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Residential Water Use and Family Income

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Residential Water Use and Family Income

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A paper presented on May 3, 1951, at the Annual Conference, Miami, by Bernt O. Larson, Assoc. Engr., Eng. Subdiv., State Water Survey Div.; Assoc. Prof., College of Eng., Univ. of Illinois, Urbana, Ill., and H. E. Hudson Jr., State Water Survey Div., Urbana, Ill.

AT a time when many communities in the United States are suffering from water shortages, a study of actual water use requirements seems appropriate. Excessive unaccounted-for water and water shortages have even been experienced simultaneously in some communities.

Per capita water consumption is the usual basis of comparison for the rate of consumption between different cities and towns, but such a comparison requires accurate data.

Per capita use is most commonly taken as the total of water supplied divided by the population served. The per capita pumpage for the entire state of Illinois, as of January 1, 1948, was computed to be 186 gpcd. If Chicago and connected suburbs are excluded, this figure drops to a mean of 88 gpcd., with individual cities as low as 8 and as high as 220 gpcd. This is gross per capita pumpage, however, and for comparisons of daily per capita use in cities and towns includes too many variables to allow tracing any detailed relationships.

Nearly all attempts to correlate water use have related the gross daily per capita pumpage with population. This article proceeds by classifying the actual water sold into the various categories: residential, commercial, industrial, public, and loss and waste. When the data are so taken for basic unit uses, a better comparison becomes possible.

To collect data on metered use, thirteen Illinois communities (some of them groups of cities) were visited. The information gathered was separated into use categories. Dependable data from two other communities, "N" and "O," were obtained by correspondence and were used to check the curve that was plotted from the data obtained at the communities visited. With these facts available, a correlation between the use of residential water and estimated net family income has been found. This correlation succeeded where attempts to relate domestic or residential use and population factors failed.

One attempt to relate the gross daily per capita pumpage and the size of small Illinois communities using ground water is shown on Fig. 1. Each point represents the gross daily per capita pumpage in an Illinois community. These data on total ground water production were obtained, for another study now in progress, by engineers of the Illinois State Water Survey in visits made to every incorporated town and city of Illinois which use wells as a source of supply.

Classification of Uses

Five categories were used for sorting the data: domestic use, commercial use, industrial use, public use, and loss and waste. Domestic use was taken as that water purchased for the family dwelling. The definition of a commercial user varies somewhat from city to city, but generally it includes stores, hotels, local bakeries, dairies and laundries. Typical industrial users would be manufacturers, railroads or canneries. Public use in a city having a municipally owned and operated system is quite often not metered, and may be considered to be free or unaccounted-for water. A private water company will usually meter or estimate the use of water for. public buildings, street sprinkling, fountains, parks, firefighting and other such purposes. Lost and wasted water sometimes amounts to more than is actually used for all other purposes. Unaccounted-for water (loss and waste) should not be more than 20 per cent of the total amount metered, or estimated to be pumped from the source of supply.

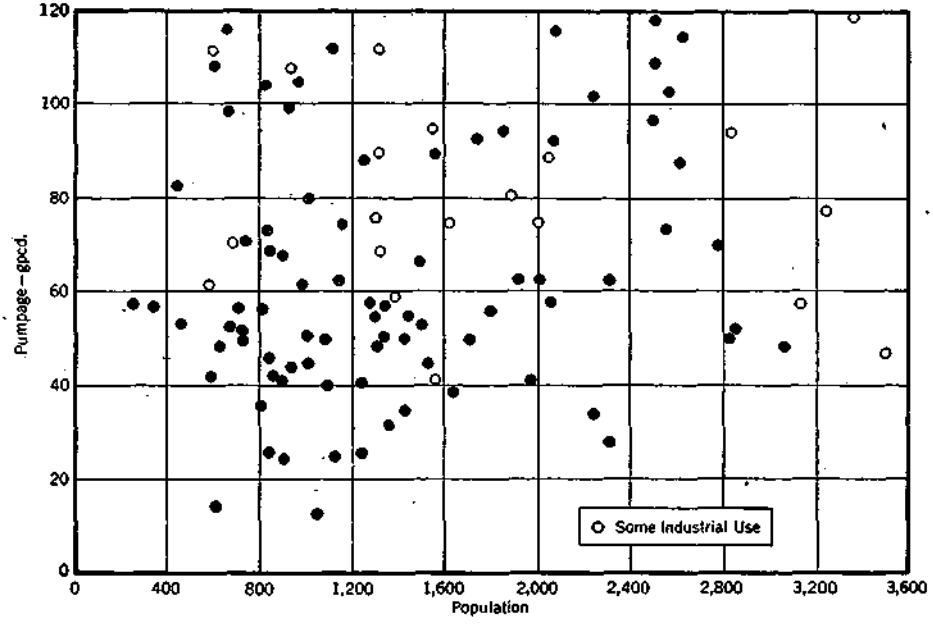

Fig. 1. Per Capita Production in Illinois Communities During 1947

An attempt is made to relate the gross daily per capita pumpage to the sise of small Illinois communities that use ground water.

Factors that may affect the rate of water consumption are numerous. Some of them are: size of the community, geographical location, variations within the community, standards of living of the consumers, quantity of the supply, quality, water rates, existence of sewers, distribution system pressure, the age of the water works system and whether or not meters are used.

TABLE 1

Per Capita Water Consumption in Illinois Cities

City	Corrected Resid. Accts.	Consumption--*gpcd.*					Unaccounted-for Water		Total Prod. *gpcd.*	Qtrly. Resid. Cost per Acct.	Calculated Qtrly. Resid. Cost for Eq. Use
		Resid.	Coml.	Ind.	Munic.	Sales to Other Water Utils.	*gpcd.*	*Per cent*			
A	10,420	39.0	8.8	16.0	2.0	1.1	9.9	13.0	76.0	$4.25	$4.25
B	6,861	39.0	7.4	20.0	0.02		17.5	20.1	83.9	4.83	4.83
C	1,773	24.0 30.5*	13.0	19.6	—		79.0	58.0	135.6	3.75	6.10
D	4,218	24.3	27.3	26.9	2.0		16.2	16.7	96.8	5.85	10.90
E	160	21.2	3.7	15.5	—		—	—	56.0	11.85	21.00
F	1,681	31.0	19.6	11.3	—		12.2	16.5	74.1	5.25	6.60
G	1,691	31.4	18.9	35.0	0.5		14.4	14.4	100.2	4.56	5.75
H	389	25.8	12.8	0.0	—		6.2	13.8	44.8	3.00	4.50
I	2,511	52.3	3.2	0.0	—		21.2	27.6	76.6	7.07	5.28
J	2,434	51.5	13.0	0.0	—		36.4	36.1	100.9	—	—
K	226	28.7	4.3	17.2	—		—	—	—	4.86	6.63
L	1,215	46.3	23.5	92.9	5.8		37.4	18.1	205.9	5.62	4.77
M	35,187	27.3	19.7	126.3	13.3		31.2	13.1	237.7	3.65†	5.22
N	2,020	36.7	16.2	8.8	5.1	50.4	20.2	14.6	137.4	—	
0	4,881	28.4	12.5	77.9	18.5		27.5	16.6	165.8	—	

* Average of 2 metered districts.
† $3.75 minimum.

KEY

Surface water supply represented by (5); *well water supply represented by (W)*

A—College community (W)
B—County seat, light industry (W)
C—County seat (W)
D—Marketing center (S)
E—Good rural community, excellent agricultural region, no sewers (W)
F—County seat, marketing center (W)
G—County seat, oil production center, agriculture, trading center (S)
H—Not progressive (W)
I—Suburban residential (W)
J—Residential, light commercial (W)
K—Rural, new water works, few sewer connections (W)
L—Good residential, light industry (W)
M—Heavy industrial, railroad center (S)
N—Residential, in good agricultural area (S)
O—Industrial, coal mining region (S)

Procedure Used

A list of cities known to keep the necessary records was compiled. These communities employed universal metering of their services, and also metered the actual pumpage. Consideration was then given to geographical location and the utilities studied were chosen to provide the most complete state coverage possible. A diverse population range and use of various sources of supply were deemed necessary. The primary use for which water was sold in the various cities was also considered. One city, for example, was selected because it was wholly residential; another, because of its heavy industrial requirements. The age of the water utility to be selected was also considered. The cities finally used comprised a reasonably good sample of the variety of conditions found throughout the state.

Many cities were eliminated from the study after visits had revealed the lack of accurate or complete records. All the privately operated utilities visited had excellent and complete records of pumpage, plant use, quantities sold, unaccounted-for water and the costs of operation. A number of the publicly owned utilities had just as complete and accurate records.

A few of the communities had multi-family dwelling units with single service meters, but the number of such installations was small. Where such meters were found, the number of family units was obtained and an appropriate correction was made to the actual total of residential accounts.

The data for each of the cities visited appear in summary form in Table 1. In computing the daily per capita consumption for the various accounts—residential, commercial, industrial and public—the total average daily quantity sold for each of these categories was divided by the total number of corrected residential accounts. This quotient was in turn divided by 3.6 persons per family * to obtain the daily per capita consumption.

When the amount used commercially was obtained and then computed to a daily per capita basis, it was "seen that there was considerable variation, ranging from a minimum of 3.2 to 27.3 gpcd. Most of the utilities classified their accounts much the same way. In several communities, it was necessary to go through the records and do the actual classification, as only the total amount of water used or sold was tabulated. An account was generally designated as commercial if the user operated a business establishment that served the community, such as a grocery or other store, gas station or bakery. If the user produced or manufactured some product that would be sold elsewhere, and used water in its manufacture, the user was ordinarily classified as an industrial account.

* Population per household in Illinois in 1940 (1). It was assumed that a residential account is the same as a household.

Discussion

It can be seen from Table 1 that there is little correlation between the residential daily per capita use and the population of the community served by the utility. As city after city was visited, it became increasingly clear that a good correlation between daily per capita use and population of the community served was impossible without considering additional factors.

Residential use ranged from a low of 21.2 to a high of 52.3 gpcd. With but one exception, the highest values were for those cities located in the more prosperous part of Illinois. The lowest values were for those cities in the less prosperous part of the state, and the middle values were geographically distributed in the area that separates these two regions.

Another factor governing use might be water rates. The cost of water per account was recalculated on a basis of equal use in each community, as shown in Table 1. No correlation between rates and use, however, was apparent.

Other factors that might cause variations in per capita, use—such as quantity and quality of supply available, the existence of sewers, pressure and age of the distribution system and the use of meters—were considered, but, with only a single exception, they seemed of little importance. Community "E" was selected because the utility was one of the newest of those having metered services. A municipal sanitary sewer system had been placed in operation in

February 1949, but at the time of the visit only 45 of the 178 water services had been connected to it. When all the water users are connected to this system, the per capita use will undoubtedly increase.

A small rural community, "K," is in the northern part of the state. It is comparable in size and general character with "E." The principal difference is in the age of the two utilities.

TABLE 2

Estimated Average Annual Effective Buying Income per Family (2)

Community	Income		Increase Since 1940 *per cent*
	1940	1947-48 Avg.	
A	$2,815	$5,550	95.5
B	2,451	5,200	112.0
C	1,746*	4,050	132.0
D	1,555	2,750	77.0
E	1,091*	2,100	92.5
F	1,532*	3,600	135.0
G	1,428*	3,450	141.0
H	1,428*	3,450	141.0
I	3,198†	7,500	137.0
J	2,546†	6,400	151.0
K	2,825*	5,300	87.6
L	3,150†	5,700	81.0
M	2,030	4,500	121.0
N		4,650(?)	—
0	2,209	4,978	125.0

* County data.
† Comparable nearby city

Although the village has no sanitary sewer system, many of the homes have their own septic tanks. Residential use at "K" was higher than in five of the communities served by sewer systems.

As none of the above factors were found to govern the use of water, there must be something else that does cause the variations that exist. The one remaining factor that might cause this variation is the standard of living.

Effect of Family Income

In *Sales Management* magazine's annual "Survey of Buying Power" (2) can be found estimates of average net effective buying income or a per-family basis for states and larger cities. This information, however, was not available for all communities included in the study, and therefore a few cities of similar character and geographical location (some county figures) were substituted. This information is presented in Table 2.

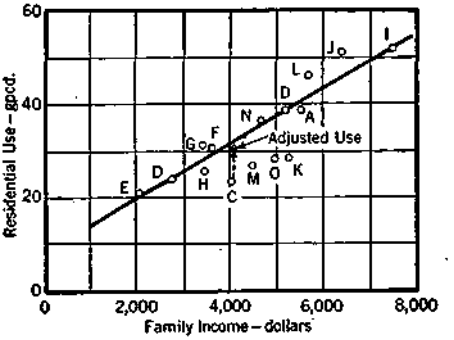

Fig. 2. Residential Use and Family Income

A good, positive corrclation is shown between residential water use and effective buying income. An estimated adjustment was made for the per capita consumption in Community "C" because of faulty data obtained by computing incomplete meter readings.

When daily per capita residential use was plotted against net effective buying income, a good correlation appeared, and can be seen in Fig. 2. Although a straight line can be drawn through several of the values, a number of points do not fit exactly. Detailed examination of some of these departures proves profitable. In Community "C" there are three residential meter zones. Two of them reveal resi-

dential use of 30.5 gpcd.—an excellent fit. The superintendent reports that the meters in the third zone are in need of repair. Consumption in that zone registered 15 gpcd., indicating serious underregistration. This conclusion is bolstered by the 58 per cent unaccounted-for water for the community as a whole.

In Community "M," there was a great industrial expansion during World War II, and family income increased greatly. The net effective buying income in one portion of the community had risen 150 per cent in 1944 since 1937. In two other parts of the community the income had approximately doubled since 1937. In "A," the increase was 87 per cent, while in "B," the increase was 50 per cent for the same period. Although there was a general decrease in income for all cities when the war was terminated in 1945, there was a general increase for every community subsequently. Proportionally, however, Community "M" still showed the greatest increase in net effective buying income per family for the twelve years considered.

These higher wages do not necessarily parallel the actual standards of living. The people of this community are not investing in indoor baths or showers and the usual standard sanitary facilities. A new car appears to have had more appeal. During the past decade, there has been a very small increase in residential water use, probably due only to the building of new homes in accordance with the approximately 25 per cent increase in the number of accounts, as residential water use has only increased 15 per cent. This situation is graphically repre-

TABLE 3

Sanitary Facilities (3)

Community	Homes Lacking:		Consumption Allowance for Complete Facility Installation		Total Consumption (Including Improvement Allowance) *gpcd.*
	Bath and Shower *per cent*	Flush Toilets *per cent*	Bath or Shower *gpcd.*	Flush Toilet *gpcd.*	
A	13.2	9.6	3.4	2.0	44.4
B	14.5	5.2	6.8	1.1	43.7
C	27.0	20.4	5.8	4.0	34.9
					41.3†
D	37.7	35.0	9.3	7.0	40.6
E	38.0*	29.0*	10.7	7.7	39.6
F	27.4	24.1	6.9	4.8	42.7
G	24.0	22.4	6.0	4.5	41.9
H	24.0*	22.4*	6.0	4.5	36.3
I	0.2	0.0	0.4	0.0	52.7
J	2.4	2.0	0.6	0.4	52.5
K	42.6*	38.6*	10.6	7.7	47.0
L	4.2	0.7	1.0	0.1	47.4
M	34.8	38.6	8.8	5.5	41.6
N	18.5	12.6	4.6	2.5	43.8
O	24.9	18.0	6.2	3.6	38.1

* Estimated.
† Average of accurately metered zones.

sented in Fig. 3. The rise in income apparently failed to be followed promptly by' increased water use in the home.

Effect of Sanitary Facilities

Sanitary facilities in the various communities are not at all standard. Some are almost completely served with showers or baths and indoor flush toilets, while others have relatively few of these modern facilities. Table 3 summarizes the available data on sanitary facilities.

To make use of the data in Table 3, it was necessary to make further assumptions. For homes with complete sanitary facilities, it was assumed that each person would require or use four toilet flushes per day, each of 5 gal. This would amount to 72 gpd. for each residential account. It was assumed that each person would require 25 gpd. of water for bath or shower, which is equivalent to 90 gpd. per residential account.* Considering the percentages of dwelling units without sanitary facilities to be applicable to the residential accounts that were served by each water utility, estimated increases in the average per capita consumption were computed.

The estimated values fqr daily consumption per capita for each city are plotted on Fig. 4. It can be seen that the correlation is better than in Fig. 2.

The value for Community "M" falls far below the original curve in Fig. 2, but when the corrections for sanitary facilities are applied, as shown in Fig. 4, the calculated use more nearly correlates with the other values along the curve.

* These values are rough, but compensate reasonably well for other residential uses not included specifically such as laundering, sprinkling, etc.

Community "H" shows a considerable departure from the curve in Fig. 4. This variance is believed to be due to two factors: [1] the income (estimated value) used is probably too high, and [2] the estimated values used to calculate the allowance for 100 per cent sanitary facilities are probably too low. The values used for "H" were those available for "G" because the two communities are similar, close to each other and no values for "H" were available.

Residential use at "J" is comparatively high. This is not surprising as the area is a residential suburb.

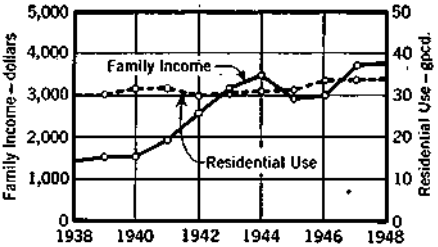

Fig. 3. Family Income and Residential Use for Community "M"

The trend in residential water consumption from 193S to 1948 is related to the annual family income during the same period.

For Community "N," data obtained by correspondence were used to check the curve obtained from the values computed for those cities visited. On the basis of the average net effective buying income value for the city, but without correcting for sanitary facilities, it was predicted from Fig: 2 that the city would be found to be using 35 gpcd. for residential purposes. Calculations showed the city use to be 36.7 gpcd., a reasonable check. On the same basis, an estimated use of 36 gpcd. was predictcd for Community

"O." The actual calculated value from available data showed a use of 28.4 gpcd., which was not a satisfactory check.

Community "O" is a much more industrialized city than "N," but it is similar in many respects to Community "M." Income alone does not indicate the standard of living of a community. Although the family income has increased rapidly, the people have neither invested their earnings in modern sanitary facilities nor become accustomed to the greater water use that seems

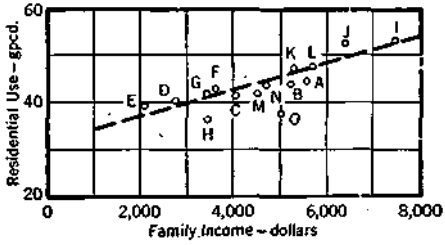

Fig. 4. Residential Use Based on Completion of Sanitary Facilities

The estimated daily per capita consumption for rcsidential-use-is-bascd upon the installation of a bath or shower and a flush toilet in every home in each community.

usually to accompany greater income. They apparently preferred gasoline to water.

If income values for cities alone are considered, certain quantitative conclusions can be drawn. Communities "A," "B," "I," "J" and "L" had relatively high income values as well as high per capita water use. Communities "D," "M" and "O" had much lower reported incomes as well as relatively low use. It therefore appears that prior income is a factor. Communities "M" and "O" with low incomes in 1940 showed increases by 1947-1948 that were nearly equal. These increases were higher than those for any other community with low per capita use as is shown in Table 2. It would appear that these two communities with low per capita use and with a rapid increase in income for this period have used a portion of their increased incomes for the luxuries rather than the necessities of life. Communities "I" and "J" showed higher income increases than "M" and "O" for the same period. Their per capita use (and standard of living), however, was already high, and the proportional increase in income is therefore not applicable to the same degree as it is for the two previously discussed communities.

Communities "F," "G" and "H" are not considered applicable since the only income values available were those for the county rather than the community.

Summary

Detailed data on water use were obtained from fifteen Illinois communities". The data were separated into five use categories: domestic or residential, commercial, industrial, public use, and loss and waste.

No correlation between population of community and water use was found. Uses varied as shown below.

Use	Consumption *gpcd.*
Residential	21.2- 52.3
Commercial	3.2- 27.3
Industrial	0-126.3
Public	Up to 18.5
Loss and Waste	Up to 79.0

There was an apparent relationship between family net effective buying income and residential use, with use ranging from about 10 gpcd. for low incomes to 52 gpcd. for high family incomes.

The income-use correlation was improved by making allowance for the status of sanitary facilities in each community.

There are indications that the standard of living of the community, taking into consideration prior as well as present income; is related to residential use.

Acknowledgment

This paper is condensed and revised from a thesis by Bernt O. Larson, entitled "Investigation of Per Capita Use of Water in Selected Illinois Cities" submitted to the Dept. of Civil Eng., Univ. of Illinois. The data were gathered under sponsorship of the Illinois State Water Survey.

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