SIGNIFICANT FACTORS GOVERNING MUNICIPAL WATER CONSUMPTION

by

WARREN CYRIL WESTGARTH

A THESIS

Submitted to

OREGON STATE COLLEGE

In partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

1954

APPROVED:

[redacted]

Professor of Civil Engineering

In charge of Major

[redacted]

Chairman of Department of Civil Engineering

[redacted]

Chairman of School Graduate Committee

[redacted]

Dean of Graduate School

Date thesis is presented May 6, 1954

Typed by Betty Jean Mock

ACKNOWLEDGMENTS

The writer is greatly indebted to those persons who have contributed their time, energy, and resources to make this study possible. Professor Fred Merryfield made timely suggestions and corrections during the thesis preparation. John Geren, Manager, Salem Water Department; Norman Johnson, Superintendent of Water Operations, Eugene; and H. D. Taylor, Water Engineer of Corvallis have shown the utmost in cooperation by allowing the writer the use of their consumption records. Wm. G. Dunaven, Plant Operator, Corvallis personally searched the attic of City Hall to find water records for this study. Without the encouragement and assistance given by the writer's wife this paper could not have been completed. Her efforts in typing the first draft of the manuscript and the numerous tables are gratefully acknowledged. Thanks are also expressed to the members of the Civil Engineering Department who gave encouragement and aid when the task appeared hopeless.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

SIGNIFICANT FACTORS GOVERNING MUNICIPAL WATER CONSUMPTION

SECTION I, INTRODUCTION

HISTORICAL RESUME' OF DOMESTIC WATER CONSUMPTION AND USE

Where no water exists, there can be no life. All the members of the plant and animal kingdom depend for their existence on a plentiful supply of water, and it is this necessity that has greatly influenced man throughout the centuries since his creation. Air, which is needed continuously for existence, has been supplied by nature in bountiful quantities almost any place man might care to go, but water, without which man will die in three or four days, concentrates in pools, lakes, streams and springs, and forces man to develop these sources or to transport it to his home in enough quantity for both present and future needs. It is this necessity for a plentiful supply of water that has brought about changes in transportation, storage, and consumption of water from ancient times to our modern times.

<u>Ancient Times</u>

When ancient man first appeared on the scene, he braved the wrath of other animals to get water from their drinking places which he instinctively felt were a source of safe water. It wasn't until about 10,000 B.C. that man conceived the idea of transporting water in gourds and shells, or in folded animal skins from the water source to his cave. This momentous discovery must have led to the use of man-made pottery jars and bowls which were uncovered as part of the archeological evidence of civilizations along the Euphrates and the Nile and in Greece as early as 5000 B.C.

Precise times and places of the origin of various water developments in ancient history are hard to find, but records in history place the Egyptians and Mesopotamians as leaders in the field of irrigation. Both areas show evidence of large networks of canals, since silted in. The Egyptians are credited with developing the first system of counter-balanced lifting about 3000 B.C. During this same period, water vendors sold cups of drinking water along the streets of Old Egypt, and in Asia Minor rain water was collected from roofs of houses and stored in brick cisterns.

Probably, the first "public water systems" were wells. History traces them through Egypt, Persia, Palestine, India and China. From wells in Persia which were 80-300 feet deep, to one well in China 1500 feet deep, and to Joseph's well in Cairo which is 297 feet deep and cut into solid rock. Biblical references to wells are frequent, especially in the book of Genesis i.e. 26:18-19.

Abimelech had forced Isaac to abandon his home and the wells Abraham, his father, had dug and to move to the valley of Gerar

> "(18) And Isaac digged again the wells of water which they had digged in the days of Abraham his father; for the Philistines had stopped them after the death of Abraham; and he called their names after the names by which his father had called them.
> (19) And Isaac's servants digged in the valley and found there a well of springing water."

In the book of Exodus when Moses brought the people of Israel from the Red Sea to the wilderness of Shur, he found bitter waters which the people could not drink. These waters were purified by a tree which God showed to Moses; then in Exodus 15:27

> "And they came to Elim, where were twelve wells of water, and three score and ten palm trees: and they encamped there by the waters."

The first mention of purification of waters may be found in the second Book of Kings, 2:19-22

> "(19) And the men of the city said unto Elisha, Behold, I pray thee, the situation of this city is pleasant, as my lord seeth: but the water is nought, and the ground barren.
>
> (20) And he said, Bring me a new cruse, and put salt herein. And they brought it to him
>
> (21) And he went forth unto the spring of the waters, and cast the salt in there, and said. Thus saith the Lord, I have healed these waters: there shall not be from thence any more death or barren land.

> (22) So the waters were healed unto this
> day, according to the saying of Elisha
> which he spake."

Ancient Egyptian history points to methods of purification using coagulants, filtering wicks leading from one vessel to another, and distillation processes.

As population increased wells could not supply the demand for water and it had to be brought to the cities from another source. The Bible again is the first source of information in II Kings 20:20, Hezikiah

> "Made a pool and a conduit and brought
> water into the city of Jerusalem."

In the 7th century B.C. the mighty city of Babylon was flourishing under the rule of Nebuchadnezzar who boasted of his mighty deeds:

> "That which no king before had done, I did...
> A wall like a mountain that cannot be moved,
> I builded...great canals I dug and lined
> them with burnt brick laid in bitumen and
> brought abundant waters to all the people...
> I paved the streets of Babylon with stone
> from the mountains...Magnificent palaces
> and temples I have built...Huge cedars from
> Mount Lebanon I cut down...with radiant
> gold I overlaid them and with jewels I
> adorned them." (22, p.4)

A journey through the ruins of Babylon at the present time would tend to belie the great civilization which even included air conditioning in the Hanging Gardens of Babylon. From Nebuchadnezzar's boast it appears that water had a great share in building the civilization he knew. From the ruins of today it is equally apparent that the silt carried by water in the canals is mostly responsible for the destruction of a powerful city.

As water became more plentiful its uses multiplied. People used water for cleansing their houses and their utensils--and even began to bathe in it! As water use increased larger and longer aqueducts had to be built. In Greece in 625 B.C. one of the first hydraulic engineers, Eupalmus, cut a tunnel eight feet by eight feet, 4200 feet long through a hill to bring water to the town of Samos. Nearly all the major cities of Greece by the 6th century B.C. had water systems composed of aqueducts, lead or copper distribution pipes laid beneath the streets, and baths and fountains of unsurpassed beauty.

The history of water supply in ancient times was climaxed by the engineering and ingenuity of the water engineers of the Roman Empire, whose work still stands as mute tribute. Fortunately the development of the Roman water supply was recorded by Sextus Julius Frontinus, a surveyor and water commissioner of Rome in A.D. 97, in his two books entitled, "The Aqueducts of Rome." These books were translated into English in 1899 by an eminent American hydraulic engineer, Clemens Herschel, who spent many years in a painstaking effort to reproduce the Latin and make an authentic translation of the work. An outline of the books could well be an outline for a water supply report for one of our modern cities!

I. Source

A. Names of waters

B. By whom established

C. Year of establishment

D. Point of intake of each system

E. Quantity and quality of water

II. Transmission

A. Type of conduit or aqueduct used

B. Elevation (plan) of each system

III. Storage

A. Number of reservoirs

B. Type of reservoirs

IV. Distribution

A. Number of fountains supplied

B. Number of private lines

C. Type of pipe

D. Quantities of flow at each point

E. Method of measurement of quantities

V. Administration

A. Number of paying customers

B. Number of "favorite sons" of the emperor

C. Laws and rules of the water department

1. Pollution laws
2. Workmen's rules
3. "Eminent domain"
4. Public relations

D. Records and plans

Frontinus was well pleased with the system which served the Roman people a fair quality of water in quantities estimated by Mr. Herschel to be about 50 gallons per capita per day. That Frontinus was serious about his work was evidenced by his closing remark after his description of the aqueducts: "With such an array of indispensable structures carrying so many waters, compare, if you will, the idle pyramids or the useless, though famous, works of the Greeks!" (13 p. 357) Perhaps Frontinus was boasting as Nebuchadnezzar did before him, but even today the Roman works are considered as the beginning of muncipal water supply.

It would be unfortunate to leave the study of water in ancient history with the thought that the only monumental water supplies were those of Greece and Rome. The ancient Peruvians had built aqueducts extending as much as 450 miles in length. Geologists indicate that there are evidences of water works in New Mexico and Arizona that were constructed long before Columbus' discovery of the "New World." It is reasonable to assume that wherever men lived together in cities, whether they be on one of the continents or on an island, building and maintaining an adequate water system was a primary problem if they were to survive.

Middle Ages

With the fall of the Roman Empire in the latter part of the fourth century A.D. began the period often referred to as the "dark ages." Under the rule of the Goths in Europe and the Saxons in England it was a period of retrogression of the civilization the Romans had known. The aqueducts were partially destroyed and the entire field of water supply was neglected. Undoubtedly as the feudal system developed and the feudal lords' castles became small cities, the problems of water supply became increasingly apparent; but the prevalence of pestilence and disease during the period indicated a gross neglect of the problem.

The feudal cities had to supply their own food, clothing, and other necessities of life and as a result low-grade production techniques were set up in the dyeing, weaving and tanning industries. Seaworthy boats had been sailing the seas for centuries, and when the industries produced more goods than the home populace could use, the surplus was shipped to a foreign land and traded for usable items. Thus the feudal cities were slowly transformed from walled fortresses to trading centers. As the commercial trend developed more water was needed and in the ninth century A.D. new water works systems appeared in Spain; in Paris in 1183 a small aqueduct was built which supplied about a quart of water per day per person. Small quantities of spring water were brought to citizens of London in 1235 through lead and masonry conduits.

The thirteenth century was probably the beginning of the "Renaissance" in the old world. Shipping was developing rapidly, literature was again appearing, universities were being developed and the "Magna Carta" was signed by King John as a guarantee of constitutional rights. However, it was not until the fifteenth century that major improvements were made to start bringing the water supply field out of the "dark ages".

The first use of pumps was probably for pumping water out of ships. From the ships the use spread to wells and mines, to city water systems, and to draining of low lands. The first pumps were crude pumps with a wooden plunger in a hollow log. Next came water-driven wheels and windmill pumps. All of these labor-saving devices were in use in England, France and Germany in the fifteenth century.

Under the London Bridge a pumping plant was built in 1582 utilizing sixteen pumps connected to water wheels turned by the current of the Thames and supplying water to a distribution system of lead and wooden pipe laid in the streets. In 1583 Paris also boasted a pump house on the Seine with pumps driven by water power, and in Hanover pumps had been introduced as early as 1527. It would be unpardonable to leave this period without a brief mention of the great Italian artist Leonardo da Vinci (1452-1519) who applied his genius for a time to hydraulics and developed a number of water-lifting mechanisms and measuring devices, the principles of which are still in use in our present day hydraulics. If da Vinci had applied all his talents to hydraulic structures our history study might have been set ahead a full century or more.

Modern European History

Modern water works were inaugurated in 1619 by the New River Water Company of London when the newly incorporated company laid mains throughout the city employing for the first time the idea of supplying water to individual houses on an intermittent basis. The obstacles confronting the water works industry at that time are vividly portrayed by noting that no large diameter pressure pipe was available and as many as ten bored log mains had to be laid side by side to meet the requirements of flow.

It was not until the advent of steam-driven pumps in London (1761 and 1787) and in Paris (1781 and 1783) that any other major changes occurred. The steam-driven pump, though crude according to present standards, gave the industry a prime mover which could pump the quantity of water desired without the monstrous water wheel pumps.

During the early part of the nineteenth century, sanitation came to the forefront. The development of the water-distribution system made practicable the use of the water closet for disposal of fecal wastes. Previously most cities were unsewered and the ones that did have sewers forbade putting household wastes into them. These sewers were only for storm drainage. Water closets require considerable amounts of water. This water carries fecal matter, along with contaminating organisms down the sewers to the streams and rivers. These streams and rivers in their turn become contaminated, and any water supply taken from the river would be contaminated. As a greater number of water closets were put into use, contamination increased to a point dangerous to public health. This public health danger was probably the main impetus for the development of slow sand filtration on the Seine in Paris, on the Thames in London, and in parts of Scotland in the early part of the nineteenth century. The first slow sand filter was constructed by James Simpson in London in 1829. Robert Thom near Glasgow, Scotland had also constructed a sand filter and concluded that partial failure of sand filters was due to surface clogging. He devised a sand filter washed by reverse flow. Undoubtedly these men had done a great deal of original research prior to the installation of the first units.

In Europe quality of water seems to take precedence over quantity. In Paris in 1890 the supply was about 65 gallons per capita, per day about one-fourth (16 g pcd) of which was drawn from springs for domestic use. The remainder was taken from rivers for street washing and other public use. About 1904 the London system was brought under municipal management and served 7,250,000 people 46 gallons per capita daily. Since 1900 the progress in water supply has run a close parallel in Europe and America, so the scene can be shifted to the development of the American water works industry.

United States History

That the early settlers in America brought some of their knowledge with them is evidenced by the appearance of the first water supply of Boston in 1642. Water was piped from a spring through wooden conduits to a wooden tank 12 feet square from which people dipped the water in buckets. The first instance, where machinery was used was at Bethlehem, Pennsylvania in 1754. Here a wooden pump of 5 inch bore forced water to a wooden reservoir. Water power from water wheels was used in grist mills as early as 1645. Cast iron pipe came into use as early as 1800. Bethleham, Pennsylvania in 1764 was the first city to install a steam-driven pump with Philadelphia following in 1800. By 1840 steam pumpers and fire hydrants for fighting fires were in use in all major cities. Only the larger cities had adequate water systems; the smaller ones were mainly limited to well sweep and windlass on private wells or a larger town well. Water use even in larger cities was confined mainly to drinking and washing of utensils as is evidenced by a Boston ordinance as late as 1856 restraining Bostonians from bathing oftener than once a week, unless by doctor's prescription, and a Philadelphia decree stating that none of the citizens were to bathe between November 1 and March 15.

In 1850 there were less than 100 water supply systems in the United States and very few people realized the degree of treatment necessary to make water safe for human consumption. Cities were growing in population; industries were concentrating in the cities; and as a result domestic and industrial wastes were contaminating the streams adjacent to the cities. It was becoming apparent that the popular notion that "a river purifies itself in 20 miles of flow" no longer applied as pollution loads became high.

As the century drew to a close, Koch and Pasteur, the famed bacteriologists, revealed their spectacular findings regarding the spread of disease by pathogenic, or disease-causing, organisms. Typhoid fever scourges which had taken hundreds of lives both in European and American cities, had been traced to polluted supplies. It was found that the typhoid bacilli--tiny but potent bacteria which have their origin in the human intestinal tract--could find their way into the human body either by direct contact with a diseased person or by its ingress via water, milk, or other food taken into the mouth. The bacteriological need for treating waters containing even slight amounts of sewage was now established. Table 1 (41, p. 279) shows the decrease in typhoid cases from 1881 to 1937 and shows that the decrease is due in the main to sand filtration, liquid chlorination which came into general practice in 1912 or a combination of the two.

Entirely apart from the health angle were other factors calling for vast amounts of water which only municipal water supplies could adequately furnish. Mrs. O' Leary's cow, whose ill-placed kick had started the great Chicago conflagration of 1871, in which 18,000 buildings were destroyed, had also started a wave of modern thinking regarding the need for lots of water for fire-fighting purposes if similar disasters were not to occur in other sprouting cities.

And, too, the plumbing industry was doing its bit to provide American homes with modern conveniences, which even if they do look somewhat ornate compared with today's streamlined fixtures, did, nevertheless, use just about as much water.

These various factors added up to one thing. The water works industry was about to get a tremendous impetus.

Typhoid Fever Death Rates (per 100,000 Population) in Certain Large Cities in the United States, 1881–1937

City	Average rate for five year periods[1] and listing of significant water works improvements[2]												
	1881–1885	1886–1890	1891–1895	1896–1900	1901–1905	1906–1910	1911–1915	1916–1920	1921–1925	1926–1930	1931–1935	1936	1937
New York	31.6	24.2^{N}	20.0	18.0^{N}	18.2	13.5	8.0^{C}	3.2^{N}	2.6	1.3	0.8	0.4	0.3
Chicago	76.0	61.2	85.6	34.0	28.6	15.8	8.2^{C}	2.4	1.4	0.6	0.4	0.3	0.3
Philadelphia	69.2	68.0	43.6	44.6	49.8^{f}	41.7	11.2^{CF}	4.9	2.2	1.1	0.9	0.7	1.4
Detroit		40.0	44.4	20.0^{N}	21.2	22.8	15.4^{C}	8.1	4.1^{F}	1.3	0.6^{NF_2}	0.5	0.3
Los Angeles			47.5^{3}	37.4^{3}	31.2	19.0	10.7^{N}	3.6	3.0	1.5^{C}	0.8	1.0	0.7
Cleveland	65.2	59.6	45.0	37.2	49.2^{N}	15.7	10.0^{C}	4.0^{Nf}	2.0^{F_2}	1.0	1.1	1.0	0.5
St. Louis	42.4	30.6	44.2^{N}	22.4	34.8	14.7	12.1^{NCF}	6.5	3.9	2.1^{NF_2}	1.6	0.8	1.1
Baltimore	44.8	45.6	42.2	35.0	35.6	35.1	23.7^{CF}	11.8	4.0	3.2^{F_2}	1.4	0.9	1.2
Boston	52.2	39.2	31.2	30.8	22.4	16.0	9.0	2.5	2.2	1.2	0.6	0.1	0.4
Pittsburgh	112.4	102.0	89.2	90.8	126.8	65.0^{NF}	15.9	7.7^{C}	3.9	2.4	0.9	0.7	0.7
San Francisco	32.8	40.8	35.4	24.2	24.8	26.3	13.6	4.6	2.8^{C}	2.0	0.8^{N}	0.3	0.6
Milwaukee	32.6	34.4	29.8^{N}	16.2	18.2	27.0^{C}	13.6	6.5^{N}	1.6	0.8	0.2	0.3	0.0
Buffalo	47.0	32.2	41.4	23.4	28.2	22.8	15.4^{NC}	8.1	3.9	2.7^{F}	0.6	0.3	0.2
Washington	63.0	88.4	86.8	65.6	56.2^{f}	36.7	17.2	9.5	5.4^{C}	2.8^{F_2}	2.6	1.6	1.9
Minneapolis			55.8	45.8	39.0	32.1	10.6^{CF}	5.0	1.9	0.8	0.8	0.0	0.2
New Orleans	25.6	17.0	26.4	49.2	40.0	35.6^{NF}	20.9^{C}	17.5	11.6	9.9	9.6	6.5	2.3
Cincinnati	55.0	76.8	48.0	38.6	55.6	30.1^{NF}	7.8	3.4^{C}	3.2	2.5	1.4	1.9	1.3

[1] Note: Rates for 5 year periods, 1881–1905, inclusive, calculated from table 3, pages 14–15, Water Works Practise Manual, A. W. W. A. (1925). Rates for 5 year periods, 1906–1937, inclusive, from A. M. A. Annual Reports on Typhoid Fever in Large Cities of the United States.

[2] Code for Water Works Improvements: N, New or improved source of supply for water; C, 100 per cent of water supply chlorinated; F, 100 per cent of water filtered; F_2, Second filtration plant put into operation; f, Part of water filtered.

[3] From Dept. of Health, City of Los Angeles.

And water works men, rising to the need, began getting together to compare problems. Seeing the necessity for a meeting of minds they founded the American Water Works Association and the New England Water Works Association in the years 1881 and 1882, respectively.

In keeping with the new developments the city of Poughkeepsie, New York, installed a slow sand filter in 1870; Hudson, New York followed in 1882 and St. Johnsbury, Vermont installed a third filter in 1882. The Massachusetts State Board of Health, established in 1887, set up the Lawrence Experiment Station to test various methods of treating water. Able men such as George C. Whipple, Allen Hazen, and George W. Fuller ran experiments which have given much of the data on sand filtration that is used today. James B. Kirkwood of St. Louis had recently returned from visiting in England and Scotland where rapid sand filters using backwash and surface wash were already in use. The rush to the use of slow and rapid sand filters, coupled with use of chloride of lime or other hypochlorites for disinfectants and alum for coagulation accounts for the rapid growth in the number of water works as shown by Table 2.

Table 2 (36 p.38)

GROWTH IN NUMBER OF WATER WORKS IN THE UNITED STATES

Year	Number of Works	Increase for period	Average yearly increase for period
1800	16		
1810	26	10	1.0
1820	30	4	0.4
1830	44	14	1.4
1840	64	20	2.0
1850	83	19	1.9
1855	106	23	4.6
1860	136	20	4.0
1865	162	26	5.2
1870	243	81	16.2
1875	422	179	35.8
1880	598	176	35.2
1885	1,013	415	83.0
1890	1,878	865	173.0
1896	3,196	1318	219.6
1924	9,850	6654	237.8
1935	10,790	940	104.4
1939	12,760	1970	492.5
1948	16,747	3987	443.0

The average yearly increases which have been computed by the author as a means of comparison show that the number of water works installed each year increased rapidly from 1885 to 1924 then dropped off--probably due to the depression years of the early 1930's. In all probability a good share of the increase in the number of plants put into service each year after 1935 is due to the establishment of state sanitary authorities who are seriously engaged in fighting pollution of rivers and in seeing that the people have potable water at all times. An increase in interstate commerce also forced commercial carriers to replenish supplies with water that met the United States Public Health Service Drinking Water Standards. Cities who wished to have railroad or bus terminals had to comply with these standards and many of them were forced to put in some form of treatment.

Man's Competition for Water

This brief historical resume' has led through ancient times, the middle ages, and modern times to show the effect of water on civilizations of the earth. Many of the ancient civilizations were developed because there was sufficient water available to promote so-called civilized living. The ancient civilizations along the Nile, Euphrates, in Mesopotamia and at Babylon existed because water was brought to the cities and surrounding lands in the great canals of the era. These same canals proved the undoing of the lands when their immense silt loads filled the canals faster than they could be dredged. These lands and many others are now virtual deserts due to man's conquest for water and food. Dr. W.C. Lowdermilk of the U.S. Soil Conservation service, after an 18-month tour of western Europe, North Africa, and the Middle East, set up what he calls the "Eleventh Commandment". Though his interests were on agriculture and its relation to soil erosion, his commandment is the lesson we should learn from a historical study of water supply. (22 p.38)

"THOU SHALT INHERIT THE HOLY EARTH AS A FAITHFUL STEWARD, CONSERVING ITS RESOURCES AND PRODUCTIVITY FROM GENERATION TO GENERATION AND THOU SHALT SAFEGUARD THY FIELDS FROM SOIL EROSION, THY LIVING WATERS FROM DRYING UP, THY FORESTS FROM DESOLATION, AND PROTECT THY HILLS FROM OVER-GRAZING BY THY HERDS, THAT THY DESCENDANTS MAY HAVE ABUNDANCE FOREVER. IF ANY SHALL FAIL IN THIS STEWARDSHIP OF THE LAND, THY FRUITFUL FIELDS SHALL BECOME STERILE, STONY GROUND AND WASTING GULLIES, AND THY DESCENDANTS SHALL DECREASE AND LIVE IN POVERTY OR PERISH FROM OFF THE FACE OF THE EARTH."

In the present civilization in the United States, water is considered by the people as an endless resource, and the demand for this resource is increasing steadily each year. In many areas keen competition has developed among the various water uses such as water power, irrigation, recreation, industry, municipal, and rural. Our complex system of living which has built up since the 1890 period has created a critical demand for water especially in the larger cities. As examples of this critical demand, the cities of New York, Los Angeles, and Dallas have held the attention of the nation for the past few years. In these cities the resource is almost stretched to its limit and something must be done to cut down on the use of the water within the cities. A number of smaller cities and towns in the United States are faced with the same problem during drought periods and they will have to find a solution in conservation of water or they will never be able to develop.

Figure I is a graphical representation of the water cycle beginning at the ocean, going into the atmosphere, down to earth, through its processes on earth, and back to the ocean. A study of the diagram shows how dependent we are on the vagaries of nature and how diversified the claims of earth are upon the life-giving water that nature chooses to give us.

A quantitative evaluation of total water use was set up in the summary of the United States Geological Survey Circular No. 115 (23 p.13) in 1950 which is quoted below:

> "Water use is divided into two general types, withdrawal and nonwithdrawal. The withdrawal uses can be evaluated in terms of quantity of water used. The estimated withdrawal use in the United States during 1950 is as follows:
>
> | Use | Million gallons per day |
> |---|---|
> | Water power | 1,100,000 |
> | Rural (Not including irrigation | 3,600 |
> | Municipal | 14,000 |
> | Industrial (from private sources) | 77,000 |
> | Irrigation | 79,000 |
>
> Generation of water power is the largest use of water. Other uses total about 170,000 million gallons per day which is 1,100 gallons per day for each man, woman, and child living in the United States. The estimate is very rough and represents only a general approximation of the quantity used. In this estimate a considerable part of the water was used several times and for several different uses. The

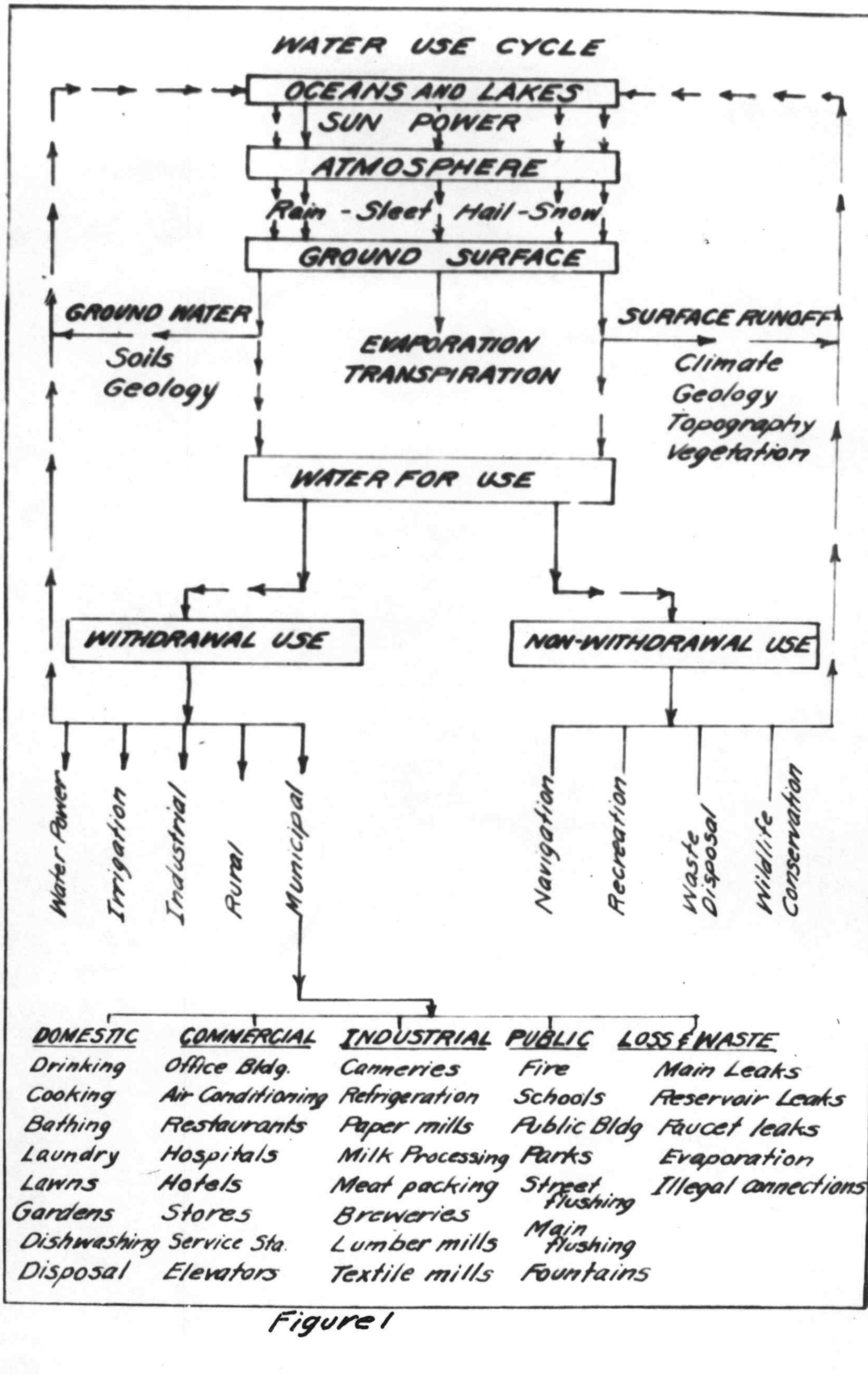

WATER USE CYCLE
OCEANS AND LAKES
SUN POWER
ATMOSPHERE
Rain - Sleet Hail - Snow
GROUND SURFACE
GROUND WATER
Soils
Geology
EVAPORATION
TRANSPIRATION
SURFACE RUNOFF
Climate
Geology
Topography
Vegetation
WATER FOR USE
WITHDRAWAL USE
NON-WITHDRAWAL USE
Water Power
Irrigation
Industrial
Rural
Municipal
Navigation
Recreation
Waste Disposal
Wildlife Conservation
DOMESTIC
Drinking
Cooking
Bathing
Laundry
Lawns
Gardens
Dishwashing
Disposal
COMMERCIAL
Office Bldg.
Air Conditioning
Restaurants
Hospitals
Hotels
Stores
Service Sta.
Elevators
INDUSTRIAL
Canneries
Refrigeration
Paper mills
Milk Processing
Meat packing
Breweries
Lumber mills
Textile mills
PUBLIC
Fire
Schools
Public Bldg
Parks
Street flushing
Main flushing
Fountains
LOSS & WASTE
Main Leaks
Reservoir Leaks
Faucet leaks
Evaporation
Illegal connections

Figure 1

> quantity was counted each time it was used.
>
> The principal withdrawal uses are navigation, recreation, waste disposal, and conservation of wildlife. Although these uses do not lend themselves to evaluation in terms of quantity of water, they are of great economic importance."

Figure I and the foregoing quotation vividly point out the increasing competition for the water supply of the nation. Municipal use, the subject of this paper, is only about 1.1 percent of the total withdrawal use in the United States, but to water works engineers it is one of the biggest problems of the twentieth century.

Municipal use

Municipal water use is generally divided into five classes (1) domestic use (2) public use (3) commercial use (4) industrial use and (5) loss and waste. Again the competition is keen. The consumption of water by each of the five classes varies within individual cities depending on a number of factors such as climate, quality of water, nature of industries in the cities, wealth and habits of the people, population, civic pride, pressure of water, water rates, and quantity of water available economically.

Water is necessary for domestic use primarily for physical existence, but the average person drinks only a small portion of the three quarts of water needed each day to replenish his body losses. The rest is taken into the body in foods. Even three quarts a day would account for only a very small percentage of the 50 gallons per person per day used in the average American home. The remainder of the 50 gallons is divided for washing of foods and utensils, bathing, washing of clothes, disposal of wastes, car washing, and irrigation. New mechanical devices for the home have made the work of the housewife easier and more pleasant, but in so doing they have increased the demand for domestic water to a point where it is difficult and sometimes impossible for cities to obtain sufficient supplies to satisfy the increased demand.

Demand for water for public uses depends to a great extent on civic pride. Water for fire fighting is, of course, the primary public use, but the number of public buildings in the city, the frequency of street washing and the number of parks, public fountains, or swimming pools in the city determine the amount of water that will be consumed for public use.

Commercial demand is extremely variable depending on the type of commercial establishment. Probably the most important use for water in commercial establishments is for cleanliness, but in the past few years, air conditioning has come to the forefront as a major water use.

In some areas air conditioning is restricted to allow other more necessary uses to enjoy the use of the water available.

Municipalities ordinarily furnish water to industries located within the corporate limits, and the demands of industries oftentimes exceed all other demands combined. The demand will vary considerably depending on whether the industry is a pulp and paper mill, a cannery, a freezing plant for fruits and vegetables, a lumber industry, or a manufacturing plant. Predictions of demand are difficult to make and often are underestimated.

Loss and waste use is probably a misnomer and should be called unaccounted for water. In some cities the unaccounted for water amounts to as high as 30 to 50 percent and is a major part of water consumption often consisting of unmetered services, leaks in mains, intentional waste at overflows, illegal connections, bad plumbing, or worn or improperly calibrated meters.

SECTION II

SCOPE AND PURPOSE OF STUDY

Scope of study

In this paper an analysis of the significant factors affecting each class of municipal water use is made from available data in national literature and from records obtainable in the State of Oregon. The data and analyses are divided into three basic categories: national, statewide, and city; with each category further subdivided into domestic, public, commercial, industrial, and loss and waste depending on available data. Since a complete study of each city in Oregon would be prohibitive, regarding both time and financing, three cities, Corvallis, Eugene and Salem, have been chosen for detailed study.

Purpose of study

The state of Oregon is still a young and aggressive state, and it is feeling the effects of "growing pains" very decidedly in the water works field. Every new home, every new community development, every new business enterprise, every new industry increases the demand for water. The primary purpose of this study is to gather enough pertinent facts to point out how the competitive demands for water have increased per capita water consumption to such an extent that it has become a major problem in our Oregon cities.

A second, no less important purpose is to promote better use and conservation of water supplies. The yearly production of water by nature does not seem to be increasing, but the demand due to water-power, population increase, industries, irrigation, recreation, municipal use and rural use is increasing at an alarming rate. In parts of Oregon it has been necessary to limit the use of water for irrigation during summer months. In Eastern Oregon and on the coast some towns have found it necessary to stop nearly all of the use of water for irrigation and car washing during the critical summer months. Even in the Willamette Valley where water stands on the fields for most of the winter months, the period of summer drought keeps the city water works officials busy trying to meet the demands of their customers. Water as a resource has definite limitations, and its competitive uses must be understood, so that proper conservation measures may be undertaken to prevent curtailment of use in the near future with a probably slump in the development of the state.

A third purpose of the study is to provide data for water works operators who must predict from day to day, month to month, and year to year how much water their customers, individually and collectively, are going to require. It is hoped that this paper will provide some information that will help the operators make their predictions.

Since industrial demand may be one of the larger demands in a city that is favorably situated to attract industry, it is important as a fourth purpose to point out how much industrial demand influences municipal use. Some industries settle only in areas where there is sufficient water to supply their demands. When the industry moves in, people are needed to run it; commercial establishments are necessary to supply goods and services to the people; more public buildings and facilities are required; and as a result, the water demand for the municipalities receives a terrific impetus.

SECTION III

METHOD OF STUDY OF MUNICIPAL WATER USE

Available Information

As a preliminary step to the study, all available literature pertaining to municipal water consumption was critically read and was included in the bibliography when any part of the information was pertinent to the subject. The literature includes various water supply books, articles from the Journal of the American Water Works Association (AWWA), pamphlets from United States governmental organizations, reports from cities or organizations, and magazine or newspaper articles. Nearly all of the information herein on the national and statewide level was taken from published literature, expanded and correlated to the problem.

Individual cities were the main source of information for finding the relative effects of various factors. Detailed records of total water production, total metered water, loss and waste, industrial use, total number of customers, and other similar factors for various periods of time were taken from the files of Corvallis, Eugene, and Salem. These records were critically examined, plotted and compared to national and statewide averages.

Detailed information was extremely difficult to obtain since it entailed a time-consuming search of yearly, monthly, and daily records of water consumption. These records had to be checked and reworked to fit this study. The national data were condensed and tabulated from carefully selected sources to obtain the most pertinent information available. A thorough search for statewide data was made through various cities, the United States Public Health Service, the Oregon State Board of Health, and the Bureau of Municipal Research. Data from the Bureau of Municipal Research for 1952 were chosen since fifty-two cities were included and a good estimate of per-capita consumption could be obtained by an expansion of the data. Daily water consumption charts for 1952 were plotted together with daily temperature and precipitation for Corvallis, Eugene, and Salem. The year 1952 was chosen because it is the highest water-use year on record at the three cities. Corvallis and Salem data were pieced together from available data and were expanded to obtain residential, irrigation, commercial, industrial and public per capita use as well as loss and waste.

Finally national, statewide, and municipal data were compared on a per-capita basis. Comparison had to be made by the use of a series of tables, charts, and graphs rather than by a written analysis. As a result the text content is brief and the major portion of the work and material is in the form of graphs, tables, or charts.

Choice of towns:

The cities of Corvallis, Eugene, and Salem were chosen for the study for several reasons:

(1) It would be impossible with the time and resources available to the author to cover each city in the state.

(2) Eugene and Salem are both within a 40-mile radius of Corvallis.

(3) All three cities have fairly complete consumption records which cover at least a ten-year period.

(4) The similarities and dissimilarities as tabulated below bring out nearly all the significant factors of water consumption:

A. Similarities

	Corvallis	Eugene	Salem
Location	Willamette basin		
Topography	Alluvial basin & hills		
Soil Classes	Silt, clay, sand, gravel		
Climate	Heavy winter rain--summer drought		
Water Treatment	Chlorination Coagulation Settling Filtration Fluoridation	Chlorination Settling Filtration	Screening Chlorination
State institutions	OSC	U of O	State Buildings
Lumbering	High	Predominates	High

B. Dissimilarities

	Corvallis	Eugene	Salem
Source	Filter-Rock Cr. Filter-Willamette River	Filter-McKenzie R.	Gravity-N. Santiam
Water districts	Urban-Metropolitan	Metropolitan	Urban
Population (1950)	16,100	35,900	43,100
Industry	Slight	High	Medium

(5) Climatological records are available for all three cities.

Factors considered in study

The foremost factor in the mind of any water works superintendent is the quality of his supply. He is responsible for furnishing his customers with a potable supply, and when he does, they enjoy it so much they start consuming more. Unless there is an adequate supply available, it might be necessary to find a new one to augment the first. Quality again becomes a problem, and a repetitive contest between quality and quantity is under way.

Geographic location in the state is a prime factor since water consumption is influenced by such factors as climate (rain, snow, drought, tornadoes, hail, sleet, etc.), topography and soils.

The tendency for city dwellers to squeeze into multiple units in one part of a city, and single family, large lot units in another area materially influences the rates of water consumption. Population density, then, is a very important factor to consider if one is to predict the action of a water system.

Residential, irrigation, industrial, commercial, and public uses coupled with loss and waste account for nearly all the water used in a municipality. In this paper an attempt has been made to further subdivide these categories and find the reasons for variations and possible ways to conserve water in critical supplies.

SECTION IV

PRESENTATION OF DATA ON WATER CONSUMPTION

General

The data presented are divided into three basic levels: (1) national, (2) statewide, and (3) municipal. Wherever it is possible to obtain a breakdown, each level is further subdivided into domestic, public, commercial, industrial, and loss and waste.

National Data

In section I it was pointed out that use of water may be divided into withdrawal and non-withdrawal use, and that municipal use, which is discussed herein, is only a small, though vital portion of the withdrawal use, amounting to about 13,600 million gallons per day. The United States Geological Survey (23, p.4) in 1950 estimated that there were 93.5 million people in the United States served by municipal water systems an average of 145 gallons per person per day (gpcd). This estimate was verified by the American Water Works Association in its 1954 cartoon pamphlet, "The Story of Water Supply" (5, p.2) in which the municipal consumption was estimated at 140 gpcd. This use was further subdivided as follows:

Use	Gallons
Residential	50
Industrial	50
Public	10
Commercial	20
Loss	10
Total	140

In 1945 and again in 1950 task groups of the American Water Works Association compiled water works operation data and subsequently a statistical analysis was performed on the data with the following results: (30 p. 1334)

	1945	1950	% above 1945
Mean production-gpcd	125	138	10
Mean sales--gpcd	99	110	10
Mean per cent sold	81	83	2

The preceding data indicates a trend toward higher consumption of water per person. This increase in per capita consumption coupled with an increase in the number of water users throws an overload on municipal water systems. Table 3 shows the number of households, the rate of increase in the number of households, and the number of persons per household from 1890 to 1960. (2, p.904) Estimates of residential water consumption often assume an average of 4 persons per family (or "household"). Table 3, however, shows that in the United States as a whole, this figure has been decreasing since 1890. The current figure is probably below 3.60 and is expected to fall to 3.43 by 1960. Consideration should also be given to

Table 3-A (for 1940) which shows that the average varies for different sections of the country. These tables are taken from data on pp 46-48, Statistical abstract of the United States, 1948, (U.S. Dept. of Commerce), which defines "household" as comprising the occupants of a dwelling unit (a house, apartment or room constituting "separate living quarters")."

The following figures show a trend toward fewer persons per household, but they also indicate a much higher average per capita consumption than the 100 gpcd recommended in nearly all the older textbooks on water supply. Since the early 1930's a number of analyses have been run, with emphasis on eastern cities, to determine the important variables of water consumption. In one of the outstanding papers average consumption values (gpcd) for cities in the United States and for cities in New Jersey were plotted on log-log paper against population in thousands as shown in figure 2 (9, p. 207). From the curves general equations, based on population only, were derived to give a reasonable estimate of per capita consumption. Since these curves indicate an increase in per capita consumption with increased population, it would be well to check other articles to see if population is a complete criterion.

TABLE 3--Persons per Household, 1890-1960

Date	Households: Number	Annual Increase Over Preceding Date: Number	Annual Increase Over Preceding Date: %	Persons per Household*	
1890 (June 1)	12,690,152			4.93	
1900 (June 1)	15,963,965	327,381	2.32	4.76	
1910 (Apr. 15)	20,255,555	434,371	2.44	4.54	
1920 (Jan. 1)	24,351,676	418,398	1.90	4.34	
1930 (Apr. 1)	29,904,663	541,755	2.02	4.11	
1940 (Apr. 1)	34,948,666	504,400	1.56	3.77	
1941 (July 1)	35,850,000	721,000	2.06	3.67	
1942 (July 1)	36,450,000	600,000	1.67	3.59	
1943 (July 1)	36,875,000	425,000	1.17	3.46	
1944 (July 1)	37,100,000	225,000	0.67	3.41	
1945 (July 1)	37,500,000	400,000	1.08	3.40	
1946 (June 15)	38,183,000	711,000	1.90	3.61	
1947 (Apr. 15)	39,138,000	1,151,000	3.02	3.63	
1955 (July 1)	42,925,000	461,000	1.13	3.49	Forecast
1960 (July 1)	44,775,000	370,000	0.85	3.43	Forecast

* Obtained by dividing total population by number of households (members of armed forces excluded 1941 to 1947); hence not strictly average size of household because about 2.5 per cent of total population are members of quasi households (hotels, institutions, etc.).

TABLE 3A--Regional Variation in Household Population, 1940

Region	Number of Households, 1940: Urban	Rural: Nonfarm	Rural: Farm	Persons per Hshld.*
New England	1,683,480	404,840	133,260	3.8
Middle Atlantic	5,702,460	1,195,380	427,260	3.8
East North Central	4,875,000	1,280,260	1,161,780	3.6
West North Central	1,732,720	814,080	1,159,640	3.6
South Atlantic	1,854,260	1,189,300	1,274,540	4.1
East South Central	867,020	589,680	1,173,000	4.1
West South Central	1,449,160	760,520	1,195,540	3.8
Mountain	513,740	344,280	270,980	3.7
Pacific	2,057,360	632,780	346,520	3.2
United States	20,735,200	7,211,120	7,142,520	3.8

* Obtained by dividing total population by number of households; hence not strictly average size of household because about 2.5 per cent of total population are members of quasi households (hotels, institutions, etc.).

Domestic use, in general, is determined by habits of the people using the water. The American Water Works Association in 1953 estimated that each member of a family for all purposes including drinking, cooking, laundry, house cleaning, toilet flushing, bathing, and lawn and garden watering uses about 50 gallons per day. The estimate was further broken down to individual uses as follows:

Filling lavatory	$1\frac{1}{2}$	gallons per day
Filling bathtub	36	" " "
Shower bath	25	" " "
Flushing toilet	7	" " "
Garden hose with sprinkling nozzle	275-300	gall. per hr.
Lawn sprinkler	120-150	" " "

In December, 1939, another estimate (28, p. 2004) shows a basic per capita use of 20 gallons per day plus one or more of the following uses:

Tub bath	25 gall. per bath
Shower bath	5 gall. per min.
Additional toilet flush/person	6 gall. per day
Sprinkling lawn (5/8 inch hose)	7 gall. per min.
Washing automobile	150 gallons

From the preceding tabulations it is possible to estimate the per capita demand for domestic use; however it must be kept in mind that modern homes contain work-saving garbage disposers, dishwashers and automatic clothes washers which use a large quantity of water which must be added to the basic quantities listed above.

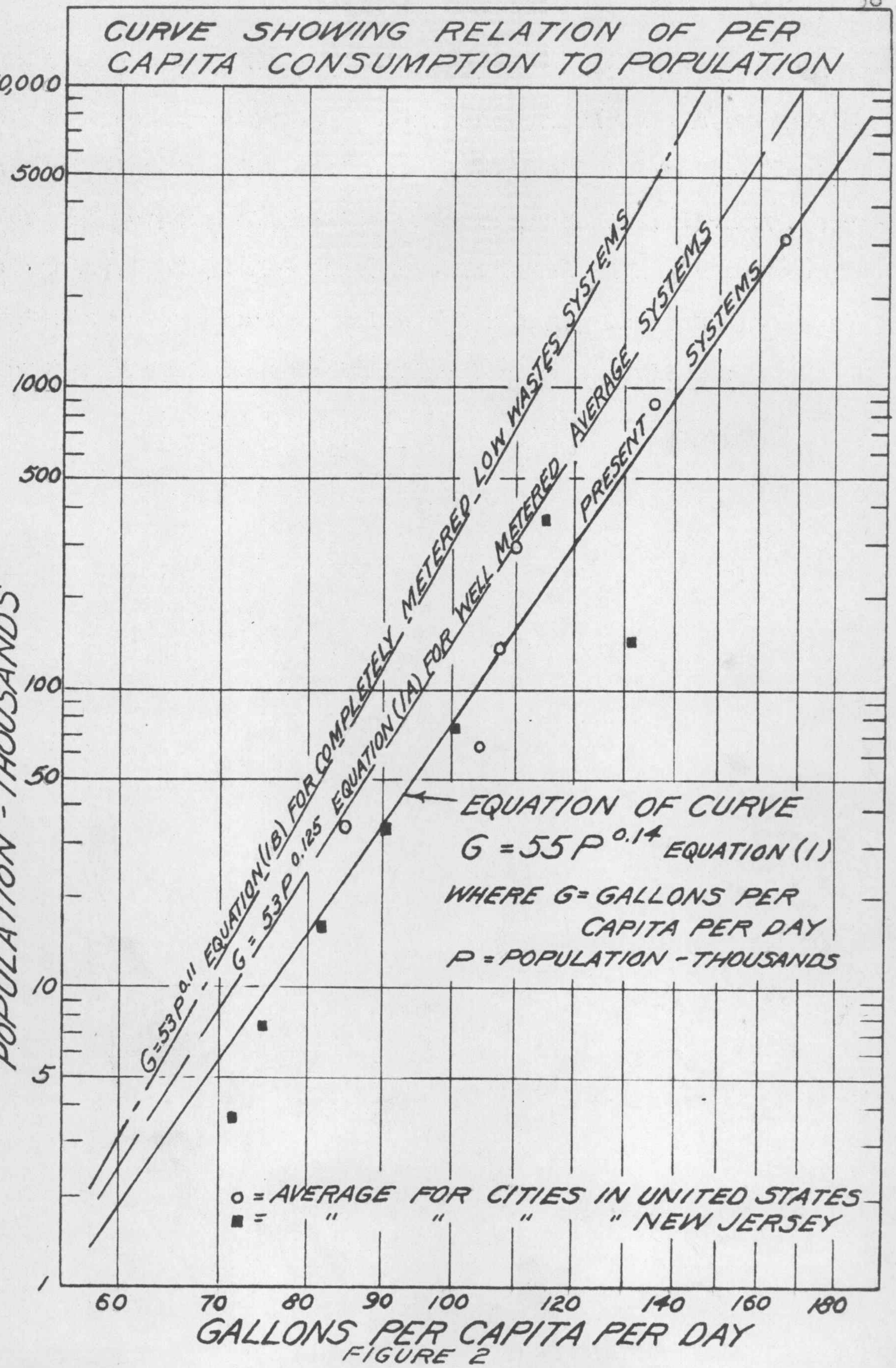

CURVE SHOWING RELATION OF PER CAPITA CONSUMPTION TO POPULATION
POPULATION - THOUSANDS
10,000
5000
1000
500
100
50
10
5
1
60
70
80
90
100
120
140
160
180
GALLONS PER CAPITA PER DAY
G=53P^0.11 EQUATION (1B) FOR COMPLETELY METERED LOW WASTES SYSTEMS
G = 53P^0.125 EQUATION (1A) FOR WELL METERED AVERAGE SYSTEMS
PRESENT SYSTEMS
EQUATION OF CURVE
G = 55P^0.14 EQUATION (1)
WHERE G = GALLONS PER CAPITA PER DAY
P = POPULATION - THOUSANDS
o = AVERAGE FOR CITIES IN UNITED STATES
■ = " " " " NEW JERSEY

FIGURE 2

Public use includes the water used for schools and other public buildings, parks, street sprinkling, fountains, sewer flushing and the flushing of water mains, fire extinguishing, and a few other occasional uses. Unfortunately few cities have completely metered public water and it is difficult to estimate since it varies greatly with civic pride, but the studies conducted to date indicate a consumption for public purposes averaging about 10 gped.

Commercial use is extremely variable depending on size and type of establishment, which in turn depend on habits of the patrons. Climate may also have a great effect since hot-dry weather usually leads to some form of air conditioning which requires a great deal of water at the time when the water system is already overloaded. It has been estimated that commercial use amounts to about 20 gped, but in cities where air conditioning is prevalent it has gone to as much as twice this amount.

Industrial use in some cities is as high as domestic, ranging from 10 to 50 gped, and varies with the character of the city, the type of industry, the quantity of goods produced, and the methods of processing. Practically all industrial uses of water fall within one or more of the classifications listed below:

(a) Cooling
(b) Processing
(c) Power generation
(d) Sanitary services
(e) Fire Protection
(f) Miscellaneous (air conditioning, washing, etc.)

Tables 4 and 5 point out how widely varied these uses can become. The tables are the best information available, but they give only a general guide to industrial use. All of the six classifications previously listed vary depending mainly on the amount of money industry is willing to put into water conservation. Even with such a wealth of data each new industry becomes a separate, complicated problem to a municipal water system.

TABLE 4

INDUSTRIAL REQUIREMENTS

The quantities reported below are clearly those of water intake--that is, the amount which is piped into an establishment--rather than consumptive use--the amount discharged to the atmosphere or incorporated into the products of a process. Thus, the wide ranges sometimes given reflect not only differences in processes or products, but differences in the use of water. In arid areas, where even the most rigorous conservation methods are economically feasible, "intake" is only a fraction of what it may be in areas where water is abundant, although "consumptive use" is virtually the same.

CHEMICALS	UNIT	WATER REQUIRED gal
Alcohol, industrial, (100 proof)	gal	120
Alumina (Bayer process)	ton	6,300
Amonium sulfate	ton	200,000
Butadiene	ton	20,000-660,000*
Calcium carbide	ton	30,000
Carbon dioxide (from flue gas)	ton	20,000
Cottonseed oil	gal	20
Gunpowder or explosives	ton	200,000
Hydrogen	ton	660,000
Oxygen, liquid	1,000 cu ft	2,000
Soap (laundry)	ton	500
Soda ash (ammonia soda process) 58%	ton	18,000

TABLE 4 (continued)

CHEMICALS	UNIT	WATER REQUIRED gal.
Sodium chlorate	ton	60,000
Sulfuric acid (contact process) 100%	ton	650-4,875*
FOODS		
Bread	ton	500-1,000 ≁
Canning	100 cases #2 cans	750-25,000≁
Corn (wet-milling)	bu corn	140-240≁
Corn syrup	bu corn	30-40≁
Gelatin (edible)	ton	13,200-20,000≁
Meat:		
Packing	ton live animals	4,130
Packing house operation	100 hog units	55,000
Milk and milk products:		
Butter	ton	5,000
Cheese	ton	4,000
Receiving & bottling	ton	9,000
Sugar:		
Beet sugar	ton	2,160
Cane sugar	ton	1,000
PAPER & PULP		
Ground wood pulp	ton dry	4,000-50,000*
Kraft pulp	ton dry	93,000
Soda pulp	ton dry	85,000
Sulfate pulp	ton dry	70,000
Sulfite pulp	ton dry	70,000-1,333,000*
Paper	ton	39,000
Paperboard	ton	15,000-90,000*
Strawboard	ton	26,000
PETROLEUM		
Gasoline natural	gal	20
Oil refining	100 bbl	77,000
Refined products	100 bbl	15,000-1,500,000*
SYNTHETIC FUEL		
By coal hydrogenation	100 bbl	728,600
From coal	100 bbl	1,115,000
From natural gas	100 bbl	373,600
From shale	100 bbl	87,300

TABLE 4 (continued)

TEXTILES	UNIT	WATER REQUIRED gal.
Cotton:		
Bleaching	ton produced	60,000-80,000
Dyeing	ton produced	8,000-16,000
Rayon:		
Cuprammonioum (11% moisture)	ton yarn	90,000-160,000⌿
Viscose	ton yarn	200,000
Weave, dye & finish	1,000 yard	15,000
Woolens	ton produced	140,000
MISCELLANEOUS		
Cement, portland	ton	750
Coal & coke:		
By-product coke	ton	1,500-3,600⌿
Washing	ton	200
Electric power, steam-generated	kwhr	80-170*
Hospitals	bed per day	135-150
Iron ore (brown)	ton	1,000
Laundries:		
Commercial	ton work	8,600-11,400⌿
Institution	ton work	6,000
Leather tanning:		
Vegetable	100 bbl rawhide	800
Rock wool	ton	5,000
Rubber, synthetic:		
Buna S	ton	631,450
GR-S	ton	28,000-670,000*
Steel (rolled)	net ton	15,000-110,000*
Sulfur mining	ton	3,000

*Range from no reuse to maximum recycling.
⌿Range covers various products or processing involved.

Compiled by the American Water Works Assn., New York (Nov. 1953).

TABLE 5 (24, pp. 49-51)

WATER USE PER UNIT OF PRODUCT

For purposes of comparison, a few of the data on water use per unit of product are presented below along with similar data from other sources. This is a preliminary tabulation, given only to indicate the considerable scope of the information on this subject received through a questionnaire. Some of the variations in figures reported for the same product undoubtedly may be accounted for by more specific identification of the manufacturing processes involved from plant to plant.

Product	Unit	Consumption	Source of Data
Apparel and Textile			
Viscose Rayon	1 ton	180-200,000	Chem. Engineer.-1948
		200,000	Ohio Water Res.Bd.
Rayon Manufacture	1 ton	320	J.AWWA-1946
Rayon Yarn	1 ton	250,000	NAM-Conservation Fdn.
	1 ton	334,000	" " "
	1 ton	365,000	" " "
	1 ton	403,974	" " "
Weave, Dye & Finish Rayon Textiles	1 M yds.	15,000	" " "
Cotton Goods			
Bleaching	1 ton	60-80,000	Chem. Engineer.-1948
Dyeing	1 ton	8-16,000	" " "
Bleaching & Dyeing	1 ton	55,000	NAM-Conservation Fdn.
Bleach, Dye & Treat	1 M yds.	1,000	" " "
	1 M yds.	10,000	" " "
	1 M yds.	15,000	" " "
Cotton Cloth Processing	1 ton	10-16,000	Ohio Water Res. Bd.
Woolens & Worsteds	1 ton	140,000	J. AWWA-1946
Woolen Cloth	1 M yards	40,000	NAM-Conservation Fdn.
Worsted Cloth	1 M yards	77,000	" " "

TABLE 5 (continued)

Product	Unit	Consumption	Source of Data
Apparel and Textile			
Woolens & Worsteds			
Woolen Cloth	1 M yards	146,000	NAM-Conservation Fdn.
Woolen Cloth	1 M yards	510,000	" " "
Raw Wool to finished Cloth	1 M yards	8,335	" " "
Wool Scouring	1 ton	2,520	J. AWWA-1946
Scoured Wool	1 M lbs. raw	31,000	NAM-Conservation Fdn.
Chemicals and Drugs			
Soap	1 ton	500	Chem. Engineer-1948
	1 ton	4,493	NAM-Conservation Fdn.
Ice	1 ton	240	" " "
	1 ton	300	" " "
	1 ton	5,000	" " "
	1 ton	9,000	" " "
Electrical			
Steam generation of power	1M kwh	80,000	Ohio Water Res. Bd.
	1M kwh	80,000	NAM-Conservation Fdn.
	1M kwh	52,000	" " "
	1M kwh	68,000	" " "
	1M kwh	80,000	" " "
	1M kwh	90,000	" " "
	1M kwh	170,000	" " "
Food, Beverages and Tobacco			
Cane Sugar			
Refining	1 ton	1,000	J. AWWA-1946
"Condensing"	1 ton	4-9,000	Chem. Engineer-1948
"Processing"	1 ton	1,500	Chem. Engineer-1948

TABLE 5 (continued)

Product	Unit	Consumption	Source of Data
Food, Beverages and Tobacco			
Cane Sugar (refined)	1 ton	4,000	NAM-Conservation Fdn.
	1 ton	8,000	" " "
	1 ton	27,920	" " "
Beet Sugar (refined)	1 ton	24,000	" " "
	1 ton	26,000	" " "
	1 ton	34,000	" " "
Corn Syrup	1 bu. corn	30-40	Ohio Water Res. Bd.
	1 bbl. (50 gal.)	3,180	NAM-Conservation Fdn.
Beer & Ale	1 bbl.	470	J. AWWA-1946
	1 bbl.	298	NAM-Conservation Fdn.
	1 bbl.	362	" " "
	1 bbl.	527	" " "
	1 bbl.	2,500	" " "
"Brewing"	1 bbl.	470	Ohio Water Res. Bd.
Whiskey Manufacturing	1M gal.	80,000	J. AWWA-1946
Mashed Grain	1M bu.	600,000	Chem. Engineer-1949
	1M bu.	3-600,000	Ohio Water Res. Bd.
Distilled Whiskey	1M gal.	70,000	NAM-Conservation Fdn.
Distilling 100 Proof Alcohol			
Processing	1M gal.	8,400	Chem. Engineer-1949
Cooling	1M gal.	120,000	" " "
Dairying	1 gal. milk	5	Ohio Water Res. Bd.
Milk, cream, butter	100 lbs.	11-25	in Engineers Jt. Council Rept. on Nat. Water Policy, 1950*

TABLE 5 (continued)

Product	Unit	Consumption	Source of Data
Food, Beverages and Tobacco			
Canned tomatoes	1 bu.	60	Ohio Water Res. Bd.
Canned corn	1 ton corn on cob	1,000	" " " "
	100 cases (24-#2)	7,200	NAM-Conservation Fdn.
Canned peas & corn	100 cases (24-#2)	5,000	NAM-Conservation Fdn.
Green beans	100 cases	3,500	Fed.Res.Bk. of Dallas
Spinach	100 cases	16,000	" " " " "
Meat packing (hogs)	1 ton live animals	6,000	Ohio Water Res. Bd.
	100 hogs (dressed & by-products)	24,000	NAM-Conservation Fdn.
Steel			
Highly finished	1 ton	65,000	Ohio Water Res. Bd.
Rolled Steel			
Cold rolled strip	1 ton	6,000	NAM-Conservation Fdn.
Steel sheets and coils	1 ton	13,000	" " "
Hot rolled steel plates	1 net ton	15,000	" " "
Cold rolled, high carbon, strip	1 ton	62,000	" " "
Rolled steel	1 ton	80,000	" " "
Rolled steel	1 net ton	110,000	" " "
Paper and Pulp			
Sulphate pulping	1 ton	70,000	Chem. Engineer-1948
	1 ton	64,000	J. AWWA-1946
Unbleached sulphate pulp	1 ton	35,000	NAM-Conservation Fdn.
Bleached sulphate pulp	1 ton	53,000	" " "
Soda pulp	1 ton	85,000	J. AWWA-1946
Soda pulp & bleaching	1 ton	60,000	Chem. Engineer-1949

TABLE 5 (continued)

Product	Unit	Consumption	Source of Data
Paper and Pulp			
Soda pulp, plain & Coated book paper	1 ton	53,000	NAM-Conservation Fdn.
Sulphite pulp	1 ton	60,000	J. AWWA-1946
	1 ton	80,000	NAM-Conservation Fdn.
Paperboard	1 ton	7,692	" " "
	1 ton	15,360	" " "
	1 ton	90,000	" " "
Petroleum Products			
Oil refining	1M bbl.	770,000	Chem. Engineer-1949
	1M bbl.	770,000	J. AWWA-1946
	1M bbl.	770,000	Ohio Water Res.Bd.
Aviation gasoline	1M bbl.	1,050,000	Fed.Res.Bk.of Dallas
Refined Petroleum products (Processed crude)	1M bbl.	151,000	NAM-Conservation Fdn.
	1M bbl.	260,000	" " "
	1M bbl.	470,000	" " "
	1M bbl.	2,100,000	" " "
	1M bbl.	15,000,000	" " "
Synthetic gasoline	1M bbl.	15,834,000 (estimated)	Std. Oil of N.J.
Coal and Coke			
Coal Washing	1 ton	200	Ohio Water Res. Bd.
Washed coal	1 ton	30	NAM-Conservation Fdn.

Chemical Engineering, January 1948, p.137
Chemical Engineering, July 1949, p.119
Ohio Water Resources Board, Seventh Annual Report 1948, (State of Ohio, Dept. of Public Works)

TABLE 5 (continued)

Federal Reserve Bank of Dallas, Monthly Business Review, July 1, Aug. 1, 1948. Water Resources in the Southwest.
Standard Oil of New Jersey, The Lamp, (n.d.)
Engineers Joint Council, National Water Policy, 1950.
National Association of Manufacturers-Conservation Foundation, Water in Industry, Survey of Industrial Plant Water Supply and Waste Disposal, 1950.

Loss and waste is listed above as about 10 gpcd or about 7 per cent of total municipal use. Since loss and waste in a metered city includes only leaks, flushing, meter error, pump slip, fire use, etc., it should remain low. Very often, however, public buildings, parks, and the like are not metered, and the unaccounted for water may range as high as 50 per cent.

So far, average consumption is all that has been considered. Variations from average consumption occur hourly, daily, and monthly, and these are the values used in water works design. To show the tendency for use of higher per capita consumption values Table 6 has been set up from various standard text books from the water supply field. For design purposes fire demand must be added also to the consumption for the maximum day. The National Board of Fire Underwriters uses the formula

$$G = 1,020 \quad P \quad (1 - 0.01 \quad P)$$

where G is the necessary demand for extinguishing fires in gallons per minute and P is the population in thousands. From this equation, Table 7 has been set up to show the requirements in cities of various sizes.

TABLE 6

AVERAGE CONSUMPTION ESTIMATES FROM STANDARD TEXT BOOKS

Source	Yearly Average gpcd	Monthly Ratio	Weekly Ratio	Daily Ratio	Hourly Ratio
Water Supply Engineering, Folwell, First Edition, 1900	60-85	115-130	------	150-200	-----------
Waterworks Handbook, Flinn, Weston, & Bogert, Third Edition, 1927	50-400	125	135	150	-----------
Public Water Supplies, Turneasure and Russell, Fourth Edition, 1940	110	-------	------	150	(1.40) (150)
Water Supply and Sewerage, Steel, Second Edition, 1947	100-120	125	150	175	(1.50) (175)
Public Health Engineering, Phelps	110	-------	------	150-200	200-300
Water Supply Engineering, Babbitt and Doland, Fourth Edition, 1949	110	140	------	150-180	250-350
Water Supply and Sewerage, Steel, Third Edition, 1953	135	128	148	180	(1.50) (180)

TABLE 7

NATIONAL BOARD OF FIRE UNDERWRITERS FIRE DEMAND

Population	Required Fire Flow for Average City GPM	Duration hr.
1,000	1,000	4
1,500	1,250	5
2,000	1,500	6
3,000	1,750	7
4,000	2,000	8
5,000	2,250	9
6,000	2,500	10
10,000	3,000	10
13,000	3,500	10
17,000	4,000	10
22,000	4,500	10
28,000	5,000	10
40,000	6,000	10
60,000	7,000	10
80,000	8,000	10
100,000	9,000	10
125,000	10,000	10
150,000	11,000	10
200,000	12,000	10

For cities over 200,000 population, 12,000 gpm with 2,000 to 8,000 gpm additional for a second fire, for a 10-hr. duration.

Mr. Harry E. Jordan, Secretary of the American Water Works Association in an address before the Water Works Management Short Course, Monticello, Illinois on September 30, 1953, summarized on a national basis "The Future Needs for Water Supply":

"The magnitude of water production for use in the United States in 1950 and, as estimated in the 1952 report of the President's Materials Policy Commission in 1975, is as follows:

	1950 production, bgd	Percentage of total
Municipal Rural	17	9
Direct Industrial	80	43
Irrigation	88	48
Total	185	100

	1975 production, bgd	Percentage of total
Municipal Rural	25	7
Direct Industrial	215	62
Irrigation	110	31
Total	350	100

The growth of water production in the 25-year period is estimated at 50 per cent for municipal supply, 170 per cent for industrial, and 25 per cent for irrigation. The growth in population for the same period is estimated at 49 million persons or 33.1 per cent. This contemplates a per capita increase in water use at more than 1½ times the rate of population increase.

This is consistent with the experience of the industry over the past 60 years. In 1890 public water supplies were used at the rate of 90 gallons per capita daily and in 1950 at the rate of 140 gpcd. The commission's estimate amounts to a per capita use in 1975 of 155 gpcd. The rate of increase in per capita rates from

1890 to 1950 is 0.83 gpcd per year. The commission's estimate is at the rate of 0.6 gpcd per year. It is conservative. A higher estimate might be based upon the potential increase in water demand for household sanitation and air conditioning. Such an estimate would be predicated upon an expanding economy with improved economic status for the average person and increased ability to provide for the family the comfort and conveniences that adequate domestic water supply will afford.

The increases forecast by the President's commission prophesy that the city of 10,000 in 1950 will be a city of 13,300 in 1975 and, whereas the average daily consumption of water increased rate per person, the city must meet an average consumer demand of 2,067,000 gallons.

It means simply that any city in the U.S. can--by 1957--expect a combination growth in population and consumer rate of use that will require it to provide 142 per cent of today's supply for tomorrow's city. This, mind you, is an average--not a peak-day.

Assuming that 1975 peak demand will correspond to the 1953 record, we can compute that the average city will need to provide facilities to meet a 1975 peak day reaching 235 per cent of its 1952 average day."

The preceding data are summaries of the information available on factors affecting municipal water consumption. Nearly all of the data are based on water use in eastern cities and to the author's knowledge has not been checked against records in the west. In the next article, some Oregon data has been expanded to check the data from eastern cities.

<u>Statewide Data</u>

Published per capita consumption data for the State of Oregon is limited to a few city reports. However, nearly all the cities in the state have records (varying widely in degree of completeness) from which estimates of consumption can be derived. The Bureau of Municipal Research and Service graciously consented to allow the author to expand Table 1 (27, pp. 3-6) of their 1953 study on water rates and practices. Tables 8 and 9 are a result of the expansion. The last six columns of the tables were computed to find a population factor, which is approximately equivalent to the number of persons per household as shown in Table 3-A; to find average daily per capita consumption for the year; to find the gpcd for the maximum month and for the minimum month; and to find the percentage variations between the average and the maximum and minimum.

The data for the fiscal year 1951-52 is valuable because that period was one of severe summer drought in Oregon and the data would show an average per capita use which would probably be higher than that normally encountered. This condition is good from a design standpoint since it would be more on the conservative side.

The author feels that a statistical analysis on a one-year record doesn't give adequate results, but an attempt was made to plot the Oregon data on a log-log curve similar to the curves shown in figure 2 under national data. The curve is shown in figure 3 with 50 cities plotted showing geographic locations. Points considerably to the right of the curve were checked regarding metering and it is apparent from the curve that a lack of metering tends to allow higher per capita consumption. It might also be noted that according to the data the national average per capita consumption estimate of 140 gpcd might possibly fit Oregon cities with a population below 2,000 persons, but would be inadequate above that population.

Further breakdown of the factors in statewide consumption was not attempted though some interesting information showing the consumption by laundromats and drive-in theaters in Portland and vicinity was furnished by the Oregon State Board of Health. Their survey indicated that automatic washers in a laundromat produced 1 batch of clothes each per hour and ran 10 hours per day for 6 days a week using 35 gallons per machine per batch. The three drive-in theaters checked showed a use of 5 gallons per car with 28% being used during the 10-15 minute intermission. Other studies are being made at the present time to try to find the consumption at public schools,

FISCAL YEAR 1951 - 52 WATER CONSUMPTION ESTIMATE FOR OREGON

Size Range	City	Population 1950 census	Customers Total	Customers Total city	Water usage in thousands of gal Max Month	Water usage in thousands of gal Min Month	Water usage in thousands of gal Total	% metered (Approx) Residential	Population Divided by City customers	Per Capita Consumption, gal/day Ave. Year	Per Capita Consumption, gal/day Max Month	Per Capita Consumption, gal/day Min Month	Max Month Divided by Ave yr	Min Month Divided by Ave yr
Over 50,000	Portland	373,628	148,521	109,967	---	---	10,043,408	100	3.40	185	---	---	---	---
25,000-	Eugene	35,879	14,450	9,437	435,774	161,870	2,978,295	100	3.80	227	405	150	1.78	0.66
50,000	Salem	43,140	13,375	11,987	478,289	115,175	2,705,592	100	3.60	172	370	89	2.15	0.52
10,000-	Albany	10,115	3,246	3,118	108,950	45,600	803,670	95	3.24	218	359	150	1.65	0.69
25,000	Corvallis	16,207	4,498	3,803	102,616	41,813	741,199	100	4.26	125	211	83	1.69	0.66
	Springfield	10,807	3,348	3,318	184,187	76,388	1,200,897	5	3.26	305	568	236	1.87	0.77
5,000-	Hillsboro	5,142	4,710	2,239	73,487	27,626	569,674	100	2.30	304	476	179	1.57	0.59
10,000	Lebanon	5,873	1,942	1,861	103,069	21,643	612,193	25	3.16	286	585	123	2.04	0.43
	McMinnville	6,635	2,250	2,125	74,969	24,365	480,693	98	3.12	198	376	122	1.90	0.62
	Milwaukie	5,253	1,550	1,200	---	---	---	100	4.38	---	---	---	---	---
	Oregon City	7,682	2,903	2,721	79,241	41,384	695,386	30	2.82	248	344	180	1.39	0.72
2,500-	Dallas	4,793	1,900	1,650	55,838	32,000	473,360	100	2.90	271	388	222	1.43	0.82
5,000	Forest Grove	4,343	1,580	1,300	43,075	9,887	267,321	99	3.34	169	331	76	1.96	0.45
	Gresham	3,049	1,181	1,094	15,394	5,930	109,996	100	2.79	99	168	65	1.70	0.66
	Newberg	3,946	1,803	1,360	33,362	9,528	209,958	100	2.90	146	282	80	1.93	0.55
	Sweet Home	3,603	1,135	1,001	29,429	16,444	240,820	100	3.60	183	272	152	1.49	0.83
	West Linn	2,945	1,100	1,087	25,404	15,318	230,369	30	2.71	214	287	173	1.34	0.81
1,000-	Canby	1,671	674	667	12,935	2,572	68,505	100	2.51	112	258	51	2.30	0.46
2,500	Carlton	1,081	442	367	6,170	2,328	42,149	95	2.95	107	190	71	1.78	0.66
	?Gladstone	2,434	963	952	75,215	29,175	578,797	100	2.53	679	1030	400	1.52	0.59
	Independence	1,987	650	595	17,800	2,127	112,814	95	3.34	156	294	36	1.88	0.23
	Mill City	1,792	509	494	13,634	6,976	104,822	95	3.63	160	253	129	1.58	0.81
	Mt. Angel	1,315	418	399	8,613	2,222	53,050	90	3.29	110	218	56	1.98	0.51
	Sheridan	1,922	770	740	11,704	3,393	74,477	90	2.60	106	203	59	1.94	0.56
	Woodburn	2,395	1,100	1,000	22,092	4,597	110,327	100	2.39	126	307	64	2.50	0.51
500-	Creswell	662	293	231	2,052	876	15,891	99	2.87	66	103	44	1.56	0.67
1000	Turner	610	191	183	43,334	15,953	298,927	100	3.33	134	237	87	1.77	0.65
0-500	Columbia City	405	113	113	1,422	408	8,491	100	3.58	57	117	33	2.05	0.58
	Sublimity	367	86	86	1,254	651	10,759	100	4.26	80	114	59	1.43	0.74

Water Consumption Estimate for Oregon, 1952, Willamette
Table 8

FISCAL YEAR 1951 - 52 WATER CONSUMPTION ESTIMATE FOR OREGON

Size Range	City	Population 1950 census	Customers Total	Customers Total city	Water usage in thousands of gal Max Month	Water usage in thousands of gal Min Month	Water usage in thousands of gal Total	% metered (Approx) Residential	Population Divided by City customers	Per Capita Consumption gal/day Ave Year	Per Capita Consumption gal/day Max Month	Per Capita Consumption gal/day Min Month	Max Month Divided by Ave yr	Min Month Divided by Ave yr
10,000-25,000	Astoria	12,331	6,500	3,314	106,945	62,369	943,746	100	3.72	210	289	168	1.38	0.79
5,000-10,000	Coos Bay-North Bend	12,322	4,687	4,373	70,115	53,704	738,317	100	2.82	164	190	145	1.16	0.88
2,500-5,000	Newport	3,241	1,400	1,200	20,000	11,000	170,000	100	2.70	144	206	113	1.43	0.79
1,000-2,500	Florence	1,026	340	340	1,500	1,498	17,988	100	3.31	48	49	48	1.02	1.00
500-	Eastside	890	272	270	17,483	9,494	152,250	95	3.30	469	655	355	1.40	0.76
1,000	Gearhart	568	493	421	5,516	608	27,988	55	1.35	134	324	36	2.42	0.27
	SOUTH													
10,000-	Klamath Falls	15,875	7,938	4,953	224,186	81,444	1,460,692	100	3.21	252	470	171	1.87	0.68
25,000	Medford	17,305	7,622	4,607	334,805	115,956	2,705,237	4	3.76	428	645	223	1.51	0.52
5,000-	Ashland	7,739	2,649	2,516	136,299	28,101	779,236	---	3.07	276	587	121	2.13	0.44
10,000	Grants Pass	8,116	3,230	2,985	81,253	19,371	505,862	100	2.72	171	334	80	1.96	0.47
	Roseburg	8,390	4,296	---	113,100	42,086	760,821	100	---	248	450	167	1.82	0.67
1,000-	Central Point	1,667	540	514	12,428	3,535	78,533	100	3.24	129	248	71	1.92	0.55
2500	?Myrtle Creek	1,781	627	613	94,776	75,304	1,019,737	98	2.91	1,570	1,770	1,410	1.13	0.90
500-1000	Merrill	835	244	229	52,867	16,662	37,404	68	3.65	114	211	66	1.85	0.58
	CENTRAL AND EASTERN													
10,000-	Bend	11,409	3,681	3,507	157,980	42,950	1,007,959	0	3.25	242	462	125	1.91	0.52
25,000	Pendleton	12,218*	3,458	3,350	---	---	---	100	3.65	---	---	---	---	---
5,000-	Baker	9,471	3,140	3,140	164,921	---	---	97	3.02	---	580	---	---	---
10,000	La Grande	8,635	2,536	2,377	112,695	40,629	734,294	100	3.63	233	435	157	1.87	0.67
	The Dalles	7,676	3,030	3,030	223,200	86,800	1,877,900	0	2.53	670	970	377	1.45	0.56
2,500-5,000	Ontario	4,465	1,402	1,387	25,975	10,462	189,153	100	3.22	116	194	78	1.67	0.67
	Prineville	3,233	1,055	1,055	---	---	129,697	---	3.06	110	---	---	---	---
	Redmond	2,956	1,193	1,039	62,946	14,812	369,225	3	2.85	342	710	167	2.08	0.47
0-	Boardman	120	62	59	677	246	4,676	89	2.03	107	188	68	1.76	0.64
500	Wasco	305	126	126	1,109	1,044	12,932	100	2.42	116	121	111	1.04	0.96

* Special count by Secretary of State

Water Consumption Estimate
for Oregon, 1952, Coast, South,
Central and Eastern
Table 9

CURVE SHOWING RELATION OF PER CAPITA CONSUMPTION TO POPULATION

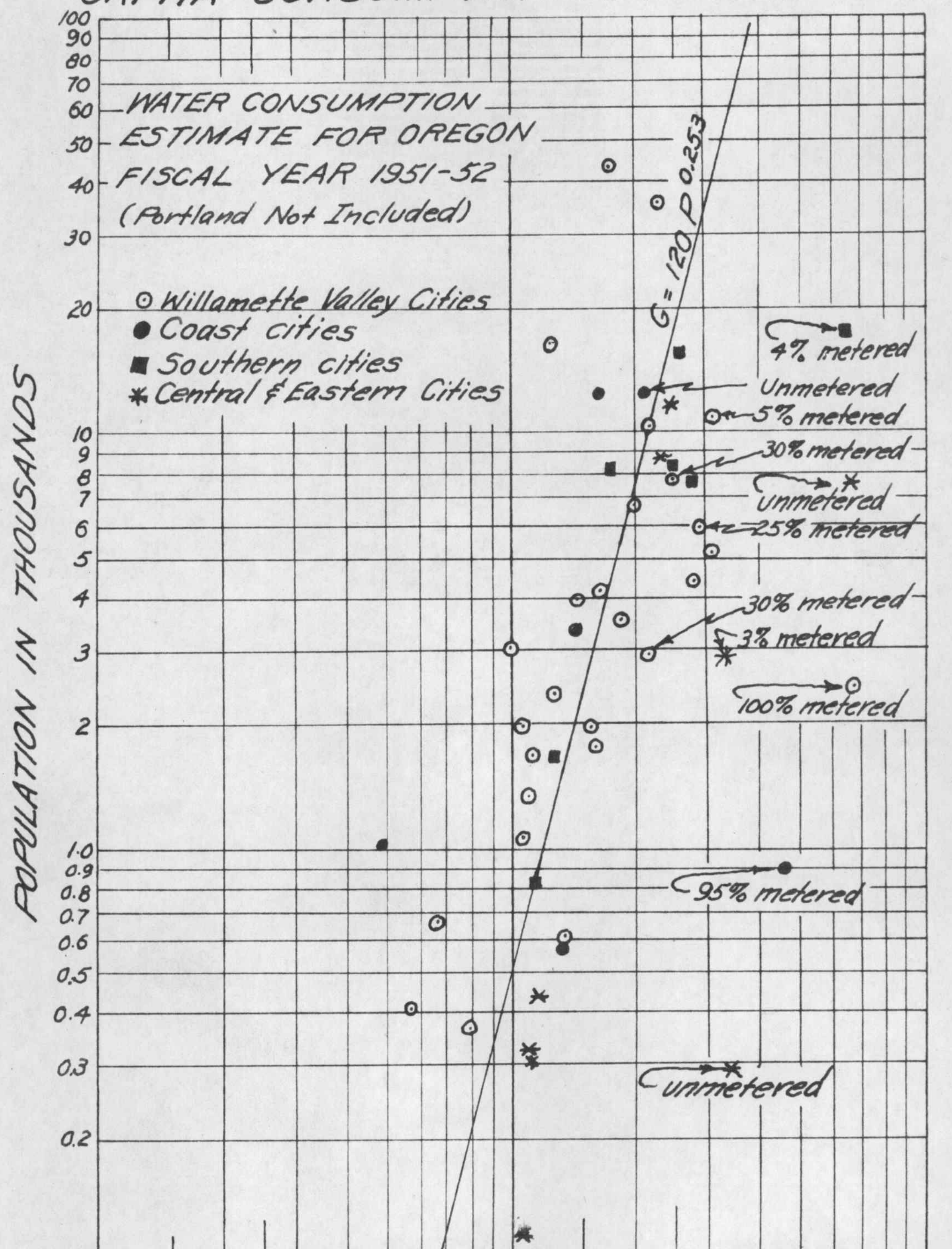


FIGURE 3

especially where there is city water and only a septic tank for sewage disposal.

Since the Oregon State College Agricultural Experiment Station was established in 1888, there has been a great deal of work done on soil and water conservation. The college staff estimates (31, p.24) that at the present time there are about 80,000 acres of land under irrigation in the Willamette Valley and that because of our knowledge of sprinkler irrigation, water storage, and utilization of power, 1,200,000 acres could be irrigated. The amount of water needed for irrigation would depend on the type of crops raised and upon the type of soil and its capacity for irrigation water. This accelerated program of irrigation is mostly rural, but it is carried on in urban areas also as more people tend to raise larger gardens or lawns. Lawns and gardens require a lot of water depending mainly on the type of soil in the area.

The foregoing data give a reasonable estimate of average per capita consumption in Oregon, show the variation between average and maximum or minimum monthly values, and show that population is a big factor in water consumption. It also shows the effect on consumption of non-metering. In the next article data from Corvallis, Eugene, and Salem will be analyzed to determine other factors involved.

Municipal Data

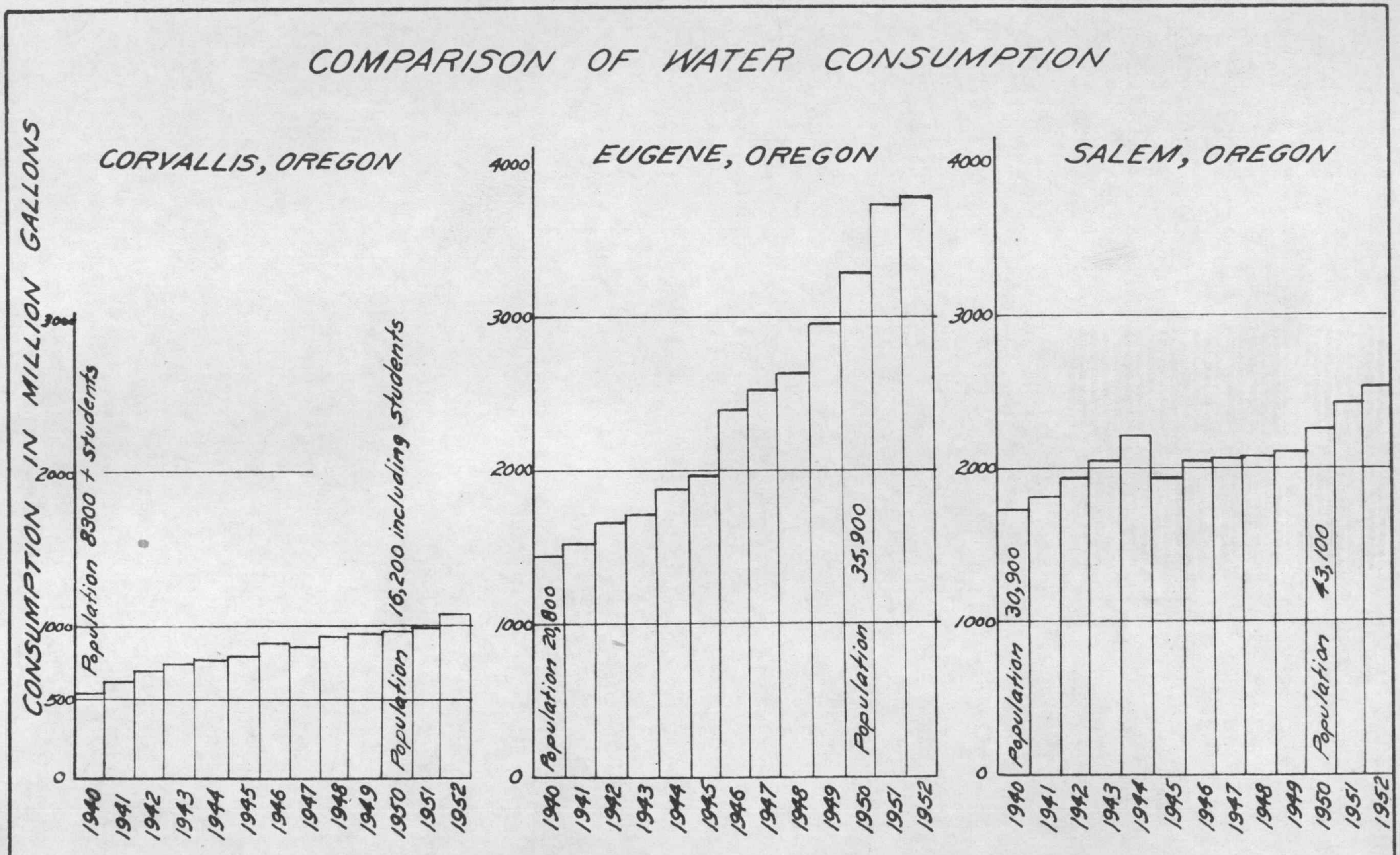
Since the cities of Eugene and Salem have approximately the same 1950 census population, it seemed logical that they might be similar in water consumption. A bar graph (figure 4) showing the comparison of water consumption for Eugene, Salem, and Corvallis for the years 1940-1952 was plotted. The graph shows a striking dissimilarity between Eugene and Salem, and a similarity between Corvallis and Salem. The rapid increase in consumption in Eugene can probably be explained mostly by the metropolitan attitude of the Eugene Water and Electric Board. The board sells water to a number of large districts outside the corporate limits of Eugene. Salem, on the other hand, is strictly urban and maintains a policy of selling water only to people within the corporate limits. Corvallis also has a limiting policy on out-of-city connections, though water is sold to Philomath and to a few outside customers.

In a previous section it was noted that the three cities are similar in location, topography, soil type, and climate and lend themselves to comparison using any of these factors as criteria. A comparison of rainfall showing accumulative percent of annual rainfall by months was plotted in 1939-40 in a senior thesis (39, pp. 11,12,14,19) under the direction of

Professor Fred Merryfield. Figure 5 is a composite curve from the foregoing analysis comparing the three cities and also comparing them with Riverside, a city in south-eastern Oregon. Corvallis, Eugene, and Salem show almost identical curves. This data substantiates the previous assumption that climatic conditions in the three cities are similar.

A further substantiation of this assumption was found by plotting in figures 6, 7, and 8 the daily water consumption, daily maximum and minimum temperatures, and the daily precipitation for each of the cities for the year 1952. In all three cases July and August are shown to be maximum-use months. In these two months, maximum temperatures also occur and there are only small amounts of precipitation in the month of August which immediately reflect on the consumption chart as well as on the temperature chart. Figure 9 is an enlarged portion of the Salem chart for June 5 to July 10, 1952. December, January, and February are the minimum-use months and also have the largest rainfall and lowest temperatures recorded for the year.

In the month of April the consumption curve begins its upward climb as a few warm days occur. The first part of May a few of the hardy gardeners begin their summer watering program and the curve begins a



COMPARISON OF WATER CONSUMPTION
CONSUMPTION IN MILLION GALLONS
CORVALLIS, OREGON
EUGENE, OREGON
SALEM, OREGON
Population 8300 + students
Population 16,200 including students
Population 20,800
Population 35,900
Population 30,900
Population 43,100
0
500
1000
2000
3000
4000
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952

Figure 4

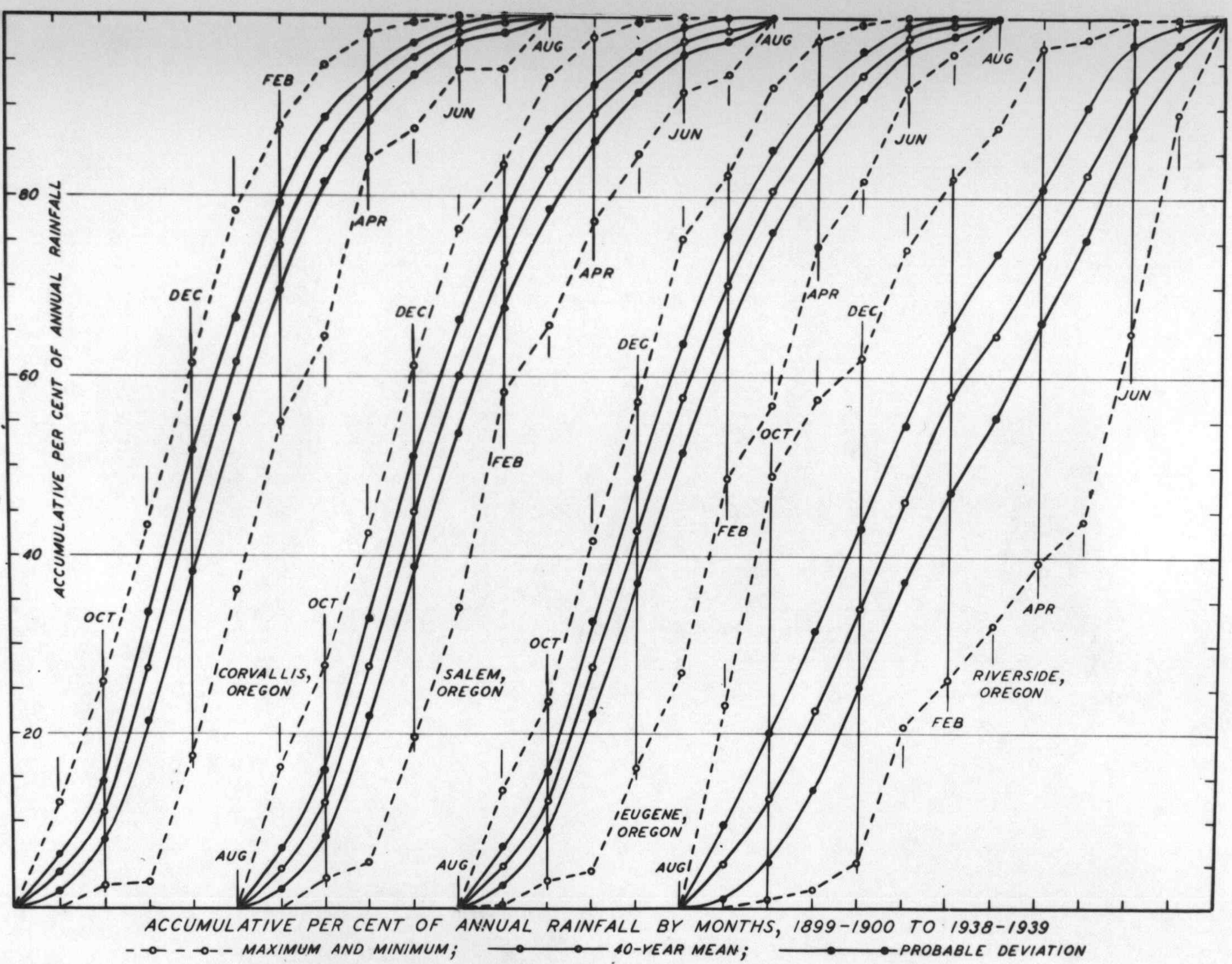
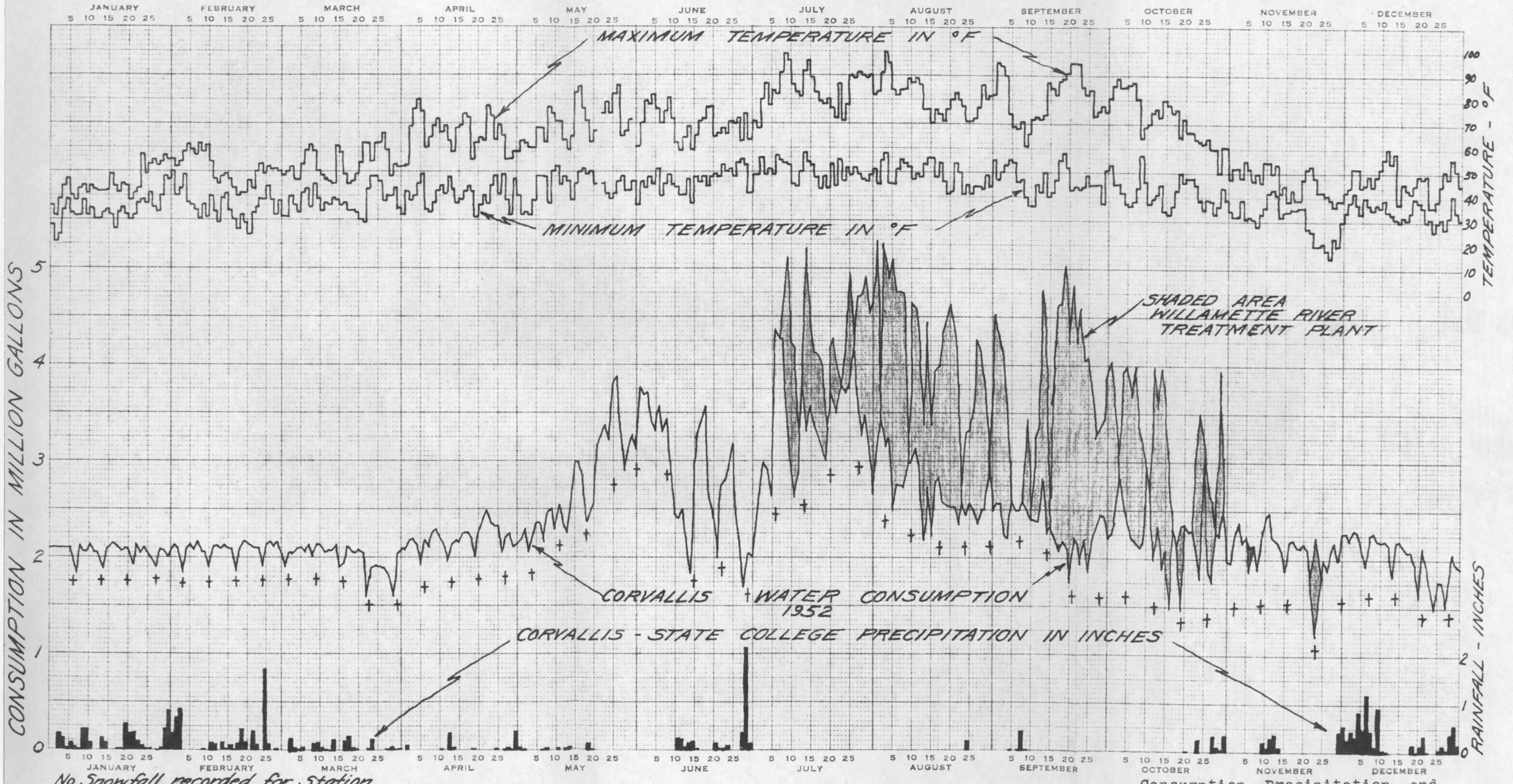

ACCUMULATIVE PER CENT OF ANNUAL RAINFALL
80
60
40
20
CORVALLIS, OREGON
SALEM, OREGON
EUGENE, OREGON
RIVERSIDE, OREGON
AUG
OCT
DEC
FEB
APR
JUN
ACCUMULATIVE PER CENT OF ANNUAL RAINFALL BY MONTHS, 1899-1900 TO 1938-1939
MAXIMUM AND MINIMUM; 40-YEAR MEAN; PROBABLE DEVIATION

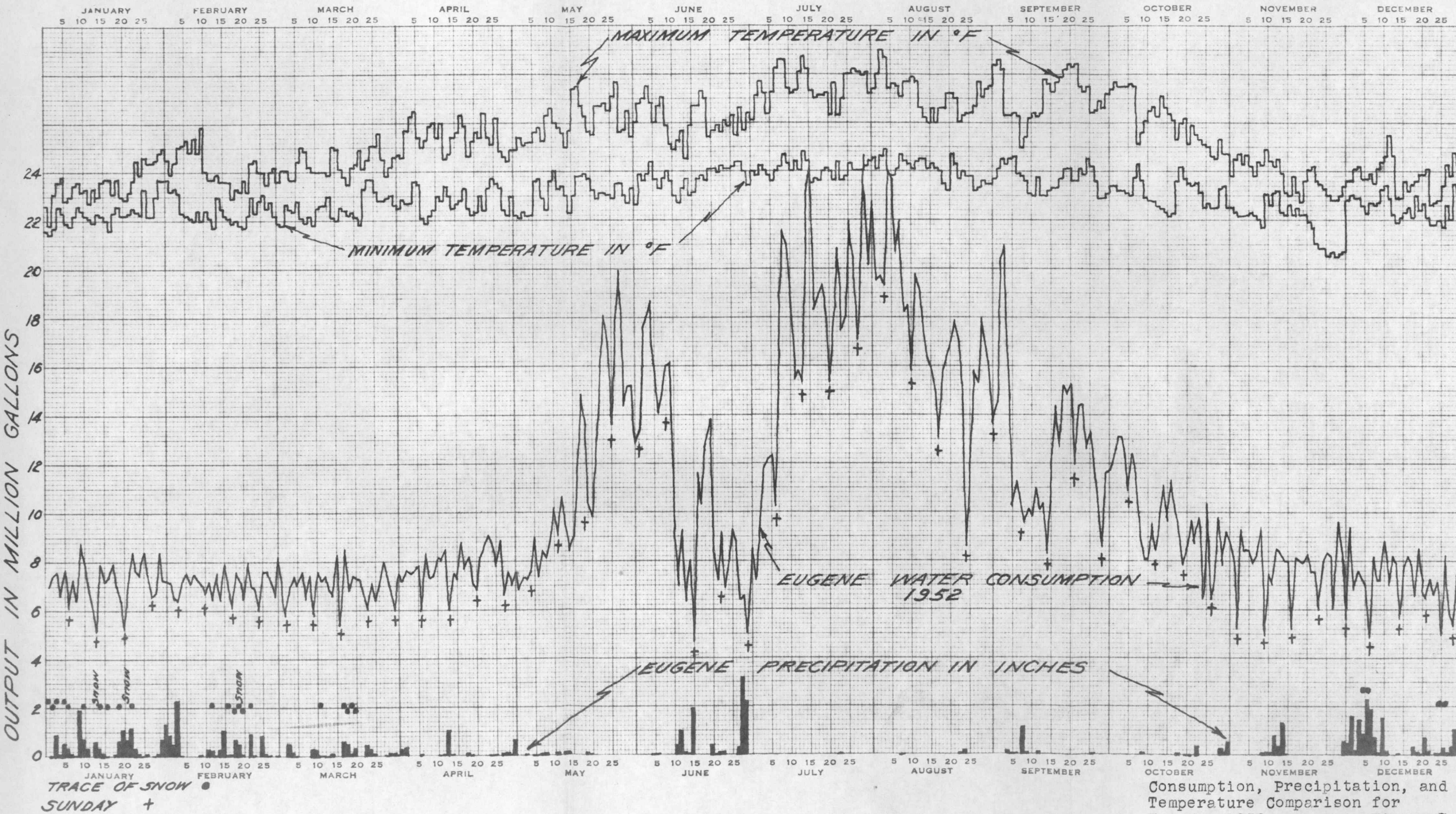
Figure 5

decidedly steeper climb, paralleling closely the maximum temperature curve and dipping sharply at the slightest rainfall. During the last of May and the first of June, it remained warm and dry. Gardens and lawns were watered, and consumption increased. On June 10 heavy rains began and lasted with two short rests for the entire month causing consumption to dip to the winter values. Then from July 1 to the latter part of August the rains ceased. Temperatures soared to the 90's, and water consumption increased to maximum values. The year of 1952 was unique in that the fall rains held off, except for showers, until October 20, and the water consumption curve remained high until that date, making 1952 the maximum water-use year on record in Oregon.

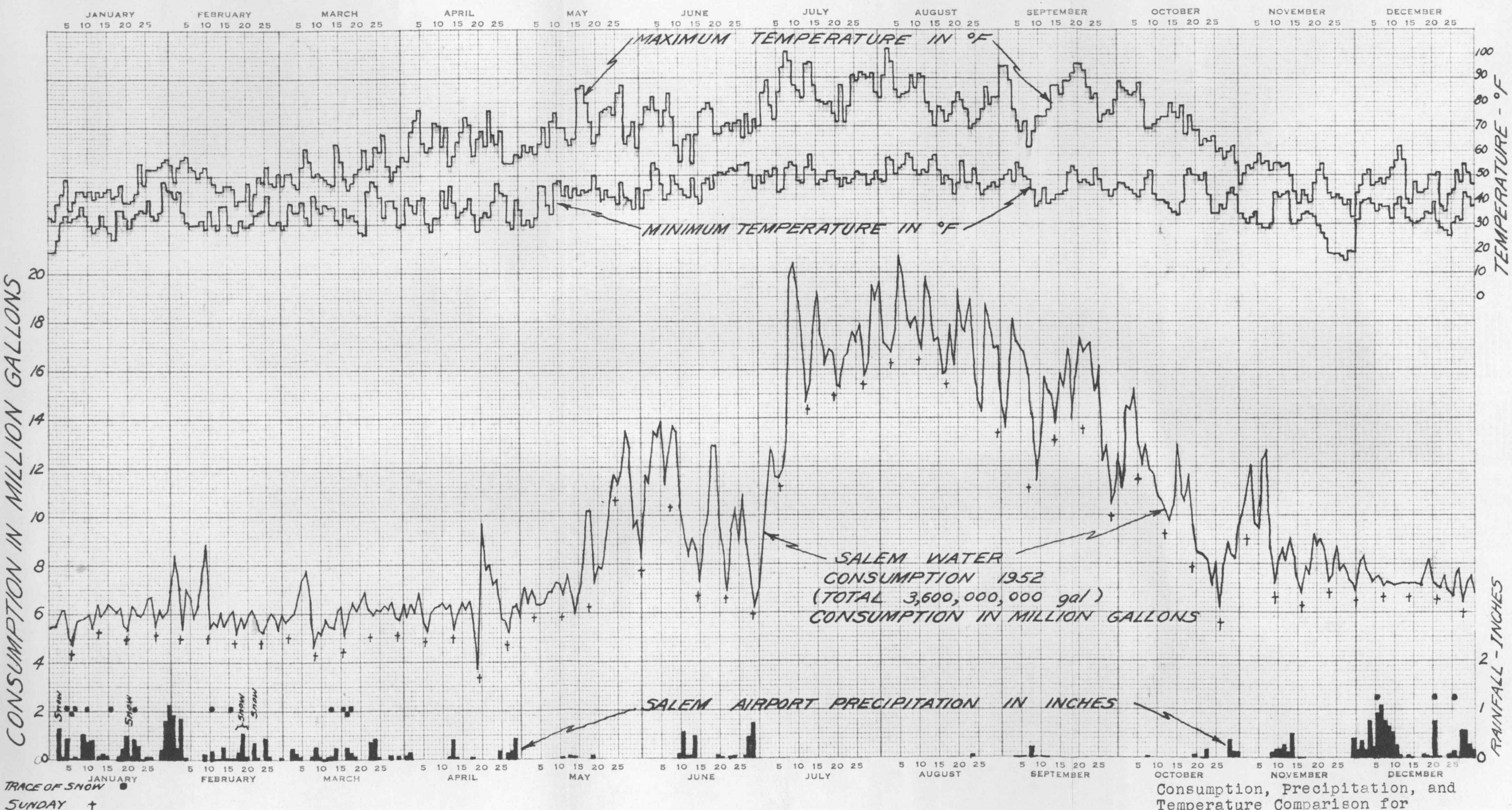
The three charts also show that variations occur on certain days of the week. On each chart Sundays have been marked with small crosses and in nearly all cases, except very hot days, the crosses correspond with a definite dip in the consumption curve. This trend probably indicates that the people in these cities whether due to lassitude or for religious reasons refrain from gardening, washing, cleaning, or even lawn watering on Sundays. Part of the Sunday decrease is probably also due to people leaving the college, the university, and



Consumption, Precipitation, and Temperature Comparison for Corvallis, 1952. Figure 6



Consumption, Precipitation, and Temperature Comparison for Eugene, 1952. Figure 7



Consumption, Precipitation, and Temperature Comparison for Salem, 1952. Figure 8

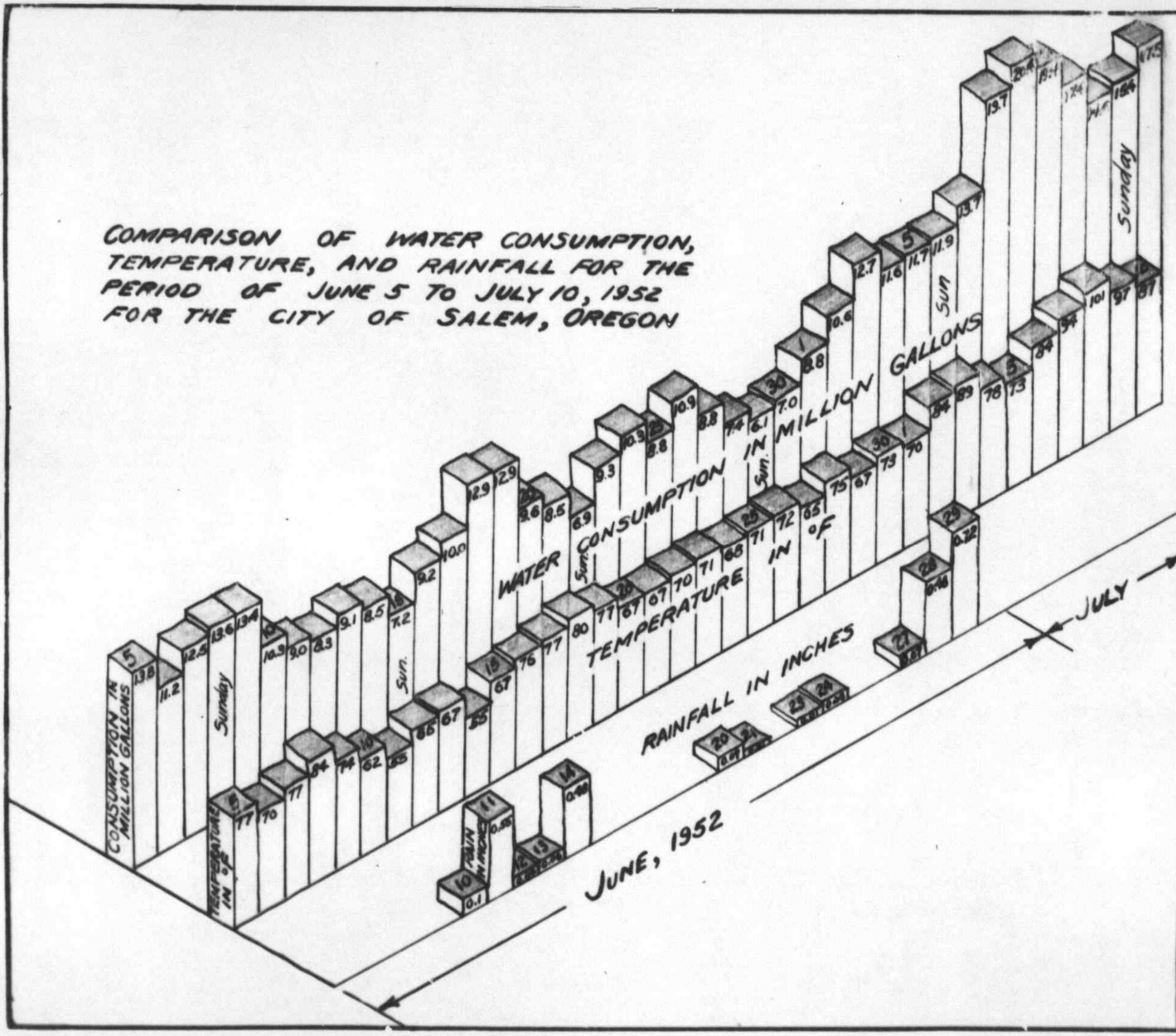

COMPARISON OF WATER CONSUMPTION, TEMPERATURE, AND RAINFALL FOR THE PERIOD OF JUNE 5 TO JULY 10, 1952 FOR THE CITY OF SALEM, OREGON
WATER CONSUMPTION IN MILLION GALLONS
TEMPERATURE IN °F
RAINFALL IN INCHES
CONSUMPTION IN MILLION GALLONS
TEMPERATURE IN °F
RAIN IN INCHES
JUNE, 1952
JULY
Sunday
Sun.

Figure 9

the state office buildings for weekends at the beach, in the mountains, in Portland, or their home towns.

Another factor in municipal use is brought out in Table 10 in which metered readings of water consumption in Corvallis' four grade schools and the high school are tabulated. Monthly consumption per student, average, maximum, and minimum has been computed for the schools for the years 1952 and 1953. From this data a rough average value of 4 gallons per student per day was obtained. Maximum consumption was 20 gpcd and minimum 0.3 gpcd. The average and maximum values compare favorably to values published in July, 1953 Public Works magazine (40 p.98).

"The following is a summary of the ranges in per capita water use of the group of schools surveyed:

(1) 31 grade schools without cafeterias and showers varied from 2.36 gallons per capita per day to 14.6 gallons per capita per day.

(2) 10 grade schools with cafeterias varied from 2.62 gallons per capita per day to 11.07 gallons per capita per day.

(3) 16 Junior high schools with and without cafeterias and showers varied from 2.27 gallons per capita per day to 8.92 gallons per capita per day.

(4) 30 high schools with cafeterias and showers varied from 2.63 gallons per capita per day to 20.92 gallons per capita per day.

In order to resolve these variations into useful information graphs were made on normal probability paper. The mean water use, the 90 percent probability and the 97.9 percent probability, all in gallons per pupil per day, are shown in Table 1 for the groups listed in the preceding paragraph.

TABLE 1 - SCHOOL WATER USE

Group Number	Mean Use	90 % Probability	97 % Probability
	Gallons per pupil per day		
1	6.0	10.25	12.75
2	6.25	10.50	13.00
3	5.5	9.75	12.25
4	9.0	15.5	19.25

These summaries of water use will assist the planner in deciding upon the quantity of water needed, or the quantity which must be disposed of at schools."

The article continues in an explanation of precautions to be observed when using the above values. The main precaution was to increase quantities if the school also serves as a community hall or a hall for other evening meetings.

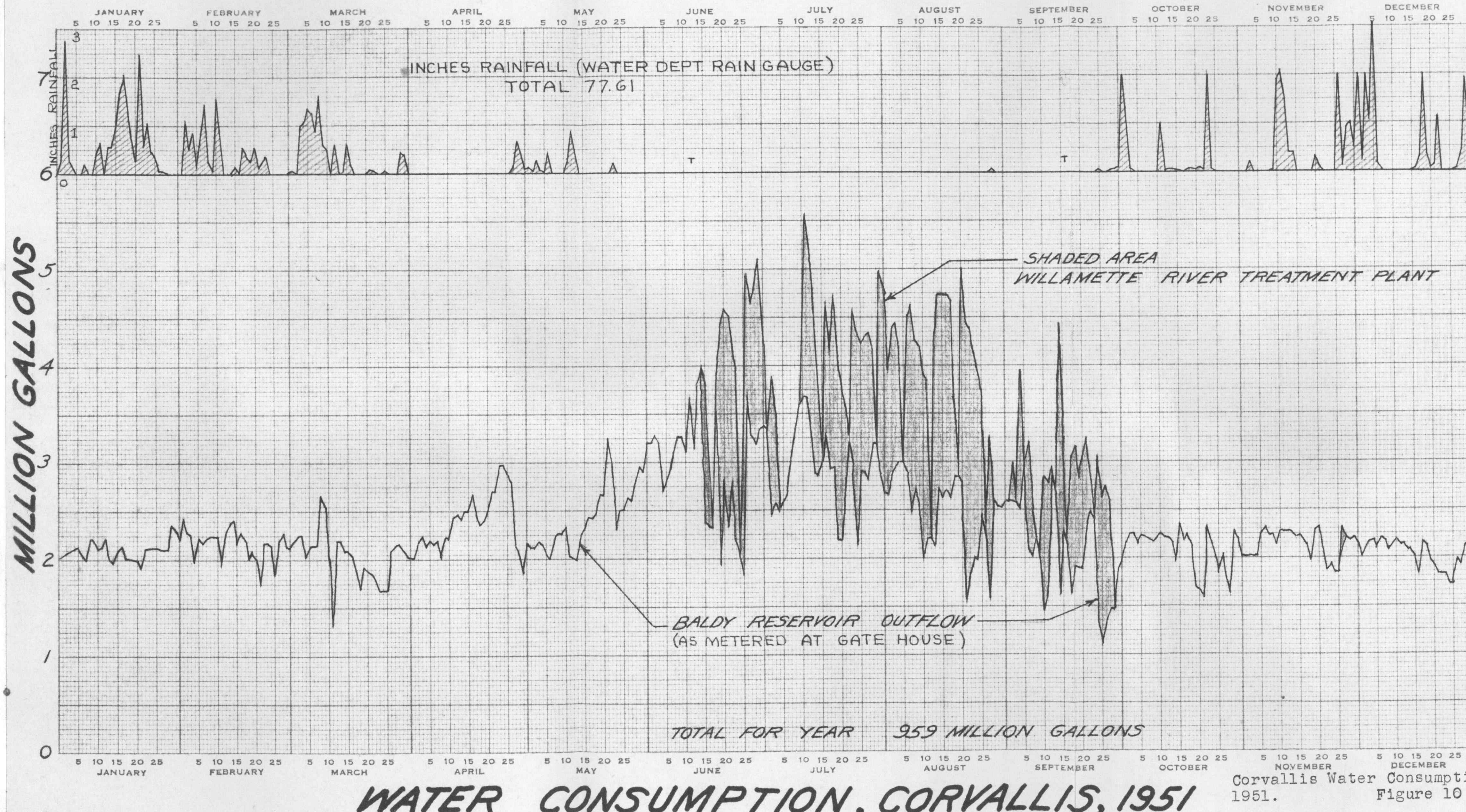
WATER CONSUMPTION IN CORVALLIS SCHOOLS
(Monthly values in Thousand Gallons)

	Franklin		Harding		Roosevelt		Washington		High School	
January	44	48	10.5	11	22	14	7.5	39	67	78
February	56	79	28	18	36	36	9.7	40	96	101
March	53	52	---	16.5	30	34	9	49	90	79
April	53	58	15	20	24	15	8.3	46	95	75
May	61	60	16.5	20	32	27	12	51	99	85
June	103	42	36	14	35	20	12	42	214	118
July	44	158	27	21	53	31	12	29	270	302
August	72	204	31	79	59	135	143	135	310	297
September	94	126	55	33	67	42	109	3	242	230
October	133	79	45	31	45	28	39	2.2	142	143
November	56	66	17	25	24	26	11	9	99	82
December	58	--*	13.5	--*	26	--*	39	--*	100	--*
Total	827	972	294.5	289	453	408	412	445	1,824	1,590
Average	69	88	24.5	26.2	37.7	37.1	34.3	40.5	152	145
Meter size	1½"		2"		2"		2"		3"	
No. of Students	536	553	460	529	458	476	234	267	1052	1065
Consumption per student:										
Average	129	159	53	50	82	78	147	152	144	136
Maximum	249	370	120	150	146	284	610	500	294	284
Minimum	82	76	23	21	48	30	31	8	64	73

* Not available at time of record
Data from Corvallis Public School records and from Corvallis Water Dept. records

The year 1951 was chosen for a study of hourly variations since peak days occurred in July, August, and September, and clear charts were available for the peak days. The three days chosen were July 11, August 20, and September 14. Figure 10 is the 1951 Corvallis water consumption chart and shows the flows for these three days as 5.6, 5.0, and 4.5 million gallons respectively. These total consumption estimates are the sum of three recordings: (1) Adams Street main line meter chart, (2) Harrison Street main line meter chart, and (3) the pumping chart from the Willamette River filtration plant. Figures 12, 13, and 14 are photographs of the July 11, 1951 charts; figures 15, 16, and 17 are the August 20, 1951 charts; figures 18, 19, and 20 are the September 14, 1951 charts. Figure 11 is the combined flow chart showing hourly variations for each of the three days. Minimum and maximum temperatures plotted on figure 11 indicate high temperatures for all three days. Temperature records for days preceding and following the three days are tabulated below:

July 9----78 F	Aug. 13---86 F	Sept. 10--79 F
10----90	14---94	11--72
11----99	15---98	12--82
12----96	16---91	13--95
13----78	17---93	14--92
	18---90	15--90
	19---99	16--88
	20---98	17--92
	21---98	18--83
	22---85	
	23---79	

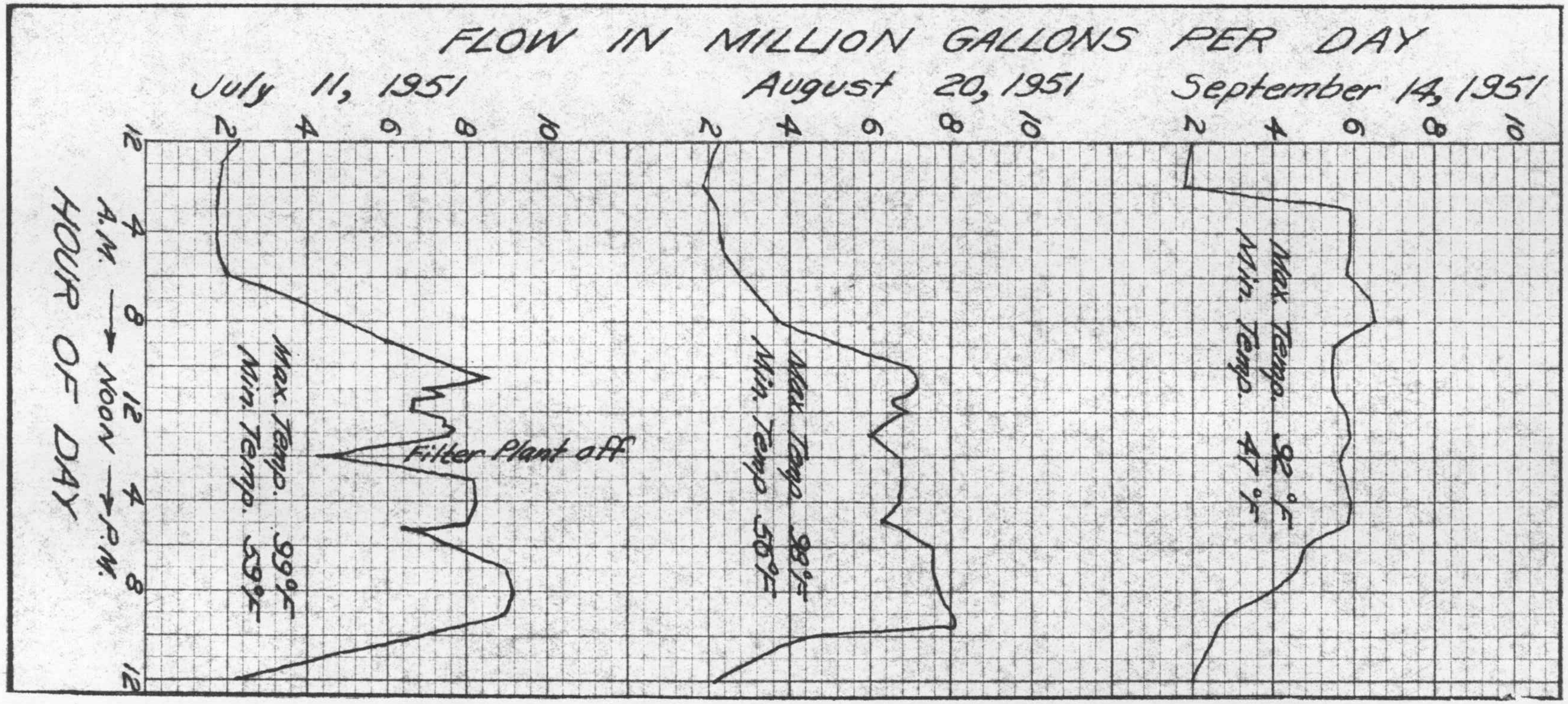


Corvallis Water Consumption, 1951. Figure 10

The temperature record for the July 11 peak shows only three days of hot weather. This short period of increased temperature following the Independence Day holiday is responsible for the sharp peak. The second peak comes at the culmination of a prolonged heat wave and the flow curve remained high during the heat wave except for natural Sunday lows on August 12 and 19. "Indian summer" is the term often used for the unseasonal heat wave in September. It is interesting to note that the heat wave corresponded with the first faculty meeting at Oregon State College. Undoubtedly much of the increase in consumption could be attributed to increased irrigation caused by faculty members who returned to Corvallis to find their lawns withering in the heat.

The charts of figures 11 through 20 show a great deal about the habits of people who use the water. For example it may be noted on the July and August curves of figure 11 that people start using water about 6:00 a.m. and continue at a fairly steady rate until about 10:00 a.m. when most housewives have sent their husbands to work, their children to school, and have completed their dishwashing and morning cleaning. During this time also the college starts its lawn watering and water-using industries start their daily use. Probably the 10:00 a.m. drop is due mostly to domestic use. House wives do their morning shopping, vacuuming or other chores and do not use much water until 11:30 or 12:00 when they realize lunch must get on the table. Even the lunch period shows some variation when it is studied on the individual charts. Following the lunch period there seems to be a rise which can probably be attributed to irrigation of lawns. At 5:00 p.m. the shutdown of industrial establishments and the college is reflected, but the drop is only momentary as home-loving citizens start all the sprinklers they can muster to keep their lawns green in the blistering heat. The consumption reaches its peak about 8:00 or 9:00 p.m. and by midnight the curve is once more down almost to minimum use where it will stay until alarm clocks ring the following morning.

The September 14 curve shows a rapid climb from 2:00 a.m. to 3:00 a.m. which is easily traced on figures 18, 19, and 20, and is found to be due to the Willamette river filtration plant being started at 2:00 a.m. to fill the reservoir on Mount Baldy. Aside from this early pumping the curve is similar to the other two except that evening peak is reached at 5:00 p.m., probably due to shorter days and cooler evenings during September.



Daily Flow Charts For Corvallis
Figure 11

The individual charts are more susceptible to variation than the composite and show some rather interesting phenomena. Figures 12 and 13 show small momentary peaks between 6:00 a.m. and 7:30 a.m., which are duplicated in figures 15 and 16 between 3:00 a.m. and 5:00 a.m. and are found again in figures 18 and 19 between 4:00 a.m. and 6:00 a.m. It is believed that each of these peaks represents a filling of the street flusher and indicate the approximate area of street washing. The filter plant charts fail to reflect small variations since they are pump charts and are not as susceptible to small surges or changes in flow.

Since each of the three charts for a single day reflects the flow change in the other two, it is imperative to check all three charts for comparison of any factors at a particular time. It was assumed for this study that the maximum hourly flow rate occurred on the day of the maximum daily use. Using this assumption, the following figures were derived:

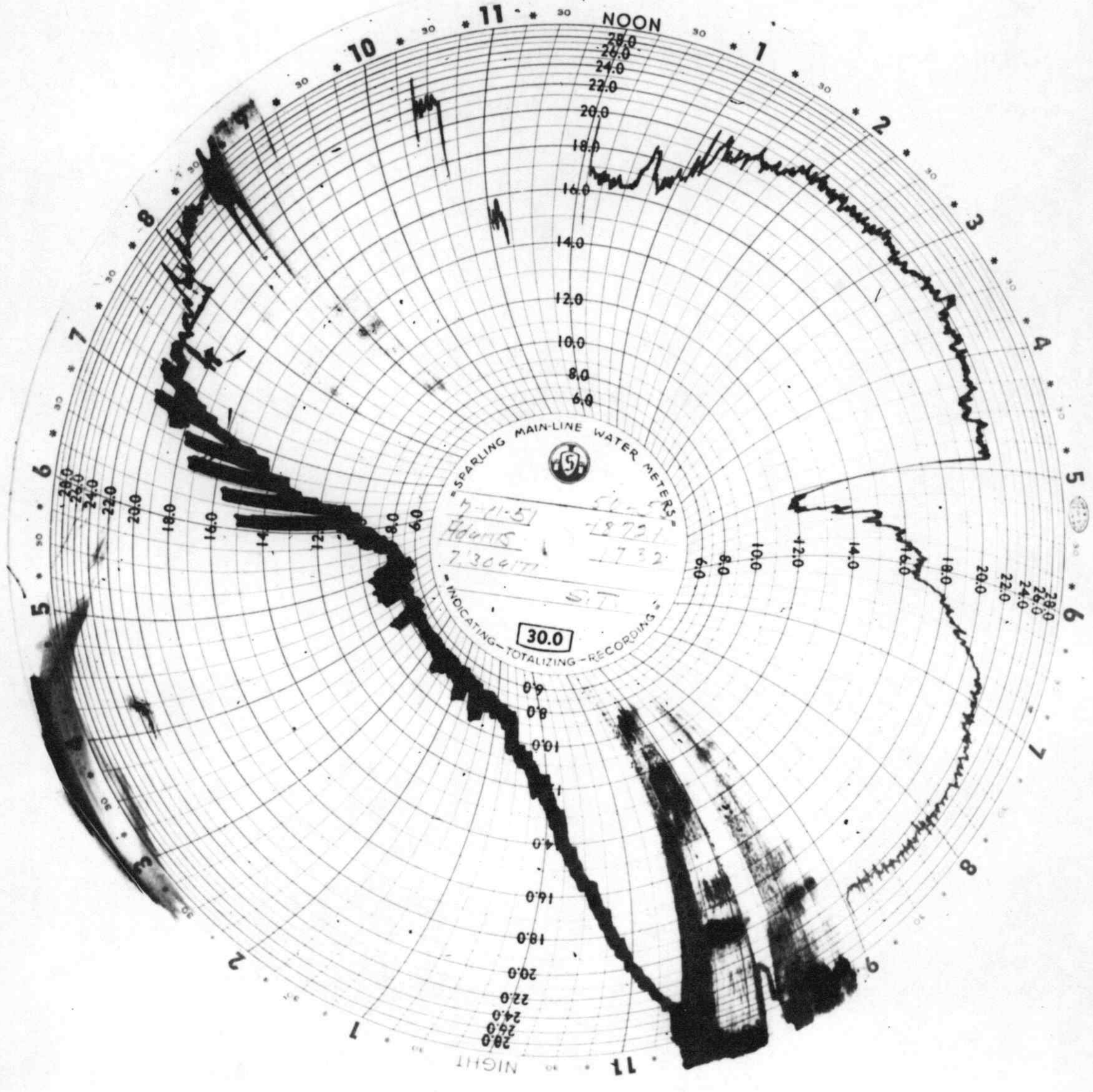
	Maximum Daily (mgd)	Maximum Hourly (mgd)	Max. hourly divided by max. daily (100)
July 11, 1951	5.6	9.2	164
Aug. 20, 1951	5.0	8.1	162
Sept. 14, 1951	4.5	6.5	144

The average daily flow for the year is about 2.7 mgd. The daily ratio is 207 gallons for July 11, 186 for August 20, and 167 for September 14. These figures show an hourly ratio of (1.6) (187) or about 300 which correlates closely with the top limits of textbook data shown in Table 6.

Consumption charts for the city of Corvallis for the period 1947 through 1953 are shown in the appendix (figures 21-26) to point out how the total use and daily peak have varied through those years. (1951 chart is included as Figure 10 in the foregoing analysis.)

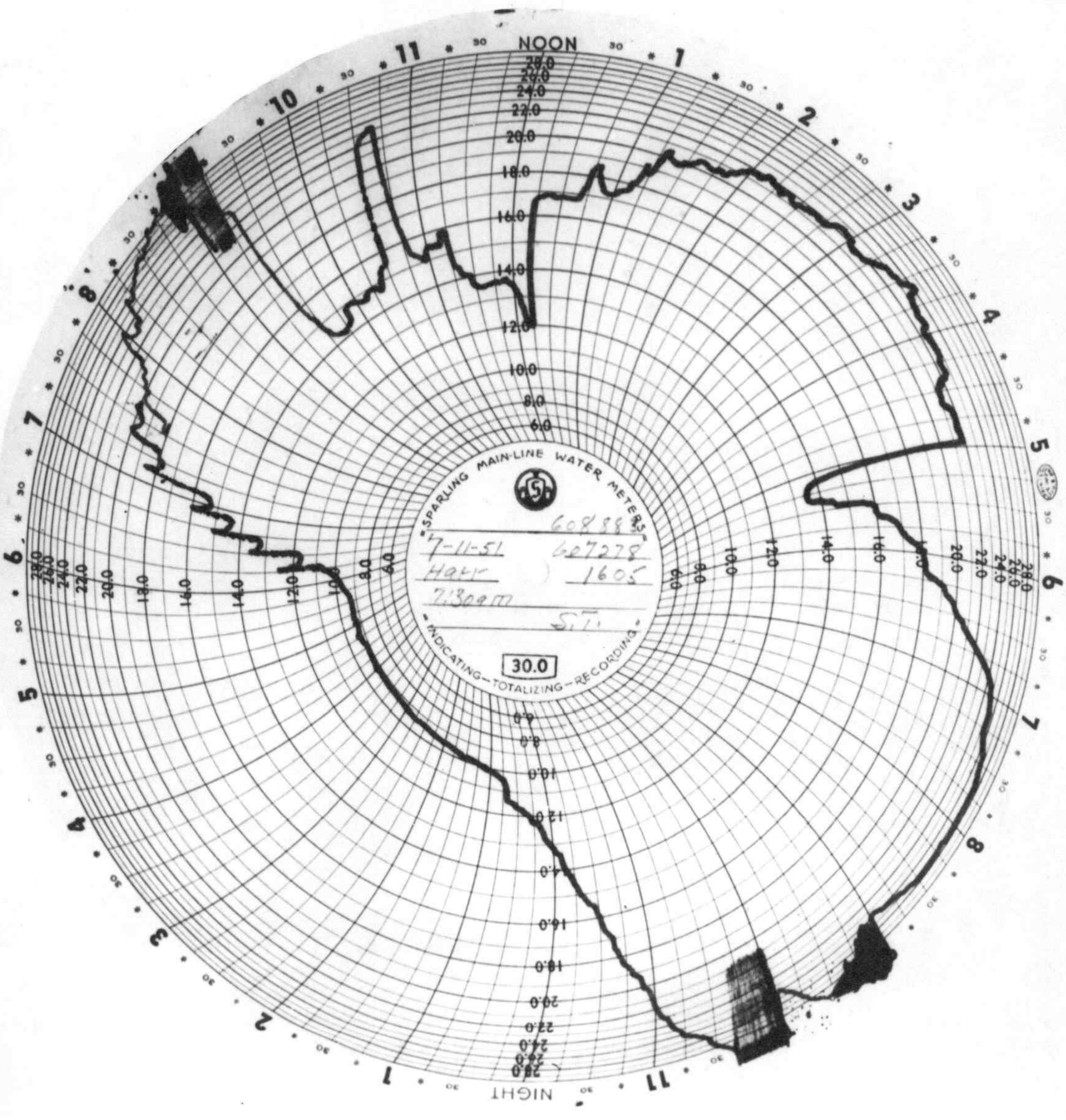
The city of Salem was chosen for a detailed analysis of water use because data were available for a thirteen-year period from 1940-1953, with use divided into residential, irrigation, commercial, industrial, and municipal use. The irrigation use listed is only for special irrigation meters. Other irrigation is combined with residential use. Loss and waste was also accounted for during the thirteen-year period. Daily fluctuations in use as shown in figures 6 and 8 follow about the same as Corvallis.

Table 11 was set up using Salem water department records and census populations as a basis for expanding the data to obtain a population factor (about 4 persons per family) and average daily per capita use (150-160 gpcd.) These values correspond closely to the upper



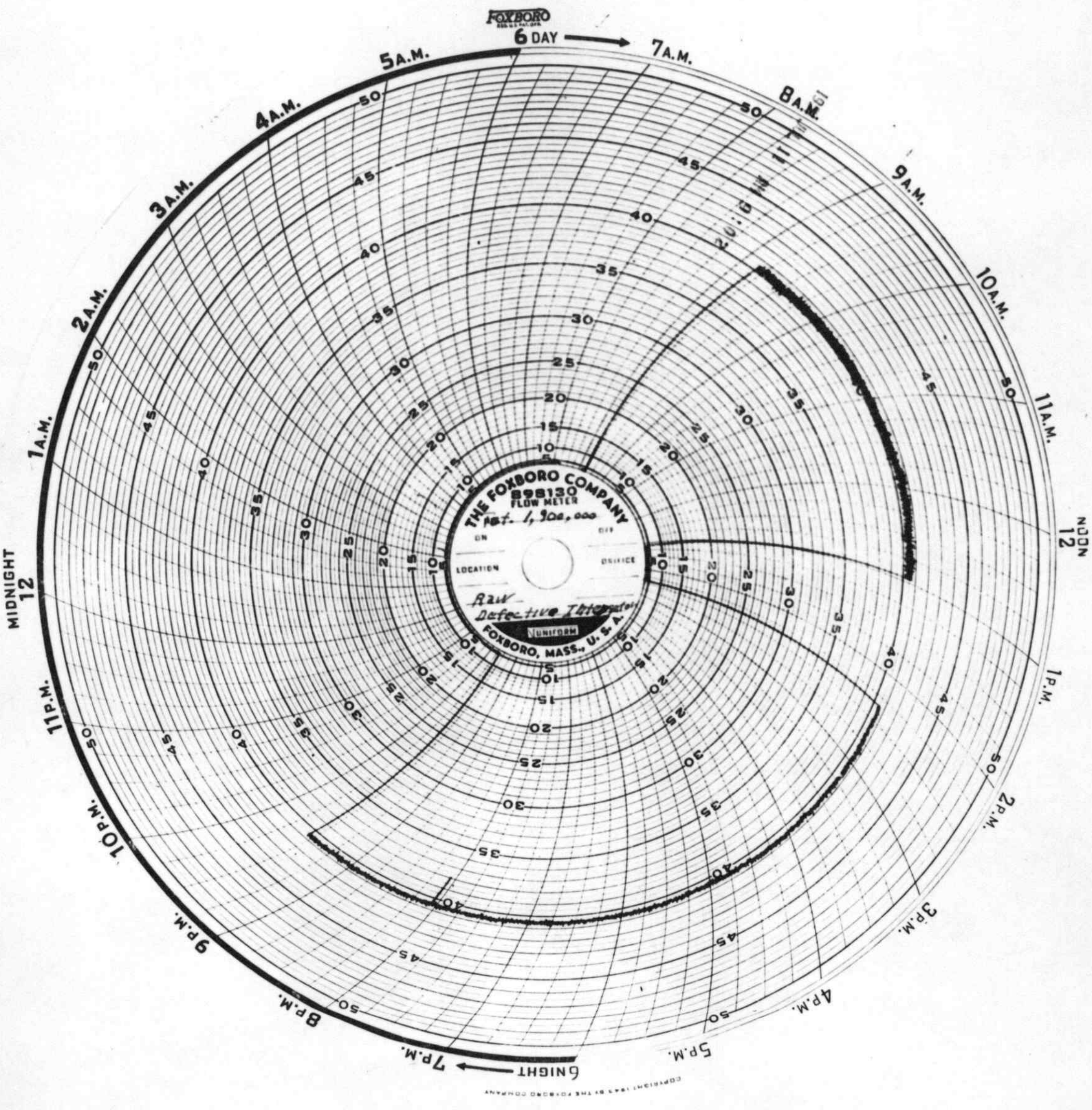
Adams Street Flow Chart
Corvallis, Oregon
July 11, 1951

Figure 12



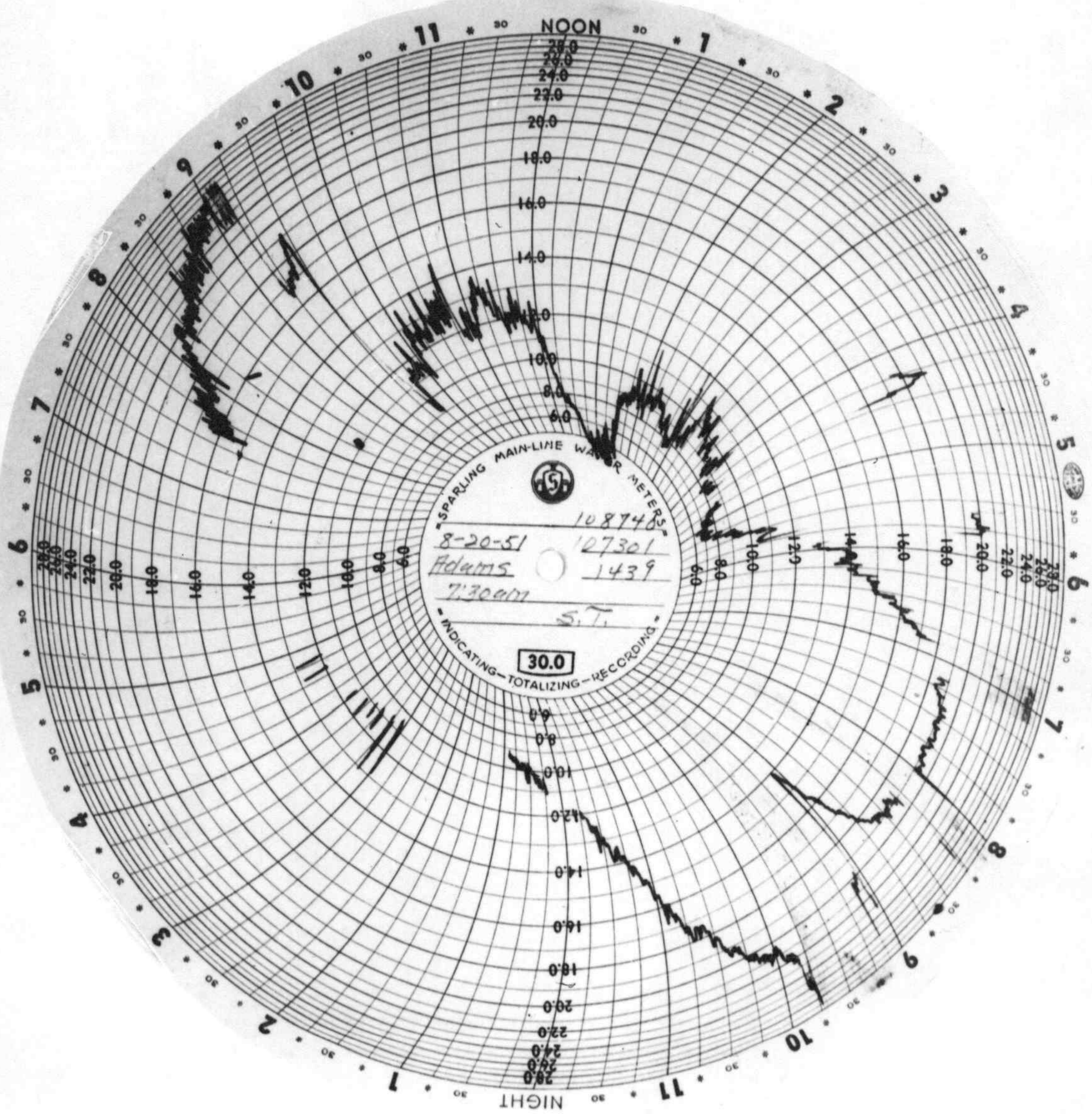
Harrison Street Flow Chart
Corvallis, Oregon
July 11, 1953

Figure 13



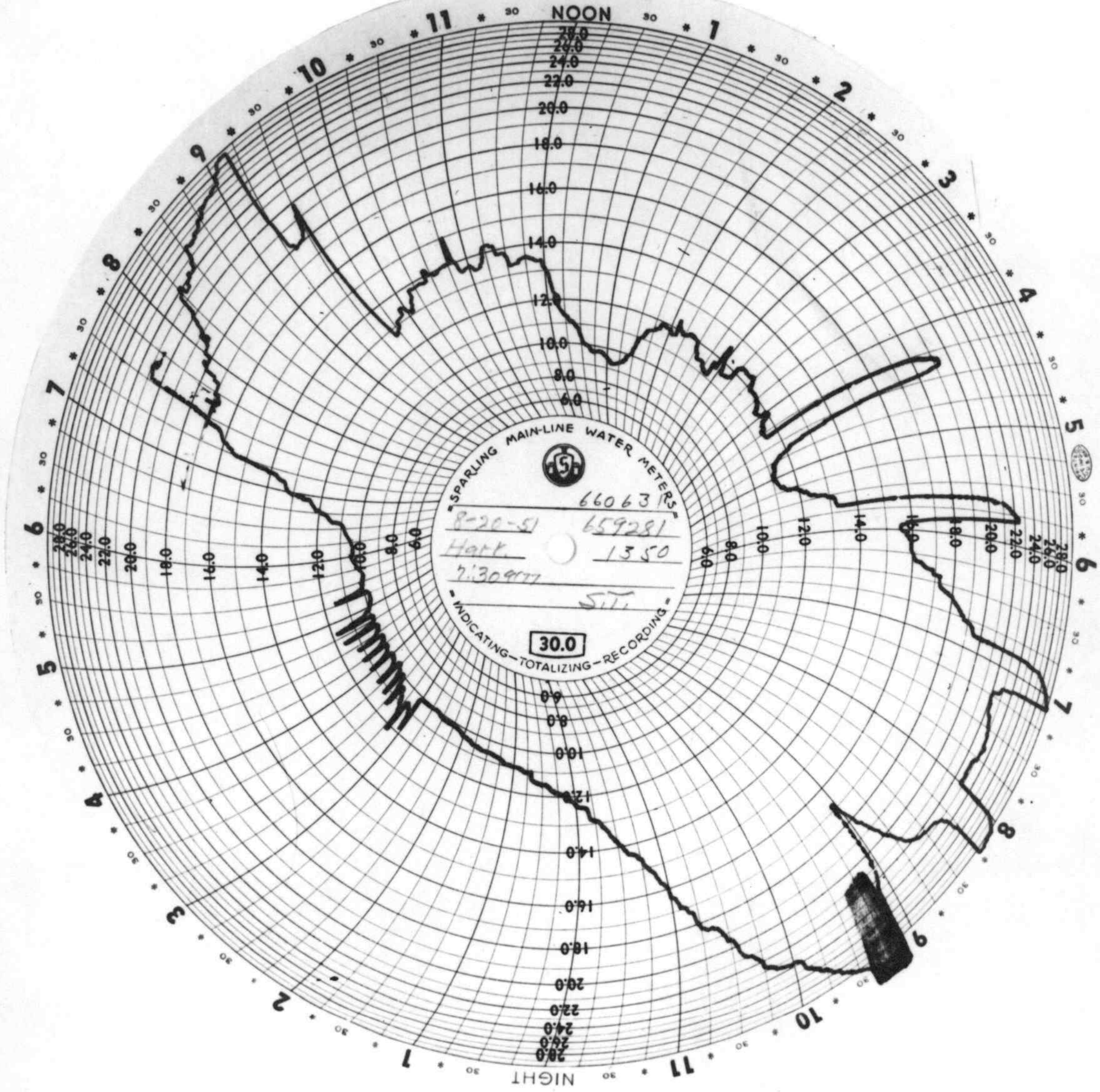
Willamette River
Water Treatment Plant
Flow Chart
Corvallis, Oregon
July 11, 1951

Figure 14



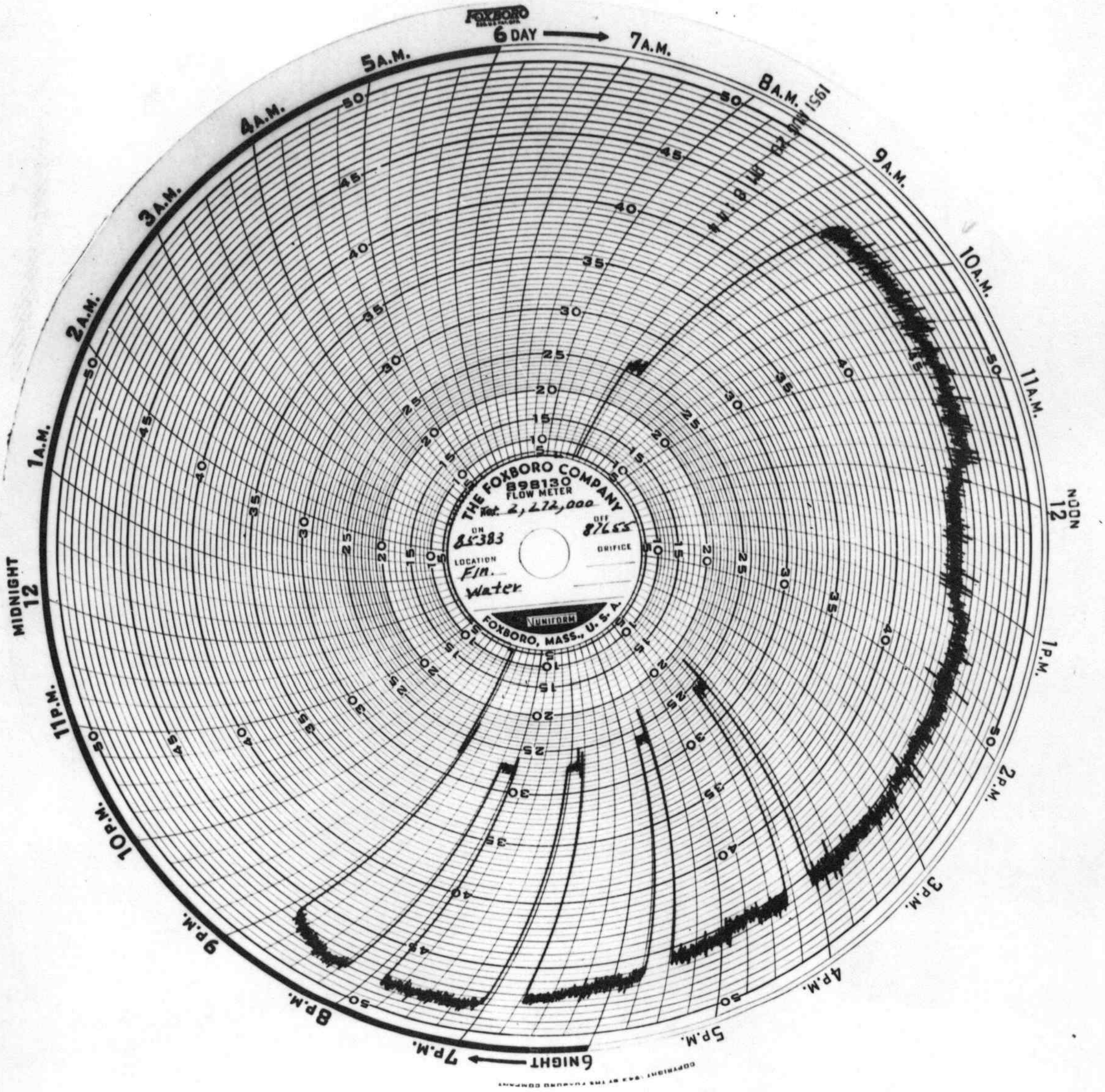
Adams Street Flow Chart
Corvallis, Oregon
August 20, 1951

Figure 15



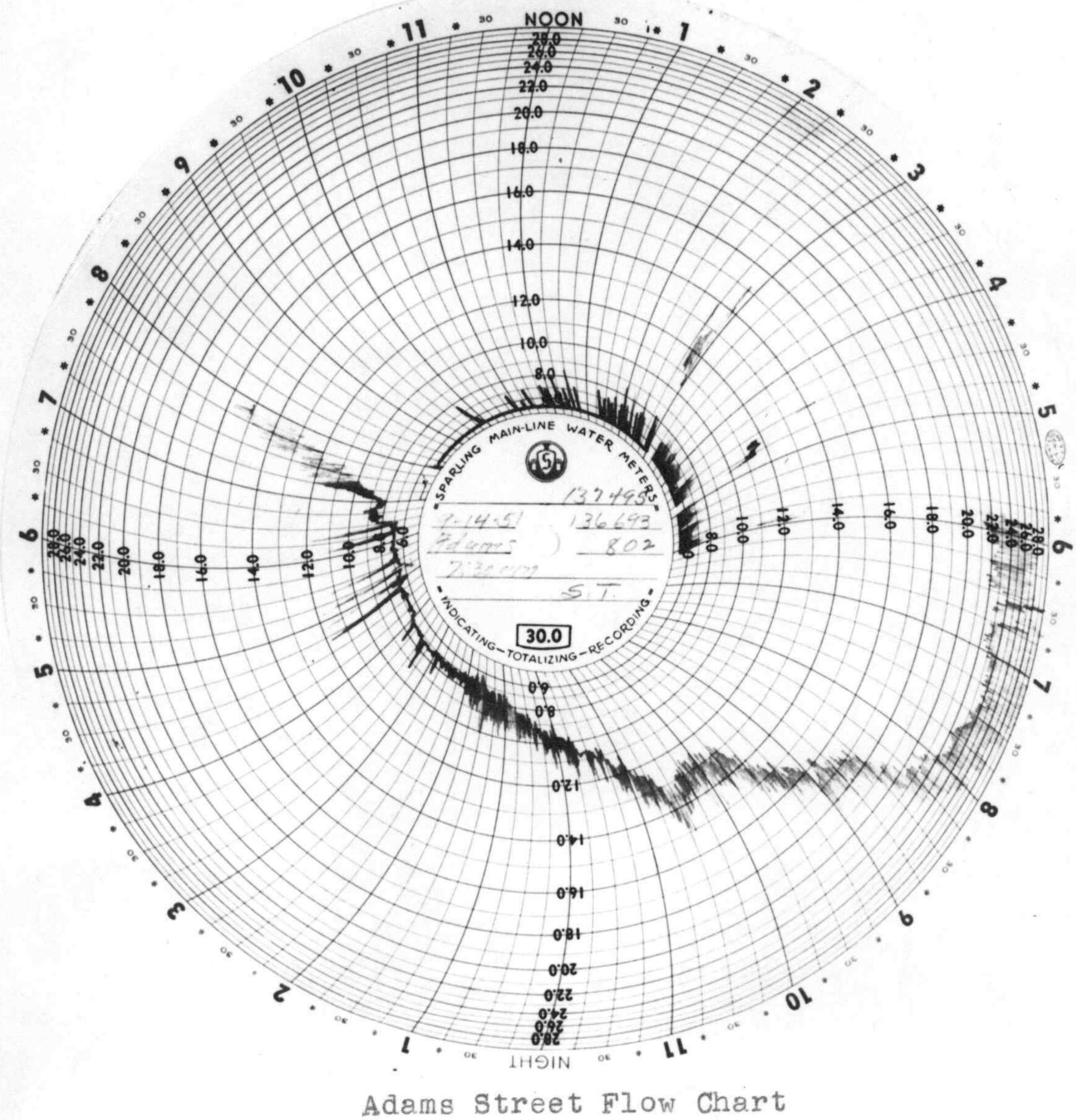
Harrison Street Flow Chart
Corvallis, Oregon
August 20, 1951

Figure 16



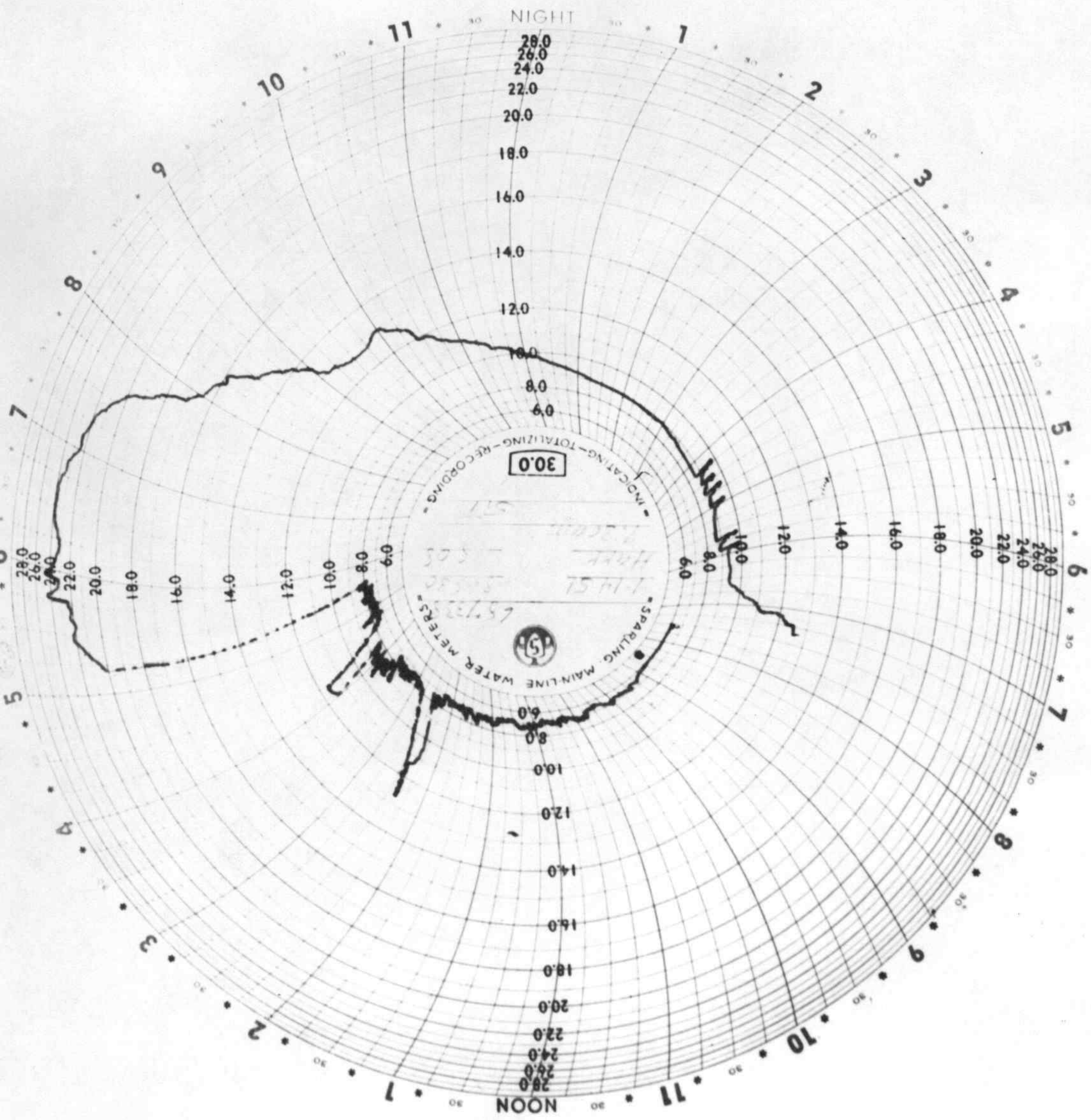
Willamette River
Water Treatment Plant
Flow Chart
Corvallis, Oregon
August 20, 1951

Figure 17



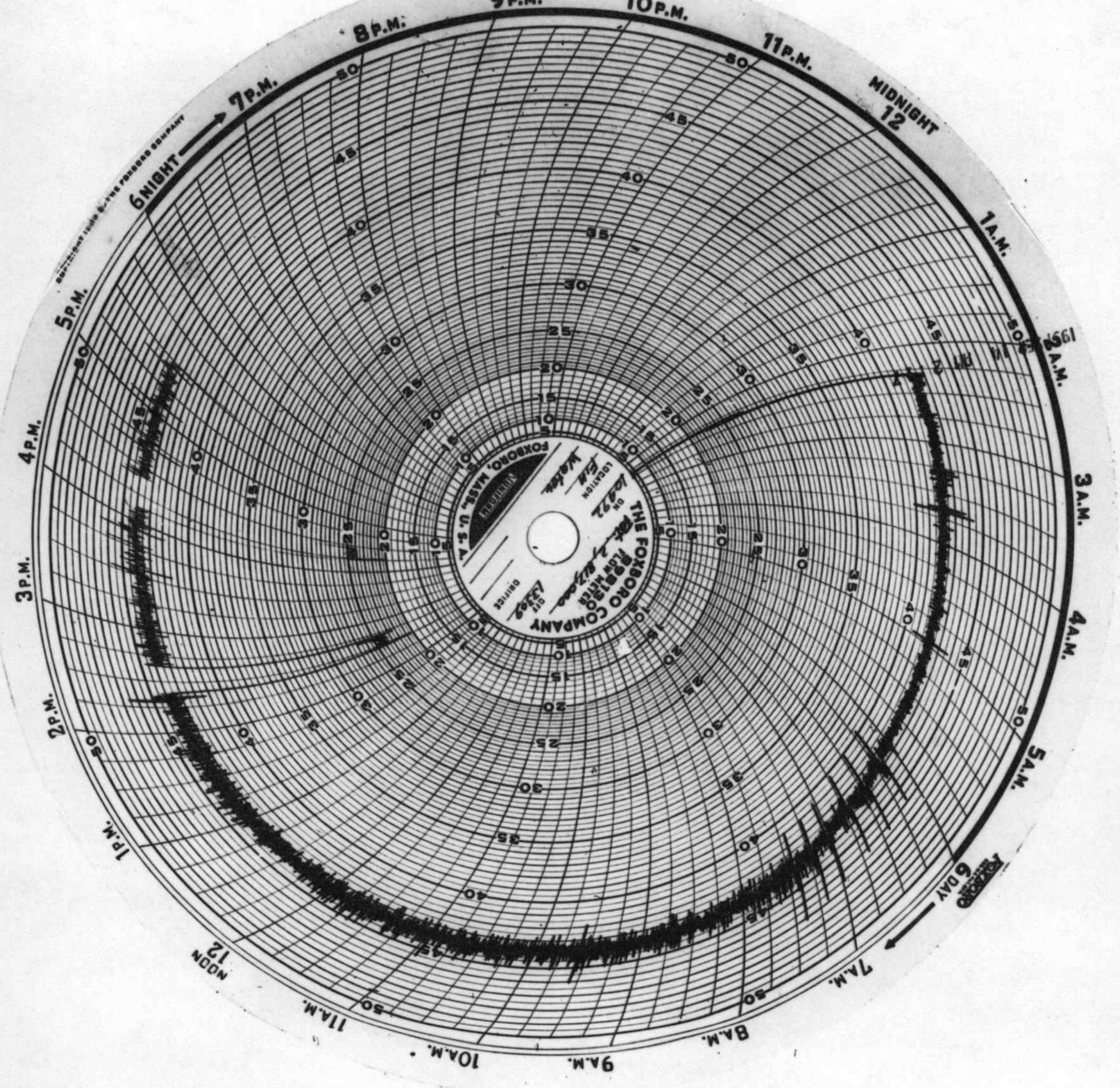
Adams Street Flow Chart
Corvallis, Oregon
September 14, 1951

Figure 18



Harrison Street Flow Chart
Corvallis, Oregon
September 14, 1951

Figure 19



Willamette River
Water Treatment Plant
Flow Chart
Corvallis, Oregon
September 14, 1951

Figure 20

limits of national averages, and further division of data was attempted in Tables 12 through 16. In these tables, average use per person for residential, irrigation, commercial, industrial, and municipal was found. Table 17 shows the five uses (Columns 51-55) listed in percentages of total water billed. The percentages were close enough during the thirteen-year period that average values are reasonably close estimates. The averages determined are: (1) residential 39.6%, (2) irrigation 0.4%, (3) commercial 28.2%, (4) industrial 25.4%, and (5) municipal 6.4%. Since these percentage figures are percent of total billed, they are also applicable to per capita daily use figures; and if it is assumed that the average daily use in Salem is 160 gpcd, the divided use is: (1) residential 63.5 gpcd, (2) irrigation 0.6 gpcd, (3) commercial 45.1 gpcd, (4) industrial 40.6 gpcd, and (5) municipal 10.2 gpcd. These figures are based on metered water only and do not take into account the 20% to 38% unmetered water that is part of the net production listed on column 2 of Table 11. The figures presented are based only on net production and do not include intentional waste at the reservoir overflows. If the foregoing values are compared to the national averages as reported by the American Water Works Association (5, p.2), it may be seen that the Salem values are in general higher. The following tabulation compares the consumption estimates:

	National		Salem	
	gpcd	%	gpcd	%
Average daily use	140	100	160	100
Loss	10	7.2	----	---
Residential	50	35.6	63.5	39.6
Irrigation	----	-----	0.6	0.4
Commercial	20	14.4	45.1	28.2
Industrial	50	35.6	40.6	25.4
Municipal (public)	10	7.2	10.2	6.4

Each of the categories listed above could be further subdivided by a thorough search of meter records of individual customers, but such a search followed by a resulting statistical analysis is beyond the scope of this paper.

SALEM WATER CONSUMPTION ANALYSIS 1938 - 1953

Time Period	YEARLY AVERAGES										MONTHLY AVERAGES			
	Net Production	Water sold metered	Water unmetered	% unmetered (4)÷(2)	Total No. of acc'ts billed	Ave No. of Customers (6)÷12	Population	Population factor (8)÷(7)	Total Billed		Average use per billed	monthly account	Ave. use per account (13)÷30	Ave use per/person (14)÷(9)
(1)	(2) gallons	(3) gallons	(4) gallons	(5) %	(6)	(7)	(8)	(9)	(10) cu ft	(11) Millon gallons	(12) cu ft	(13) gallons	(14) gal/day	(15) gal/day
1938 - 39					91,353	7,613	30,900	4.05			2,229	16,700	557	137
1939 - 40					94,380	7,865	30,900*	3.9			2,417	18,000	600	154
Jan 1,1940 to Jan 1,1941	2,182,792,650	1,710,798,000	471,994,650	21.6	96,431	8,036	32,120	4.0	148,631,760	1,100	1,541	11,500	383	96
Jan 1,1941 to Jan 1,1942	2,251,453,255	1,778,380,350	473,072,905	21.0	98,215	8,185	33,340	4.1	159,819,980	1,195	1,639	12,200	307	75
Jan 1,1942 to Jan 1,1943	2,446,497,880	1,909,601,050	536,896,836	21.9	99,587	8,300	34,560	4.2	168,962,708	1,265	1,710	12,800	329	78
Jan 1,1943 to Jan 1,1944	2,506,284,140	2,122,582,201	383,701,939	15.3	99,921	8,327	35,780	4.3	199,793,350	1,490	2,015	15,000	500	116
Jan 1,1944 to Jan 1,1945	2,753,197,800	2,209,336,995	543,860,805	19.7	101,014	8,418	37,000	4.4	208,944,876	1,560	2,085	15,500	517	117
Jan 1,1945 to Jan 1,1946	2,459,045,805	1,911,638,035	547,407,770	21.9	103,101	8,675	38,220	4.4	227,417,610	1,700	2,223	16,600	553	126
Jul 1,1945 to Jan 1,1947	3,699,760,255	3,129,637,864	570,122,391	15.4	106,510	8,876	39,440	4.4	241,767,840	1,800	2,270	17,000	567	129
Jan 1,1947 to Jan 1,1948	2,453,876,391	2,124,704,320	329,172,071	13.4	---	---	---	---	---	---	---	---	---	---
Jul 1,1947 to Jul 1,1948	2,289,094,315	1,703,009,400	586,084,915	25.6	112,701	9,375	40,660	4.4	225,815,722	1,690	2,004	15,100	503	114
Jan 1,1948 to Jan 1,1949	2,217,608,510	1,847,119,095	370,489,415	16.7	---	---	41,000	---	---	---	---	---	---	---
Jul 1,1948 to Jul 1,1949	2,352,138,430	2,008,157,217	343,981,213	14.6	119,745	9,979	41,880	4.2	268,907,840	2,010	2,246	16,800	560	133
Jul 1,1949 to Jul 1,1950	2,842,911,865	2,157,372,680	685,539,085	24.1	122,435	10,718	43,100*	4.0	287,628,040	2,150	2,349	17,600	587	147
Jul 1,1950 to Jul 1,1951	3,350,674,445	2,210,158,200	870,430,535	26.0	139,452	11,621	44,320	3.8	314,086,141	2,350	2,252	16,900	563	148
Jul 1,1951 to Jul 1,1952	3,427,530,692	2,385,000,108	801,237,300	23.4	143,211	11,934	45,540	3.8	361,710,150	2,710	2,526	19,000	633	167
Jul 1,1952 to Jul 1,1953	3,794,856,075	2,514,239,315	1,280,616,760	33.8	147,130	12,260	46,760	3.8	334,618,320	2,510	2,274	17,100	570	150

Salem Data: Columns (1),(2),(3),(4),(6),(10),(12)
Computed: Columns (5),(8),(9),(11),(13),(14),(15)
* Column (8) Population figured as straight line increase based on 1940 and 1950 U.S. census population

Salem Water Consumption
Analysis 1938-1953
Table 11

SALEM WATER CONSUMPTION ANALYSIS

1938 - 1953

RESIDENTIAL USE

Time Period (1)	No. of Accounts Billed (16)	Ave no. of Customers (16)÷12 (17)	(18) cu ft/mo	(19) gal/mo	(20) gal/day	Ave use per person (21) gal/day
1938 - 39	81,608	6,801	829	6,200	207	---
1939 - 40	84,258	7,021	864	6,400	213	---
Jan 1,1940 to Jan 1,1941	85,862	7,155	803	6,000	200	44
Jan 1,1941 to Jan 1,1942	87,211	7,267	763	5,700	190	31
Jan 1,1942 to Jan 1,1943	88,204	7,350	736	5,500	183	27
Jan 1,1943 to Jan 1,1944	88,271	7,356	800	6,000	200	41
Jan 1,1944 to Jan 1,1945	89,056	7,421	919	6,900	230	46
Jan 1,1945 to Jan 1,1946	89,285	7,440	993	7,400	247	49
Jul 1,1945 to Jan 1,1947	92,385	7,698	1,012	7,600	253	50
Jan 1,1947 to Jan 1,1948	---	---	---	---	---	---
Jul 1,1947 to Jul 1,1948	98,114	8,176	877	6,600	220	43
Jan 1,1948 to Jan 1,1949	---	---	---	---	---	---
Jul 1,1948 to Jul 1,1949	103,408	8,617	1,011	7,600	253	52
Jul 1,1949 to Jul 1,1950	110,330	9,194	1,037	7,750	258	56
Jul 1,1950 to Jul 1,1951	119,768	9,981	1,094	8,200	273	62
Jul 1,1951 to Jul 1,1952	123,143	10,262	1,231	9,200	306	70
Jul 1,1952 to Jul 1,1953	125,789	10,482	1,116	8,350	278	63

Table 12

SALEM WATER CONSUMPTION ANALYSIS

1938 -1953

IRRIGATION USE

Time Period (1)	No. of Accounts Billed (22)	Ave No. of Customers (22) 12 (23)	Average Use per Account (24) Cu ft/mo	(25) gal/mo	(26) gal/day	Ave use per person (27) gal/day
1938 -39	157	13	3,621	27,100	903	
1939 - 40	140	12	3,923	29,400	980	
Jan 1,1940 to Jan 1,1941	128	11	2,502	18,700	623	0.2
Jan 1,1941 to Jan 1,1942	98	8	2,909	21,800	727	0.2
Jan 1,1942 to Jan 1,1943	170	14	2,260	17,700	590	0.2
Jan 1,1943 to Jan 1,1944	195	16	1,900	14,200	473	0.2
Jan 1,1944 to Jan 1,1945	213	18	1,847	13,800	460	0.2
Jan 1,1945 to Jan 1,1946	273	23	2,625	19,700	657	0.4
Jul 1,1945 to Jan 1,1947	236	19	2,819	21,100	703	0.4
Jan 1,1947 to Jan 1,1948	---	---	---	---	---	---
Jul 1,1947 to Jul 1,1948	235	19	2,529	18,900	630	0.3
Jan 1,1948 to Jan 1,1949	---	---	---	---	---	---
Jul 1,1948 to Jul 1,1949	259	21	3,950	29,600	987	0.5
Jul 1,1949 to Jul 1,1950	296	24	6,137	45,800	1,527	0.9
Jul 1,1950 to Jul 1,1951	382	32	5,615	42,000	1,400	0.9
Jul 1,1951 to Jul 1,1952	337	28	6,124	45,700	1,523	1.0
Jul 1,1952 to Jul 1,1953	441	37	4,095	30,300	1,010	0.9

Table 13

SALEM WATER CONSUMPTION ANALYSIS

1938 - 1953

COMMERCIAL USE

Time Period (1)	No. of Accounts Billed (28)	Ave No. of Customers (28) 12 (29)	(30) cu ft/mo	(31) gal/mo	(32) gal/day	Ave use per person (33) gal/day
1938 - 39	8,237	686	4,048	30,200	1007	
1939 - 40	8,607	769	4,341	32,400	1080	
Jan 1,1940 to Jan 1,1941	9,004	750	4,486	33,600	1120	26
Jan 1,1941 to Jan 1,1942	9,024	752	4,704	35,200	1173	20
Jan 1,1942 to Jan 1,1943	9,121	760	4,850	36,200	1207	20
Jan 1,1943 to Jan 1,1944	9,395	783	5,117	38,300	1219	28
Jan 1,1944 to Jan 1,1945	9,785	815	5,590	41,800	1393	31
Jan 1,1945 to Jan 1,1946	11,603	966	5,501	41,200	1340	35
Jul 1,1945 to Jan 1,1947	12,064	1,005	5,739	42,900	1430	37
Jan 1,1947 to Jan 1,1948	---	---	---	---	---	---
Jul 1,1947 to Jul 1,1948	12,596	1,050	5,548	41,400	1380	35
Jan 1,1948 to Jan 1,1949	---	---	---	---	---	---
Jul 1,1948 to Jul 1,1949	14,384	1,198	5,612	42,000	1400	40
Jul 1,1949 to Jul 1,1950	16,090	1,341	6,031	45,000	1500	48
Jul 1,1950 to Jul 1,1951	17,103	1,425	5,728	42,800	1427	46
Jul 1,1951 to Jul 1,1952	17,520	1,460	5,628	42,100	1403	45
Jul 1,1952 to Jul 1,1953	18,574	1,548	5,061	37,900	1263	42

Table 14

SALEM WATER CONSUMPTION ANALYSIS

1938 - 1953

INDUSTRIAL USE

Time Period	No of Accounts Billed	Ave No of Customers (34) 12	Average Use per account			Ave use per person
(1)	(34)	(35)	(36) cu ft/mo	(37) gal/mo	(38) gal/day	(39) gal/day
1938 - 39	834	69	110,311	826,000	27,530	
1939 - 40	837	70	127,113	953,000	31,770	
Jan 1,1940 to Jan 1,1941	856	71	33,270	249,000	8,300	18
Jan 1,1941 to Jan 1,1942	767	64	48,731	365,000	12,170	18
Jan 1,1942 to Jan 1,1943	779	65	60,931	455,000	15,170	24
Jan 1,1943 to Jan 1,1944	775	65	86,824	650,000	21,670	39
Jan 1,1944 to Jan 1,1945	739	61	82,886	620,000	20,670	34
Jan 1,1945 to Jan 1,1946	730	61	88,404	662,000	22,070	36
Jul 1,1945 to Jan 1,1947	658	55	93,307	698,000	23,270	34
Jan 1,1947 to Jan 1,1948	---	---	---	---	---	---
Jul 1,1947 to Jul 1,1948	624	52	88,288	660,000	22,000	26
Jan 1,1948 to Jan 1,1949	---	---	---	---	---	---
Jul 1,1948 to Jul 1,1949	612	51	104,933	785,000	26,170	32
Jul 1,1949 tp Jul 1,1950	713	58	104,861	785,000	26,170	34
Jul 1,1950 to Jul 1,1951	883	74	73,666	552,000	15,070	31
Jul 1,1951 to Jul 1,1952	778	65	116,502	873,000	29,100	42
Jul 1,1952 to Jul 1,1953	780	65	101,633	760,000	25,300	35.5

Table 15

SALEM WATER CONSUMPTION ANALYSIS

1938 - 1953

MUNICIPAL USE

Time Period	No of Accounts Billed (40)	Ave No. of Customers (40) 12	Average Use per account			Ave use per person
(1)	(40)	(41)	(42) cu ft/mo	(43) gal/mo	(44) gal/day	(45) gal/day
1938 - 39	517	43	19,497	146,000	4,870	
1939 - 40	538	45	20,426	150,000	5,000	
Jan 1,1940 to Jan 1,1941	581	48	18,393	138,000	4,150	7
Jan 1,1941 to Jan 1,1942	487	41	27,080	202,000	6,730	6
Jan 1,1942 to Jan 1,1943	507	42	25,400	189,000	6,300	6
Jan 1,1943 to Jan 1,1944	517	43	26,059	195,000	6,500	8
Jan 1,1944 to Jan 1,1945	431	34	24,812	185,000	6,170	6
Jan 1,1945 to Jan 1,1946	426	35	22,816	171,000	5,700	5.5
Jul 1,1945 to Jan 1,1947	429	36	35,087	263,000	8,770	8
Jan 1,1947 to Jan 1,1948	---	---	---	---	---	---
Jul 1,1947 to Jul 1,1948	402	33	44,661	334,000	11,130	9
Jan 1,1948 to Jan 1,1949	---	---	---	---	---	---
Jul 1,1948 to Jul 1,1949	379	31	48,649	364,000	12,130	9
Jul 1,1949 to Jul 1,1950	410	34	44,070	330,000	11,000	9
Jul 1,1950 to Jul 1,1951	518	43	34,639	260,000	8,670	8.5
Jul 1,1951 to Jul 1,1952	603	50	32,777	245,000	8,170	9
Jul 1,1952 to Jul 1,1953	634	53	30,141	226,000	7,530	8.5

Table 16

SALEM WATER CONSUMPTION ANALYSIS

1938 - 1953

WATER USE COMPARISON

Time Period	AMOUNT BILLED IN CUBIC FEET PER YEAR						% OF TOTAL BILLED				
	Total	Residential	Irrigation	Commercial	Industrial	Muncipal	Res	Irr	Comm'l	Indust.	Municipal
(1)	(10)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)
1938 - 39											
1939 - 40											
Jan 1,1940 to Jan 1,1941	148,631,760	68,746,410	320,300	40,399,300	28,479,420	10,686,330	46.2	0.2	27.2	19.2	7.2
Jan 1,1941 to Jan 1,1942	159,819,980	66,522,370	285,100	42,448,260	37,376,490	13,187,760	41.7	0.2	26.5	23.4	8.2
Jan 1,1942 to Jan 1,1943	168,962,708	59,038,780	320,000	44,358,190	52,906,030	12,737,708	35.0	0.2	26.1	31.2	7.5
Jan 1,1943 to Jan 1,1944	199,793,350	70,587,060	370,540	48,075,200	67,288,220	13,472,330	35.4	0.2	24.0	33.7	6.7
Jan 1,1944 to Jan 1,1945	208,944,876	81,876,170	393,486	54,728,460	61,252,820	10,693,940	39.1	0.2	26.3	29.3	5.1
Jan 1,1945 to Jan 1,1946	227,417,610	88,618,130	716,594	63,828,680	64,534,550	9,719,660	39.0	0.3	28.0	28.4	4.3
Jul 1,1945 to Jan 1,1947	241,767,840	93,446,850	665,340	69,233,010	63,370,160	15,052,480	38.7	0.3	28.6	26.2	6.2
Jan 1,1947 to Jan 1,1948	---	---	---	---	---	---	---	---	---	---	---
Jul 1,1947 to Jul 1,1948	225,815,722	86,037,452	594,440	69,882,190	51,347,760	17,953,880	38.1	0.3	30.9	22.8	7.9
Jan 1,1948 to Jan 1,1949	---	---	---	---	---	---	---	---	---	---	---
Jul 1,1948 to Jul 1,1949	268,907,840	104,503,340	1,023,130	80,723,340	64,219,970	18,438,060	38.8	0.4	30.0	23.9	6.9
Jul 1,1949 to Jul 1,1950	287,628,040	108,625,660	1,816,760	93,948,150	65,433,050	17,804,420	37.9	0.6	32.4	22.9	6.2
Jul 1,1950 to Jul 1,1951	314,086,141	130,984,183	2,144,761	97,967,151	65,047,251	17,942,795	41.7	0.7	31.2	20.7	5.7
Jul 1,1951 to Jul 1,1952	361,710,150	150,672,550	2,033,740	98,601,240	90,638,300	19,764,320	41.7	0.6	27.2	25.1	5.4
Jul 1,1952 to Jul 1,1953	334,618,320	140,421,930	1,805,720	94,007,590	79,273,500	19,109,580	41.9	0.6	28.1	23.7	5.7

Salem Water Consumption
Analysis 1938-1953
Water Use Comparison

Table 17

SECTION V CONCLUSIONS

General

Factors affecting municipal water consumption are so variable that an analysis would have to be made for such city to obtain an accurate picture of the particular cities water use. It behooves a city, therefore, to set up and maintain adequate records from which an estimate of per capita use can be made and projected into the future. A study such as the foregoing thesis may serve as a guide for the type of records that should be kept, but it does not answer the problem completely.

Factors affecting Oregon's Municipal water use:

1. Per capita water consumption in Oregon cities varies with population according to an exponential curve such as that of figure 3 for the year 1952.
2. Water consumption varies directly with temperature change and is also affected by precipitation, whether it be in the form of rain or snow. Most of this variation is undoubtedly due to irrigation since maximum points occur on the consumption curve during high temperatures when no precipitation is recorded.
3. Habits of the people within a city determine

the time of occurence of the maximum hourly variations for that city.

4. Industrial use in Oregon at the present time is low, but it should be carefully investigated for each city because this state is not fully developed and is capable of sustaining large water using industries in areas along the major rivers.
5. Commercial use is higher than that listed for the east coast for larger cities probably because Oregon cities have smaller units which require more water for operation. Air conditioning is not a major problem at the present time in Oregon cities, although its use is spreading.
6. Public use for street flushing, parks, playgrounds, public buildings, fire fighting, and other uses correlates with the national average and may be assumed as 10 gpcd.
7. Loss and waste is a major factor in water consumption unless water is cheap and plentiful. The only way to combat this factor is to institute within the city concerned a program of conservation to locate and repair leaks and to keep unaccounted for water at a minimum.

8. Unmetered cities in Oregon, figure 3, tend to show a higher per capita use.
9. Records of most cities are inadequate for a detailed study of water use.

Recommendations

1. Wherever possible a conservation program should be established for municipal water systems.
2. All systems should be metered wherever possible and records should be divided into residential, commercial, industrial, municipal, and loss and waste if it is at all practicable to do so.
3. A further study should be carried out for the Pacific Northwest area to determine whether the entire region has a similar problem that can be solved or partially solved by a detailed investigation.
4. More instrumentation is needed for measuring and recording flow of water.

BIBLIOGRAPHY

1. American water works association. Committee report. Regulation of water use in air conditioning. Journal of American water works association 41:715-728. 1949

2. American water works association. Persons per household, 1890-1960. Journal of American water works association 42:904. 1950.

3. American water works association. Staff report. 1952 summer water service problems. Journal of American water works association 45:580-582. 1953.

4. American water works association. Staff report. A survey of operating data for water works in 1950. Journal of American water works association 45:583-678. 1953.

5. American water works association. The story of water supply. N.Y., Vital publications, 1953. 15p.

6. Babbitt, H.E., and J. J. Doland. Water supply engineering. N.Y., McGraw-Hill, 1949. 637p.

7. Baker, M.N. The quest for pure water. N.Y. American water works association 1948. 527p.

8. Bell, A.E. and E. Walasyk. Recording customer use of water. Journal of American water works association 42:919-930. 1950.

9. Capen, Charles H., Jr. How much water do we consume? How much do we pay for it? Journal of American water works association 29:201-212. 1937.

10. Case, E.D. Water waste surveys and unaccounted-for water. Journal of American water works association 42:245-248. 1950.

11. Eugene, Oregon. Eugene water board. Report and data book, water and electric utilities. Eugene, 1946. 65p.

12. Eugene, Oregon. Eugene water and electric board. Progress report, summary of activities 1946-1950. Eugene, 1950. 40p.

13. Frontinus, Sextus, Julius. The stratagems, and the aqueducts of Rome. N.Y., Putnam, 1925. 483p.

14. Hatcher, M.P. Distance and demand factors in suburban water rates. Journal of American water works association 42:1003-1008. 1950.

15. Hooper, H.R. Increased water consumption in Canada. Journal of American water works association 41:559-562. 1949.

16. Hosmon, R.T. Effect of metering on water use and revenue. Journal of American water works association 42:509-511. 1950.

17. Green, R.R. Water use in industry. Journal of American water works association 43:591-602. 1951.

18. Jordan, H.E. Industrial requirements for water. Journal of American water works association 38:65-68. 1946.

19. King, Thompson. Water. N.Y., Macmillan, 1952. 238p.

20. Langbein, W.B. Municipal water use in the United States. Journal of American water works association 41:997-1001. 1949.

21. Larson, B.O. and H.E. Hudson. Residential water use and family income. Journal of American water works association 43:603-611. 1951.

22. Lowdermilk, W.C. Conquest of the land through seven thousand years. Washington, Gov't printing office, 1950. 38p. (U.S. Dept. of agriculture. Soil conservation service. SCS-MP32).

23. MacKichan, Kenneth A. Estimated use of water in the United States-1950. Washington, Gov't printing office, 1951. 13p. (U.S. Geological survey. Circular 115).

24. National association of manufacturers and The Conservation foundation. Water in industry. N.Y., The Association, 1950. 51p.

25. Nordell, E. Water treatment for industrial and other uses. N.Y., Reinhold, 1951. 526p.

26. Norris, A.O. Considerations involved in adding industrial customers to public water supply systems. Journal of American water works association 43:612-614. 1951.

27. Oregon. University. Bureau of municipal research and service. Water rates and service practices and sewer service charges in Oregon cities. Eugene, Oregon, The Bureau, 1953. 17p.

28. Pond, M.A. Urban domestic water consumption. Journal of American water works association 31:2003-2017.

29. Powers, W.L. Climate and its relation to agriculture. Corvallis, Oregon State College, 1950. 13p. (Oregon. Agricultural experiment station. Circular of information 487).

30. Seidel, H.F., A.S. Johnson, and D.O. Dencker. A statistical analysis of water works data for 1950. Journal of American water works association 45:1309-1334. 1953.

31. Soil and water conservation and use; an analysis by a committee of the agricultural staff of Oregon State College. Oregon agriculture 9, March, 1952.

32. Steel, E.W. Water supply and sewerage. N.Y., McGraw-Hill, 1953. 582p.

33. Stockton, J.R. Evaluating water supply requirements for a region. Journal of American water works association 45:459-464. 1953.

34. Turneaure, F.E. and H.L. Russell, Public water supplies. N.Y., Wiley, 1940. 704p.

35. U.S. Congress. House Committee on interior and insular affairs. The physical basis of water supply and its principal uses. Washington. 1952. 93p.

36. U.S. Dept. of public health and welfare. Statistical summary of water supply and treatment practices in the United States. Washington, Govt. printing office, 1953, 53p.

37. U.S. Weather bureau. Climatological data, Oregon. Washington, Gov't. printing office, 1952. 195p.

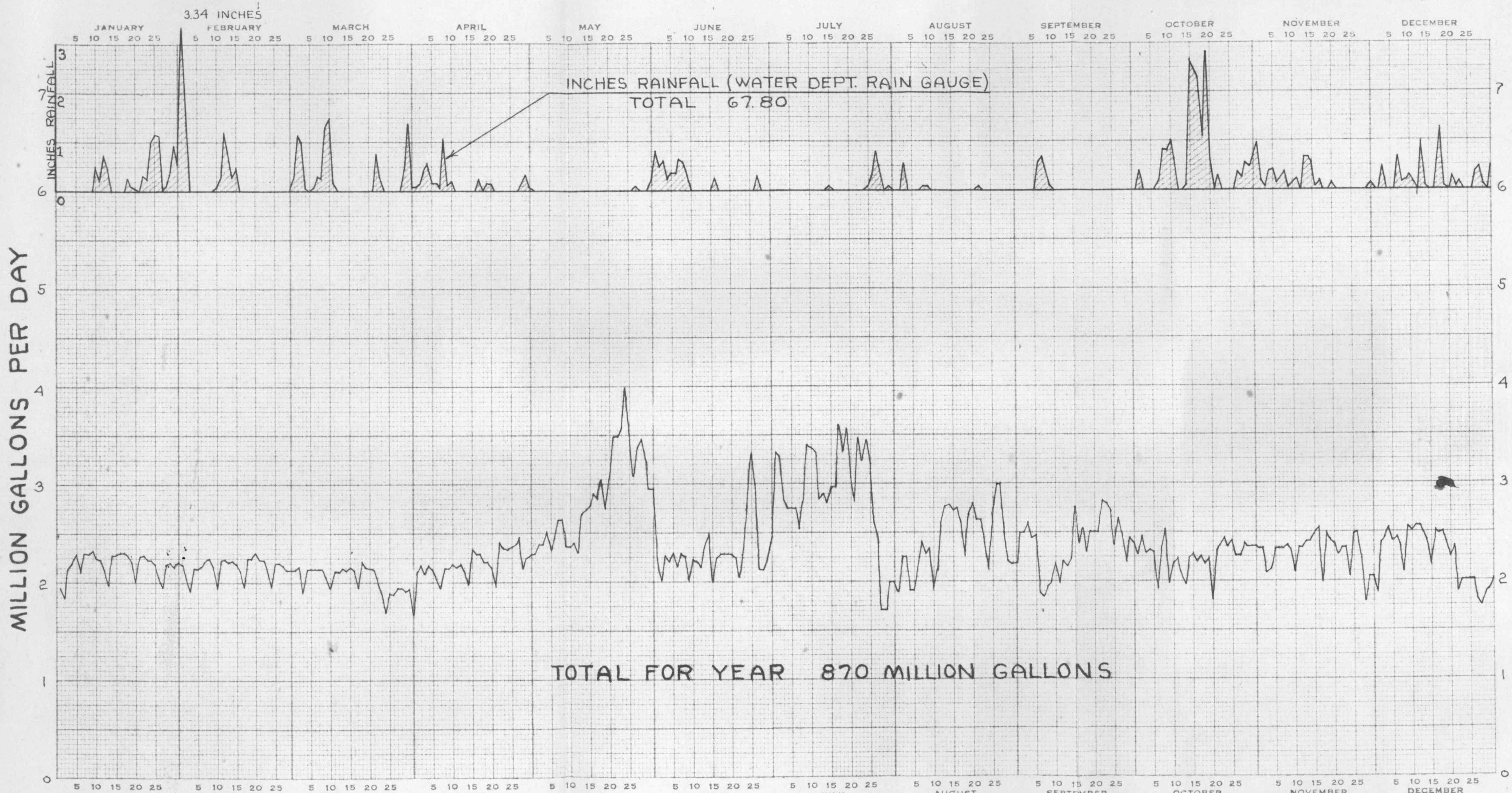
38. VanDorp, G.J. Using water demands to rate television programs. Public works: 64-65, 112-114. March, 1953.

39. Warren, Vernon J. The characteristics of yearly rainfall distribution in Oregon and Washington. Undergraduate thesis. Corvallis, Oregon State College, Civil engineering department, 1940. 46 numb. leaves.

40. Wisnieski, K.S. and M. Garber. Per capita use of water in public schools. Public works: 97-98. July, 1953.

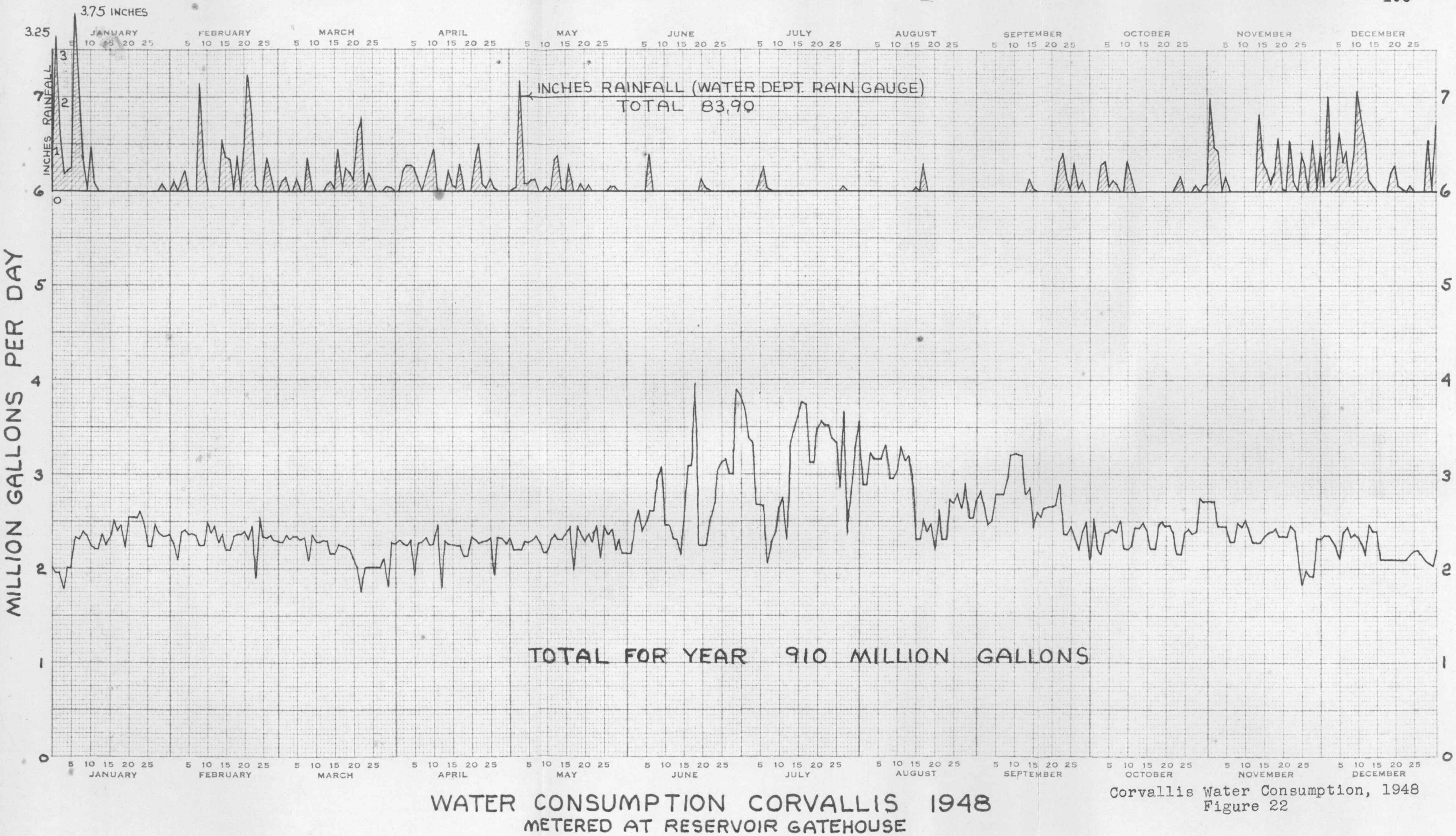
41. Wolman, A. and A.E. Gorman. Water borne outbreaks in the United States and Canada, and their significance. Journal of American water works association 31:225-373.

APPENDIX

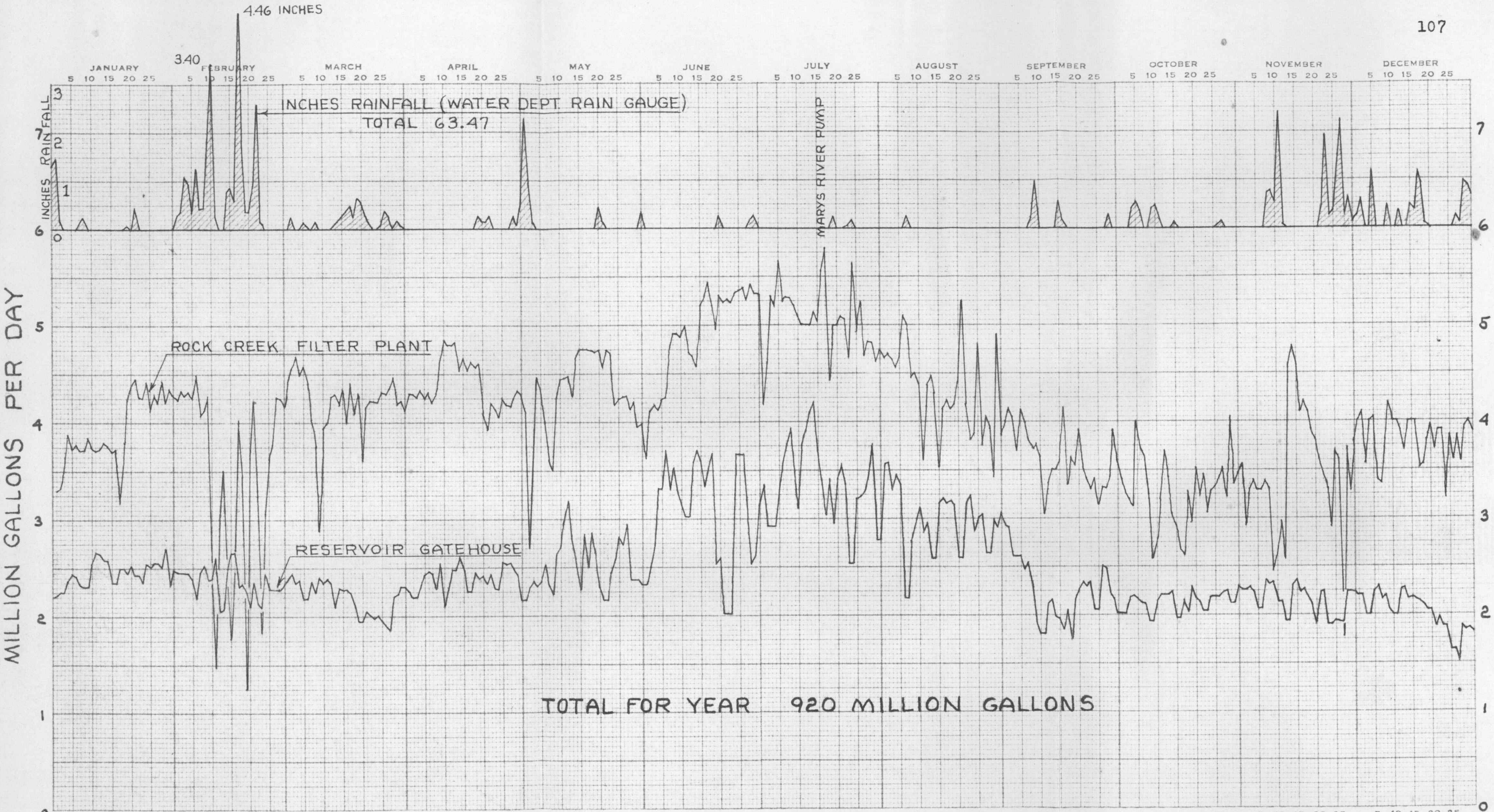


WATER CONSUMPTION CORVALLIS 1947
METERED AT RESERVOIR GATEHOUSE

Corvallis Water Consumption, 1947
Figure 21



Corvallis Water Consumption, 1948
Figure 22



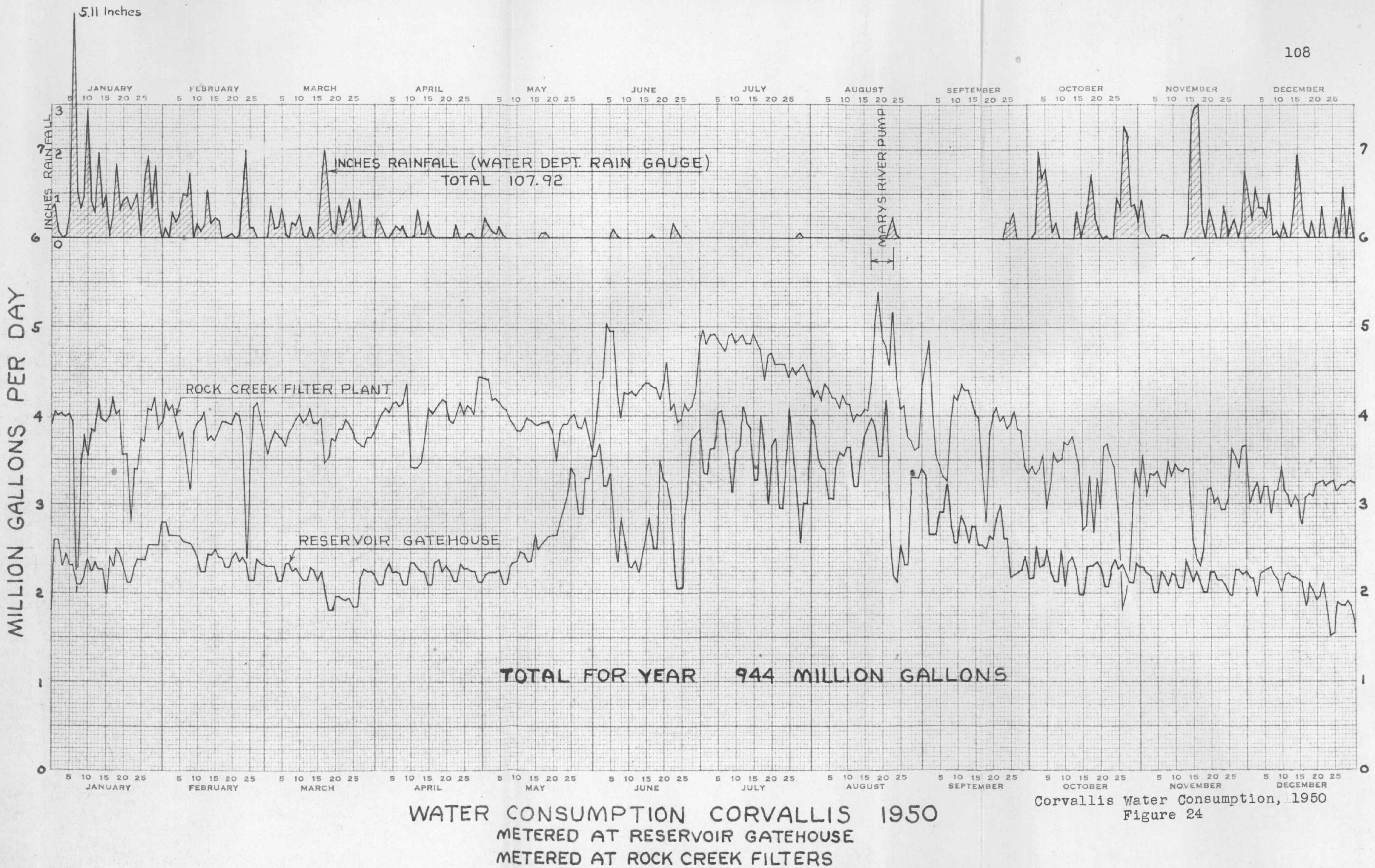
WATER CONSUMPTION CORVALLIS 1949

METERED AT RESERVOIR GATEHOUSE

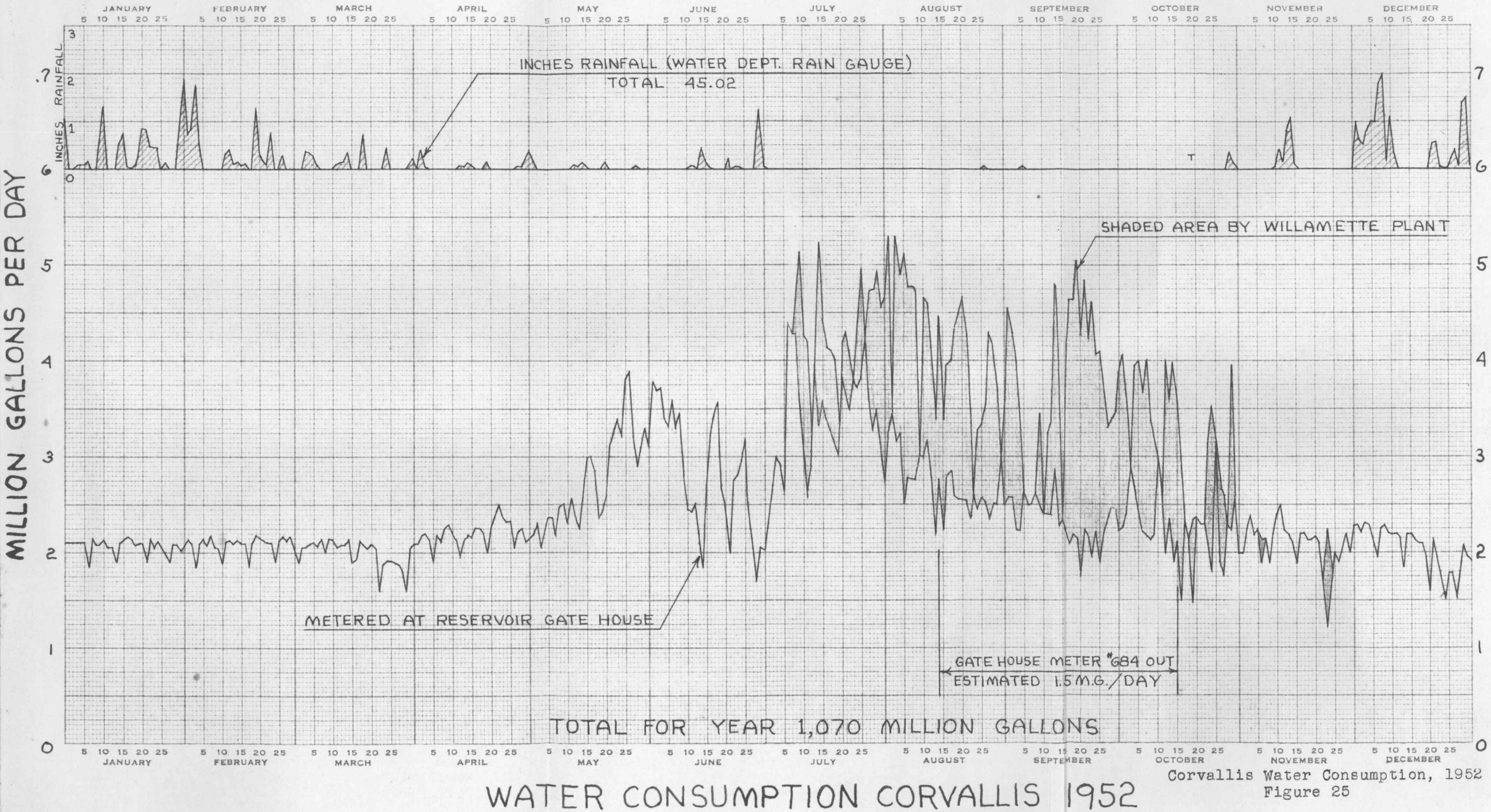
METERED AT ROCK CREEK FILTERS

Corvallis Water Consumption, 1949

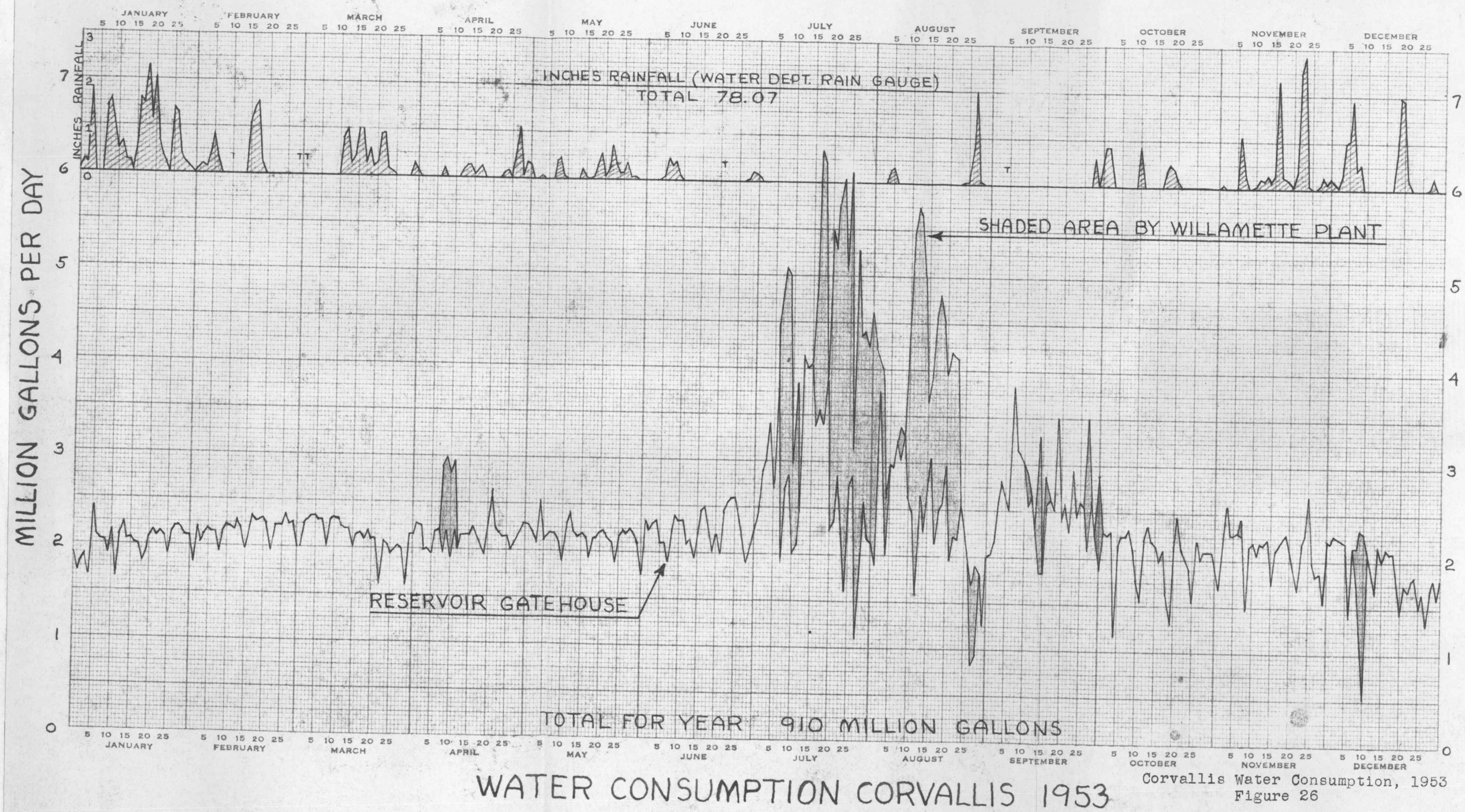
Figure 23



Corvallis Water Consumption, 1950
Figure 24



Corvallis Water Consumption, 1952
Figure 25



Corvallis Water Consumption, 1953
Figure 26