the sampling period. A validation study was conducted to determine the level of accuracy of the models. Recommendations for further research are suggested to investigate the validity and reliability of the developed models using data from other cities.

This volume is the first in a series. The others in the series are:

Vol. No.	Title
II	Accident Prediction Model (Report)
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METRIC (SI*) CONVERSION FACTORS

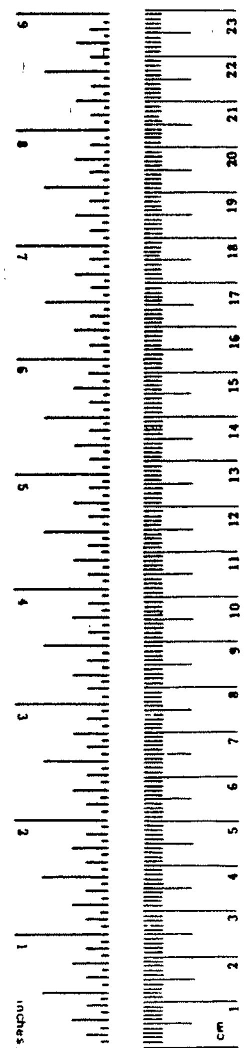
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

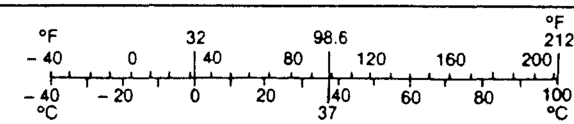


APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

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INTRODUCTION

Background

Despite the large volume of research on pedestrians that has been conducted in the past several decades, there have been few, if any, studies conducted with the single objective of developing a method for measuring pedestrian volumes. Many researchers have used pedestrian volume counts to develop improved pedestrian facilities and to evaluate pedestrian safety. However, any developments or improvements to these measurement techniques have relied on data that were collected to satisfy other primary objectives.

While some of these measurement techniques have been adequate for making relative comparisons among alternative pedestrian facilities or for evaluating alternative safety countermeasures, none have been universally accepted by the research or user community, with the exception of manual pedestrian counting.

Presently, the methods for collecting pedestrian volume data using manual counts at specific sites for limited periods of 4-10 hours are labor intensive and expensive. Techniques that may be more economical include sampling over shorter time periods, automated counting devices, or analytical methods.

Thus, more efficient and cost-effective methods are needed to measure pedestrian volumes that can be used to warrant pedestrian facilities and determine exposure to accident risk.

Objective of the Study

The objectives of this study were to critically evaluate existing methods of measuring pedestrian volumes and to develop new methods to more economically gather the required data.

Scope of the Research

This study was concerned with a thorough examination of the various methods or techniques of measuring pedestrian volumes. Existing methods were identified and evaluated in terms of data requirements, data collection procedures and cost-effectiveness, uses of data, and other evaluative criteria such as accuracy of data, cost to collect data, ease of data collection, and feasibility of methodology.

An extensive literature review was conducted to identify existing methods of measuring pedestrian volumes and to ascertain the common practices utilized by cities today in measuring pedestrian flows and volumes. The literature review was conducted using the automated searchers TRIS, Compendix-Dialog, and Psych-Info and through personal contacts. The literature search concentrated on locating and reviewing studies that involved the use of the following:

1. Manual data collection methods

2. Mechanical or automated data collection methods

3. Analytical models.

A state-of-the-practice report was prepared describing all the current standards, procedures, and techniques used in collecting pedestrian volume data. Based on the findings of the report, a data collection plan was developed for manual collection of pedestrian volumes at 14 locations in Washington, D.C. The data were used to develop various sampling schemes for taking manual pedestrian counts.

Finally, several conclusions were drawn and recommendations were made to further validate the methodology developed for using various sampling schemes of manual counting to determine pedestrian volumes.

STATE-OF-THE-PRACTICE

The measurement of pedestrian volumes is considerably more difficult than the measurement of vehicle volumes. When compared to vehicles, pedestrians are less confined to marked traffic lanes, have greater choice of travel speeds, have shorter reaction times, can stop quicker, and generally suffer little or no damage during collisions with each other. Pedestrians frequently tend to form groups, object to being controlled, observed, or measured, and display a great curiosity for unfamiliar objects and situations. In part, due to this variability and unpredictability of pedestrian movements, most pedestrian studies have used manual counts at specific sites for limited periods of 4 to 10 hours. This technique is labor intensive and, therefore, expensive. Past studies have not generally concerned themselves with developing new data collection techniques. While manual counting is the most prevalent method of collecting pedestrian volume data, mechanical counting devices and analytical models have been developed for measuring pedestrian volumes.

Mechanical Counting Devices

A 1974 TRB report by R. Cameron describes an automatic pedestrian counter which was developed and refined during 1971 and 1972 in Seattle, Washington.

The counter was made up of eight 28-inch by 36-inch hand-constructed detector pads. The pads were composed of silicon conductor disks sealed in neoprene and mounted 3 inches apart on two stainless steel plates 1/4 inch in thickness. The two plates were placed on the sidewalk with the 36-inch dimension in the direction of the pedestrian flow. Leads from the detector pads ran back to automatic summators housed in a traffic signal control box. In order to provide weather protection and durability, a 4-foot by 14-foot rubber carpet was installed over the detectors and glued to the sidewalk. The maximum rise in height of less than 5/8 inches was located 6 inches in from the carpet edge and no tripping problems were experienced. More than fifty 15-minute checks were made during the initial 2-month operating period. The checks showed an over-counting of 15 to 20 percent which was attributed to the pads being too long in the direction of pedestrian flow. Based upon the inital test, a number of refinements were made. New 17-inch by 23-inch detector pads were developed that would give a maximum rise of less than 1/2 inch including the protective carpet overlay and a "portable" equipment box was included to house the counter, summator, and dc batteries. A compact solid-state summator was also developed. Further experimentation showed that detector pad durability could be increased by placing a cushioning material between the pad and sidewalk.

The counter units proved to be quite versatile and can be installed anywhere traffic patterns permit, direct traffic flows producing the most accurate results and doorways or lingering areas producing the least accurate results. Manual count checks of the refined equipment showed a counter accuracy within 5 percent of volume measurements.

The automatic pedestrian counter was used to record pedestrian volumes for a downtown employee population, a downtown shopper population, and a mixed population of employees, shoppers, visitors, and residents. Weekday volumes, hourly volumes, and Saturday volumes were recorded, analyzed, and reported. It was noted that although different types of pedestrian populations had different volume patterns, the daily and weekly volumes for each recurred in regular patterns. This would imply that a sampling and factoring procedure, similar to that used for traffic volumes, could be developed for pedestrian volumes. Cameron concluded that the automatic pedestrian counter could be used to provide a reliable, economic data base for planning and designing pedestrian movement systems.

In a second paper by Cameron (1975), the continued development process of the automatic pedestrian volume counter is described. The original detector pads were replaced by 17-inch by 23-inch commercially available pads. A commercially available summator and recording device was also used.

S. Musaly, in a 1979 South African Electronic Letters, describes a computer-based infrared pedestrian data acquisition system.

The combined hardware-software instrumentation system enables pedestrian flow conditions at any point in a pedestrian traffic stream to be sampled, event by event, stored on magnetic cassette tape, and analyzed remotely by a digital computer. A photocell detector senses infrared reflections, off the human body and clothing, from a linear lamp. Both the lamp and detectors are located above and along a pedestrian traffic stream. The spacing between the detectors is such that more than one detector senses the presence of a pedestrian, thus eliminating errors due to secondary objects. The length of the photosensor unit can theoretically be made such that any number of pedestrians walking in parallel can be detected and when two rows of detectors are employed, the direction of movement can also be determined. A typical installation consists of two rows of detectors, one on each side of a pedestrian traffic stream, with a series of linear incandescent lamps mounted between the rows. The detector spacing is approximately 12 inches. The detector output is transmitted by cable to an interface module where it is decoded and stored on a digital cassette tape and then forwarded to a mini-computer for statistical analyses.

The effectiveness of the technique was evaluated by observation and by manually and automatically recording count comparisons of two photosensor units in a long straight corridor. The error between observed number of pedestrians and automated count number was found to be approximately 5 percent. The pedestrians were walking in both series and parallel and at various speeds and wearing clothing of different shades and textures. The highest error was experienced with clothing of very high or very low reflective coefficients, bright items on the lower portion of the pedestrian, very heavy persons, large carried articles, and very fast walking groups. It should also be noted that the equipment requires an overhead installation with some form of weather protection. Greatest accuracy is achieved where pedestrians are channeled into relatively narrow streams parallel to the sensing units.

The problem caused by non-parallel movement and a solution for the problem is described in a second paper by Mudaly (1980). The data processing program was rewritten to compensate for non-parallel flow and a microprocessor was included in the system. This resulted in improved accuracy and the ability to handle higher volumes.

Vozzolo and Attanucci (1982) summarize the application of automatic passenger counting programs for 12 North American transit groups. The automatic passenger counting devices record the number of passengers boarding and exiting a bus at each stop. The sensors, which can count bidirectionally, are installed at both the front and rear doors. While the units used on transit vehicles may not be satisfactory for counting pedestrians on sidewalks or in other areas, the general principles used are of interest. Four types of sensors are in general use and are mentioned in the research literature cited in the bibliography of the Vozzolo and Attanucci interim report. The following descriptions of the four types of sensors are taken directly from the report. While the units are for transit passenger counting, it is easy to visualize modified units for counting pedestrians.

Treadle sensor mats

> This system uses pressure sensitive mats which are installed on the two steps of each door on the bus. The mats contain pressure sensitive elements which are activated when a specified design weight is applied to the treadle. The logic processor is designed to produce a count whenever two steps are sequentially activated and to differentiate between boarding and alighting movements. Mats are sealed for protection from dust, moisture, and other environmental factors.

Infrared beam interruption

This system projects at least two light beams horizontally across the bus doorways to a light-sensitive receiver. When the light beam is interrupted, a count is registered. This information is sent to a counting logic unit which identified the direction of movement and number of passengers. The sequence in which the beams are broken determines the direction of movement. For example, a passenger boarding the bus first interrupts the beam closest to the door, then both beams simultaneously, then only the inner beam. Finally, neither beam is interrupted and a boarding count is recorded. In many cases, multiple beams are projected across the doorway in order to increase the detection ability of the sensors. The use of multiple beams allows more accurate identification of individual passengers during heavy boarding loads and helps prevent the inaccurate detection of extraneous objects (e.g., parcels and handbags).

Reflective infrared beams

Reflective techniques are very similar to the infrared interruption system except that they utilize a two beam device which both transmits and receives infrared light beams. Two beams of light are projected across the doorway of the bus. The reflectors are mounted on the opposite side of the doorway and transmit the light beams back to sensors which are located within the same unit as the light source. Thus, all of the "working" components are contained in a single device rather than two separate devices (i.e., a light transmitter and a receiver) as in the above infrared systems.

Ultrasonic interruption sensors

While ultrasonic systems have been discussed in the research literature, no applications were discovered. Sonic beam sensors count passenger activity similarly to interruptable light sensors, except the sound energy is used as the medium in place of infrared light.

Although these four types of sensing units are described in terms of use on transit vehicles, their application to pedestrian counting can be readily imagined. The treadle sensing mats system described above is similar to the automatic pedestrian counter developed and used in Seattle, Washington. It has an added advantage of directional sensing but shares the disadvantage of moisture problems. The reflective infrared beam system uses the same principles as the computer-based infrared pedestrian data acquisition system reported by Mudaly (1979, 1980). The major difference is that the Mudaly system, using a reverse principle, senses light reflected from the pedestrian rather than a stationary reflector. No pedestrian counter equivalent to the ultrasonic sensor has been found in the reported literature. However, sonic detectors have been used to detect vehicles but, for various reasons, are not widely accepted.

Overmeyer (1987) conducted research involving the comparison among three types of sensing systems for acquiring pedestrian count data. These sensing systems consisted of infrared, acoustic, and microwave doppler. All systems were compared by the use of an overhead detection device. The infrared and microwave systems were also investigated using a curbside apparatus.

Table 1 summarizes the sensor properties of the three systems. The results of this research favored the acoustic and infrared systems over the microwave doppler system. The microwave system was found to be more costly, less flexible, and would require the Federal Communications Commission's (FCC) approval.

The infrared and acoustic systems have various characteristics that provide both advantages and disadvantages. The infrared system has low cost, low power consumption, and suitable performance. The acoustic system has the feature of ranging but slightly greater cost and power requirements.

In terms of operational devices, the overhead array was easier to implement. The curbside array had the worst environmental effect, required different variations for various curb types, and could be a pedestrian hazard. In addition, the curb system would be limited to curbs or steps only.

Although automatic pedestrian counters have been developed, they have not been widely accepted and used. The mechanical counter developed and used in Seattle, Washington has seen little or no use there or elsewhere. It is yet to be seen if the systems recommended by the Overmeyer study will become acceptable in the user community. It appears that research interest in mechanical devices has been revived, but practical use and operation has not yet occurred.

Mathematical Models

An early article by Morth Schneider (1968) states that the amount of travel to any place depends on the attractiveness of the destination and its accessibility. In many urban transportation studies, the amount and type of building floor space has been used as a basic measure of travel attractiveness for vehicle trips. Intuitively, this measure should also be valid for pedestrian trips. Accessibility depends upon the amount and type of transportation facilities serving the study location. The

Table 1. Sensor characteristics.

	Acoustic Electro-static	Acoustic Piezo-electric	Pulse Infrared	Microwave Doppler
<u>Capabilities:</u>				
Presence detection	Yes	Yes	Yes	No
Ranging	Yes	Yes	No	No
<u>Operating Range:</u>				
Temperature (C)	0 to 60	-20 to 140	-40 to 140	-40 to 70
Humidity	5 - 95%			
Power requirements per sensor	medium	medium	low	high
<u>Performance:</u>				
Affected by background reflections?	No	No	Yes	No
Affected by dirt on sensor surface?	Yes	No	Yes	No
<u>Cost:</u>	medium	medium	low	high
<u>Notes:</u>				Motion detection only. Requires FCC approval.

number and size of traffic lanes is most frequently used for vehicle trips and the corresponding measure for pedestrian trips would be the area of sidewalks serving the location.

Pushkarev and Jeffrey (1971) used the two measures, amount and type of building floor space, and the amount of walkway surface as starting points for a localized pedestrian circulation study. While the results may be valid only for the study area, the methodology is of interest. The study area was midtown Manhattan where pedestrians visible on surface streets in a 1.2 sq. mile area were counted twice: once during midday and once during the evening rush hour. The counts were made from aerial photographs taken from a Port of New York Authority helicopter. The photographs revealed all pedestrians except those walking through covered passageways or otherwise concealed from view. In some cases, deep shadows during the evening shots resulted in unsatisfactory photographs. The photographs were taken on several weekdays during the months of April and May, 1969.

The counts were tabulated by block sectors that matched an inventory of floor space and sidewalk area. This made it possible to use multiple correlation analysis to relate the number of pedestrians to building floor space and walkway space at two points in time for 600 block sectors. The number of pedestrians visible on any block sector was the dependent variable and the sidewalk area and building floor space were the independent variables.

Initially the study considered floor space in each of ten building use categories. However, early in the analysis it became apparent that of the ten uses inventoried, only office, retail, and restaurant floor space appeared to be significantly associated with the presence of pedestrians. Only office, retail, and restaurant use, plus the walkway area available for pedestrian circulation, were retained as significant variables affecting the presence of pedestrians on a block sector in midday, 1:28 p.m. to 1:59 p.m. For the evening, 5:02 p.m. to 5:30 p.m., the factor of proximity to transit facilities was added. Distance to the nearest transit entrance was used as the independent variable. Due to the unique geometry of the Manhattan street grid, a differentiation between streets and avenues was necessary, the east-west streets having approximately twice as much sidewalk area as compared to the north-south avenues.

The final result of the correlation analysis was four equations for estimating the number of pedestrians on any block or block sector at midday or evening. The equations are as follows:

Avenues, midday

$$P = 2.97\ \text{walkway} + 0.05\ \text{office} + 0.35\ \text{retail} + 1.22\ \text{restaurant} + 26.66$$

Streets, midday

$$P = 3.12\ \text{walkway} + 0.06\ \text{office} + 0.12\ \text{retail} + 0.74\ \text{restaurant} - 4.01$$

Avenues, evening

$$P = 0.06\ \text{office} + 0.20\ \text{retail} - 1.98\ D + 56.70$$

Streets, evening

$$P = 3.17 + 0.04\ \text{office} + 46.12\ D + 2.17$$

where:

P = number of pedestrians

Walkway = sidewalk space on the block in thousands of square feet.

Office, retail, and restaurant = gross office, retail, and restaurant floor space respectively in the block in thousands of square feet.

D = distance from the centroid of the sidewalk to the nearest transit entrance in hundreds of feet.

Intuitively, the equations seem to make good sense. The midway equations indicate that the number of pedestrians on a block sector depends upon the amount of office, retail, and restaurant space and the amount of sidewalk available to walk on. These building uses are obviously those that attract pedestrian trips during lunchtime. It appears that retail uses attract 2 to 7 times the pedestrian trips that offices do, per unit of floor space, and that restaurants attract 13 to 25 times the trips that offices do during the noon hours. When comparing the avenue with the street equation, the retail uses on the avenues attract approximately three times as many pedestrians as retail uses on the streets. The authors point out that this is reflected in much higher ground floor rents on avenues than on streets.

The evening equations both include office space because most pedestrians during the evening rush hour are leaving office buildings. The retail floor space on the avenues attracts substantially fewer pedestrians since fewer people are shopping and the retail space on the streets is no longer significant. Restaurant space also ceases to be statistically significant during the evening rush hour, as does the walkway area on the avenues. However, a new factor, the distance to the nearest transit entrance, is significant in the evening equations.

The relationship between pedestrians and building floor space used in the correlation equations is based upon a very large sample, i.e., all buildings in the study area. However, there is a limitation that they apply only to two points in time, while pedestrian flow varies greatly during the day. In order to investigate cyclical variation, manual counts of pedestrian flow during a 12-hour period were taken at selected locations. Daily counts at five buildings (two office buildings, a department store, a restaurant, and an apartment house) are reported for 15-minute intervals.

The results of the cyclical analysis show that the variations during the course of the day depend upon the predominant building uses in the area. This would imply that amount of floor space and type of building use could be used to estimate pedestrian volumes in a given area. However, this study does not establish a direct relationship between pedestrian volumes and land-use data.

Behnam and Patel (1977) used eight land-use variables to develop two models for predicting pedestrian volumes. The site of their study was the core of the CBD in the City of Milwaukee, in an area characterized by intense land use and high pedestrian activity. The pedestrian survey was conducted during the summers of 1971-1973 by field observers stationed at midblock locations. Using hand counters each location was counted for six minutes out of each hour between 6:00 a.m. and 6:00 p.m. on weekdays and the pedestrian hourly volumes were derived by expanding the six-minute counts. Land-use data was taken from the files of the Department of Development, the City of Milwaukee.

The initial selection of variables for this study was based upon previous studies including Pushkarev and Zupan (1971). Since the City of Milwaukee had no well-developed transit system at the time and the sidewalk area for the study site did not vary appreciably, the independent variables finally selected were all land-use related. Using a stepwise regression technique, two equations, one for noon-hour pedestrian volumes and one for average hourly pedestrian volumes, were developed:

<u>Noon-hour Model</u>

$$Y = 5.128 + 0.00000403x_1 + 0.00000199x_2 + 0.5038 \ln(x_3) + 0.0560 \ln(x_7) + 0.0389 \ln(x_8)$$

Average-hour Model

$$Y = 5.159 + 0.00000357x_1 + 0.00000190x_2 + 0.0322 \ln(x_3) + 0.0342 \ln(x_5) + 0.0382 \ln(x_7) + 0.0359 \ln(x_8)$$

where:

Y = Pedestrian Volume in pedestrians per hour per block.

x_1 = Commercial space in square feet per block.

x_2 = Office space in square feet per block.

x_3 = Cultural and entertainment in square feet per block.

x_5 = Residential space in square feet per block.

x_7 = Vacant space in square feet per block.

x_8 = Storage and maintenance in square feet per block.

ln = Natural logarithm ($\log_e$)

A statistical evaluation of the two models indicated that they provided relatively accurate results. The coeffecient of multiple determination showed that approximately 60 percent of the variation in pedestrian volume was explained by land-use variables, and the correlation coefficients for the models were found to be highly significant.

The models developed were not intended to estimate the interblock pedestrian trip interchanges, but were designed to measure pedestrian volumes for each block and its surrounding sidewalks. The results of this study were not compared with other studies previously noted (Hass, 1967; Ness, 1969; Pushkarev, 1971). The reasons cited for not making a comparison included differences in estimating procedures, variables used, methodology, data type, geographical location, and urban structure. The models are considered to be representative only of the City of Milwaukee, an auto-oriented community with a reasonable supply of low-cost parking and no well-developed transit system. The models do have the advantage of simplicity and low cost with regard to data collection since the required land-use data should be readily available from the appropriate city planning agency. The models would be of greatest value in cities having characteristics similar to those of the City of Milwaukee at the time the models were developed.

The above report by Behnam and Patel (1977) makes reference to two earlier studies that attempted to develop models for determining pedestrian volumes, one of which should be briefly mentioned here. Ness, et al. (1969) employed conventional gravity model techniques to develop predictive tools for the journey to work and lunch hour pedestrian volumes. The journey to work model considered the relative location of transit terminals and offices by dividing the study area into office zones and transit zones. The inputs to the gravity model were the "generation and attraction rates of office and transportation zone, a family of friction factors, and a set of minimum-path walking trees from all office zones to all transportation zones." Data were collected by use of a questionnaire-type survey. The office generation rate was based upon number of employees working in each office zone, while the attraction rate was assumed to be proportional to the number of commuters and total office employment. Similarly, the gravity model was also developed for the noon-hour circulation. However, the minimum path was replaced by walking time, waiting time at intersections, and street attractiveness for model calibration purposes. The study models appear to accurately predict pedestrian volumes for the study site and associated conditions. Data collection for this technique would be relatively difficult and costly.

Rutherford (1976) uses data from a 1963 survey of Chicago's CBD to develop models for predicting pedestrian volumes and trip lengths with emphasis on the latter. A pedestrian survey was conducted using Chicago city employees from various departments as interviewers. The survey was taken from 7:00 a.m. to 7:00 p.m., with each interviewer collecting a predetermined number of interviews. The interviews were taken randomly for 98 stations on one side of a street for each hour in the time period, for a total of 11,632 interviews. The sample rate for each station was based on existing pedestrian volume counts made during the previous year. This sampling technique produced a sample that was uniform across the test site, thus ensuring that areas with low pedestrian volumes would not be ignored. A survey such as this produces a great deal of generally useful data as well as pedestrian volume data. This report is recommended reading for further insight into sampling techniques and sample expansion procedures.

A 1978 FHWA report by L.S. Kagan, W.G. Scott, and U.P. Arvin identifies the significant data, procedures, and criteria that should be considered in the planning and evaluation of comprehensive pedestrian systems and individual system components. The 3-volume report, "A Pedestrian Planning Procedures Manual," incorporates a demand modeling phase in which the existing and projected movement of pedestrians is examined using a gravity model.

This projected demand is used in development of a network plan which shows the distribution and assignment of future pedestrian volumes.

Mathematical models for predicting pedestrian volumes have been developed and they suffer from various deficiencies and limitations. Most models are site specific, i.e., they are limited to the area for which they have been developed and no record has been found of any attempt to generalize models from one city to another. The accuracy of the models depends upon the amount and type of input data and data collection costs increase rapidly as the amount and complexity of data increases. Finally, the reported models have not been tested over an extended period of time and temporal effects could have a significant influence upon their accuracy.

Manual Counts

Manual counting procedures using direct observation is the method most commonly used by cities to gather pedestrian volume data for routine use. Continuous counting procedures and sampling procedures are generally employed in this method. Pedestrian counts are generally carried about in a routine fashion in accordance with procedures that are widely recognized and accepted, but which may vary from city to city.

Several research studies have also used manual counting procedures. However, the pedestrian volume counts were usually included as part of a larger study and were not the main focus of the research. Most studies have employed sampling techniques such as those commonly used by cities for routine pedestrian volume data collection, while two of the more recent studies by Zegeer (1983) and Tobey (1983) used a continuous counting procedure.

Time lapse and real-time photography have been used to record and count pedestrians in urban areas both in the U.S. and abroad. A study by Lautso and Murole (1984) describes the use of aerial photography to count pedestrians in Helsinki, Finland. Time-lapse photography was used by Berger and Knoblauch (1975) to record pedestrian volume and behavior. DiPetro and King (1970) also used both time-lapse photography and real-time photography to record pedestrian volumes and behavior at a mid-block crosswalk. It would seem reasonable to assume that photographic techniques could be used for video taping with a resultant reduction in film and processing costs. However, the major problem of high data reduction costs would still remain.

Summary

Manual counts, using direct observation procedures, appear to be the most practical method for gathering pedestrian volume data at the present time. Mathematical models offer the potential of being the least costly system for measuring (predicting) pedestrian volumes. However, universally applicable models or models requiring easily acquired input data would have to be developed. Mechanical counters are attractive from an engineer's viewpoint, but they have not been widely used.

METHODOLOGY

At present, three methods are generally recognized for measuring pedestrian volumes: mechanical counts, mathematical models, and manual counts. Each of these methods has both advantages and disadvantages. Various types of mechanical counters have been developed, tested, and reported; however, they have not been widely accepted. Cost and installation problems seem to be the major factor deterring their use. Mathematical models which have been developed for predicting pedestrian volumes are generally site specific and the accuracy of the model is highly dependent upon the type and amount of input data. Also, data collection costs increase rapidly as the complexity of the model increases. Direct observation manual counting is the method most commonly used to gather pedestrian volume data for routine use. The major disadvantage of continuous manual counting is its labor-intensive nature. Photographic and video recording techniques may reduce data collection costs but also increase data reduction and analysis costs. Based upon the state-of-the-practice review, this current study elected to investigate two distinctly different methods for predicting pedestrian volumes at a specific street-crossing site. In a general sense, both are sampling based models and will be referred to as the Base Curve Model and the Expansion Model.

Base Curve Model

The Base Curve Model recognizes that trip generation for pedestrians is related to land use, just as it is for vehicles, and the generation rate will vary with time. For example, an intersection or midblock crossing located in proximity to several restaurants may experience relatively higher pedestrian volumes at the traditional breakfast, lunch, and dinner hours, while a site in a recreational area may show a more even volume distribution throughout the day. The approach used here assumes that for all sites within a given land use, the volume distribution will be similar throughout the day, although the actual volume count for a particular site at any given time may be different. This approach eliminates the need for floor area data and relates pedestrian volumes only to land use.

A base curve of pedestrian volume versus time of day may be established for a specific land use. This is done by first making continuous counts at several sites within the same land use category. The counts are then averaged to produce a single pedestrian volume versus time of day curve, or base curve, for the 12-hour time period of 7am to 7pm.

Once the base curve has been established, it may be used to predict pedestrian volumes for any individual site (intersection or midblock crossing) which falls within the same land use category. Ideally, this could be done with a single count taken at any time during the day from the individual site in question. However, with a single count there is a chance of obtaining an extreme value. Thus, the average of two or more counts should produce more accurate results. The optimum number of count periods were investigated as part of this study. Figure 1 illustrates this procedure. Volume counts have been made at several sites and a base curve established for the land use category. The pedestrian volume count for the base curve 8:00 - 8:15 am and 2:00 - 2:15 pm periods are 200 and 400, respectively. Pedestrian counts made at an individual site within the same land use category for the corresponding 8:00 - 8:15 am and 2:00 - 2:15 pm time periods are 250 and 480, respectively. The average difference, (250 - 200) + (480 - 400) / 2 = 65, between the base curve and individual site values is used to determine the position of the individual site curve. The new curve has the same shape as the base curve, but is moved upward 65 units. This new curve may now be used to predict pedestrian volumes for the individual site at any time during the time period encompassed by the graph.

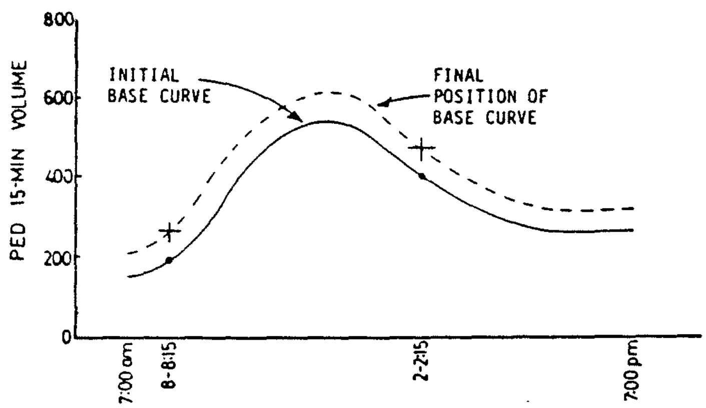

Figure 1. Base curve example.

The accuracy of the base curve procedure will be influenced by both the length of the counting period and the number of counting periods. The detailed procedure used in this study for investigating the effect of each of these parameters is given in Section V.

The base curve procedure has the potential for realizing a considerable savings in both cost and time. Once the base curve has been established for a land use category, only a small number of counts will be required to establish a similar curve for an individual intersection within the same land use category. This procedure also eliminates the need for floor area data which may be difficult and costly to obtain.

Expansion Model

Short term traffic counts of 5-, 6-, 10-, or 15-minute duration are routinely used to estimate hourly and daily vehicle volumes. In most cases the accuracy of the expanded counts is adequate for their intended use such as analysis of maximum flow rates, flow variations within peak hours, capacity limitations, and peak volume characteristics. One of the major uses for pedestrian volume data is to determine whether or not Warrant 3, the minimum pedestrian volume warrant for the installation of traffic signals as specified in the MUTCD, is satisfied. To make this determination, a knowledge of hourly pedestrian volumes for each of the highest volume 8 hours during the day is required. In view of this requirement and considering the variable nature of pedestrian activities, pedestrian counts are usually made continuously for a 10- to 12-hour period. This technique provides great accuracy, but is labor intensive and therefore expensive.

The Expansion Model method uses a sampling technique to predict hourly pedestrian volumes, thus reducing manpower requirements and data collection costs. For this method, a short term count is taken within each hour of the study period and then expanded, based upon the length of the count period, to predict the total count for the hour. In this way, hourly volume counts may be determined for the entire study period. The accuracy of the expanded counts will be determined by the length of the count period and the position of the count period within the hour. For example, a 5-minute count may be selected for a given crossing site. It could be specified that this count be made for the first 5 minutes of each hour, the last 5 minutes of each hour, some 5-minute period within the hour, or for a randomly chosen 5-minute period within each hour. It is conceivable that the placement of the 5-minute period within the hour could have a significant effect upon the accuracy of the expanded count. The length of the count period may also effect the accuracy of the expanded count. Intuitively it would seem that a longer count would result in greater accuracy, however, intuition cannot always be relied upon. This study investigated sampling schemes with sampling periods of varying length, occurring at differing positions within the hour, in order to determine an optimum procedure. Regression analysis techniques were used to compare and evaluate the numerous schemes. The details of this procedure are given in the Data Analysis section.

DATA COLLECTION

This section presents details for the collection of pedestrian volume data. The data collection effort is discussed in terms of expected application, measures of effectiveness (MOE's), site selection, sample size, and data collection procedures.

Background

The first step in developing a new or improved technique is to clearly understand the need for the technique and why existing techniques are inadequate. In the case of pedestrian volume measurements, economy is the key criterion. Pedestrian volumes are collected for use in signal warrant studies, safety studies, traffic operations analyses, sidewalk capacity analyses, and as an exposure measure. For the purpose of this study, the techniques examined and developed were primarily for use in street crossing applications.

The predominant method of collection has been manual counting. This is both labor intensive and time consuming, but generally reliable. Mechanical counters and mathematical models have also been employed to some extent. All three methods were discussed in detail in the state-of-the-practice section of this report. In summary, mechanical counters have been used to a very limited extent and are difficult to employ in other than relatively narrow walkway situations. While it offers some potential, significant hardware development would be required to produce a practical and reliable mechanical counter. Mathematical models (once developed) offer the potential of being the least costly system for measuring (predicting) pedestrian volumes. However, the cost to develop the large family of models required to represent the numerous typical situations would be prohibitive. Based on these findings and the judgement of the research team, manual counts appeared to offer the most cost effective method when used with an efficient sampling scheme.

Thus, the main thrust of this effort was to determine the most efficient sampling scheme and the most cost effective counting procedure to accomplish it. The approach was to construct a data base of continuous pedestrian counts and then analyze those data to determine optimal sampling schemes. These schemes were designed for the crossing applications discussed above.

Experimental Design

The MOE for this study was the number of pedestrians observed crossing at either an intersection or midblock crossing. Since the manual counting method was tested, it was not necessary to make special provisions for the various types of pedestrians (e.g., the elderly, young, handicapped, etc.), because they could be readily recorded by the observer, if necessary. The principal thrust was the recording of volume.

Data were collected in Washington, D.C. during the month of July, 1986 at eight intersections and six midblock locations. The principal criterion for site selection was land use, since this is usually the dominant factor in the generation of pedestrian trips. Table 2 shows the sites by identification number, name, primary land use, and type of crossing. A mixture of signalized and unsignalized locations was sought. Care was taken to select locations where pedestrian volumes were significant so that an adequate amount of data could be collected within the limited resources of the study.

Table 2. Sites selected.

Identification Number	Site	Land Use	Type of Crossing
1	Connecticut Ave. NW at Zoo	R	M
2	14th & E St. NW	O	I
3	14th & U St. NW	Rs	I
4	23rd & H St. NW	S	I
5	Jefferson Dr. & 7th St. SW	C	I
6	12th & Monroe St. NE	Rs	I
7	15th & Constitution Ave. NW	R	I
8	1st & Independence SE	C	I
9	Connecticut Ave. & Desalle St. NW	O	M
10	Howard Univ. on Georgia Ave. NW	S	M
11	Connecticut Ave. & Woodley NW	Rs	I
12	17th NW between Const. & Indep.	C	M
13	4200 block Mass. Ave. NW	Rs	M
14	7th St. South of D St. SW	O	M

Rs - Residential (multi-family)
O - Office/Retail
S - Schools, Institutions
R - Recreation, Parks, Zoo
C - Cultural/Entertainment
M - Midblock
I - Intersection

A 100 percent sample of pedestrians crossing was taken at each site during each 12-hour data collection period. These 12-hour samples consisted of continuous counts which were made at each site by one or two data collectors (depending on the level of pedestrian activity). The counts were made on weekdays for the 12-hour period from 7am to 7pm. Pedestrian volumes were recorded by crosswalk every 5 minutes. Three days of data were recorded at each site. Each data collector worked 6-hour shifts each day with 15-minute breaks every 2 hours. The Principal Investigator trained the data collectors and supervised the data collection activity. He double-checked and verified all counts to ensure quality control. The data collectors were positioned at a vantage point that offered the clearest view of the crosswalks. For low to moderate locations, one observer was used, while for high volume locations, two observers operated as a team. Data collection equipment consisted of board counters, audible interval timers, and data forms. A sample data form is shown in appendix A.

DATA ANALYSIS

The total number of pedestrians crossing at each site was entered into the computer by location, time period (day and 5-minute period), and crosswalk. This procedure produced a data base of 18,432 5-minute intervals of pedestrian counts that in turn would permit a complete and thorough analysis of any combination of variables.

The data were entered using the data base management program Lotus. The Statistical Analysis System (SAS) package was used in analyzing the data base. The following two sections discuss the two analysis approaches used in this study.

Base Curves

The first approach in the analysis was to develop a set of base curves representing 12-hour pedestrian count distributions for different groupings of sites based on land use. If these curves represented certain land uses, then the user could reproduce a pedestrian count that occurred at sites with a particular land use. The following discussion details the steps and findings in this analysis approach.

The first step was to examine the 14 12-hour count distribution patterns for the 14 sites for count intervals of 5, 10, 15, 30, and 60 minutes. In examining these count interval distributions, the objective was to group intersections with similar distribution patterns and thus determine which count interval produced the clearest patterns in making the distinction among distributions. In viewing the 5- and 10-minute count distributions, too much variation existed from interval to interval such that group patterns were difficult to identify. For the 30- and 60-minute distributions, little variation existed between count intervals. With little variation, some site distributions did not show distinct patterns which made grouping of these distributions difficult. The 15-minute count interval distributions revealed adequate variation to detect distinct patterns in distributions among sites. Thus, the grouping process was conducted using the 15-minute count distributions.

Table 3 shows the 6 groups developed in the grouping process. Also, Figure 2 shows the 12-hour distribution patterns for each group. Refer to appendix B for group site samples of actual count distributions of 10-, 15-, 30-, and 60-minute count intervals.

After grouping was complete, the primary and secondary land uses associated with each site were examined to see if any land uses were common for sites within the groups. As shown in table

Table 3. Intersection distribution groupings with various attributes presented.

	GROUP					
	I	II	III	IV	V	VI
Intersection ID #	8,9,14,2	4,13	5,1	12,7	3,11,6	10
Land Use	C,O,O,O	S,Rs	C,R	C,R	Rs,Rs,S	S
2nd Land Use	O,O,C,C	Rs,Rs	O,Rs	R,O/C	O,R,Rs	Rs
Type	I,M,M,I	I,M	I,M	M,I	I,I,I	M
Pedestrian Signal	P,P,P,P	N,P	P,P	P,P	N,N,N	N

C - Cultural
O - Office
S - School (University)
R - Recreation
Rs - Residential

I - Intersection
M - Midblock
P - Pedestrian Signal
N - No Pedestrian Signal

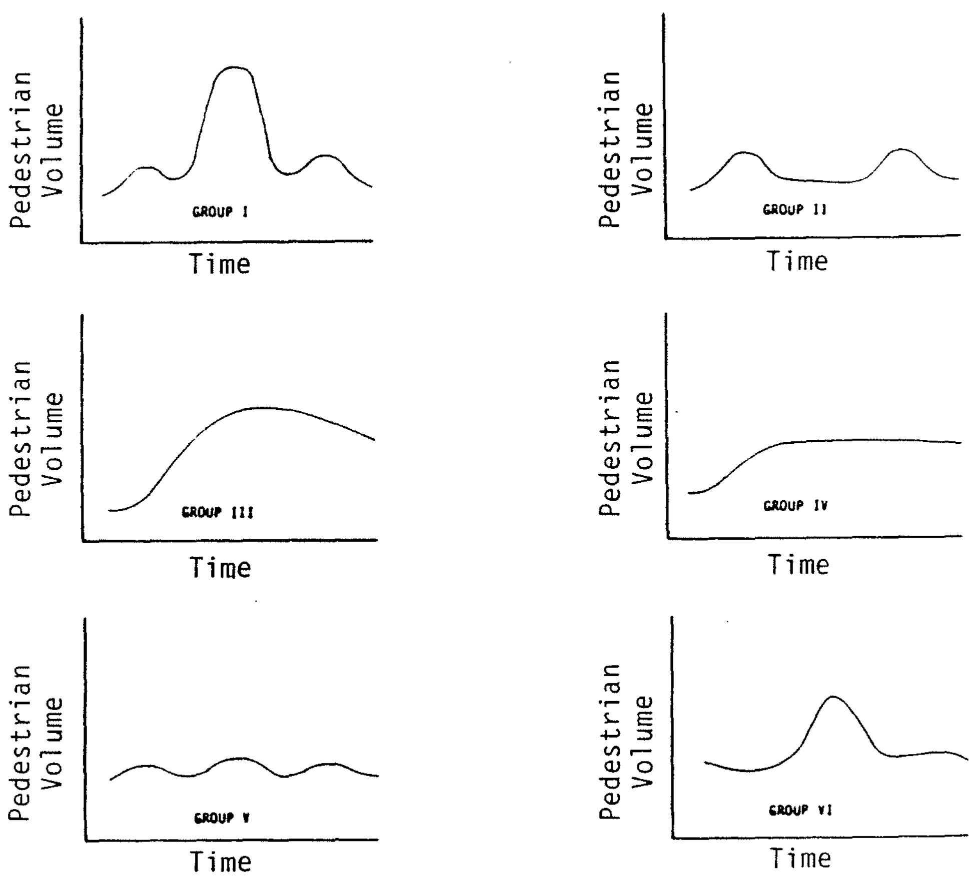

Figure 2. Group distribution patterns.

3, group I is primarily office/cultural, groups II and V are residential/school, groups III and IV are cultural/recreation, and group VI is school.

Beginning with group I, the next step was to develop a base curve. The base curve was developed using data for three of the sites while the data for the fourth site was used to test the reliability of the base curve. Thus, four base curves were developed so that each site was used to test the base curve produced by the other three.

Using all three data sets (1 set for each day of data collected) for sites 8, 9, and 14, a base curve was generated by averaging 15-minute count intervals. This process was repeated for the remaining 3 combinations of sites. For the sites used to test the base curves, an average distribution of 15-minute count intervals over the 3 days of data were used.

Shown in figure 3 is the overlay of base curve 8914 (sites 8, 9, & 14) and the omitted site curve 2.

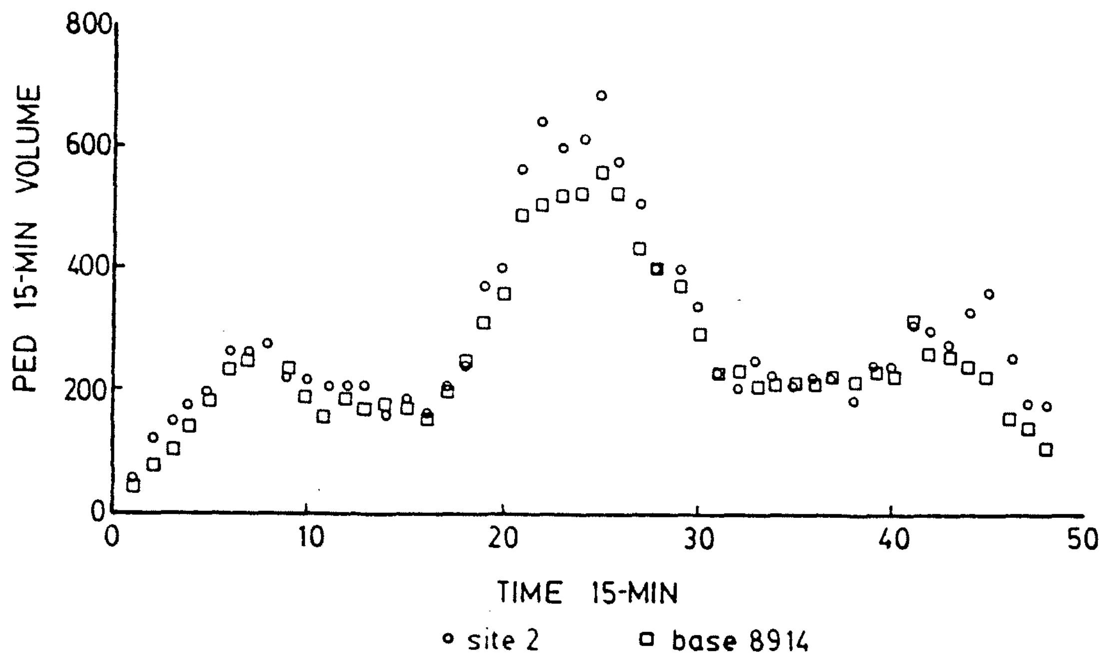

Figure 3. Overlay of base curve 8914 and site curve 2.

The nonparametric Kolgomov-Smirnoff (K-S) goodness of fit test was used to determine if both curves had the same distribution. If the same distribution did exist, the base curve could be used to predict pedestrian count distributions at other sites with the same land use.

The K-S test compared the expected cumulative frequency (base curve) to the observed cumulative frequency (test site curve). The maximum difference (D_{max}) between these frequencies was compared to the critical value with respect to the degrees of freedom and confidence level. Using a confidence level of 0.05, the critical value (D_c) was $1.36/\sqrt{n}$, where "n" was the total number of observed counts (total 12-hour pedestrian volume of site 2). If the observed value of D_{max} was greater than or equal to the critical value of D_c, the null hypothesis was rejected, where the null hypothesis states that there existed no difference between distributions.

For the base curve 8914 and site curve 2, the null hypothesis was rejected at the 0.05 confidence level since D_{max} (0.0209) was greater than D_c ($1.36/\sqrt{1407} = 0.0115$). Therefore, the 12-hour pedestrian count distributions were not the same.

The three remaining base and site curves are shown in figures 4, 5, and 6. On these figures, the values of D_{max} and D_c are listed. In all cases, the null hypothesis was rejected.

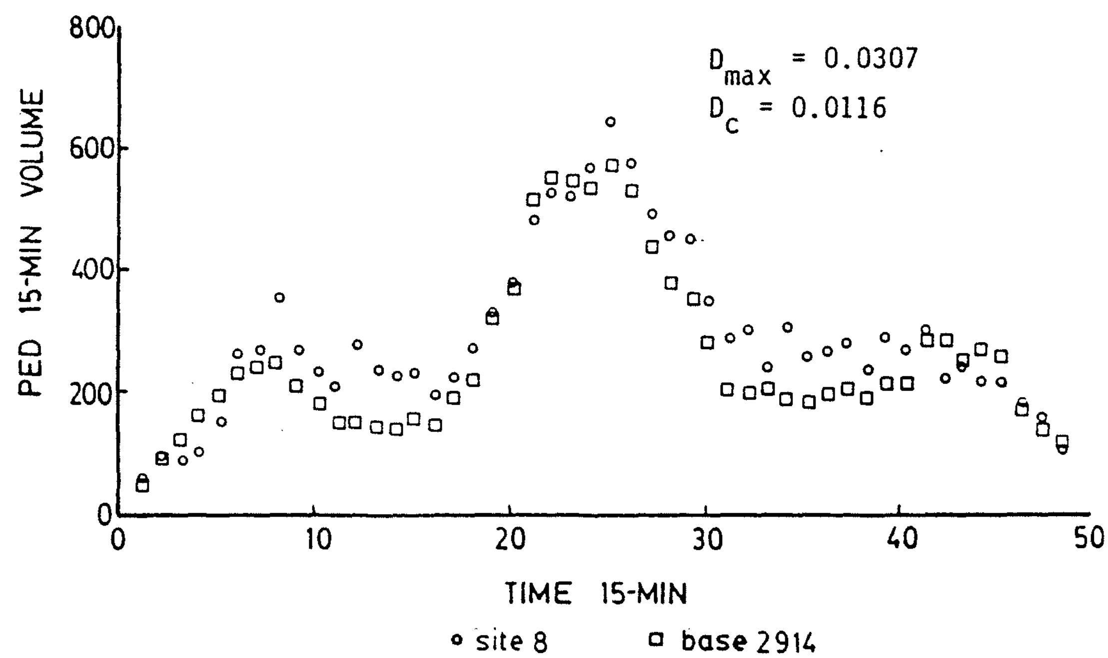

Figure 4. Overlay of base curve 2914 and site curve 8.

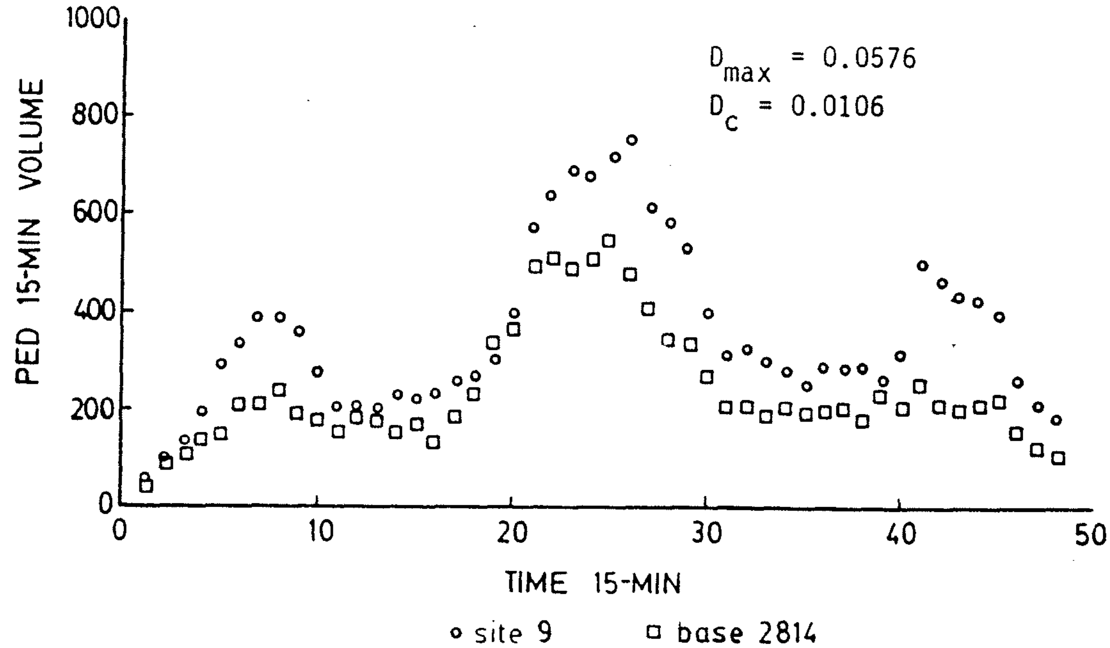

Figure 5. Overlay of base curve 2814 and site curve 9.

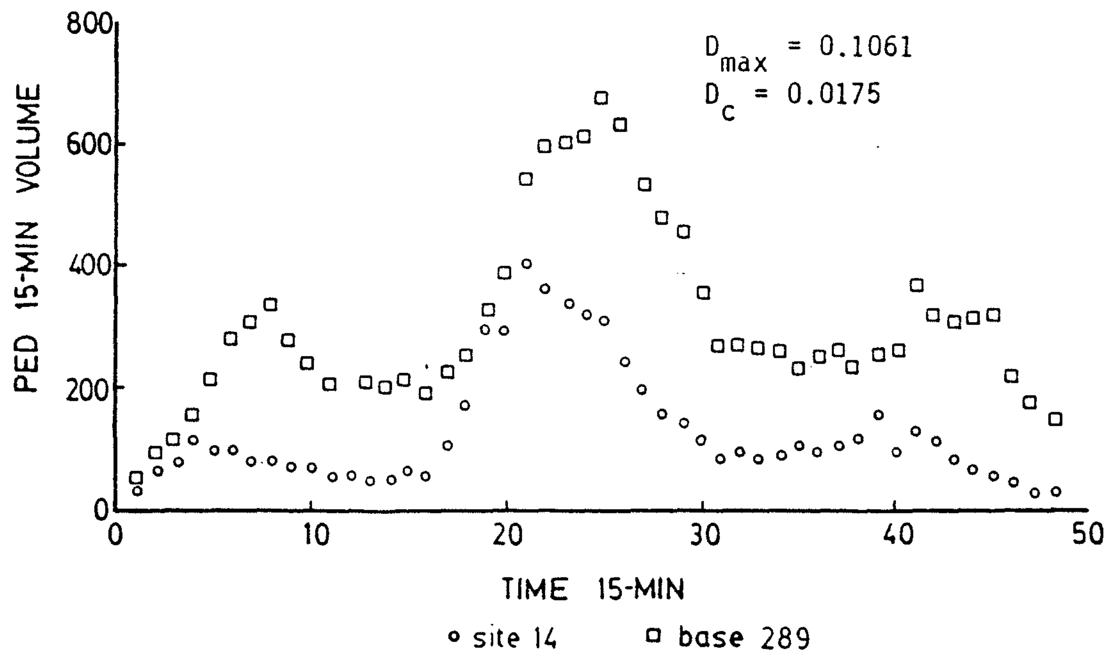

Figure 6. Overlay of base curve 289 and site curve 14.

Despite these results, additional considerations were given to this approach. Curve smoothing would eliminate extreme cases of high and low 15-minute count intervals. However, reviewing the base curve 289 and site curve 14, curve smoothing could not correct for the skewness or shift between these curves.

Increasing the count interval to 30 or 60 minutes would have decreased the variation between intervals. However, this would defeat the objective of using small count intervals to predict 1-hour counts or 12-hour count distributions.

Investigations began on land use characteristics in order to explain the differences between the base curves and their site curves for group I. By the existence of secondary land uses, it became apparent that all sites were not homogenous with respect to land use (table 3). Site 8 was defined by cultural with office. Site 9 was primarily office while sites 2 and 14 were office with cultural. Looking back at the base-site curve overlays, the goodness of fit by eye between these curves appears good for sites 2, 8, and 9. However, the site 14 curve was moderately skewed to the left with respect to its base curve. Since sites 2 and 14 have basically the same land uses, their goodness of fit on the overlays should be approximately the same. This was shown not to be the case. Further examination of land use for sites 2 and 14 revealed a subway station in the same block as site 14. This station apparently caused pedestrian volume peaks to occur earlier than existed in the other three sites. Refer to figure 7 for the comparison of distribution patterns of sites 2 and 14. Other factors that could have contributed to a nonhomogenous group were possible variations in office hours or additional land uses not covered by the primary or secondary land uses.

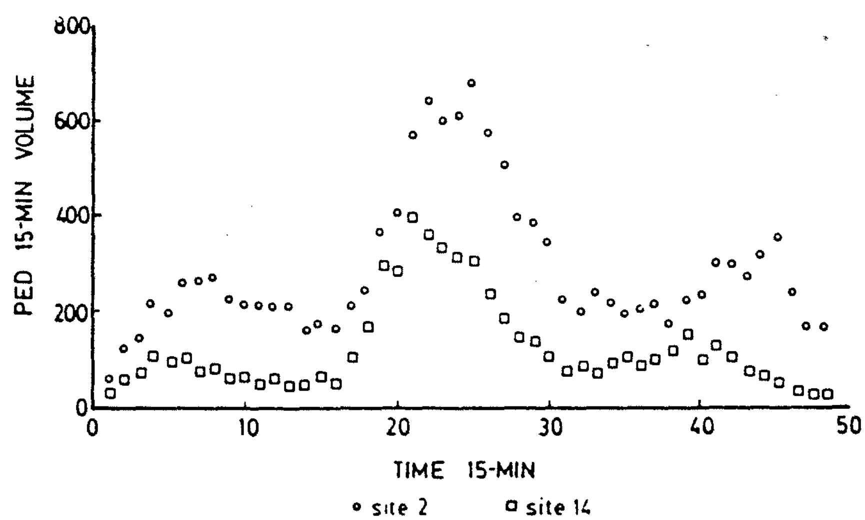

Figure 7. Overlay of sites 2 and 14.

With these efforts exhausted, further attempts in using the base curve approach for the remaining groups were abandoned. Since four of the remaining groups consisted of two or less sites, the data base was considered too small for finding significant results. Thus, efforts were next directed towards predicting 1-hour and multihour counts using regression techniques. The following section discusses this approach together with validation of the models developed.

Expansion Modeling

In this analysis, 10 sites were randomly selected from the 14-site data base. The remaining 4 sites (4, 5, 12, 14) were used to validate the expansion models developed. Only the first data set (one 12-hour day of data per site approach) was used for both modeling and validation. Thus, 408 hours of observations were used in the expansion modeling and 120 hours in the validation.

The analysis will be discussed in two sections: expansion modeling of 1-, 2-, 3-, and 4-hour counts and validation of these models.

Modeling

The sampling interval times investigated were 5, 10, 15, & 30 minutes. All of these sampling intervals were analyzed for the first, middle, last, and random positions in the time frame being predicted. These positions (events) were chosen for the convenience of the user since in most counting procedures, the user collects data in predetermined hour or half-hour increments.

In reviewing the data distributions for use in the 1-hour prediction models, all variables showed positive skewness. (Normality of data is a requirement in regression). The skewness values associated with each variable are shown in table 4. For a sample size greater than 250, the critical skewness value (B_1) at 98 percent is 0.13. As shown in this table, all variables had skewness values greater than 3. Thus, all variables were not normally distributed. Their distributions are approximated in figure 7.

Since the data were not normally distributed, one could either use a distribution free (nonparametric) test or one could transform the data so parametric tests could be applied. The use of parametric tests are more desirable since they are more powerful than nonparametric tests. Therefore, the data were transformed. The transformation of data raised a contentious issue. On the one hand there are statisticians who argue that transforming data is nothing more than "fudging" the data to fit the model and that the implications of transforming data are not fully

Table 4. Skewness values for 1-hour model variables.

Variable	Sample Size	Skewness
PED6O	408	3.80
PED5F	402	4.07
PED5M	404	3.88
PED5L	404	3.81
PED5R	404	4.09
PED10F	408	4.00
PED10M	404	3.78
PED10L	404	3.84
PED10R	404	5.07
PED15F	408	3.90
PED15M	404	3.86
PED15L	404	3.68
PED15R	404	3.45
PED30F	408	4.01
PED30M	404	3.88
PED30L	404	3.71
PED30R	404	3.86

Note: Not all samples will have 408 observations due to missing data.

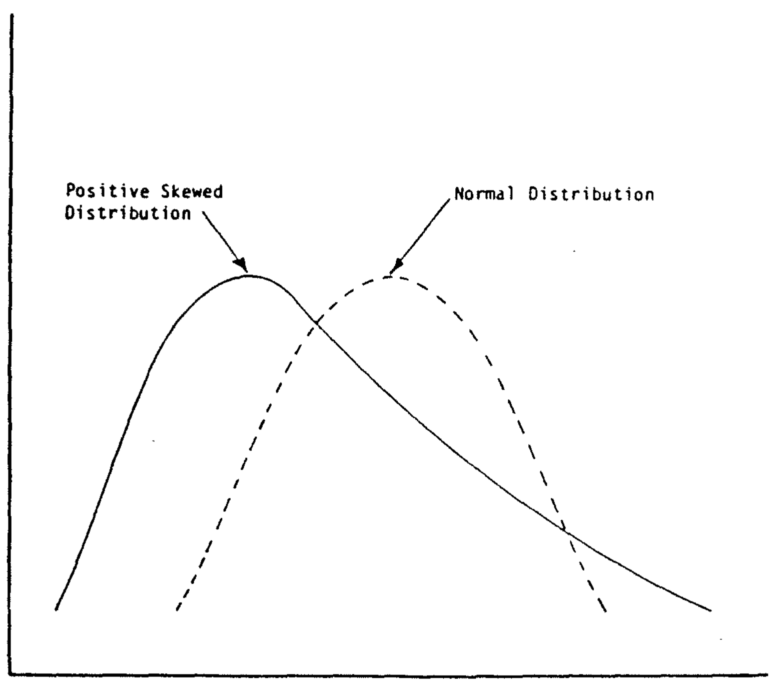

Figure 8. Positive skewed distribution.

understood. On the other hand, there are statisticians who argue that all measurement systems are arbitrary: hence transformed data are just as valid as untransformed data. This latter group has no reservation in using a transformation to normalize data if normally distributed data are required. Thus, since statisticians have used transformation processes to normalize their data and a normal distribution is required for parametric testing, it was applied here.

To adjust these data in order to produce a normal distribution, the logarithms were calculated for all observations for all variables. Table 5 shows the skewness values for the logarithmic transformation. All variables except for PED10L, PED15F, PED15L are less than the critical value of 0.13, thus at the 98 percent confidence level, these variables constitute a normal distribution. As for the three exceptions, they are slightly skewed to the negative side of the normal distribution. However, regression was performed on all variables while recognizing that these three exceptions were not normally distributed.

Table 5. Skewness values for logarithm data.

Variable	Sample Size	Skewness
PED6O	408	-0.06
PED5F	358	0.02
PED5M	366	-0.02
PED5L	374	-0.04
PED5R	370	0.03
PED10F	394	-0.08
PED10M	396	-0.08
PED10L	393	-0.19*
PED10R	394	-0.07
PED15F	402	-0.16*
PED15M	399	0.02
PED15L	400	-0.21*
PED15R	401	-0.10
PED30F	408	-0.08
PED30M	404	-0.01
PED30L	403	-0.04
PED30R	403	-0.00

Note: Not all samples will have 408 observations due to missing data and logarithms of observations with counts of zero.

* Exceeded critical skewness value.

From the regression analysis of 1-hour modeling, table 6 was constructed to evaluate the count intervals and the position of the events within the interval. For all count intervals, the middle event produced the better model since it exhibited the highest coefficient of determination (R^2) and the lowest standard error about the mean (SE_y). Also, it was apparent that as the count interval increased from 5 to 10 to 15 to 30 minutes, the prediction models became better. This was as expected since the variation among count intervals decreased as the count interval increased. Therefore, based on R^2 and SE_y values, the middle event count intervals were selected as the best predictors of 1-hour counts.

Table 6. Coefficients of determination and standard error of estimates for 1-hour models.

Variables correlated with PED60	R^2	SE_y
PED5F	0.72	0.26
PED5M	0.77	0.22
PED5L	0.75	0.24
PED5R	0.73	0.25
PED10F	0.80	0.22
PED10M	0.86	0.18
PED10L	0.82	0.20
PED15R	0.70	0.27
PED15F	0.85	0.19
PED15M	0.91	0.15
PED15L	0.88	0.17
PED15R	0.90	0.15
PED30F	0.94	0.12
PED30M	0.96	0.09
PED30L	0.94	0.12
PED30R	0.95	0.11

Note: All F- and t-statistics were significant at p=0.0001.

The expansion models developed for the middle event of the four count intervals are presented in table 7. As stated earlier, the larger the count interval for the middle event became, the better the volume prediction became. However, all expansion models are presented in order to give the user the option of choosing the degree of accuracy. The user may just need a rough 1-hour estimation, thus using a middle 5-minute count is adequate. If a more accurate 1-hour estimation is desired, a middle 30-minute count may be required.

Expansion models were also developed for 2-, 3-, and 4-hour volume counts. The same procedures discussed above were used.

Table 7. Expansion models based on the middle count interval.

PED5M: V1 = INVLOG 0.7862 log (I5) + 1.2991
where, V1 = one hour prediction
I5 = the middle 5-minute count

PED10M: V1 = INVLOG 0.8465 log (I10) + 0.9922
where, I10 = the middle 10-minute count

PED15M: V1 = INVLOG 0.8996 log (I15) + 0.7598
where, I15 = the middle 15-minute count

PED30M: V1 = INVLOG 0.9625 log (I30) + 0.3751
where, I30 = the middle 30-minute count

Note: Log is the logarithm base 10 (log_{10}) and INVLOG is the inverse logarithm (10^x).

Thus, only a brief description of each of these models will follow. Since the random sampling scheme did not produce adequate results in the 1-hour expansion modeling, this scheme was not used for the modeling of 2-, 3-, and 4-hour volumes. Also, the middle event was defined as the middle event of the time interval being modeled.

Skewness values were examined for the observations of the first, middle, and last count interval variables. Table 8 lists these values and their associated combined skewness value (B_1) at 98 percent confidence. Again, all variables had positive skewed distributions and the logarithm was taken to correct this skewness. The transformed skewness values are shown in table 9. Several variables still exhibited skewness. However, as before, regression was used on all sampling schemes.

Table 8. Skewness values for variables used in multihour expansion models.

Two-Hour Data

Variable	Sample Size	Skewness	B_1
PED120	204	3.12	0.16
PED5F	198	4.31	0.16
PED5M	204	3.66	0.16
PED5L	200	3.75	0.16
PED10F	204	4.30	0.16
PED10M	204	3.46	0.16
PED10L	200	3.93	0.16
PED15F	204	4.32	0.16
PED15M	204	3.50	0.16
PED15L	166	3.89	0.18
PED30F	204	4.50	0.16
PED30M	204	3.32	0.16

Note: Not all samples will have 204 observations due to missing data.

Three-Hour Data

Variable	Sample Size	Skewness	B_1
PED180	136	2.66	0.24
PED5F	130	4.93	0.25
PED5M	136	2.93	0.24
PED5L	132	4.13	0.25
PED10F	34	1.36	0.85
PED10M	136	3.27	0.24
PED10L	132	4.02	0.25
PED15F	136	4.87	0.24
PED15M	136	3.30	0.24
PED15L	132	4.00	0.25
PED30F	136	4.85	0.24
PED30M	136	2.87	0.24
PED30L	132	4.14	0.25

Note: Not all samples will have 136 observations due to missing data.

Table 8. Skewness values for variables used in multihour expansion models (Continued).

Four-Hour Data

Variable	Sample Size	Skewness	B_1
PED240	102	3.18	0.31
PED5F	96	2.44	0.34
PED5M	68	3.19	0.57
PED5L	98	2.25	0.33
PED10F	102	2.68	0.31
PED10M	102	3.43	0.31
PED10L	98	2.47	0.33
PED15F	102	2.53	0.31
PED15M	102	3.46	0.31
PED15L	98	2.27	0.33
PED30F	102	2.23	0.31
PED30M	102	3.71	0.31
PED30L	98	2.22	0.33

Note: Not all samples will have 102 observations due to missing data.

Table 9. Corrected skewness values for variables used in multihour expansion models.

Two-Hour Data

Variable	Sample Size	Skewness
PED120	204	0.12
PED5F	168	0.12
PED5M	190	-0.08
PED5L	184	-0.01
PED10F	194	0.04
PED10M	199	-0.21*
PED10L	194	-0.15
PED15F	200	-0.11
PED15M	203	-0.27*
PED15L	164	-0.33*
PED30F	204	-0.02
PED30M	204	-0.14
PED30L	199	-0.16

Table 9. Corrected skewness values for variables used in multihour expansion models (Continued).

Three-Hour Data

Variable	Sample Size	Skewness
PED180	136	0.11
PED5F	108	0.21
PED5M	119	-0.08
PED5L	118	0.13
PED10F	30	0.03
PED10M	131	-0.12
PED10L	127	-0.24
PED15F	133	0.03
PED15M	132	0.04
PED15L	132	-0.31*
PED30F	136	0.04
PED30M	136	-0.23
PED30L	132	-0.04

Four-Hour Data

Variable	Sample Size	Skewness
PED240	102	0.18
PED5F	75	-0.01
PED5M	63	0.35
PED5L	88	-0.17
PED10F	95	-0.07
PED10M	98	0.09
PED10L	96	-0.36*
PED15F	99	-0.24
PED15M	100	0.09
PED15L	98	-0.50*
PED30F	102	-0.20
PED30M	102	-0.21
PED30L	98	-0.38*

Note: Not all samples will have the initial number of observations due to missing data and logarithms of observations with counts of zero.

* Exceeded critical skewness value.

By the use of R^2 and SE_y, the sampling scheme models were evaluated to find the optimum counting event. Tables 10, 11, and 12 give the values of R^2 and SE_y for each set of multihour models. Reviewing these tables showed the middle event of all counting intervals to produce the better models. Also, as the count interval increased, the expansion models' predictability improved. These results corresponded to the results found in the 1-hour models. Based on these results, it appeared that the middle event produced the best predictor of multihour volumes.

Table 10. Coefficents of determination and standard error of estimates for 2-hour models.

Variables correlated with PED120	R^2	SE_y
PED5F	0.67	0.27
PED5M	0.74	0.24
PED5L	0.70	0.25
PED10F	0.70	0.26
PED10M	0.84	0.19
PED10L	0.78	0.22
PED15F	0.73	0.25
PED15M	0.86	0.18
PED15L	0.80	0.22
PED30F	0.83	0.20
PED30M	0.92	0.14
PED30L	0.86	0.18

Note: All F- and t-statistics were significant at $p = 0.0001$.

The equations for the three multihour expansion models based on the middle event are given in table 13.

In summary, this analysis effort produced significant expansion models based on the evaluation of the parameters R^2 and SE_y. Additionally, four observations were made:

1. The middle event for any counting interval of any hour or multihour expansion model was determined to be the best sampling scheme. This phenomenon indicated that the position of a count during any time period was important in order to produce an accurate expanded count.

Table 11. Coefficients of determination and standard error of estimates for 3-hour models.

Variables correlated with PED180	R^2	SE_Y
PED5F	0.61	0.29
PED5M	0.75	0.23
PED5L	0.68	0.26
PED10F	0.43	0.33
PED10M	0.81	0.20
PED10L	0.75	0.23
PED15F	0.68	0.27
PED15M	0.85	0.18
PED15L	0.78	0.23
PED30F	0.75	0.24
PED30M	0.90	0.15
PED30L	0.84	0.20

Note: All F- and t-statistics were significant at $p = 0.0001$.

Table 12. Coefficients of determination and standard error of estimates for 4-hour models.

Variables correlated with PED240	R^2	SE_Y
PED5F	0.58	0.30
PED5M	0.85	0.17
PED5L	0.51	0.31
PED10F	0.59	0.30
PED10M	0.86	0.17
PED10L	0.67	0.27
PED15F	0.63	0.28
PED15M	0.91	0.14
PED15L	0.72	0.26
PED30F	0.72	0.25
PED30M	0.90	0.15
PED30L	0.76	0.23

Note: All F- and t-statistics were significant at $p = 0.0001$.

Table 13. Expansion models based on the middle count interval.

PED5M:	V2 = INVLOG	0.7686	log	(I5)	+	1.6339	
PED10M:	V2 = INVLOG	0.8226	log	(I10)	+	1.3200	
PED15M:	V2 = INVLOG	0.8241	log	(I15)	+	1.1659	
PED30M:	V2 = INVLOG	0.8918	log	(I30)	+	0.7880	
where, V2 = two-hour volume prediction							
PED5M:	V3 = INVLOG	0.7851	log	(I5)	+	1.7795	
PED10M:	V3 = INVLOG	0.8184	log	(I10)	+	1.5072	
PED15M:	V3 = INVLOG	0.8842	log	(I15)	+	1.2401	
PED30M:	V3 = INVLOG	0.8901	log	(I30)	+	0.9752	
where, V3 = three-hour volume prediction							
PED5M:	V4 = INVLOG	0.8113	log	(I5)	+	1.7954	
PED10M:	V4 = INVLOG	0.7618	log	(I10)	+	1.6522	
PED15M:	V4 = INVLOG	0.8087	log	(I15)	+	1.4334	
PED30M:	V4 = INVLOG	0.8134	log	(I30)	+	1.1922	
where, V4 = four-hour volume prediction							

2. As the counting interval increased, the volume prediction became more accurate. Since small count intervals have more variation from one interval to the next, the potential for extracting a count not representative of the time period being predicted is high. Thus, a larger count interval will reduce this variation and produce a better representation of the time period.

3. As the sampling period increased (from 1 to 2 to 3 to 4 hours), the prediction became less accurate based on the four sample count intervals used in this study. This result was due to the variation that exists with small sample intervals.

4. The different volume distributions of the 10 sites used in this analysis did not affect the outcome of the position of the counting interval. This observation was based on the high values of R^2 for the middle event. Thus, these expansion models were reliable in predicting volumes regardless of the volume distribution patterns.

Validation

As stated earlier, 4 sites (4, 5, 12, 14) were excluded from the modeling effort and used in validating the models developed. These sites produced 120 observations for the 1-hour models, 60 observations for the 1-hour models, 60 observations for the 2-hour models, 40 observations for the 3-hour models, and 30 observation for the 4-hour models. All four counting intervals were studied for each model.

The purpose of the validation study was to investigate the accuracy of the expansion models using data that were not incorporated into the development of the models. Even though these four sites were from the same city from which the models were developed, their volume distribution patterns were all different. As was observed in the development of the models, the result was that the middle counting interval produced the best models regardless of the volume distributions. Therefore, the hourly or multihourly observations contained in these four sites are intuitively representative of any observation that could have been taken from any site in any city.

The actual and predicted volume counts and the percent difference between these volume counts are presented in appendix E for all models.

The primary use of the validation study was to determine the percent error in the predictions of volume counts. Statistically, the SE_y is used for this purpose. Looking at figure 9,

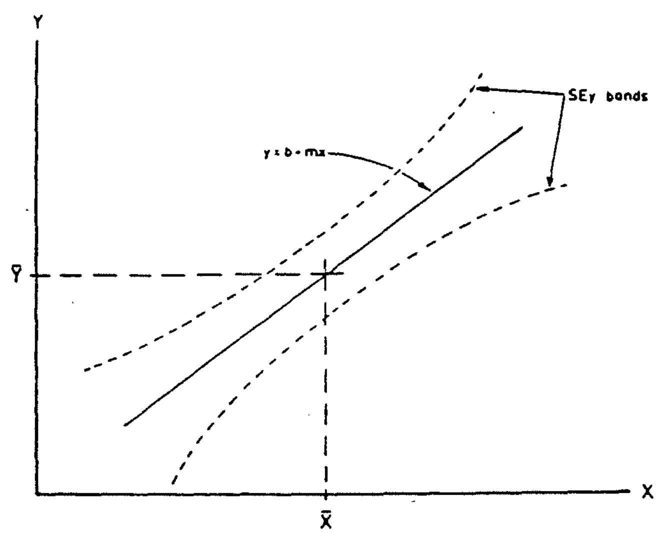

Figure 9. Representation of SE_y bands around a regression line.

the SE_y bands diverge at the ends of the regression line as values of X move away from the mean of X ($\overline{X}$). The nature of these SE_y bands is due to the mathematics of their calculation which will not be discussed here. The important fact of the SE_y is that it is of little value when X moves away from $\overline{X}$. In other words, the SE_y may turn out to be so wide as to render them meaningless. Therefore, the use of percent change between actual and predicted volume counts was used to determine empirically the error or prediction ranges associated with the expansion models.

For various predicted volume ranges, the average percent differences were calculated for each count interval expansion model as presented in tables 14, 15, 16, and 17. The volume ranges increased in size from one set of models to the next due to the volume sizes being predicted and the number of observations per range. Looking at these tables, the percent error (average percent difference) decreased as the count interval increased. As found earlier, the expansion models became more accurate as the count interval increased. From the results of the validation, this previous finding was supported by the percent error reduction as the count interval increased.

Another finding observed in these tables was the reduction in percent error as the volume range increased. At low volume sites, the flow of pedestrians is often erratic causing large peaks and small valleys over short time intervals. The probability of sampling at a volume peak or valley is approximately 50 percent, thus, reducing the potential of acquiring a true representative sample of the overall volume. It can be deduced that at a site with high pedestrian volumes, the flow is smoother for one time interval to the next. Therefore, a sample taken from a high volume site is often more representative of the whole count than that taken from a low volume site.

The next section of this report discusses the procedures for applying the expansion model approach to estimating pedestrian volumes for use in traffic signal warrants and exposure data applications.

Table 14. One-hour percent error.

Predicted	Count Interval (min)			
Volume Range	5	10	15	30
0 - 100	(+)34	35	27	16
101 - 200	35	26	19	13
> 201	27	22	15	9

Table 15. Two-hour percent error.

Predicted Volume Range	Count Interval (min) 5	10	15	30
0 - 500	(+)42	32	24	22
> 501	24	25	23	19

Table 16. Three-hour percent error.

Predicted Volume Range	Count Interval (min) 5	10	15	30
0 - 500	(+)35	37	34	26
> 501	32	27	24	22

Table 17. Four-hour percent error.

Predicted Volume Range	Count Interval (min) 5	10	15	30
0 - 750	(+)34	30	29	26
> 751	33	27	26	21

APPLICATION OF THE PEDESTRIAN COUNTING PROCEDURE

The pedestrian counting procedure developed in this study provides a means of obtaining a reasonable estimate of pedestrian volumes at street crossing locations, such as midblock and intersection crosswalks. The procedure produces these volume estimates at some significant savings in time and resources relative to currently used continuous counting techniques.

The procedure is designed specifically for two applications; however, pedestrian volumes produced by this procedure may be appropriate to other applications. The procedure produces estimates, based on sample counts, of hourly pedestrian volumes at a given crosswalk location. The two primary uses of these data addressed by the procedure are for 1) evaluation of traffic signal warrants and 2) exposure data to be used in conjunction with accident or conflict data to produce accident rates or hazard indices.

Each of these applications generally requires a different level of accuracy. Thus, the counting procedure allows the user to select an appropriate sampling scheme based on the level of accuracy desired. The remainder of this section describes the procedure for using sample counts to produce estimates for use in both applications.

The procedure is a seven step process. Each step is described and its implementation is illustrated with an example.

STEP 1: Select Type of Application

The two basic applications of pedestrian volume counts are for 1) evaluating traffic signal warrants and 2) exposure data for rate calculations. To evaluate signal warrants, you must have hourly counts by crosswalk, because the pedestrian volume warrant is based on the number of pedestrians crossing the highest volume crosswalk exceeding a stated minimum for each of four hours in a given day. Therefore, the user must make a sample count during at least one hour on a given day to check the muted pedestrian volume warrant.

For exposure data applications, a daily total pedestrian volume count for the crossing or entire intersection is usually required. Therefore, samples may be taken every hour, every two hours, every three hours, or every four hours depending on the level of accuracy desired.

STEP 2: Select Count Interval

The sample count interval (5, 10, 15, or 30 minutes) is established by the user's desired level of accuracy. For a higher level of accuracy, you must select a longer sample count interval. The Prediction Range Factors indicate the relative levels of accuracy. For the signal warrant application, only table 18 is used. For exposure data, tables 18, 19, 20, or 21 may be used.

The values in the tables are percentages that indicate the expected degree of accuracy of an expanded sample crosswalk count. For example, assume that a 10-minute sample count produces an hourly expanded count of 150 pedestrians crossing at a crosswalk. From table 18, we see that the corresponding prediction range factor is 26 percent; therefore, our expanded hourly count would be 150 $\pm$ 39 (i.e., 150 x .26 = 39), or we would expect the actual hourly volume (based on our 10-minute sample) to lie between 111 and 189.

Notice in each table that as the count interval increases, the prediction range factor decreases, thus the level of accuracy increases. In other words, for more accuracy the user should select a longer count interval. Also note that it is not necessary to know *a priori* the pedestrian volume level in order to select the count interval.

STEP 3: Schedule Data Collection

Through careful scheduling, greater economies in time and resources may be achieved. Not only will time be saved at a specific site by sampling, but also that time saved may be employed to sample additional sites. As discussed in the previous section, the selected count interval (5, 10, 15, or 30 minutes) must be positioned in the middle of the period to be sampled (i.e., 1-hour, 2-hours, 3-hours, or 4-hours). For example, a 10-minute sample for the period 8-9am would be from 8:25 to 8:35am.

In order to schedule a data collector to cover more than one site, you simply redefine for each site the period from which the sample is drawn as illustrated in the following example.

Given: 3 sites within 10 minutes travel time of one another

the count interval selected is 10 minutes

1-hour periods are to be sampled

The schedule for the first hour might be as follows:

Site	Period	Sample Count
1	7:40-8:40	8:05-8:15
2	8:00-9:00	8:25-8:35
3	8:20-9:20	8:45-8:55

If for some reason the hourly volume counts for one site are to be compared to the hourly volume counts at other sites, the periods and sample count times then must be the same and more than one data collector would be required.

STEP 4: Collect Data

Collect data by crosswalk according to the schedule developed in Step 3.

STEP 5: Select Expansion Model

Select from table 22 the expansion model that corresponds to the period (1-, 2-, 3-, or 4-hour) and count interval (5, 10, 15, or 30 minutes). For example, the model for a 3-hour period and a 15-minute count interval would be:

$$V = \text{INVLOG}\ [0.8842 \log I15 + 1.2401]$$

STEP 6: Compute Estimated Volumes

Substitute the sample count, I, in the model selected in Step 5 and perform the calculation to obtain the expanded period count. For example, in the model shown in Step 5 a sample count of 20 would predict an expanded 3-hour volume of 246.

$$V = \text{INVLOG}\ [0.8842 \log (20) + 1.2401] = 246$$

Note that the predicted volumes correspond to the period selected in accordance with the application selected in Step 1, i.e., the 1-hour models produce 1-hour volumes, the 2-hour models produce 2-hour volumes, etc.

STEP 7: Determine Estimated Volume Ranges

Since the estimated or predicted volumes do not correspond exactly to the actual volumes, it is important to establish the range in which the actual volumes should fall. The Prediction Range Factors in tables 18-21 are used for this purpose. First choose the table that corresponds to the count period (1-, 2-, 3-, or 4-hour). Select the volume level (row) that corresponds

Table 18. One-hour prediction range factors (in percent).

Pedestrian Volume Level	Count Interval (min) 5	10	15	30
0 - 100	(+)34	35	27	16
101 - 200	35	26	19	13
> 201	27	22	15	9

Table 19. Two-hour prediction range factors (in percent).

Pedestrian Volume Level	Count Interval (min) 5	10	15	30
0 - 500	(+)42	32	24	22
> 501	24	25	23	19

Table 20. Three-hour prediction range factors (in percent).

Pedestrian Volume Level	Count Interval (min) 5	10	15	30
0 - 500	(+)35	37	34	26
> 501	32	27	24	22

Table 21. Four-hour prediction range factors (in percent).

Pedestrian Volume Level	Count Interval (min) 5	10	15	30
0 - 750	(+)34	30	29	26
> 751	33	27	26	21

Table 22. Expansion models.

PED5M:	V1 = INVLOG [0.7862 log (I5) + 1.2991]	
where,	V1 = one hour prediction	
	I5 = the middle 5-minute count	
PED10M:	V1 = INVLOG [0.8465 log (I10) + 0.9922]	
where,	I10 = the middle 10-minute count	
PED15M:	V1 = INVLOG [0.8996 log (I15) + 0.7598]	
where,	I15 = the middle 15-minute count	
PED30M:	V1 = INVLOG [0.9625 log (I30) + 0.3751]	
where,	I30 = the middle 30-minute count	
PED5M:	V2 = INVLOG [0.7686 log (I5) + 1.6339]	
PED10M:	V2 = INVLOG [0.8226 log (I10) + 1.3200]	
PED15M:	V2 = INVLOG [0.8241 log (I15) + 1.1659]	
PED30M:	V2 = INVLOG [0.8918 log (I30) + 0.7880]	
where,	V2 = two-hour volume prediction	
PED5M:	V3 = INVLOG [0.7851 log (I5) + 1.7795]	
PED10M:	V3 = INVLOG [0.8184 log (I10) + 1.5072]	
PED15M:	V3 = INVLOG [0.8842 log (I15) + 1.2401]	
PED30M:	V3 = INVLOG [0.8901 log (I30) + 0.9752]	
where,	V3 = three-hour volume prediction	
PED5M:	V4 = INVLOG [0.8113 log (I5) + 1.7954]	
PED10M:	V4 = INVLOG [0.7618 log (I10) + 1.6522]	
PED15M:	V4 = INVLOG [0.8087 log (I15) + 1.4334]	
PED30M:	V4 = INVLOG [0.8134 log (I30) + 1.1922]	
where,	V4 = four-hour volume prediction	

to the estimated volume from Step 6. Select the sample count interval (column) that was used. Read the Prediction Range Factor. The estimated volume range will be the estimated volume (Step 6) ± the prediction range factor x the estimated volume.

For example, a 2-hour period with an estimated volume (EV) of 624 and a 10-minute count interval produces a prediction range factor of 25 percent (see table 19). The estimated volume range (EVR) is calculated as follows:

$$EVR = EV \pm (0.25)EV = 624 \pm 156$$

Therefore, the actual volume lies between 468 and 780 for the 2-hour period.

CONCLUSIONS AND RECOMMENDATIONS

The first analysis effort investigated the development of land use base curves to aid in the prediction of pedestrian crosswalk volumes using small count intervals. A base curve is a curve that represents a condition based on specific variables. In this study, the base curve represented a 15-minute pedestrian volume distribution over a 12-hour period described by land use(s). With a base curve developed by averaging respective 15-minute counts of similar 12-hour period pedestrian crosswalk volume distributions and defined by their land use(s), the curve would be used to identify the 15-minute distributions and magnitudes of pedestrian crosswalk volumes at sampled sites with respect to land use. The volume distribution is the shape of the base curve for a particular land use. The volume magnitude is determined by sampling an optimum number of 15-minute count intervals and adjusting the curve with respect to these sampled counts. Thus, a site curve could be used to predict 15-minute (or any multiple) pedestrian crosswalk volume over the 12-hour period.

The first step in the base curve approach was to determine if the curve developed would accurately represent the land use for which it was defined. A base curve was developed for a particular pedestrian volume distribution group (Group I) with the omission of one site from this group's curve development in order to compare the site curve (distribution) with the base curve (distribution). The goodness of fit test, Kolmogorov-Smirnov (K-S) test, was utilized to evaluate these distributions. This test was performed four times (four sites were in Group I, removal of each site was performed and then compared to its respective base curve).

The base curves and respective site curves showed significant differences in 12-hour pedestrian volume distributions. The findings of this approach were hampered due to nonhomogenous site land uses. Even though a group may have been defined by similar site volume distribution patterns, the land use description did not encompass all the characteristics that truly existed. As was demonstrated with sites 2 and 14, the same land uses defined these sites, but site 14 was located in the vicinity of a subway station. This station apparently altered the volume peaking characteristics. Additional factors, such as office hours and other minor land uses, could have also affected the pedestrian volume distributions.

Since the K-S test compares point to point, these poor results could have been due to extreme 15-minute variations. Curve smoothing was considered to smooth out these extreme cases, i.e., a 15-minute valley between two 15-minute peaks would be mathematically adjusted to eliminate this valley. However, the smoothing technique would not have corrected the distribution shift of site 14. Thus, the base curve approach was abandoned.

Additional research on the base curve approach should be further pursued. By exercising caution in finding homogenous land use sites, this method could produce base curves that would predict pedestrian volumes at a site with the same homogenous land use. These curves, while limited in their use, could prove beneficial in certain situations.

The second approach on this study was to develop expansion models. Using the linear regression techniques, count intervals of 5, 10, 15, and 30 minutes were used to explain 1-, 2-, 3-, and 4-hour counts. Basically, once the model was developed, the count interval would be expanded to predict the hourly count. The count intervals were investigated in terms of position (first, middle, last, random) inside the hourly counts. For example, for a 1-hour prediction, the first 1-minute position is 0:00 to 0:10, the middle is 0:25 to 0:35, the last is 0:50 to 0:00, and the random 10 minute occurs at any position inside the 1 hour. Based on the coefficients of determination (R^2) and the standard error of the estimate (SE_y), the middle position of all count intervals best defined all hourly and multihourly counts. However, it was apparent that the larger the count interval, the better the volume prediction. All middle count interval models were presented in order to leave the determination of the prediction accuracy to the user.

Additional findings were that when the multihour volume period increased, the multihour prediction became less accurate. This was due to the increase in variation of the counting intervals as the 1-hour volumes increased to 4-hour volumes. Also, the expansion models for the middle counting intervals were not affected by the different volume distributions that existed for the hour or multihour volume counts. This was evident by the constant result of the middle event being the best predictor of pedestrian volumes.

A validation study was conducted using the middle count expansion models. The purpose of this study was to determine the prediction error associated with various volume ranges since the SE_y calculated in regression is meaningless when values of X move far away from the mean of X. The prediction error (percent error) was empirically derived for various prediction volume ranges. Findings of this validation reflected the earlier findings in the modeling effort. As the count interval increased, the smaller the percent error became, thus, the better the volume prediction. Also, as the prediction of hourly volumes increased to multihour volumes, the percent error became larger which was reflected in the modeling effort by the decrease of R^2 and increase of SE_y.

An observation that was not found in the modeling effort was the increase in accuracy as the prediction volume range increased. This was the result of the erratic occurrence of volume peaks and valleys that often existed at low volume sites. Thus, the probability of sampling at a peak or valley would be approximately 50 percent, which in turn may not be a true representation of the hourly or multihour volume.

Regardless of the findings of the expansion modeling approach, one question will arise for studies constrained to using data in one city: Are these models valid in other cities that have different characteristics? The answer, at present, is unknown. However, the hourly expansion models were derived with approximately 400 hourly observations and validated with 120 observations. This means that there were possibly 400 different 1-hour volume distributions in the modeling derivations and 120 different distributions in the modeling validations. Thus, the potential of encompassing many of the typical 1-hour distributions from any city is good.

As for the multihour models, the sample sizes were less than for the 1-hour models. Confidence in the reliability and validity of these models was not as great as in the 1-hour models. Therefore, additional empirical data should improve these multihour models.

Additional research on these models could take two approaches. To test the validity of the models developed in this study, data should be collected at several sites for several cities throughout the country. These data then would be inputed into these models. The validity would be tested by comparing the percent errors calculated in this study to the percent errors calculated for the additional data. If these percent errors are found to be statistically the same then the models developed here would be valid.

The second approach would test the models' reliability. In testing model reliability, expansion models would have to be developed for various cities and then compared to the models of this study. The models developed in this study would be reliable for use in other cities if the expansion models developed for other cities had the following characteristics: positively skewed data (corrected by logarithmic transformation), optimum counting intervals occurring at the middle event, and regression equations and parameters similar to those of this study.

With respect to practicality, the pedestrian volume sampling method offers a tool to aid in saving time and effort. When used to estimate pedestrian volumes for checking the warrant for signals (appendix F), it would serve as a screening device to quickly eliminate those intersections whose range of estimated hourly counts do not include the volume required by the warrant. Should the estimated range of values include the warrant values, a full count of those hours identified by the sample count would then be made, along with a gap study, to complete the signal warrant analysis. When used for exposure data applications, the levels of accuracy possible from the sampling method should be sufficient. Thus, considerable savings could be achieved over having to make full counts.

In conclusion, promise has been shown for the use of expansion models in predicting pedestrian volumes. As presented in the application section of this report, the ease and cost reduction in the use of these models is clear. With the additional research conducted in other cities, these models could prove to be very beneficial in the prediction of pedestrian volumes for use in signal warrants and exposure data applications.

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APPENDIX A - Data Collection Form

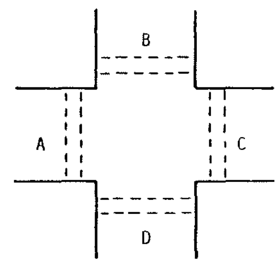
This appendix contains a sample data collection form used to collect pedestrian volume data. The data was collected for 5-minute intervals.

Location:

Coder:

Date:

5-Minute Intervals Beginning	A	B	C	D	Total
:00					
:05					
:10					
:15					
:20					
:25					
:30					
:35					
:40					
:45					
:50					
:55					
Total					
:00					
:05					
:10					
:15					
:20					
:25					
:30					
:35					
:40					
:45					
:50					
:55					
Total					
:00					
:05					
:10					
:15					
:20					
:25					
:30					
:35					
:40					
:45					
:50					
:55					
Total					



North

Page of

Figure 10. Data collection form.

APPENDIX B - Site Histogram Examples for Each Group

This appendix contains a set of 10-, 15-, 30-, and 60-minute histograms for the first data for one site in each group. The 5-minute histograms were not presented since they were exceptionally long.

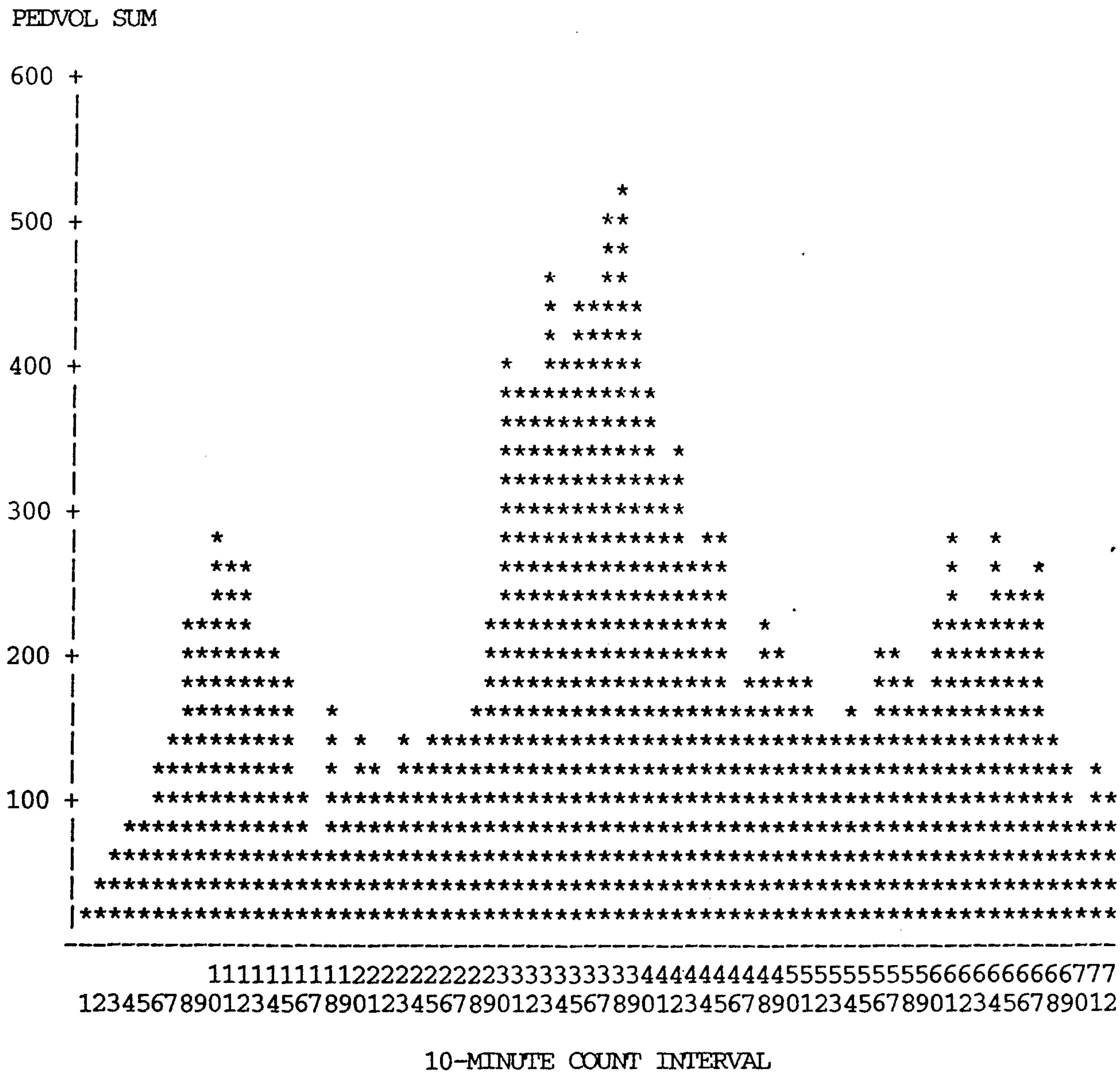


Figure 11. 10-minute count histogram for site 9 in group I.

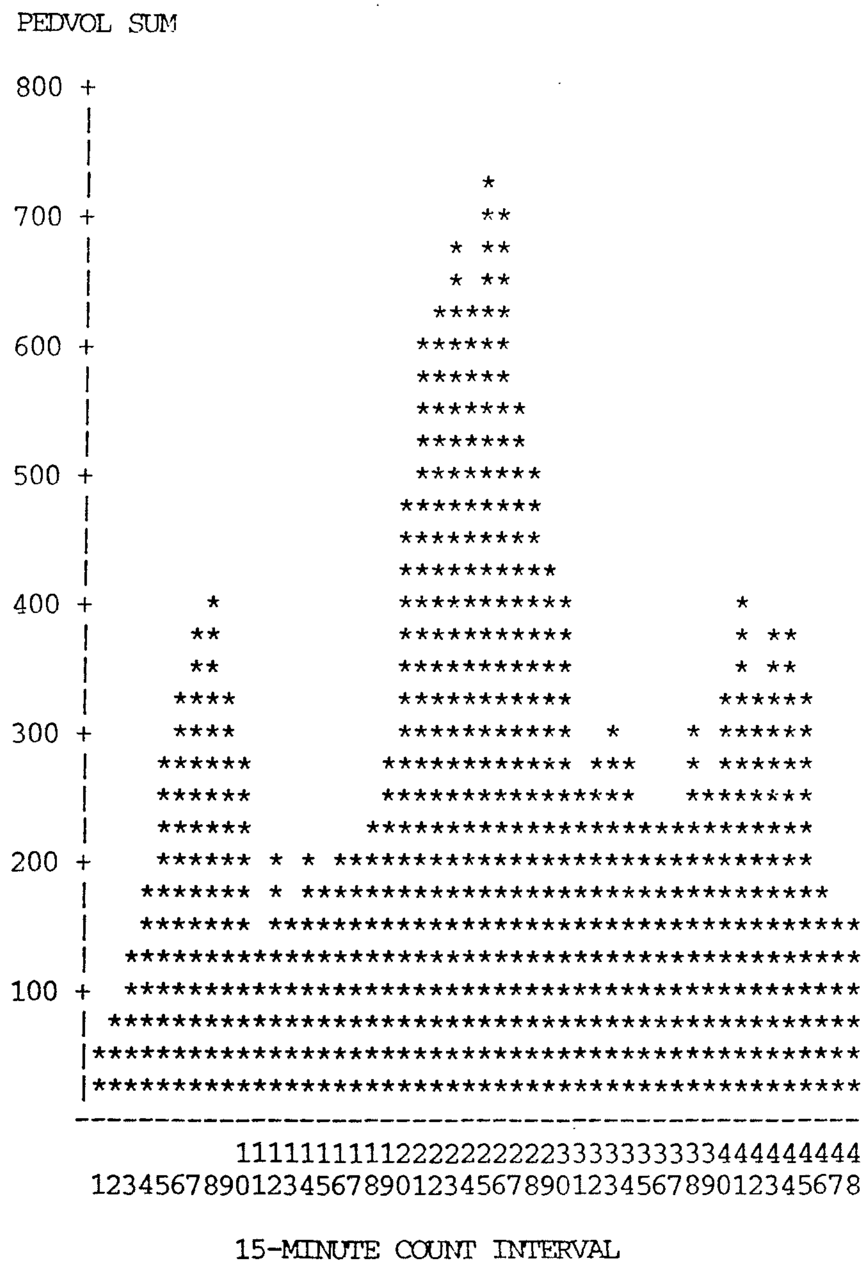


Figure 12. 15-minute count histogram
for site 9 in group I.

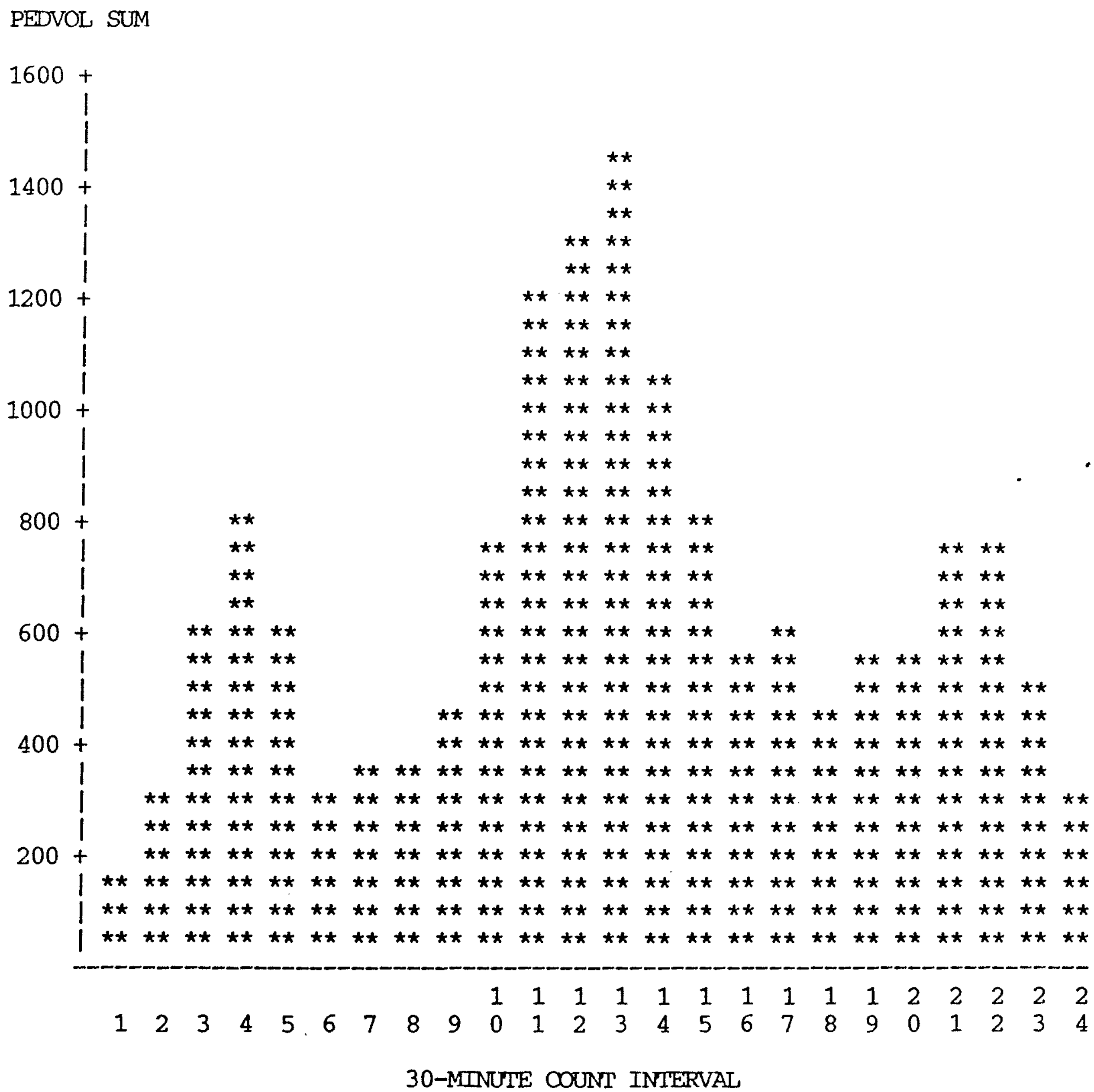


Figure 13. 30-minute count histogram
for site 9 in group I.

```
PEDVOL SUM
     |                                                  *****     *****
2400 +                                                  *****     *****
     |                                                  *****     *****
     |                                                  *****     *****
     |                                                  *****     *****
2100 +                                                  *****     *****
     |                                                  *****     *****
     |                                                  *****     *****
     |                                                  *****     *****
1800 +                                                  *****     *****
     |                                                  *****     *****
     |                                                  *****     *****
     |                                                  *****     *****
1500 +                                                  *****     *****                                   *****
     |                                                  *****     *****                                   *****
     |           *****                                   *****     *****     *****                         *****
     |           *****                                   *****     *****     *****                         *****
1200 +           *****                         *****     *****     *****     *****                         *****
     |           *****                         *****     *****     *****     *****               *****     *****
     |           *****                         *****     *****     *****     *****     *****     *****     *****
     |           *****                         *****     *****     *****     *****     *****     *****     *****
 900 +           *****     *****               *****     *****     *****     *****     *****     *****     *****
     |           *****     *****               *****     *****     *****     *****     *****     *****     *****     *****
     |           *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
     |           *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
 600 +           *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
     |           *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
     |           *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
     | *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
 300 + *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
     | *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
     | *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
     | *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****     *****
      -----------------------------------------------------------------------------------------------------------------------
                                                                                                   1         1         1
         1         2         3         4         5         6         7         8         9         0         1         2

                                          60-MINUTE COUNT INTERVAL
```

Figure 14. 60-minute count histogram
for site 9 in group I.

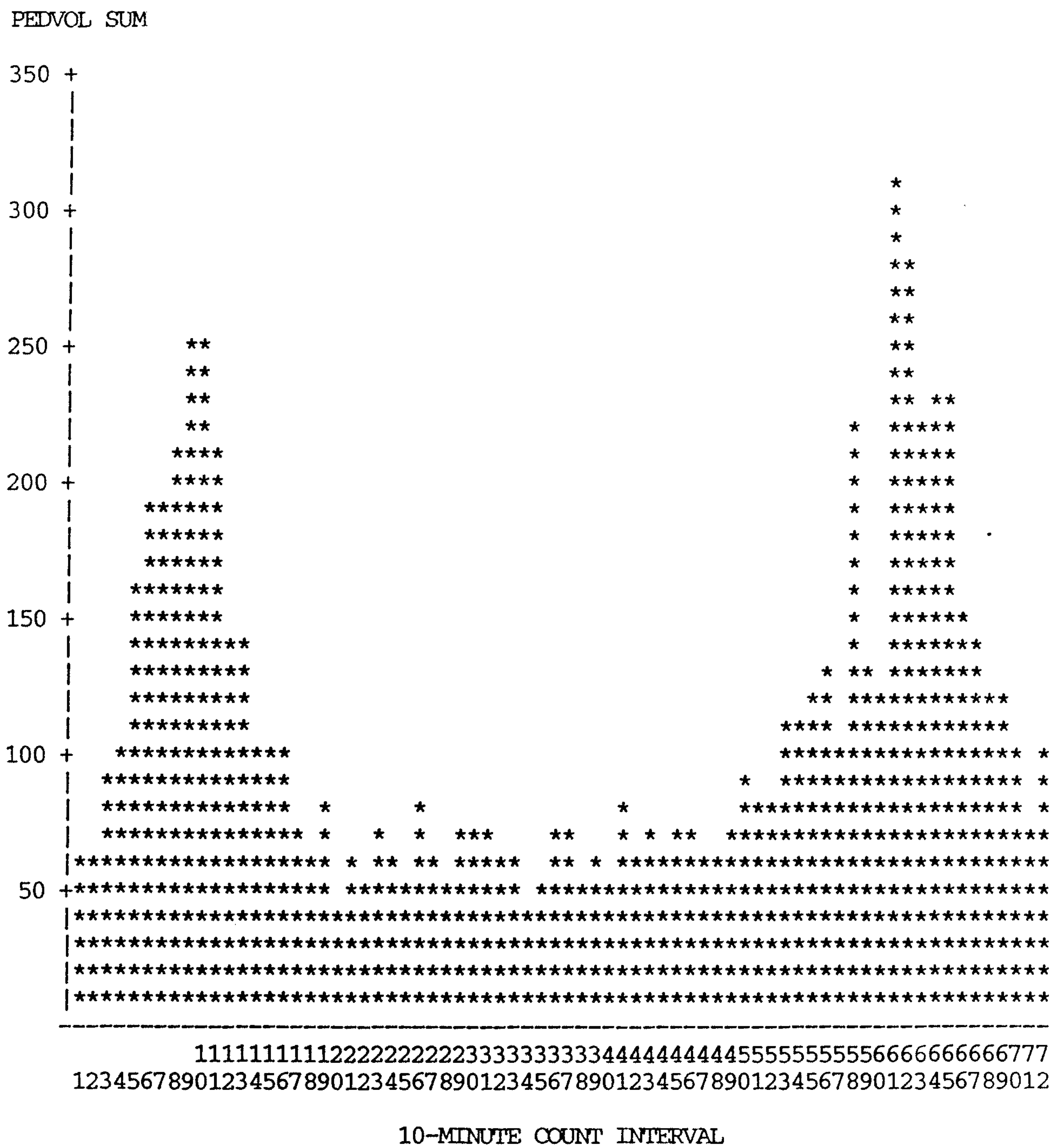


Figure 15. 10-minute count histogram
for site 4 in group II.

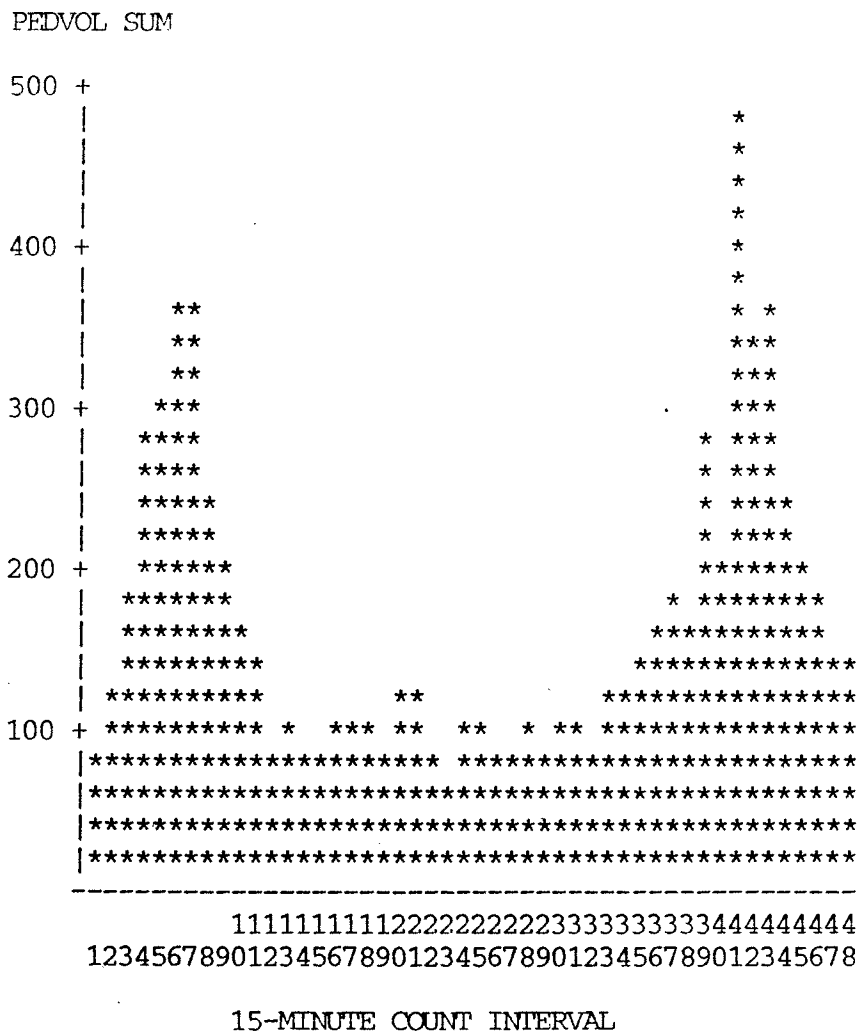


Figure 16. 15-minute count histogram for site 4 in group II.

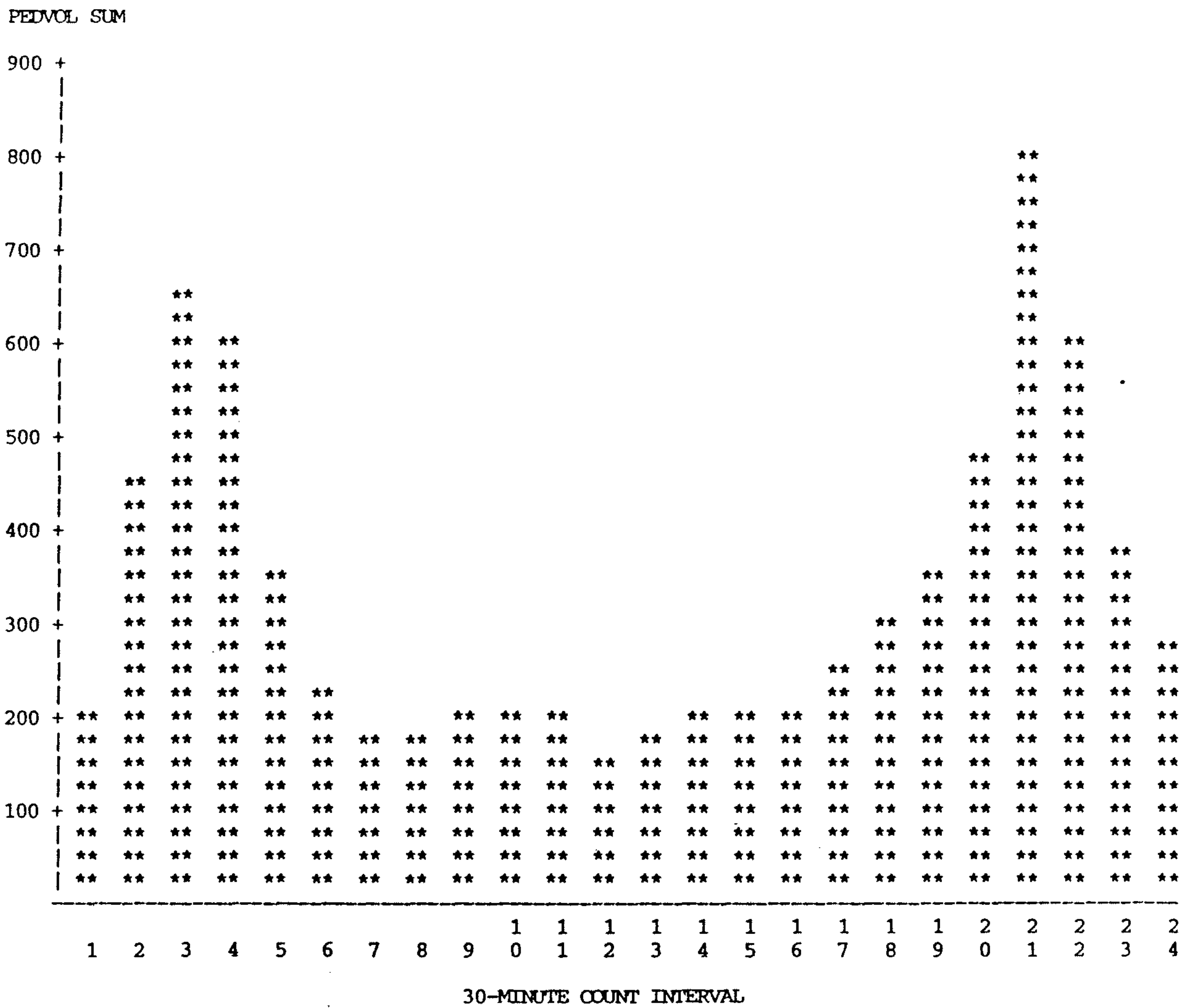


Figure 17. 30-minute count histogram for site 4 in group II.

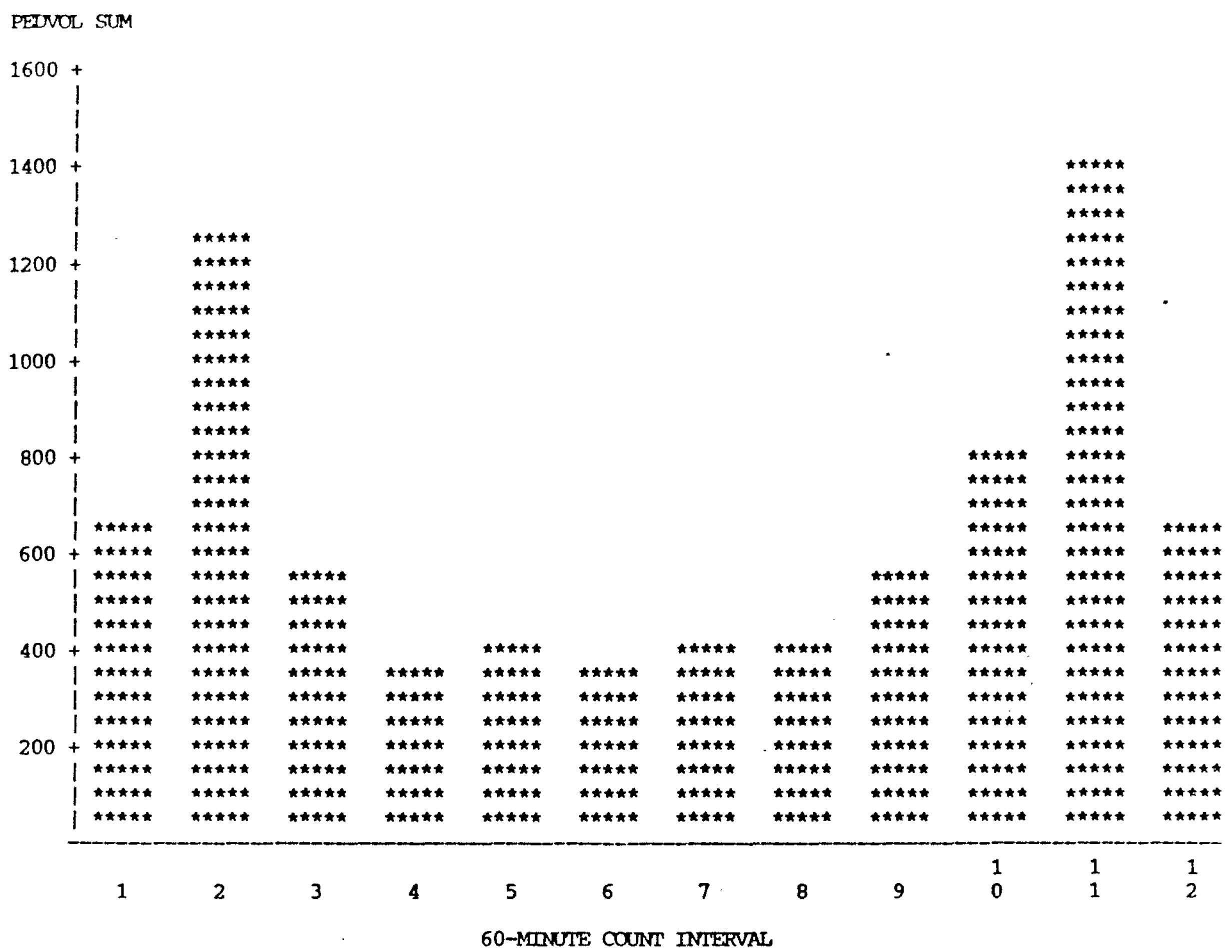


Figure 18. 60-minute count histogram
for site 4 in group II.

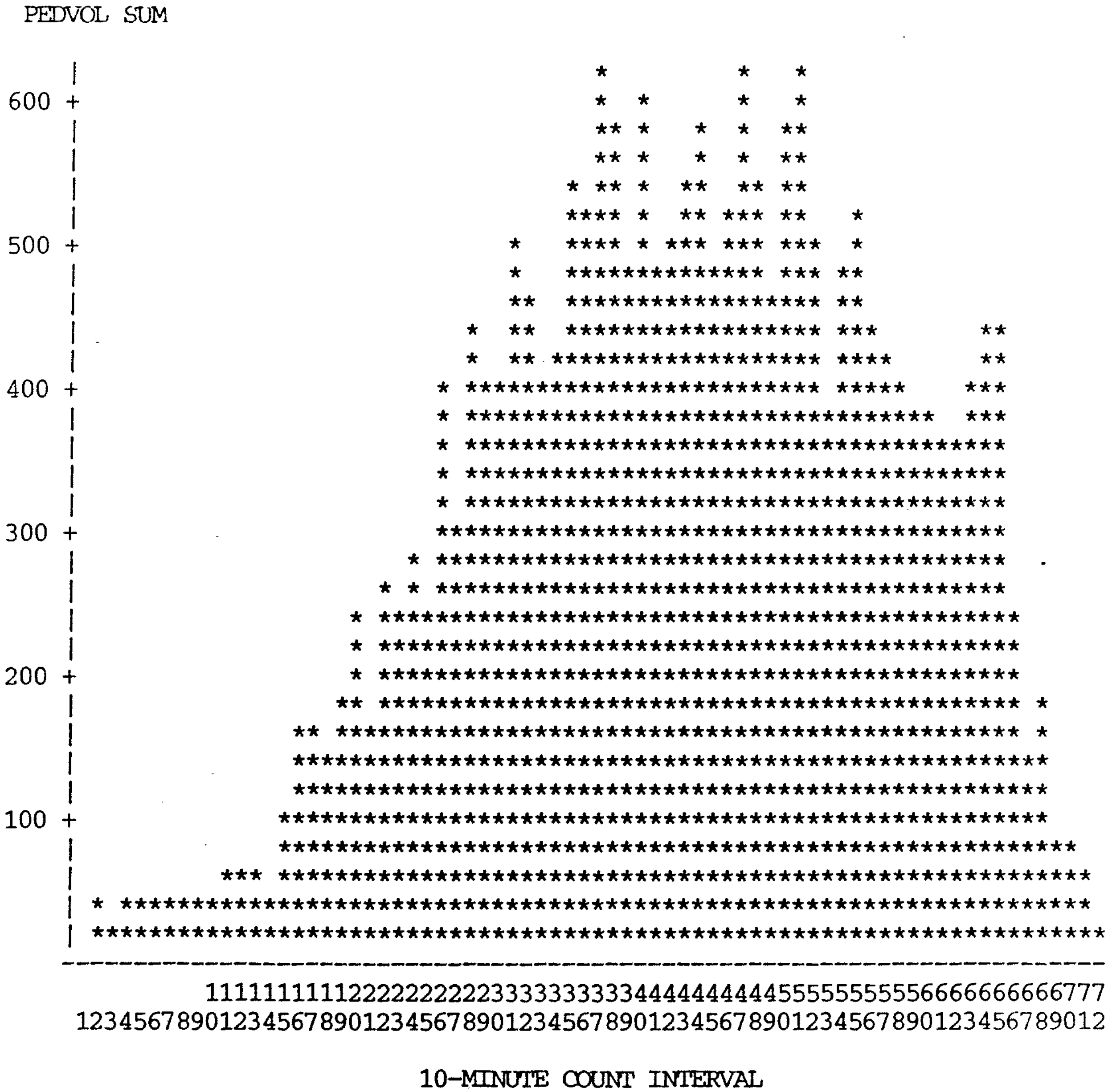


Figure 19. 10-minute count histogram
for site 5 in group III.

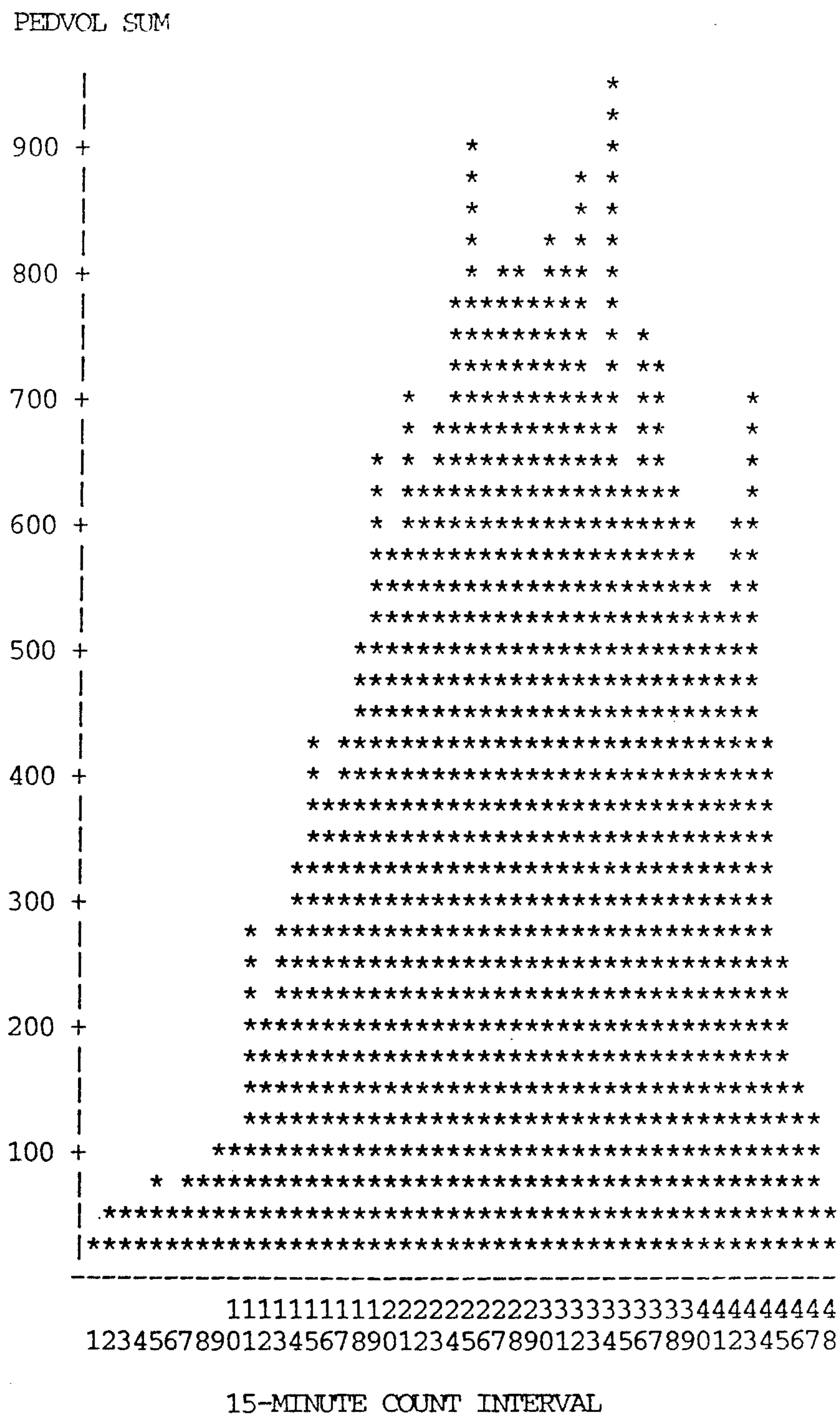


Figure 20. 15-minute count histogram for site 5 in group III.

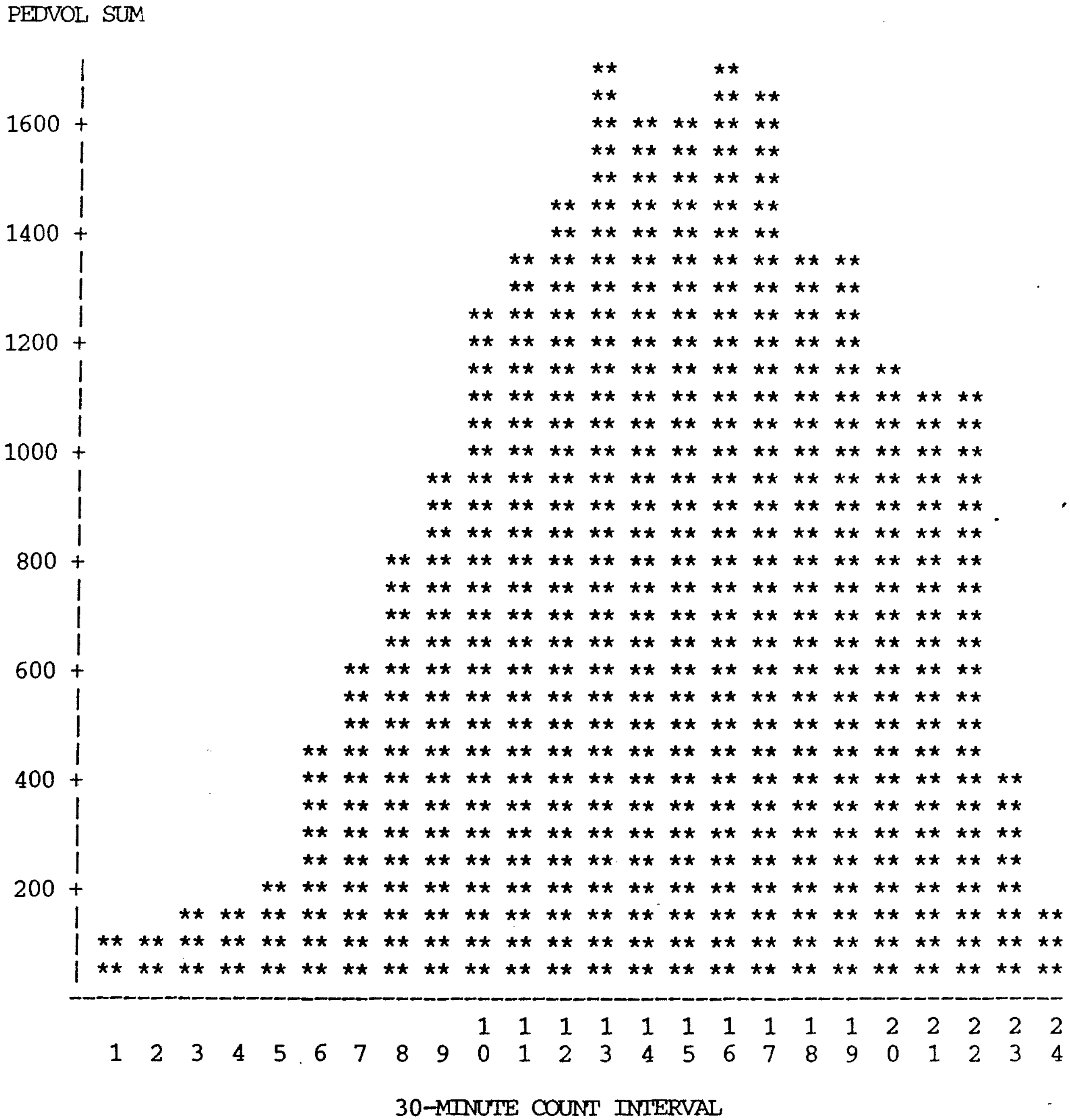


Figure 21. 30-minute count histogram
for site 5 in group III.

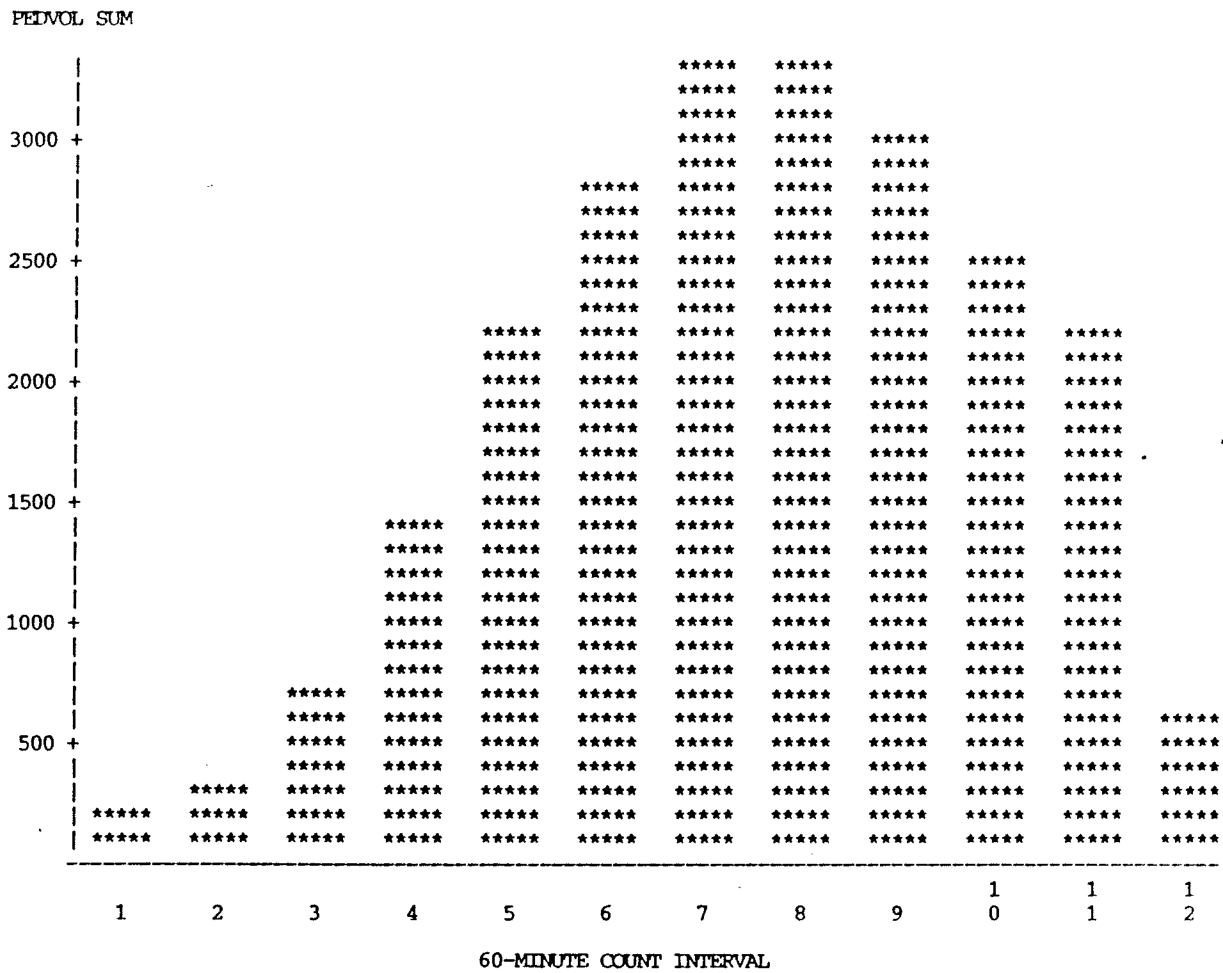


Figure 22. 60-minute count histogram
for site 5 in group III.

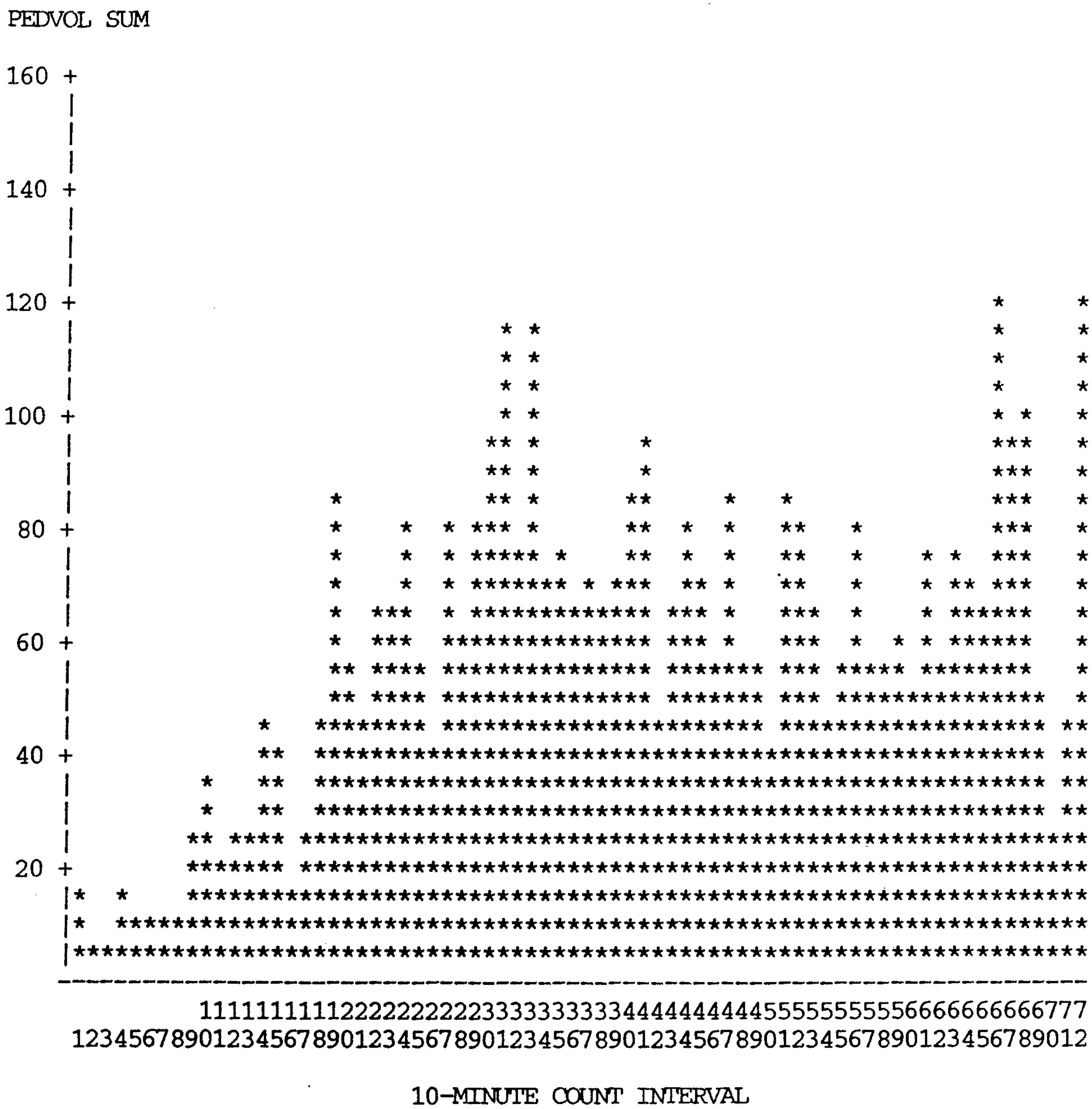


Figure 23. 10-minute count histogram for site 12 in group IV.

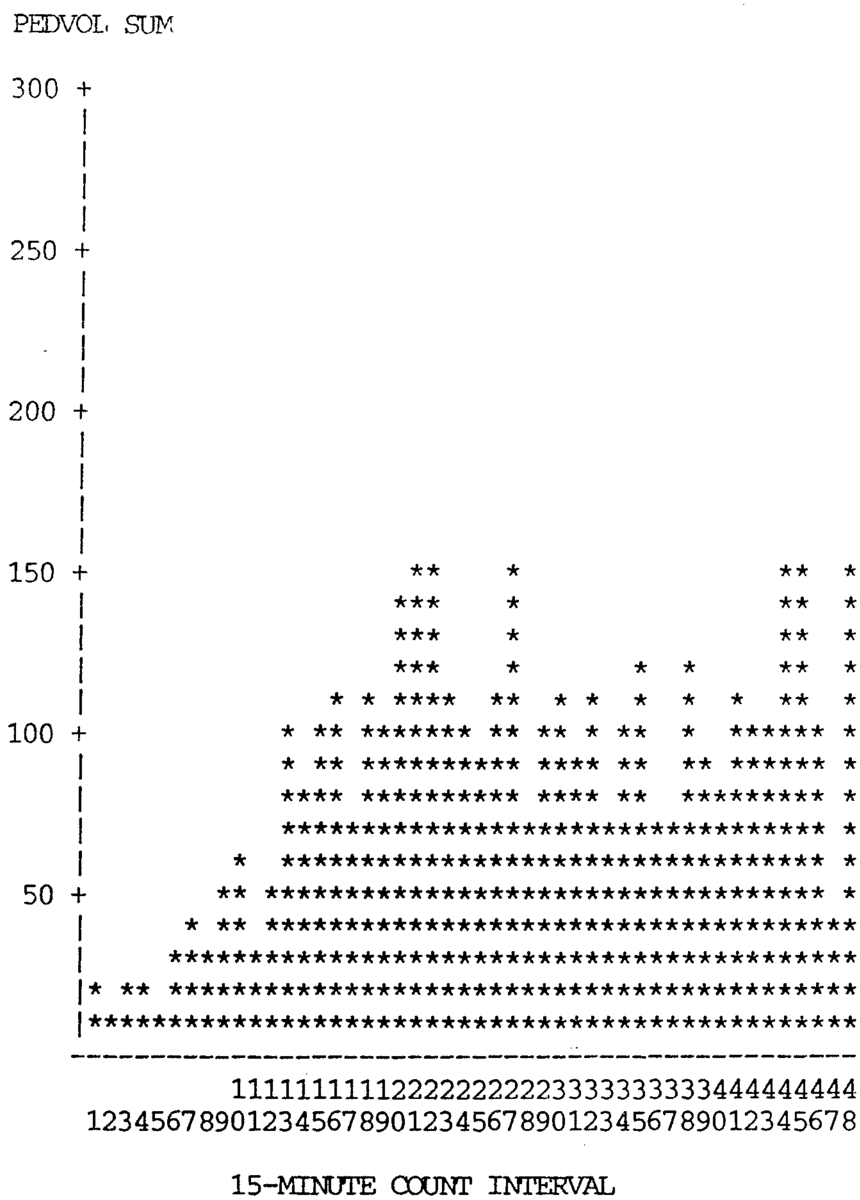


Figure 24. 15-minute count histogram
for site 12 in group IV.

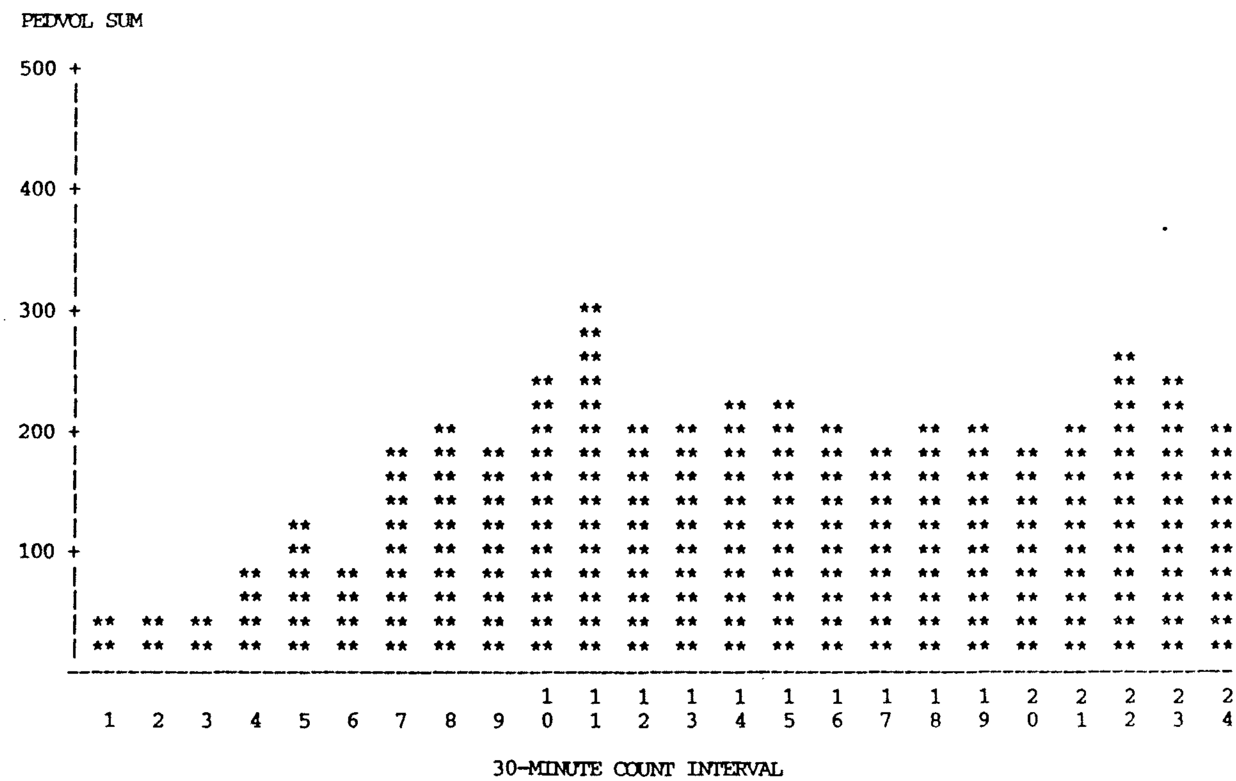


Figure 25. 30-minute count histogram
for site 12 in group IV.

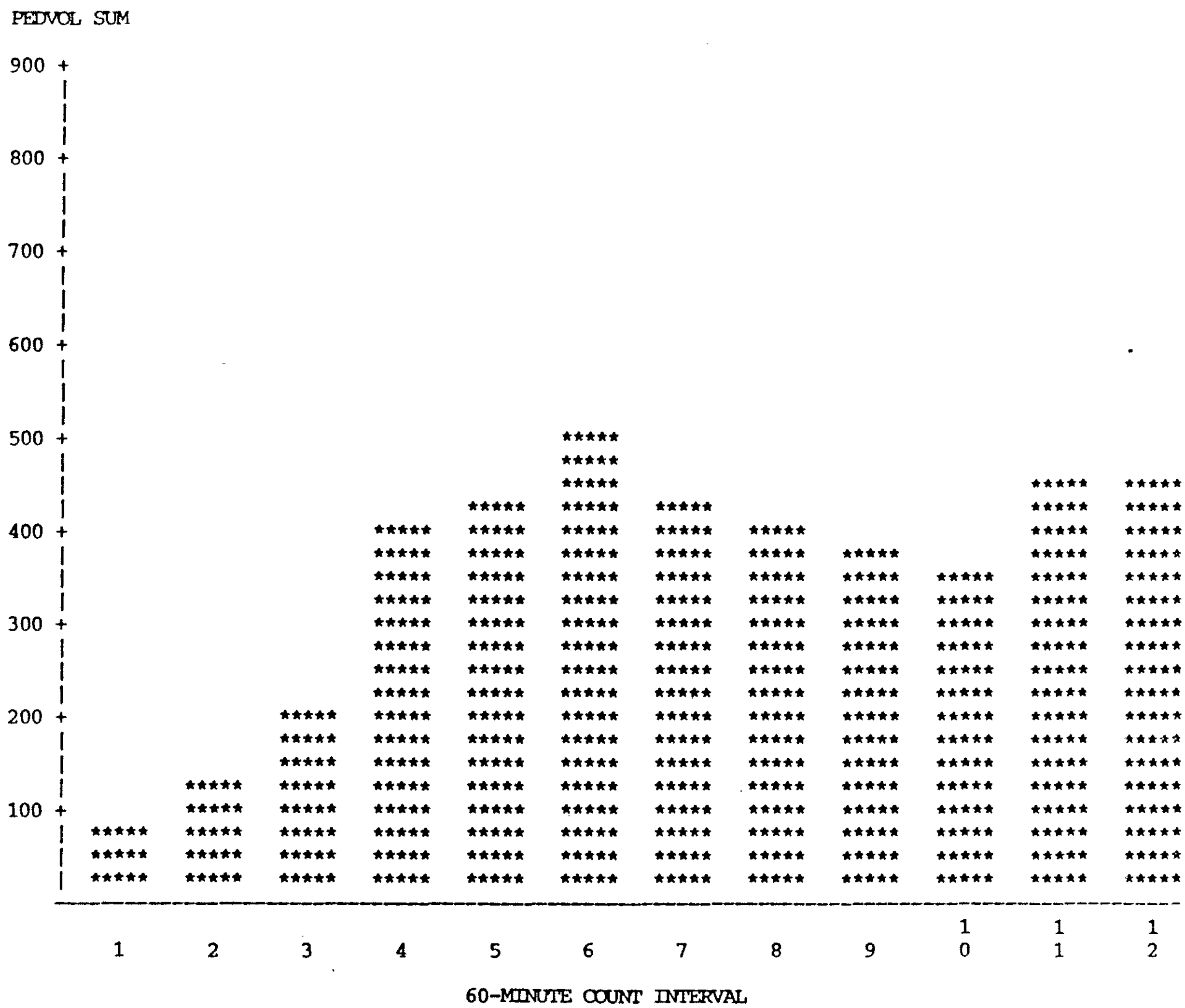


Figure 26. 60-minute count histogram
for site 12 in group IV.

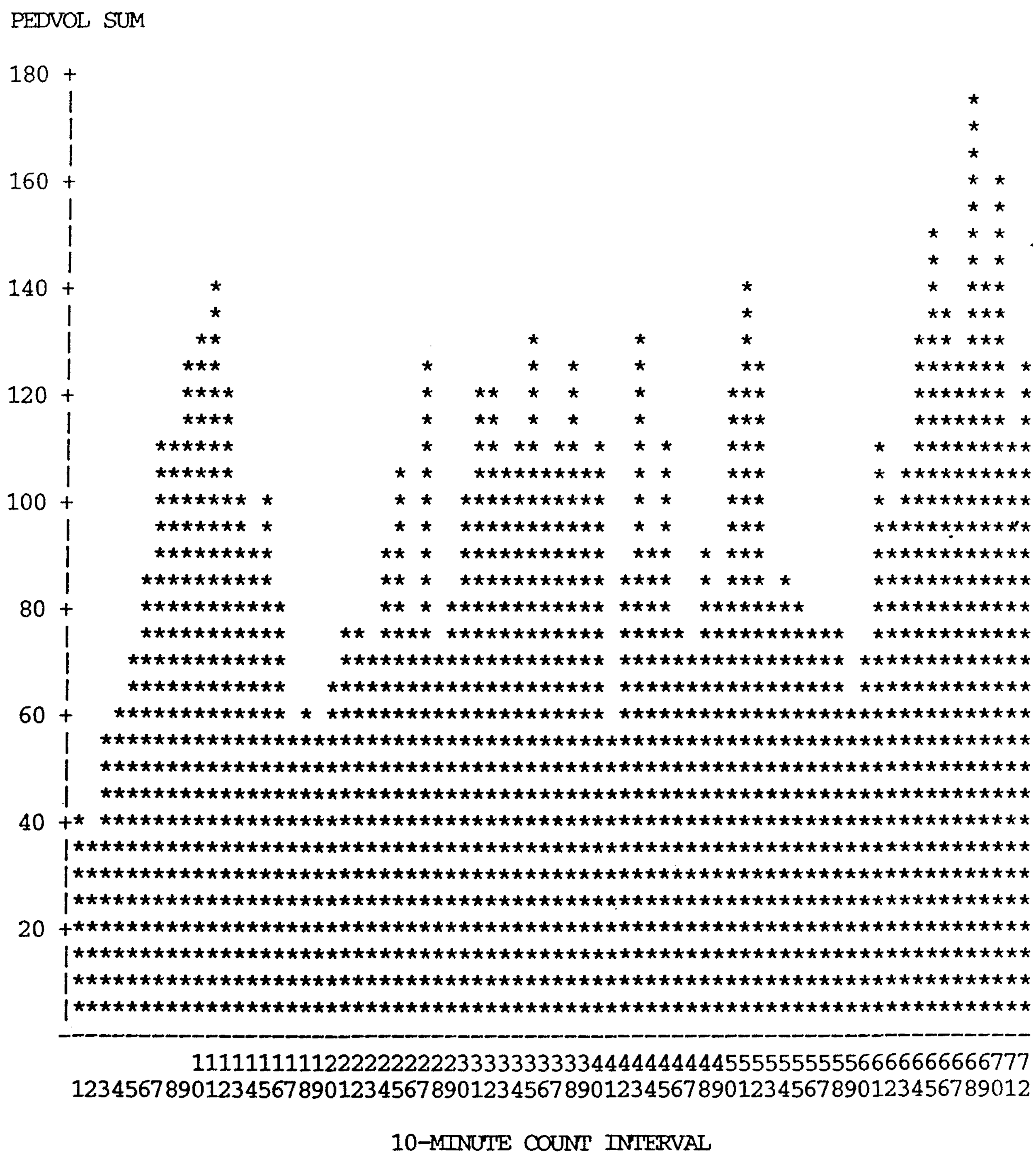


Figure 27. 10-minute count histogram
for site 11 in group V.

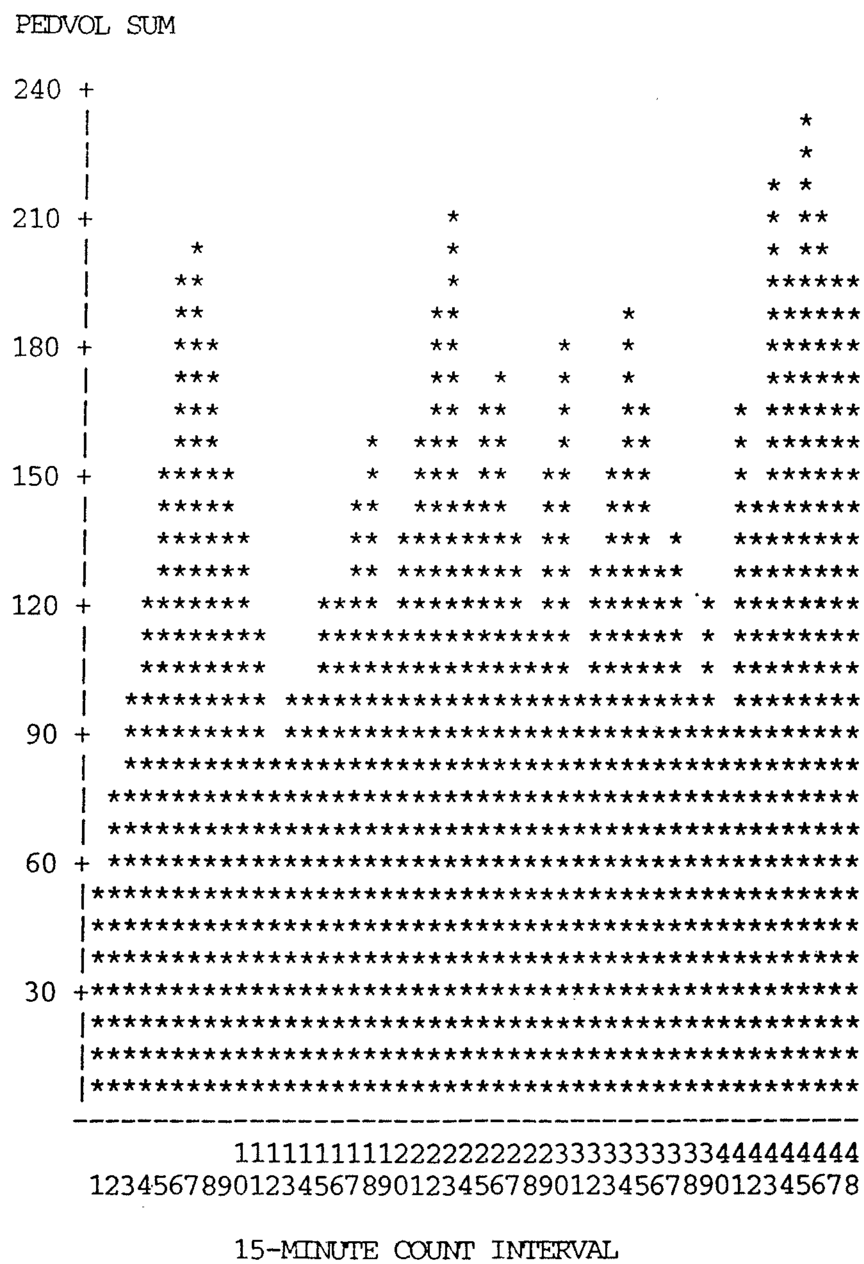


Figure 28. 15-minute count histogram for site 11 in group V.

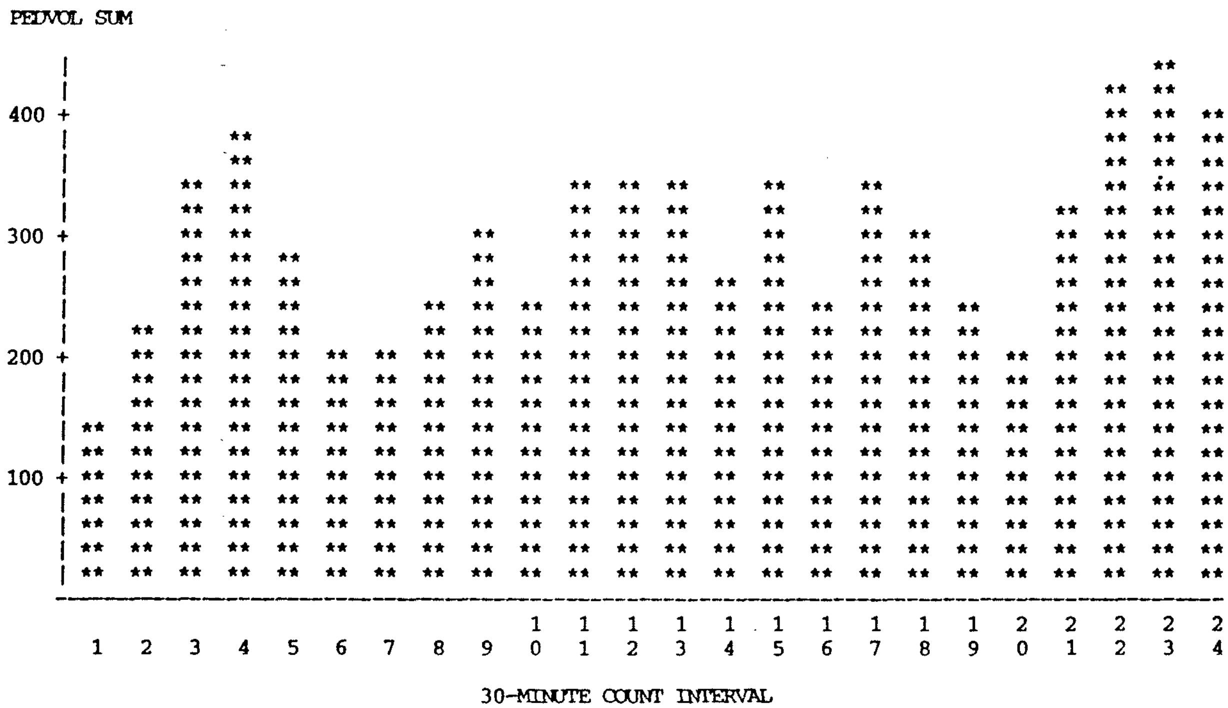


Figure 29. 30-minute count histogram
for site 11 in group V.

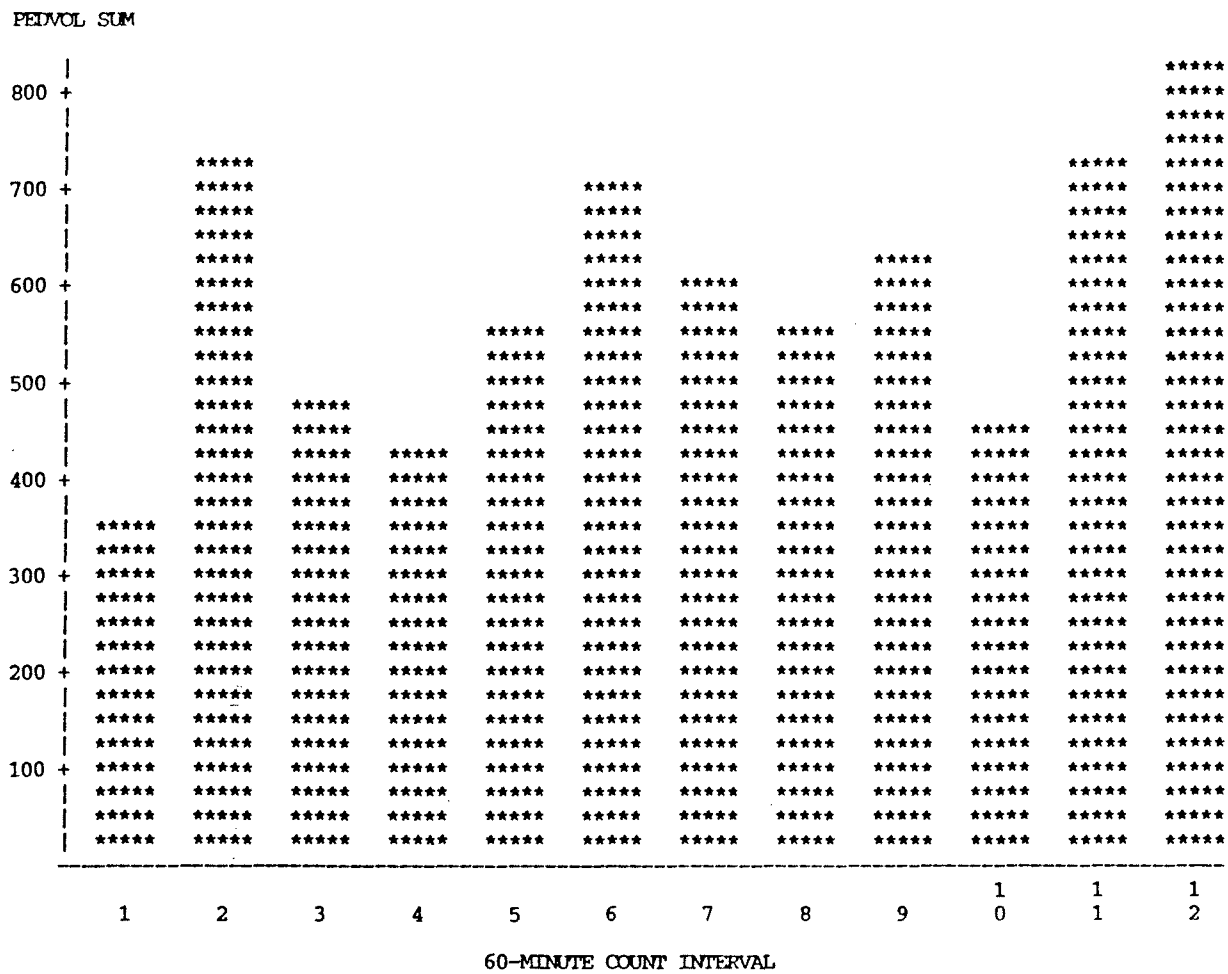


Figure 30. 60-minute count histogram
for site 11 in group V.

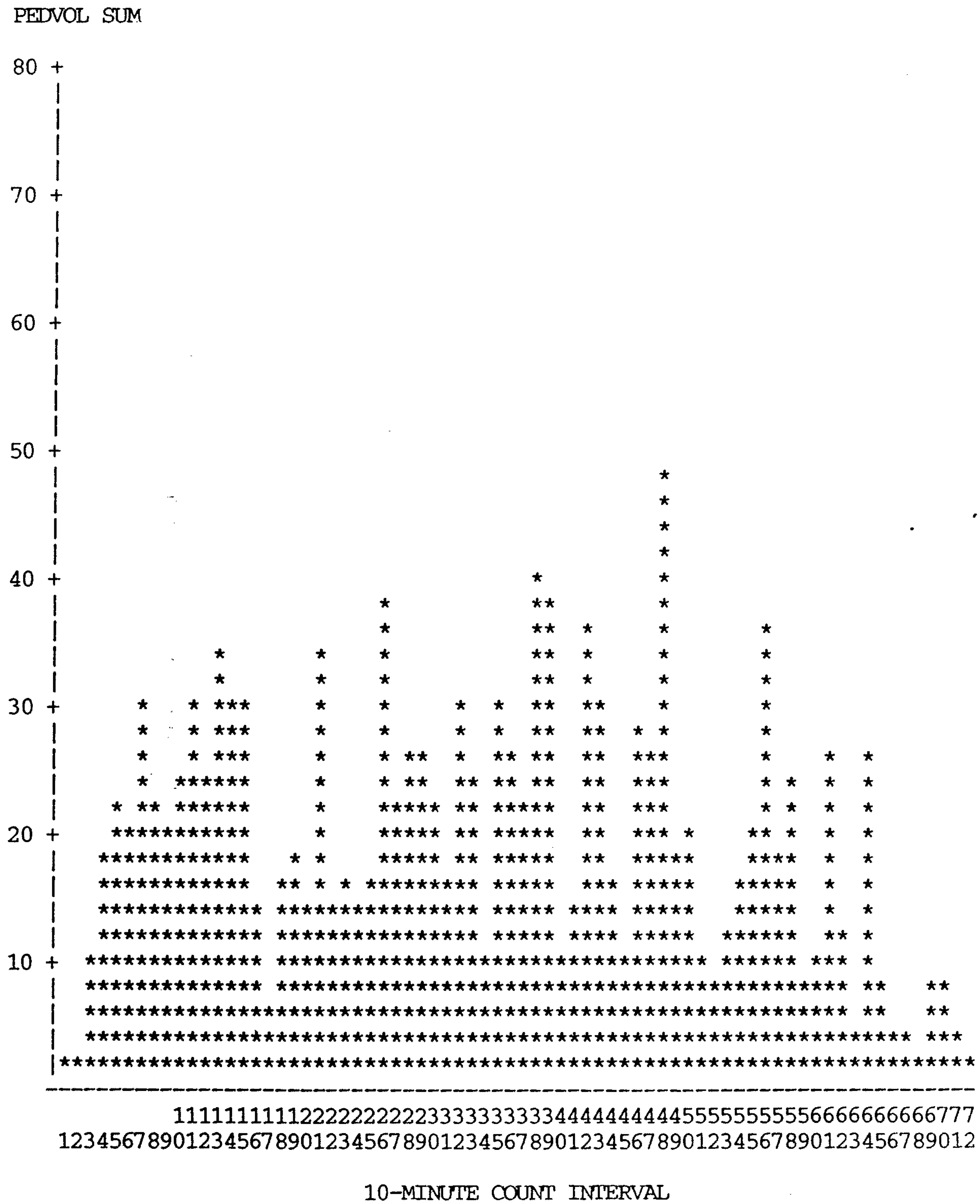


Figure 31. 10-minute count histogram
for site 10 in group VI.

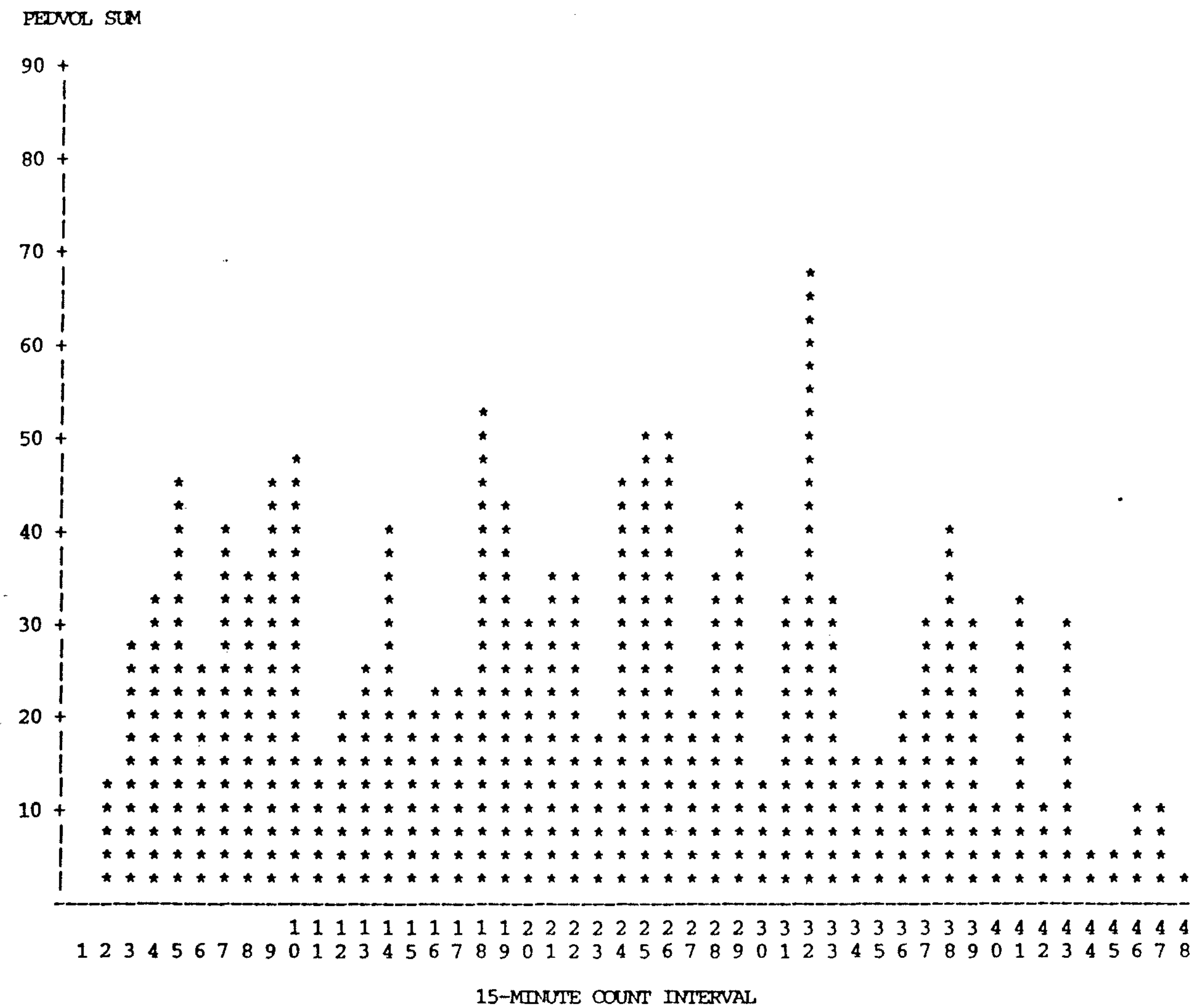


Figure 32. 15-minute count histgram
for site 10 in group VI.

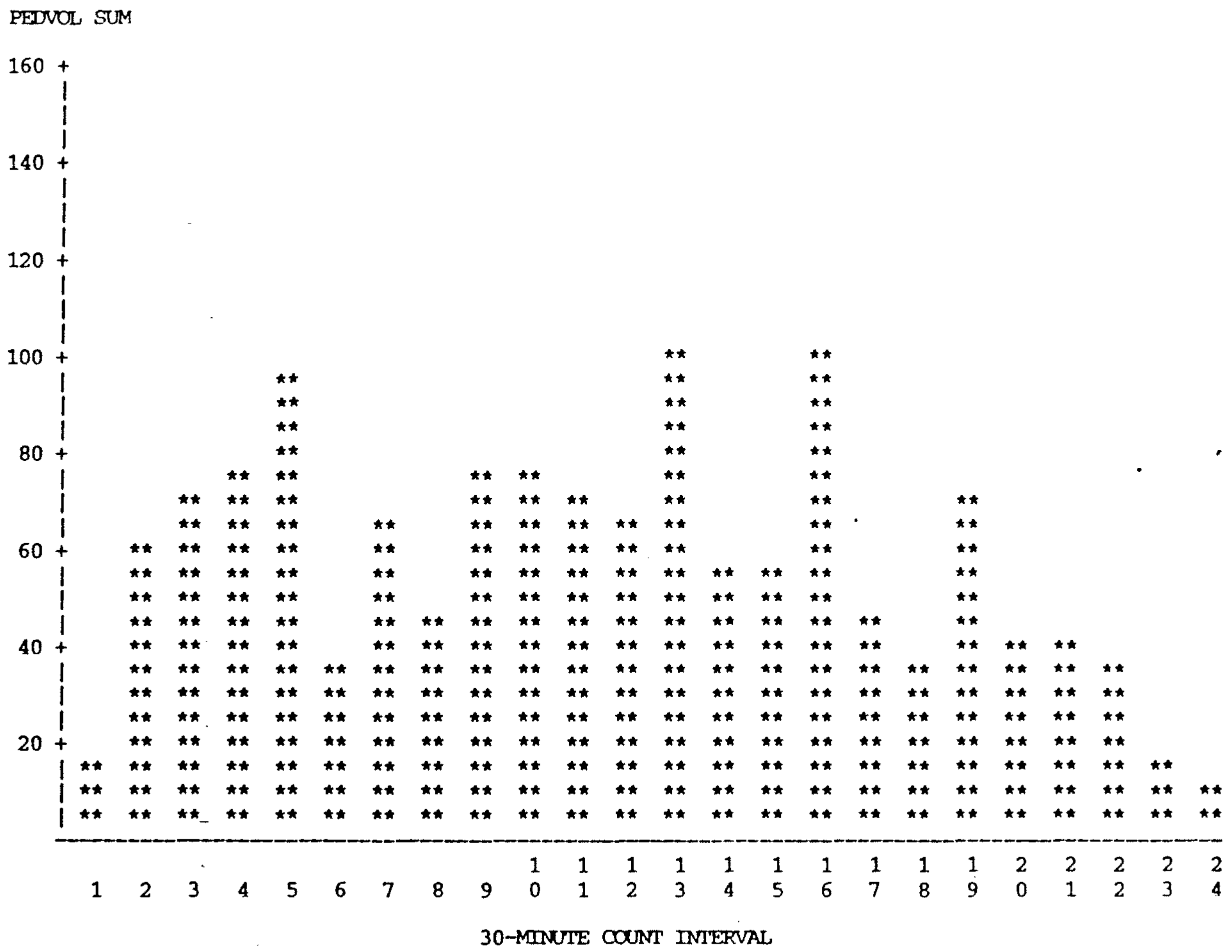


Figure 33. 30-minute count histogram for site 10 in group VI.

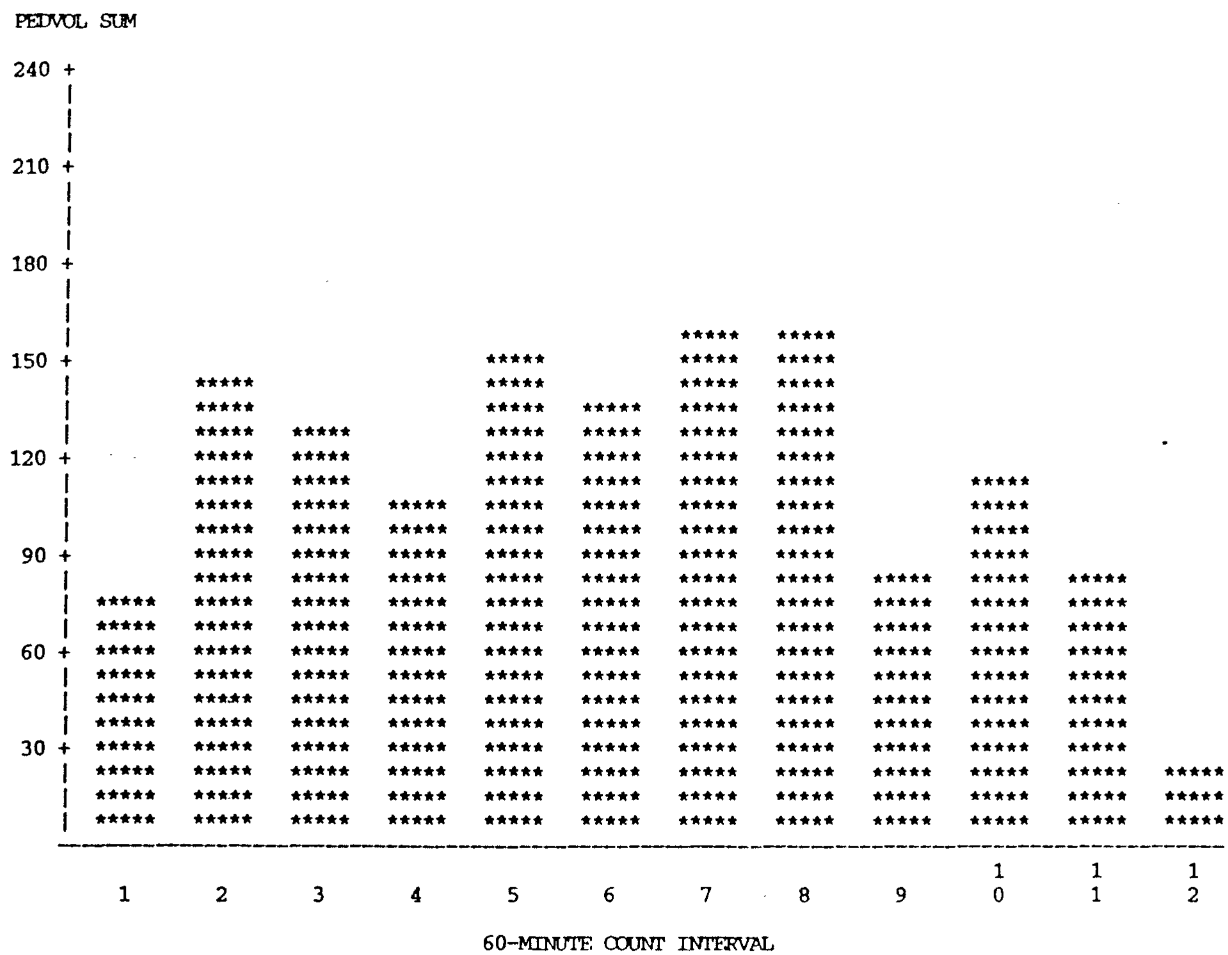


Figure 34. 60-minute count histogram
for site 10 in group VI.

APPENDIX C - K-S Procedure for Group I

This appendix contains tables showing the K-S procedure for group I. These four tables present cumulative and relative cumulative frequencies for the base and site curves. In addition, the differences between the base and site relative cumulative frequencies are given with D_{max} indicated. Also, the critical value (D_C) is calculated.

Table 23. K-S procedure for base curve 8914 versus site curve 2.

Obs.	Base 8914	Site 2	Cum. Base 8914	Cum. Site 2	Rel. Cum. Base 8914	Rel. Cum. Site 2	Difference
1	54.222	56.000	54.2	56.0	0.00450	0.00400	0.000498
2	94.000	116.000	148.2	172.0	0.01229	0.01228	0.000010
3	93.000	141.000	241.2	313.0	0.02000	0.02235	-0.002346
4	128.778	174.000	370.0	487.0	0.03068	0.03477	-0.004091
5	173.667	192.000	543.7	679.0	0.04508	0.04847	-0.003399
6	225.000	254.333	768.7	933.3	0.06373	0.06663	-0.002901
7	238.444	263.000	1007.1	1196.3	0.08350	0.08541	-0.001908
8	266.222	262.333	1273.3	1458.7	0.10557	0.10414	0.001437
9	225.222	486.667	1498.6	1945.3	0.12425	0.13888	-0.014634
10	181.333	210.000	1679.9	2155.3	0.13928	0.15387	-0.014592
11	148.556	197.667	1828.4	2353.0	0.15160	0.16798	-0.016386
12	172.556	199.000	2001.0	2552.0	0.16590	0.18219	-0.016287
13	188.556	202.000	2189.6	2754.0	0.18154	0.19661	-0.015075
14	160.889	150.000	2350.4	2904.0	0.19488	0.20732	-0.012444
15	165.222	176.667	2515.7	3080.7	0.20857	0.21993	-0.011358
16	152.000	254.667	2667.7	3335.3	0.22118	0.23811	-0.016936
17	188.444	204.333	2856.1	3539.7	0.23680	0.25270	-0.015900
18	233.556	224.667	3089.7	3764.3	0.25617	0.26874	-0.012575
19	301.444	364.000	3391.1	4128.3	0.28116	0.29473	-0.013568
20	351.222	395.667	3742.3	4524.0	0.31028	0.32297	-0.012696
21	482.000	563.333	4224.3	5087.3	0.35024	0.36319	-0.012950
22	501.667	642.667	4726.0	5730.0	0.39183	0.40907	-0.017237
23	512.556	596.000	5238.6	6326.0	0.43433	0.45162	-0.017290
24	516.111	609.000	5754.7	6935.0	0.47712	0.49510	-0.017976
25	552.889	683.000	6307.6	7618.0	0.52296	0.54386	-0.020896 *
26	517.778	575.667	6825.3	8193.7	0.56589	0.58496	-0.019065
27	424.889	509.667	7250.2	8703.3	0.60112	0.62134	-0.020223
28	392.778	393.000	7643.0	9096.3	0.63368	0.64940	-0.015714
29	367.778	390.667	8010.8	9487.0	0.66418	0.67729	-0.013112
30	282.000	329.667	8292.8	9816.7	0.68756	0.70082	-0.013266
31	221.222	215.333	8514.0	10032.0	0.70590	0.71620	-0.010298
32	230.667	189.000	8744.7	10221.0	0.72502	0.72969	-0.004666
33	199.667	241.000	8944.3	10462.0	0.74158	0.74689	-0.005317
34	215.667	208.333	9160.0	10670.3	0.75946	0.76177	-0.002309
35	197.333	195.333	9357.3	10865.7	0.77582	0.77571	0.000107
36	212.667	198.667	9570.0	11064.3	0.79345	0.78990	0.003556
37	216.111	212.000	9786.1	11276.3	0.81137	0.80503	0.006339
38	209.000	174.333	9995.1	11450.7	0.82870	0.81748	0.011221
39	227.444	224.333	10222.6	11675.0	0.84756	0.83349	0.014064
40	218.667	228.000	10441.2	11903.0	0.86569	0.84977	0.015916
41	301.889	301.667	10743.1	12204.7	0.89071	0.87131	0.019409
42	256.889	292.667	11000.0	12497.3	0.91201	0.89220	0.019814
43	241.889	269.000	11241.9	12766.3	0.93207	0.91140	0.020665
44	229.111	319.333	11471.0	13085.7	0.95106	0.93420	0.016863
45	212.889	347.667	11683.9	13433.3	0.96872	0.95902	0.009694
46	151.333	240.333	11835.2	13673.7	0.98126	0.97618	0.005083
47	126.667	167.333	11961.9	13841.0	0.99176	0.98813	0.003639
48	99.333	166.333	12061.2	14007.3	1.00000	1.00000	0.000000

* $D_{max} = 0.0209$
$D_c = 1.36/\sqrt{1407.3} = 0.0115$

Table 24. K-S procedure for base curve 2914 versus site curve 8.

Obs.	Base 2914	Site 8	Cum. Base 2914	Cum. Site 8	Rel. Cum. Base 2914	Rel. Cum. Site 8	Difference
1	56.889	48.000	56.9	48.0	0.00467	0.00352	0.001153
2	104.444	84.667	161.3	132.7	0.01324	0.00972	0.003523
3	112.779	81.667	274.1	214.3	0.02250	0.01571	0.006796
4	154.333	97.333	428.4	311.7	0.03517	0.02284	0.012334
5	188.778	146.667	617.2	458.3	0.05067	0.03359	0.017083
6	224.444	256.000	841.7	714.3	0.06909	0.05234	0.016749
7	238.889	261.667	1080.6	976.0	0.08871	0.07152	0.017186
8	239.111	343.667	1319.7	1319.7	0.10833	0.09670	0.011632
9	299.222	264.667	1618.9	1584.3	0.13290	0.11610	0.016801
10	174.889	229.333	1793.8	1813.7	0.14725	0.13290	0.014353
11	146.889	202.667	1940.7	2016.3	0.15931	0.14775	0.011561
12	146.778	276.333	2087.4	2292.7	0.17136	0.16800	0.003361
13	177.333	235.667	2264.8	2528.3	0.18592	0.18527	0.000649
14	135.889	225.000	2400.7	2753.3	0.19708	0.20176	-0.004683
15	146.667	232.333	2547.3	2985.7	0.20912	0.21878	-0.009668
16	174.556	187.000	2721.9	3172.7	0.22345	0.23249	-0.009041
17	184.222	217.000	2906.1	3389.7	0.23857	0.24839	-0.009819
18	217.667	272.333	3123.8	3662.0	0.25644	0.26834	-0.011907
19	316.111	320.000	3439.9	3982.0	0.28239	0.29179	-0.009405
20	358.667	373.333	3798.6	4355.3	0.31183	0.31915	-0.007319
21	510.333	478.333	4308.9	4833.7	0.35373	0.35420	-0.000476
22	542.222	521.000	4851.1	5354.7	0.39824	0.39238	0.005859
23	538.889	517.000	5390.0	5871.7	0.44248	0.43026	0.012212
24	530.333	566.333	5920.3	6438.0	0.48601	0.47176	0.014249
25	567.222	640.000	6487.6	7078.0	0.53258	0.51866	0.013915
26	519.556	570.333	7007.1	7648.3	0.57523	0.56045	0.014774
27	432.556	486.667	7439.7	8135.0	0.61074	0.59612	0.014621
28	373.333	451.333	7813.0	8586.3	0.64139	0.62919	0.012196
29	348.667	448.000	8161.7	9034.3	0.67001	0.66202	0.007991
30	276.556	346.000	8438.2	9380.3	0.69271	0.68737	0.005339
31	198.667	283.000	8636.9	9663.3	0.70902	0.70811	0.000911
32	194.889	296.333	8831.8	9959.7	0.72502	0.72982	-0.004805
33	200.333	239.000	9032.1	10198.7	0.74146	0.74734	-0.005873
34	186.667	295.333	9218.8	10494.0	0.75679	0.76898	-0.012190
35	178.111	253.000	9396.9	10747.0	0.77141	0.78752	-0.016108
36	190.444	265.333	9587.3	11012.3	0.78704	0.80696	-0.019917
37	196.000	272.333	9783.3	11284.7	0.80313	0.82692	-0.023783
38	189.667	232.333	9973.0	11517.0	0.81870	0.84394	-0.025238
39	208.333	281.667	10181.3	11798.7	0.83581	0.86458	-0.028776
40	208.222	259.333	10389.6	12058.0	0.85290	0.88359	-0.030686 *
41	305.111	292.000	10694.7	12350.0	0.87795	0.90498	-0.027036
42	284.111	211.000	10978.8	12561.0	0.90127	0.92044	-0.019174
43	253.667	233.667	11232.4	12794.7	0.92209	0.93757	-0.015473
44	265.111	211.333	11497.6	13006.0	0.94386	0.95305	-0.009195
45	258.333	211.333	11755.9	13217.3	0.96507	0.96854	-0.003474
46	172.778	176.000	11928.7	13393.3	0.97925	0.98144	-0.002187
47	132.556	149.667	12061.2	13543.0	0.99013	0.99240	-0.002273
48	120.222	103.667	12181.4	13646.7	1.00000	1.00000	0.000000

* $D_{max} = 0.0307$
$D_c = 1.36/\sqrt{13646.7} = 0.0116$

Table 25. K-S procedure for base curve 2814 versus site curve 9.

Obs.	Base 2814	Site 9	Cum. Base 2814	Cum. Site 9	Rel. Cum. Base 2814	Rel. Cum. Site 9	Difference
1	59.778	39.333	59.8	39.3	0.00532	0.00239	0.0029342
2	106.667	78.000	166.4	117.3	0.01481	0.00712	0.0076959
3	98.222	125.333	264.7	242.7	0.02356	0.01472	0.0088346
4	126.000	182.333	390.7	425.0	0.03477	0.02578	0.0089876
5	144.333	280.000	535.0	705.0	0.04762	0.04277	0.0048475
6	200.667	327.333	735.7	1032.3	0.06548	0.06263	0.0028496
7	200.444	377.000	936.1	1409.3	0.08332	0.08550	-0.0021810
8	227.778	377.667	1163.9	1787.0	0.10359	0.10841	-0.0048194
9	271.889	346.667	1435.8	2133.7	0.12779	0.12944	-0.0016511
10	165.000	259.000	1600.8	2392.7	0.14247	0.14515	-0.0026780
11	149.333	195.333	1750.1	2588.0	0.15576	0.15700	-0.0012368
12	174.444	193.333	1924.6	2781.3	0.17129	0.16873	0.0025606
13	193.222	188.000	2117.8	2969.3	0.18849	0.18013	0.0083528
14	138.444	217.333	2256.2	3186.7	0.20081	0.19332	0.0074902
15	154.889	207.667	2411.1	3394.3	0.21459	0.20592	0.0086775
16	163.889	219.000	2575.0	3613.3	0.22918	0.21920	0.0099784
17	173.667	248.667	2748.7	3862.0	0.24464	0.23429	0.0103498
18	221.667	260.333	2970.3	4122.3	0.26437	0.25008	0.0142856
19	325.333	292.333	3295.7	4414.7	0.29332	0.26782	0.0255066
20	353.000	390.333	3648.7	4805.0	0.32474	0.29149	0.0332449
21	479.222	571.667	4127.9	5376.7	0.36739	0.32617	0.0412167
22	505.889	630.000	4633.8	6006.7	0.41242	0.36439	0.0480231
23	481.889	688.000	5115.7	6694.7	0.45531	0.40613	0.0491748
24	495.667	670.333	5611.3	7365.0	0.49942	0.44680	0.0526246
25	542.556	714.000	6153.9	8079.0	0.54771	0.49011	0.0575985 *
26	461.778	743.667	6615.7	8822.7	0.58881	0.53523	0.0535834
27	394.111	602.000	7009.8	9424.7	0.62389	0.57175	0.0521399
28	331.556	576.667	7341.3	10001.3	0.65340	0.60673	0.0466657
29	324.667	520.000	7666.0	10521.3	0.68229	0.63828	0.0440160
30	260.778	393.333	7926.8	10914.7	0.70550	0.66214	0.0433643
31	192.556	301.333	8119.3	11216.0	0.72264	0.68042	0.0422218
32	190.889	308.333	8310.2	11524.3	0.73963	0.69912	0.0405064
33	183.667	289.000	8493.9	11813.3	0.75598	0.71665	0.0393210
34	195.556	268.667	8689.4	12082.0	0.77338	0.73295	0.0404272
35	182.667	239.333	8872.1	12321.3	0.78964	0.74747	0.0421659
36	186.000	278.667	9058.1	12600.0	0.80619	0.76438	0.0418150
37	194.222	277.667	9252.3	12877.7	0.82348	0.78122	0.0422566
38	174.333	278.333	9426.7	13156.0	0.83899	0.79811	0.0408876
39	219.000	249.667	9645.7	13405.7	0.85849	0.81325	0.0452331
40	193.667	303.000	9839.3	13708.7	0.87572	0.83163	0.0440884
41	239.444	489.000	10078.8	14197.7	0.89703	0.86130	0.0357344
42	203.889	451.667	10282.7	14649.3	0.91518	0.88870	0.0264807
43	191.667	419.667	10474.3	15069.0	0.93224	0.91416	0.0180804
44	197.556	414.000	10671.9	15483.0	0.94982	0.93927	0.0105480
45	202.556	378.667	10874.4	15861.7	0.96785	0.96225	0.0056042
46	151.000	241.333	11025.4	16103.0	0.98129	0.97689	0.0044031
47	113.556	206.667	11139.0	16309.7	0.99140	0.98942	0.0019724
48	96.667	174.333	11235.7	16484.0	1.00000	1.00000	0.0000000

* $D_{max} = 0.0576$
$D_c = 1.36/\sqrt{16484.0} = 0.0106$

Table 26. K-S procedure for base curve 289 versus site curve 14.

Obs.	Base 289	Site 14	Cum. Base 289	Cum. Site 14	Rel. Cum. Base 289	Rel. Cum. Site 14	Difference
1	47.778	75.333	47.8	75.33	0.00325	0.01245	-0.00920
2	92.889	119.333	140.7	194.67	0.00956	0.03216	-0.02260
3	116.000	72.000	256.7	266.67	0.01745	0.04406	-0.02661
4	151.222	106.667	407.9	373.33	0.02772	0.06168	-0.03395
5	206.222	94.333	614.1	467.67	0.04174	0.07726	-0.03552
6	279.222	91.667	893.3	559.33	0.06072	0.09241	-0.03169
7	300.556	76.667	1193.9	636.00	0.08115	0.10507	-0.02392
8	327.889	77.333	1521.8	713.33	0.10343	0.11785	-0.01441
9	366.000	64.333	1887.8	777.67	0.12831	0.12848	-0.00017
10	232.778	55.667	2120.6	833.33	0.14413	0.13767	0.00646
11	198.556	47.667	2319.1	881.00	0.15763	0.14555	0.01208
12	222.889	48.000	2542.0	929.00	0.17278	0.15348	0.01930
13	208.556	142.000	2750.6	1071.00	0.18695	0.17694	0.01001
14	197.444	40.333	2948.0	1111.33	0.20037	0.18360	0.01677
15	205.556	55.667	3153.6	1167.00	0.21434	0.19280	0.02155
16	220.222	50.000	3373.8	1217.00	0.22931	0.20106	0.02825
17	223.333	99.667	3597.1	1316.67	0.24449	0.21752	0.02697
18	252.444	168.000	3849.6	1484.67	0.26165	0.24528	0.01637
19	325.444	292.000	4175.0	1776.67	0.28377	0.29352	-0.00975
20	386.444	290.000	4561.4	2066.67	0.31004	0.34143	-0.03139
21	537.778	396.000	5099.2	2462.67	0.34659	0.40685	-0.06026
22	597.889	354.000	5697.1	2816.67	0.38722	0.46533	-0.07811
23	600.333	332.667	6297.4	3149.33	0.42803	0.52029	-0.09226
24	615.222	311.667	6912.7	3461.00	0.46984	0.57178	-0.10194
25	679.000	304.667	7591.7	3765.67	0.51600	0.62212	-0.10612 *
26	629.889	239.333	8221.6	4005.00	0.55881	0.66166	-0.10285
27	532.778	186.000	8754.3	4191.00	0.59502	0.69238	-0.09736
28	473.667	150.333	9228.0	4341.33	0.62721	0.71722	-0.09001
29	452.889	135.333	9680.9	4476.67	0.65800	0.73958	-0.08158
30	356.333	106.667	10037.2	4583.33	0.68222	0.75720	-0.07498
31	266.556	79.333	10303.8	4662.67	0.70033	0.77031	-0.06997
32	264.556	87.333	10568.3	4750.00	0.71832	0.78473	-0.06642
33	256.333	71.000	10824.7	4821.00	0.73574	0.79646	-0.06073
34	257.444	83.000	11082.1	4904.00	0.75324	0.81018	-0.05694
35	229.222	99.667	11311.3	5003.67	0.76882	0.82664	-0.05783
36	247.556	94.000	11558.9	5097.67	0.78564	0.84217	-0.05653
37	254.000	98.333	11812.9	5196.00	0.80291	0.85842	-0.05551
38	228.333	116.333	12041.2	5312.33	0.81843	0.87764	-0.05921
39	251.889	151.000	12293.1	5463.33	0.83555	0.90258	-0.06704
40	263.444	93.667	12556.6	5557.00	0.85345	0.91806	-0.06461
41	360.889	124.667	12917.4	5681.67	0.87798	0.93865	-0.06067
42	318.444	108.000	13235.9	5789.67	0.89963	0.95650	-0.05687
43	307.444	72.333	13543.3	5862.00	0.92052	0.96845	-0.04792
44	314.889	62.000	13858.2	5924.00	0.94192	0.97869	-0.03676
45	312.556	48.667	14170.8	5972.67	0.96317	0.98673	-0.02356
46	219.222	36.667	14390.0	6009.33	0.97807	0.99279	-0.01472
47	174.556	23.667	14564.6	6033.00	0.98993	0.99670	-0.00676
48	148.111	20.000	14712.7	6053.00	1.00000	1.00000	0.00000

* $D_{max} = 0.1061$
$D_c = 1.36/\sqrt{6053.0} = 0.0175$

APPENDIX D - Confidence Limits for Testing for Skewness and Regression Procedures for 1-, 2-, 3-, and 4-hour Expansion Models

This appendix contains confidence limits for testing for skewness. A two-failed test was used in this study at the 2 percent confidence level.

The regression procedures are given for only the middle count intervals for all expansion models.

Table 27. Confidence limits for testing for skewness (B1) and kurtosis (B2).

N	β_1		β_2			
	Upper and lower limits		*Lower limits*		*Upper limits*	
(two-tailed test)	10%	2%	2%	10%	10%	2%
(one-tailed test)	5%	1%	1%	5%	5%	1%
25	.51	1.13	–	–	–	–
30	.44	.97	–	–	–	–
35	.39	.85	–	–	–	–
40	.34	.76	–	–	–	–
45	.31	.68	–	–	–	–
50	.29	.62	1.95	2.15	3.99	4.88
75	.20	.42	2.08	2.27	3.87	4.59
100	.15	.32	2.18	2.35	3.77	4.39
125	.12	.26	2.24	2.40	3.70	4.24
150	.10	.22	2.29	2.45	3.65	4.14
175	.09	.18	2.33	2.48	3.61	4.05
200	.08	.16	2.37	2.51	3.57	3.98
250	.06	.13	2.42	2.55	3.52	3.87

SOURCE: Modified from Pearson (1930). A further development of tests of normality, *Biometrika*, 22, 239–48.

Note that the distribution of β_1 is symmetrical so that a single confidence interval is given. However the distribution of β_2 is asymmetrical for samples less than 1,000, hence lower and upper limits are given.

Also note that the sample β_1 will always be a positive value. However, when negative skewness is present (π_3 is negative) one can attach a minus sign both to the sample β_1 and (where appropriate) to the critical values in this table to obtain the lower limit to the region where H_0 is accepted.

Table 28. Regression procedure for 1-hour versus middle 5-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 408

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 366 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED60

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	61.76934260	61.76934260	1233.68	0.0001
ERROR	364	18.22522714	0.05006931		
CORRECTED TOTAL	365	79.99456974			

R-SQUARE	C.V.	ROOT MSE	PED60 MEAN
0.772169	11.0602	0.22376172	2.02312572

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED5M	1	61.76934260	1233.68	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED5M	1	61.76934260	1233.68	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.29905423	54.81	0.0001	0.02370178
PED5M	0.78616355	35.12	0.0001	0.02238269

Table 29. Regression procedure for 1-hour versus middle 10-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 408

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 396 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED60

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	80.94453889	80.94453889	2521.15	0.0001
ERROR	394	12.64982074	0.03210614		
CORRECTED TOTAL	395	93.59435963			

R-SQUARE	C.V.	ROOT MSE	PED60 MEAN
0.864844	9.0726	0.17918187	1.97497259

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED10M	1	80.94453889	2521.15	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED10M	1	80.94453889	2521.15	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.99217479	46.05	0.0001	0.02154509
PED10M	0.84651202	50.21	0.0001	0.01685906

Table 30. Regression procedure for 1-hour versus middle 15-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 408

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 399 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED60

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	86.50836095	86.50836095	3832.27	0.0001
ERROR	397	8.96174564	0.02257367		
CORRECTED TOTAL	398	95.47010658			

R-SQUARE	C.V.	ROOT MSE	PED60 MEAN
0.906130	7.6305	0.15024535	1.96901669

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED15M	1	86.50836095	3832.27	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED15M	1	86.50836095	3832.27	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.75976418	36.30	0.0001	0.02093201
PED15M	0.89963078	61.91	0.0001	0.01453237

Table 31. Regression procedure for 1-hour versus middle 30-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 408

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 404 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED60

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	96.97449936	96.97449936	11051.69	0.0001
ERROR	402	3.52740082	0.00877463		
CORRECTED TOTAL	403	100.50190018			

R-SQUARE	C.V.	ROOT MSE	PED60 MEAN
0.964902	4.7864	0.09367299	1.95705150

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED30M	1	96.97449936	11051.69	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED30M	1	96.97449936	11051.69	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.37514309	23.81	0.0001	0.01575276
PED30M	0.96250464	105.13	0.0001	0.00915563

Table 32. Regression procedure for 2-hour versus middle 5-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 204

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 190 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED120

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	30.28179386	30.28179386	521.81	0.0001
ERROR	188	10.91001601	0.05803200		
CORRECTED TOTAL	189	41.19180987			

R-SQUARE	C.V.	ROOT MSE	PED120 MEAN
0.735141	10.4086	0.24089832	2.31441871

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED5M	1	30.28179386	521.81	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED5M	1	30.28179386	521.81	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.63390686	47.31	0.0001	0.03453852
PED5M	0.76863817	22.84	0.0001	0.03364844

Table 33. Regression procedure for 2-hour versus middle 10-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 204

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 199 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED120

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	37.79926141	37.79926141	1043.96	0.0001
ERROR	197	7.13289519	0.03620759		
CORRECTED TOTAL	198	44.93215660			

R-SQUARE	C.V.	ROOT MSE	PED120 MEAN
0.841252	8.3232	0.19028292	2.28618510

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED10M	1	37.79926141	1043.96	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED10M	1	37.79926141	1043.96	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.32003483	40.24	0.0001	0.03280378
PED10M	0.82263499	32.31	0.0001	0.02546041

Table 34 . Regression procedure for 2-hour versus middle 15-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 204

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 203 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED120

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	40.80383038	40.80383038	1253.34	0.0001
ERROR	201	6.54375794	0.03255601		
CORRECTED TOTAL	202	47.34758832			

R-SQUARE	C.V.	ROOT MSE	PED120 MEAN
0.861793	7.9458	0.18043284	2.27079524

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED15M	1	40.80383038	1253.34	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED15M	1	40.80383038	1253.34	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.16591228	34.62	0.0001	0.03368060
PED15M	0.82412071	35.40	0.0001	0.02327855

Table 35. Regression procedure for 2-hour versus middle 30-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED120

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	44.30985375	44.30985375	2426.93	0.0001
ERROR	202	3.68803721	0.01825761		
CORRECTED TOTAL	203	47.99789096			

R-SQUARE	C.V.	ROOT MSE	PED120 MEAN
0.923163	5.9608	0.13512072	2.26683251

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED30M	1	44.30985375	2426.93	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED30M	1	44.30985375	2426.93	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.78799612	25.04	0.0001	0.03147413
PED30M	0.89176337	49.26	0.0001	0.01810179

Table 36. Regression procedure for 3-hour versus middle 5-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 136

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 119 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED180

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	17.77123378	17.77123378	348.42	0.0001
ERROR	117	5.96756044	0.05100479		
CORRECTED TOTAL	118	23.73879422			

R-SQUARE	C.V.	ROOT MSE	PED180 MEAN
0.748616	8.9276	0.22584240	2.52972425

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED5M	1	17.77123378	348.42	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED5M	1	17.77123378	348.42	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.77946719	39.36	0.0001	0.04521213
PED5M	0.78514462	18.67	0.0001	0.04206262

Table 37. Regression procedure for 3-hour versus middle 10-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 136

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 131 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED180

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	22.04972336	22.04972336	542.21	0.0001
ERROR	129	5.24600695	0.04066672		
CORRECTED TOTAL	130	27.29573031			

R-SQUARE	C.V.	ROOT MSE	PED180 MEAN
0.807809	8.1148	0.20165991	2.48509332

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED10M	1	22.04972336	542.21	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED10M	1	22.04972336	542.21	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.50721460	33.10	0.0001	0.04554182
PED10M	0.81838218	23.29	0.0001	0.03514586

Table 38. Regression procedure for 3-hour versus middle 15-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 136

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 132 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED180

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	23.79323491	23.79323491	763.18	0.0001
ERROR	130	4.05291741	0.03117629		
CORRECTED TOTAL	131	27.84615233			

R-SQUARE	C.V.	ROOT MSE	PED180 MEAN
0.854453	7.1213	0.17656808	2.47945142

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED15M	1	23.79323491	763.18	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED15M	1	23.79323491	763.18	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.24010237	26.15	0.0001	0.04742138
PED15M	0.88923911	27.63	0.0001	0.03218874

Table 39. Regression procedure for 3-hour versus middle 30-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED180

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	27.86520899	27.86520899	1212.61	0.0001
ERROR	134	3.07926611	0.02297960		
CORRECTED TOTAL	135	30.94447510			

R-SQUARE	C.V.	ROOT MSE	PED180 MEAN
0.900491	6.1789	0.15159023	2.45333463

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED30M	1	27.86520899	1212.61	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED30M	1	27.86520899	1212.61	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	0.97522719	21.97	0.0001	0.04439265
PED30M	0.89005392	34.82	0.0001	0.02555974

Table 40. Regression procedure for 4-hour versus middle 5-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 102

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 63 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED240

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	10.30153014	10.30153014	346.40	0.0001
ERROR	61	1.81407654	0.02973896		
CORRECTED TOTAL	62	12.11560669			

R-SQUARE	C.V.	ROOT MSE	PED240 MEAN
0.850269	6.4932	0.17244988	2.65586635

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED5M	1	10.30153014	346.40	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED5M	1	10.30153014	346.40	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.79537569	35.15	0.0001	0.05108422
PED5M	0.81131854	18.61	0.0001	0.04359166

Table 41. Regression procedure for 4-hour versus middle 10-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 102

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 98 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED240

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	17.13430291	17.13430291	613.92	0.0001
ERROR	96	2.67933446	0.02790973		
CORRECTED TOTAL	97	19.81363737			

R-SQUARE	C.V.	ROOT MSE	PED240 MEAN
0.864773	6.3963	0.16706207	2.61186691

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED10M	1	17.13430291	613.92	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED10M	1	17.13430291	613.92	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.65219530	39.11	0.0001	0.04224858
PED10M	0.76183363	24.78	0.0001	0.03074714

Table 42. Regression procedure for 4-hour versus middle 15-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE INFORMATION

NUMBER OF OBSERVATIONS IN DATA SET = 102

NOTE: ALL DEPENDENT VARIABLES ARE CONSISTENT WITH RESPECT TO THE PRESENCE OR ABSENCE OF MISSING VALUES. HOWEVER, ONLY 100 OBSERVATIONS CAN BE USED IN THIS ANALYSIS.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED240

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	19.34273132	19.34273132	966.07	0.0001
ERROR	98	1.96216712	0.02002211		
CORRECTED TOTAL	99	21.30489845			

R-SQUARE	C.V.	ROOT MSE	PED240 MEAN
0.907901	5.4539	0.14149952	2.59447968

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED15M	1	19.34273132	966.07	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED15M	1	19.34273132	966.07	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.43343716	35.89	0.0001	0.03994481
PED15M	0.80866817	31.08	0.0001	0.02601755

Table 43. Regression procedure for 4-hour versus middle 30-minute count interval.

SAS

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: PED240

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F
MODEL	1	20.15801564	20.15801564	891.40	0.0001
ERROR	100	2.26138217	0.02261382		
CORRECTED TOTAL	101	22.41939781			

R-SQUARE	C.V.	ROOT MSE	PED240 MEAN
0.899133	5.8293	0.15037893	2.57972994

SOURCE	DF	TYPE I SS	F VALUE	PR > F
PED30M	1	20.15801564	891.40	0.0001

SOURCE	DF	TYPE III SS	F VALUE	PR > F
PED30M	1	20.15801564	891.40	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT	1.19218437	24.43	0.0001	0.04880102
PED30M	0.81335926	29.86	0.0001	0.02724241

APPENDIX E - Validation of Expansion Models

This appendix contains tables showing the actual and predicted volumes and the percent error between these volumes for 5-, 10-, 15-, and 30-minute count intervals.

Tables 44 and 45 are for 1-hour predictions.
Tables 46 and 47 are for 2-hour predictions.
Tables 48 and 49 are for 3-hour predictions.
Tables 50 and 51 are for 4-hour predictions.

Table 44. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts.

	5-minute count interval			10-minute count interval		
Obs.	PED60	EXP5M	%ERROR	PED60	EXP10M	%ERROR
1	180	121.703	0.3239	180	144.727	0.19596
2	348	288.677	0.1705	348	283.009	0.18676
3	48	.	.	48	17.661	0.63206
4	86	81.448	0.0529	86	102.680	-0.19396
5	38	59.216	-0.5583	38	51.001	-0.34212
6	36	19.911	0.4469	36	24.893	0.30852
7	54	70.572	-0.3069	54	102.680	-0.90149
8	58	102.120	-0.7607	58	80.487	-0.38771
9	70	70.572	-0.0082	70	74.772	-0.06817
10	560	.	.	560	97.221	0.82639
11	316	444.858	-0.4078	316	409.490	-0.29585
12	660	530.167	0.1967	660	585.106	0.11348
13	131	81.448	0.3783	131	102.680	0.21618
14	143	158.557	-0.1088	143	179.737	-0.25690
15	51	70.572	-0.3838	51	57.104	-0.11968
16	40	19.911	0.5022	40	9.822	0.75445
17	64	47.229	0.2620	64	44.762	0.30060
18	130	140.460	-0.0805	130	129.258	0.00570
19	119	102.120	0.1419	119	86.130	0.27622
20	376	311.140	0.1725	376	323.191	0.14045
21	165	121.703	0.2624	165	174.817	-0.05950
22	244	193.195	0.2082	244	241.759	0.00918
23	68	121.703	-0.7897	68	102.680	-0.51001
24	88	81.448	0.0745	88	80.487	0.08537
25	139	131.173	0.0563	139	184.633	-0.32830

Table 44. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts (continued).

	5-minute count interval			10-minute count interval		
Obs.	PED60	EXP5M	%ERROR	PED60	EXP10M	%ERROR
26	87	91.94	-0.0568	87	108.09	-0.24238
27	138	121.70	0.1181	138	154.87	-0.12227
28	290	149.58	0.4842	290	353.82	-0.22008
29	192	193.19	-0.0062	192	134.45	0.29974
30	247	201.58	0.1839	247	189.51	0.23277
31	108	140.46	-0.3006	108	118.76	-0.09962
32	89	47.23	0.4693	89	51.00	0.42696
33	108	158.56	-0.4681	108	169.87	-0.57288
34	62	47.23	0.2382	62	57.10	0.07897
35	239	167.40	0.2996	239	264.82	-0.10803
36	135	59.22	0.5614	135	51.00	0.62222
37	239	112.03	0.5313	239	102.68	0.57037
38	764	318.53	0.5831	764	573.20	0.24974
39	394	325.87	0.1729	394	362.49	0.07999
40	551	193.19	0.6494	551	203.99	0.62978
41	113	121.70	-0.0770	113	118.76	-0.05096
42	132	176.11	-0.3342	132	144.73	-0.09641
43	81	59.22	0.2689	81	44.76	0.44739
44	61	140.46	-1.3026	61	97.22	-0.59379
45	388	193.19	0.5021	388	278.48	0.28226
46	233	176.11	0.2442	233	199.18	0.14513
47	328	281.08	0.1430	328	345.12	-0.05220
48	1207	593.30	0.5085	1207	667.31	0.44714
49	413	376.10	0.0894	413	345.12	0.16435
50	905	451.57	0.5010	905	709.63	0.21588

Table 44. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts (continued).

	5-minute count interval			10-minute count interval		
Obs.	PED60	EXP5M	%ERROR	PED60	EXP10M	%ERROR
51	126	158.56	-0.25839	126	134.45	-0.06706
52	101	131.17	-0.29874	101	86.13	0.14723
53	68	70.57	-0.03782	68	68.98	-0.01436
54	54	34.34	0.36412	54	24.89	0.53901
55	460	303.70	0.33978	460	422.14	0.08231
56	408	325.87	0.20130	408	396.77	0.02752
57	539	318.53	0.40904	539	362.49	0.32749
58	1401	587.07	0.58096	1401	759.06	0.45820
59	507	376.10	0.25819	507	463.81	0.08518
60	1501	841.60	0.43930	1501	1023.53	0.31810
61	117	102.12	0.12718	117	108.09	0.07618
62	59	91.94	-0.55835	59	74.77	-0.26732
63	146	218.09	-0.49374	146	199.18	-0.36427
64	56	70.57	-0.26021	56	44.76	0.20069
65	551	397.06	0.27938	551	413.71	0.24916
66	365	376.10	-0.03040	365	323.19	0.11454
67	642	458.26	0.28621	642	455.53	0.29045
68	1716	824.59	0.51947	1716	1269.12	0.26042
69	424	403.98	0.04722	424	413.71	0.02426
70	969	648.59	0.33066	969	647.91	0.33136
71	101	102.12	-0.01109	101	108.09	-0.07017
72	68	59.22	0.12918	68	108.09	-0.58952
73	154	131.17	0.14823	154	129.26	0.16066
74	61	112.03	-0.83652	61	91.71	-0.50338
75	678	417.73	0.38388	678	451.38	0.33424

Table 44. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts (continued).

	5-minute count interval			10-minute count interval		
Obs.	PED60	EXP5M	%ERROR	PED60	EXP10M	%ERROR
76	441	257.96	0.4151	441	383.98	0.12930
77	527	383.12	0.2730	527	331.99	0.37003
78	1639	1001.65	0.3889	1639	1175.51	0.28279
79	407	376.10	0.0759	407	383.98	0.05656
80	413	361.94	0.1236	413	353.82	0.14329
81	177	121.70	0.3124	177	129.26	0.26973
82	56	70.57	-0.2602	56	51.00	0.08927
83	229	265.73	-0.1604	229	241.76	-0.05572
84	78	70.57	0.0952	78	51.00	0.34615
85	537	325.87	0.3932	537	388.25	0.27700
86	388	296.22	0.2366	388	314.34	0.18984
87	456	555.65	-0.2185	456	585.11	-0.28313
88	1641	1257.55	0.2337	1641	1502.98	0.08411
89	367	376.10	-0.0248	367	492.58	-0.34219
90	414	288.68	0.3027	414	392.52	0.05189
91	166	112.03	0.3251	166	134.45	0.19006
92	93	19.91	0.7859	93	51.00	0.45161
93	477	265.73	0.4429	477	488.49	-0.02409
94	86	34.34	0.6007	86	91.71	-0.06635
95	363	265.73	0.2680	363	296.51	0.18316
96	300	361.94	-0.2065	300	340.76	-0.13585
97	489	484.74	0.0087	489	413.71	0.15396
98	1369	1023.16	0.2526	1369	1073.43	0.21590
99	361	296.22	0.1795	361	318.77	0.11697
100	547	599.51	-0.0960	547	573.20	-0.04789

Table 44. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts (continued).

	5-minute count interval			10-minute count interval		
Obs.	PED60	EXP5M	%ERROR	PED60	EXP10M	%ERROR
101	319	149.583	0.5311	319	218.291	0.31570
102	175	70.572	0.5967	175	91.706	0.47597
103	742	438.119	0.4095	742	480.292	0.35271
104	170	167.395	0.0153	170	149.815	0.11873
105	407	325.871	0.1993	407	388.253	0.04606
106	380	296.216	0.2205	380	392.517	-0.03294
107	417	234.256	0.4382	417	345.122	0.17237
108	1025	925.327	0.0972	1025	904.074	0.11798
109	459	234.256	0.4896	459	269.388	0.41310
110	481	383.118	0.2035	481	336.381	0.30066
111	171	91.942	0.4623	171	118.759	0.30551
112	92	184.705	-1.0077	92	159.900	-0.73805
113	271	281.085	-0.0372	271	264.820	0.02280
114	113	59.216	0.4760	113	91.706	0.18844
115	115	121.703	-0.0583	115	144.727	-0.25849
116	113	70.572	0.3755	113	113.446	-0.00394
117	128	70.572	0.4487	128	57.104	0.55388
118	222	121.703	0.4518	222	144.727	0.34808
119	441	318.529	0.2777	441	273.942	0.37882
120	174	140.460	0.1928	174	208.777	-0.19987

Table 45. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts.

	15-minute count interval			30-minute count interval		
Obs.	PED60	EXP15M	%ERROR	PED60	EXP30M	%ERROR
1	180	122.636	0.31869	180	157.12	0.12709
2	348	309.658	0.11018	348	319.40	0.08219
3	48	37.344	0.22200	48	42.40	0.11672
4	86	104.085	-0.21029	86	88.58	-0.02995
5	38	33.117	0.12850	38	42.40	-0.11573
6	36	37.344	-0.03733	36	36.26	-0.00717
7	54	88.975	-0.64769	54	58.61	-0.08542
8	58	85.154	-0.46818	58	74.65	-0.28710
9	70	88.975	-0.27107	70	70.66	-0.00937
10	560	173.081	0.69093	560	559.80	0.00036
11	316	410.775	-0.29992	316	368.29	-0.16549
12	660	642.251	0.02689	660	706.72	-0.07079
13	131	151.696	-0.15798	131	151.30	-0.15498
14	143	180.143	-0.25974	143	162.94	-0.13941
15	51	49.732	0.02486	51	44.44	0.12870
16	40	10.730	0.73175	40	38.31	0.04228
17	64	53.781	0.15967	64	64.65	-0.01008
18	130	151.696	-0.16689	130	145.47	-0.11902
19	119	162.428	-0.36494	119	149.36	-0.25513
20	376	378.497	-0.00664	376	377.67	-0.00443
21	165	173.081	-0.04898	165	164.87	0.00078
22	244	232.211	0.04832	244	255.00	-0.04509
23	68	88.975	-0.30846	68	82.62	-0.21499
24	88	77.454	0.11984	88	80.63	0.08374
25	139	158.859	-0.14287	139	159.06	-0.14433

Table 45. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts (continued).

	15-minute count interval			30-minute count interval		
Obs.	PED60	EXP15M	%ERROR	PED60	EXP30M	%ERROR
26	87	111.55	-0.28214	87	129.88	-0.49289
27	138	155.28	-0.12523	138	147.42	-0.06824
28	290	322.89	-0.11342	290	302.40	-0.04278
29	192	126.31	0.34215	192	182.25	0.05076
30	247	225.35	0.08765	247	245.48	0.00615
31	108	111.55	-0.03284	108	102.41	0.05172
32	89	41.52	0.53351	89	42.40	0.52362
33	108	129.97	-0.20340	108	118.14	-0.09390
34	62	73.57	-0.18664	62	66.65	-0.07502
35	239	259.44	-0.08550	239	245.48	-0.02712
36	135	92.78	0.31276	135	184.18	-0.36431
37	239	137.25	0.42572	239	264.51	-0.10673
38	764	690.96	0.09560	764	743.26	0.02715
39	394	368.75	0.06408	394	357.03	0.09382
40	551	218.47	0.60351	551	226.40	0.58912
41	113	107.82	0.04582	113	118.14	-0.04549
42	132	155.28	-0.17638	132	125.97	0.04566
43	81	49.73	0.38602	81	50.53	0.37617
44	61	85.15	-0.39597	61	70.66	-0.15829
45	388	404.34	-0.04212	388	402.00	-0.03607
46	233	276.29	-0.18578	233	234.04	-0.00446
47	328	319.59	0.02564	328	323.17	0.01473
48	1207	967.40	0.19851	1207	1248.66	-0.03451
49	413	375.25	0.09140	413	400.13	0.03117
50	905	864.55	0.04469	905	917.71	-0.01404

Table 45. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts (continued).

	15-minute count interval			30-minute count interval		
Obs.	PED60	EXP15M	%ERROR	PED60	EXP30M	%ERROR
51	126	126.31	-0.00244	126	120.10	0.04682
52	101	73.57	0.27157	101	90.56	0.10339
53	68	73.57	-0.08194	68	52.56	0.22713
54	54	41.52	0.23115	54	40.36	0.25268
55	460	391.44	0.14904	460	379.54	0.17491
56	408	362.24	0.11215	408	394.52	0.03305
57	539	394.67	0.26777	539	550.57	-0.02146
58	1401	882.28	0.37025	1401	1184.21	0.15474
59	507	397.90	0.21519	507	495.06	0.02354
60	1501	1077.69	0.28202	1501	1334.39	0.11100
61	117	85.15	0.27219	117	82.62	0.29385
62	59	69.67	-0.18079	59	54.58	0.07496
63	146	169.54	-0.16122	146	133.79	0.08366
64	56	57.80	-0.03208	56	70.66	-0.26171
65	551	502.88	0.08734	551	552.41	-0.00257
66	365	322.89	0.11537	365	379.54	-0.03984
67	642	531.07	0.17279	642	524.69	0.18272
68	1716	1437.99	0.16201	1716	1505.23	0.12283
69	424	455.50	-0.07429	424	498.77	-0.17635
70	969	675.78	0.30260	969	854.27	0.11840
71	101	92.78	0.08141	101	122.06	-0.20851
72	68	85.15	-0.25227	68	84.61	-0.24422
73	154	148.10	0.03831	154	153.24	0.00491
74	61	85.15	-0.39597	61	70.66	-0.15829
75	678	568.39	0.16166	678	651.78	0.03867

Table 45. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts (continued).

	15-minute count interval			30-minute count interval		
Obs.	PED60	EXP15M	%ERROR	PED60	EXP30M	%ERROR
76	441	413.99	0.06125	441	413.20	0.06303
77	527	430.01	0.18405	527	478.37	0.09229
78	1639	1209.55	0.26202	1639	1538.95	0.06105
79	407	358.98	0.11798	407	390.77	0.03987
80	413	362.24	0.12290	413	357.03	0.13551
81	177	137.25	0.22457	177	157.12	0.11230
82	56	65.74	-0.17388	56	42.40	0.24290
83	229	245.87	-0.07365	229	237.85	-0.03867
84	78	53.78	0.31050	78	76.65	0.01735
85	537	401.12	0.25303	537	489.50	0.08845
86	388	342.63	0.11693	388	328.82	0.15252
87	456	549.76	-0.20562	456	491.35	-0.07753
88	1641	1465.90	0.10670	1641	1636.39	0.00281
89	367	430.01	-0.17168	367	441.18	-0.20212
90	414	468.18	-0.13088	414	435.59	-0.05214
91	166	151.70	0.08617	166	168.74	-0.01651
92	93	73.57	0.20890	93	74.65	0.19729
93	477	605.45	-0.26928	477	537.64	-0.12712
94	86	104.08	-0.21029	86	82.62	0.03931
95	363	355.72	0.02006	363	321.28	0.11492
96	300	329.49	-0.09829	300	300.51	-0.00172
97	489	378.50	0.22598	489	385.16	0.21235
98	1369	1235.16	0.09777	1369	1321.90	0.03440
99	361	322.89	0.10556	361	407.60	-0.12909
100	547	657.52	-0.20204	547	602.18	-0.10087

Table 45. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts (continued).

	15-minute count interval			30-minute count interval		
Obs.	PED60	EXP15M	%ERROR	PED60	EXP30M	%ERROR
101	319	312.97	0.01890	319	296.73	0.06980
102	175	126.31	0.27824	175	149.36	0.14651
103	742	540.42	0.27167	742	712.21	0.04015
104	170	162.43	0.04454	170	180.33	-0.06074
105	407	391.44	0.03822	407	457.93	-0.12513
106	380	394.67	-0.03861	380	457.93	-0.20507
107	417	404.34	0.03035	417	452.35	-0.08476
108	1025	1034.31	-0.00909	1025	1083.68	-0.05724
109	459	336.07	0.26783	459	385.16	0.16087
110	481	332.78	0.30816	481	465.36	0.03251
111	171	158.86	0.07100	171	159.06	0.06981
112	92	137.25	-0.49187	92	114.22	-0.24149
113	271	221.91	0.18114	271	245.48	0.09417
114	113	107.82	0.04582	113	110.29	0.02400
115	115	122.64	-0.06640	115	137.69	-0.19727
116	113	104.08	0.07890	113	88.58	0.21615
117	128	118.95	0.07068	128	100.44	0.21530
118	222	140.88	0.36541	222	214.92	0.03191
119	441	232.21	0.47344	441	275.90	0.37438
120	174	173.08	0.00528	174	145.47	0.16395

Table 46. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts.

	5-minute count interval			10-minute count interval		
Obs.	PED120	EXP5M	%ERROR	PED120	EXP10M	%ERROR
1	496	572.66	-0.1546	496	538.99	-0.0867
2	1008	843.53	0.1632	1008	854.10	0.1527
3	179	192.06	-0.0730	179	214.87	-0.2004
4	229	252.64	-0.1032	229	235.45	-0.0282
5	89	124.92	-0.4036	89	150.19	-0.6876
6	76	212.82	-1.8003	76	204.41	-1.6896
7	118	212.82	-0.8036	118	150.19	-0.2728
8	188	100.14	0.4673	188	214.87	-0.1429
9	189	124.92	0.3390	189	103.56	0.4521
10	936	843.53	0.0988	936	807.50	0.1373
11	273	212.82	0.2204	273	214.87	0.2129
12	333	396.92	-0.1920	333	460.99	-0.3844
13	176	100.14	0.4310	176	115.58	0.3433
14	150	73.33	0.5111	150	78.52	0.4765
15	378	430.40	-0.1386	378	416.42	-0.1016
16	222	43.04	0.8061	222	51.58	0.7677
17	377	192.06	0.4906	377	265.63	0.2954
18	1054	542.06	0.4857	1054	930.58	0.1171
19	586	557.42	0.0488	586	704.44	-0.2021
20	798	430.40	0.4607	798	1659.21	-1.0792
21	239	252.64	-0.0571	239	204.41	0.1447
22	233	271.84	-0.1667	233	295.08	-0.2665
23	149	124.92	0.1616	149	115.58	0.2243
24	115	.	.	115	115.58	-0.0050
25	848	495.14	0.4161	848	614.63	0.2752

Table 46. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts (continued).

	5-minute count interval			10-minute count interval		
Obs.	PED120	EXP5M	%ERROR	PED120	EXP10M	%ERROR
26	641	542.06	0.15435	641	606.33	0.05409
27	867	857.01	0.01153	867	861.81	0.00599
28	2608	1437.06	0.44898	2608	1831.29	0.29782
29	920	857.01	0.06847	920	815.30	0.11380
30	2406	1662.04	0.30921	2406	2076.75	0.13685
31	218	232.99	-0.06875	218	235.45	-0.08006
32	127	212.82	-0.67576	127	172.32	-0.35683
33	300	362.57	-0.20855	300	342.83	-0.14277
34	117	73.33	0.37326	117	65.35	0.44144
35	1229	690.59	0.43809	1229	830.87	0.32395
36	806	761.25	0.05552	806	728.49	0.09616
37	1169	747.28	0.36075	1169	752.38	0.35639
38	3355	1716.84	0.48828	3355	2259.90	0.32641
39	831	495.14	0.40416	831	530.45	0.36167
40	1382	1089.99	0.21130	1382	1217.32	0.11916
41	343	463.11	-0.35018	343	398.30	-0.16124
42	149	73.33	0.50786	149	183.15	-0.22919
43	706	345.02	0.51130	706	398.30	0.43583
44	164	212.82	-0.29769	164	255.66	-0.55888
45	900	463.11	0.48543	900	555.99	0.38223
46	688	690.59	-0.00376	688	631.16	0.08262
47	945	290.64	0.69244	945	589.65	0.37603
48	3010	1962.54	0.34800	3010	1890.04	0.37208
49	728	327.20	0.55055	728	389.18	0.46541
50	961	587.78	0.38837	961	663.94	0.30912

Table 46. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts (continued).

	5-minute count interval			10-minute count interval		
Obs.	PED120	EXP5M	%ERROR	PED120	EXP10M	%ERROR
51	490	572.663	-0.16870	490	460.99	0.05920
52	267	362.566	-0.35792	267	265.63	0.00513
53	1013	572.663	0.43469	1013	647.59	0.36072
54	283	252.639	0.10728	283	255.66	0.09662
55	522	719.105	-0.37760	522	555.99	-0.06512
56	493	232.987	0.52741	493	370.79	0.24789
57	545	446.846	0.18010	545	469.79	0.13800
58	1247	747.284	0.40073	1247	581.28	0.53386
59	900	962.643	-0.06960	900	1028.04	-0.14227
60	655	495.143	0.24406	655	564.45	0.13825

Table 47. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts.

	15-minute count interval			30-minute count interval		
Obs.	PED120	EXP15M	%ERROR	PED120	EXP30M	%ERROR
1	496	570.08	-0.1494	496	589.14	-0.18778
2	1008	895.34	0.1118	1008	1028.70	-0.02053
3	179	207.94	-0.1617	179	218.80	-0.22237
4	229	228.30	0.0031	229	267.85	-0.16963
5	89	151.33	-0.7003	89	112.17	-0.26033
6	76	165.85	-1.1823	76	127.44	-0.67681
7	118	121.31	-0.0281	118	116.01	0.01688
8	188	180.11	0.0420	188	211.69	-0.12603
9	189	128.95	0.3177	189	161.03	0.14798
10	936	803.96	0.1411	936	744.14	0.20498
11	273	241.65	0.1148	273	200.97	0.26383
12	333	445.39	-0.3375	333	312.42	0.06180
13	176	113.57	0.3547	176	127.44	0.27592
14	150	72.84	0.5144	150	96.64	0.35571
15	378	318.87	0.1564	378	319.21	0.15554
16	222	143.95	0.3516	222	312.42	-0.40730
17	377	318.87	0.1542	377	445.26	-0.18107
18	1054	829.56	0.2129	1054	984.47	0.06596
19	586	731.34	-0.2480	586	623.63	-0.06421
20	798	1280.86	-0.6051	798	1380.74	-0.73026
21	239	248.27	-0.0388	239	236.46	0.01063
22	233	287.25	-0.2328	233	291.95	-0.25301
23	149	121.31	0.1858	149	92.72	0.37774
24	115	113.57	0.0125	115	123.64	-0.07515
25	848	624.80	0.2632	848	734.96	0.13330

Table 47. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts (continued).

	15-minute count interval			30-minute count interval		
Obs.	PED120	EXP15M	%ERROR	PED120	EXP30M	%ERROR
26	641	678.52	-0.05853	641	639.23	0.00277
27	867	834.66	0.03730	867	969.68	-0.11843
28	2608	1851.58	0.29004	2608	2058.08	0.21086
29	920	974.91	-0.05968	920	1013.98	-0.10215
30	2406	2147.61	0.10739	2406	2437.87	-0.01325
31	218	241.65	-0.10851	218	267.85	-0.22865
32	127	165.85	-0.30592	127	142.49	-0.12194
33	300	349.85	-0.16615	300	295.37	0.01542
34	117	81.31	0.30505	117	76.79	0.34366
35	1229	788.52	0.35840	1229	892.30	0.27396
36	806	731.34	0.09263	806	786.81	0.02381
37	1169	829.56	0.29037	1169	889.30	0.23926
38	3355	2030.31	0.39484	3355	2421.98	0.27810
39	831	586.61	0.29409	831	670.29	0.19340
40	1382	1077.30	0.22048	1382	928.11	0.32843
41	343	343.70	-0.00204	343	359.57	-0.04832
42	149	173.01	-0.16116	149	172.03	-0.15459
43	706	525.48	0.25569	706	607.98	0.13884
44	164	221.56	-0.35096	164	186.57	-0.13764
45	900	694.46	0.22838	900	648.56	0.27938
46	688	559.00	0.18750	688	554.41	0.19418
47	945	880.25	0.06852	945	795.92	0.15776
48	3010	2038.74	0.32268	3010	2187.34	0.27331
49	728	491.50	0.32486	728	611.11	0.16056
50	961	720.85	0.24990	961	771.60	0.19708

Table 47. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts (continued).

	15-minute count interval			30-minute count interval		
Obs.	PED120	EXP15M	%ERROR	PED120	EXP30M	%ERROR
51	490	433.701	0.114896	490	389.490	0.205122
52	267	241.655	0.094925	267	186.572	0.301227
53	1013	646.402	0.361893	1013	620.501	0.387462
54	283	241.655	0.146096	283	285.089	-0.007383
55	522	468.563	0.102369	522	412.565	0.209645
56	493	325.118	0.340531	493	332.728	0.325095
57	545	386.256	0.291273	545	346.183	0.364801
58	1247	630.216	0.494614	1247	676.477	0.457517
59	900	930.327	-0.033697	900	901.266	-0.001407
60	655	480.060	0.267084	655	425.680	0.350106

Table 48. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts.

	5-minute count interval			10-minute count interval		
Obs.	PED180	EXP5M	%ERROR	PED180	EXP10M	%ERROR
1	661	1338.86	-1.0255	661	1184.31	-0.79169
2	1252	1595.21	-0.2741	1252	1672.29	-0.33569
3	247	245.71	0.0052	247	310.92	-0.25879
4	317	477.89	-0.5075	317	534.23	-0.68528
5	228	212.94	0.0660	228	176.31	0.22669
6	163	60.19	0.6308	163	32.15	0.80275
7	256	142.59	0.4430	256	139.33	0.45575
8	478	423.41	0.1142	478	388.42	0.18740
9	381	307.98	0.1917	381	262.33	0.31146
10	1183	936.88	0.2080	1183	942.09	0.20364
11	347	366.94	-0.0575	347	357.88	-0.03134
12	322	530.71	-0.6482	322	433.28	-0.34558
13	257	178.72	0.3046	257	139.33	0.45787
14	177	423.41	-1.3922	177	294.93	-0.66625
15	1087	582.12	0.4645	1087	815.79	0.24951
16	776	530.71	0.3161	776	590.02	0.23967
17	1106	846.50	0.2346	1106	1003.83	0.09238
18	3372	1784.89	0.4707	3372	1898.92	0.43686
19	1314	1132.17	0.1384	1314	1003.83	0.23605
20	2957	1359.03	0.5404	2957	2015.23	0.31849
21	395	307.98	0.2203	395	326.74	0.17282
22	183	178.72	0.0234	183	326.74	-0.78545
23	529	395.46	0.2524	529	388.42	0.26574
24	195	337.81	-0.7324	195	278.73	-0.42941
25	1766	1257.31	0.2880	1766	1301.26	0.26316

Table 48. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts (continued).

	5-minute count interval			10-minute count interval		
Obs.	PED180	EXP5M	%ERROR	PED180	EXP10M	%ERROR
26	1194	776.95	0.34928	1194	1112.90	0.06792
27	1625	1153.28	0.29029	1625	966.89	0.40499
28	4996	3011.16	0.39729	4996	3282.80	0.34291
29	1198	1132.17	0.05495	1198	1112.90	0.07103
30	1796	1089.63	0.39330	1796	1028.29	0.42746
31	656	450.88	0.31269	656	644.65	0.01729
32	360	212.94	0.40849	360	278.73	0.22574
33	1490	1318.60	0.11503	1490	1381.74	0.07265
34	369	504.49	-0.36717	369	448.00	-0.21408
35	885	981.18	-0.10868	885	1124.87	-0.27104
36	793	892.01	-0.12485	793	1136.82	-0.43356
37	1034	705.66	0.31755	1034	1003.83	0.02918
38	2616	2782.04	-0.06347	2616	2546.88	0.02642
39	1261	705.66	0.44040	1261	790.02	0.37350
40	1202	1153.28	0.04053	1202	979.24	0.18533

Table 49. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts.

	15-minute count interval			30-minute count interval		
Obs.	PED180	EXP15M	%ERROR	PED180	EXP30M	%ERROR
1	661	1181.61	-0.78760	661	1003.41	-0.51802
2	1252	1837.93	-0.46800	1252	1833.33	-0.46432
3	247	441.41	-0.78709	247	440.75	-0.78441
4	317	523.15	-0.65031	317	472.00	-0.48896
5	228	146.59	0.35706	228	141.94	0.37745
6	163	32.19	0.80249	163	123.74	0.24085
7	256	158.38	0.38132	256	200.75	0.21581
8	478	441.41	0.07655	478	425.02	0.11083
9	381	472.27	-0.23955	381	435.52	-0.14308
10	1183	1089.79	0.07879	1183	1027.00	0.13186
11	347	314.99	0.09225	347	350.61	-0.01041
12	322	451.73	-0.40287	322	372.06	-0.15545
13	257	146.59	0.42961	257	159.85	0.37800
14	177	249.45	-0.40930	177	217.96	-0.23139
15	1087	1163.32	-0.07021	1087	1088.04	-0.00096
16	776	798.40	-0.02887	776	659.75	0.14980
17	1106	921.98	0.16639	1106	889.17	0.19605
18	3372	2755.33	0.18288	3372	3103.43	0.07965
19	1314	1080.55	0.17766	1314	1083.36	0.17552
20	2957	2465.61	0.16618	2957	2334.33	0.21057
21	395	271.51	0.31264	395	361.35	0.08518
22	183	249.45	-0.36309	183	257.48	-0.40698
23	529	431.07	0.18513	529	445.98	0.15694
24	195	249.45	-0.27921	195	217.96	-0.11772
25	1766	1628.87	0.07765	1766	1701.13	0.03673

Table 49. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts (continued).

	15-minute count interval			30-minute count interval		
Obs.	PED180	EXP15M	%ERROR	PED180	EXP30M	%ERROR
26	1194	1190.74	0.00273	1194	1116.07	0.06527
27	1625	1236.27	0.23922	1625	1277.91	0.21359
28	4996	3436.14	0.31222	4996	3765.24	0.24635
29	1198	1034.23	0.13670	1198	1059.92	0.11526
30	1796	1043.52	0.41898	1796	975.01	0.45712
31	656	903.11	-0.37669	656	821.69	-0.25257
32	360	368.31	-0.02310	360	435.52	-0.20976
33	1490	1549.62	-0.04002	1490	1846.48	-0.23925
34	369	472.27	-0.27986	369	518.41	-0.40490
35	885	1126.63	-0.27302	885	1227.34	-0.38682
36	793	1135.81	-0.43230	793	1227.34	-0.54771
37	1034	1163.32	-0.12506	1034	1213.50	-0.17360
38	2616	2943.64	-0.12524	2616	2722.25	-0.04061
39	1261	968.95	0.23160	1261	1045.83	0.17063
40	1202	959.58	0.20168	1202	1245.76	-0.03640

Table 50. Percent error (%ERROR) of expanded 5-minute (EXP5M) and 10-minute (EXP10M) counts.

	5-minute count interval			10-minute count interval		
Obs.	PED240	EXP5M	%ERROR	PED240	EXP10M	%ERROR
1	769	371.17	0.51733	769	673.71	0.12392
2	1341	1038.79	0.22536	1341	963.76	0.28131
3	355	230.40	0.35100	355	316.81	0.10757
4	379	651.33	-0.71855	379	717.26	-0.89252
5	467	230.40	0.50665	467	239.41	0.48735
6	298	230.40	0.22686	298	239.41	0.19661
7	495	500.20	-0.01050	495	456.53	0.07772
8	1242	371.17	0.70115	1242	568.39	0.54236
9	775	561.78	0.27513	775	568.39	0.26660
10	1734	766.49	0.55796	1734	1066.96	0.38468
11	457	468.75	-0.02571	457	405.94	0.11172
12	360	230.40	0.36001	360	175.79	0.51169
13	449	436.80	0.02717	449	439.87	0.02033
14	232	302.71	-0.30479	232	316.81	-0.36557
15	2077	1418.97	0.31682	2077	1264.66	0.39111
16	1447	1270.14	0.12223	1447	937.43	0.35216
17	2036	1142.95	0.43863	2036	1733.27	0.14869
18	5963	2828.67	0.52563	5963	3479.12	0.41655
19	1751	1295.22	0.26030	1751	1429.98	0.18334
20	3788	3117.40	0.17703	3788	3003.48	0.20711
21	833	.	.	833	924.17	-0.10945
22	416	.	.	416	521.38	-0.25331
23	1719	.	.	1719	1989.44	-0.15732
24	447	.	.	447	568.39	-0.27156
25	1422	.	.	1422	1028.64	0.27662
26	1181	.	.	1181	924.17	0.21746
27	1490	.	.	1490	1418.37	0.04807
28	4257	.	.	4257	2512.61	0.40977
29	1628	.	.	1628	1079.64	0.33683
30	1616	.	.	1616	1028.64	0.36346

Table 51. Percent error (%ERROR) of expanded 15-minute (EXP15M) and 30-minute (EXP30M) counts.

	15-minute count interval			30-minute count interval		
Obs.	PED240	EXP15M	%ERROR	PED240	EXP30M	%ERROR
1	769	703.33	0.08540	769	653.81	0.14980
2	1341	938.49	0.30016	1341	1205.29	0.10120
3	355	293.45	0.17339	355	362.85	-0.02210
4	379	652.10	-0.72057	379	498.90	-0.31636
5	467	255.37	0.45317	467	206.47	0.55787
6	298	202.36	0.32093	298	148.47	0.50179
7	495	378.17	0.23602	495	319.18	0.35519
8	1242	578.71	0.53405	1242	521.64	0.58000
9	775	535.78	0.30867	775	549.76	0.29063
10	1734	919.47	0.46974	1734	876.74	0.49438
11	457	469.79	-0.02799	457	510.30	-0.11663
12	360	268.20	0.25499	360	234.06	0.34985
13	449	480.94	-0.07113	449	475.91	-0.05994
14	232	280.89	-0.21074	232	240.83	-0.03807
15	2077	1577.09	0.24069	2077	1523.06	0.26670
16	1447	900.36	0.37778	1447	971.03	0.32894
17	2036	1864.83	0.08407	2036	1821.94	0.10514
18	5963	3711.59	0.37756	5963	3915.78	0.34332
19	1751	1214.16	0.30659	1751	1130.05	0.35463
20	3788	3131.62	0.17328	3788	3138.21	0.17154
21	833	966.85	-0.16068	833	659.17	0.20867
22	416	589.32	-0.41664	416	344.29	0.17238
23	1719	2103.27	-0.22354	1719	980.83	0.42942
24	447	578.71	-0.29465	447	344.29	0.22978
25	1422	957.42	0.32671	1422	1316.19	0.07441
26	1181	966.85	0.181331	1181	1163.11	0.015151
27	1490	1346.39	0.096382	1490	1509.78	-0.013274
28	4257	2599.66	0.389321	4257	3456.95	0.187939
29	1628	1169.33	0.281740	1628	846.49	0.480045
30	1616	1424.26	0.118650	1616	1256.40	0.222523

APPENDIX F - Warrant 3, Minimum Pedestrian Volume

A traffic signal may be warranted where the pedestrian volume crossing the major street at an intersection or mid-block location during an average day is:

100 or more for each of any 4 hours; or
190 or more during any 1 hour.

The pedestrian volume crossing the major street may be reduced as much as 50 percent of the values given above when the predominant pedestrian crossing speed is below 3.5 feet per second.

In addition to a minimum pedestrian volume of that stated above, there shall be less than 60 gaps per hour in the traffic stream of adequate length for pedestrians to cross during the same period when the pedestrian volume criterion is satisfied. Where there is a divided street having a median of sufficient width for the pedestrian(s) to wait, the requirement applies separately to each direction of vehicular traffic.

Where coordinated traffic signals on each side of the study location provide for platooned traffic which result in fewer than 60 gaps per hour of adquate length for the pedestrians to cross the street, a traffic signal may not be warranted.

This warrant applies only to those locations where the nearest traffic signal along the major street is greater than 300 feet and where a new traffic signal at the study location would not unduly restrict platooned flow of traffic. Curbside parking at nonintersection locations should be prohibited for 100 feet in advance of and 20 feet beyond the crosswalk.

A signal installed under this warrant should be of the traffic-actuated type with push buttons for pedestrians crossing the main street. If such a signal is installed within a signal system, it shall be coordinated if the signal system is coordinated.

Signals installed according to this warrant shall be equipped with pedestrian indications conforming to requirements set forth in other sections of this Manual.