Increasing the Traffic-Carrying Capability of Urban Arterial Streets*

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● TRAFFIC CONGESTION on many major urban arterial routes has reached intolerable proportions. Construction of the urban freeways contemplated in current highway programs will provide substantial relief to cities, but arterial streets must remain the urban transportation system's bulwark for providing traffic distribution services. Presently the urban arterials are overtaxed in their ability to provide traffic service for through traffic as well as to provide land-use services along the facility itself. These two services clash and in practically every major city the freeways that are being planned and built have as one of their major considerations the need to separate those two service functions.

Highway administrators and engineers recognize that the tremendous cost, taking of land, and other difficulties involved in urban freeway construction preclude their adoption as a wholesale solution to this problem. Proposed circumferential freeway routes will also provide relief to the urban areas of today and tomorrow, but they, too, can only slightly ease the impact of the work trip rushes imposed on major urban arterial routes. It is obvious that the major arterial street systems must be used to the maximum capacity and efficiency so that the standards of our cities' economic life may be advanced.

It is well known that many urban arterial streets could operate more efficiently and safely if all presently known methods of increasing their carrying capacity could be applied. Recognizing an important and timely need, the Bureau of Public Roads, in December 1958, undertook a pilot study, with the cooperation of the District of Columbia Department of Highways and Traffic, for the purpose of demonstrating theoretically the effectiveness of these various known methods of increasing traffic capacity, when used in combination.

As a convenient "test track," Wisconsin Avenue in the District of Columbia was selected, and the pilot study has thus become known as the Wisconsin Avenue Study.

The basic objective of the Wisconsin Avenue Study was to estimate how great an increase in the traffic-carrying capability of an existing urban arterial street could be developed within existing right-of-way limits, if all known traffic control techniques could be adopted and if major construction were carried out.

This research study was not intended to develop entirely new techniques of traffic operations, but rather was intended to predict the level of increased capacities that can be obtained by using existing tools now available.

It was not within the scope of this study to evaluate the changes in the composition of the city inself or, more specifically, of the neighborhoods through which the study street passes, that might be invoked to produce an efficient transportation system. That area of study properly belongs within the framework of the over-all transportation planners. The nature of the city's plan, whether organic or other, must ultimately be decided by the citizens themselves. Of course, it is recognized that changes in land use, changes in zoning, and introduction of residential land uses mixed with commercial development, would tend to change trip lengths as well as characteristics of traffic flow. Such an area of study encompasses radical changes in land values and land patterns which are associated with the economic and sociological responsibilities

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* This is a summary report of a comprehensive study. The full report will be published by the Bureau of Public Roads probably late in 1960.

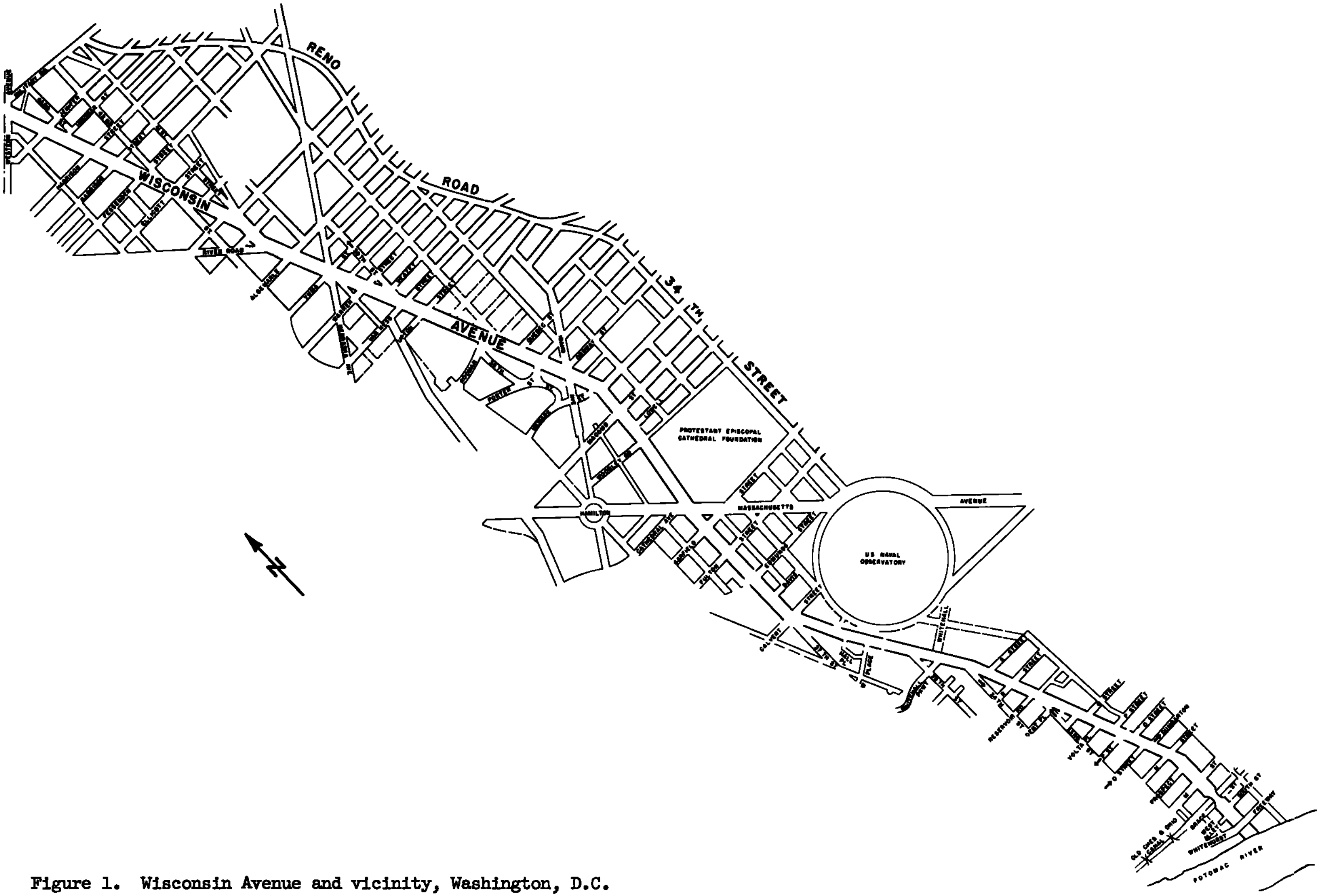

Figure 1. Wisconsin Avenue and vicinity, Washington, D.C.

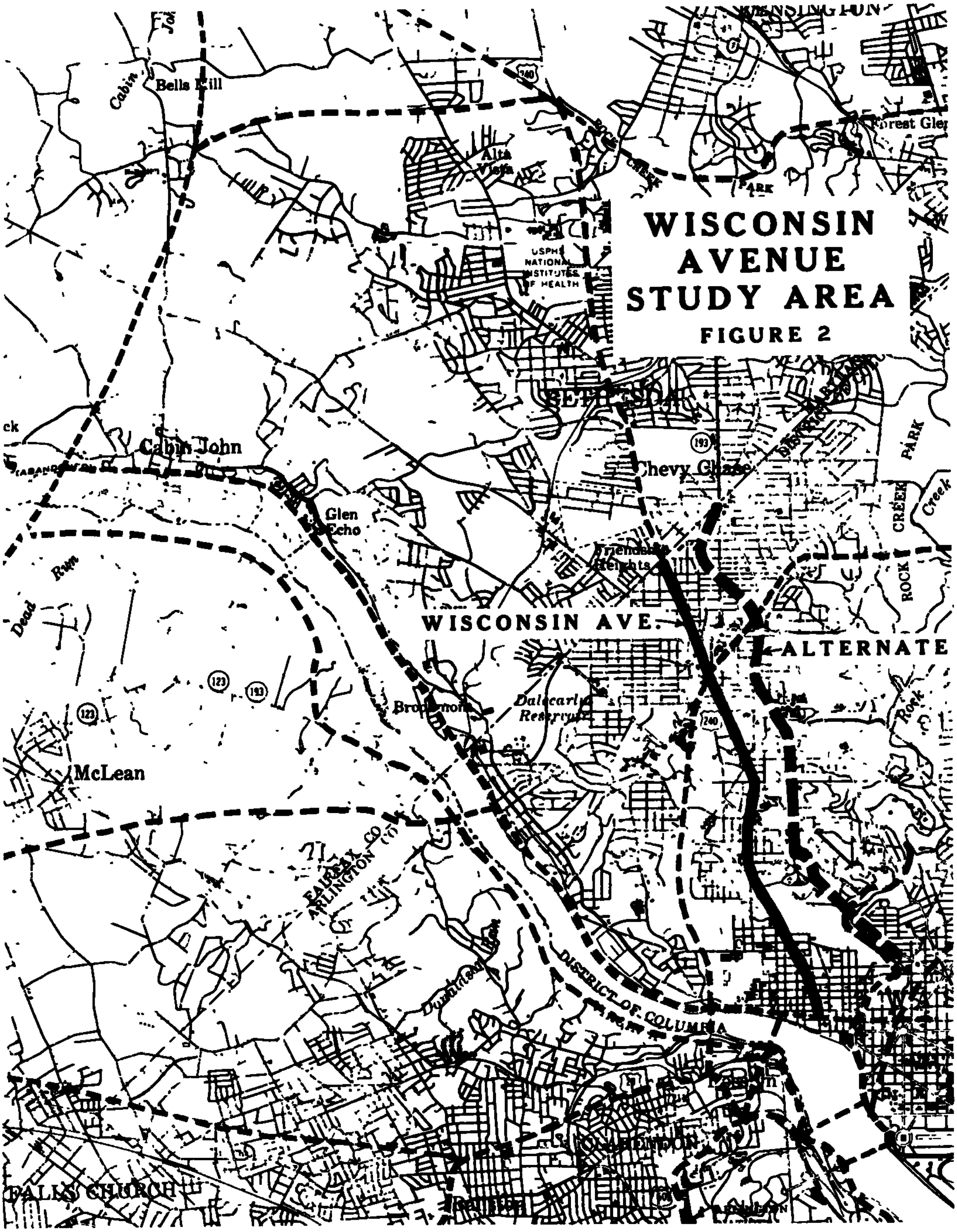

Figure 2.

of the community. Although it is recognized that traffic volumes are a direct function of these over-all planning considerations, the purpose of this study was to treat the existing disease with existing medicines rather than to develop new antibiotics.

It should be stressed that this study was limited to consideration of improvements possible without destruction of or damage to any fronting buildings, except in very special cases. That is, all potential improvements would have to fit within existing building lines, with adequate provision for sidewalks.

The study recognized that as pressure increases to push the capacity levels of our existing streets to greater and greater heights, a real danger exists that these highly developed major arterial routes will no longer adequately serve the adjacent land. It was the hypothesis that these two services can and must be maintained in balance on an arterial such as Wisconsin Avenue. This involved the use of the best-known traffic operation techniques, which provide a traffic stream having minimum friction while at the same time providing conditions conducive to patronage of the adjacent land services.

Wisconsin Avenue is the central artery in what is known as the Wisconsin Avenue corridor in northwest Washington, D.C. Figures 1 and 2 show the geographical location of the study route as well as its adjacent alternate route. The study section, from K Street at the Potomac River north to the D.C. boundary at Western Avenue, is about 4½ mi long. The southern end in Georgetown is of variable width, ranging from 35 to 56 ft. The remaining 3-mi section from Calvert Street to Western Avenue is generally 60 ft wide. The street contains many, though by no means all, of the traffic problems associated with urban arterial routes. On it throughout its length, at the time of the field study, was a streetcar operation, complete with center-of-street loading platforms along most of its length. There exist various grades ranging up to 7 percent, and curvature as high as 10 degrees.

The street traverses several commercial strip areas including Georgetown, a commercial section having many of the characteristics of a downtown area. In fact, Wisconsin Avenue, in its length in the District of Columbia from the Potomac River to Western Avenue, falls into eight very general land subdivisions. Within each of these groupings will be found a mixture of several land uses and a variation in the intensity of use. For example, in one study control section, multistory building units are located on one side of the street, and on the other side, single family dwelling units are present. Figures 3 through 6 show current conditions along the street.

While there has been considerable discussion concerning the desirability of developing a fully controlled access freeway to serve the travel desires in this area, this research study is not in any way related to that problem. Wisconsin Avenue could be "Any Street, U.S.A." It was selected for study because it offered a convenient "test track." This pilot study, therefore, while necessarily geographically related to Wisconsin Avenue, should be interpreted as national in scope.

The magnitude of the Wisconsin Avenue problem is comparable, relatively speaking, to the magnitude of the problems in most of our cities regardless of size. Basic

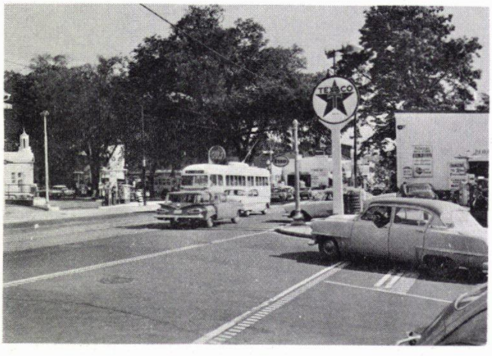

Figure 3. Looking south on Wisconsin Avenue at the "dog-leg" Q Street intersection. The street is 45 ft wide here, but narrows to 35 ft just to the north.

Figure 4. Looking south on Wisconsin Avenue at the intersection with 37th Street (right) and Calvert Street. At this curve, the street narrows, southbound, from 60 ft to 55 ft.

Figure 5. Looking north on Wisconsin Avenue at Upton Street, showing congestion ahead at the Van Ness intersection and a conflict at one of the four driveways now present on the west side of the street in this area.

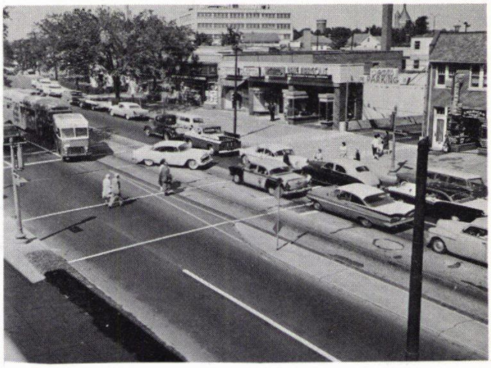

Figure 6. Looking north on Wisconsin Avenue north of Albemarle Street, showing turbulence due to pedestrians, turning vehicles, double parking, and streetcars in this major department store neighborhood.

arterial traffic operations problems exist regardless of the population groups within which these major arterials are located. Fortunately, cures for many of these problems, or at least effective remedies, fall within the purview of improved traffic operation techniques.

A variety of data-gathering procedures were employed on this study. First, all available existing data regarding current conditions on the study street were reviewed. Most of this material was in the files of the D.C. Department of Highways and Traffic, but other sources were also used. Material obtained included data on traffic volumes, traffic accidents, signal system features, existing lighting, and right-of-way locations, as well as historical background material.

Then, field crews conducted a variety of actual field studies. Two of these studies involved use of a test car traveling in the traffic flow. In one case, the car was equipped with a digital "Traffic Impedance Analyzer" which recorded vehicle speed, travel distance, and time. Frictional events occurring during the trip also could be entered in coded form by an observer. In the other case, the driver's tension level was continuously recorded by means of a galvanic skin resistance recorder.

The remaining field studies were conducted manually. Included were a series of intersection capacity studies, special studies of traffic interference at problem locations, parking regulation and usage investigations, studies of speed distributions, studies of vehicle occupancy, state-of-registration checks, and accumulation of physical feature and land-use data.

A special study was also made of police power and planning controls which relate to this problem, to determine whether or not suggested street improvements could be legally implemented.

SUMMARY OF FINDINGS

Through study of several efficiently operating urban streets, combined with other available criteria for free-flow and interrupted-flow volumes, capacity curves were developed showing traffic volumes which are considered attainable on a typical urban arterial, given any width. These curves (Fig. 7) make allowances for bus transit operations, and for continued service to intersecting streets and to businesses along the street, including some turning movements. Therefore, in either direction of travel, the curb and the extreme left lanes would carry considerably less traffic than do the remaining lanes; 1,000 vehicles per hour of green signal per 10 ft of width in the curb and left lanes as compared to 1,750 in the lanes between them. Attainment of these volumes would require efficient traffic control techniques and a smooth street surface free of streetcar tracks.

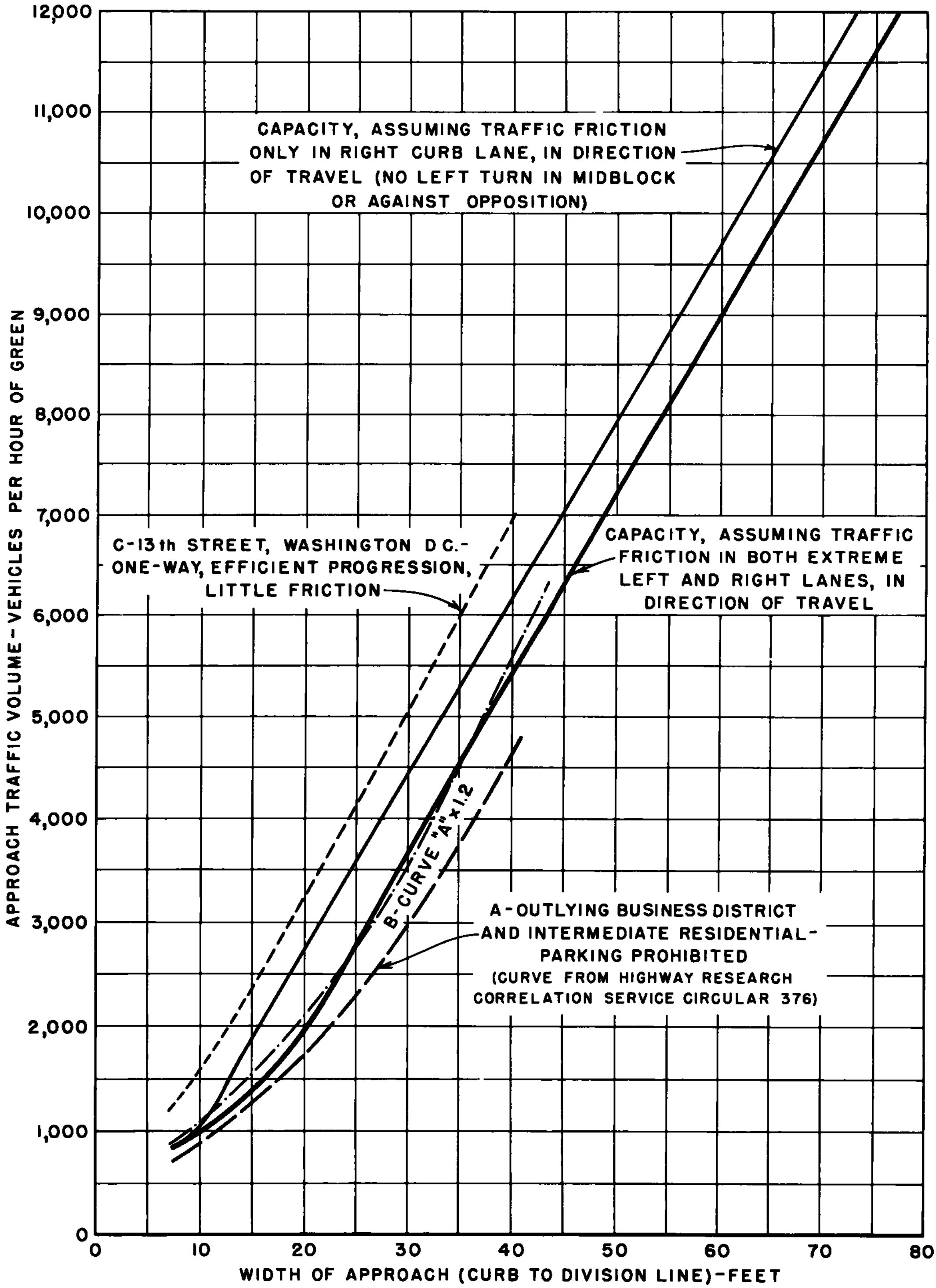

Figure 7. Intersection approach capacities of efficiently-operated two-way urban arterial streets (with progressive signalization, no parking and separate left-turn lanes in addition to width shown where opposing traffic is significant).

The steps that would be required to develop these increased volumes on the street have been classified into three phases in order of increasing complexity and expense. In the first phase, these volumes per lane may not be attained, inasmuch as resurfacing is not considered until Phase 2. They would be attainable in the remaining phases.

Phase 1

In the first phase, the suggested steps do not involve general widening, channelization, and other physical improvements. Rather, they develop more efficient use of the presently available street width at relatively little cost and without appreciable construction.

At present, very few of the intersections are operating at capacity. However, traffic flow friction throughout the street, in midblock as well as at intersections, creates turbulence for all vehicles using the street. This turbulence may cause many drivers to avoid using the street at all. The several frictional factors creating turbulence at the time of the study can be grouped into a few basic categories. These include streetcars and their loading platforms; streetcar tracks; U-turns; turning movements into and out of side streets, parking areas, and driveways; parking and parking turnover; and absence of lane markings. Because these factors produce irregular travel times, efficient signal progression cannot be established and as a result the signals themselves become a serious frictional factor.

Removal of streetcars, along with the platforms, in January 1960, is expected to result in increasing the street's traffic-carrying capability by 25 to 30 percent. However, this step is of localized interest only because streetcars remain in so few cities. In this study, removal of the unused rails is not contemplated until resurfacing is considered in Phase 2.

Other important steps will be described briefly in the suggested order of adoption.

1. Encourage drivers to signal all turns well in advance.

2. Adopt "spot" turning movement controls to alleviate special current problems at several intersections.

3. Change parking regulations. Eliminate curb parking at all times on the sections of the street narrower than 50 ft. Elsewhere, remove parking progressively as necessary. First, "spot" removal of parking at critical points may suffice. Next, complete removal of parking during the rush hours in the heavy flow direction may become necessary. Later, total elimination of parking on both sides during peak periods may be required together with widespread off-peak restrictions. Finally, may come total removal of parking at all times except at night. It is believed that reasonably adequate substitute parking is available except in the area where the narrow street width requires immediate elimination of parking. Here, development of off-street parking facilities is badly needed.

Prohibit double parking, and parking close to driveways and intersections, on the intersecting streets as well as on the study street itself.

4. Establish a few pedestrian controls.

5. Install lane markings on the existing street, to make full use of the pavement between the curbs and the remaining streetcar rails, and to guide motorists in using the center car track area on the wider part of the street in one of two possible ways, either as a two-way operation or as a reversible-flow segment.

6. Enforce prohibition of U-turns where necessary.

7. Prohibit left turns into and out of minor intersections where they are few in number yet interfere with through traffic.

8. Control turning movements in midblock into driveways and parking areas, though they need not be eliminated except in special cases. The problem here appears to be concerned more with smoothing the internal operations of the facilities served, to eliminate backups into the street, than with changes on the street itself. Where many driveways presently are located close together, serving adjacent facilities, consolidation of access points is suggested.

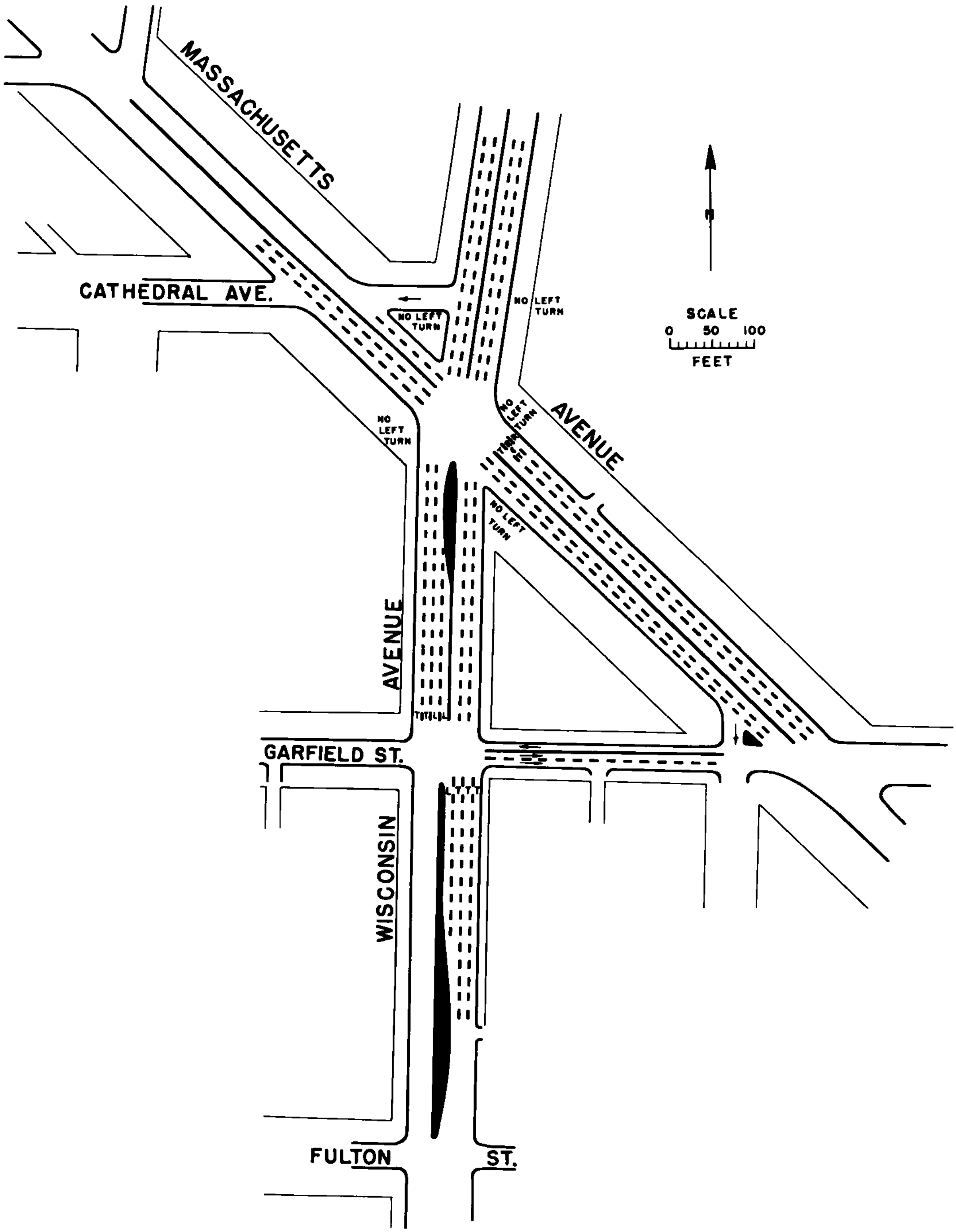

Figure 8. Proposed improvements (Massachusetts Ave.-Garfield St.).

9. Re-time the existing traffic signals to establish the best possible progression, once the foregoing steps have established a more orderly and predictable flow.

10. Make certain intersecting streets one way, particularly where a "Y" intersection is involved.

With all of the foregoing improvements, it is expected that the narrow section in lower Georgetown can accommodate about 900 vehicles per hour in one direction, not far above current peak volumes in this section. A reversible, 3 lane-2 lane, operation of the 56-ft wide section (that between 34th and Calvert Streets) can carry about 1,600 vehicles per hour in the heavy-flow direction.

The main 60-ft wide portion of the street (that from Calvert Street to Western Avenue) might handle an estimated 1,600 vehicles per hour in the heavy direction under balanced flow operation as compared with about 1,150 vehicles per hour currently. If the entire center area now occupied by the car tracks were operated reversibly, then about 1,950 might be accommodated.

Phase 2

The next series of improvements to the study street, grouped into study Phase 2, involves moderate expenditures and some construction. In this phase, it is suggested that signalization be upgraded, that improvements to specific intersections be made to permit them to handle the loads which the now smoothly operating midblock sections can accommodate, that resurfacing be accomplished, and that associated improvements be made. Briefly, the steps contemplated are as follows:

1. Widen the narrow 35-ft and 40-ft sections in lower Georgetown to 44 ft.
2. Install a modern, flexible progressive signal system.
3. Channelize several major at-grade intersections. In most cases, some widening would be involved. (On the study street, the intersections included are those at Q Street, Reservoir Road, Calvert Street, Garfield Street, Massachusetts Avenue, Upton Street, Van Ness Street, Tenley Circle, River Road, and Western Avenue.) Figure 8 shows typical proposed improvements.
4. Resurface the entire street within the existing curb lines.
5. Mark the street for five lanes, for reversible lane operations (3-2), except on the 44-ft section where only four lanes can be provided.
6. Provide bus bays at bus stops.
7. Install a modern lighting system.

With these improvements, the capacity of the improved 44-ft section in lower Georgetown should be about 1,150 vehicles per hour in the heavy direction, and that of the 56-ft segment about 2,100 vehicles per hour. The capacity of the 60-ft street sections, including major intersections, should approach 2,600 vehicles per hour in the heavy-flow direction.

Phase 3

Further improvements to increase capacity involve major expenditures and construction. Grade separations at major intersections, and widening throughout, are required. In practice, these improvements may not function efficiently unless corresponding improvements are made on a few connecting streets to prevent their overloading.

At this stage, few generalized recommendations are possible, because each improvement must be designed to fit specific conditions. For example, for the study street the following improvements are suggested:

1. Reconstruct the Q Street intersection to reduce the "dog-leg." In this one case land taking will be required.
2. Construct a grade separation at Massachusetts and Wisconsin Avenues. Three different designs have been considered in the study. The three are independent, not successive steps of progressive stage construction. One separates only the southbound Wisconsin-to-eastbound Massachusetts left turns, all other flows being at grade. The second design depresses Massachusetts Avenue under Wisconsin Avenue, but leaves the previously mentioned left turns at grade. The ultimate design (Figs. 9 and 10) separates all three of these flows.

At this location, improvement of the intersecting street, Massachusetts Avenue, east of Wisconsin Avenue will very likely be necessary if any one of the suggested grade separations is to operate efficiently.

3. Widen the street within the existing right-of-way lines, with allowance for adequate sidewalks.

a. South of Massachusetts Avenue, varying amounts of widening are possible and necessary. In Georgetown, restricted right-of-way limits widening to possibly 48 ft at most points and only 44 at some. From 34th Street to Calvert Street, a median is not considered feasible, but widening from the present 56 ft to 60 ft could be

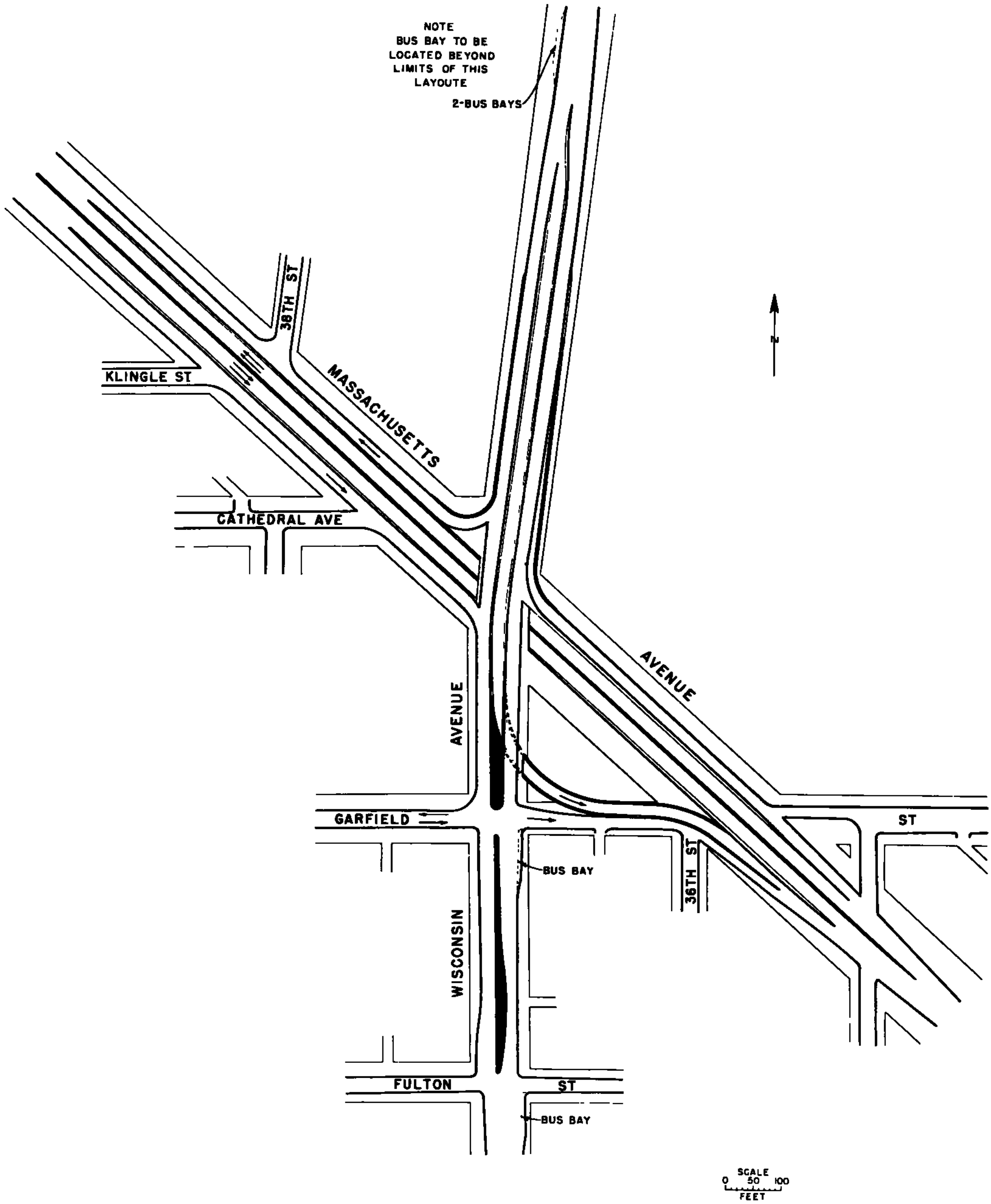

Figure 9. Proposed improvements: full grade separation of all movements (Massachusetts Avenue—Garfield Street).

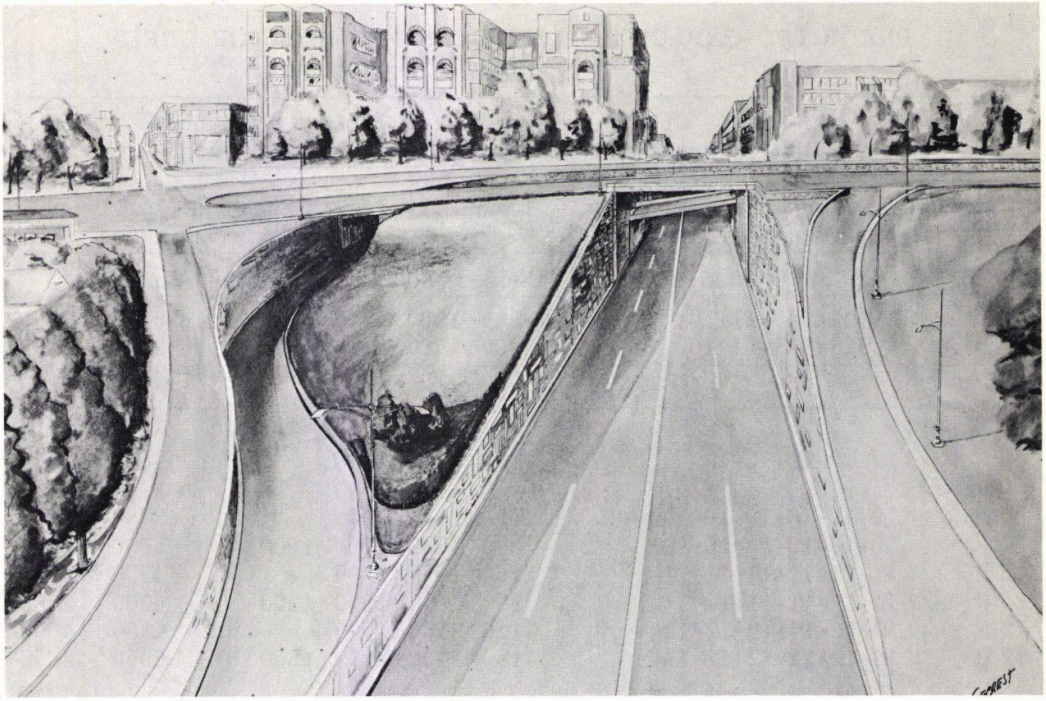

Figure 10. Ultimate design of Wisconsin Avenue at Massachusetts Avenue.

accomplished. Between Calvert Street and the Massachusetts Avenue interchange, the current 60-ft street could be widened to at least 76 ft within available right-of-way limits, with allowance for sidewalks, to provide six 12-ft lanes and, if desirable, a 4-ft median. Widening of the adjacent sections of some intersecting streets might also be needed.

b. North of Massachusetts Avenue, 120 ft of right-of-way generally are available. Four lanes in the heavy direction are needed during peak periods. Either a 4-4 balanced lane operation of eight 11-ft lanes, or a 4-3 reversible operation of seven 12-ft lanes, would be adequate to equal the capacity of controlling major intersections, the latter plan being somewhat superior from a heavy-flow volume standpoint. Appropriate modification of bus bays and of already-widened major intersections is necessary.

TABLE 1

	Traffic Volumes						
	Current Peak Hour-	Phase 1 Peak Hour		Phase 2 Peak Hour		Phase 3 Peak Hour	
Location	VPH in Heavy Direction (avg)	VPH in Heavy Direction	Percent Increase Above Current	VPH in Heavy Direction	Percent Increase Above Current	VPH in Heavy Direction	Percent Increase Above Current
Lower Georgetown	600	900	50	1,150	92	1,200 to 1,300	100-117
Upper Georgetown	1,000	1,300 to 1,600	30-60	2,100	110	2,400	140
North of Mass. Ave.	1,150	1,600 to 1,950	39-70	2,600	126	3,600	213

TABLE 2

PREDICTED CAPACITIES, VEHICLES PER HOUR OF GREEN (NO PARKING)

Curb-to-Curb Width	Width Distrib. into Lanes (Vertical Line Represents Division Line Between Directions of Travel)	Volume Distrib. by Lanes—Heavy Flow Direction: Curb Lane 1	Lane 2	Lane 3	Lane 4	Lane 5	Total, All Lanes	Volume, Opposing Direction—Total
(a) Car Tracks Present but Unused (No Platforms Remaining)								
60 ft	10-11-9+9-11-10	900	1500	800			3200	3200
60 ft	10-11-9-9+11-10	900	1500	1000	500		3900	1800
(b) No Car Tracks								
5 lanes								
60 ft	12-12-12+12-12	1150	2150	1500			4800	2650
6 lanes								
60 ft	10-10-10+10-10-10	1000	1750	1000			3750	3750
60 ft	10-10-10-10+10-10	1000	1750	1750	1000		5500	2000
66 ft	11-11-11+11-11-11	1100	1950	1200			4250	4250
66 ft	11-11-11-11+11-11	1100	1950	1950	1200		6200	2300
72 ft	12-12-12+12-12-12	1150	2150	1500			4800	4800
72 ft	12-12-12-12+12-12	1150	2150	2150	1500		6950	2650
7 lanes								
70 ft	10-10-10-10+10-10-10	1000	1750	1750	1000		5500	3750
70 ft	10-10-10-10-10+10-10	1000	1750	1750	1750	1000	7250	2000
77 ft	11-11-11-11+11-11-11	1100	1950	1950	1200		6200	4250
77 ft	11-11-11-11-11+11-11	1100	1950	1950	1950	1200	8150	2300
84 ft	12-12-12-12+12-12-12	1150	2150	2150	1500		6950	4800
84 ft	12-12-12-12-12+12-12	1150	2150	2150	2150	1500	9100	2650
8 lanes								
80 ft	10-10-10-10+10-10-10-10	1000	1750	1750	1000		5500	5500
80 ft	10-10-10-10-10+10-10-10	1000	1750	1750	1750	1000	7250	3750
88 ft	11-11-11-11+11-11-11-11	1100	1950	1950	1200		6200	6200
88 ft	11-11-11-11-11+11-11-11	1100	1950	1950	1950	1200	8150	4250
96 ft	12-12-12-12+12-12-12-12	1150	2150	2150	1500		6950	6950
96 ft	12-12-12-12-12+12-12-12	1150	2150	2150	2150	1500	9100	4800

Note: At any level, provision of a continuous midblock nontraversable median, together with separate L. T. lanes outside the continuous through lane limits, will increase capacity by 700 vphg. Width of median will be in addition to widths shown.

Median dividers are desirable, provided that their restriction of service to fronting businesses is found acceptable. If the medians are provided, or if pedestrian refuge islands are adopted to aid pedestrians in crossing the wide street, then the reversible plan will not be feasible. The preferred design is an 8-lane divided facility, composed of four 11-ft lanes in each direction plus a 4-ft median, with bus bays and with appropriate widening at important intersections to provide for a left-turn lane.

4. Although not critically needed, a grade separation at Tenley Circle would provide more flexible operation and lower travel times through this busy location, particularly helping Nebraska Avenue cross traffic.

It is estimated that, following Phase 3, the 44-ft street in lower Georgetown can accommodate 1,200 vehicles in the heavy direction, while 2,400 can be handled from 34th to Massachusetts on the 56- to 76-ft street. Assuming that the "ultimate" improvement is adopted at the Wisconsin-Massachusetts Avenue intersection, the 8-lane

TABLE 3

Location	Current Actual Average Speeds			Estimated Future Average Speeds (Volumes at or Below Practical Capacity)								
				Phase 1			Phase 2			Phase 3		
	Peak Period		Daytime	Peak Period		Daytime	Peak Period		Daytime	Peak Period		Daytime
	Heavy Dir.	Light Dir.	Off-peak Period	Heavy Dir.	Light Dir.	Off-peak Period	Heavy Dir.	Light Dir.	Off-peak Period	Heavy Dir.	Light Dir.	Off-peak Period
Lower Georgetown (M-Reservoir)	14	14	13	18	18	16	23	21	22	25	21	22
Upper Georgetown (Reservoir-Massachusetts	19	20	19	24	22	22	30	25	25	30	25	25
North of Massachusetts Avenue (Massachusetts-Western)	20	22	21	25	23	23	30	25	26	30	25	26

divided facility north of Massachusetts Avenue can accommodate 3,600 vehicles per hour in the heavy direction. If this is expanded on the basis of a 60-40 traffic split between directions, assuming desirable achievement of 10 percent of the ADT in the peak hour, the equivalent ADT is 60,000, adequate for the predicted 1980 ADT of 58,000. If the current value of 7 percent of the ADT in the peak hour on Wisconsin Avenue is acceptable, then the equivalent ADT is higher, 86,000. Table 1 is a compilation of the traffic volumes developed in three phases of the study, while Table 2 gives the predicted capacities of the originally-60-ft-wide section for the various improvement levels considered.

Peak hour speeds in the heavy direction, after completion of all improvements considered in the three phases, are estimated to be 25 mph in Georgetown and 30 mph throughout the remainder of the street. Table 3 gives the current average speeds as well as speeds that could be provided by each of the several phases of improvements.

From a research standpoint, it would be both interesting and valuable to use the street as a test track, actually carrying out each of these improvements separately in the order suggested, and making detailed observations to determine the volume increase produced by each. From a practical standpoint, however, time probably would not permit such an incremental approach, even if research funds and manpower were continuously available. Traffic demand is increasing at too rapid a rate to permit a series of minor improvement steps, each necessarily followed by a familiarization period for traffic before useful observations could be recorded. More rapid adoption of improvements is desirable.

ACKNOWLEDGMENTS

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