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A COMPREHENSIVE STUDY OF HOURLY AND DAILY SEWAGE FLOW RATES IN FLORIDA PUBLIC SCHOOLS.

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A DETERMINATION OF THE HOURLY AND DAILY SEWAGE FLOW RATES IN FLORIDA PUBLIC SCHOOLS WAS MADE TO IDENTIFY THE FLOW CHARACTERISTICS AND TO PROVIDE A MORE PRECISE BASIS FOR THE ESTABLISHMENT OF DESIGN CRITERIA FOR SEWAGE DISPOSAL FACILITIES IN SCHOOLS. WATER FLOW DATA WAS COLLECTED FOR 158 SCHOOLS AND SEWAGE FLOW DATA FROM 42 SCHOOLS. THE FINDINGS SHOWED THAT DESIGN CRITERIA IN USE IN MANY STATES ARE EXCESSIVE. THE FOLLOWING CRITERIA WERE RECOMMENDED--(1) SCHOOLS WITH CAFETERIAS SHOULD DESIGN SEWAGE FACILITIES FOR A DAILY FLOW RATE OF 9.5 GALLONS FOR 100 PERCENT ATTENDENCE, (2) SCHOOLS WITH CAFETERIAS AND SHOWER FACILITIES SHOULD DESIGN SEWAGE FACILITIES FOR A DAILY FLOW RATE OF 11.5 GALLONS FOR 100 PERCENT ATTENDANCE. A BIBLIOGRAPHY IS PROVIDED. (JT)

A COMPREHENSIVE STUDY OF HOURLY AND DAILY SEWAGE FLOW RATES in FLORIDA PUBLIC SCHOOLS

Sponsored by The

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by M.E.Reeder* and W.J.Fogarty+

INTRODUCTION

The per pupil per day and hourly flow rates of sewage from public schools are the bases for establishing the design criteria governing the construction of individual school treatment facilities, the service fees to be charged schools by privately owned sewerage utilities, and load factors incurred in municipal treatment plants due to new school construction. The accurate quantification of these flow rates is vital for the safe, economical and equitable control of public health relative to schools.

A survey, conducted by the Florida State Board of Health in 1958, showed a wide variation in the recommended sewage flow rates used as a basis for sewerage design in public schools among the 43 state boards of health responding to their questionnaire. A summary of the range of values reported is shown in figure 1.

Figure 1 - SUMMARY OF RECOMMENDED DESIGN SEWAGE FLOW RATES IN PUBLIC SCHOOLS OF 43 STATES

	gallons per capita day		
	Classrooms only	Classrooms plus cafeteria	Classrooms plus cafeteria and gymnasium
Minimum reported	3	10	12
Maximum reported	20	25	40
Mean	12	16	20

From a review of the literature it appears that, historically, the various standards for sewage flow in schools

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have been established as direct functions of water consumption with little or no regard for leaks, lawn watering or other water uses not contributing to sewage flow. These factors are erratic in their occurance and extent, and their effects make uncontrolled water consumption a questionable, if conservative, estimate of sewage flow.

The purpose of this research was to accurately determine the sewage flow rates in Florida public schools and to identify the characteristics of these flows to provide a more precise basis for the establishment of the criteria governing sewerage design for schools.

The preferred basis for sewerage design criteria is the direct measurement of sewage flow, however, the means to accomplish this economically have not been available until recent years. The rapid expansion of metropolitan areas has resulted in schools being established in suburbia beyond the range of existing sewerage systems. Where septic tanks were inadequate to handle the sewage flow from these schools, collection wells were provided from which the sewage was pumped periodically to individual treatment facilities or through force mains to adjacent sewer lines. These collection wells, when instrumented with a liquid level sensing device, provide a simple but accurate means of measuring sewage flow.

A preliminary survey showed that there were many schools in the state served by collection wells, but they were insufficient in number to adequately reflect the overall characteristics of the state school system. In order to insure an adequate sample size for this research, it was decided to measure "controlled" water input at all schools tested and to measure simultaneously the corresponding sewage output at a subset of this group where sewage collection wells were provided. Based on these simultaneously recorded data a correlation factor was determined to convert the recorded "controlled" water input data to equivalent sewage output.

Idealy, controlled water input may be defined as that water input contributing solely to sewage flow. The mechanisms and effectiveness of this control are discussed in the sections entitled "Testing Procedures" and "Errors in Data Collection".

The justification of using controlled water input as a measure of sewage output was born out by subsequent statistical analyses of the test data which indicated a correlation of 98.9 percent. Statistically this infers that 97.8 percent of the variability in sewage flow is a function of the controlled water input. This indicates that controlled water input, as affected in this study, is in fact, an excellent measure of sewage flow.

Adjunct to the study of sewage flow rates, strength characteristic determinations were made of sewage samples from a subset of schools tested in the immediate vicinity of State Board of Health and University of Miami laboratories. These chemical analyses included Biochemical Oxygen Demand, grease and solids determinations. The testing procedures and results of this phase of the study are discussed in the section entitled "Chemical Characteristics".

SAMPLE SELECTION

In order to establish an overall profile of the identifiable characteristics of the public school system of the state, and to facilitate the selection of a representative sample of these schools, all county school systems were surveyed by questionnaire to determine for each school:

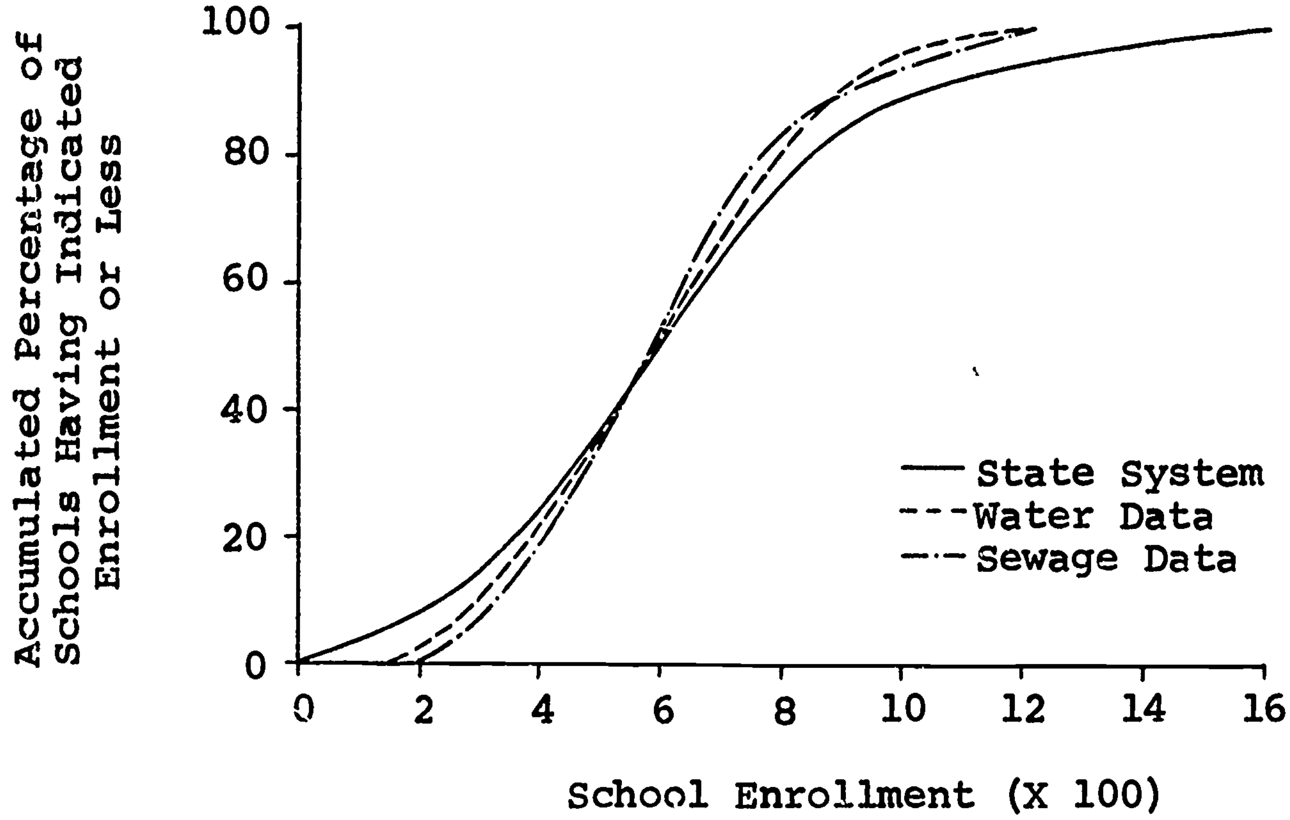
1. Enrollment
2. Grade levels
3. Location
4. Race
5. Date of construction
6. If served by cafeteria and/or shower facilities
7. If water system was metered and number of meters
8. If served by a central sewage collection well from which sewage was pumped periodically to a separate treatment facility or adjacent sewer line

Replies were received from 1667 schools comprising some 95 percent of the schools in the state. From these replies, a list was formed of schools having metered water service and constructed during the previous 7 years. Only schools having 1 or 2 meters were listed so as not to require a disproportionate number of water recording devices. The age limitation was imposed to reflect only the current practice of student/plumbing fixture ratios and the use of modern kitchen and dishwashing equipment.

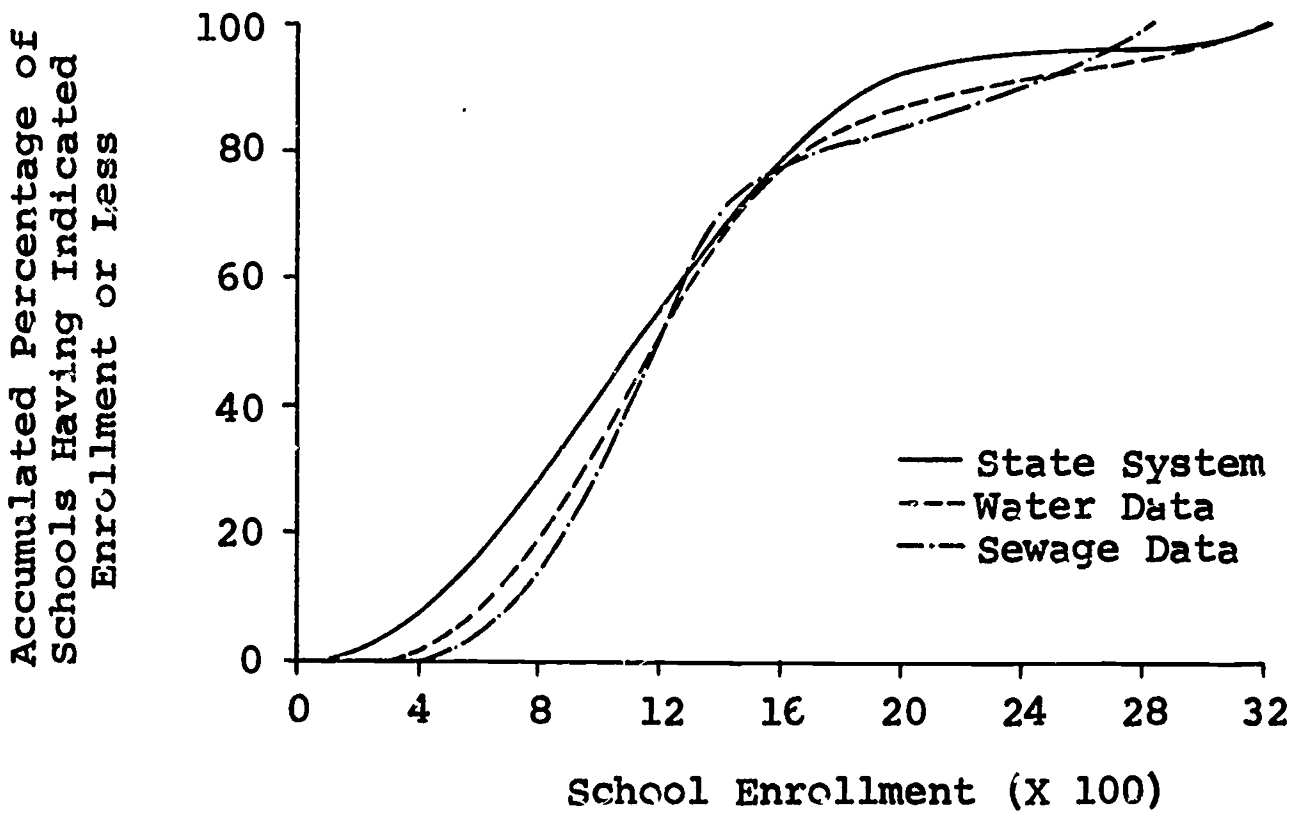
Schools to be tested for water input data were selected from this list. In so far as possible within the limitations imposed by the measuring and recording techniques and the optimization of the itinerary of the field crew, schools were selected with due regard for enrollment, grade level, race and

Figure 2 - COMPARSION OF DISTRIBUTION OF SCHOOL ENROLLMENTS

Schools Without Shower Facilities



Schools With Shower Facilities



location distributions. As the effect of showers on sewage flow was a parameter of major concern, schools with and without shower facilities were selected in equal number.

A subset of this sample group, having the additional requirement of schools with central sewage collection wells, was established to facilitate the correlation study of simultaneously recorded water input versus sewage output.

During the period of data collection the list of test schools was continuously adjusted to take advantage of new schools not included in the original questionnaire and to replace those schools where testing was invalidated for various reasons.

REPRESENTATIVENESS OF SAMPLE

During the 12 months of data collection, 5,480,000 gallons of water were metered for 743,000 student days and 1,590,000 gallons of sewage were metered for 221,000 student days. In all, 158 schools were tested for water flow data and 42 schools for sewage flow data for an average of 5 days at each school. These two groups of schools tested represent 9.0 and 2.4 percent of the public schools in the state, respectively.

The effectiveness of the sample selected in reflecting the characteristics of the state school system with respect to enrollment, grade level and race is shown in figures 2 through 4.

This study was conducted in 11 of the 67 counties of the state, representing 3 geographical sections, south-east, midwest, and north, each containing a major population center, Miami, Tampa-St. Petersburg and Jacksonville. These 11 counties have 54.3 percent of the schools and 63.9 percent of the student population of the state. The distribution of days of recorded data in each of the three geographic sections is compared with the student populations of these sections in figure 5.

INSTRUMENTATION

The volume of water input was measured by the existing commercial water meter(s) serving each school. The meters encountered were of various manufacture, but were generally of two basic types; the disc or displacement type used to meas-

Figure 3 - COMPARISON OF DISTRIBUTION OF DAYS OF RECORDED DATA AND STATE ENROLLMENTS BY GRADE GROUPING

Grade Group	Water Data		Sewage Data		
	Days of data	% of total in this group	Days of data	% of total in this group	% of state total in this group[a]
1-6	404	55.9%	99	47.8%	59.1%
7-9	203	28.2	56	27.0	25.2
10-12	115	15.9	52	25.1	15.7
Total	722	100.0	207	100.0	100.0

Figure 4 - COMPARISON OF DISTRIBUTION OF DAYS OF RECORDED DATA AND STATE ENROLLMENTS BY RACE

Race	Water Data		Sewage Data		
	Days of data	% of total in this group	Days of data	% of total in this group	% of state total in this group[a]
Negro	154	21.3%	46	22.2%	21.0%
White	568	78.7	161	77.8	79.0
Total	722	100.0	207	100.0	100.0

Figure 5 - COMPARISON OF DISTRIBUTION OF DAYS OF RECORDED DATA AND STUDENT ENROLLMENTS BY GEOGRAPHIC LOCATION

Geographic Section	County tested	Days of data[b]		% of total days of data recorded in this section	% of total enrollment of 3 sections in this section
		by County	by Section		
South-East	Dade	252	430	56%	44%
	Broward	127			
	Palm Beach	51			
Mid-West	Sarasota	37	243	32	32
	Manatee	25			
	Pinellas	99			
	Hillsborough	53			
	Polk	29			
North	Escambia	30	92	12	24
	Leon	31			
	Duval	31			
	Total	765	765	100	100

Notes: a - 1960-61 tabulation by Fla. State Dept. of Ed.
b - Days of recorded water and sewage data combined

ure low and intermediate flows, and the impeller or current type for high flows.

Typical performance curves for new meters indicate calibration errors of ±1.0 percent for all but very low flows. With continued use other factors may cause over or under-registration of the meter. Two important causes of these errors are excessive wear and deposit build-up occuring with most waters. Wear is normally a function of time and speed of operation and results in under-registration. Deposit build-up causes over-registration but according to the American Water Works Association Standards this error is limited and generally can not exceed +3.0 percent. These two types of errors are accumulative and tend to cancel, however, with time the error due to wear exceeds that due to deposits resulting in progressive under-registration.

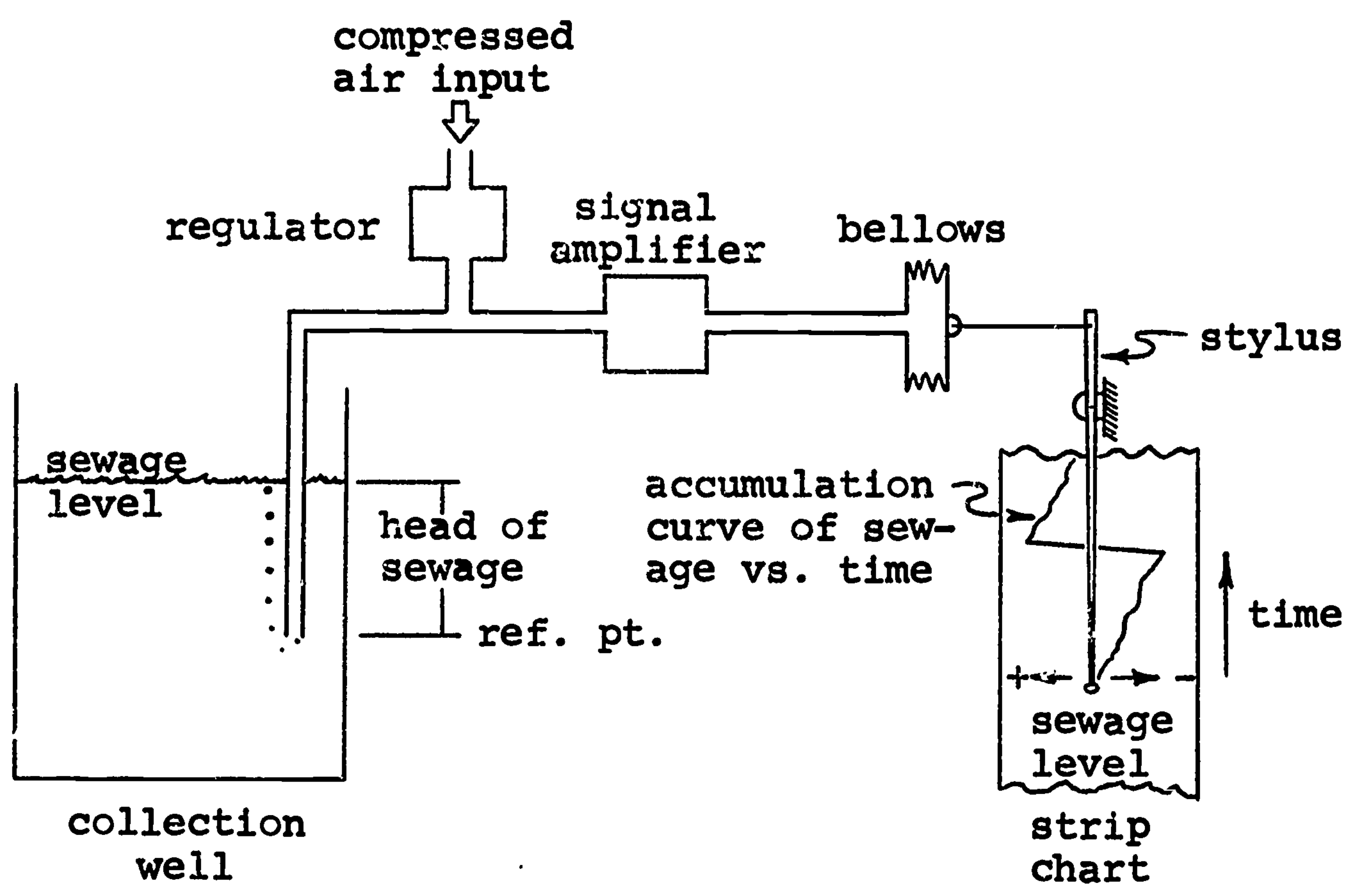
Due to varying conditions, the magnitudes of these under-registration errors were numerically indeterminate, however, they were assumed to be small for two reasons. First, the meters were relatively new and in good condition and second, they were found to have been conservatively sized for the flow rates encountered and over-speeding did not occur.

Water flow was recorded on a commercially available circular chart recorder that attached to the water meter in place of the totalizing register. The mechanism was a simple gear train operating a stylus that indicated water volume radially on a circular chart of pressure sensitive paper. The chart was rotated by a clock mechanism so that the resulting plot was an accumulation curve of water volume versus time. Where conditions did not permit installation of the recorder, water volume was determined by periodic reading of the totalizing register.

The level of sewage in the collection well was determined by a pressure sensing device that measured the head of sewage above a reference point in the well and recorded this information continuously on a strip chart. The total calibration error of all components of this system was set at ±1.5 percent by the manufacturer and period calibration checks of the device showed that it was a very stable system. A schematic diagram of this sewage level sensor and recorder is shown in figure 6.

Compressed air was pumped into the system at a constant rate, causing air to bubble out of the submerged end of the tube (reference point). As the collection well filled, the head of sewage above the reference point increased causing a corresponding increase in the pressure in the tube. As this change in pressure was insufficient to activate the stylus mechanism, the pressure signal was magnified by the signal amplifier. This amplified pressure increase caused the bellows to expand, moving the pen end of the stylus to the left. This motion of the pen combined with the time actuation of the strip chart plotted an accumulation curve of sewage level versus time. The sewage level was readily converted to sewage volume by multiplying by the cross sectional area of the well at any given installation.

Figure 6 - SCHEMATIC DIAGRAM OF SEWAGE LEVEL SENSOR AND RECORDER



The accumulation curve as plotted was segmented periodically due to pump down of the collection well. These pumping periods were relatively short in duration, however, during data analysis the indicated accumulated volume was adjusted by graphical extrapolation to include the normal sewage flow into the well during the time of pump down.

TESTING PROCEDURE

Prior to the start of testing in a county the field representative met with his liaison, appointed to assist him by the county school superintendent. Together they reviewed the selection of schools to be tested; adding to the list any new schools recently constructed and deleting other schools where difficulties in the operation of the water or sewage systems were known to exist. A physical reconnaissance of each school selected was then made to determine the adaptability of the water meter and/or the sewage pumping system to the installation of the flow monitoring equipment.

The standard procedure followed at each school is listed below:

1. At each school the principal was assessed of the purposed and procedures of the study. He was given a tabulation form and requested to report the actual attendance, meal and shower count at his school for each day of the five day test period.

2. With the consent of the principal, the custodial personnel were instructed not to water lawns, wash windows or otherwise use water that did not return to the school sewer system.

3. Water input data was recorded in either of two ways: (a) Continuous monitoring by a recording device attached to the existing water meter(s) serving each school. Or where conditions did not permit this method, by (b) visual reading of the totalizing register twice each day, prior to and following normal school hours.

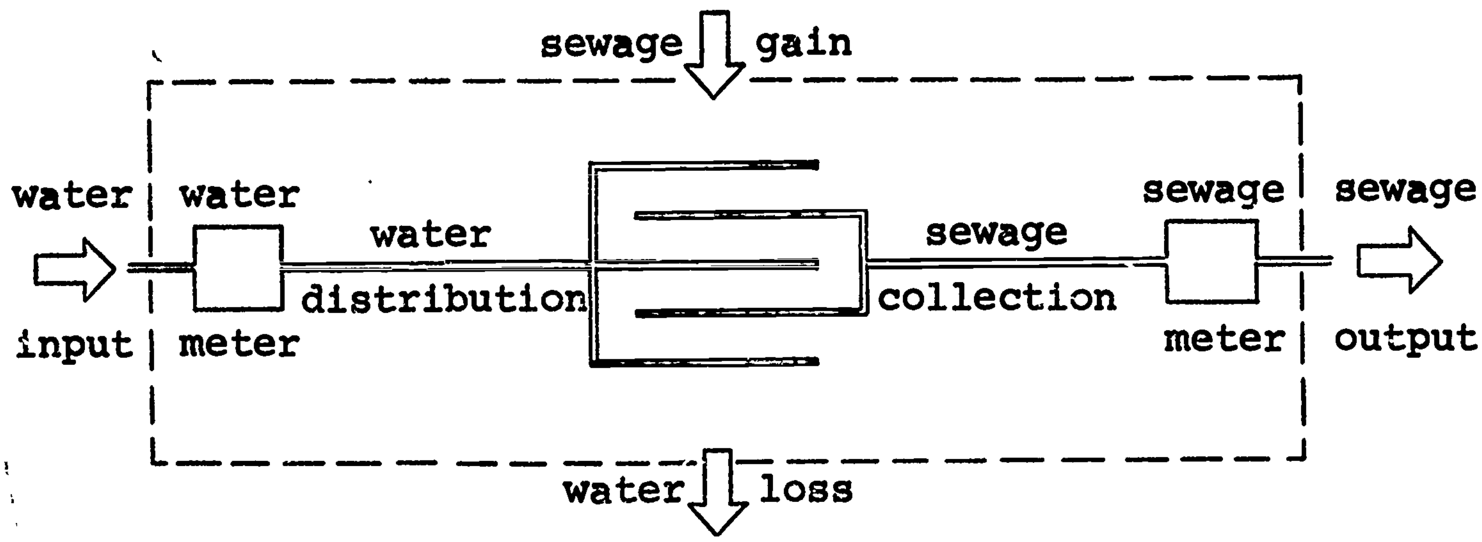
4. At those schools having a central sewage collection well, sewage output data was recorded simultaneously with water input. The sewage flow recorder was installed and operated as discussed previously in the section entitled "Instrumentation".

5. The dimensions of the collection well were determined from the "as built" plans and verified in the field.

ERRORS IN DATA COLLECTION

The over-all test system for this research is shown schematically in figure 7. It can be seen that by its very nature it is not a closed system. However, by imposing certain controls and adjustments the conditions of a closed system can be simulated.

Figure 7 - SCHEMATIC DIAGRAM OF A TYPICAL SCHOOL WATER-SEWAGE SYSTEM



The major sources of divergence from the ideal closed system and the compensating controls and adjustments imposed are as follows:

1. Leaks in the water distribution system;
   As this system was pressurized these leaks resulted in water loss (exfiltration). Where excessive night flow indicated leakage and the volume could be accurately determined, the daily water flow was adjusted accordingly. When accurate determination was impossible the data were abandoned. Minor leakage through various shutoff and flush valves was not adjusted as this was considered contributory to normal sewage flow.

2. Lawn watering, window or patio washing and other use of water (by custodial personnel) not returning to the school sewer system;
   This use of water was specifically suspended during the period of testing at each school by consent of the principal.

3. Water consumed and sewage contributed by students;
   It may logically be assumed that the effects of this item, extended over an entire school day and the total school population would be minor and tend to be self canceling.

4. Leaks in the sewage collection system;
   All identifiable leaks in the sewer lines resulted in sewage gain (infiltration). The major source of these leaks was rainwater runoff into manholes. Due to the non-uniformity of this inflow, adjustment was usually impossible and the data were abandoned. Other minor leaks were also assumed to be infiltration as the major portion of the testing was conducted in coastal areas and the attendant high water table would tend to negat exfiltration in a gravity system.

5. Back flow through sewage lift pumps;
   Back flow resulted from sporadic failure of the check valve on the pressure side of the pump to close following pump down. However, this condition was readily identifiable on the recorded sewage flow charts. Due to the non-uniformity of this back flow, adjustment was impossible and these data were abandoned.

The degree to which these controls, assumptions and adjustments are valid determine to a large extent the total error incurred in this study. Quantification of these errrors would be, at best, highly subjective, however, qualitatively it is significant that at any given installation each of these errors has an accumulative positive or negative effect.

Other sourses of error encountered in the total system are of a counting and measuring nature. These include: instrumental errors in the water meter and sewage level recorder; errors in visual reading of the totalizing register and chart interpretation; errors in counting attendance, number of meals served and students showering; and errors in determining the dimensions of the sewage collection well.

Generally it can be said that counting and measuring errors are of a random nature, are relatively small, may be either positive or negative and, in sufficient number, tend to be self canceling. During data collection concerted efforts were directed towards minimizing instrumental error and the occurance of mistakes. The sewage level recorders were calibrated periodically. Schools constructed within the previous seven years were selected for testing so that water meters were relatively new and accurate. Data was continually rechecked to the field and compared during analysis as a continuous check for mistakes. For these reasons it may be assumed that the counting and measuring errors incurred during this study were of a random nature.

The significant sources of both accumulative and random errors for water and sewage data are listed in figure 8 in the order of decreasing magnitude and with the appropriate sign(s).

Figure 8 - ACCUMULATIVE AND RANDOM ERRORS INCURRED IN DATA COLLECTION

Source of Error	Sign
Water Data	
1. Leaks (exfiltration)	+
2. Meter error	-
3. Attendance, shower and meal count	+ or -
4. Reading of meter or chart interpretation	+ or -
Sewage Data	
1. Leaks (infiltration)	+
2. Backflow through pumps	+
3. Attendance, shower and meal count	+ or -
4. Well dimensions	+ or -
5. Instrumental error and chart interpretation	+ or -

Accepting the applicability of figure 8, not necessarily to discrete data, but rather to the average of these data, it may be concluded that, whereas, the magnitude of the total error is indeterminate, its effect will be to cause the averages of these data to be conservative estimates of the parameters measured.

ANALYTICAL PROCEDURE

The analyses of the mass of data recorded during this study were performed on an IBM 7040 computer using standard statistical techniques. The order in which these analyses were conducted is as follows:

1. The correlation factor between water input and sewage output was determined.

2. Using this correlation factor, all recorded water flow data were converted to equivalent sewage flow. This equivalent sewage flow data was combined with the actual recorded sewage flow data to establish the statistic population upon which all further analyses were based.

3. The effect of the percentage of students eating meals prepared in the school cafeteria on sewage flow was determined.

4. Using the factor determined in 3 above, all data from schools without shower facilities were adjusted to 100 percent of students eating cafeteria prepared meals.

5. The effect of the percentage of students showering on sewage flow was determined.

6. Using the factors determined in 3 and 5 above, all data from schools with shower facilities were adjusted to 100 percent of students eating cafeteria prepared meals and 100 percent of students showering.

7. It was determined if sewage flow was significantly affected by variations in population, economic status, race, geographic location, type of cafeteria, day of the week, and month of the year.

8. The hourly rates of equivalent sewage flow were determined using only those schools having continuously recorded water input data.

9. The histograms and corresponding accumulation curves of hourly sewage flows were plotted for a typical 24 hour day.

10. The accumulation curves of maximum continuous sewage flow rates for consecutive hours were plotted for periods of 1 to 24 hours.

11. All significant sewage flow rates were reported as mean values plus two standard deviations, thereby statistically inferring, for normally distributed data, values that would not be exceeded 97.5 percent of the time.

RESULTS

In the course of this study the following parameters of the rate of sewage flow were considered:

1. Day of the week
2. Geographic location
3. Season of the year
4. Economic status
5. Race
6. Type of cafeteria facility
7. Enrollment
8. Percent of students eating cafeteria prepared meals
9. Percent of students showering

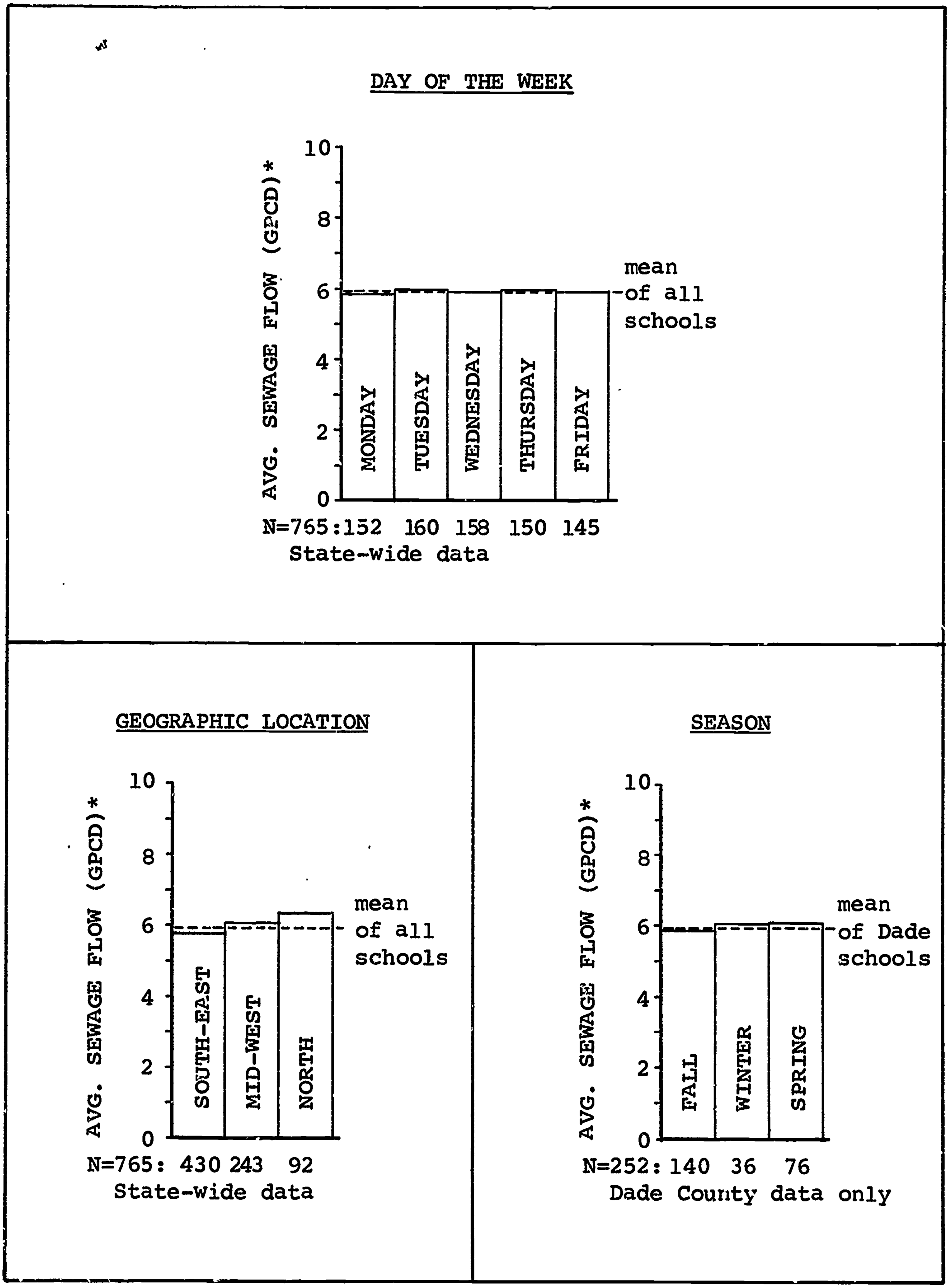
The comparative effects of the first six parameters on the average rate of sewage flow in gallons per capita day are shown in figures 9a and 9b. For purposes of these comparisons, all data were adjusted to 100 percent of students eating meals and 0 percent of students showering. In this way the effects of varying percentages of student meals and showers from school to school were minimized. These comparisons were based on 765 pieces of data recorded throughout the state with the exception of the seasonal comparisons. As Dade County was the only location where data were recorded during all three seasons, only these data were used for seasonal comparisons so as to eliminate geographic effects. Socio-economic data relative to individual school neighborhoods were not found to be available. For this reason, the comparison by economic status is based on the relative economic rank assigned each school neighborhood by the study field representative.

Study of figures 9a and 9b shows that day of the week, geographic location, season of the year, economic status, race and type of cafeteria have little or no significant effect on the average rate of sewage flow. For this reason further statistical analyses of these parameters were not deemed necessary.

Whereas, enrollment was initially considered to be a parameter of major concern, subsequent statistical analysis indicated that the effect of enrollment on the rate of sewage flow per capita day, was not significantly different than zero. Reference is made to figures 20 and 21 of the appendix, wherein, the gallons of sewage flow per capita day are plotted against enrollment. It can be seen that the straight line of best fit for these data is essentially horizontal, indicating that enrollment has little or no significant influence on the mean rate of sewage flow.

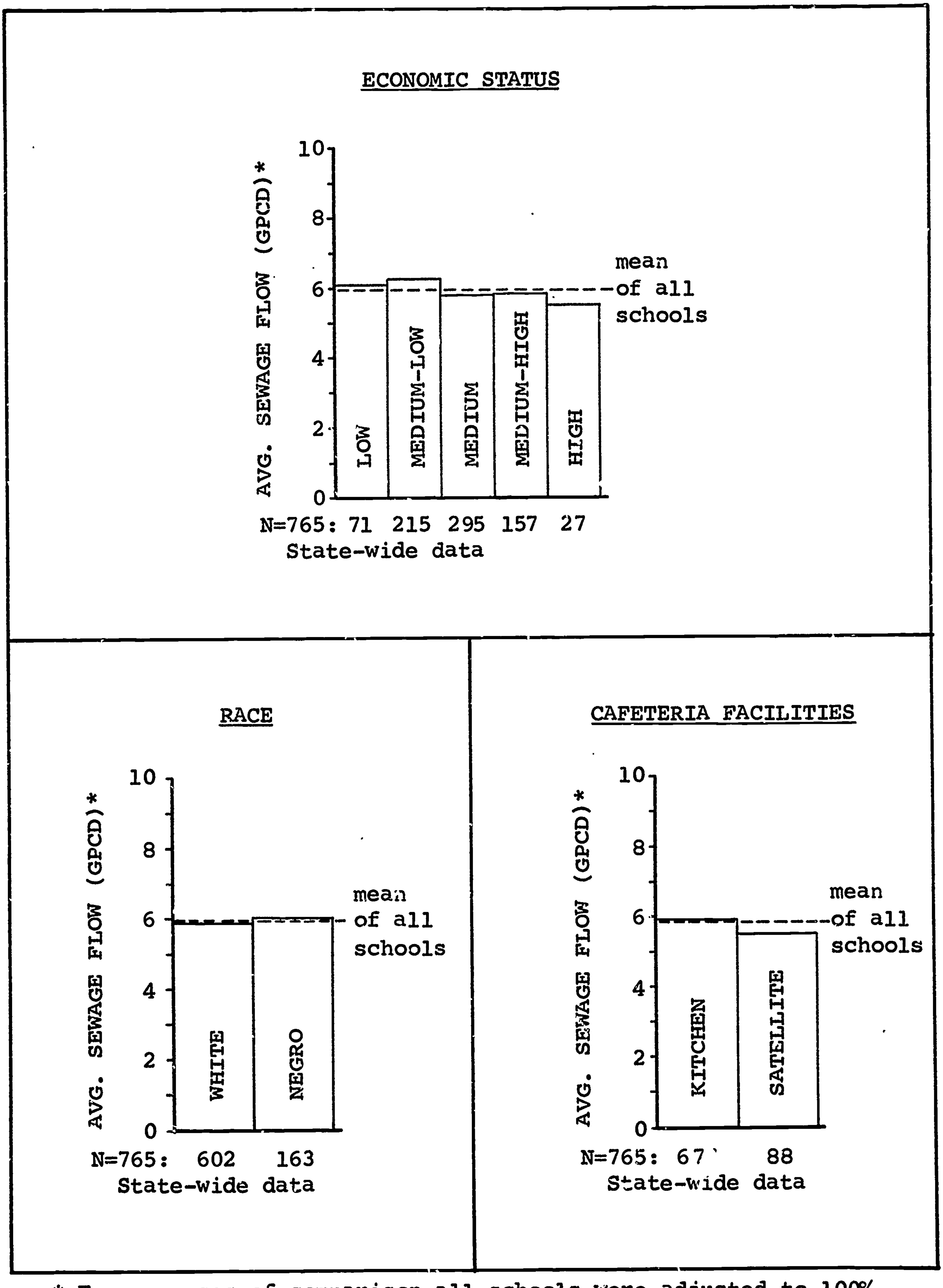
The range of effects on the gallons of sewage flow per capita day due to the percentages of students eating meals and showering are indicated by the slopes of the three lines shown on each of figures 16 and 17 of the appendix. The slope of the middle line represents the average gallons of sewage pro-

Figure 9a - THE COMPARATIVE EFFECTS OF VARIOUS PARAMETERS ON THE RATE OF SEWAGE FLOW



* For purposes of comparison all schools were adjusted to 100% of students eating meals and 0% of students showering.

Figure 9b - THE COMPARATIVE EFFECTS OF VARIOUS PARAMETERS ON THE RATE OF SEWAGE FLOW



* For purposes of comparison all schools were adjusted to 100% of students eating meals and 0% of students showering.

duced by one student-meal and by one student-shower. The slopes of the other two lines represent the limits between which these values fall statistically 95 percent of the time. These effects are summarized in figure 10.

Figure 10 - GALLONS OF SEWAGE PRODUCED PER STUDENT-MEAL AND PER STUDENT-SHOWER

	gals. of sewage produced per student meal	gals. of sewage produced per student shower
Mean value	0.47	1.51
Mean + 2 std. dev.	1.00	2.18
Mean - 2 std. dev.	-0.07*	0.67

* minus sign indicates that 2 std. dev. exceed the mean

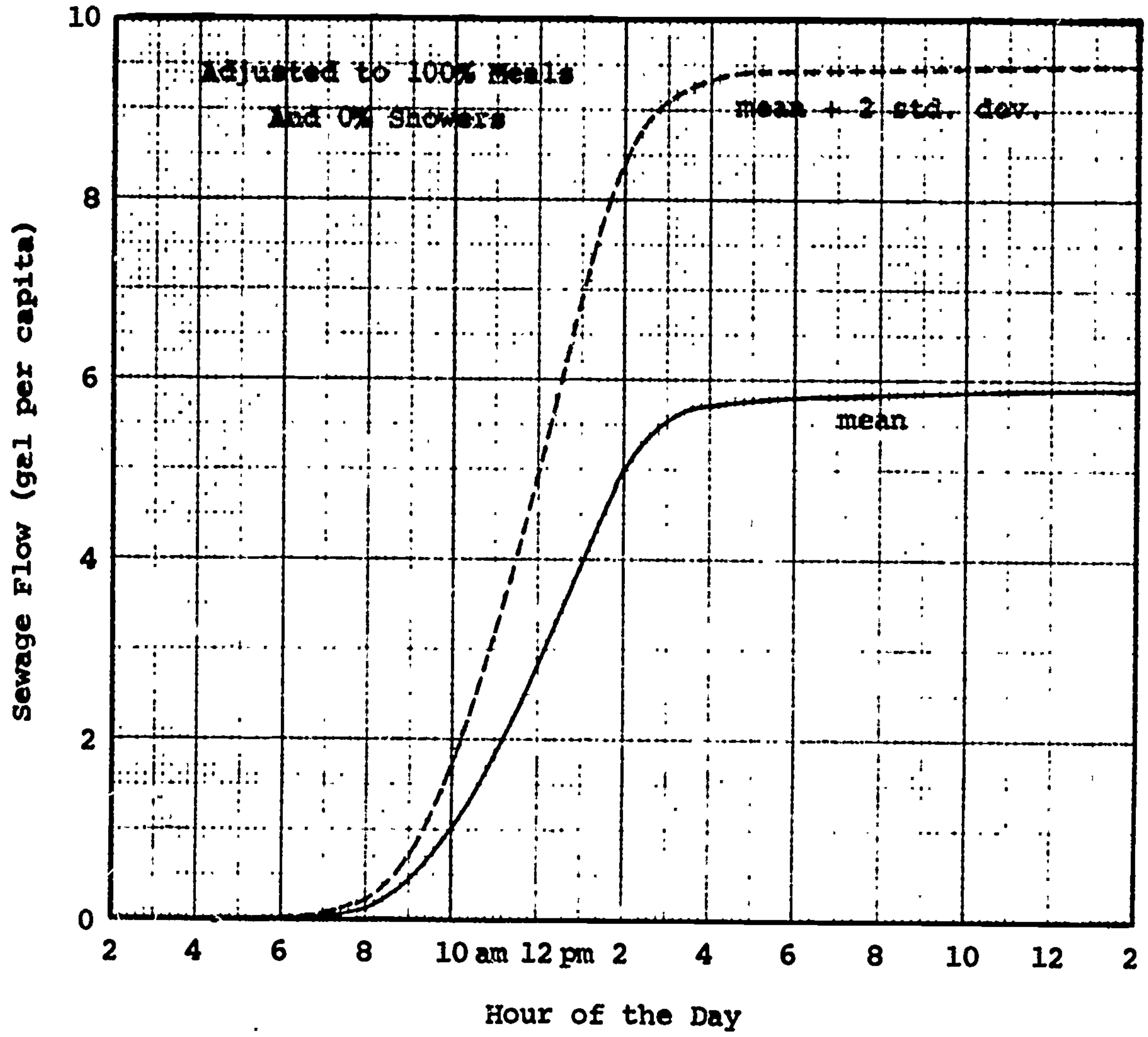
Two basic categories of schools were considered in this study; First, schools with cafeteria but without shower facilities, and secondly, schools with both cafeteria and shower facilities. Daily and hourly flow rates were analyzed statistically for schools in each of these categories. A condensation of the results of the analysis of daily flow rates is shown in tabular form in figure 11. The results of the analysis of hourly flow rates are presented graphically in figures 12 and 13. Figure 12 shows the accumulation curves of hourly flows in the chronological order of their occurance, whereas, figure 13 shows the accumulation of maximum continuous hourly flows in the selected order of decreasing magnitude.

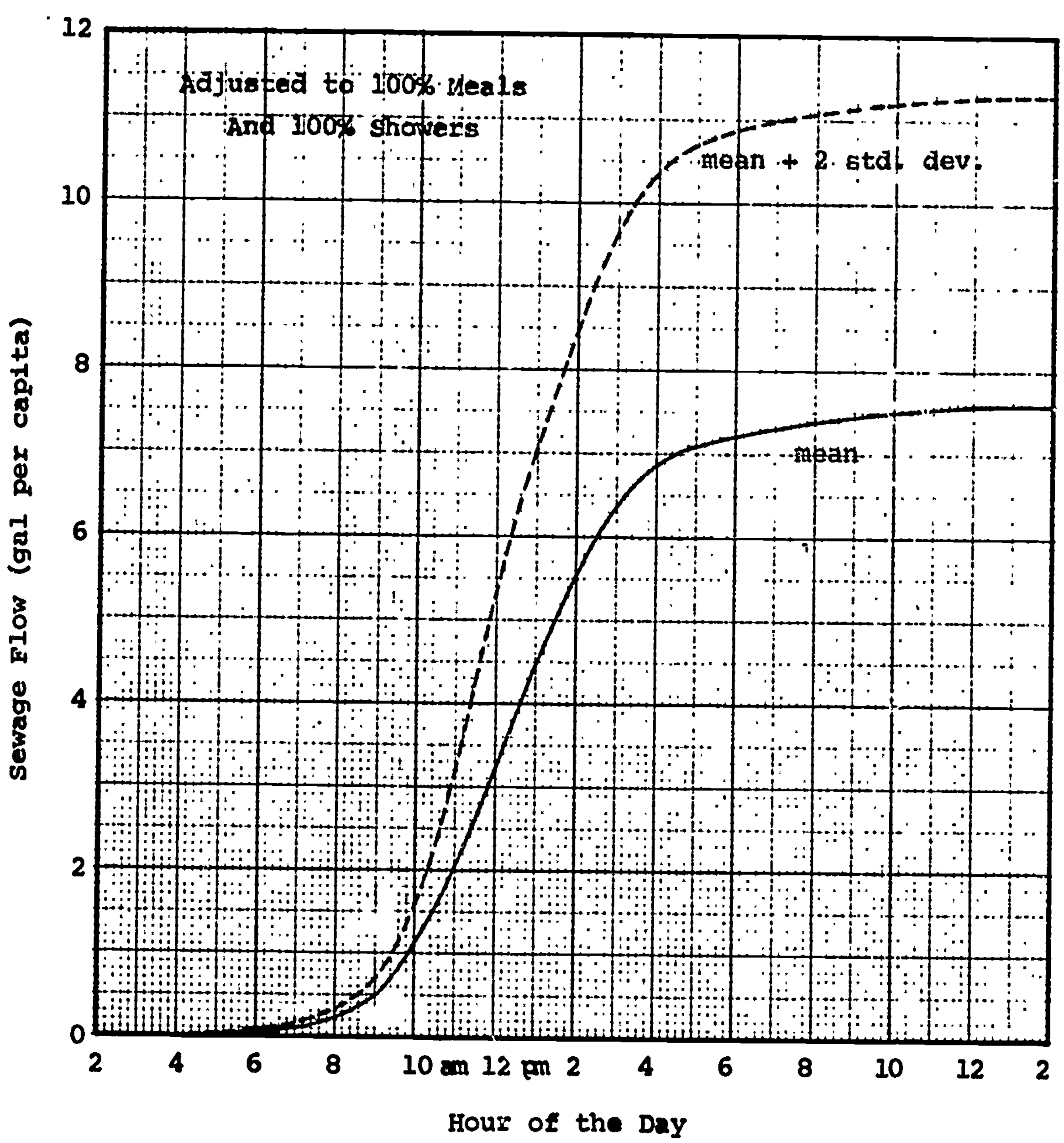
Figure 11 - A CONDENSATION OF THE RESULTS OF THE STATISTICAL ANALYSES OF DAILY SEWAGE FLOW RATES

	schools with cafeteria	
	without showers[1]	with showers[2]
Mean value (gpcd)	5.82	7.58
Mean + 2 std. dev. (gpcd)	9.16	11.32
No. of days of data	425	340
No. of days flow exceeded line 2	21	15
% of time line 2 not exceeded	95.1	95.6

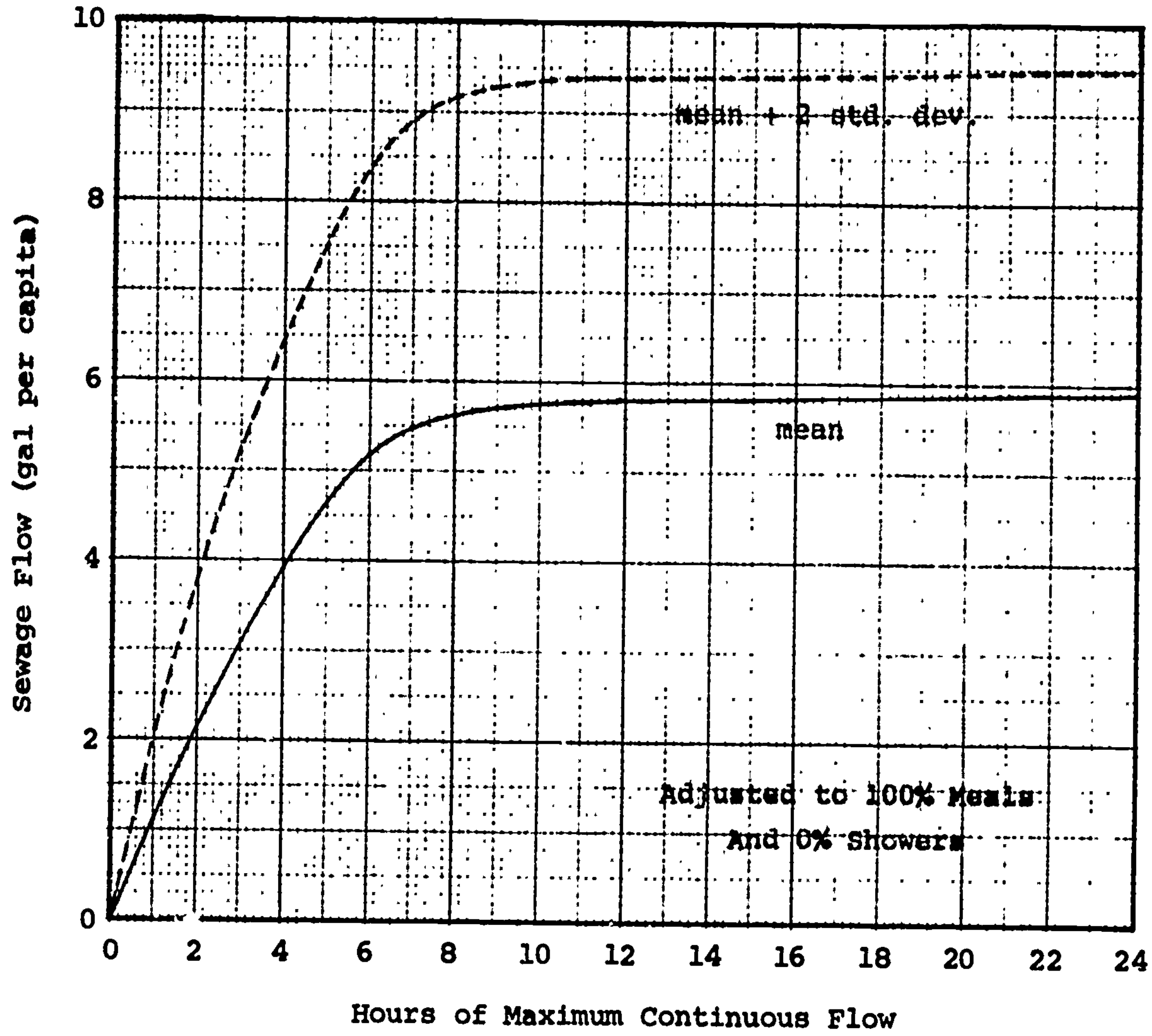
1 adjusted to 100% meals served
2 adjusted to 100% meals served and 100% of students showering

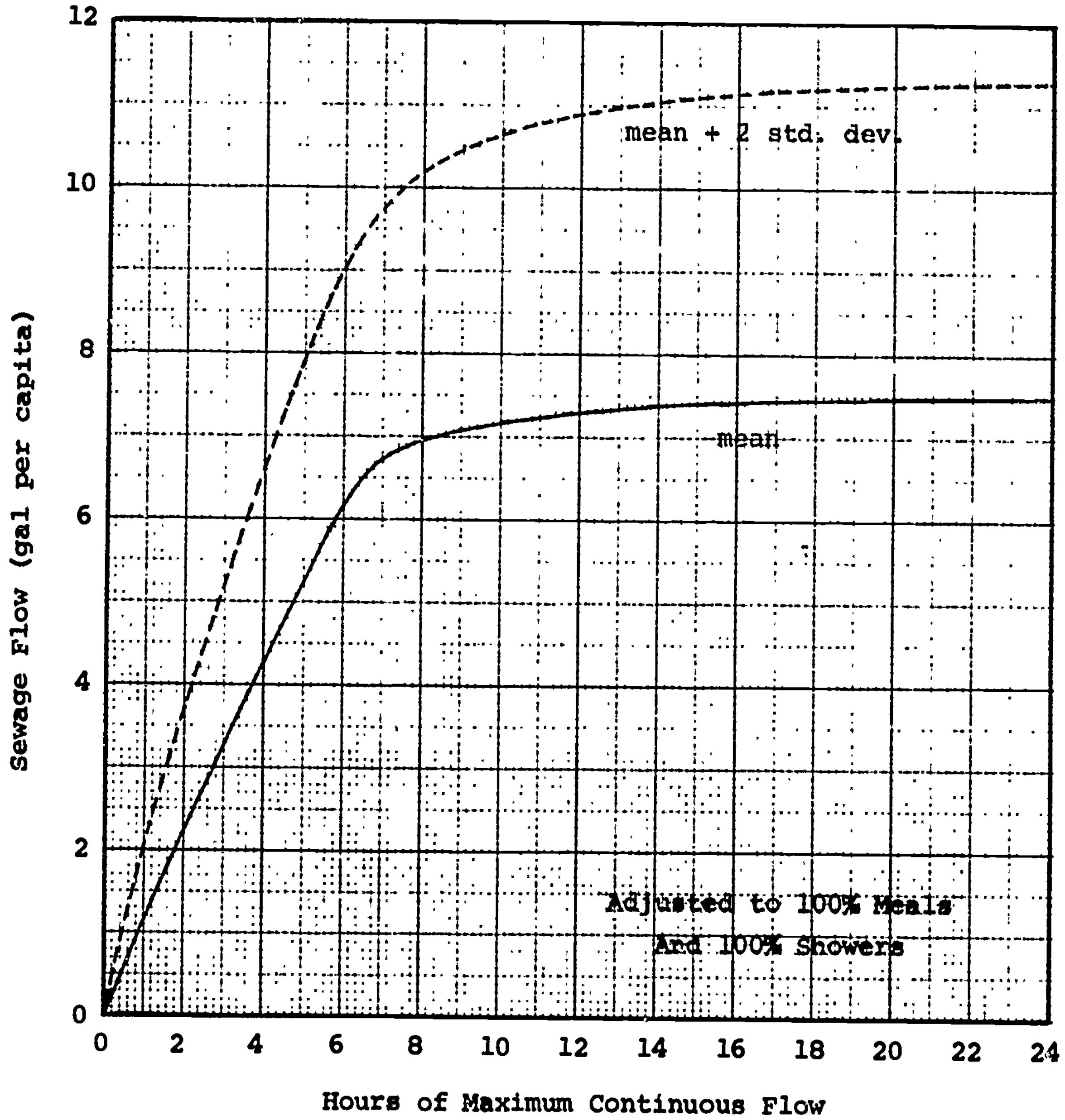
ACCUMULATION OF CONSECUTIVE HOURLY SEWAGE FLOWS - Figure 12





ACCUMULATION OF MAXIMUM CONTINUOUS SEWAGE FLOW - Figure 13





CHEMICAL CHARACTERISTICS

In order to further identify the characteristics of sewage flow unique to Florida public schools, sewage samples from 17 schools, for an average of 5 days at each school, were chemically analyzed for Biochemical Oxygen Demand, grease and solids contents. To insure the organic integrity of the sewage tested, sampling was limited to those schools in close proximity of Florida State Board of Health and University of Miami laboratories in Escambia, Leon, Duval and Dade Counties.

Several grab samples were combined to form a daily composite sample for each school. These samples were chemically analyzed in accordance with the 11th edition of "Standard Methods for Examination of Water and Waste Water". The means of the five daily values of BOD, grease content and volatile solids content were assumed to describe the sewage strength characteristics for each school. These mean values were statistically analyzed and the results are presented in the following table.

	B.O.D.	Grease	Volatile Solids
	pounds per capita day		
Mean value 2 std. dev.	0.0214 ±0.0216	0.0089 ±0.0072	0.0322 ±0.0353
N=	17	14	16

The mean value of B.O.D. found in this study was .021 pounds per capita per school day. Assuming the school day to be an average of 7 hours duration, the adjusted mean value of B.O.D. expressed in pounds per capita per 24 hour day would be .072. This is significantly less than the general range of values (.17 to .24) recommended by various authorities as design means for municipal sewage.

Because of the smallness of the sample size utilized (85 days of data) in relation to the wide variation of the values of daily samples, no recommendations of design criteria for sewage strength characteristics are made. However, the need for further study is clearly indicated.

RECOMMENDATIONS

Based on the results of this research the following criteria governing sewerage design for Florida public schools are recommended:

DAILY SEWAGE FLOW RATE

	Cafeteria	Cafeteria + Showers
gallons per capita day	9.5	11.5

CONTINUOUS HOURLY SEWAGE FLOW RATE

Duration of Continuous Flow	Cafeteria	Cafeteria + Showers
	gallons per capita	
1 hour	2.0	2.2
2	3.7	3.9
3	5.2	5.3
4	6.5	6.8
5	7.6	8.2
6	8.4	9.2
7	8.9	9.8
8	9.1	10.3
9	9.3	10.7
10	9.4	10.9
11	9.4	11.1
12	9.4	11.1
18	9.5	11.4
24	9.5	11.5

The above values are based on 100 percent of students eating meals and 100 percent of students showering. Whenever cafeteria or shower facilities are provided for the general enrollment the above values should be used. Where physical conditions are known to exist which will increase or decrease the actual 100 percent use of these facilities (i.e. parent cafeteria preparing meals for other schools, or combined elementary and junior high school where only the junior high students are authorized to shower) the following adjustment factors are recommended:

	Meals	Showers
For each student in excess of 100% of enrollment, ADD	+1.0 gal	+2.2 gal
For each student less than 100% of enrollment, SUBTRACT	0.0	-0.7

ACKNOWLEDGMENTS

The success of a study of this magnitude, encompassing data recorded at 158 schools, in 11 counties, over a period of 12 months depends, in large measure, on the cooperation and ready assistance of many individuals and organizations.

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Charles E. Cook, Florida State Board of Health
Ralph H. Baker, Florida State Board of Health

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Shelley S. Boone	Polk County
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Joe Hall	Dade County
Howell L. Watkins	Palm Beach County
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Dave G. Knowles

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"Tentative AWWA Standard for Cold-Water Meters - Displacement Type", American Water Works Association, 2 Park Ave., New York 16, N.Y., 1961.

Company Publications: Descriptive literature and performance curves for the family of meters produced by the following manufacturers:

Badger Meter Manufacturing Company
Buffalo Meter Company, Inc.
Gamon Meter Division of Worthington Corp.
Hersey-Sparling Meter Company
Neptune Meter Company

APPENDIX

The results of the various statistical analyses performed in this study are presented as distributions and curves in figures 14 through 23 of this appendix. The distribution plots are print-outs of the IBM 7040 computer and, as such, are digitized representations of these data. For this reason many pieces of data appear to plot at the same address. To facilitate the interpretation of these distributions the following symbols were used to indicate the number of pieces of data plotted at any given point:

Number of pieces of data	0	1	2	3	4	5	6	7	8	9
0		*	2	3	4	5	6	7	8	9
10	A	B	C	D	E	F	G	H	I	J
20	K	L	M	N	O	P	Q	R	S	T
30	U	V	W	X	Y	Z	+	+	+	+
40	+	+	+	+	+	+	+	+	+	+

Generally, in interpreting the following curves, a heavy solid line represents the curve of best fit passing through the X and Y mean as indicated by a small circle. Two light solid lines passing through the X and Y mean indicate ± 2 standard errors in the slope of the line of best fit.

The following abbreviations were used in preparing the various figures in this appendix:

gal : gallons
gpch : gallons per capita hour
gpcd : gallons per capita day
std dev: standard deviation

DISCUSSION

Figure 14 is a plot of the gallons of sewage output resulting from the simultaneously measured gallons of water input at 37 schools for a total of 152 days. The validity of using water input as a measure of sewage output, as affected in this study, is clearly indicated by the excellent correlation of 98.9 percent. The slope of the best fitting straight line for these data (.869) represents the mean value of the sewage-water ratio used to convert measured water input to equivalent sewage output.

Figure 15 shows that the sewage-water ratio determined above is not significantly affected by variations in student population. This is demonstrated by the straight line of best fit approximating zero slope and further amplified by the poor correlation of 12.3 percent.

Figure 16 shows the effect, of the percent of students eating meals, on the daily rate of sewage flow in gallons per capita. Note that the percentage of students eating meals may exceed 100 percent of the enrollment in the case of parent cafeterias preparing meals for other schools. The vertical projection of the straight line of best fit between 0 and 100 percent of student eating meals (0.47) represents the gallons of sewage produced per student-meal. This factor was used to adjust all data to 100 percent of students eating meals.

Figure 17 shows the effect, of the percent of students showering, on the daily rate of sewage flow in gallons per capita. Note that the percentage of students showering may exceed 100 percent of the enrollment due to after-school athletic activities. The vertical projection of the straight line of best fit between 0 and 100 percent of students showering (1.51) represents the gallons of sewage produced per student-shower. This factor was used to adjust all data for schools with shower facilities to 0 or 100 percent of students showering.

Figures 18 and 19 show the effects of student population on the total daily sewage flow in gallons for schools with and without shower facilities. In both cases the correlation of 88.1 indicates that 77.6 percent of the variability in total sewage flow is a function of student population.

Figure 20 shows the distribution of 765 pieces of data representing the sewage flow in gallons per capita day at 142 schools. These data were recorded at 80 schools without shower facilities and 62 schools with shower facilities wherein the data were adjusted to 0 percent of students showering. All data were adjusted to 100 percent of students eating meals. The mean of these data plus two standard deviations equals 9.50 gallons of sewage produced per student day. Of the 765 pieces of data, this value was not exceeded 96.1 percent of the time. It is also of interest that the gallons of sewage flow per student day is not significantly affected by variations in student population as evidenced by a correlation factor of 1.9 percent.

Figure 21 shows the distribution of 340 pieces of data representing the sewage flow in gallons per capita day from 62 schools with shower facilities adjusted to 100 percent of students showering and 100 percent of students eating meals. The mean of these data plus two standard deviations equals 11.30 gallons of sewage produced per student day. Of the 340 pieces of data, this value was not exceeded 95.6 percent of the time. It is also of interest that the gallons of sewage flow per student day is not affected by variations in student population as evidenced by a correlation of 1.3 percent.

Figure 22 shows the histogram of hourly sewage flows per capita for the 24 hour periods of 190 days of data at 42 schools. These data were recorded at schools without shower facilities and were adjusted to 100 per of the students eating meals.

Figure 23 shows the histogram of hourly sewage flows per capita for the 24 hour periods of 84 days of data at 19 schools. These data were recorded at schools with shower facilities and were adjusted to 100 percent of students showering and 100 percent of students eating meals.

Figure 14

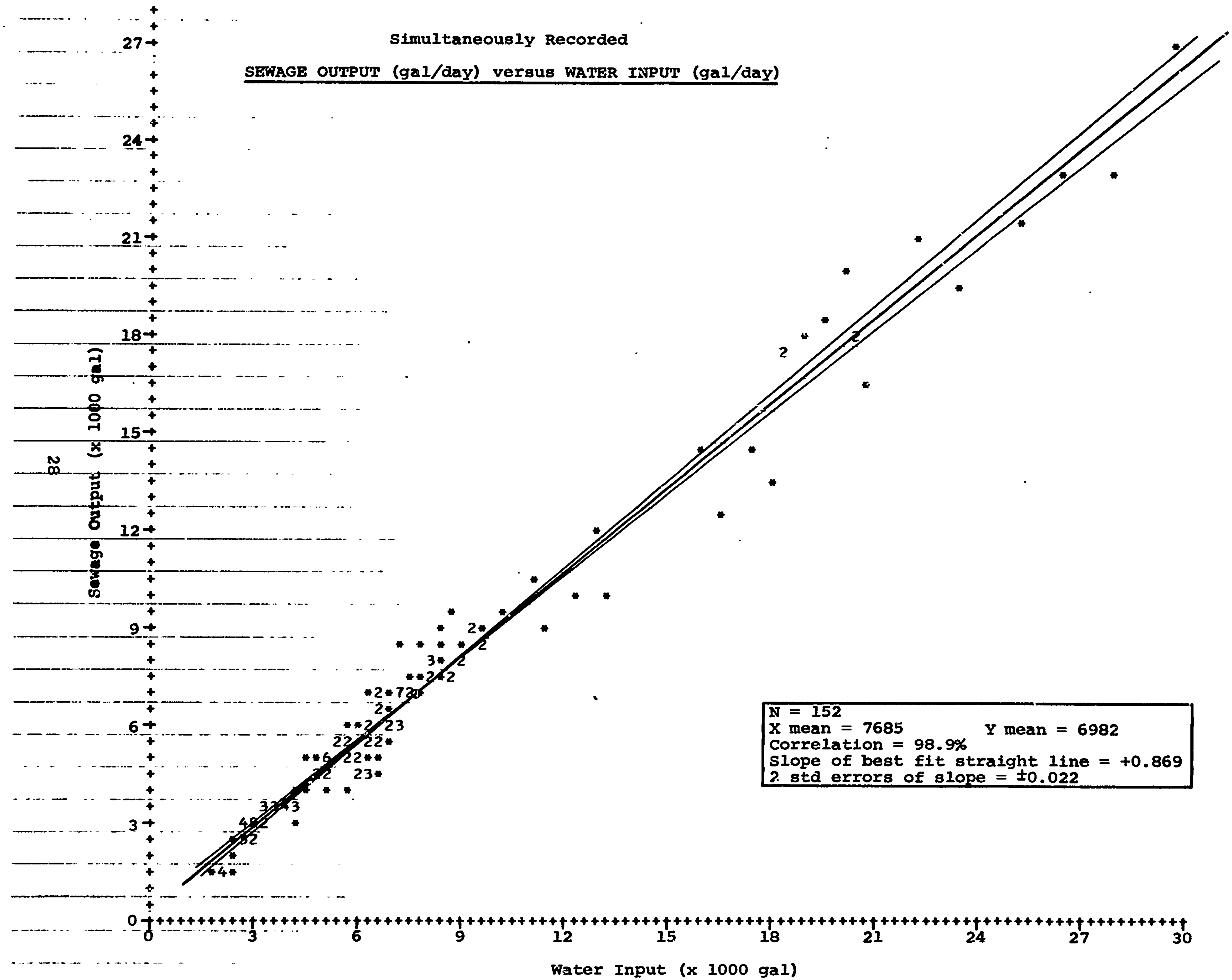

Simultaneously Recorded
SEWAGE OUTPUT (gal/day) versus WATER INPUT (gal/day)
Sewage Output (x 1000 gal)
Water Input (x 1000 gal)
N = 152
X mean = 7685
Y mean = 6982
Correlation = 98.9%
Slope of best fit straight line = +0.869
2 std errors of slope = ±0.022

Figure 15

SEWAGE - WATER RATIO versus STUDENT POPULATION

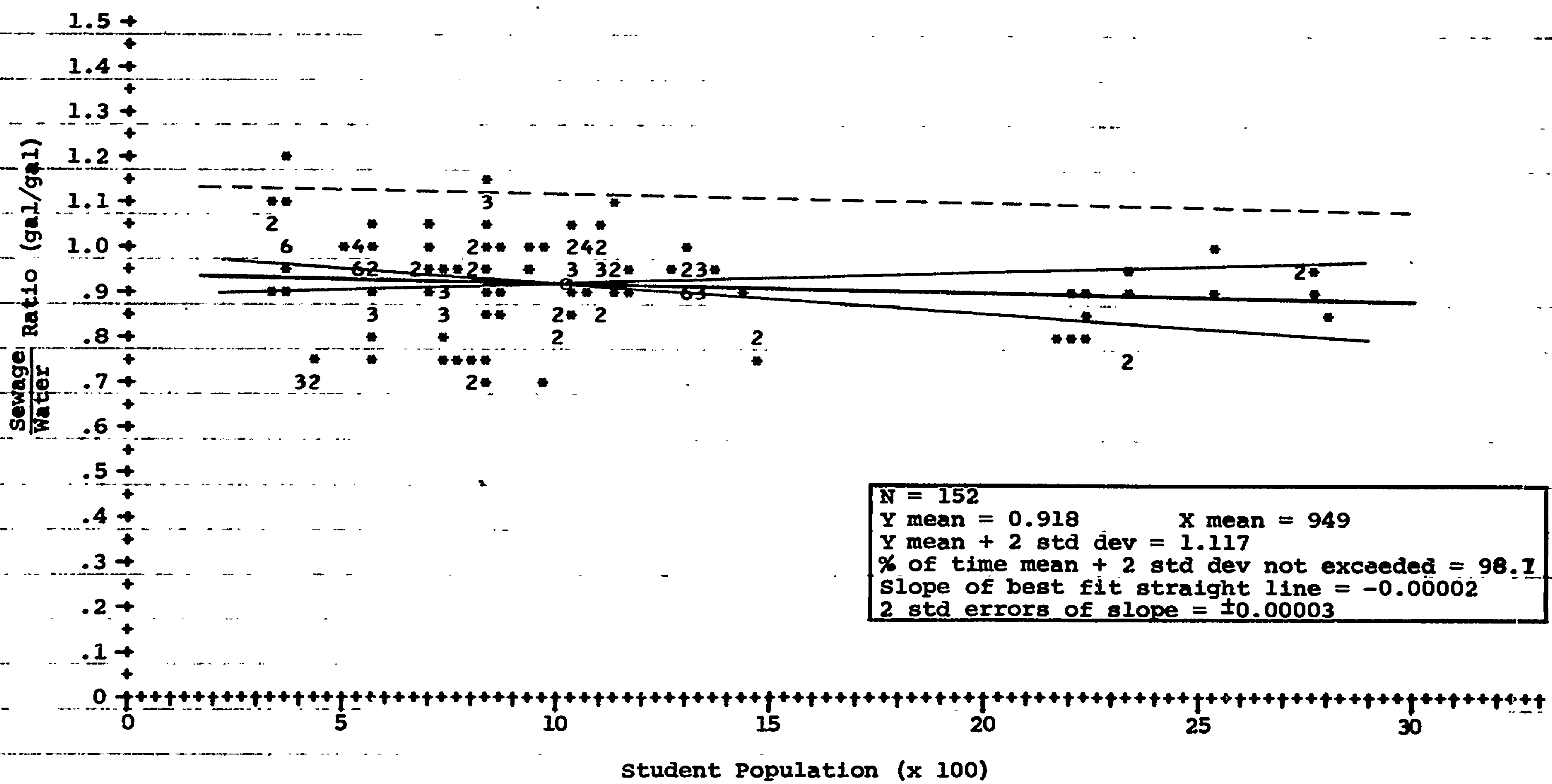


Figure 16

SEWAGE FLOW (gpcd) versus PERCENT OF STUDENTS EATING MEALS

Adjusted to 0% Showers

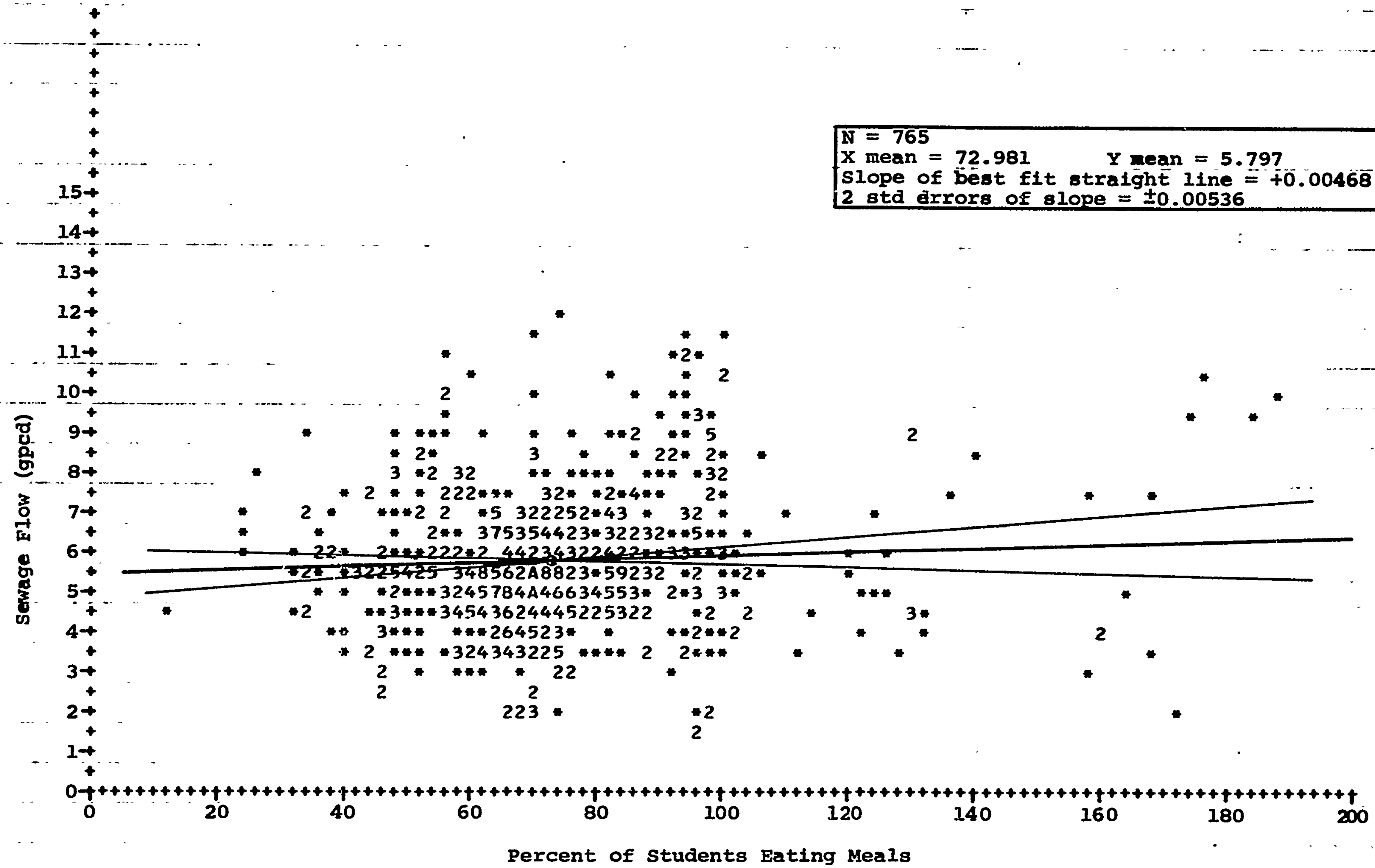


Figure 17

SEWAGE FLOW (gpcd) versus PERCENT OF STUDENTS SHOWERING

Adjusted to 0% Meals

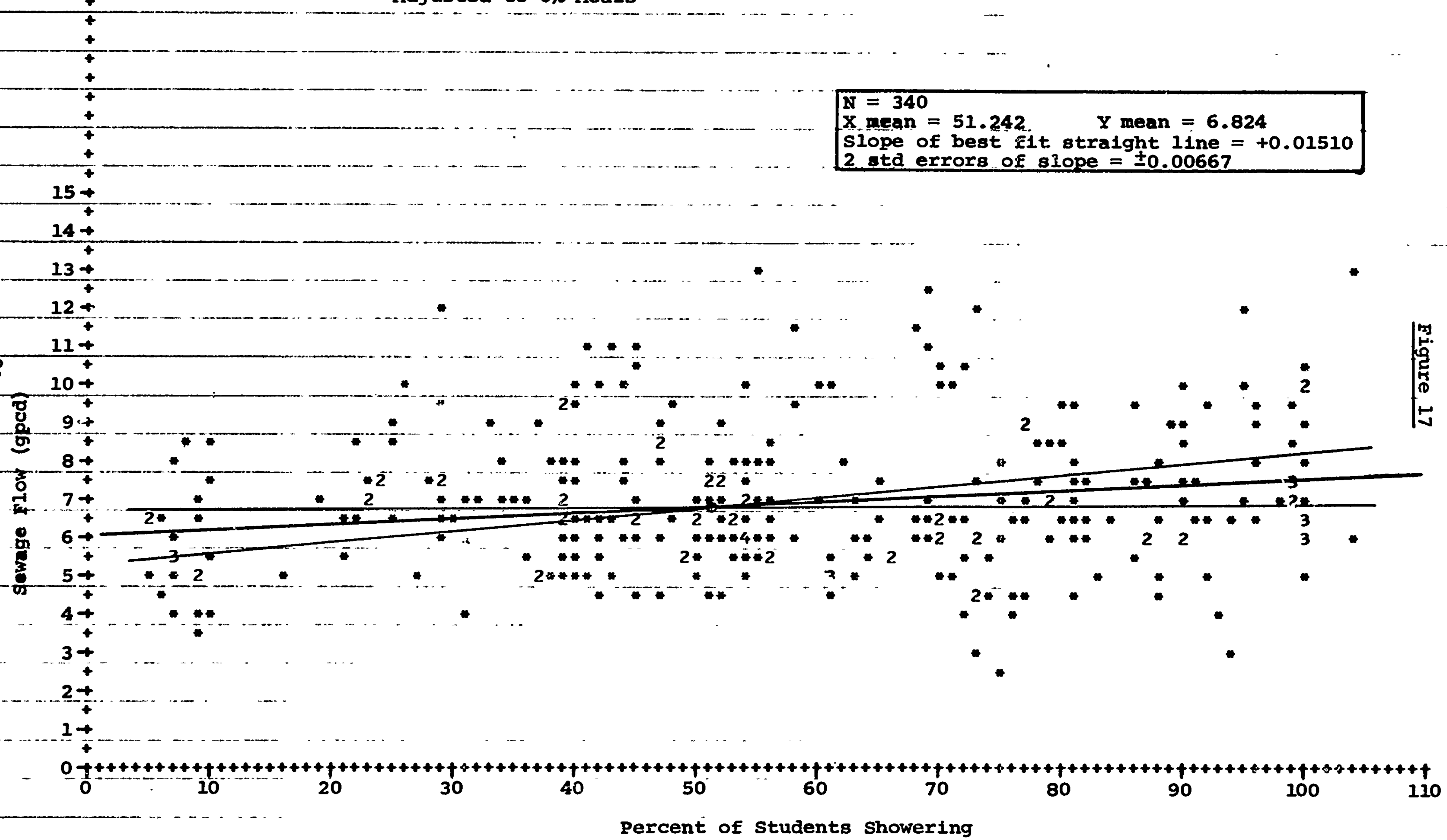
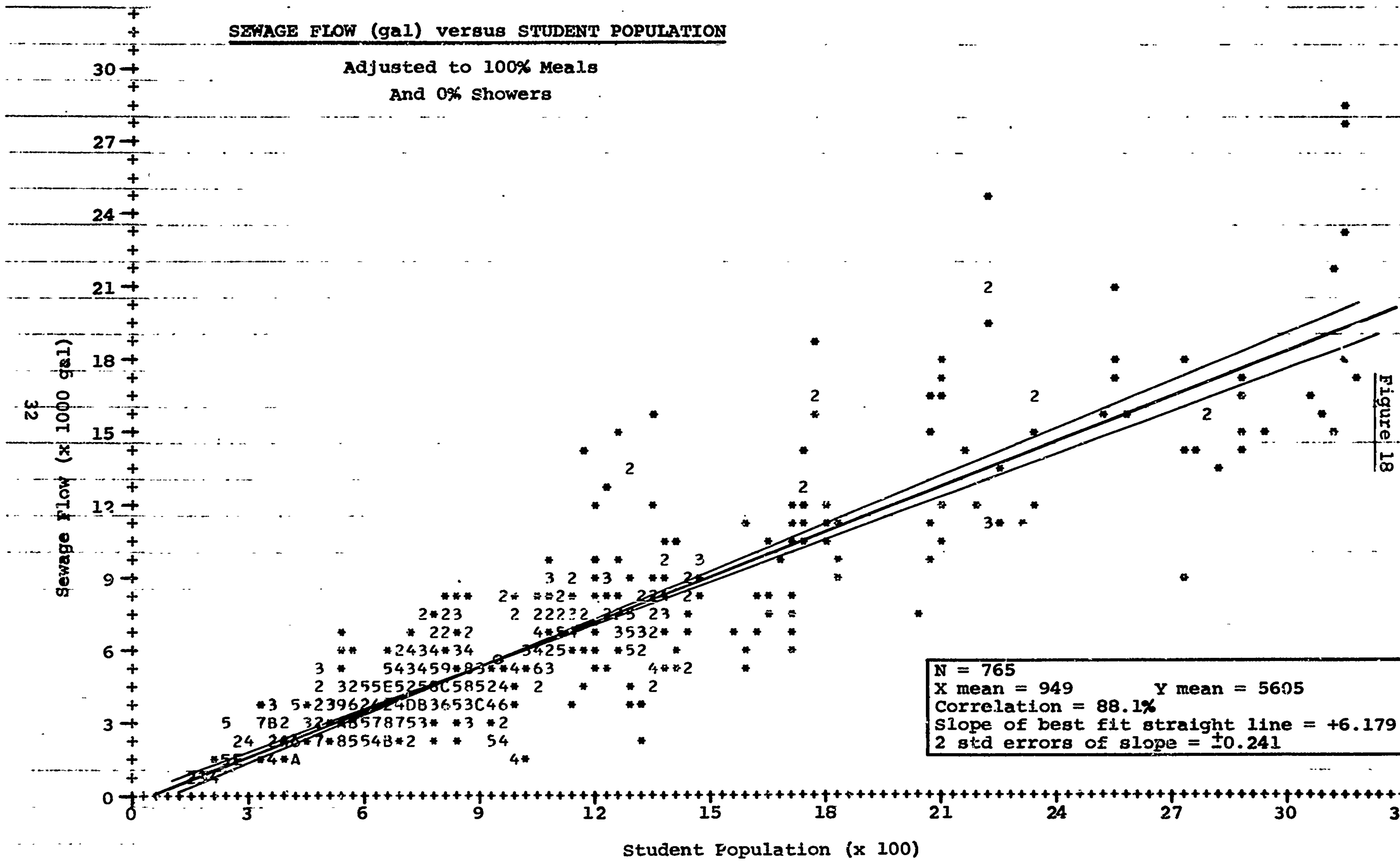


Figure 18


SEWAGE FLOW (gal) versus STUDENT POPULATION
Adjusted to 100% Meals
And 0% Showers
Sewage Flow (x 1000 gal)
Student Population (x 100)
N = 765
X mean = 949
Y mean = 5605
Correlation = 88.1%
Slope of best fit straight line = +6.179
2 std errors of slope = ±0.241

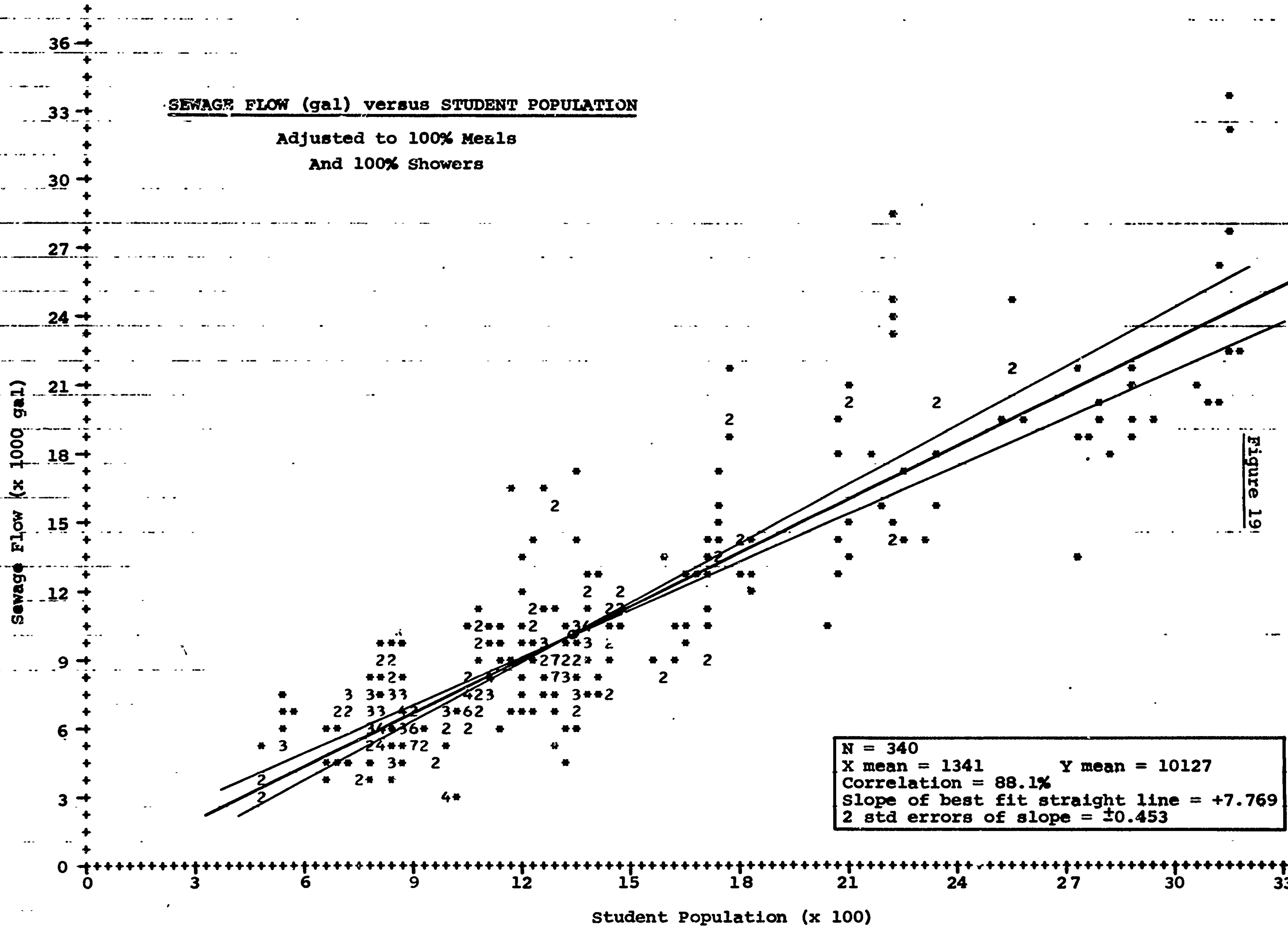

SEWAGE FLOW (gal) versus STUDENT POPULATION
Adjusted to 100% Meals
And 100% Showers
Sewage Flow (x 1000 gal)
Student Population (x 100)
N = 340
X mean = 1341
Y mean = 10127
Correlation = 88.1%
Slope of best fit straight line = +7.769
2 std errors of slope = ±0.453

Figure 19

Figure 20

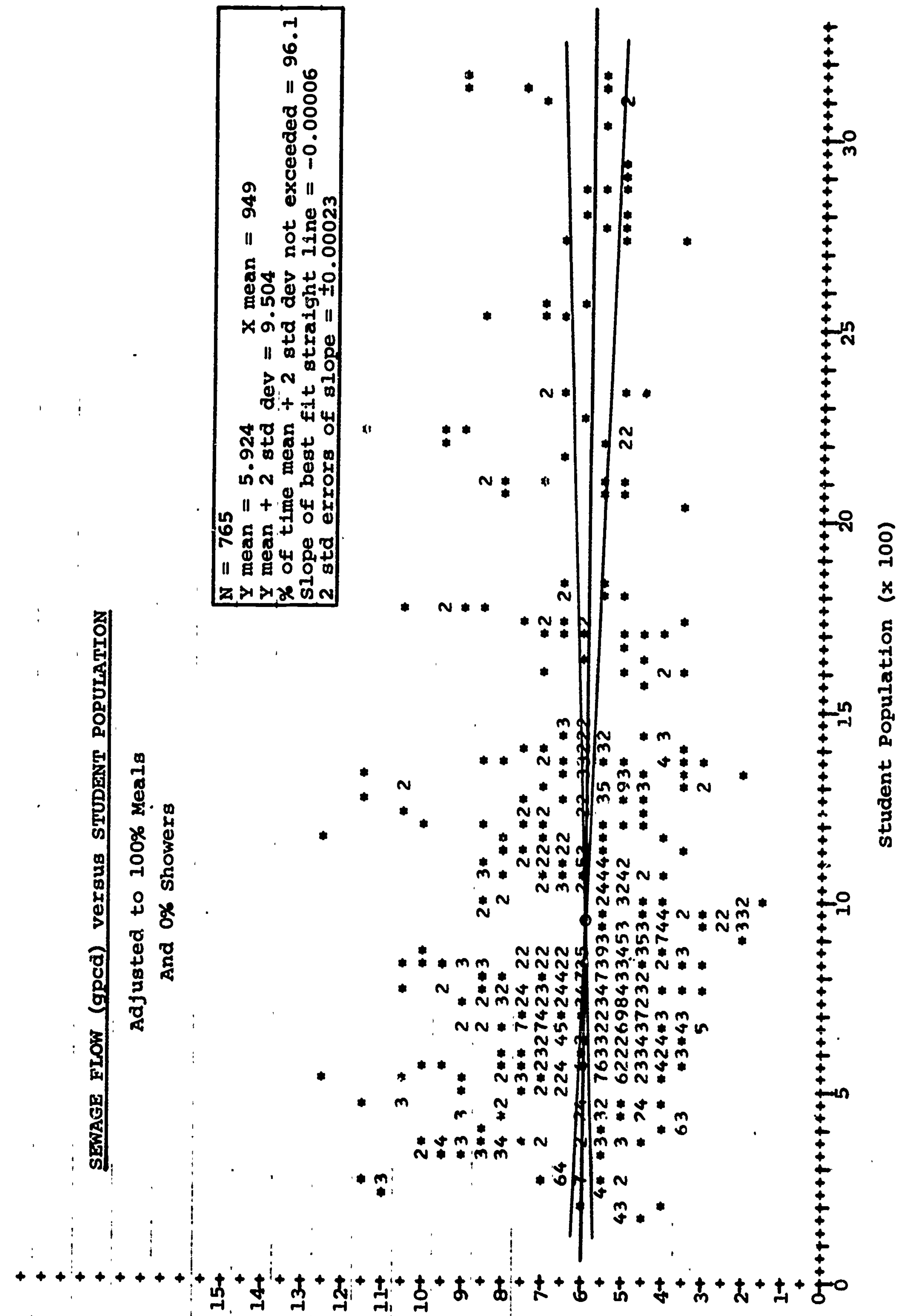
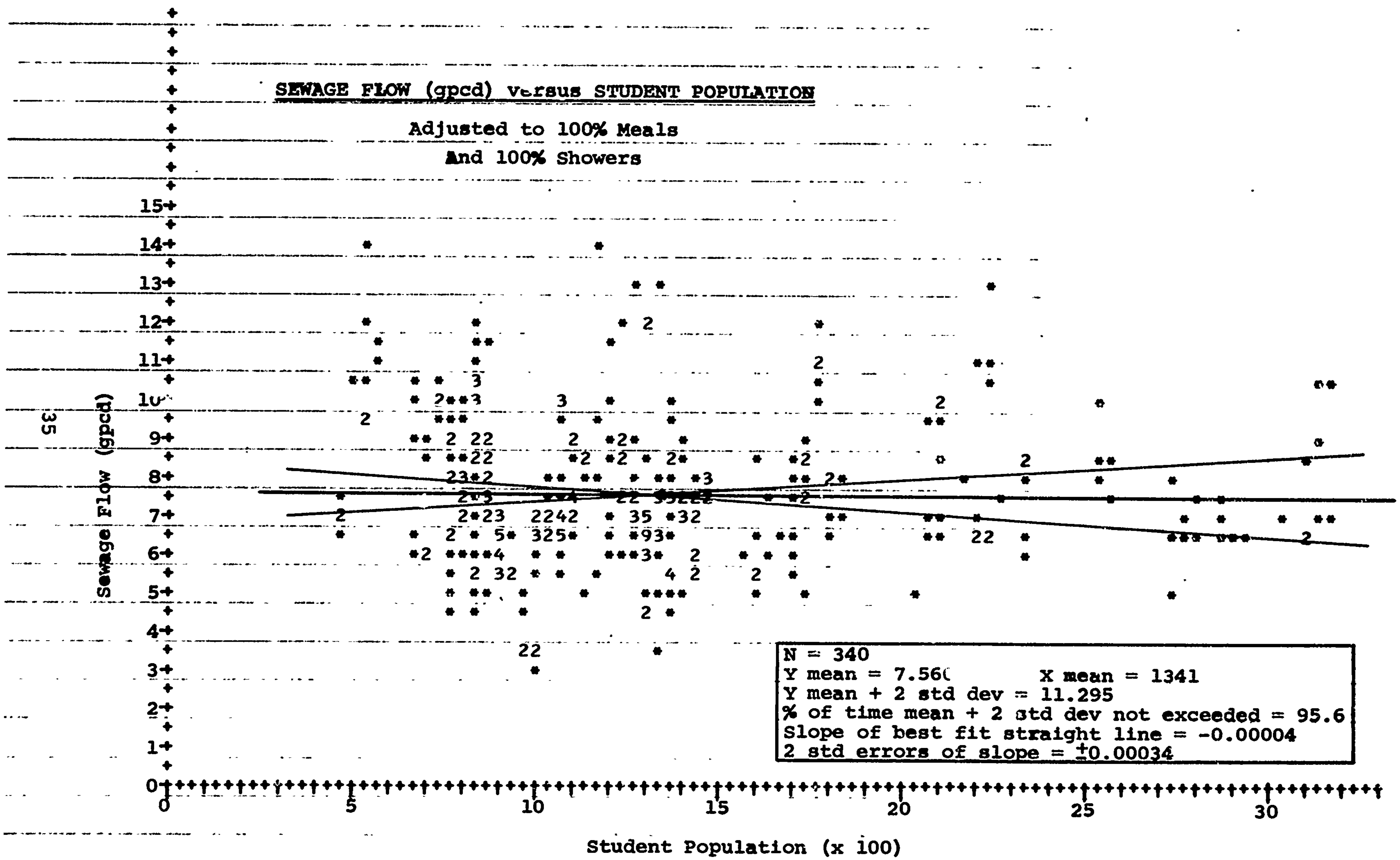

SEWAGE FLOW (gpcd) versus STUDENT POPULATION
Adjusted to 100% Meals
And 0% Showers
N = 765
Y mean = 5.924 X mean = 949
Y mean + 2 std dev = 9.504
% of time mean + 2 std dev not exceeded = 96.1
Slope of best fit straight line = -0.00006
2 std errors of slope = ±0.00023
Sewage Flow (gpcd)
Student Population (x 100)

Figure 21



SEWAGE FLOW (gpcd) versus STUDENT POPULATION
Adjusted to 100% Meals
And 100% Showers
Sewage Flow (gpcd)
Student Population (x 100)
N = 340
Y mean = 7.56(
X mean = 1341
Y mean + 2 std dev = 11.295
% of time mean + 2 std dev not exceeded = 95.6
Slope of best fit straight line = -0.00004
2 std errors of slope = ±0.00034

Figure 22

HISTOGRAM OF HOURLY SEWAGE FLOWS FOR A 24 HOUR DAY

Adjusted to 100% Meals

And 0% Showers

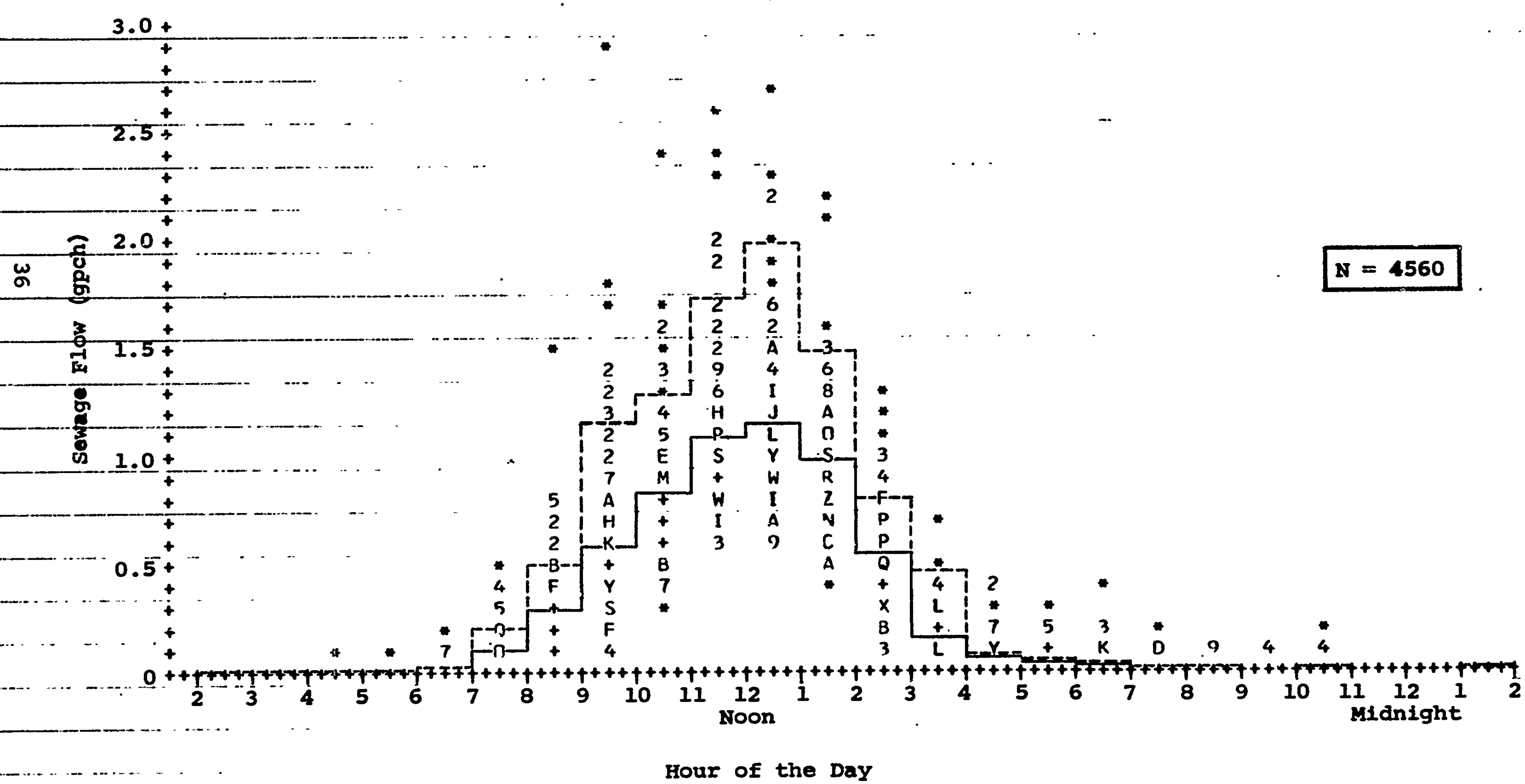


Figure 23

HISTOGRAM OF HOURLY SEWAGE FLOWS FOR A 24 HOUR DAY

Adjusted to 100% Meals

And 100% Showers