Technical record. vol. 2, no. 3 February-March 1965

[s.l.]: Southeastern Wisconsin Regional Planning Commission, February-March 1965

TECHNICAL RECORD

SEWRPC

VOL. 2 NO. 3

FEBRUARY - MARCH

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* DETERMINATION OF HISTORICAL FLOOD FREQUENCY FOR THE ROOT RIVER OF WISCONSIN * THE REGIONAL MULTIPLIER * * A BACKWARD GLANCE—THE STREET RAILWAY IN MILWAUKEE

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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THE TECHNICAL RECORD

Volume two Number three

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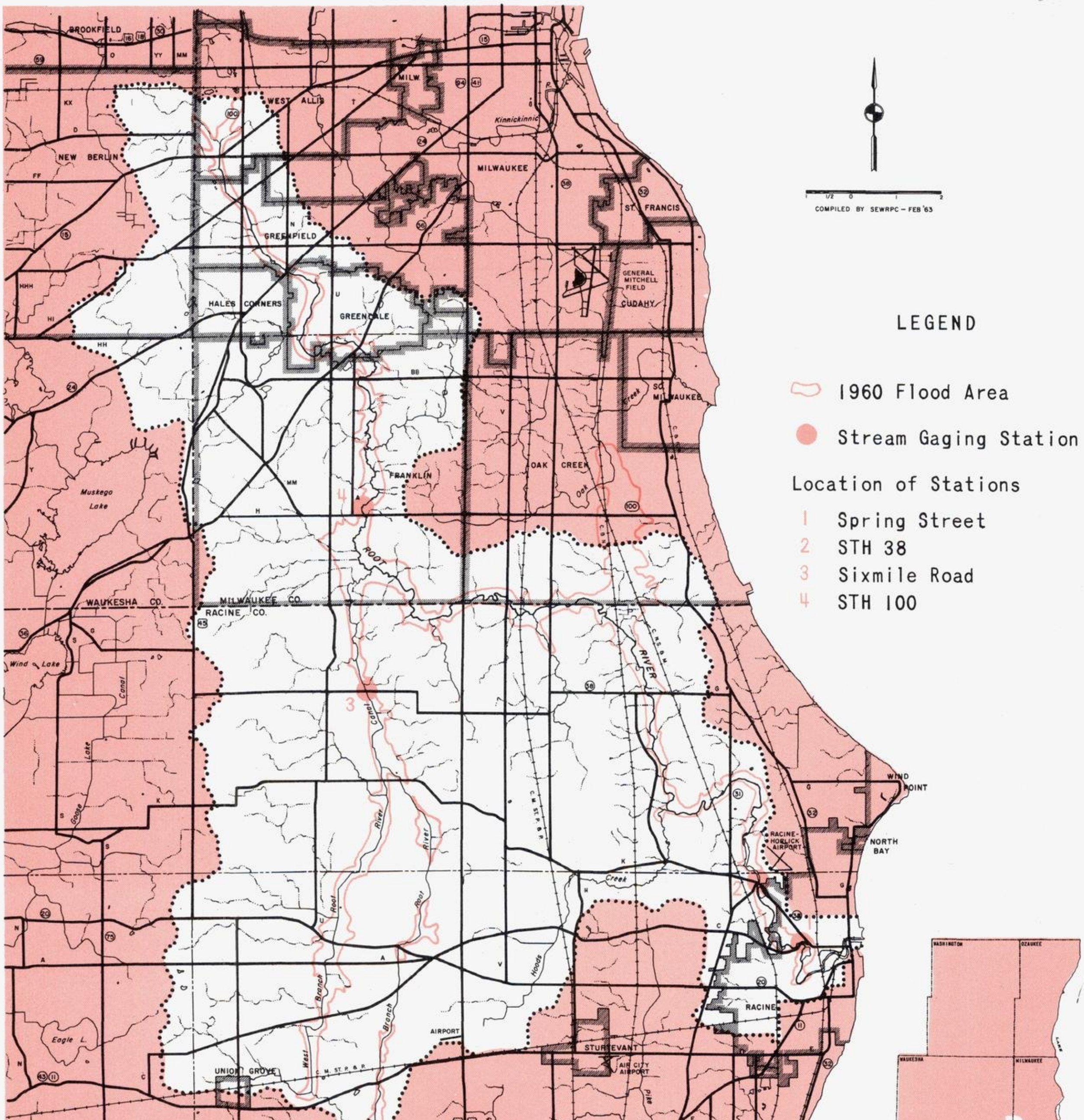
The preparation of this publication was financed in part through a joint planning grant from the State Highway Commission of Wisconsin; the U. S. Department of Commerce, Bureau of Public Roads; and the Housing and Home Finance Agency; under the provisions of the Federal Aid Highway Legislation and Section 701 of the Housing Act of 1954, as amended.

50¢ per copy $3.00 per year

MAP I

AREA OF INUNDATION AND HYDRAULIC STUDY CONTROL POINTS FOR 1960 FLOOD IN ROOT RIVER BASIN



THE DETERMINATION OF HISTORICAL FLOOD FREQUENCY FOR THE ROOT RIVER OF WISCONSIN

by James C. Ringenoldus, P. E., Harza Engineering Company

PREFACE By K. W. Bauer, Executive Director, SEWRPC

The following article on historic flood frequency determination departs somewhat from the format for the SEWRPC 'Technical Record' in that the work on which this article is based is not a direct output of the SEWRPC regional land use-transportation study. The article is, however, presented not only because it is believed that the information will be of interest and use to planners and engineers within the Region but also because it illustrates the parallel and interlocking nature of the Commission's total work program.

The regional land use-transportation study is the first major work program undertaken by the Southeastern Wisconsin Regional Planning Commission that is actually directed toward the preparation of long-range development plans. This program, however, is only one of a series of such planning programs, all closely interrelated, which together comprise the comprehensive regional planning program for southeastern Wisconsin.

Another major work program actually directed toward the preparation of long-range development plans presently being carried out by the Commission is a comprehensive watershed planning program for the Root River basin. This program, the first of a series, was initiated in July 1964 and has as its objective the preparation of a comprehensive watershed plan, including proposals for land use and for water control facilities, which will offer workable solutions to the drainage and flood control, water pollution, land use, and park and open-space reservation problems of that watershed.

A close interrelationship exists between the watershed planning programs and the land use-transportation planning programs. This interrelationship extends through all phases of the planning process from study design; formulation of objectives and standards; inventory of basic planning and engineering data; preparation of analyses and forecasts; through plan design, test, and evaluation; to plan selection and adoption.

The Commission's regional planning program not only embodies a recognition of watershed problems in rapidly urbanizing areas but recognizes the need to consider watersheds as rational planning units if workable solutions are to be found to such related problems as drainage and flood control, water quality and stream pollution, sewerage and water supply, recreation and public open-space reservation, and changing land use, not only in relation to the stream channels and their floodways and flood plains, but in relation to the watershed as a whole. Although recognizing the importance of the watershed as a rational planning unit within the Region, the Commission's planning program also recognizes the necessity to correlate individual watershed planning programs within the broader framework of areawide regional planning. Thus, certain outputs of the regional land use-transportation planning program become important inputs to the watershed planning studies, while certain outputs of watershed planning studies become important inputs to the land use-transportation planning study. Among the former are such items as economic activity, population, and land use inventory data, analyses and forecasts; proposals for future spatial distribution of land use; and proposals for future transportation route location. Among the latter are such items as the delineation of floodways and flood plains which should be withheld from urban development, modification of the future spatial distribution of land use in view of watershed planning needs, and the location of proposed water control facilities, including reservoir sites.

INTRODUCTION

The flood which occurred in the spring of 1960 was by far the most damaging which ever occurred on the Root River (see Map 1). Living memory and historical records show no evidence of overall damage from any other flood approaching that incurred in 1960. That is not to say, however, that the 1960 flood was the largest which ever occurred on the Root River. It is almost certain that larger flood discharges occurred prior to urban development. It is also almost certain that larger flood discharges will occur in the future.

A most important characteristic of floods and of flood damages is the probability of their occurrence. Probability or risk is defined as the chance of a flood equaling or exceeding a specified magnitude occurring in any year and may be expressed as a decimal fraction or a percentage. "Recurrence interval" is defined as the average time interval between floods of a given magnitude and is equal to the reciprocal of the probability. For example, a flood of such magnitude that it occurred on the average of once in 100 years would have a recurrence interval of 100 years and a probability or risk of happening in any year of 1 percent. It may also be said that such a flood has one chance in one hundred of happening in any year.

A common misconception is that a flood, for example, of a 100-year average recurrence interval will occur at 100-year intervals. It should be recognized that a flood of a given magnitude has an equal risk of occurring in any year or even in successive years. By statistical analysis it can be shown that the 100-year event has a 10 percent chance of occurring once within a 10-year period, a 40 percent chance within a 50-year period, and a 64 percent chance within a 100-year period. It is also possible that a 100-year flood might occur twice or even more frequently in any of the above periods.

A long and continuous record of river discharge is the best basis for determination of flood frequency. Unfortunately, the discharge records for the Root River (1963 to date by USGS) are much too short for meaningful flood frequency analysis. Inferences as to flood frequency can be made from other sources, however. Periodic measurements of river water levels have been recorded at the Spring Street Bridge in Racine since 1940. Climatological records at Milwaukee span a period of almost 100 years. Long-term discharge records, from which estimates of Root River flood frequency can be synthesized, exist for other Wisconsin rivers with hydrologic regimens similar to that of the Root River.

SPRING STREET GAGE RECORD

The most reliable, available indication of Root River flood frequency is the Spring Street stage record, which has been kept from 1940 to date by the Racine City Engineer's Office. The Spring Street gage is above the influence of Lake Michigan water levels. Spring and summer peak water levels for each year are given in Table 1. High flows prior to May 1 are likely to include snowmelt runoff and ice effects, while high flows after May 1 are caused by rainfall only. The flood stage on the Spring Street gage is 8.00 feet.

The possibility exists that channel deposition downstream from Spring Street may have produced peak stages at the Spring Street gage to become progressively higher for equivalent discharges. If this were the case, an examination of annual peak stages plotted against time would show an upward trend. The sequence of peak stages, as shown in Figure 1, however, does not indicate any regular increase or decrease in peak stages between 1940 and 1964. Rather, the sequence appears to have random variations.

Table I
PEAK STAGES[a] AT SPRING STREET GAGE RECORD
IN THE CITY OF RACINE BY YEAR
(1940 - 1964)

Year	Spring Peak (Before May 1)		Summer Peak (After May 1)	
	Stage[a] (feet)	Date	Stage[a] (feet)	Date
1940	4.9	March 30	10.0	August 26
1941	7.0	January 3	5.5	November 3
1942	4.2	March 24	4.8	May 25
1943	10.2	February 23	4.3	May 21
1944	6.6	March 15	4.2	June 19
1945	5.4	March 6	5.6	May 28
1946	9.3	January 7	3.5	July 1
1947	7.5	March 14	7.5	June 2
1948	9.0	March 1	6.3	May 10
1949	5.4	March 7	3.3	June 20
1950	7.0	March 6 & April 25	6.6	July 20
1951	10.4	February 27	7.8	November 13
1952	9.5	March 20	6.0	August 4
1953[b]	5.3	March 16	4.9	May 6
1954[b]	5.3	March 16	4.9	May 4
1955	5.5	April 25	6.5	June 15
1956	5.5	April 30	5.8	May 14
1957	5.0	April 8	5.5	June 17
1958	5.0	April 7	3.8	June 2
1959	7.5	March 20	6.8	October 21
1960	15.2	March 31	6.5	May 9
1961	7.3	March 22	5.7	October 2
1962	11.4	March 20	4.0	May 14
1963	3.6	March 25	3.4	May 13
1964	3.7	March 16	6.0	July 20

[a] *Flood stage on the Spring Street gage is 8.00 feet.*

[b] *Probably the same year.*

Most floods during the period of record occurred in February, March, and April, probably associated with snowmelt, rain on frozen ground, or ice jams. Although rainfall potential within the watershed is much higher in summer, summer floods have been much less frequent and not as severe as spring floods. This is probably due to the higher water retention capacity of soils in the summer and the absence of snowmelt contribution. All stage peaks over 5.0 feet at Spring Street which occurred during the 25-year record have been plotted by date of occurrence in Figure 2. Only independent peaks, that is, only one peak for each storm or snowmelt event, were selected for plotting.

Several methods of probability analysis are applicable to a record of this type. Most methods of probability analysis will tend to assign to the highest event of a series a recurrence interval approximately equal to the number of events in the series. For

Figure 1
ANNUAL PEAK STAGE SEQUENCE
ROOT RIVER AT RACINE

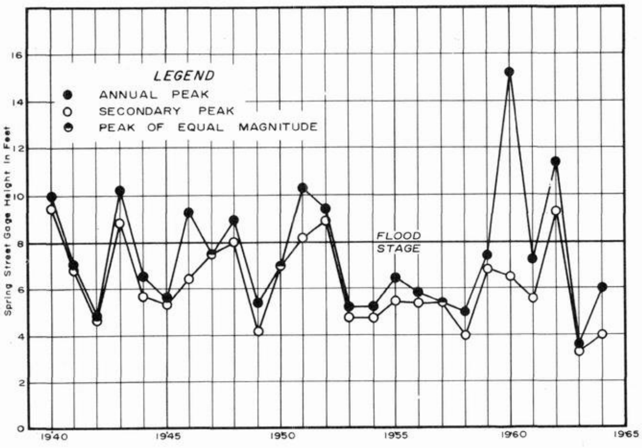
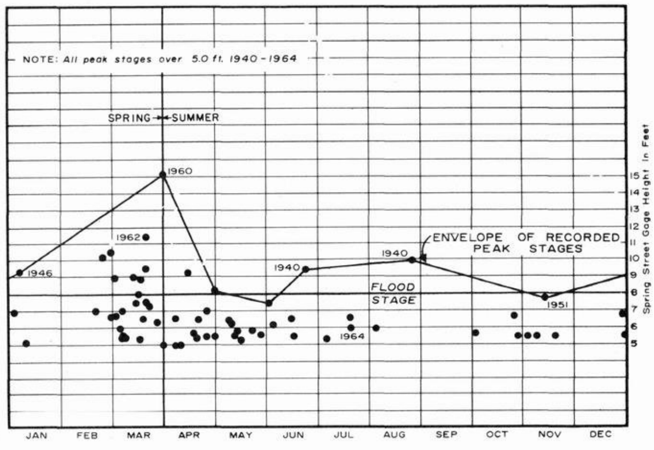


Figure 2
PEAK STAGE OCCURRENCES
ROOT RIVER AT RACINE



example, the simplest analysis would say that the 1960 flood caused the highest stage in 25 years; therefore, the recurrence interval of the 1960 flood is once in 25 years. The fact that the 1960 stage of 15.2 feet was much higher than the next highest stage (11.4 feet) indicates that such simple analysis is inadequate.

Information obtained from eye witnesses indicates that the 1960 flood was not equaled during a period of time at least twice as long as the period of record of the Spring Street gage. Therefore, the Hazen plotting point formula was selected for one analysis. It is particularly appropriate for application in this case since it is based on the assumption that the highest event in a recorded sequence will have a recurrence interval about twice the period of record. For example, the 1960 flood peak being the highest event in a 25-year period of record would be assigned a 50-year recurrence interval by the Hazen formula.

The Hazen formula is:

$$P = \frac{2m-1}{2n}$$

where

P = probability expressed as a decimal fraction,

n = number of years of record, and

m = rank in descending order of magnitude.

Random natural events exhibit a so-called "normal frequency distribution," which can be represented as a straight line on log-normal probability scales. Therefore, points representing natural flood peak stages or discharges will tend to approximate a straight line when plotted on log-normal probability scales if they have a natural frequency distribution.

The annual, spring, and summer stage-frequency relationships, as determined from the Hazen formula, were plotted on log-normal scale and a visual best-fit straight line determined, as shown in Figure 3. As theoretically required, the annual probability for any particular stage is about equal to the sum of the corresponding spring and summer probabilities. Figure 3 indicates that, as the higher stage heights are approached, the probability of a high summer stage becomes extremely small, with the result that the "annual" line and the "spring" line tend to converge. Above a stage of 15 feet, the annual and spring lines are the same, indicating the strong probability, under present conditions, that very high floods will almost invariably occur in the spring of the year.

A probability analysis based on peak discharges might result in a frequency relationship different from that obtained for peak stages. If river stage is caused by other factors than discharge alone, such as ice jams, this would be true. Under ice conditions a particular stage would have a greater probability of occurrence than would the corresponding discharge normally associated with this gage height under free-flow conditions. Flood damage, which is of particular concern in these studies, is, however, directly related to stage and only indirectly to discharge.

A discharge-frequency relationship was prepared, however, using discharges based on an estimated stage-discharge rating curve for the river at Spring Street. The low end of the rating curve was based on discharges measured at the new joint SEWRPC-Racine County-USGS gaging station at STH 38 about 2 miles upstream from Spring Street. The upper end of the curve was established by assuming a discharge of 10,000 cfs for the 1960 flood peak stage of 15.2 feet. The value of 10,000 cfs was obtained by multiplying the measured 1960 discharge of 5,000 cfs at STH 100 by the ratio of the square roots of the drainage areas above Racine (200 sq. mi.) and above STH 100 (50 sq. mi.).[1]

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[1] *Myers-Jarvis formula: peak discharge equals a constant times the square root of the drainage area.*

Figure 3

ROOT RIVER STAGE FREQUENCY RELATIONSHIPS

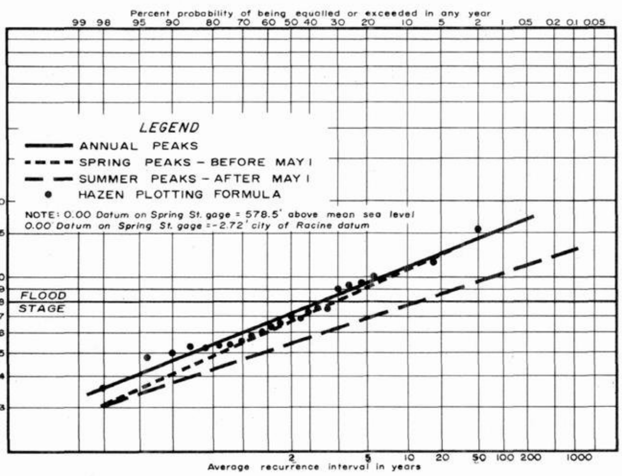
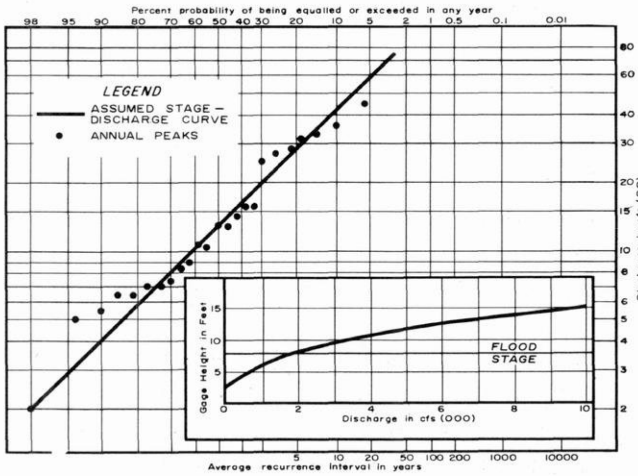


Figure 4

ROOT RIVER DISCHARGE FREQUENCY RELATIONSHIPS



Discharges corresponding to the annual peak stage were obtained using the rating curve. These discharges were then plotted on a log normal probability scale again using the Hazen formula. A straight line corresponding to the best-fit line on the graph of annual peak stages was drawn through the peak discharge points. This line was found to fit the discharge points well; and it was, therefore, concluded that the frequency relationships for both stage and discharges were equivalent. The estimated rating curve and the discharge frequency relationship are shown in Figure 4.

Both the stage and discharge frequency analyses indicate that a flood equal to or greater than that of March-April 1960 would have a probability of about 1.4 percent of occurring in any year. This probability is equivalent to a recurrence interval of about 70 years. There is reason to believe, however, that the 1960 flood has a real probability even smaller than that indicated by the statistical frequency analyses of the Spring Street record. Climatological factors and characteristics of similar streams which support this conclusion are discussed in a later section.

It is possible that the 1960 flood had a probability substantially less than 1.4 percent, but by chance it occurred during the 25-year period of record. If it were assumed that the 1960 flood had not occurred within the period of record, a similar analysis of the remaining 24 years of record indicates that a stage of 15.2 feet would have a probability of 0.31 percent, corresponding to a recurrence interval of about 300 years.

A further indication that the recurrence interval of the 1960 Spring Street stage is probably greater than 50 years is the fact that there was no indication either from municipal authorities or citizens living near the river that the stage has, in their records or memory, ever been higher. Valid living memory can be assumed to extend back at least to 1920.

REGIONAL FREQUENCY RELATIONSHIP

Discharge frequency projections for the Root River were prepared using information and the procedure presented in the U. S. Geological Survey Report "Floods in Wisconsin - Magnitude and Frequency." The Geological Survey technique uses flood data from gaged streams in a similar hydrologic environment to the Region to develop composite frequency curves which relate floods of various recurrence intervals to the mean annual flood. A formula for mean annual flood discharge based on drainage area, channel slope, lake and reservoir surface area, and a geographical factor was developed by multiple correlation. Using the mean annual flood formula and the regional frequency curves, a flood-frequency relationship can be estimated for an ungaged river in the Region.

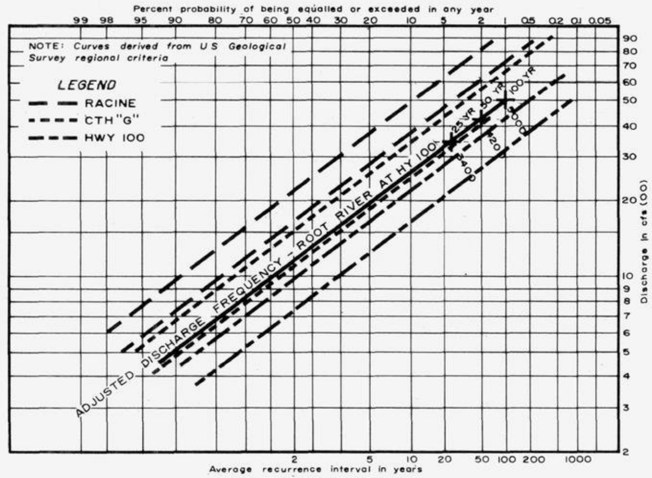
Frequency relationships were prepared, using the Geological Survey technique, for the North Branch at the STH 100, the canal at CTH G, and the Root River at STH 38 gaging stations. Because of the possible range in geographical factors, each curve developed has been shown as a range in Figure 5.

An indirect measurement of peak discharge of the 1960 flood at STH 100 of 5,000 cfs was made by the USGS shortly after the flood. The curves in Figure 5 indicate a recurrence interval for 5,000 cfs at STH 100 of from 200 years to about 1,000 years. This range indicates a probability of from 0.5 to 0.1 percent.

There is reason to believe that the recurrence interval of the 1960 flood at STH 100 is less than 200 - 1,000 years. The regional criteria are predominantly based on rivers in their natural state, whereas the drainage area tributary to the North Branch of the Root River has undergone substantial urban development and some channel improvement. These changes from the natural state cause flood discharges to increase for a given recurrence interval. The same situation probably holds true for the Root River Canal, which has had substantial channel improvement, and the Root River system as a whole.

Figure 5

ROOT RIVER DISCHARGE FREQUENCY



Climatological Factors

Inferences as to flood frequency may also be made from records of those climatological phenomena which affect the generation of floods. On a watershed basis, however, flood frequency cannot be related directly to rainfall frequency to the degree that it can in the small relatively impervious basins considered in storm-sewer design. The ability of soil to retain rainwater varies greatly with antecedent moisture conditions, with the season of a year, and with the use being made of the soil. A 100-year summer rainfall on cultivated soil after a rainless period may result in very little runoff. This situation occurred in July 1964 on the Root River Watershed. A much lower rainfall falling on frozen ground and melting snow may create a disastrous flood, such as occurred in March-April 1960.

The combination of climatological events which caused the 1960 flood was undoubtedly unusual and rare. Based on the Milwaukee station record of 94 years, March 1, 1960, had the third highest snow accumulation on the ground—20 inches. The average March temperature was the coldest ever with only one day having a maximum temperature above freezing prior to the 27th. After a sequence of below-average cold temperatures, which minimized loss of snow water content, the temperature rose to well above average two days before a rainfall of 2.57 inches in 24 hours, which was the highest 24-hour rainfall ever recorded in March. The excessive rain falling on frozen ground and melting snow resulted in the highest known flood on the Root River. The apparent individual probabilities of the principal causal factors, based on a 94-year record at Milwaukee, are: snow on ground—3 percent; cold temperatures prior to melting—1 percent; and rainfall in March—1 percent. The probability of these events in combination is impossible to calculate. The combination of these relatively rare factors would, however, substantiate a judgment that the 1960 flood, under present-day watershed conditions, would be at least a 100-year flood.

CONCLUSIONS AND RECOMMENDATIONS

It is apparent from the above discussion that the flood-frequency relationship for the Root River must be established by judgment based on the fragmentary and conflicting information that is available. A further consideration should be that selection of a design flood lower than the relatively recent 1960 flood would not be a sound procedure. It is recommended that the 1960 flood discharge at STH 100 be assigned a recurrence interval of 100 years and further that the design flood have a recurrence interval of no less than 100 years. This recommendation gives greatest weight to the Spring Street gage record, which is the most direct indication of Root River flood frequency characteristics.

Accordingly, the discharge-frequency curve for STH 100 was adjusted so that the 100-year flood discharge is 5,000 cfs, as shown in Figure 5. The slope of the adjusted frequency curve was made equal to the slope of the regional frequency curves. The adjusted curve indicates that a 50-year flood would have a peak discharge of 4,200 cfs and a 25-year flood, a peak discharge of 3,400 cfs. Under future, more highly urbanized conditions, the peak discharge values corresponding to these frequencies will probably be higher.

The general strategy recommended for flood synthesis is to select sub-basin runoff values, by trial, for the North Branch such that the 1960 flood peak can be reproduced. Comparable unit runoff values will then be used for the sub-basins in the balance of the watershed and the basin-wide flood synthesis carried out. For floods of other recurrence intervals, target discharges at STH 100 will be obtained from the adjusted frequency curve and basin-wide floods synthesized by the same procedure as for the 100-year flood. Suitable adjustments to sub-basin runoff will be made to reflect the effects of urbanization on future flood peaks.

The key criterion in this analysis will, therefore, be the estimated discharge-frequency relation for the Root River at STH 100. This is the only point in the entire system at which a reasonably well-established value of flood discharge is available. Synthetic system floods will be compared to the Spring Street stage record as a check.

* * * * * * *

The seven-county Southeastern Wisconsin Planning Region comprises only 5 percent of the total area of the state but contains over 40 percent of the state's population and over one-half of all the tangible wealth in the state.

Only about 7 percent of the Region is presently served by public water supply facilities. Over two-fifths of the present urban development within the Region is served by individual private water supply systems.

The median age of the regional population in 1963 was only 28 years compared to 31 years in 1950. Concentrations of older people occur in the central cities and rural areas of the Region.

Many of the most important industrial areas and largest population and employment concentrations in the midwest are located within 250 miles of the Region, and nearly one-sixth of the entire population of the United States lives within this radius.

There were almost one-half million households in the Region in 1963 with an average size of 3.4 persons per household. In the Region larger average household sizes are generally associated with increased distance from the central cities.

* * * * * * *

THE REGIONAL MULTIPLIER

by Kenneth J. Schlager, Chief Systems Engineer

A dual approach to socio-economic forecasting has been attempted in the land use-transportation study of the Southeastern Wisconsin Regional Planning Commission. Traditional independent projections of population and employment (by industry) have been supplemented by an experimental economic simulation model that incorporates an input-output framework for simulating the growth of the regional economy.

This economic simulation model was described in detail in an earlier issue of the Technical Record,[1] and socio-economic forecasts for the land use-transportation study are being developed through the use of this simulation model. Model forecasts will be compared with traditional extrapolation forecasts, and both will then be evaluated to determine the final best estimates of population and employment at five-year intervals to the year 1990.

Neither of these two forecasting methodologies have directly involved the use of the economic base concept of a regional economy and its associated primary parameter, the regional multiplier. The economic base type of analysis makes a distinction between basic (primary) industries that export goods or services outside the region and service industries that provide goods and services to regional residents. The underlying premise for such a classification is that regions exist and grow primarily because of the goods and services that are exported and sold beyond the borders of the region. If such a concept is valid, regional economic analysis must distinguish between basic and service industries.

Early attempts at measuring the economic base stressed the basic-service employment ratio.[2] From this same employment data, a regional multiplier may be calculated. Such a multiplier relates the change in total employment to the change in basic employment.

$$\text{Multiplier} = r = \frac{\text{change in total employment}}{\text{change in basic employment}}$$

The term multiplier is appropriate since it is a measure of the multiplying effect of a change in basic employment on total (basic and service) employment.

A regional multiplier is useful for determining the gross effects of a change of exports on income and employment within the Region. Regions with large multipliers tend to be less stable economically since small changes in exports produce large

[1] *See SEWRPC Technical Record, Vol. 2 - No. 1, October - November 1964.*

[2] *Walter Isard, Methods of Regional Analysis: An Introduction to Regional Science, John Wiley, New York, 1960.*

swings in total regional income and employment. More stable regions are characterized by smaller multipliers. This relationship of the multiplier with economic stability makes it extremely useful as a guideline for stabilizing the regional economy through the introduction of industries tending to lower the multiplier. Moreover, many economic analyses and forecasts do not require the detail needed by the land use-transportation study and are greatly aided by the application of a regional multiplier. The data required to calculate the regional multiplier is a natural outgrowth of the economic data collection program of the land use-transportation study since some of the same data needed for the economic simulation model is directly applicable to multiplier analysis.

The multiplier has also been an important concept in the theory of national income determination. Although analysis in this area has been somewhat unrelated to regional economics, it is directly transferable to a regional economy if the importance of regional exports and imports are understood. Preliminary to such a comparison, some definition of regional income is appropriate.

Individuals and business enterprises receive income as a reward for services rendered from the following sources: 1) production of goods and services for regional residents (C); 2) local private and public investment in capital goods (I); 3) local public expenditures for current expenses (G); 4) exports of goods and services (X).

Not all of the gross production revenue of the above goods and services results in income to regional residents since some of it "leaks" out of the region to pay for goods and service imports from outside the region. Total regional income, Y, may be expressed in terms of the above sources:

$$Y = aC + bI + cG + gX$$

where a, b, c, g represent the regional income generated for each dollar of expenditure in each category.

Consumption in turn is a function of income:

$$C = kY$$

where k = propensity to consume regionally (i.e., the proportion of income that is saved or spent outside of the region).

If investment (I) and current government expenditures (G) are ignored for the moment, the equation for income may be rewritten:

$$Y = aC + gX$$

but since $C = kY$

$$Y = akY + gX$$

and therefore $Y = \dfrac{gX}{(1-ak)}$

The factor $1/(1-ak)$ is the regional multiplier, and it is the result of the chain of spending that results from the injection of outside money into the regional economy. In the first round of spending resulting from the income gained from exports X, the recipients would spend akgX in the region, producing additional income. A second round of income will result in additional regional spending of $(ak)^2gX$. Successive rounds of spending will produce the following total income:

$$Y = gX\ (1 + ak + (ak)^2 + \text{---})$$

The sum of the above infinite series is equivalent to $1/(1-ak)$ if ak is less than one and therefore:

$$Y = \frac{gX}{(1-ak)}$$

which is identical to the other expression above.

Public and private investment spending (and government spending) will also produce the same multiplier effect so that the complete relationship is:

$$Y = \frac{(bI + cG + gX)}{(1-ak)}$$

The above relationship is often designated as the short-term multiplier since, in the short run, investment and regional government spending depend on factors other than the local income level.[3] In the long run, however, local investment and government expenditures will be related to income, so that only exports will remain as an exogenous input to the system. Following a similar derivation as above:

$$Y = \frac{gX}{(1-ak-bk'-ck'')}$$

where k' = propensity to invest

k'' = propensity of regional government to spend

The long-run multiplier then is equal to:

$$1/(1-ak-bk'-ck'')$$

In both the short-run and long-run multipliers above, constant parameters are assumed. In reality, these parameters vary somewhat with the level of income so that a marginal propensity to consume or invest would be a more accurate representation. As a first approximation, a linear multiplier is useful. Further refinement may be of questionable value because of the other inaccuracies resulting from aggregation of

[3] *Charles M. Tiebout, The Community Economic Base Study, Committee for Economic Development, New York, 1962.*

Table I
REGIONAL MULTIPLIER=(r)

Industry	S.I.C.	Sector	Nonbasic Employment (1962)	Basic Employment[a] (1962)	Total Employment (1962)
Agriculture	A	1	8,760 (60.0%)	5,840 (40.0%)	14,600
Mining	B	2	688 (100.0%)	---	688
Construction	C	3	24,822 (100.0%)	---	24,822
Food	20	4	6,730 (30.6%)	15,270 (69.4%)	22,000
Leather, Apparel, Textiles	22, 23, 31	5	278 (2.0%)	13,622 (98.0%)	13,900
Paper, Lumber, Furniture	24, 25, 26	6	2,718 (33.3%)	5,436 (67.7%)	8,154
Printing & Publication	27	7	4,440 (26.9%)	12,045 (73.1%)	16,485
Chemical, Petroleum, & Rubber	28, 29, 30	8	531 (10.0%)	4,779 (90.0%)	5,310
Primary Metal & Glass	32, 33	9	2,250 (10.9%)	18,449 (89.1%)	20,699
Fabricated Metals	34	10	1,124 (6.0%)	17,610 (94.0%)	18,734
Machinery, Engines, & Turbines	351	11	357 (3.0%)	11,553 (97.0%)	11,910
Machinery, Farms	352	12	70 (0.7%)	10,366 (99.3%)	10,436
Machinery, Construction, & Mining	353	13	270 (2.0%)	13,265 (98.0%)	13,535
Machinery, Metalworking	354	14	236 (4.0%)	5,657 (96.0%)	5,893
Machinery, Special	355, 6, 7, 8, 9	15	865 (5.0%)	16,436 (95.0%)	17,301
Elec. Mach. - Transmission Distribution & Industrial	361, 362	16	4,710 (21.6%)	17,088 (78.4%)	21,798
Electrical, Medical	364, 369	17	60 (2.0%)	2,972 (98.0%)	3,032
Elec. Mach., Household Appliances	363	18	56 (2.0%)	2,725 (98.0%)	2,781
Elec. Mach., Communications & Comp.	365, 366, 367	19	531 (4.0%)	12,738 (96.0%)	13,269
Transportation Equipment	37	20	652 (2.0%)	31,974 (98.0%)	32,626
Instruments	38	21	185 (5.0%)	3,513 (95.0%)	3,698
Miscellaneous Manufacturing	39, 19, 21	22	138 (2.0%)	6,763 (98.0%)	6,901
Transportation	40, 47	23	19,467 (81.0%)	4,566 (19.0%)	24,033
Communication	48	24	3,800 (58.0%)	2,731 (42.0%)	6,531
Utilities	49	25	5,192 (90.0%)	577 (10.0%)	5,769
Trade	50 to 59	26	123,075 (98.0%)	2,510 (2.0%)	125,585
Banking & Insurance	60-67 not, 65	27	16,946 (80.0%)	4,237 (20.0%)	21,183
Real Estate	65	28	5,553 (98.0%)	114 (2.0%)	5,667
Services	70-89 not, 80	29	64,625 (96.0%)	2,693 (4.0%)	67,318
Medical Services	80	30	13,850 (78.0%)	43,838 (22.0%)	17,688
Subtotal			312,979	249,367	543,016
Government		31	50,566 (95.0%)	2,661 (5.0%)	53,227
Total			363,545	252,028	615,573

r = 1/(Basic Employment/Total Employment) = 2.44

Basic Employment	252,028	41%
Nonbasic Employment	363,545	59%
Total Employment	615,573	100%

[a] *Employment associated with goods or services produced within the Region and marketed outside.*

commodities, industries, and households. Disaggregation of these units would tend to evolve into an input-output matrix, such as is used in the regional economic simulation model.

The above multipliers are also static in that they assume that production, income, and spending (consumption and investment) occur simultaneously. Actually time lags do exist between production and income, income and spending, and spending and production. Attempts to account for these dynamic effects would result in a model similar in structure to the regional economic simulation model.

In essence, the static aggregated multiplier is really a simplified regional economic model. It provides a useful measure of the gross effect of changes in regional exports on the income, employment, and general economic activity of the region.

The employment multiplier described earlier in this report is really an approximation of the long-run multiplier described above inasmuch as exports in the form of basic employment provide the only exogenous variable. Such a long-run multiplier is most meaningful in regional planning because of the interest in long-term changes. For this reason, a long-term employment-based multiplier was calculated from the data originally collected and analyzed for the regional economic simulation model. Employment data was for 1962. Estimates of basic and nonbasic employment were based upon the ratio of export sales to total sales obtained from data collected in industrial surveys of sampled firms in each industry.

The multiplier computations are shown in Table 1. It is of interest to note that the multiplier of 2.43, which results from a basic employment/total employment ratio of 0.409, is directly related to the ratio of manufacturing to total employment in southeastern Wisconsin, which is about 42 percent. Such a result seems logical. Although some manufacturing industries, such as food, provide a large share of nonbasic employment and some non-manufacturing industries, such as utilities, provide some basic employment, the overall average is close to the proportion of manufacturing employment. In some urban areas, this manufacturing/total employment ratio has been used for a first estimate of the multiplier. Such an approximation should be more accurate in a region such as southeastern Wisconsin because of the important role of manufacturing and the minor role of services in export earnings.

* * * * * * *

As of May 1963, there were approximately 3,200 route miles of arterial streets and highways open to traffic within the Region, of which 42 route miles, or less than 2 percent, consisted of freeways. These freeways were, however, carrying 6 percent of the total vehicle-miles of travel over the arterial street and highway network on an average weekday.

Only about 8 percent of the area of the Region is presently served by sanitary sewer facilities. Over one-third of the present urban development within the Region is served by individual on-site sewage disposal systems.

Of all existing recreation sites in the Region, 43 percent are in nonpublic ownership and consequently susceptible to conversion to other uses. About 17 percent of these sites are operated as private facilities and are accessible to only a very small segment of the regional population.

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Nearly 88 percent of all internal vehicle trips made within the Region on an average weekday were by auto and taxi, and only 12 percent were by truck.

More than 527,000 autos were available to the 491,000 households within the Region, an average of 1.07 autos per household. Almost 58 percent of the total households had one auto; nearly 24 percent had two or more autos; and less than 19 percent had none.

The inventory found that approximately 13 million vehicle-miles of travel occurred within the Region over the arterial system on an average weekday.

Approximately 546 miles, or 17 percent, of the arterials within the Region were operating either at or over design capacity in the spring of 1963. The most congested links in the existing arterial network are located within the intensely urbanized areas, and almost 42 percent of the existing arterial street and highway mileage in Milwaukee County was operating at or over capacity in the spring of 1963.

There were approximately 630,000 jobs in the Region in 1963. Approximately 75 percent of these jobs were concentrated in Milwaukee County, 8 percent in Racine County, and 7 percent in Kenosha County.

Although urban development within the Region has been continuous since 1850, the character of this development has changed dramatically since 1950. Compact, concentric urban development has been supplanted by a diffused pattern of areawide sprawl; and in the past 13 years, a 35 percent increase in population has been accompanied by a 146 percent increase in land devoted to urban use.

The average household income in the Region in 1963 was over $8,000 compared to less than $5,000 in 1949. Total personal income in the Region in 1963 was over $4 billion.

Approximately 49 percent of the Region is covered by soils which are generally poorly suited for development with individual on-site septic tank sewage disposal systems. Approximately one-third of this area, or 17 percent of the Region, is covered by soils which are generally poorly suited for any type of urban development.

Single-family homes in the Region had a median value of $15,700 in 1960 compared to $11,100 in 1950. Housing values throughout the Region correlate closely with family income and educational attainment.

Urban land uses presently occupy approximately 340 square miles, or approximately 16 percent of the total area of the Region; and the greatest proportion of this urban land is devoted to residential use, while transportation, communication, and utilities rank second. Non-urban land uses presently occupy approximately 84 percent of the total area of the Region, and the greatest proportion of this land is devoted to agricultural use.

Nearly 80 percent of all person trips made within the Region on an average weekday consisted of trips by family members to or from their place of residence.

The largest single concentration of person trip origins and destinations within the Region is the central business district of the City of Milwaukee. On an average weekday, there were 129,100 person trips made to this area by residents in the Region. Of these, 63,898 trips were made by auto drivers and 20,191 trips were made by auto passengers, for an average auto occupancy of 1.32 persons. There were, in addition, 44,439 transit passenger trips made to this area. The remaining 572 person trips were made as passengers of trucks or taxis.

Residents of the Region made nearly 3.4 million person trips on an average weekday, an average of 6.9 per household.

Autos accounted for 88.2 percent of all internal person trips within the Region on an average weekday, compared to 8.5 percent for transit and 3.3 percent for school buses.

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A BACKWARD GLANCE

THE STREET RAILWAY IN MILWAUKEE

by Henry M. Mayer, Administrative Assistant, Milwaukee Suburban Transport Corp.

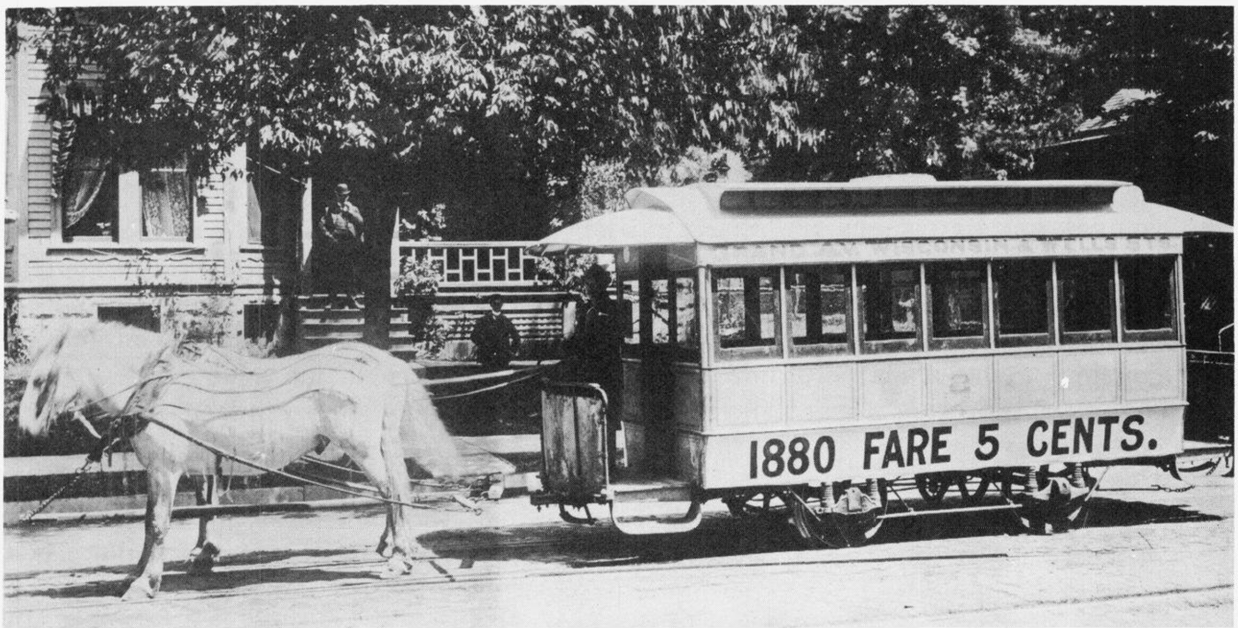
One hundred and five years of "street railway" operation in the Milwaukee area will soon come to a close with the conversion of the last two "trackless trolley" routes, the North 3rd-South 13th and the National Avenue lines, to diesel buses. The street railway system was started in a city of 45,000 people and made a major contribution to the development of that city into one of the great metropolitan areas of the world and leaves as its legacy a transit system serving over 1,000,000 residents.

The Horse Car Era 1860 - 1890

In May of 1860, two horse cars constructed in Philadelphia arrived in Milwaukee harbor aboard a sailing vessel. Their arrival was timed to coincide with the completion of a street railway track being built under the direction of Alexander Easton, an engineer from Cincinnati. By the end of May, a single track had been laid on what is now North Water Street between Erie Street and Juneau Avenue. The tracks were made of 2 1/2 inch by 1 inch strap iron rails spiked at one-foot intervals to 3 inch by 4 inch wooden stringers which, in turn, were laid on ties. The track gauge was four feet, and the ties were laid in a dirt ballast.

On the afternoon of May 30, 1860, the two single truck, wooden cars, each pulled by teams of four horses, left the horsecar barns at the corner of Erie Street and Water Street and headed north on Water Street. "The cars were... crowded with invited guests.... They were heartily cheered by the large concourse assembled on the sidewalks to watch their progress.... The horse railroad is bound to be a popular institution." Thus the Milwaukee Sentinel of May 31, 1860, noted the advent of the street railway in Milwaukee. The franchise of the River and Lake Shore Railway Company, organized by Colonel George Walker (south side Milwaukee's counterpart to the east side's Solomon Juneau and the west side's Byron Kilbourn), granted permission to construct and operate a street railway from Walker's Point Bridge (now Water Street Bridge) to Sisters' Hospital at North Point (St. Mary's Hospital) upon whatever streets it chose. By the end of the summer of 1860, the line had been extended to Prospect Avenue and Juneau Avenue over Wisconsin Avenue, Jefferson, and Van Buren Streets; and the rolling stock consisted of three two-horse cars and two one-horse cars. Much of the traffic was apparently joy riding; and on one summer Sunday in 1860, 3,362 rides were taken, producing revenue of $160.10. When the Civil War commenced in 1861, a large military camp was established in the fields north of North Avenue; and the line was extended north on Prospect Avenue to North Avenue.

With the "success" of the street railway on the east side, there was an immediate demand for service on the west and south sides. After considerable politicking, which resulted in four years of disputes, a franchise was granted to the Milwaukee City Railway in 1865. This company took over the operations of the River and Lake Shore Company and also established service on the west side on Third Street and on Walnut Street.



The postwar era was one of hard times; and as potential riders saved their nickels and walked, losses mounted. In 1869 Isaac Ellsworth bought the entire system and promptly picked up the rails on the east side and relaid them on the west and south sides. Mr. Ellsworth, in effect, started the route system which continued as the basic transit system for many years: State Street, Walnut Street, Eighth Street-South 16th, Third Street-South 11th and others. By 1880 the company operated on 14 1/2 miles of street with 32 cars, 280 horses, and 250 men. The car barn was located on 2nd Street between Wells and Wisconsin Avenue.

In 1874 the east side's pride was restored with the formation of the Cream City Railway Company. This company constructed and operated what were the forerunners of the present Holton line, Mitchell-Forest Home line, the Delaware line, and the Farwell line with a car barn at Farwell and Brady on the north side and at Kinnickinnic and Mitchell (the site of the present bus garage) on the south side. In 1881 the Cream City Company operated over 15 miles of street with 50 cars and 200 animals.

Also in 1874, another franchise was granted to a group who formed the West Side Street Railway Company. This company constructed and operated the lines which were the forerunners of the present Wells line and Twelfth Street line, with service on what is now Wisconsin Avenue from the lake to 11th Street, on 12th Street to North Avenue, and on Wells Street from 11th Street to the city limits at 35th Street. This line in 1881 operated over 5 miles of track with 160 horses and two car barns, located at 11th and Wells and 22nd and Wells.

Horsecars used by the various companies were of many makes and colors; but all were of the same basic design, their size limited by the pulling power of a team of horses or mules. Typical capacities were 12 to 16 seated passengers. Car lighting was by oil lamp. Car heating was at first by hay strewn on the floor and eventually, as an innovation by the Cream City Railway, by a coal stove in the car. The fare was

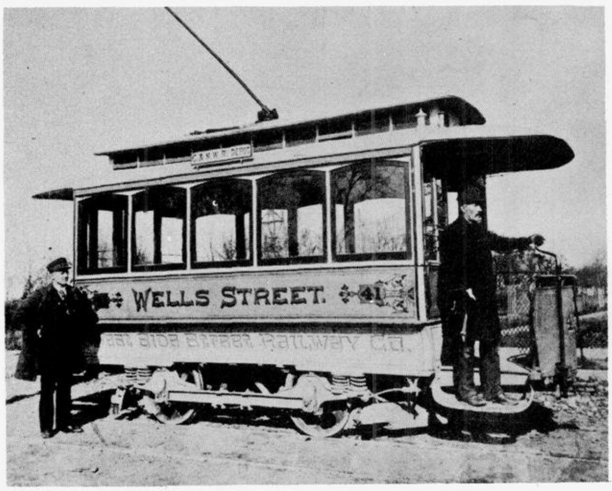
5 cents, and there were no transfers issued between the competing companies. The driver, who was also conductor and general utility man, performed his job on an open vestibule. In the summer this may have been pleasant; but to combat the winter cold, the drivers wore heavy coats and let their beards grow. It was always a sure sign of Spring when the horsecar drivers shaved off their beards.

The Electric Car Era 1890 - 1920

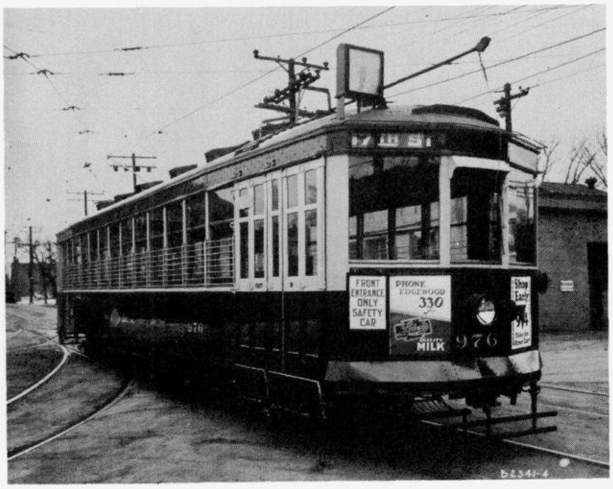
Experiments with other than horse or mule power were tried. In the 1870's a summertime service on Forest Home Avenue out to the Forest Home Cemetery was established using a combination steam engine-passenger car and, on occasion, several cars pulled by small steam engines. There were many complaints about horses being frightened by the "dummy engines"; and after an unsuccessful experiment with two stuffed mules in front of the engine, the line was converted to mule power.

In 1886 a franchise was granted to John Hinsey, then president of the Milwaukee Common Council, to construct and operate a cable car transit system. Actual construction of a cable line was never accomplished, but the "Hinsey Line" did become one of the first electric streetcar lines in the spring of 1890, operating from Wisconsin Avenue and Milwaukee Street to Wells and on Wells, 6th, and Vliet Streets. Shortly before this, the West Side Street Railway began operating its Wisconsin Avenue-Wells service as an electric line. By 1894 all of the horsecar lines had been converted to electricity.

At the same time, several steam "rapid transit" lines were started serving the suburban communities. One line originating at 35th and Wells, the City limits, operated over the Wells Street Viaduct and to West Allis and Wauwatosa over what was, until 1958, the route of the Wells-West Allis streetcar line. A second route operated from Steuben Square (Lisbon and Lloyd) to the Village in Wauwatosa. A third operated to Whitefish Bay from North Avenue along what is now Downer Avenue in Milwaukee and over what is now Oakland Avenue in Shorewood and Marlborough Drive in Whitefish Bay.



The first electric cars operated were only converted horsecars.



Car No. 976 was from the last lot of streetcars purchased and was to give thirty years of service before streetcar service was discontinued in 1958.

Starting in 1891 a series of mergers and bankruptcies occurred which resulted in the consolidation of the principal street railway companies and electric generating companies into, in effect, one company, the Milwaukee Electric Railway and Light Company and its subsidiary, the Milwaukee, Light, Heat and Traction Company, which operated the suburban lines. Obsolete equipment brought about by rapid changes in car and motor design, the financial panic of 1893, the substantial fare reduction which resulted with the consolidation of companies (free transferring between lines became possible), and the violent strike by the new company's employees in 1896 made the "Nineties" anything but gay in the street railway business. The strike, which was over a one-cent increase in pay, from 19 to 20 cents per hour, lasted several weeks. A motorman was shot, and the service was boycotted for many months after.

By the turn of the century, however, the new company's health was improving and, under the direction of John I. Beggs, embarked on a program of modernization and expansion of city, suburban, and interurban electric railway service (see Technical Record, April - May 1964, Vol. 1 - No. 4, "The Electric Interurban Railway"). The steam streetcar lines had been purchased and converted to electric power in the 1890's. In 1912 The Cold Spring Shops were constructed which had the capability of not only overhauling but of building streetcars and interurban cars.

Electric streetcars, which were originally only motorized horse cars, were rapidly improved and enlarged. One-truck cars gave way to two-truck and even three-truck "articulated" cars. The open vestibule of the motorman was finally enclosed (this had been one of the strike issues in 1896); and, if the conductor was diligent in his duty of heaping enough coal in the stove, everyone had a warm ride.

New car stations were built (Fond du Lac and Oakland Stations), and by 1920 Milwaukee and its suburbs were served by an extensive network of streetcar tracks. The company during this period continued in its role as a political football. It was constantly embroiled in rate cases (a fare reduction from 5 cents to 4 cents was the principal issue) and by threats of municipal acquisition. The fare matter was finally resolved by the inflation of World War I, and the basic fare was raised to 7 cents in 1920.

The Gasoline Bus Era 1920 - 1950

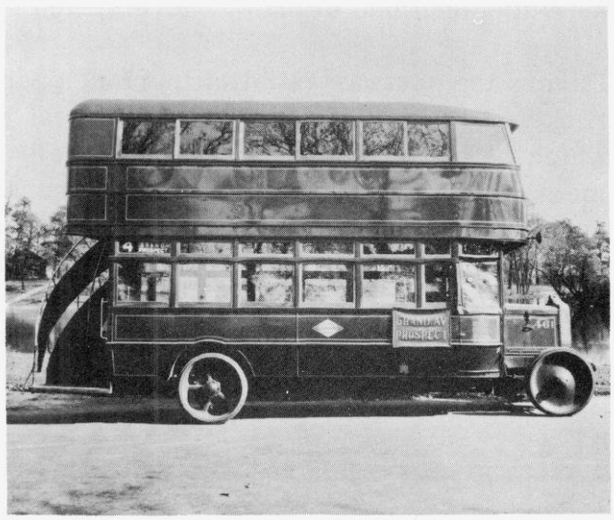
On April 17, 1920, the cycle of a major change in mass transportation in Milwaukee every thirty years was continued with the establishment of the first city motor bus service on West Mitchell Street. It was not until 1926 that a bus was substituted for a streetcar line (Wanderer's Rest Cemetery route on Lisbon and Appleton Avenue between Lloyd and Burleigh Streets), but in the next several years a number of "ends" of car lines were shortened and converted to the small capacity but flexible bus which required no expensive tracks.

The 800 and 900 series streetcars were introduced during the 20's, and a substantial change in operation was made with the introduction of the one-man car which eliminated the conductor. It was not until 1949, however, that the last two-man car was retired.

Streetcars continued to be the backbone of the transit system; and buses, with one exception, were basically used only as "feeder" lines during the 20's and early 30's. The advent of the automobile brought with it competition, not only from the private car, but also from the "jitney bus." To meet this competition, a deluxe "boulevard" bus service was started serving the Sherman Boulevard and Washington Boulevard area on the west side and the Prospect and Maryland Avenue area on the east side. The distinctive "green bus" system with plush mohair seats, a "seat per passenger" service, and a premium fare with no transfer privileges was a merchandising success; and the jitney bus competition faded away.

Competition of sorts did continue to exist in two areas. The Milwaukee Northern Railway Company, which operated the interurban electric railroad to Sheboygan, provided local transportation on Atkinson Avenue and North 6th Street to West Wells Street. This competition was eliminated by the merger of the Milwaukee Northern Company with T. M. E. R. & L. Co. in 1928. Local service was also provided by the Chicago North Shore Railway on the south side operating on South 5th and South 6th Streets to downtown Milwaukee at North 2nd and West Wells Streets. Despite a 5-cent fare, this local service was abandoned in 1951 due to lack of patronage.

A "jitney" competed for riders, circa 1915.



A double-decker coach purchased for the deluxe boulevard service was originally "open air" on top. It was soon roofed for the Milwaukee climate.

The political football characteristic of the company continued through the 20's with a referendum for municipal acquisition defeated in 1925 (by a 2 to 1 margin) and a more or less constant fare battle between city and company. The fare matter was resolved in 1930 with the increase of the cash fare to a dime and the inauguration of the "dollar" weekly pass. Another referendum to purchase the company was defeated by the voters 107,000 to 81,000 in 1936.

In 1934 another violent strike occurred, which resulted in the death of a young "sympathizer" and injury to many others. This strike was successful for the union organizers, and the Amalgamated Association of Street Railway Employees was recognized as the bargaining agent for the employees of the company.

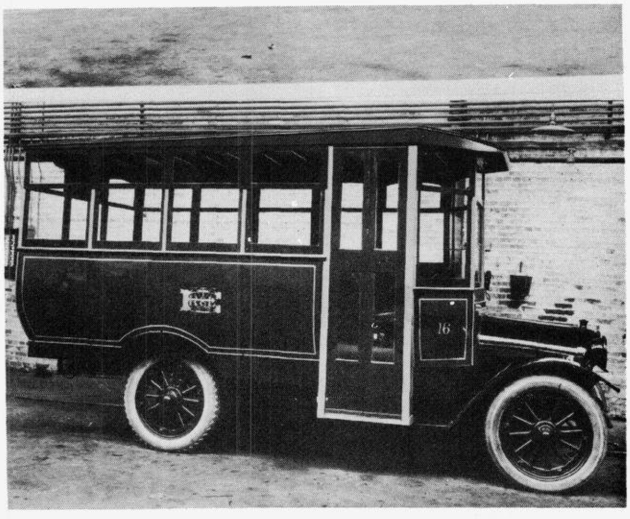
The year 1936 saw the conversion of the first entire streetcar line from track to rubber tires. In November of that year, operation of the North Avenue line was switched to fast, quiet trackless trolleys. It was a popular move, and plans were made to convert the entire rail system to this mode of transportation. Although the timetable was delayed by World War II, 400 trolleys (100 of them on the Route 19-37 Third-South 13th-West Greenfield line) were being operated in 1949, as the trackless trolley became the new "backbone" of the transit system.

During World War II, with gas rationing and high employment, the facilities of the company were taxed to the limit as riding more than doubled from prewar levels. Weekly pass sales rose to a level of 200,000 each week. Fortunately, an order for trackless trolleys for conversion of streetcar lines had been placed shortly before the war started; and when delivery was made, the streetcar lines were retained and the new trolleys used to augment the existing routes.

The Diesel Bus Era 1950 - ?

Another 30-year cycle was completed in 1950 with the delivery of the first order of diesel buses in Milwaukee. Conversion of the remaining streetcar lines continued, some to trackless trolleys (using surplus trolleys no longer needed on other routes as riding declined to prewar levels) and others to diesel bus operation.

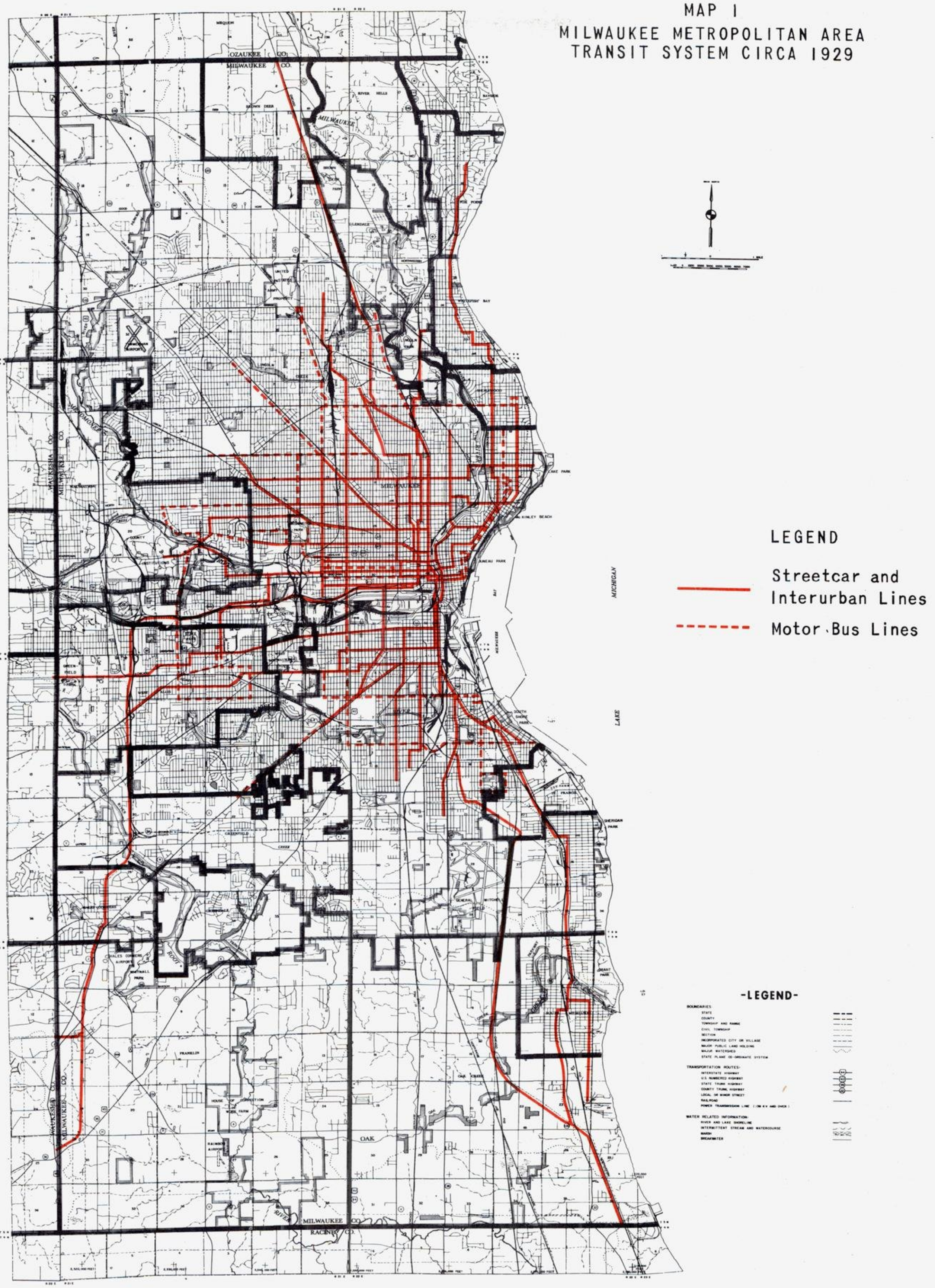
During the postwar inflation period, operators' wages and prices of new buses skyrocketed. A fare increase was almost an annual pattern as the transit operation, which had been segregated from the electric utility in 1938, struggled to make ends meet in the face of inflationary pressures, the decentralizing city, television which kept people home evenings, and the renewed competition of the automobile. In December 1952, the complete divorce of the transit operation from the electric utility was accomplished with the sale of the operating property to a group of Chicago and Milwaukee businessmen, who formed the Milwaukee & Suburban Transport Corporation.



The body for Bus No. 16 was built in Cold Spring Shops and attached to a White truck chassis.

Almost 50% of existing fleet are these "new look" buses.

MAP 1
MILWAUKEE METROPOLITAN AREA TRANSIT SYSTEM CIRCA 1929



Under the new ownership, the conversion of streetcars was rapidly completed; and on March 1, 1958, the last streetcar crossed the Wells Viaduct. Operating stations were reduced from seven to four as efficiency became the byword. Despite continuing inflation, operators' basic wages rose from $1.75 to $3.00 per hour between 1952 and 1965, the price of the weekly pass rose only 55 cents from $2.00 to $2.55, and the adult ticket from 15 cents to 20 5/6 cents. Although cities throughout the nation were reeling from one transit crisis to another with municipal ownership a fact or contemplated in almost every major city, Milwaukee's transit fleet continued to modernize and expand its routes as a private operation.

Freeway construction and wholesale street reconstruction projects raised havoc with trackless trolley routes and schedules, and the company instituted a program of replacing obsolete trackless trolleys with the still more flexible and efficient diesel bus. The first trackless trolley route converted was the Clybourn-Michigan route in 1962. The program is planned for completion in June of 1965.

An experiment in rapid transit by bus was begun in 1964. The Freeway Flyer, operating from the Mayfair Shopping Center to downtown Milwaukee via the freeway system, was an immediate success and continued to grow in popularity. Possibly it presaged the transit system of the future.

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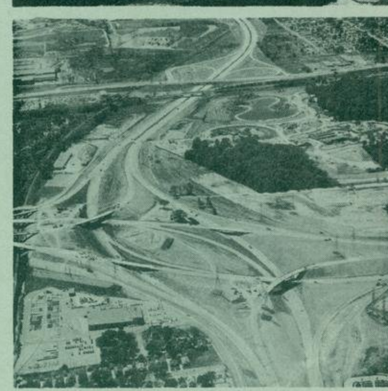
TECHNICAL RECORD BIBLIOGRAPHY

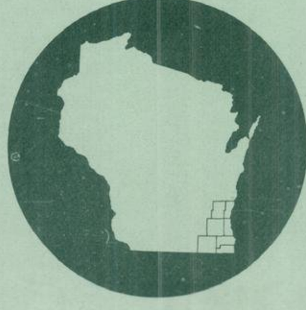
THIS IS SOUTHEASTERN WISCONSIN

Important vital statistics on the Region and percent of totals for the State of Wisconsin.

Land and Water Area (sq. mi.)	2,688	5%
Population (1960)	1,573,620	40%
Resident Employment (1960)	612,723	42%
Resident Unemployment (1960)	24,174	41%
Resident Labor Force (1960)	636,897	42%
Resident Man'f. Employment (1960)	253,292	52%
Resident Non-Man'f. Employment (1960)	359,431	37%
Disposable Personal Income (1960)	$3,572,000,000	46%
Retail Establishments (1958)	15,780	33%
Retail Sales (1960)	$2,045,000,000	42%
Property Value (1960)	$8,726,000,000	46%
Total Shared Tax (1960)	$62,777,000	54%
Total State Aids (1960)	$35,474,000	26%
Total Property Tax Levy	$239,380,000	50%
Total Long Term Public Debt	$378,592,000	55%
Total Highway (miles) (1960)	8,740.45	8.9%
Value of Mineral & Non-Metal Production (1961)	$15,494,487	20.08%
Total Vehicle Registration (1962-1963)	633,540	36.8%
Auto Vehicle Registration (1962-1963)	551,188	40%
Truck Registration (1962-1963)	55,950	23%
State Parks & Forest Areas (acres) (1963)	12,546	3.02%





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