FUTURE WATER DEMAND - CITY OF PHILADELPHIA

Submitted for the Coordinating Committee
for the Reappraisal of Water Supply
Resources of the Delaware River Basin
and Survey Area (DRBC Resolution 67-4)

Prepared by the Research and Development Unit
Philadelphia, Water Department

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Water Commissioner
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I. INTRODUCTION

The City depends on two sources for its water supply, the Delaware and Schuylkill Rivers. Approximately one-half of the water used by the City is supplied from the Delaware River by the Torresdale Water Treatment Plant. This plant has a rated capacity of 282 million gallons per day (m.g.d.) with the ability to produce 423 m.g.d. of treated water during peak demand periods. The other half of the City's water supply is withdrawn from the Schuylkill River and treated by the Belmont and Queen Lane Water Treatment Plants. The combined rate of capacity of these plants is 198 m.g.d. with a peak rate capacity of 258 m.g.d.

Consistent with the physical design capacity of the Philadelphia Treatment Plants and with the projections of consumption for the City, the Water and Power Resources Board of the Commonwealth of Pennsylvania authorized the City of Philadelphia to withdraw 423 m.g.d. from the Delaware River on December 14, 1955 and 258 m.g.d. from the Schuylkill River on January 8, 1958.

In order to provide the necessary treatment facilities for the conversion of the raw water sources to a palatable and potable supply for over two million consumers, the City entered into a capital reconstruction program during the period 1952-1965 at a total cost of $46 million. A result of this program is three modern, almost completely automatic, rapid sand filtration plants capable

of handling raw water supplies with extreme variations in their physical, chemical and biological characteristics. The location of these plants are shown in Figure No. 1.

The Torresdale Plant is located on the Delaware River and was rehabilitated by the year 1959 at a cost of $25 million. The Queen Lane and Belmont Plants, both on the Schuylkill River, were completed in 1960 and 1965 respectively. The modernization of the Queen Lane Plant cost $10,400,000 and that of the Belmont Plant $10,600,000.

The present water needs of the City of Philadelphia and its service area are adequately met by the existing facilities and current allocations.

This report will attempt to prognosticate population and consequent water demand for the City of Philadelphia and the service area to the year 2020. It will examine the adequacies of the present facilities to meet the requirements of a growing population and expanding industrialization. It is predicated on the assumption that this Metropolitan area will continue to receive its representative share of the Gross National Product. It takes into account the normal cycles of birth and decay and foreseeable changes in technology.

II. POPULATION PROJECTIONS

Records of the United States Bureau Census from 1790 to 1960 are tabulated in Table Number 1. Mathematical analysis of these revealed that the population trends of Philadelphia during this

period can be best approximated by a Gompertz-type exponential function. The curve found to be the best fit to the historical data is described by the equation:

$$Y = e^{e^{(1.30474)(e^{-0.0025x^2})\ (e^{0.0856x})}}$$

The coefficients of the x exponent have been found by Laurent polynomial expansion. Substitution of a given year x yields the population Y for that year. The coefficients above were determined for the Philadelphia census data. Comparison analysis between the Y actual (census data) and the Y estimated over the period of record yielded a correlation coefficient r = .99. Appended is Table No. 2 which compares actual census data to the corresponding computed values.

The resulting equation as modified by the constants was used in conjunction with Table No. 1 to generate the anticipated mean population in ten year increments from 1970 to 2020. To develop an adequate and reasonable range of population for the future, a plus and minus 20% variation of just the projected increase in population was assumed about the mean.

It is easily seen that the variation around the regression line is comparable to the assumed variance in projection. This generated data is shown in Table No. 1 and Figure No. 2 and its accompanying detail. Also shown in Figure 2 are the population

projections for the City of Philadelphia through the year 2020 as envisioned by the Delaware Valley Regional Planning Commission and the Planning Commission of the City of Philadelphia. The population estimate made by the Philadelphia Water Department can be seen to fall within the upper and lower population limits as stipulated by these two planning agencies. For the purposes of this report, it would appear that the projections and the variation in range as determined by the Water Department are reasonable and can be prudently applied for evaluating future water demands.

The physical boundaries of the City of Philadelphia are coincident with the political limits of the County of Philadelphia, encompassing some 130 square miles of area. Philadelphia is an old historical City that is built up to a considerable extent. There are areas in the Northeast, Northwest, and Southwest sections of the City that are vacant and can be developed for residential and industrial purposes. The realization of these projects will further add to the need of more water. Many older sections of the City are being razed and rehabilitated. This has led to transient population and in some decades to abnormal increases and decreases about the normal rate of growth. Philadelphia, with a fixed boundary, has exhibited the typical Gompertz population pattern. It can be seen that the future lies on that portion of the curve which has the characteristics of a decreasing percentage increase. The continuation of this trend will apparently follow the established pattern if no new technology is effected.

III. WATER DEMAND

In the year 1965, the population of Philadelphia was approximately 2 million and the demand was approximately 169 gallons per capita per day (g.p.c.d.). No dramatic increase in per capita consumption can be envisioned at this time; however, slight to moderate increases in the per capita consumption figures are expected because of the trend towards modernization of home appliances and to the general overall rise in the economic status or standard of living of the population. For example: It is anticipated that the City of Philadelphia will promulgate legislation in the near future requiring mandatory installation of household garbage disposal units. It is hoped that per capita use will level off by the year 2020.

A. PER CAPITA PROJECTION

Predicting a precise increase in per capita consumption is nebulous and extremely difficult. It would appear certain that a moderate increase can be definitely expected. The Water Department has cautiously applied a very conservative percentage increase in per capita demand in predicting its future total water requirements. The range of increase was chosen to lie somewhere between 1/4 of 1% and 3/4 of 1% per year of gallons per capita using 1965 as the base year, but not on an accumulative basis. For the purpose of this study, a median figure of 1/2 of 1% will be considered as being representative.

B. TOTAL RAW WATER DEMAND

The total raw water demand for Philadelphia and its service area was calculated and extrapolated by decades from 1970 to 2020. Two methods were utilized to perform these projections.

1. A projection of the population by the Gompertz equation couplied with an assumed range of per capita increase based upon literature research.
2. An analysis of trends in water usage in manufacturing and domestic consumption.

The first methods has been investigated and the results are presented in this report. The second method is experimental and is still under analysis. It is expected that the effort will prove to be fruitful and the results will be published at a later date.

An interim in-house report by Dr. Joseph S. Mamelak entitled "Water Demand Analysis" describes the second method and the problems associated with it. Briefly it involves statistical trending of the domestic and industrial demands utilizing census, employment, and Standard Industrial Classification data.

Figure No. 3 and Table No. 3, both titled "Projected Raw Water Demand", illustrate the future raw water demand as computed by the first method only for the requirements of the City of Philadelphia. These estimates are then adjusted to include water service to Bucks County. The Bucks County Planning Commission has predicted that they will require about 67 m.g.d.

from the City by the year 2020. Philadelphia's future raw water demand is depicted in Figure No. 4 and Table No. 4 which are entitled "Philadelphia Projected Total Raw Water Demand".

C. Seasonal Variations in Water Demand

Figures No. 5 to 16 exhibit several ways by which the City's historical seasonal water demands are examined.

The water demand is expressed employing two methods using annual averages and seasonal averages to evaluate three data sets. The data sets consist of the total demand of the City, the demand on the Schuylkill River and the demand on the Delaware estuary.

For the annual average method, 15 years of daily raw water pumping data from 1954 to 1968 were utilized to generate a yearly average which is depicted on the graphs as unity at 100%. Monthly averages were calculated on the basis of a percentage of the average annual. Also shown were maximum and minimum demand months for all data sets, as well as maximum and minimum demand days. For each of these figures, the monthly standard deviations were calculated and are plotted on the graphs as vertical lines.

It can be seen that if the data is looked from a monthly average basis that the variations in demand are flattened as compared to the maximum and minimum monthly average extremes. If these are contrasted with the graphs on which the minimum and maximum daily demands are plotted, it can be seen that the

daily average consumption exhibits considerable variability. Cognizance of this factor is mandatory when considering the raw water demand of the City of Philadelphia. This is because the City does not have a sufficient detention storage to permit withdrawals on an average monthly basis. Withdrawals must be made day by day and processed day by day.

It is assumed that historical variations in raw water withdrawals may be typical of those variations in raw water demand which can be reasonably expected in the future. On this basis, it would appear that the peak day rate for the year 2020 should range between 700 to 880 m.g.d. with an average expectancy of 790 m.g.d. peak rate for the total projected raw water demand of Philadelphia. On an individual source basis, peak daily rates from the Delaware River may vary from 455 to 470 m.g.d. and from the Schuylkill from 290 to 365 m.g.d.

Another viewpoint was used in examining the water demand variation. This was done by using a seasonal average method to show the use variation during winter, spring, summer and autumn. As before, the monthly averages along with the maximum and minimum monthly and daily use extremes were plotted as percentages of these seasonal means. In addition, a monthly standard deviation was calculated and plotted. The calculations conform to accepted statistical theory in that when using both

methods, for the most part, two standard deviations will fit in the ranges between the recorded maximums and minimums.

It is of interest to note that when considering the total water demand of the City of Philadelphia it would appear that this is fairly consistent year to year. However, the last nine years of record were analyzed separately since they reflected usage when the City was completely metered. When contrasted to the era proceeding, when the City was partially metered, it can be shown statistically that there is an apparent 10% less demand in requirements. It would appear that metering is a deterrent to household waste, particularly when coupled with an adequate rate schedule.

Although the variations in demand for a total use of the City of Philadelphia appear to be fairly consistent, examination of the individual sources of the Schuylkill and Delaware will show considerable variation in demand. The distribution system of the City is quite flexible and permits this variation in distribution of demand. This flexibility will be dampened as increases in demand are imposed on the Philadelphia system. Because of source allocation and other hydraulic and physical considerations, the future increases in demand will be met to a large degree from the Delaware estuary source.

IV. MANAGERIAL AND OPERATIONAL ASPECTS

The managerial and operational policies of a utility directly effect the utilization and total consumption of the product and associated services. In a water industry, pricing policy may

inhibit or promote usage; providing adequate fire flows reflect additional benefits to the consumer in the form of lower insurance rates; pressure criteria can enhance use or aggravate waste. Such things as these are indicated as to just how a water resource is being exploited or optimized. A statement of these items is warranted since it will show the degree to which the Philadelphia Water Department is cognizant of these factors. It will also have direct bearing on future water use demands and concomitant allocations.

A. CITY CHARTER

The political and operational structure of the City of Philadelphia was realigned under a Charter promulgated in 1952. Provisions in the Charter made the Water Department in essence a self-sustaining entity charged with providing water and sewer services to the citizens of Philadelphia. The provisions of the Charter were quite broad in scope, permitting the Water Department to have the latitude to sell water and sewer services outside the geographical boundaries of Philadelphia. The authors of the Charter had broad visions of a metropolitan and regionalized system. In order to have the ability to fulfill this vision, the Charter further stipulated that the Water Department could be organized in the form of an authority; and while this is not currently under contemplation, it may prove desirous in the future. If such an authority comes into being,

it would be a stepping stone to regionalization and would provide the funding for this concept since the authority would not be restricted by the debt or bonding limitations. It should be noted that the Water Department's bond issues are not used in calculating the City's indebtedness under the present system.

B. REGIONALIZATION

The Philadelphia Water Department has in effect established a regionalized system of sewer services since it has, for some time, treated the waste of some 80 square miles beyond the limits of Philadelphia boundaries.

The policy of the Delaware River Basin Commission (DRBC) in regard to regionalization will add further impetus to the regionalization of sewerage facilities. Philadelphia has been established as a focal point in the general regionalization schemes within this drainage basin.

The beginning of regionalization of water supplies is another idea advocated by the Delaware Valley Regional Planning Commission (DVRPC), and is fostered also by DRBC. The inception of such a regionalized system may have its beginning in the Philadelphia Water Department. In recent years, the City of Philadelphia Water Department has provided water service to the Bensalem Township and has just recently signed an agreement with the Bucks County Water and Sewer Authority, a political jurisdiction encompassing 617 square miles and a population of 357,000.

The Federal funding agencies have designated the DVRPC as the agency in the Delaware Valley which will process all applications for water and sewer funding in order to meet the criteria established by the Federal Water Pollution Control Administration and by the Department of Housing and Urban Development. Any proposal for water and sewer funding must be certified by the DVRPC as meeting regional criteria.

It is quite apparent that the trend all over the country is towards regionalization, particularly along the Northeast Corridor where the megalopolis is now exploding. The force of a new population and their needs, and the competition for water will force water utilities towards regionalization with its inherent features of better management, equity of resource distribution, and the optimization of cost and social service.

Philadelphia has no immediate plans to go upstream on the Delaware River for its source of supply. Philadelphia's position insofar as the future development of the Delaware River is concerned is that the City has the right to all the water which it requires from the Delaware River, consistent with the rights of others in the Basin. The City further reserves the right to go upstream on the Delaware River in the future for water supply when conditions require it or when Philadelphians desire it. When and if Philadelphia goes to an

upland source, others in the contiguous vicinity may want or find it desirable to enter into a cooperative upland supply arrangement.

The accuracy of the projections in this report is dependent upon many factors. The major factor governing population growth and per capita consumption is whether the Philadelphia metropolitan area will continue to receive its fair share of the Gross National Product. One fundamental thing that could greatly affect the raw water projections is if and when the City might begin operations as a regional water utility. There is no way at the present time to predict as to what the extent of this service may be or to the extent that this may tax our present allocations. It would be prudent to observe that the initial step has been taken with the recent extension of service to Bucks County.

C. CONSERVATION POLICY

The Philadelphia Water Department has always been cognizant of conservation and this has been documented throughout its history.

A Universal Metering program for the entire City was completed in 1959 encompassing some 520,000 metered accounts. This led directly to the saving of water because with the advent of complete metering household waste became practically negligible. It is estimated that household waste has been reduced to less than a fraction of one per cent of the total annual consumption.

The Universal Metering program produced as a spin off, information vital to operational management and to strengthening and refining an adequate and equitable pricing policy.

Residential meters are read on a semi-annual basis. Industrial installations are read on a quarterly or monthly basis, as the account would dictate.

The Water Department is making a continuous study of automatic meter reading. If this proves feasible some day, then more checks will be made on inadvertent household waste and will permit billing on a monthly basis.

All meters in the City are on a replacement schedule in keeping with our conservation measures. Exhaustive tests have proven that the smaller meters which constitute the majority of the total begin to indicate negligible under-registration after being in service for 15 years. Accordingly, meters 5/8" in diameter are replaced every 15 years and those 1 1/4" and above, according to Public Utility Commission rotation standards, about every four years.

The Department is constantly reviewing and testing new innovations in their meter program. At the present time, all new meters are the magnetic leak-proof type without stuffing boxes. This type of meter practically eliminates any leakage at the meter.

One of the most prominent factors in good waste management control is the continuous surveillance of the Water Distribution System. The Water Department employs a team of measuring consultants, the Pitometer Associates, Inc., to make continuous leak and waste surveys of all water pressure districts. This agency generally completes coverage of the entire distribution system on a six-year average. Records indicate that detected leakage amounts to some three to six million gallons per day per year, or somewhat below one per cent of the average annual consumption. This good housekeeping practice has enabled the City to keep detectable leakage to a minimum.

The unauthorized use of fire hydrants during the summer months is a major uncontrollable factor in water conservation. The Water Department has established police and departmental patrols to curtail this unauthorized activity during the summer months. In addition, the Department is continually experimenting with new hydrant appurtenances, such as special caps and fire hydrant clamps to foil access to the hydrant by unauthorized personnel. Public education has been a vital item in mitigating this waste. This has been accomplished through the use of all modes of news media. The City recognizes its civic obligation to make water available to those segments of the community which would not ordinarily have access to City

swimming facilities. In order to do this effectively, the City issues sprinkler permits to residents upon request. Despite our efforts in trying to minimize unauthorized use of fire hydrants, the problem persists to an undesirable degree.

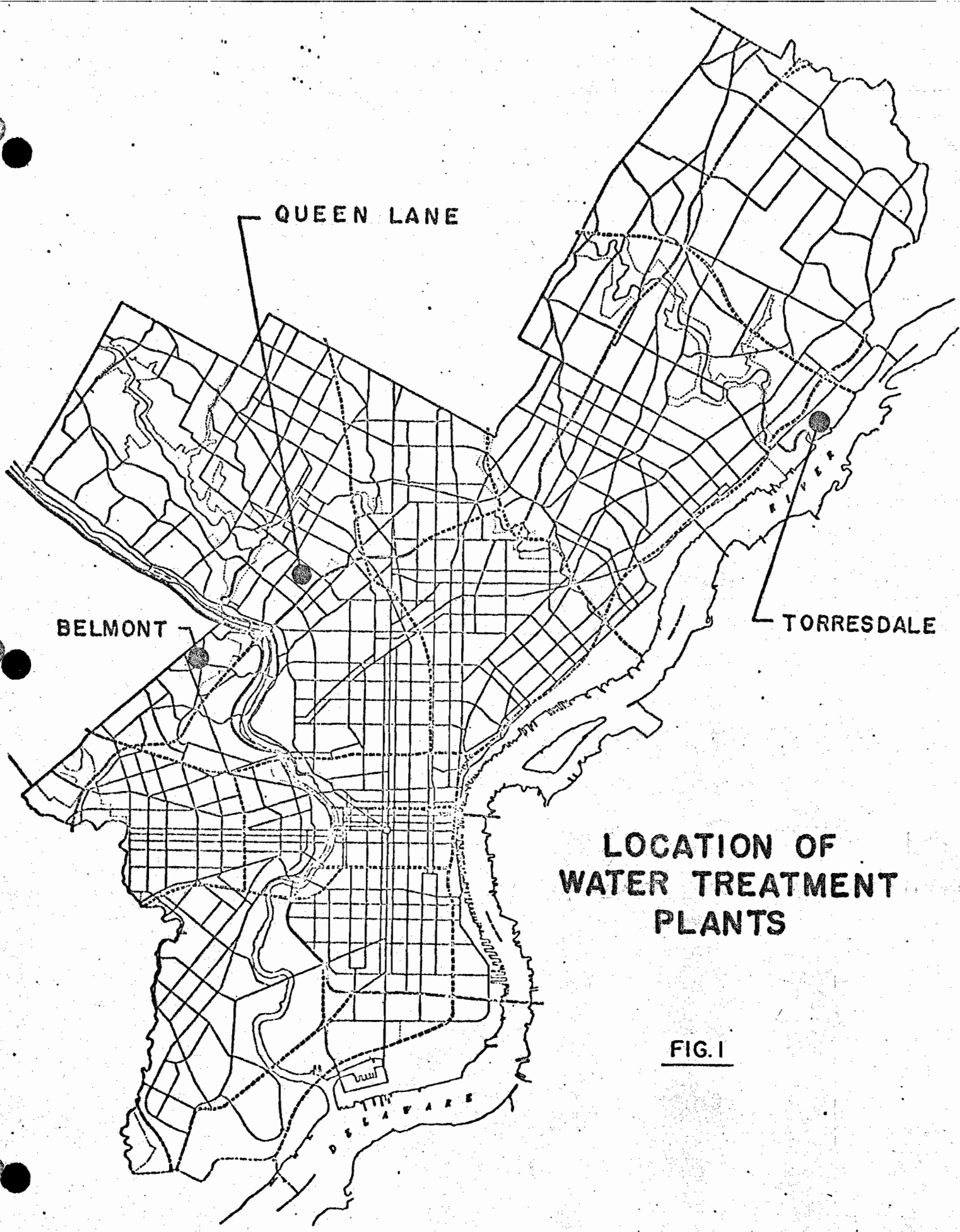
D. RATE SCHEDULE

The consumption of water is regulated to a great degree by the adequacy of charges for the services. The Commissioner of the Water Department is empowered by the provisions of the City Charter to establish an adequate rate schedule. The Department must remain self-sustaining and operate on a pay-as-you-go basis for operating expenses and for the amortization of capital expenditures.

The Water Department is a service motivated, rather than profit motivated, utility. Experience indicates that the Department must raise its rates about every four years in order to keep abreast of inflation. This raise allows the Department to operate with a surplus during the first two years of the four-year period, while the last two, the Department experiences deficit spending. These four-year raises in rates are necessitated by the cost of living, by innovations in and improvements of facilities and services to the consumer. The largest factor causing these rate adjustments is the absence of a depreciation account for system replacements. Capital financing has been substituted for this

purpose and, until bonds which were sold after World War II are paid off, substantial rate increases will be necessary periodically. The rate structure also provides for social obligations to the community in permitting reduced rates to charitable institutions.

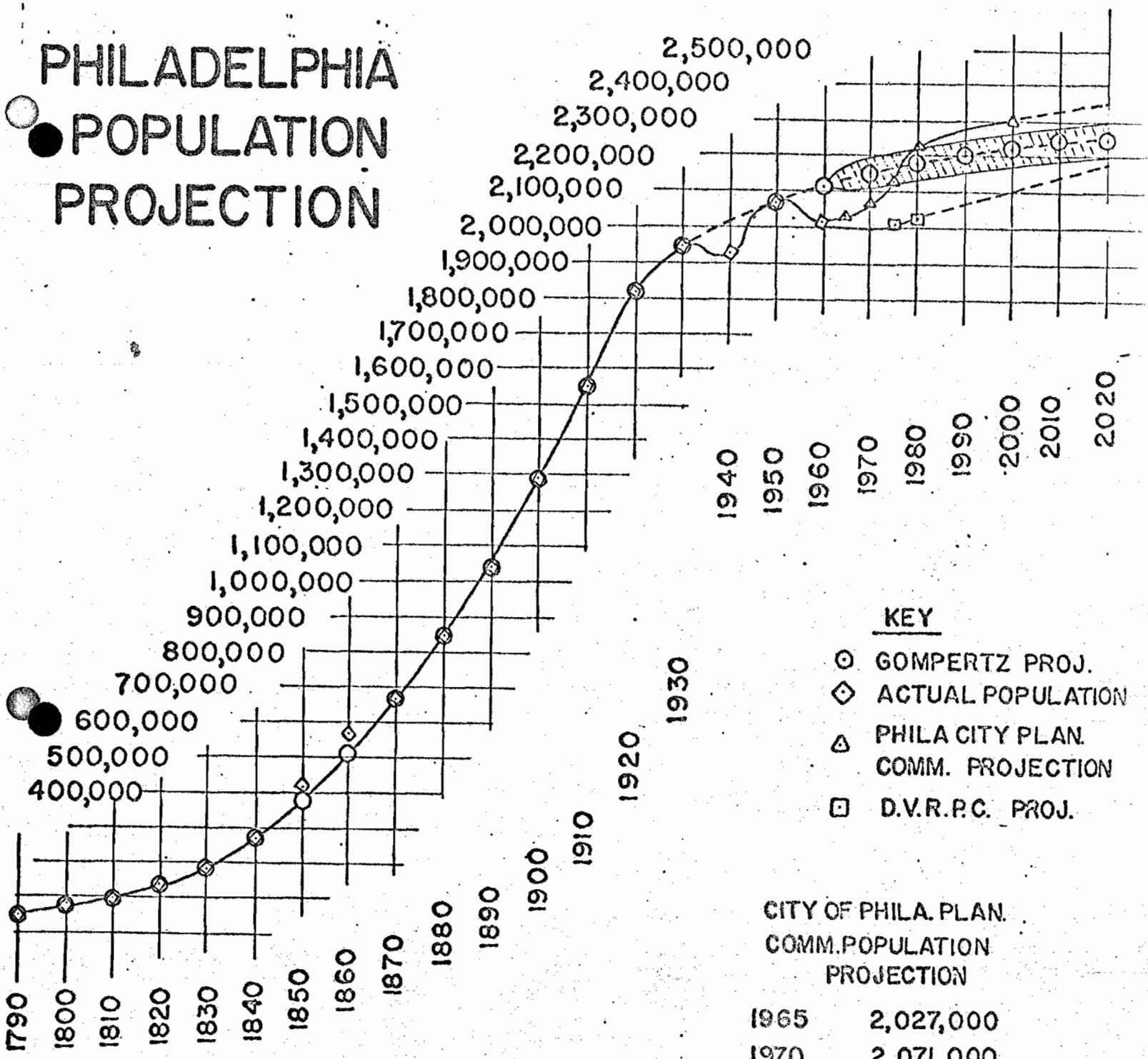
The Water Department is continually striving to improve services and to lower the cost to its customers. It is currently making feasibility studies to determine whether process control by complete automation with computers is desirable and will leak to a better and more conomical product. It would appear that automation will permit optimization in several areas, including management, personnel, chemical application and power consumption.



LOCATION OF WATER TREATMENT PLANTS

FIG. 1

PHILADELPHIA POPULATION PROJECTION



KEY

- ⊙ GOMPERTZ PROJ.
- ◇ ACTUAL POPULATION
- △ PHILA CITY PLAN. COMM. PROJECTION
- ⊡ D.V.R.P.C. PROJ.

D.V.R.P.C.
POPULATION PROJ.

1975	2,007,939
1985	2,023,906

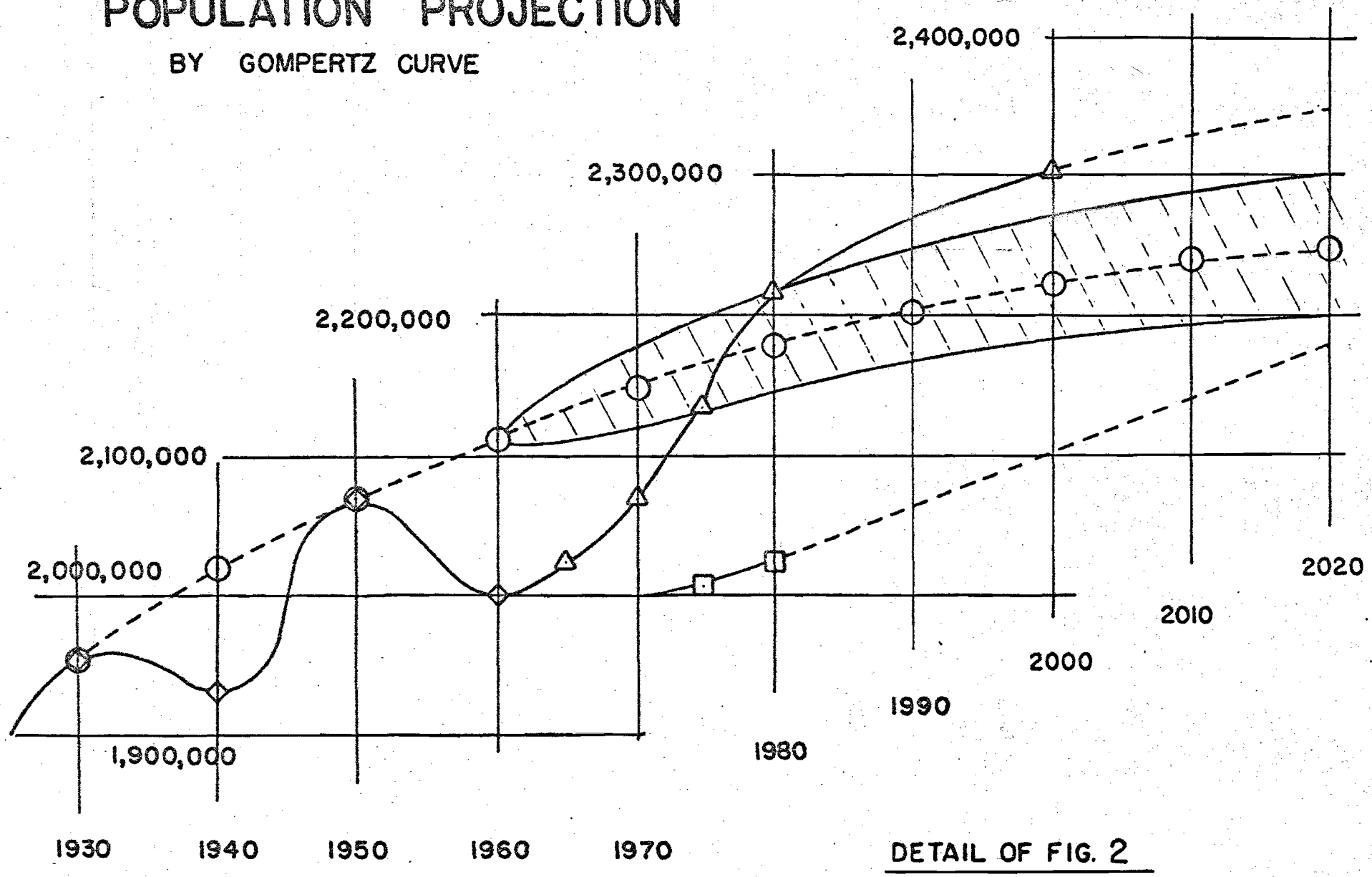
CITY OF PHILA. PLAN. COMM. POPULATION PROJECTION

1965	2,027,000
1970	2,071,000
1975	2,134,000
1980	2,218,000
2000	2,300,000

FIG. 2

PHILADELPHIA
POPULATION PROJECTION

BY GOMPERTZ CURVE



DETAIL OF FIG. 2

POPULATION BY GOMPERTZ CURVE

TABLE 1

YEAR	MIN	MEAN	MAX
1790		54,391*	
1800		81,009*	
1810		111,210*	
1820		135,637*	
1830		188,797*	
1840		258,037*	
1850		408,962*	
1860		565,529*	
1870		674,022*	
1880		847,170*	
1890		1,046,964*	
1900		1,293,697*	
1910		1,549,008*	
1920		1,823,779*	
1930		1,950,961*	
1940		1,931,338*	
1950		2,071,605*	
1960		2,002,512*	
1970	2,120,000	2,150,000	2,180,000
1980	2,144,000	2,180,000	2,216,000
1990	2,164,000	2,205,000	2,246,000
2000	2,180,000	2,225,000	2,270,000
2010	2,192,000	2,240,000	2,288,000
2020	2,200,000	2,250,000	2,300,000

* CENSUS BUREAU INFO.

CORRELATION BETWEEN ACTUAL AND DERIVED POPULATION

TABLE 2

X= 1	Y ESTIMATE=	54937.01	Y ACTUAL= 54391.00
X= 2	Y ESTIMATE=	76066.88	Y ACTUAL= 81009.00
X= 3	Y ESTIMATE=	105648.16	Y ACTUAL= 111210.00
X= 4	Y ESTIMATE=	146719.65	Y ACTUAL= 135637.00
X= 5	Y ESTIMATE=	203048.09	Y ACTUAL= 188797.00
X= 6	Y ESTIMATE=	279024.11	Y ACTUAL= 258037.00
X= 7	Y ESTIMATE=	379328.11	Y ACTUAL= 408962.00
X= 8	Y ESTIMATE=	508273.52	Y ACTUAL= 565529.00
X= 9	Y ESTIMATE=	668775.30	Y ACTUAL= 674022.00
X= 10	Y ESTIMATE=	860994.34	Y ACTUAL= 847170.00
X= 11	Y ESTIMATE=	1080872.59	Y ACTUAL= 1046964.00
X= 12	Y ESTIMATE=	1318962.99	Y ACTUAL= 1293697.00
X= 13	Y ESTIMATE=	1560087.41	Y ACTUAL= 1549008.00
X= 14	Y ESTIMATE=	1784313.45	Y ACTUAL= 1823779.00
X= 15	Y ESTIMATE=	1969453.05	Y ACTUAL= 1950961.00
X= 17	Y ESTIMATE=	2145110.66	Y ACTUAL= 2071605.00

$$Y = e^{e^{(1.30474)}(e^{-.0025X^2})(e^{-.0856X})}$$

CORRELATION COEFFICIENT R= 0.99

PROJECTED RAW WATER DEMAND

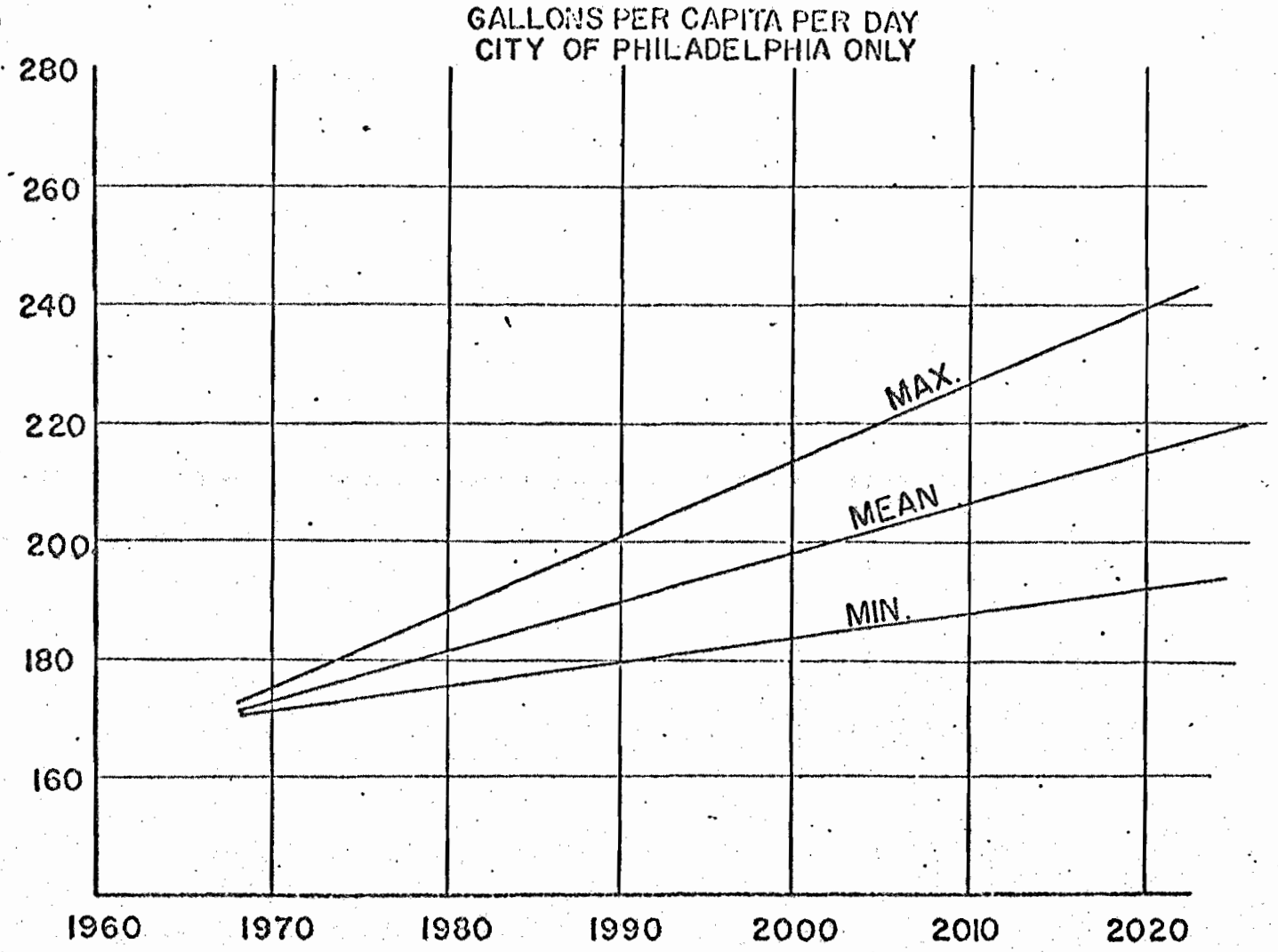


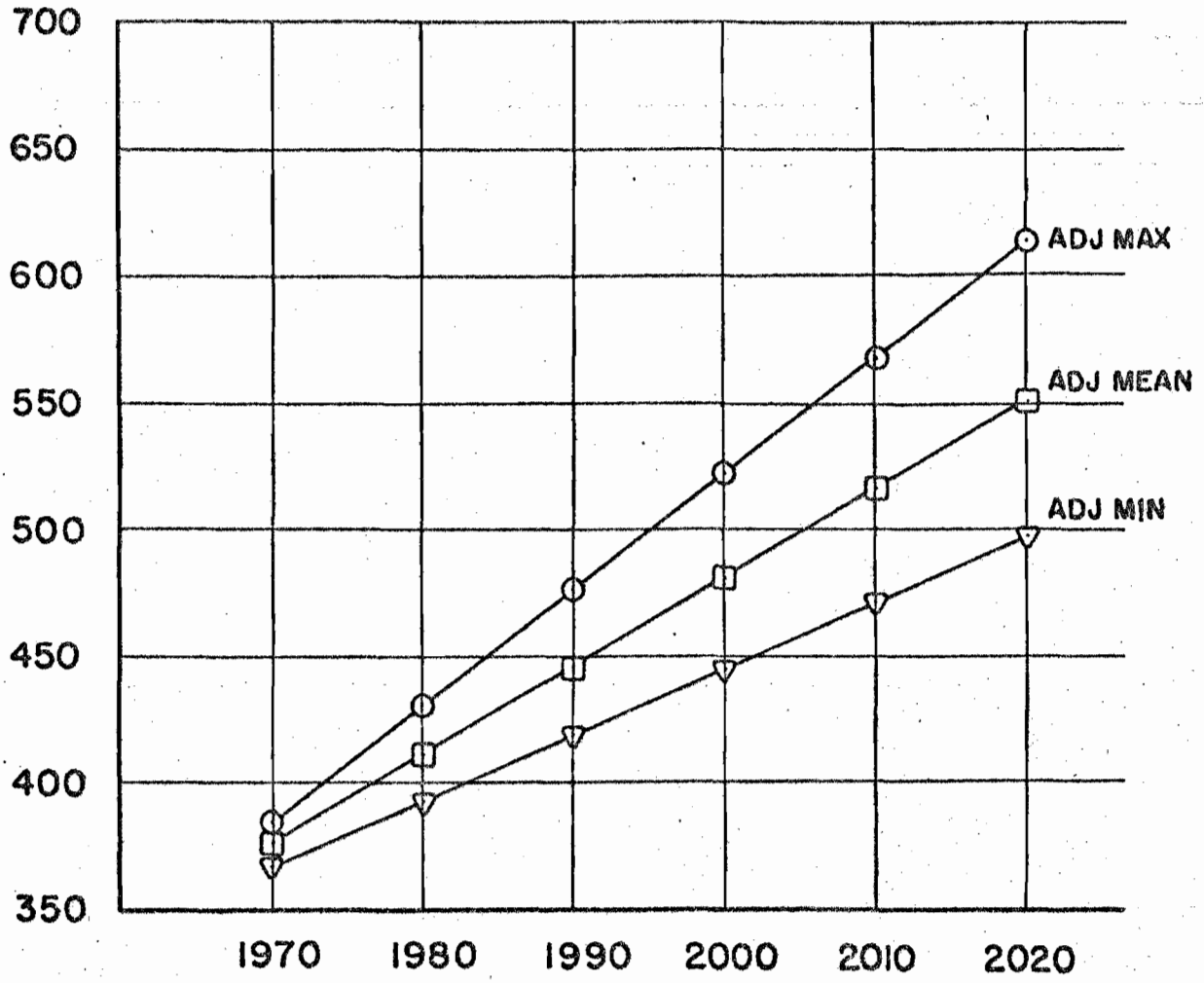
FIG. 3

TABLE 3

YEAR	MIN.	MEAN	MAX.
1970	171	173	175
1980	175	182	188
1990	180	190	201
2000	184	199	213
2010	188	207	226
2020	192	215	239

RATES OF % INCREASE
MIN 0.25
MEAN 0.50
MAX. 0.75
G. P. C. D. PER YEAR

FIG. 4



PHILADELPHIA PROJECTED TOTAL RAW WATER DEMAND

MILLION GALLONS PER DAY

TABLE 4

YEAR	MIN	MEAN	MAX	ADJ MIN	ADJ MEAN	ADJ MAX
1970	363	372	382	368	378	388
1980	375	397	417	396	418	438
1990	390	419	451	422	452	484
2000	401	443	484	445	487	528
2010	412	464	517	468	520	572
2020	422	484	556	489	551	617

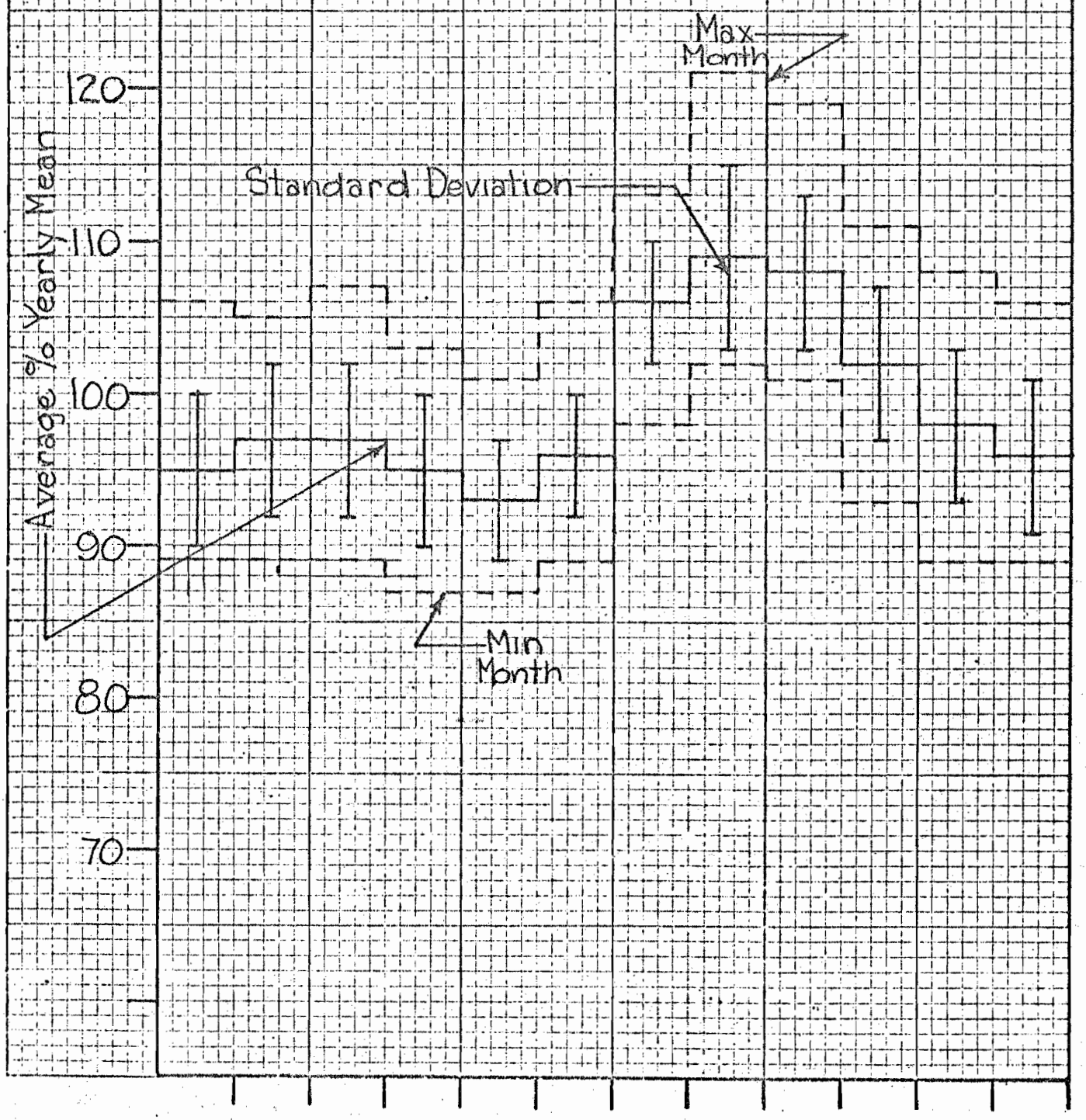
ADJUSTMENT DUE TO ADDITIONAL SUPPLY TO BUCKS COUNTY

Total Yearly Water Demand Variation for Philadelphia

Period of Record Jan 1954 - Dec 1968

Figure 5

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Yearly Mean	95	97	97	95	93	96	106	109	108	102	98	96
Standard Deviation	5.0 ±1	5.0 ±1	5.0 ±1	5.0 ±1	4.0 ±1	4.0 ±1	4.0 ±1	6.0 ±1	5.0 ±1	5.0 ±1	5.0 ±1	5.0 ±1

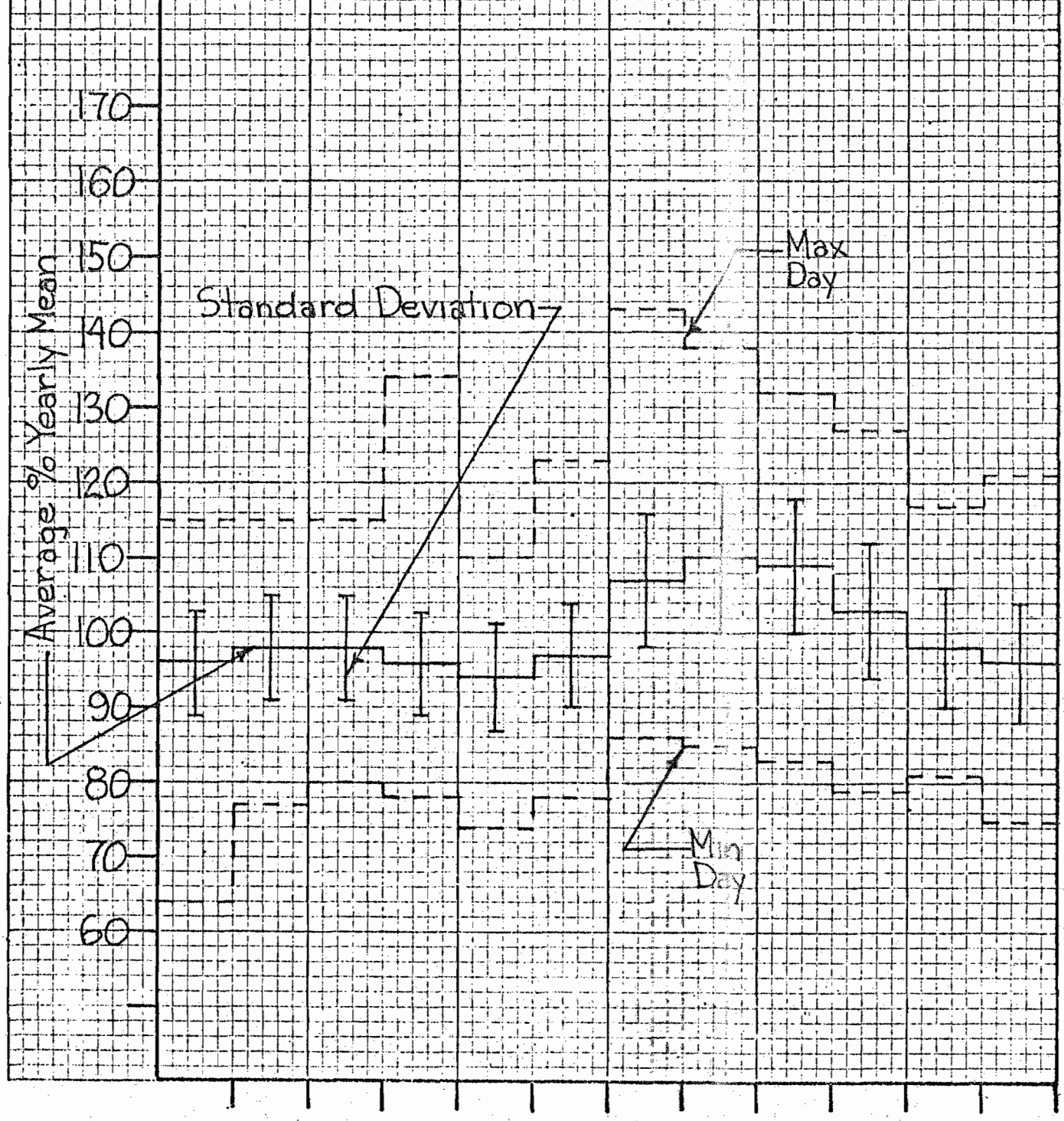


Total Yearly Water Demand Variation for Philadelphia

Period of Record Jan 1954 - Dec 1968

Figure 6

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Yearly Mean	96	98	98	96	94	97	107	110	109	103	98	96
Standard Deviation	7.15 ±1	7.09 ±1	6.87 ±1	7.05 ±1	6.82 ±1	7.23 ±1	9.04 ±1	9.50 ±1	8.62 ±1	8.54 ±1	7.51 ±1	7.59 ±1

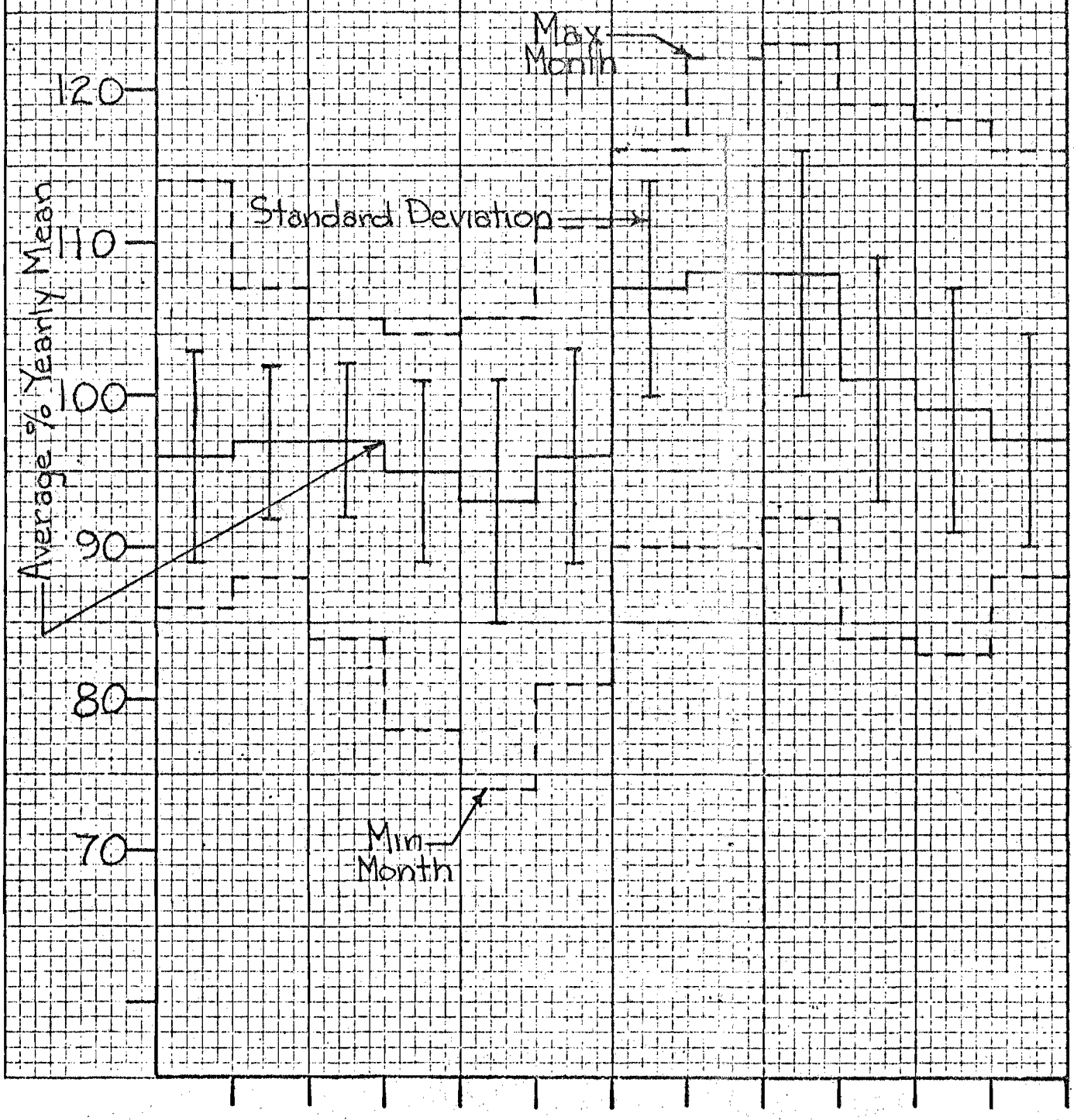


Delaware Yearly Water Demand Variation for Philadelphia

Period of Record
Jan 1954 - Dec 1968

Figure 7

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Yearly Mean	96	97	97	95	93	96	101	103	103	101	96	97
Standard Deviation ±1	7.0	5.0	5.0	6.0	8.0	7.0	7.0	6.0	8.0	8.0	8.0	7.0

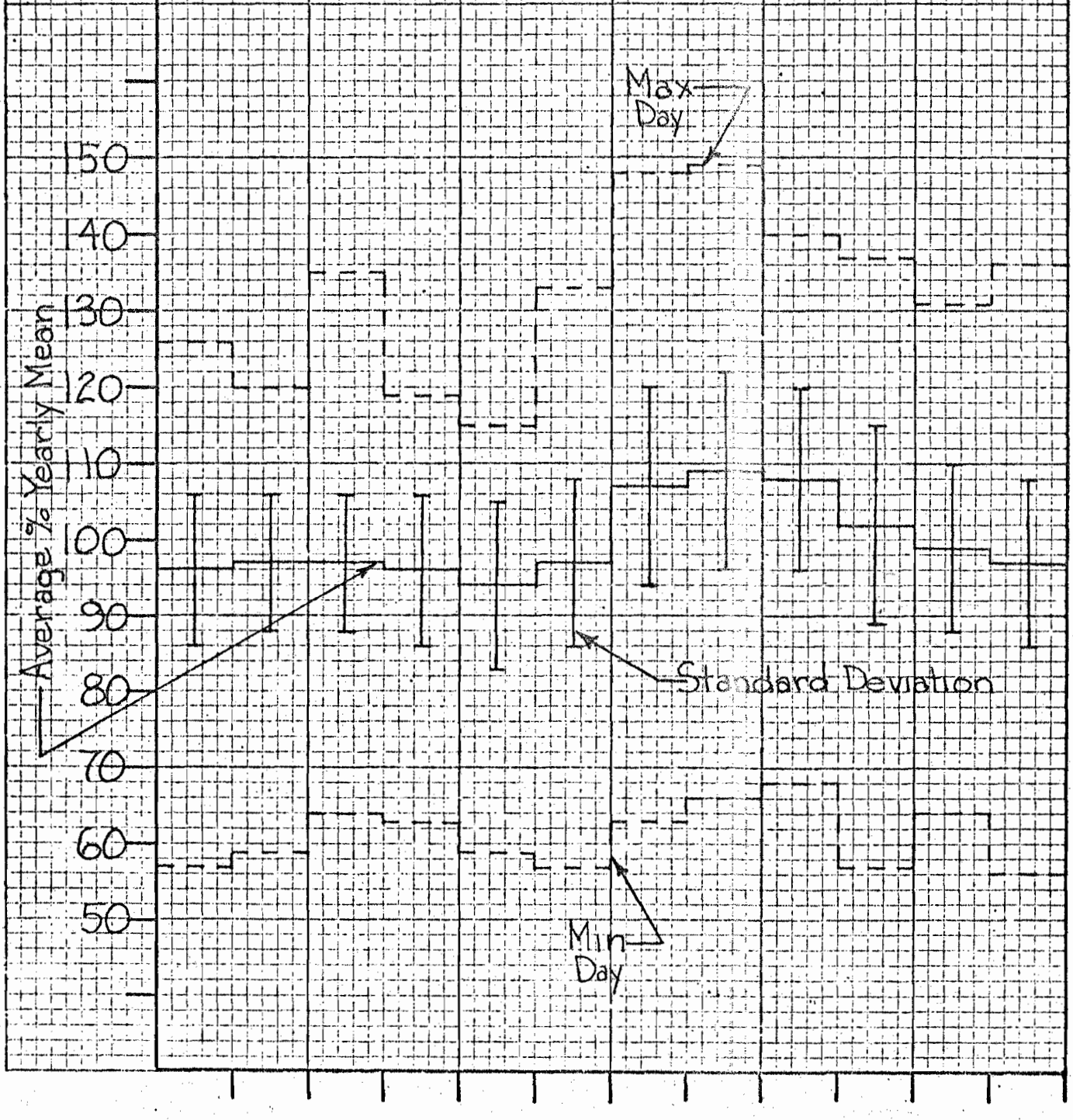


Delaware Yearly Water Demand Variation for Philadelphia

Period of Record
Jan 1954 - Dec 1968

Figure 8

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Yearly Mean	96	97	97	96	94	97	107	106	108	102	99	97
Standard Deviation	9.86 ±1	9.01 ±1	8.79 ±1	9.57 ±1	11.01 ±1	11.11 ±1	12.88 ±1	13.38 ±1	12.37 ±1	13.22 ±1	11.33 ±1	10.62 ±1

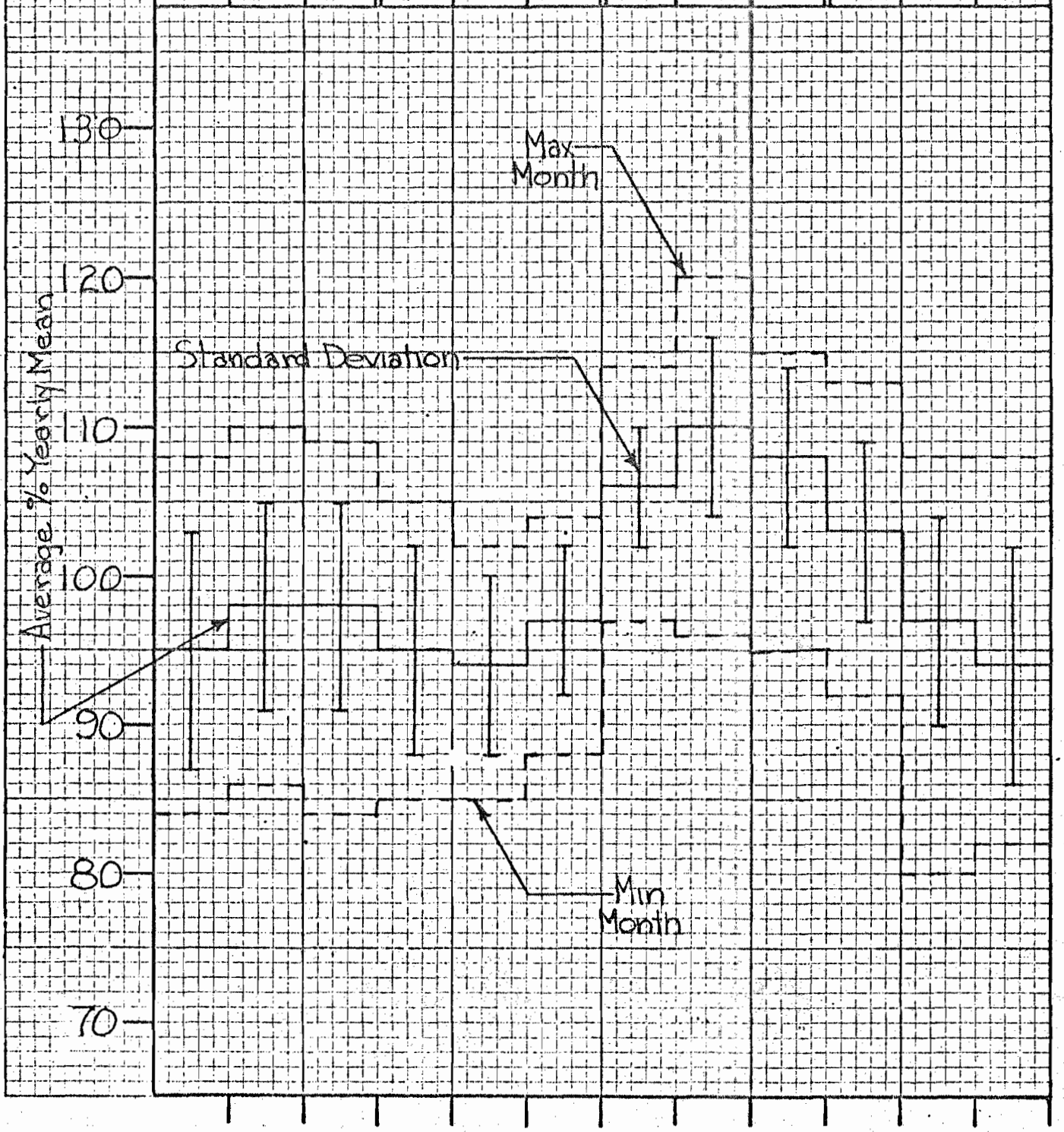


Schuylkill Yearly Water Demand Variation for Philadelphia

Period of Record Jan 1954 - Dec 1968

Figure 9

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Yearly Mean	95	98	98	95	94	97	106	110	108	103	97	94
Standard Deviation	8.0 +1	7.0 +1	7.0 +1	7.0 +1	6.0 +1	5.0 +1	4.0 +1	6.0 +1	6.0 +1	6.0 +1	7.0 +1	8.0 +1

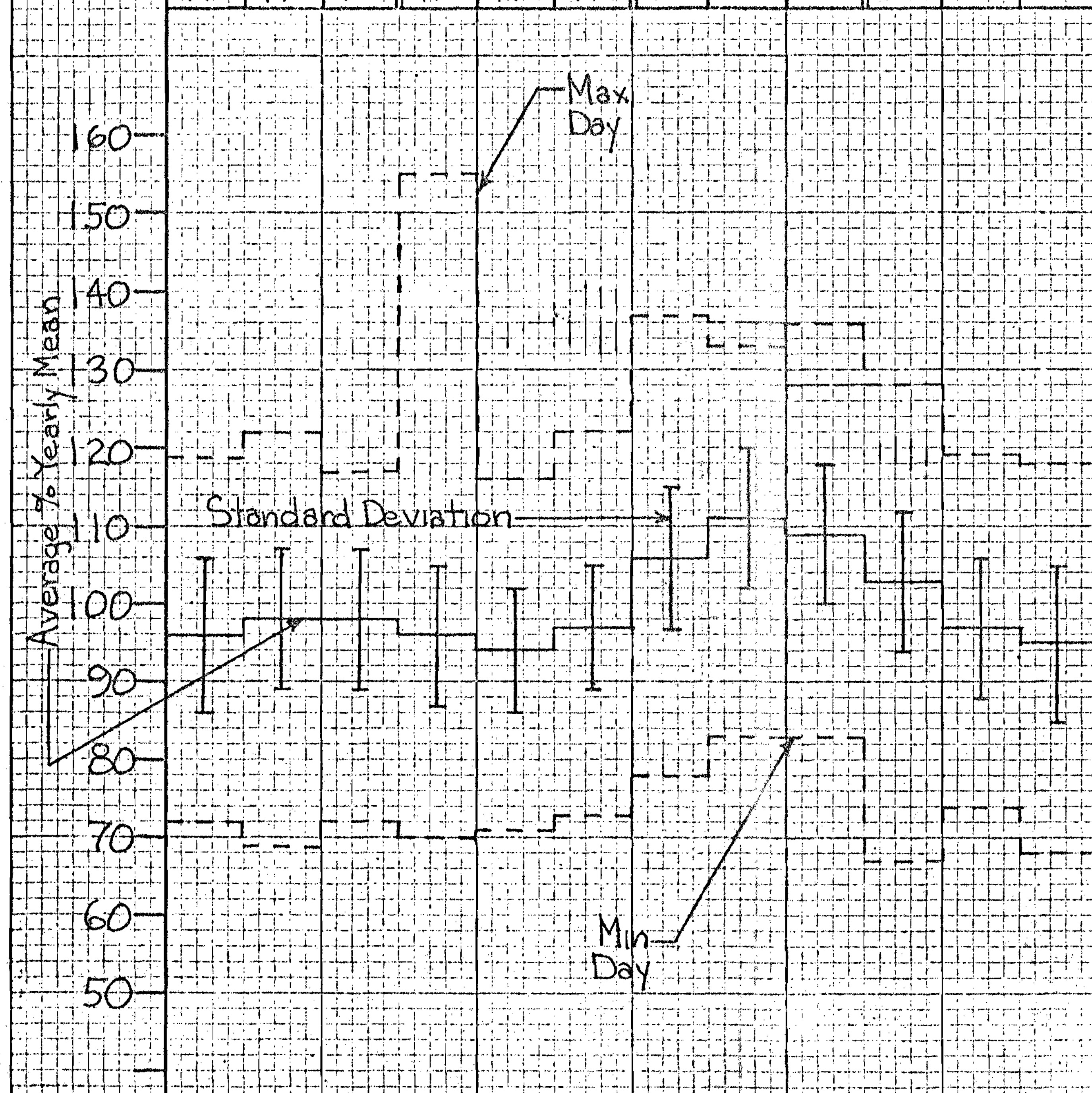


Schuylkill Yearly Water Demand Variation for Philadelphia

Figure 10

Period of Record ...
Jan 1954-Dec 1968

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Yearly Mean	96	98	98	96	94	97	106	111	109	103	97	95
Standard Deviation	±9.59	±8.90	±8.69	±8.88	±8.09	±7.99	±8.64	±8.99	±8.96	±8.85	±9.14	±9.82

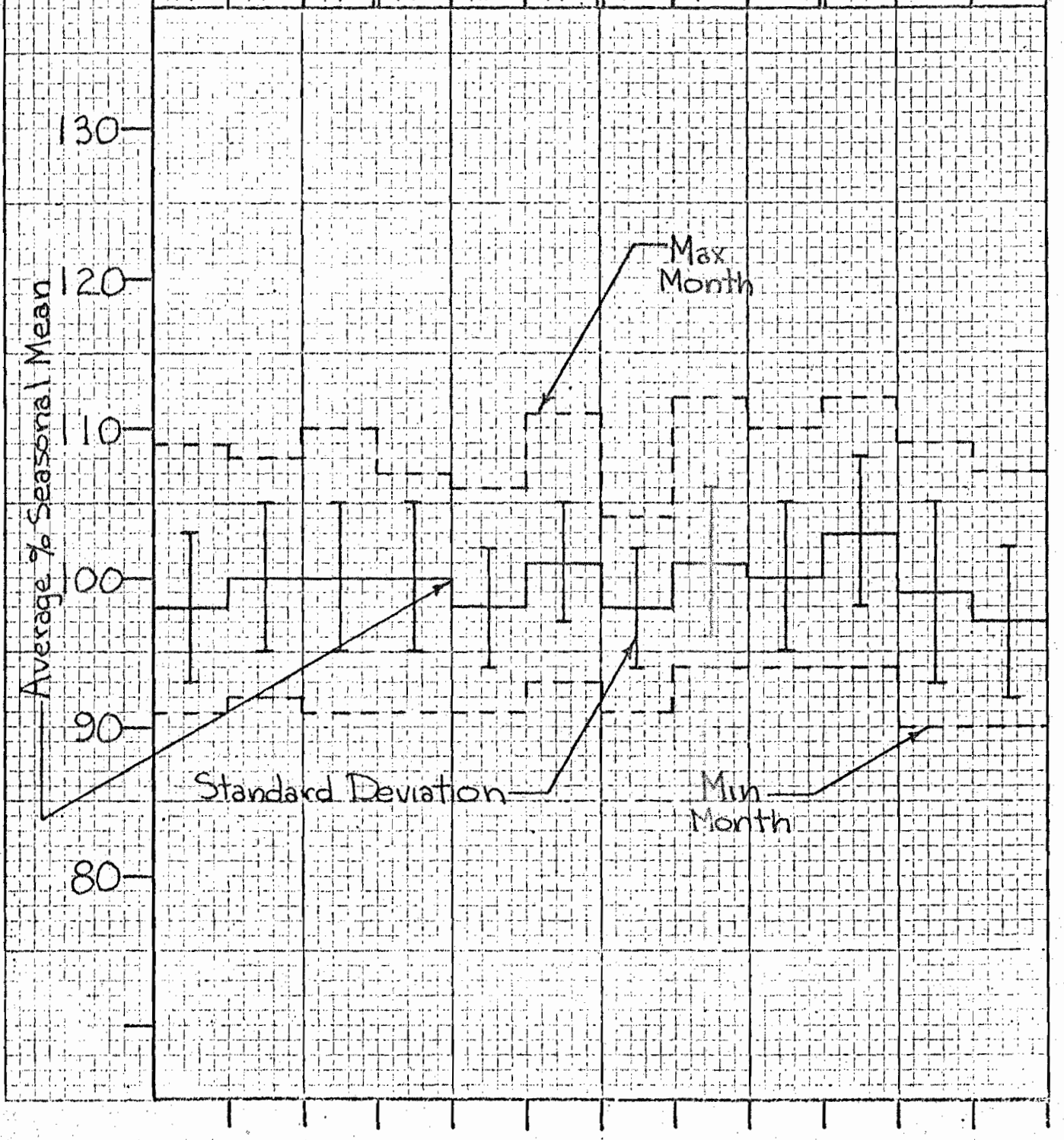


Total Seasonal Water Demand Variation for Philadelphia

Period of Record
Jan 1954 - Dec 1968

Figure 11

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Seasonal Mean	98	100	100	100	98	101	98	101	100	103	99	97
Standard Deviation	5.0 ±1	5.0 ±1	5.0 ±1	5.0 ±1	4.0 ±1	4.0 ±1	4.0 ±1	5.0 ±1	5.0 ±1	5.0 ±1	6.0 ±1	5.0 ±1

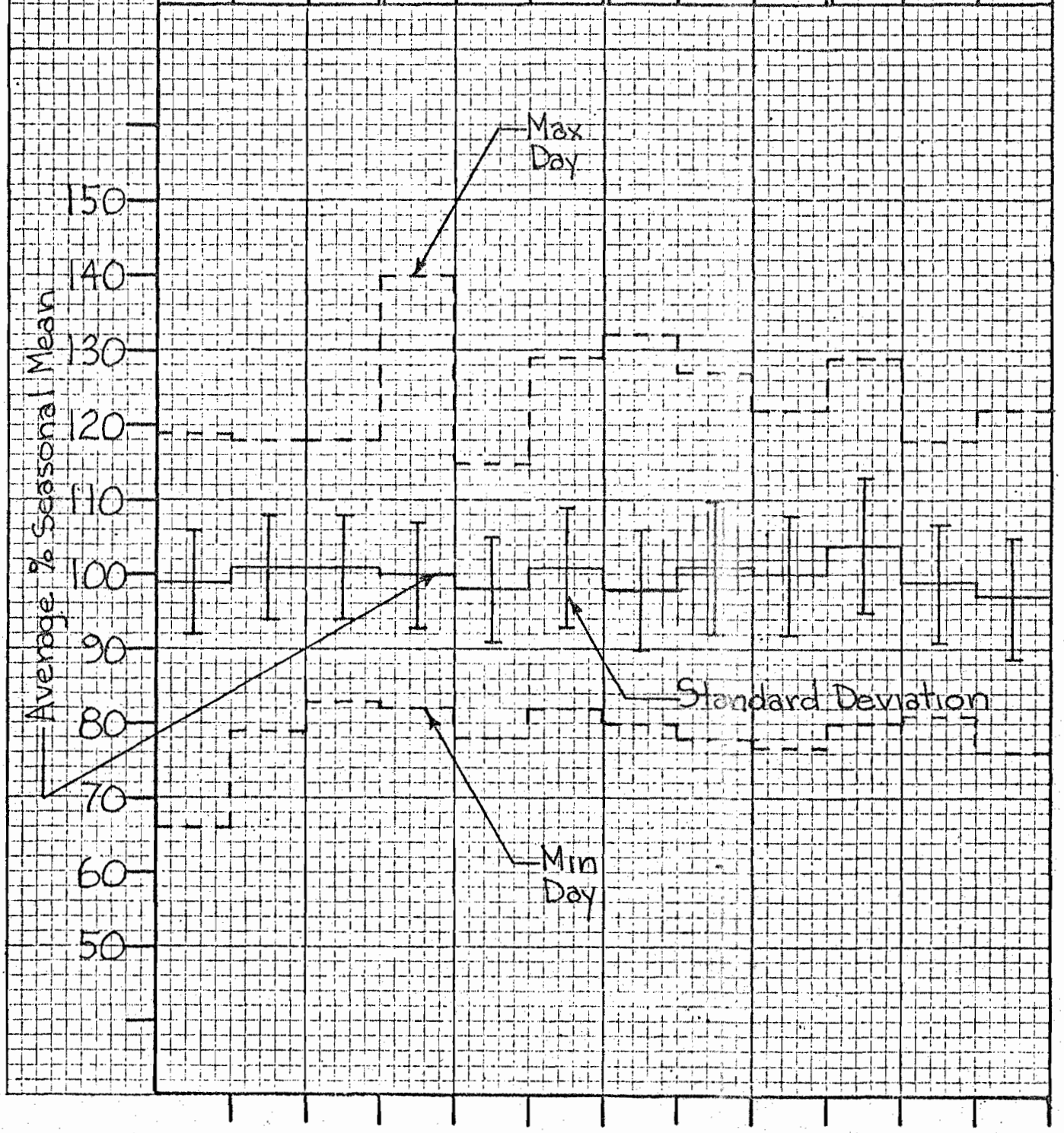


Total Seasonal Water Demand Variation for Philadelphia

Period of Record
Jan 1954 - Dec 1968

Figure 12

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Seasonal Mean	99	101	101	100	98	101	98	101	100	104	99	97
Standard Deviation	±7.36	±7.30	±7.07	±7.38	±7.14	±7.57	±8.34	±8.77	±7.95	±8.63	±7.59	±7.27

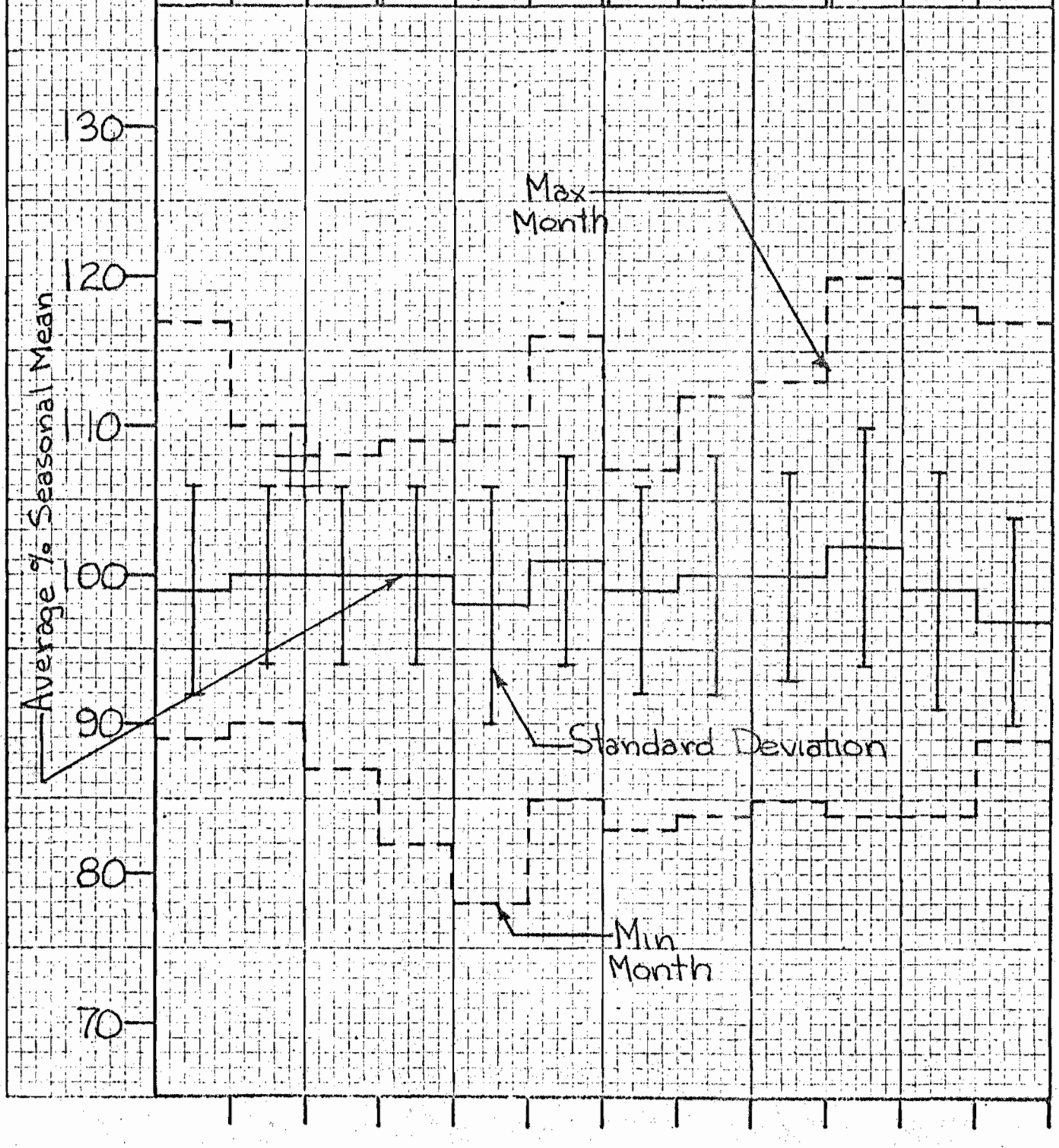


Delaware Seasonal Water Demand Variation for Philadelphia

Period of Record Jan 1954 - Dec 1968

Figure 13

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Seasonal Mean	99	100	100	100	98	101	99	100	100	102	99	97
Standard Deviation	7.0 +1	6.0 +1	6.0 +1	6.0 +1	8.0 +1	7.9 +1	7.0 +1	8.0 +1	7.0 +1	8.0 +1	8.0 +1	7.0 +1

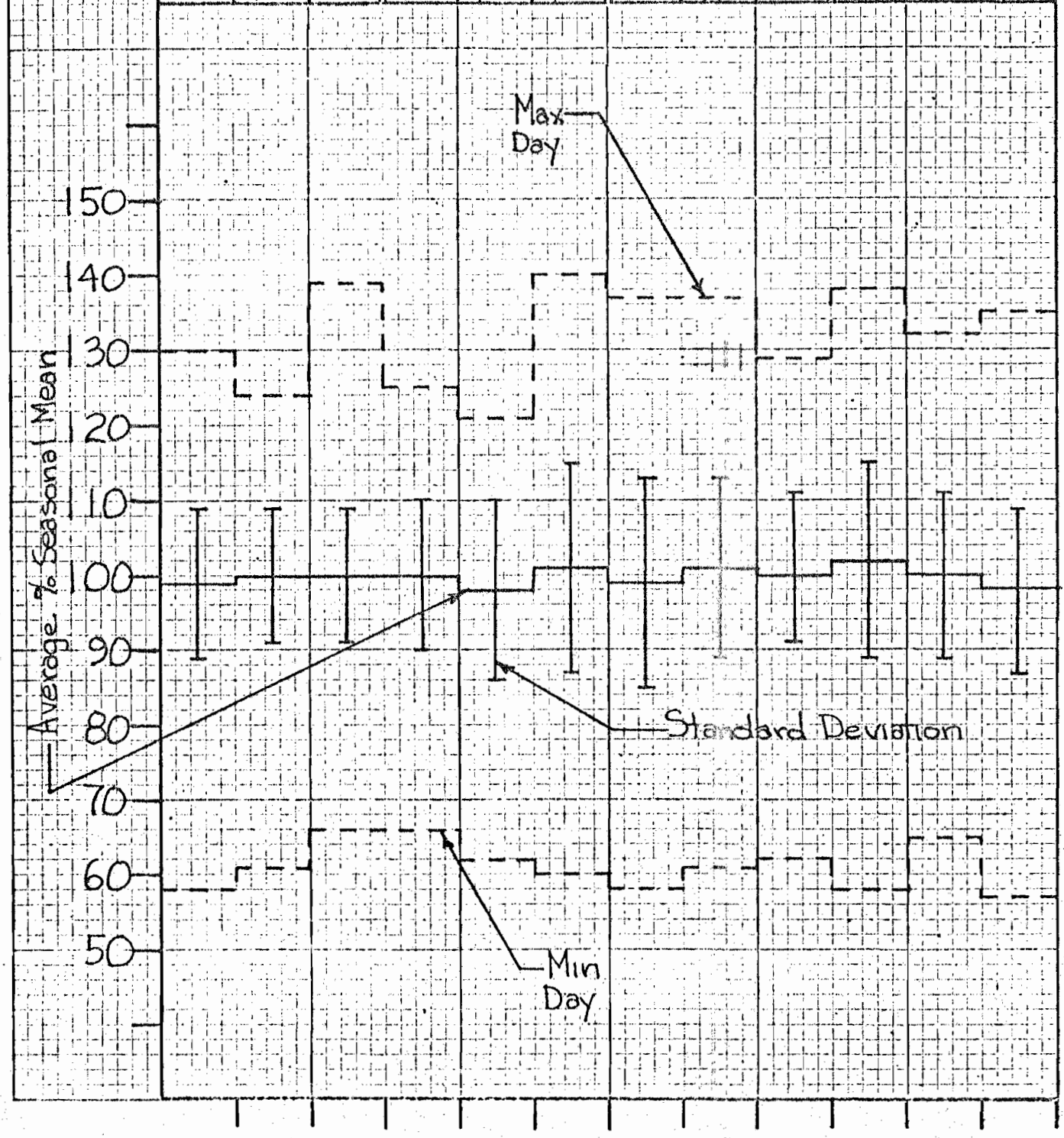


Delaware Seasonal Water Demand Variation for Philadelphia

Period of Record
Jan 1954-Dec 1968

Figure 14

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Seasonal Mean	99	100	100	100	98	101	99	101	100	102	100	98
Standard Deviation	±10.18	±9.35	±9.04	±10.03	±11.55	±11.65	±11.90	±12.36	±11.43	±13.30	±11.40	±10.68

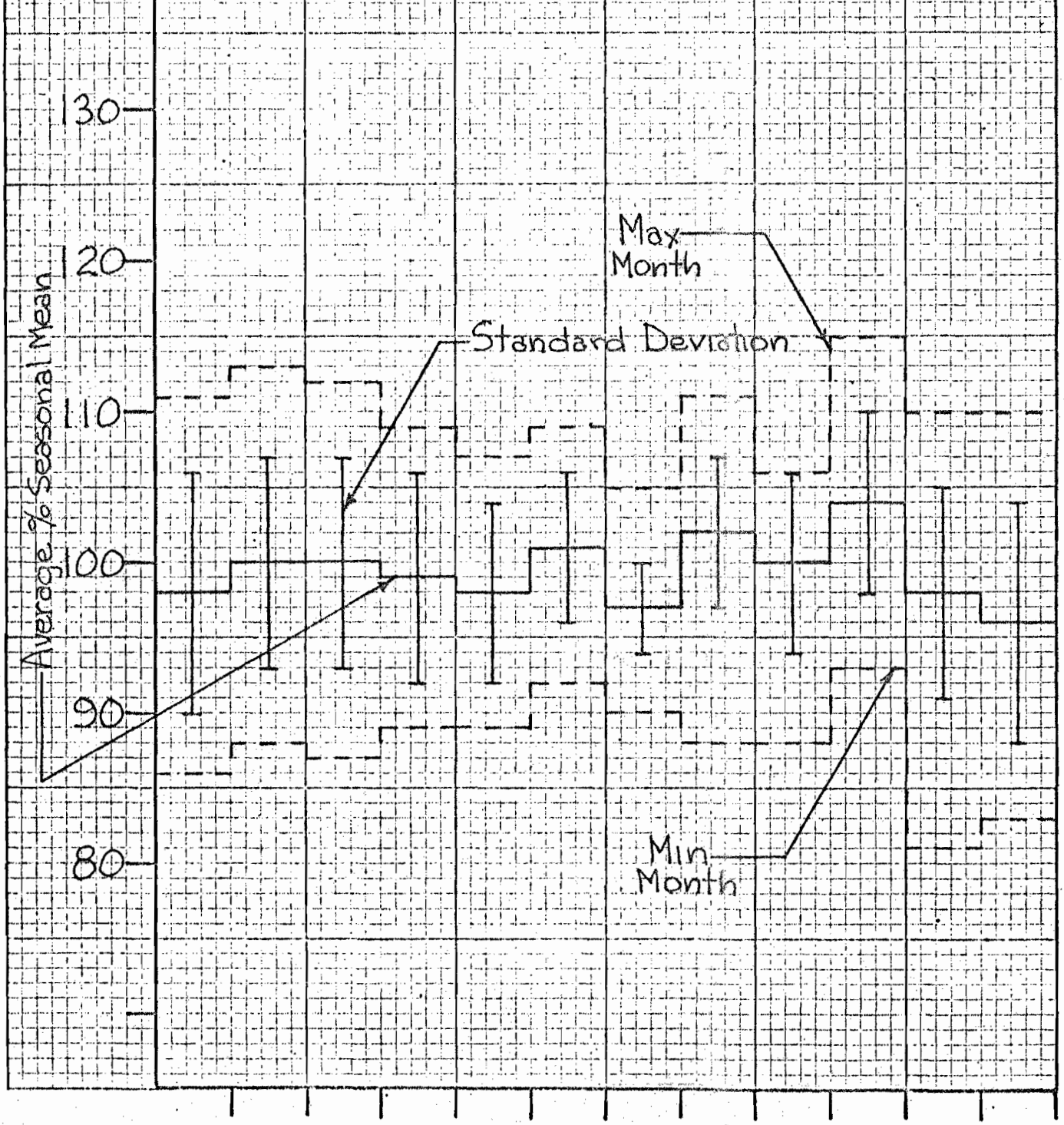


Schuylkill Seasonal Water Demand Variation of Philadelphia

Period of Record .. Jan 1954 - Dec 1968

Figure 15

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Seasonal Mean	98	100	100	99	98	101	97	102	100	104	98	96
Standard Deviation	8.0 ±1	7.0 ±1	7.0 ±1	7.0 ±1	6.0 ±1	5.0 ±1	3.0 ±1	5.0 ±1	6.0 ±1	6.0 ±1	7.0 ±1	8.0 ±1



Schuylkill Seasonal Water Demand Variation for Philadelphia

Figure 16

Period of Record
Jan 1951 - Dec 1968

	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Average % Seasonal Mean	98	101	101	109	89	101	98	102	100	95	97	99
Standard Deviation	±1 9.86	±1 9.15	±1 8.63	±1 9.28	±1 8.46	±1 8.35	±1 7.56	±1 8.28	±1 8.26	±1 8.69	±1 9.26	±1 9.68