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Presidential Address.

By Professor R. W. H. Hawken, B.A., M.E., M. Inst. C.E., M.I.E. Aust.

(Delivered before the Royal Society of Queensland, 29th March, 1926.)

Ladies and Gentlemen,—The report already submitted to you shows continued steady progress of the Royal Society of Queensland, and I would like to record here my appreciation of the keen spirit shown by the Council and officers. The several matters referred to sub-committees have been dealt with effectively, and generally an air of ordered efficiency has made the position of President as pleasant as it was honourable.

The continuous supply of good papers has been a most desirable feature of the year's activities and the attendance at meetings has been satisfactory, particularly to lectures of a semi-popular nature. This brings before us the question of rooms more suitable for members generally. The Royal Society exists for two purposes, one to encourage and record research in science, the other to interest and instruct the public in the aims and achievements of scientific work. For the latter purpose it is necessary to offer existing and potential members a central place for lectures and exhibits. Our present room is some distance from trams and trains and, especially in the evenings, it demands energetic enthusiasm on the part of those attending a meeting.

Your Council has considered the question of acting in conjunction with other societies of similar aims, but funds would not permit of any change at present. I commend the matter to the incoming President and Council to explore its possibilities.

It is my sad duty to mention the loss by death of five members of the Society during the year.

Mr. J. H. Maiden was an honorary member. His name is familiar in other countries as well as in Australia where his services to science, particularly to Botany, for forty years are recorded in his monumental volumes on Australian Flora. His ready assistance to fellow workers and his inspiring addresses and lectures will be treasured memories of a notable man.

Professor S. B. J. Skertchly, known to many of us by his racy articles on science, had a long career, forming a link with the great mid-Victorian personalities. For thirty-six years he resided in Queensland. He was first president of the Queensland Naturalists Club and a former president of the Queensland Royal Society and a member of various public bodies. His forte lay in showing that science is not necessarily dull, and he himself would have been the last to acknowledge that the scientist himself need be always solemn or even discreet.

Mr. Thomas Steel was a life member and the author of numerous papers published by the Linnean Society of New South Wales. He resided for thirty years in New South Wales and was only an occasional visitor to Brisbane.

Mrs. Lumley Hill had been a member of the Society for three years. Her membership of the Royal Society was part of a policy of using her extensive personal influence to advance the best interests of the community.

Mr. Douglas Ogilby was formerly a member. His papers on fishes are a valued portion of the Proceedings of the Society.

Mr. Kenneth Swanwick was held in affectionate regard by all who knew him. Always his actions were dictated by the idea of helping others.

The passing of those well known to us becomes endurable only because it is inevitable.

* * * * * *

THE LOCATION OF CITY BRIDGES.

(Plates I.-V., Text-figures 1-8, Tables I. and II.)

In what follows I will endeavour to traverse the rational or scientific principles to be applied to problems of "The Location of City Bridges," especially with reference to Brisbane, which furnishes a difficult example.

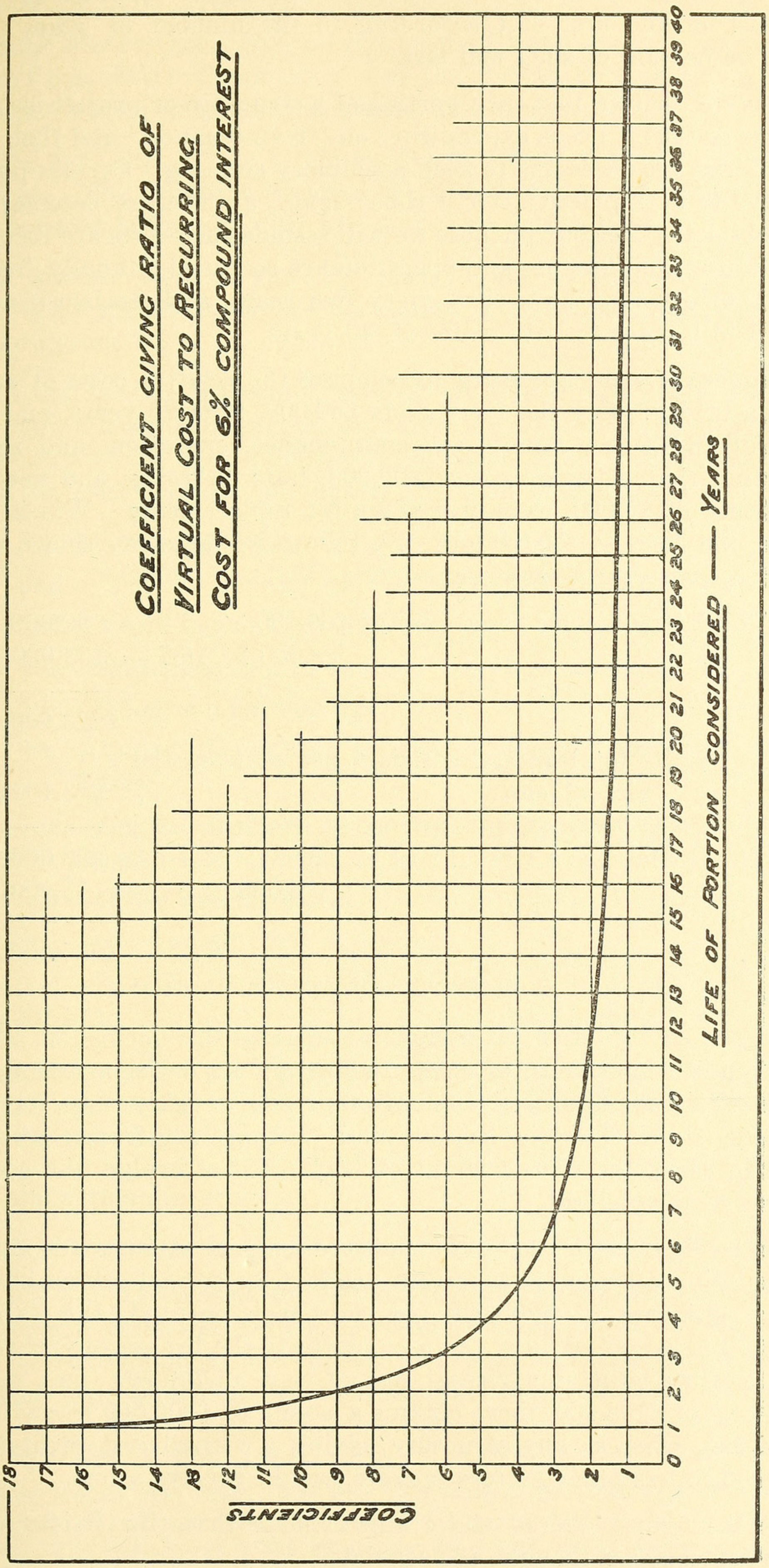
The problem is an engineering one in the broader sense—that is to say, the relative economies of various schemes have to be studied as well as the feasibility of each from a constructional point of view. The future must be visualised, yet present interests be conserved; convenience to all classes of expected traffic must be allowed for, and, not least, the æsthetic should be kept in mind. The results are to be finally embodied in one definite structure or, perhaps, more than one, as in the present case.

Such a set of conditions implies compromise and almost certain differences of opinion as to the conclusions arrived at, but I hope to show that the points of difference may be narrowed down, and in many cases eliminated.

Projects of this kind involve money, in this case millions of pounds. Money must be presumed to be always capable of earning interest. Compound interest is a schoolday nightmare gladly forgotten, but without some understanding of its results many of the comparative estimates to be given later would be vague and misleading.

I was fortunate in having simplified such computations* previously, and in expressing results graphically. It will be sufficient for our

* The details are expounded in a paper entitled "Economy of Purchase with Curves of Relative Cost," by the author, published by the Institution of Engineers, Australia, 1924.



Text-figure 1.

present purpose to explain the curve of Text-figure 1, which gives the multiplier of the first cost according to the number of years that a project or portion of such will last.

It is well known that each portion of a structure or project is subject to decay, so that it needs expenditure on "maintenance" and that wages and material are necessary to keep machinery running. Certain portions also have to be replaced after a time; again, a structure becomes worn out or obsolete. For our purpose we will assume such costs are recurring. For instance, maintenance and operation are reckoned annually; repainting of a bridge may be needed every five years, and steelwork may be assumed to last, or to have a life of, 40 years.

Suppose it were necessary to compare the relative costs of a ferry and of a bridge. Say the ferry costs £60,000, lasts 20 years, and has a charge of £8,000 per annum for maintenance, operation, and replacements, and that a bridge costs £200,000, lasts 40 years, and needs the expenditure of £5,000 every five years for replacements. Which is the cheaper, the ferry or the bridge? By the use of the curve shown we see that with money at 6 per cent.—

The Ferry has a virtual cost of £60,000 × 1·5 =	90,000
8,000 × 16·7 =	133,600
	£223,600
or its total annual cost is 6 per cent. on the virtual cost	£13,400 p.a.
The Bridge has a virtual cost of £200,000 × 1·1 =	220,000
5,000 × 3 =	15,000
	£235,000
or its total annual cost is 6 per cent. on the virtual cost	£14,100 p.a.

Other considerations, of course, affect a final decision, but when it is realised that the figures given above represent roughly those for actual conditions above Victoria Bridge, and that several ferries would be needed to carry the same amount of traffic as the bridge, the economy of a bridge is apparent.

Use has been made of the curve also to compare savings; for instance, if by building a bridge in a certain position an annual saving of traffic mileage estimated at £200,000 per annum is insured, this is worth £3,340,000 as a capital sum. Consequently if the bridge to ensure such saving may be built at a virtual cost of, say, £1,700,000, that is at an annual cost of £102,000, there obtains a saving of £200,000 less £102,000, say £98,000, whereas any structure having a virtual cost greater than £3,340,000 unless other factors operate, would involve a loss.

As the figures quoted above approximate those for Brisbane, this elaboration may be thought appropriate.

The coloured wall map of Brisbane* was prepared by the Town Planning Association. One of the most pleasing features of the work of the Cross River Commission was the public-spirited action of this and other bodies in making available data and material.

The key map (Plate 1) shows the length of river in the Brisbane city area. The numbers indicate the order of time of construction of the recommendations. Tubes are shown by dotted lines.

A contour map of the city area (Plate 2) and a model,† both prepared by the Cross River Commission, show the area affected by the main proposals.

To systematize the comparison of suitable sites a table was drawn up to show a net cost or saving computed for several alternative projects. This table with the figures deduced as outlined below is shown on page 21. It will be seen that the columns of the table are headed:—

1st.—Percentage of traffic that would use the proposed bridge.

2nd.—Vehicles per day carried by new structure 15 years hence.

3rd.—Years hence Victoria Bridge will again be saturated.

4th.—Annual saving in haulage cost 15 years hence.

5th.—Other annual savings.

6th.—Annual losses due to grades, energy, and time 15 years hence.

7th.—Annual costs due to construction, maintenance, and replacements.

8th.—Other annual costs.

9th.—Net annual costs or savings.

10th.—Factors not expressed in money.

An endeavour will be made to explain the assumptions and rational deductions made for the purpose of drawing up such a table, and then show the application of these results in the form of proposed bridges, tubes, ferries, and a canal.

Taking these in order:—

1. *Percentage of Traffic Using Any One Proposed Bridge.*

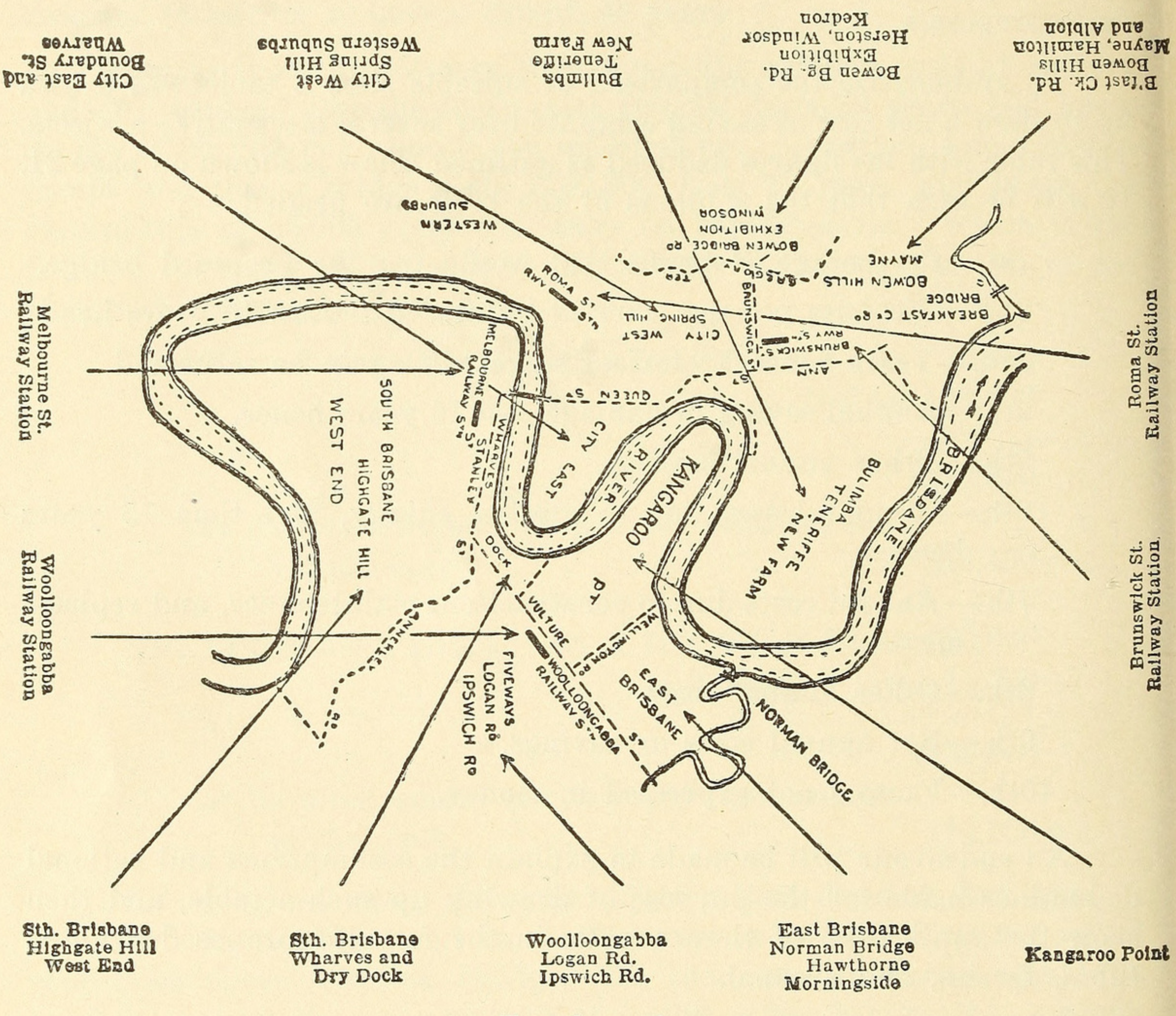
This was arrived at by an analysis of the traffic census figures; those present doubtless have some recollection of the cards (Text-figures 2 and 3) handed out at one end of the bridge and collected at the other end, each type of vehicle having a separate-coloured card. Seven areas

* The original is about 7 feet square, but is unsuitable for reproduction.

† Two models were made. The first to a scale of 200 feet to 1 inch horizontal and 20 feet to 1 inch vertical. This formed a useful table model for explanation purposes. The second was 1/200 of natural scale laid out in concrete, with which hydraulic experiments were made to determine the workability of the proposed canal.

on each side of the river were mentioned on detachable portions. Each traveller was asked to tear off the portions indicating the place or places on each side of the river between which he was journeying. From the cards collected not only the number of each kind of vehicle was found but also the places between which each vehicle was travelling.*

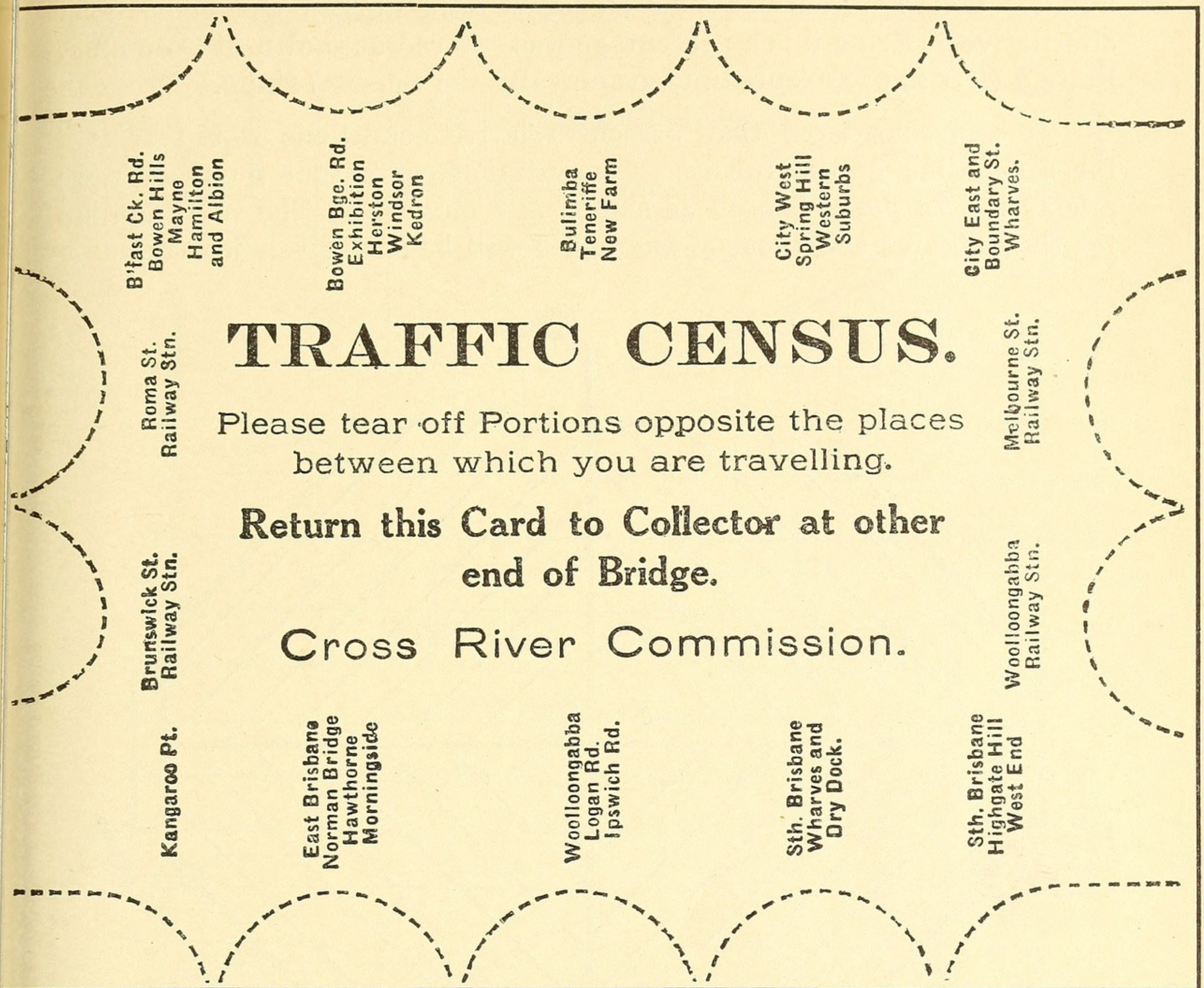
Cards were distributed and collected on the ferries and counts of foot passengers also were taken. The tram census was carried out by using special tickets, and by an analysis of the ticket collector's returns. The public in this latter case were not affected.



Text-figure 2.

Then for any assumed site, acting in conjunction with the present bridge, the route which would be followed by traffic could be discussed. For instance, assuming the Bowen Terrace site were being considered, a vehicle recorded as from Roma Street Railway Station to Melbourne Street Railway Station would certainly use the present bridge, whereas

* The small number of informal records was a tribute to the intelligence and patience of the community, and of the collecting staff. The original suggestion of such a census was made some years ago by the Institution of Engineers. The subdivisions of areas adopted was the result of much consideration and discussion among the members of the Commission. Text-figures 2 and 3 are the two faces of the one card.


B'fast Ck. Rd. Bowen Hills Mayne Hamilton and Albion

Bowen Bge. Rd. Exhibition Herston Windsor Kedron

Bulimba Teneriffe New Farm

City West Spring Hill Western Suburbs

City East and Boundary St. Wharves.

Roma St. Railway Stn.

Melbourne St. Railway Stn.

TRAFFIC CENSUS.

Please tear off Portions opposite the places between which you are travelling.

Return this Card to Collector at other end of Bridge.

Cross River Commission.

Brunswick St. Railway Stn.

Woolloongabba Railway Stn.

Kangaroo Pt.

East Brisbane Norman Bridge Hawthorne Morningside

Woolloongabba Logan Rd. Ipswich Rd.

Sth. Brisbane Wharves and Dry Dock.

Sth. Brisbane Highgate Hill West End

Text-figure 3.

if from Brunswick Street Railway Station to East Brisbane, it would use the new bridge. Decisions as to such were simple, but for a vehicle from, say, the Exhibition to Woolloongabba, opinions might differ.

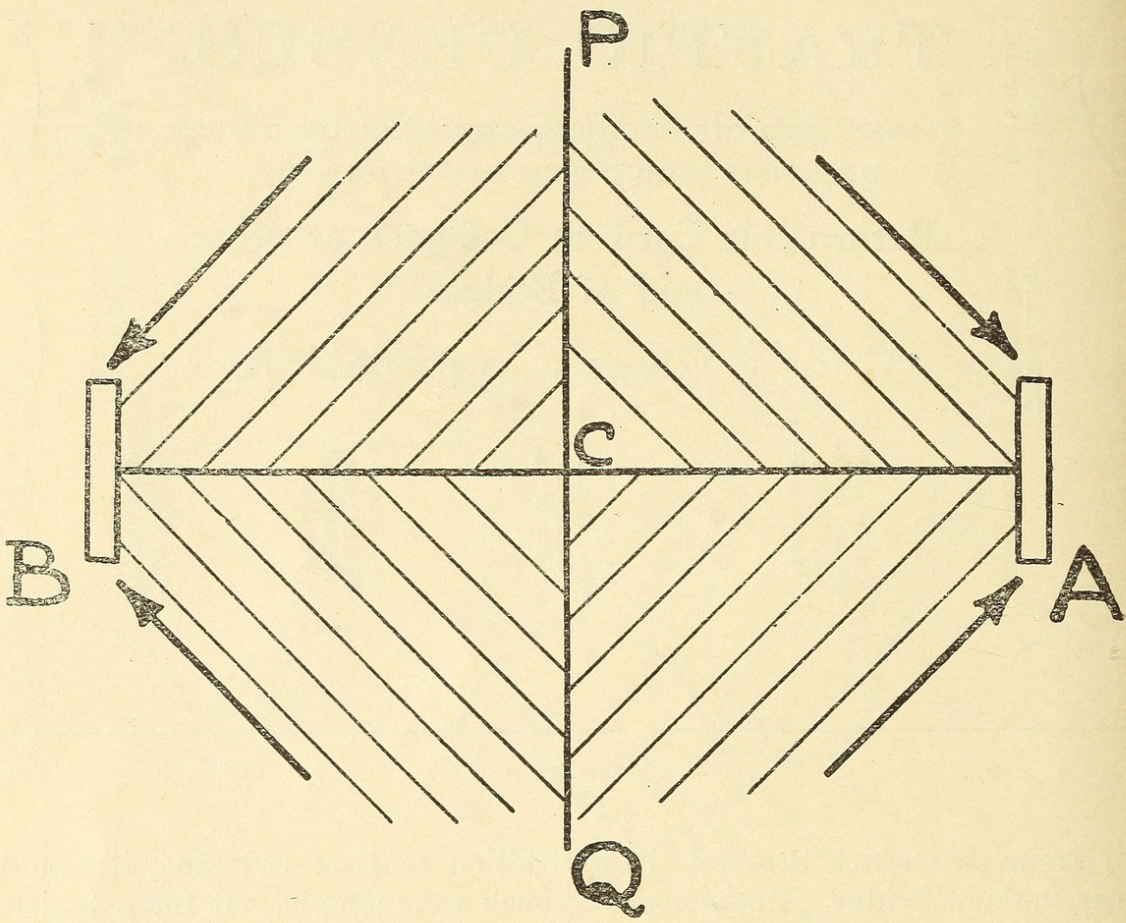
A very simple generalization assisted greatly as follows:—

Referring to Text-figure 4.—If *AB* is a line joining two bridge sites and *PCQ* bisects *AB* at right angles at *C*, it is apparent that a vehicle in the area *ACP* going to the area *ACQ* would prefer to go through *A*. Similarly one in *BCP* going to *BCQ* would go through *B*.

This is for distance only and for straight line movement, but it is reasonable to say that *PQ* is the dividing line of areas. The windings of the river, the presence of grades or other obstructions, cause modifications of the theoretic deductions, but the general principle was found most useful.

The numbers going between the several areas on the North side to the several areas on the South side being known from the census records, using the principle mentioned above and some judgment and knowledge of local conditions with regard to areas not otherwise determined, the number that would use a new structure was worked out for several alternatives. From this a percentage was entered as shown in Column 1. Plate 3 (left figure) represents graphically the census results.

It was considered that present relative conditions would remain for some time in the future. Computations of actual numbers were put as for 15 years hence* as shown in Column 2. The investigation for these figures and those of Column 3 will be now given jointly.

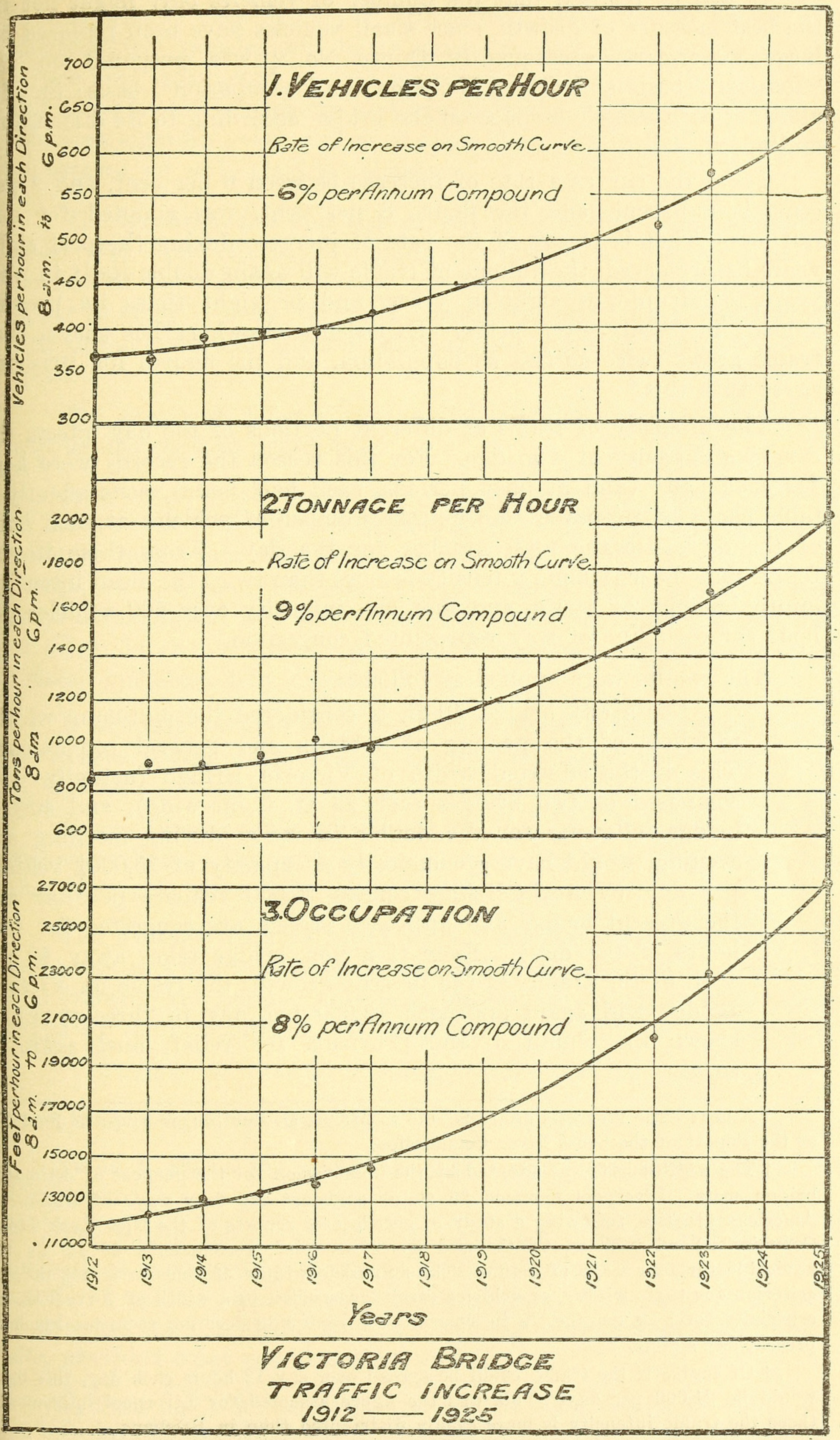


Text-figure 4.

The third column of the table, being a prediction of future events, *i.e.*, years that will elapse before traffic over Victoria Bridge again approaches 12,000 per day, has the interesting feature of prediction. The figure was necessary in order to determine the sizes of proposed new bridges or tubes. The records of previous counts of traffic were available; from these tables curves were drawn up showing the variation in numbers of each type of vehicle.

The results of the census figures for various years were condensed and rearranged, as shown in Text-figure 5.

* A definite time in the future was needed, since in the computations of virtual cost there are items such as mileage and time and energy losses, which vary with the number of vehicles, whereas the construction cost of a structure is a fixed quantity. For a comparative analysis, the time 15 years ahead was chosen since conditions then can be fairly anticipated. The more rapidly developing areas are those primarily served by the new bridge, so that the error, if any, is on the right side.



Text-figure 5.

It will be realised that the number of vehicles only might not be the best measure of growth, since small vehicles have been replaced by large motor-cars, consequently Curve No. 2 was prepared on the "tonnage" basis and Curve No. 3 on the "occupation" basis; that is, allowing each vehicle a space on the bridge according to its dimensions and speed.

From the curves a rate of increase between 6 per cent. and 9 per cent. is apparent, and the figure 8 per cent. was adopted for our purpose. That is to say, if the rate of increase during the past eight years be preserved, the volume of traffic will again double itself in nine years, quadruple in eighteen years, and be eight times its present amount in twenty-seven years. Experience elsewhere has shown that traffic grows twice as fast as population, and the figures for Brisbane agree with this.*

The intensity of traffic at different portions of the day affects the carrying capacity of a bridge. For this reason the records were kept for each hour (and at busy periods, each half hour), consequently a table could be prepared showing the number of vehicles at each hour of the day, also the total number for the day. From these it was found that the maximum intensity is more than twice the mean intensity, approximately 2·2 times, and that any intensity over 500 vehicles per hour for each line of way represented congestion.

The results were applied as follows:—

For a city bridge, 40 ft. is considered the minimum width† to allow of the passing of vehicles and general convenience. This is the effectual width of Victoria Bridge (actually it is composed of two bridges each 22 ft. 6 in. wide), and such a bridge, allowing for the double intensity during morning and evening, would have economically a capacity of 15,000‡ vehicles per day (Victoria Bridge carries 16,000 vehicles per day and the present bridge and approach streets are congested for four hours of the day). Even if a new bridge takes away 40 per cent. of the traffic, at the present growth, the traffic on Victoria Bridge will again approach 12,000 per day in three years, as shown in column 3, and provision for relief must again be sought.

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* A neat little theoretic analysis, due to Mr. G. O. Boulton, is given in Part III. of the Report of the Cross River Commission.

† The width 40 ft. was adopted by the Commission for the purpose of estimating bridge costs. Liverpool assumed 36 ft. as sufficient for four ways of traffic, but American practice, following a study of speeds (see reports of the New York Tunnel Commission) of vehicles, widths and space occupied, recommends 40 ft. as that advisable for four ways of traffic. The maximum widths of vehicles is not the only criterion for these widths, as vehicles carry loads often to a width of 7 ft. 6 in. and especially for long lengths, 15 in. clearance on each side does not seem too much for present day speeds.

‡ Of course if the traffic could be spread over say 12 hours each day, this figure would be 24,000 per day. This was the figure assumed for Liverpool; presumably there the traffic intensity is more evenly distributed than in Brisbane.

It will be clear from the figures mentioned that in fifteen years hence 52,000 vehicles will be crossing per day, the increase being at 8 per cent. compound interest on present traffic, and that bridges of say three times the capacity of Victoria Bridge will be required within the next eighteen years, and as it takes five years to build one of these structures, an early start is necessary.

The inconvenience and risk caused by congestion are undoubtedly great; yet these effects only apply for portion of the day and to a portion of the vehicles, whereas the losses due to detours and grades apply to every vehicle. Grades in themselves also tend to cause congestion through the difficulties of starting and stopping and to the loss of speed.

The effects of detours will be discussed now and those of grades will be discussed in detail later.

In order to make comparisons in terms of money it was necessary to work out a value of each vehicle-mile. That is to say, the cost of running each vehicle one mile, such cost to include the value of the occupant's time and the cost of replacements and overhead charges. Such a calculation was of the kind familiar to engineers, a compound of scientific analysis, assumption and compromise, always new, rarely precise, but necessarily decisive.

A separate-coloured card was used for each type of vehicle. From the census record was obtained the proportional number of each kind of vehicle.

It was thus possible to compute the cost of running an imaginary average vehicle. The analysis for vehicles was shown separately from that for trams, since their properties are so different.

The average distance saved by a vehicle travelling between each two areas was deduced by examining the route expected to be followed and knowing the number travelling on each route, an average mileage saved by the new project was computed; then

Number of vehicles × *mileage saved* × *value per mile*

gave the saving to be expected.

Table I. shows the results for the major recommendation of the Commission.

The fourth column of Table II. given on page 21, and the census deductions expressed by diagrams similar to Plate 3, show the relative merits of various sites from the point of view of the amount of traffic that would use it and the mileage saved, as compared with the present site, provided other conditions are equal.

Column 5, "other savings," tabulated such things as elimination of existing ferries, &c.

TABLE I.

Annual Saving in Haulage Cost (Distance only, Grade effects zero), for the Commission's Major Recommendations I. to IV., considered as a whole.

The Commission's Major Recommendations Comprising		Percentage of cross-river traffic carried	Miles saved per vehicle for given percentage	Cost per vehicle mile (pence)	Six Years Hence			Fifteen Years Hence		
					Vehicles per day =1.6 times present value *	Daily Saving	Annual Saving per year of 340 days	Vehicles per day =3.2 times present value *	Daily Saving	Annual Saving per year of 340 days
I. Petrie's Bight	Vehicular Traffic	41	.85	13.6	9,400	£450	£194,000	† 16,140	£900	£388,000
	Tramcars	32	.32	98.3	910	£120		1,820	£240	
II. Grey Street	Vehicular Traffic	21	.31	13.6	4,750	£82	£28,000	9,500	£164	£56,000
	Tramcars	—	—	—	—	—		—	—	
III. Victoria Bridge	Vehicular Traffic	38	—	—	8,850	—	—	† 16,820	—	—
	Tramcars	68	—	—	1,930	—		3,860	—	
Total					25,840	£652	£222,000	48,140	£1,304	£444,000
IV. Sydney Street Transporter	Vehicular Traffic	** 8	.57	13.6	Not yet constructed			** 3,540	£114	£39,000
	Tramcars	—	—	—				—	—	
Total								51,680	£1,418	£483,000

* Assuming annual rate of traffic increase, 8% compound.

** Comprising 6% from Petrie's Bight bridge—*i.e.*, 2,660 vehicles. 2% from Victoria Bridge—*i.e.*, 880 vehicles.

† Exclusive of vehicles using Sydney Street transporter.

It remains to investigate the cost of the kind of structure suitable to any one site in order that the net relative costs or savings for all sites may be determined.

If there were no shipping to consider the choice of sites would be simple, but having obtained estimates of the cost of building new wharves down stream and of the losses entailed to the city as a whole by the closing of the river to seagoing vessels, say from Wellington road upstream, the figures supplied us were so large that any economy of bridge construction or traffic convenience obtained by low-level bridges closing the river would be negatived. On the contrary the aim was, if possible, to increase facilities for large shipping.

To provide facilities for shipping, four methods are available:—

(*a*) A tube under the river,

(*b*) A high-level bridge in one clear span over the river,

(*c*) An opening bridge that will allow ships to go through, involving a stoppage of road traffic for a certain time,

(*d*) A diversion of portion of the river along which shipping would go and over which a high-level bridge could be built at perhaps less cost than is involved in (*a*) or (*b*).

In connection with (*a*) and (*b*), that is, a tube and a high-level bridge, two intensely important factors affect location. These are:— First, the necessary grades, and second, the rise and fall. The two are interconnected but allow of separate methods of treatment. An attempt at expressing the effects of these in terms of money has been made. Previously in an investigation of this kind, a ruling grade having been adopted, the height of the bridge was kept as low as possible, but no quantitative analysis was made that would ensure that relative effects could be determined.

The main features of this investigation will now be outlined.

The effect of grades is reflected in two ways, classified here as "time losses" and "energy losses" respectively, though as mentioned the two are interconnected. The value of time varies with each person and vehicle, and with the hour of the day.

As a conservative figure the basic wage 2s. an hour was adopted for each person, with a few exceptions, such as tram drivers.

The loss of time caused by grades is readily deduced if the assumed data is constant, since power × speed is equal to "work" done or energy used and/or stored up, so that if a grade* multiplies the

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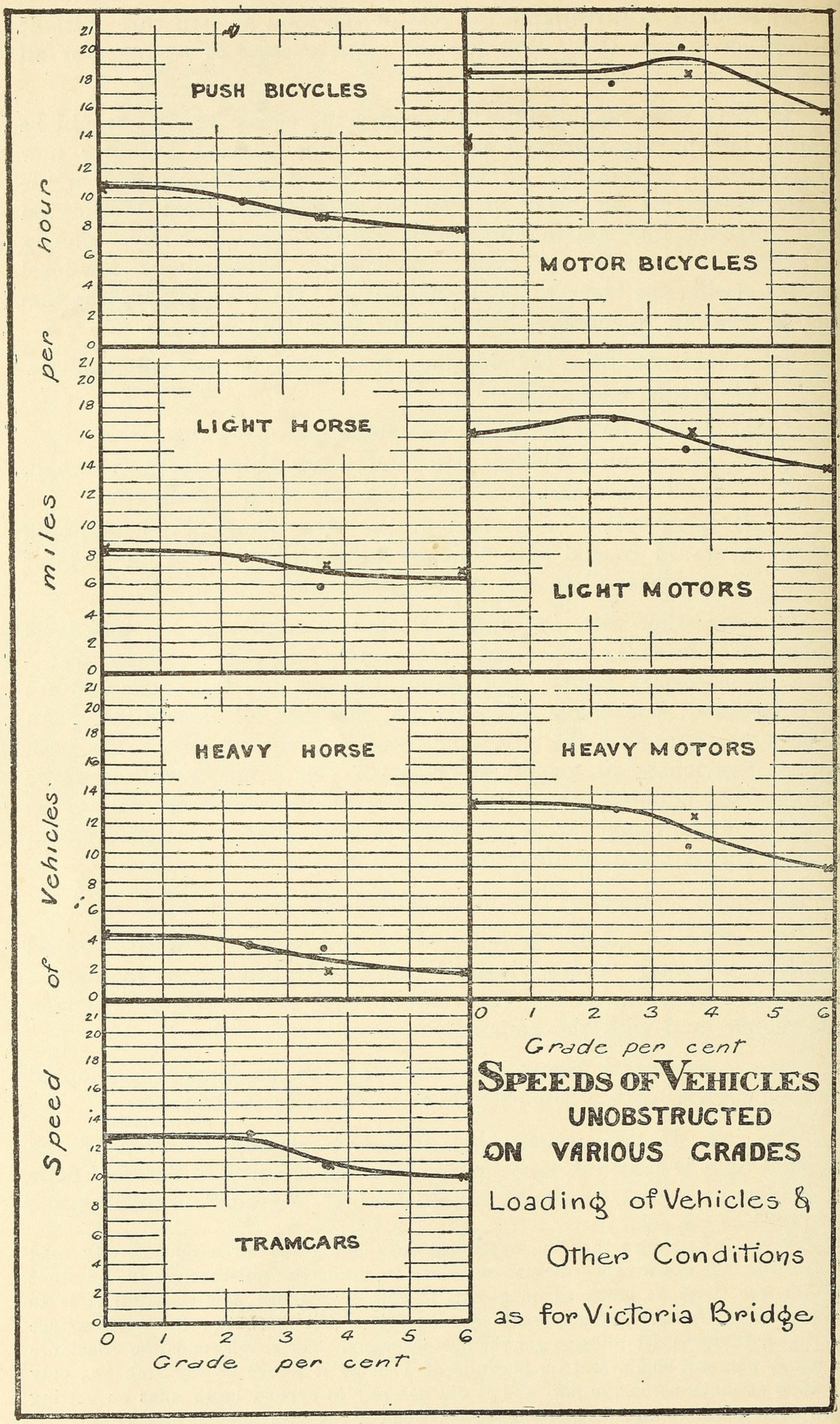
* When it is known that the resistance on a flat grade for a modern city road is say 25 lb. per ton weight, whereas on a 1 in 20 grade the resistance is 137 lb., that is, over five times as much as on a flat, it will be realised how essential it is to preserve easy grades. The apparent paradox arises that the better the road surface the easier grades ought to be to get the best economy. For rough roads the resistance on a flat was say 80 lb. and on a grade of 1 in 20 it would be say 192, *i.e.*, only 2½ times as much as on the flat, and it did not pay to expend large sums on getting easy grades, but with modern city smooth pavement the case takes a new aspect.



Text-figure 6.

resistance, the speed drops accordingly, providing the power is kept constant. Or alternatively, if the same speed is to be preserved the horse-power must be multiplied in proportion to the resistance. Men and horses have a margin of power; for instance, some people run between wickets and others to catch a train, but this can be kept up only for a limited period. Motor-cars and trams have reserves of power for quick starting, for emergencies and to preserve their speed, so that for vehicles having a range of power any theoretic estimation of average actual losses caused by grades becomes very complicated.

Many computations were made during the investigations of the Commission and strenuous discussions entered into as to the actual figures appropriate to each case. Finally experiment was decided on. Men stationed with field glasses and stop watches at convenient points observed the passage of vehicles over two separate stretches of road for some days, and also over Victoria Bridge. The plotted results are shown in Text-figure 6. The drop in speed on grades is definite. The minimum grade recommended for bridge approaches in England and America is 1 in 30. In our observations even on this grade nearly all the vehicles showed a decided loss of speed. These experimental results confirmed the Commission in their recommendation that the limiting approach grades should be 1 in 30.

Because this result has such an important bearing I have gone into some detail. It is a main cause of the great expense of tubes and high-level bridges, since it causes extra length*; again, steep grades cause waste of time and energy. In smaller country bridges and in some city bridges the effect of grades has been neglected; in the latter case with serious results on the efficiency of the structure.

The energy losses or effect of rise and fall had not, so far as we know, been done previously in a form suitable for our purpose. It is obvious that, in going up a grade, power is used to overcome resistance and to store up energy, and that, in going down, part of such energy is wasted in heat with the consequent wear. It is presumed here that the momentum acquired running down-hill cannot be used to climb the next hill; such is only possible on an open road, and then only to a limited extent. No previous estimate was available, though it is mentioned somewhere that—

> "The famous Duke of York
> He had ten thousand men,
> He marched them up a hill
> And marched them down again."

The recorded results of this experiment were useless for the present purpose.

If one is locating an approach road specifically to one point on the top of a hill, the steepness desirable is limited by the power of

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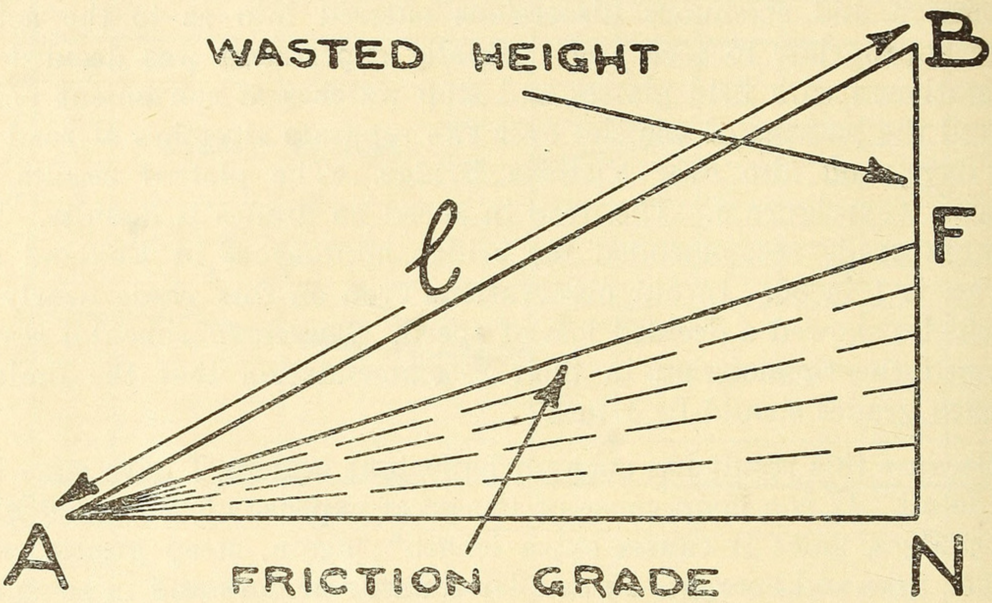
* For instance, to rise 100 ft. on 1 in 30 requires a length of 3,000 ft.; this on each side of the river and 1,000 ft. width of river makes 7,000 ft. the approximate length of a tube if built or of a high-level bridge, including approaches.

vehicles, convenience of drainage and the other factors affecting road construction. If, however, as in the present case, two points at about the same level and on different sides of a river are to be connected, then the only grade that involves no loss of energy is that on which brakes are not required, what we have called the "Friction Grade."* That is to say, one can go up and down on such a grade by using the same amount of energy as would be used in going the same distance on a flat. On any steeper grades, up and down, there is a loss of energy measured by the weight lifted multiplied by the "wasted height" (see Text-figure 7); that is, the total rise less the height that would be



Text-figure 7.

reached on the friction grade on the same length. The effect of this is the use of extra power going up (in a motor-car measured by petrol and wear and tear) and going down the energy of position or "potential energy" thus gained is lost in heat caused by the brakes. Each vehicle is presumed to return so that only the tonnage one way is to be taken for total loss.

For a long length of various grades the computation has been generalised, with the result as follows. If the "average grade" be computed over the length, always assuming that a grade less than the friction grade, including a flat, is considered as the friction grade—

If f = friction resistance per ton, say about 28 lb.

g_a = average grade.

Then the mean tractive effort is $\frac{f + g_a}{2}$

and the extra tractive effort over that for a flat or friction grade is

$$\frac{f + g_a}{2} - f = \frac{g_a - f}{2}.$$

* The "friction grade" varies with the vehicle; for trams it is about 1 in 100. For other vehicles 1 in 80 was assumed for modern smooth city streets. The apparent paradox appears that the better the road surface the easier the grade should be to get the best economic advantage.

I might state that this simple formula was the result of many weeks of joint work and thought. The Technical Assistant to the Commission, Mr. G. O. Boulton, B.E., in this, and throughout the detailed computations, did excellent work.

For example, for a one-span bridge to Bowen Terrace rising to a deck level of about 110 feet above high water, it was found $g_a = 63$ lb. per ton. That is to say, the conditions are equal in effect to going over a rough road.

Since $f = 28 \therefore \dfrac{g_a - f}{2} = 17{\cdot}5$ lb. per ton weight.

The length over which this applies in this case was 3,570 feet.

Dividing by 2,240 to bring the result to tons we get

$$\frac{17{\cdot}5 \text{ lb.} \times 3{,}570 \text{ ft.}}{2{,}240} = 28 \text{ ft. tons of excess of energy used per ton.}$$

and for this bridge, taking 33,000 tons per day as the weight of vehicles we get—

33,000 tons lifted per day $\times$ 28 ft. tons $=$ 925,000 foot tons per day.

By such methods for each respective length of bridge and approaches, the foot tons of energy lost were computed.

Turning now to the cost in money of losses of time. The value of each minute for each type of vehicle and thus for the average vehicle was computed by a detailed analysis for each vehicle, and knowing the proportion of each, for an average vehicle. Then multiplying the number of vehicles by the loss of time by the value of one minute to each respective vehicle, the daily money losses due to loss of time were obtained.*

As regards energy losses. The cost per foot ton was deduced from that per vehicle mile by computing the number of foot tons per mile for the average grade of Brisbane. Then multiplying the foot tonnage lost by the cost per foot ton, the money losses due to energy used were obtained.

The total time and energy losses due to grades for various alternative proposals are shown in separate colums of Text-figure 8.

So far as we know, this method of stating savings and losses in money values is new, and to that extent doubtful. We are aware that many assumptions have had to be made, but the fundamental reasoning is that of scientific engineering practice and the figures may be considered as reasonably accurate for the purpose of relative comparison. The accuracy is comparable with that of figures for construction cost, &c.

* The money effect of loss of time due to vehicles having to pass through congested areas, over crossings, &c., could be similarly computed, but up to the present has not been done. A series of observations of the time lost by typical vehicles in passing over a certain number of crossings would be needed so that the figures of cost mentioned in the text could be applied.

MONEY VALUE OF ENERGY LOSSES AND TIME LOSSES.

On Various Bridges due to Grades, as Compared with Level Routes.

Traffic as for 15 Years hence.

Mileage from River Mouth	Location		Vehicles per day carried fifteen years hence	Tons per day carried fifteen years hence	Energy Losses 15 Years Hence: Daily Energy Losses Ft. Tons	Power Cost per Ft. Ton Pence	Daily Loss	Annual Loss @ 340 Days per Annum	Time Losses 15 Years Hence: Daily Time Losses Vehicle Minutes	Time Cost per Vehicle Minute Pence	Daily Loss	Annual Loss @ 340 Days per Annum	Total Losses 15 Years Hence
12.7 M	George Street Deck Level 192	Vehicular Traffic	16,100	32,800	656,000	.019	£ 52	£23800	3750	1.11	£ 17	£9,200	£33,000
		Tramcars	2,040	27,500	620,000	.007	£ 18		185	12.9	£ 10		
12.1 M	Petrie Place Deck Level 192	Vehicular Traffic	18,800	38,300	820,000	.019	£ 65	£28,000	4650	1.11	£ 21.5	£10,500	£38,500
		Tramcars	1,820	24,500	590,000	.007	£ 17		175	12.9	£ 9.5		
12.1 L	Petrie Place Two Deck { 168 / 148	Vehicular Traffic	18,800	38,300	0	.019	£ 0	£ 0	0	1.11	£ 0	£ 0	£ 0
		Tramcars	1,820	24,500	0	.007	£ 0		0	12.9	£ 0		
12.0 M	Bowen Terrace Deck Level 203	Vehicular Traffic	16,200	33,000	925,000	.019	£ 73	£28800	5250	1.11	£ 24	£10,200	£39,000
		Tramcars	910	12,300	390,000	.007	£ 11.5		115	12.9	£ 6		
12.0 H	Bowen Terrace Deck Level 224	Vehicular Traffic	16,200	33,000	1680000	.019	£133	£52,000	13500	1.11	£62.5	£27,000	£79,000
		Tramcars	910	12,300	680000	.007	£ 20		305	12.9	£16.5		
11.3 L	Merthyr Road Opening Span	Vehicular Traffic	11,200	22,800	0	.019	£ 0	£ 0	0	1.11	£ 0	£ 0	£ 0
		Tramcars	510	6,900	0	.007	£ 0		0	12.9	£ 0		
	Tube	Vehicular Traffic	say 16,100	32,800	2070000	.019	£164	£75,000	11900	1.11	£ 55	£29,000	£104000
		Tramcars	say 2,040	27,500	1970000	.007	£ 57.5		580	12.9	£ 31		

Text-figure 8.

The calculations mentioned apply to tubes with equal force, and so far as energy is concerned the waste in going down and then going up is the same as going up and then going down; the figure for a tube is shown at the foot of the table in Text-figure 8.

The "waste" mentioned means, of course, to the community as a whole; no doubt if steep grades were used less loads would be carried per vehicle, and consequently more vehicles employed, so that some portions of the community might even gain. Similarly a more expensive structure provides money for some, but it seemed to us a sound economical principle to eliminate unnecessary expenditure wherever possible.

The figures for these time and energy effects should be added to any estimate of cost. When a high bridge or tube is being fully occupied the cost to the community due to the operation of the factors mentioned is comparable to and may even exceed that due to construction and maintenance.

It is quite possible that in some cases circumstances demand the construction of a tube or high-level bridge, but this would be after a close examination of alternatives. For instance, in Liverpool, England, a tube 11,000 feet long is now being built. This is to cost five and a-half millions, and has a 36-ft. road and two lines of trams. A low bridge in such a port, carrying many of the largest ships of the world, was not considered so far as the report of the investigators shows, but the alternative high-level bridge was to cost eleven millions. It is worthy of note that the rise and fall effects for the tube were less than those for the bridge, since the latter was to be 180 feet high, but no quantitative calculations have been published.

In Brisbane a low-level bridge 10 feet above highest flood level, on piers, together with a canal, giving a passage for ships practically equal to that of a single-span bridge, would virtually cost one and three-quarter millions, whilst the tube or high-level bridge would cost five millions; consequently our recommendations were in the former direction.

The constructional costs have next to be considered as shown in Column 7. To obtain these, estimates were prepared of the costs of—

(A) A bridge 40 feet wide as—
- (*a*) One span.
- (*b*) Several spans on piers with approaches above flood level.
- (*c*) A bascule bridge.

(B) A transporter bridge.

(C) Ferries—
- (*a*) To carry a tram.
- (*b*) To carry a motor-bus and vehicles.

(D) Tubes for—
- (*a*) Two ways of traffic (20 feet).
- (*b*) Four ways of traffic and two tramways, equivalent to a roadway of 60 feet.

These estimates were prepared by specialists for the general conditions of location, capacity, &c., laid down by the Commission.

In the case of the tubes the figures for the latest constructions in England and America were available and served as a basis.

A careful study of these estimates was made and the essentials for the present purpose entered in Column 7.

Other losses in Column 8 were entered as shown after a careful review of possibilities.

The detailed comparison was required mainly for the determination of the site and type of structure for the first bridge. The results of the comparison are finally summarised in Table 2, which shows the figures deduced during the investigations for the main projects in Brisbane.

This table was the main deciding factor in the recommendations made as to the first four projects to be constructed.

The results of expected traffic distribution were expressed graphically and to scale as shown in Plate No. 3.

The fact that the proposed bridgehead for the economic traffic distribution and economy of construction came to an intersection of several streets led the Commission to suggest a traffic circle, as shown in Plates 4 and 5. This is of special interest, as since January 1st, 1926, London has adopted gyratory control of traffic at Parliament Place, apparently with great success.

From the newspaper correspondence and from conversations with friends it would seem necessary to enlarge on the reasons for, firstly, building a canal, and secondly, the location chosen.

A low-level bridge could be built with an opening span in it, but for navigation purposes it would need to be placed where at least ½ mile of straight run would be allowed for ships approaching the opening. Such a site in Brisbane would not be convenient for road traffic.

Again, the Commission is of the opinion, and I think it will be generally admitted, that a main bridge opening for all shipping and blocking the traffic for at least 15 minutes on each occasion would be hopelessly inconvenient and wasteful. Consequently sufficient height for a ship to pass under must be given. For Brisbane conditions 75 feet is that economically practicable wherever a bridge be built. By cutting the canal as shown where the ground level is 90 feet above low water and putting an ordinary truss bridge over it, the necessary height is given. The bascule lift span of the Recommendations is an emergency provision so that the largest of ships may pass if required. It is not necessary to the project if such is to be compared with a one-span bridge.

The site chosen gives a shorter passage for most of the shipping and being in rock will be easy of upkeep. Again, the excavated rock we were assured by a competent authority would be of sufficient value for road metal and other purposes to pay for the excavation of the canal. In

TABLE II.

An Economic Comparison of Certain Schemes, each considered as a separate alternative, acting in conjunction with Victoria Bridge.

Traffic as for 15 years hence, assuming annual increase at 8 per cent. compound.

Mileage from River Mouth.	Location.	Percentage of cross-river traffic using proposed scheme.	Vehicles per day carried by proposed scheme 15 years hence.	Years hence that traffic on Victoria Bridge would again reach 12,000 vehicles per day.	Annual saving in haulage cost 15 years hence.	Other savings (annual).	Annual losses due to grade (energy and time) 15 years hence.	Annual cost, including first cost, maintenance, operation, &c., for 60 ft. carriage-way.	Other costs (annual).	Nett annual effect 15 years hence.	Factors not expressed in money.
14·0 L	Victoria Bridge (widened), or Bridge in immediate vicinity	100	51,700	Already in excess	..	..	..	£20,000	..	Loss £20,000	Capacity of approach streets insufficient to feed bridge
12·7 M	George Street to River Terrace. Deck level 192	35	18,100	2	£380,000	..	£33,000	£90,000	Cutting masts and funnels, £2,000	Saving £255,000	Through traffic traverses City area
12·1 M	Petrie Place to Kangaroo Point. Deck level 192	40	20,600	3	£388,000	Ferry eliminated £7,000	£38,500	£90,000	Cutting masts and funnels, £2,000	Saving £264,500	Possibility of cutting down "hump" in Main Street
12·1 L	Petrie Place to Kangaroo Point. Two deck, 168-148	40	20,600	3	£388,000	Ferry eliminated £7,000. Porphyry £12,000	..	£103,000 (80-ft. carriage-way)	Delay due to ships entering canal, £10,000	Saving £294,000	80 ft. width for traffic possible. Traffic crosses at different levels
12·0 M	Bowen Terrace to Kangaroo Point. Deck level 203	33	17,100	1·5	£332,000	..	£39,000	£91,000	Cutting masts, £1,000	Saving £201,000	Possibility of cutting down "hump" in Main Street
12·0 H	Bowen Terrace to Kangaroo Point. Deck level 224	33	17,100	1·5	£332,000	..	£79,000	£92,000	..	Saving £161,000	Possibility of cutting down "hump" in Main Street. Expenses of cutting Ivory Street precincts
11·3 L	Merthyr Road to Cairns Street. Opening span	23	11,700	Already in excess	£248,000	..	..	£42,000	..	Saving £206,000	Interruption to traffic by shipping
—	Tube	35	18,100	2	£380,000	..	£104,000	£250,000	..	Saving £26,000	Dependence on continuity of lighting and ventilation

our estimates, however, we put the cost of cutting the canal at £400,000. Even with this figure added the project has a virtual cost of about one million less than alternatives. Full provision has been made in the estimates for tractors to draw ships through the canal without delay if such desire it. Many boats will probably steam through unassisted.

Looked at from a general way a bridge a mile long and 75 feet clearance is to exist, of which nature has provided two-thirds of a mile in the form of Kangaroo Point. The subsidiary utilities of the canal for ferries, &c., are many. The hydraulic properties are now being examined experimentally, but sufficient has been done in this to show that no eddies or dangerous currents are formed; in fact it will tend to improve the river channel.

As the city grows traffic in the streets has to be regulated and it seems reasonable to expect that the same will apply to river traffic.

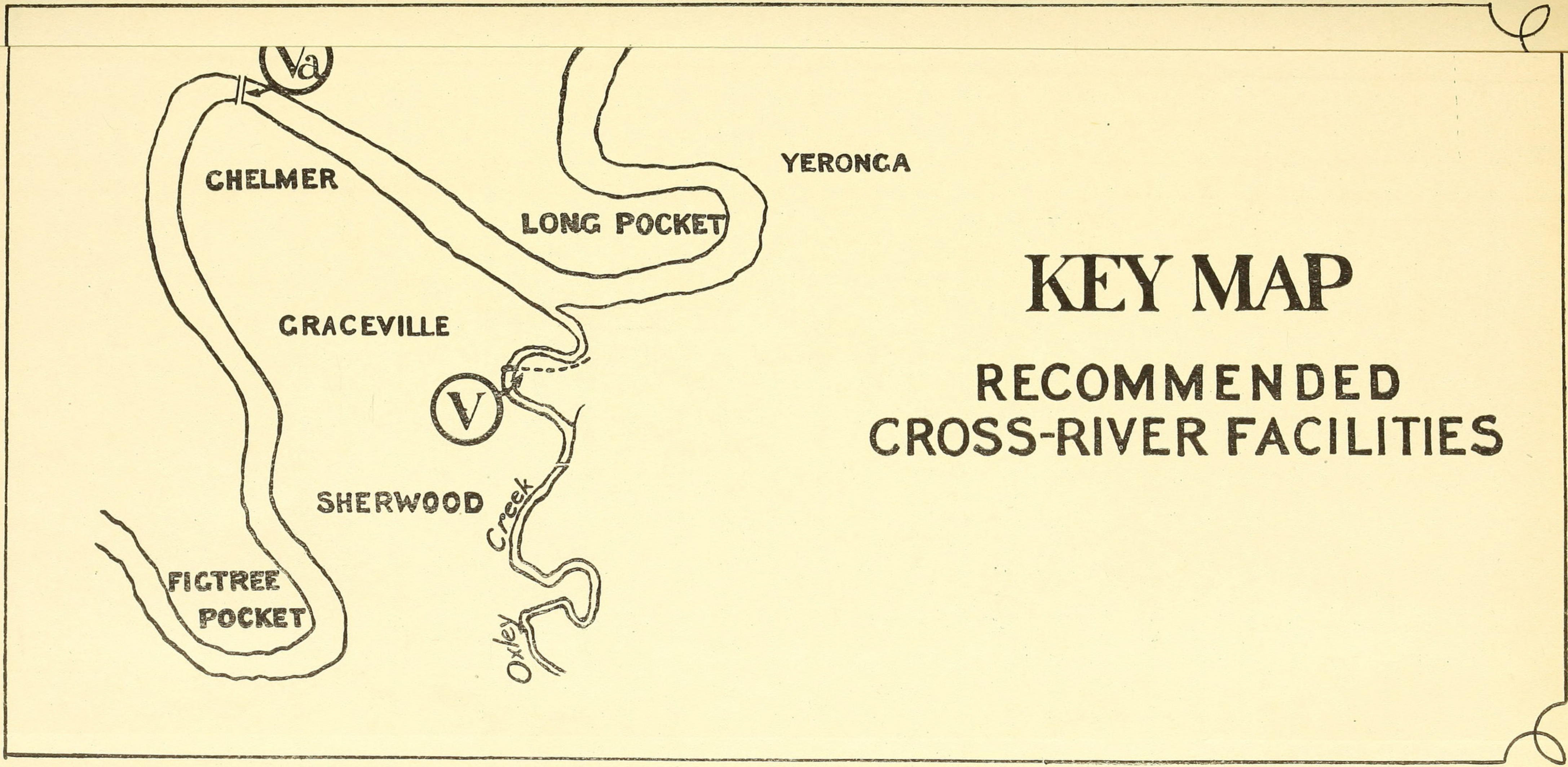
For this project the economy shown is additional to its capacity of carrying the largest percentage of traffic; of relieving city streets and saving long detours; of picking up traffic with a minimum of interference; of having a very stiff bridge of the most modern design and of ample yet not wasteful dimensions; of a certain picturesqueness; of quickest and easiest route; and of allowing facilities for shipping at least equal to that given by any economical alternative. It will fit in with the growth of the city for the next generation and can be built with Australian material and labour.

It will be remembered that the Commission was asked to recommend sites for the future and for the whole Greater Brisbane area.

The location of the other sites was gone into on the same general principles. Plate 1 shows the recommendations made.

The full details will be found in the Report of the Cross-River Commission appointed by the Brisbane City Council. The author was Chairman of the Commission and was responsible for the general procedure of the investigation. My thanks are due to the Mayor of Brisbane for the use of the model and figures from the report.

[The address was illustrated by 40 slides of which a few typical ones have been reproduced. A demonstration of river flow in the large model followed the address.]


KEY MAP
RECOMMENDED
CROSS-RIVER FACILITIES
YERONGA
CHELMER
LONG POCKET
GRACEVILLE
SHERWOOD
FIGTREE
POCKET
Oxley
Creek
V
Va

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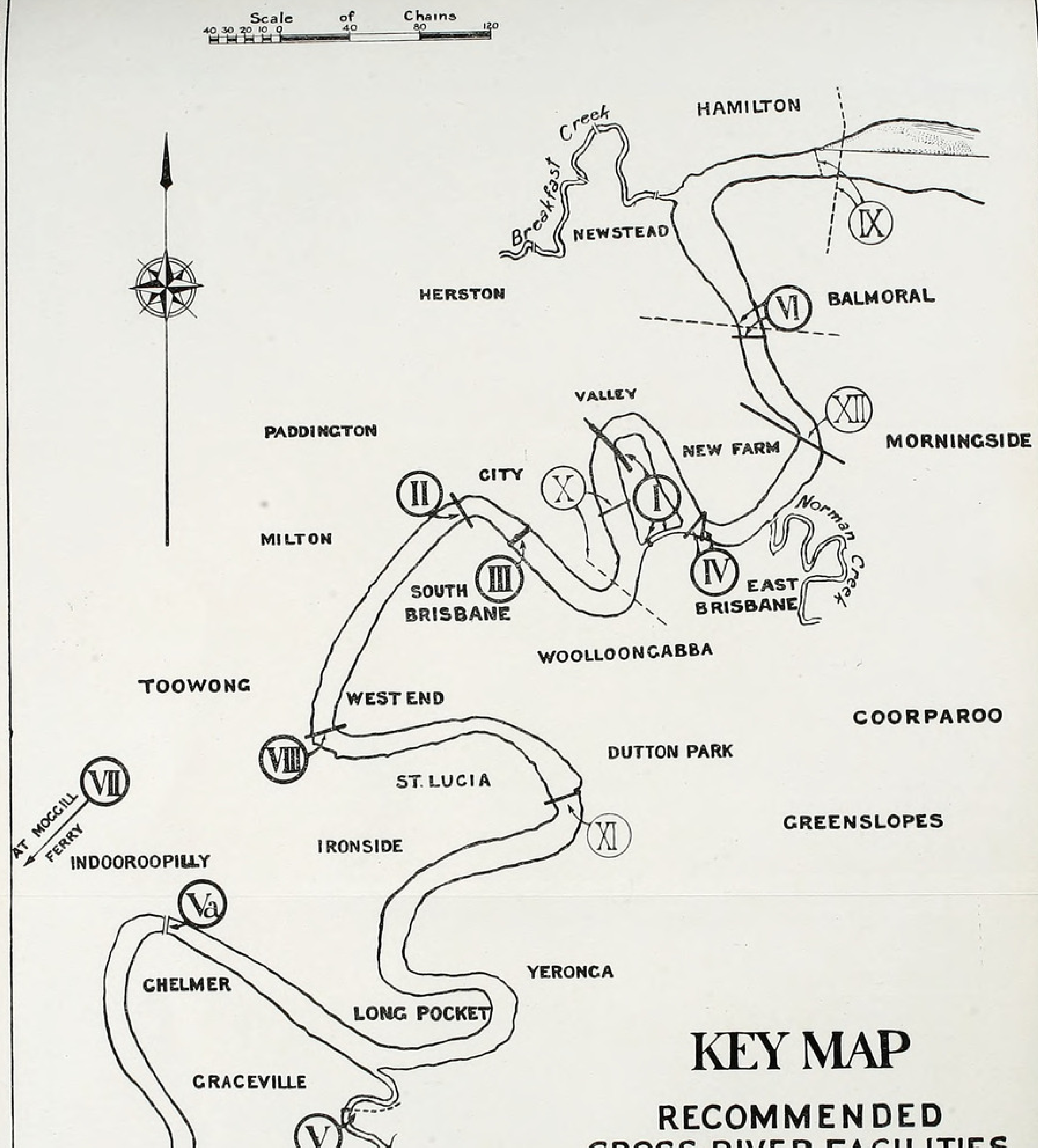

KEY MAP

RECOMMENDED CROSS-RIVER FACILITIES

LAN, BRISBANE RIVER AND ENVIRONS.

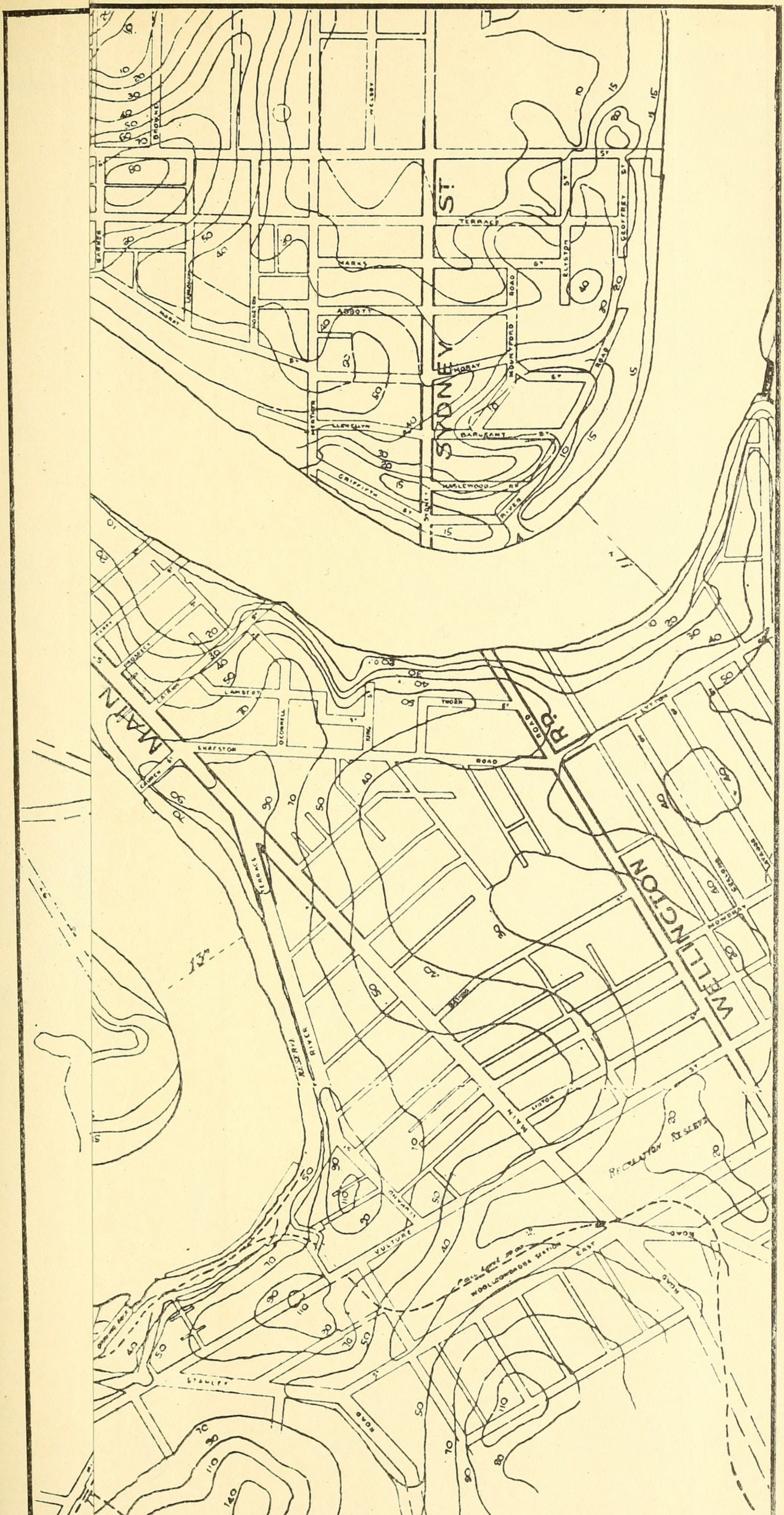

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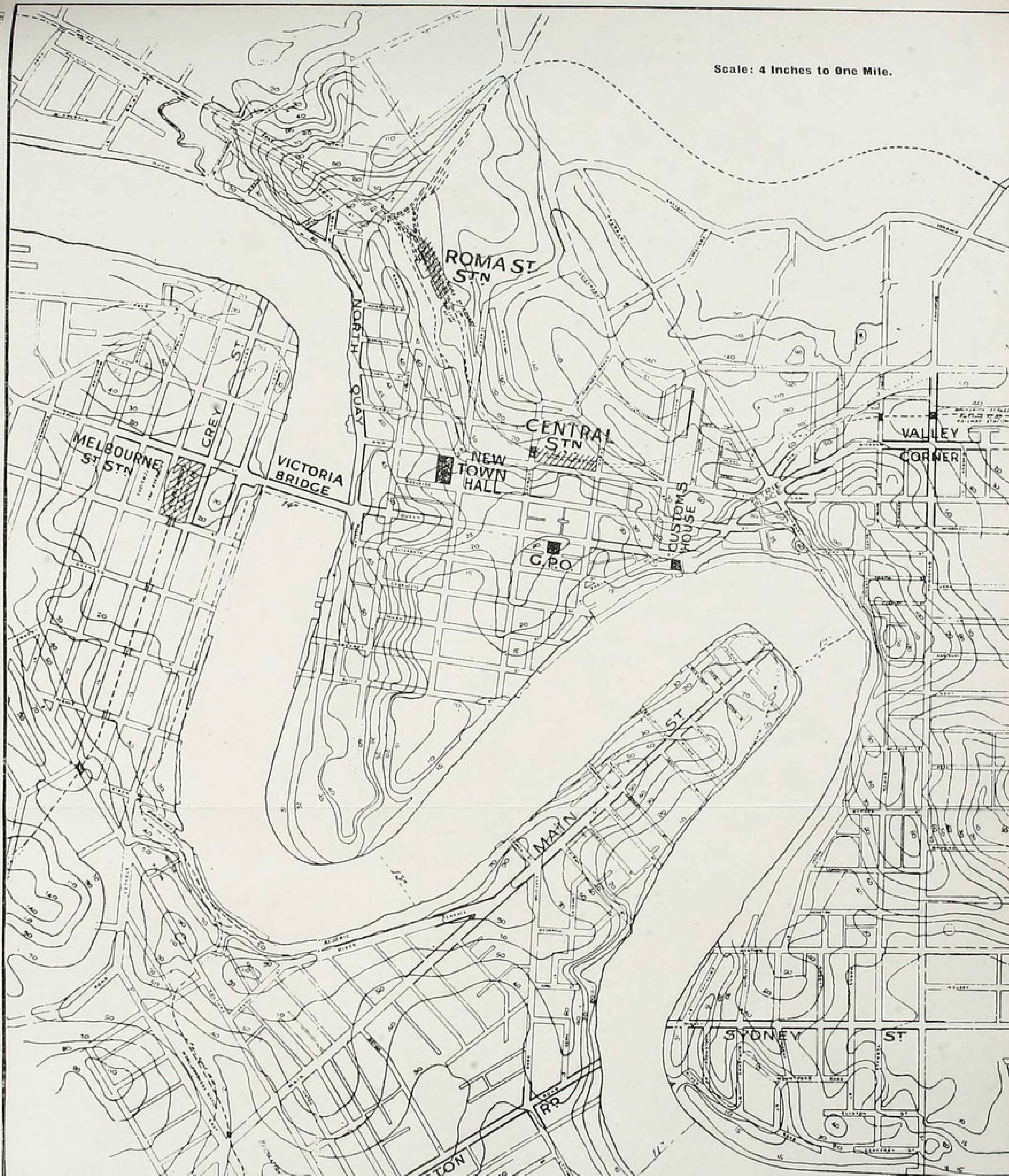
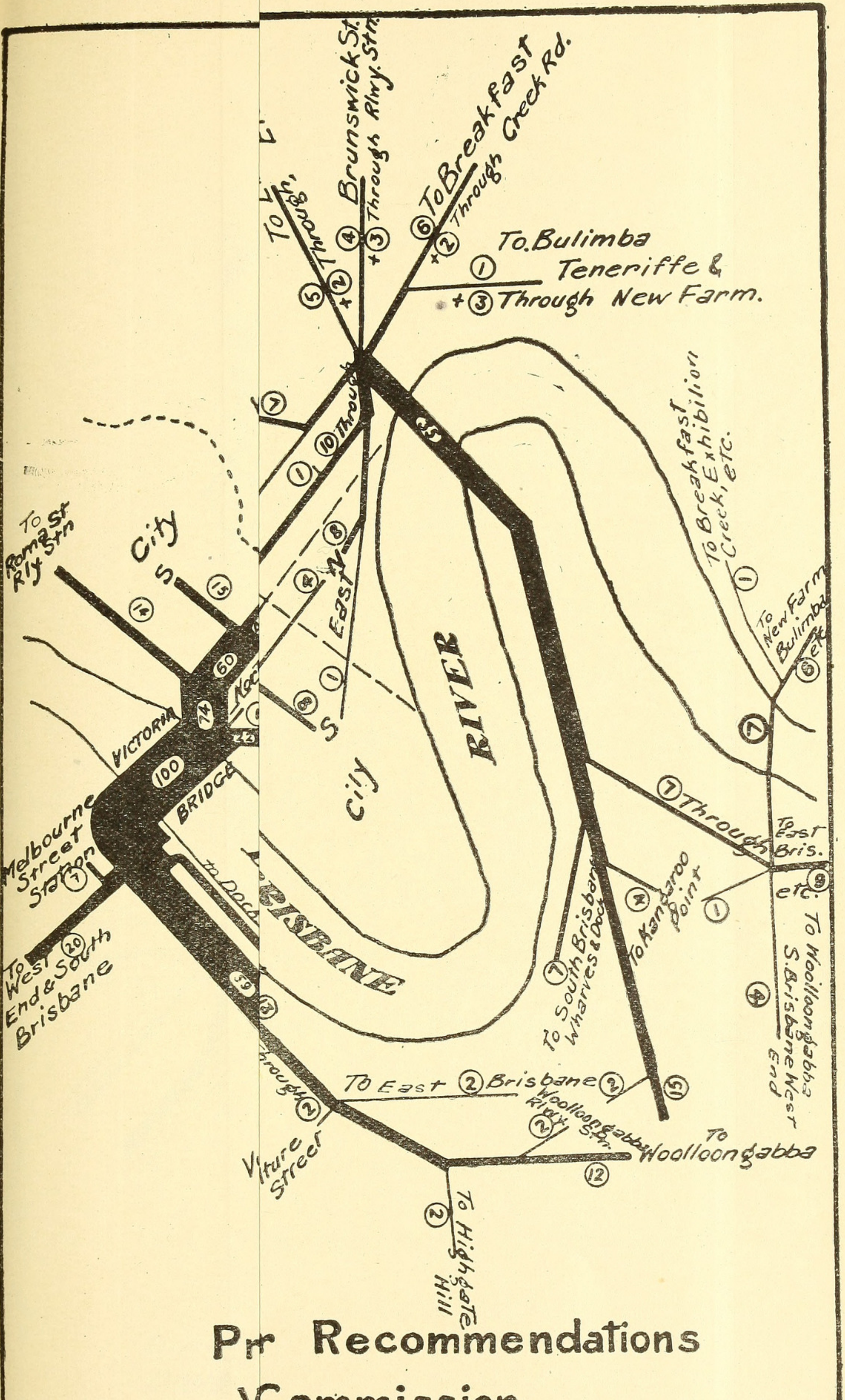
PLATE II.

CONTOUR PLAN, BRISBANE RIVER AND ENVIRONS.



[Face page 22.]



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Commission
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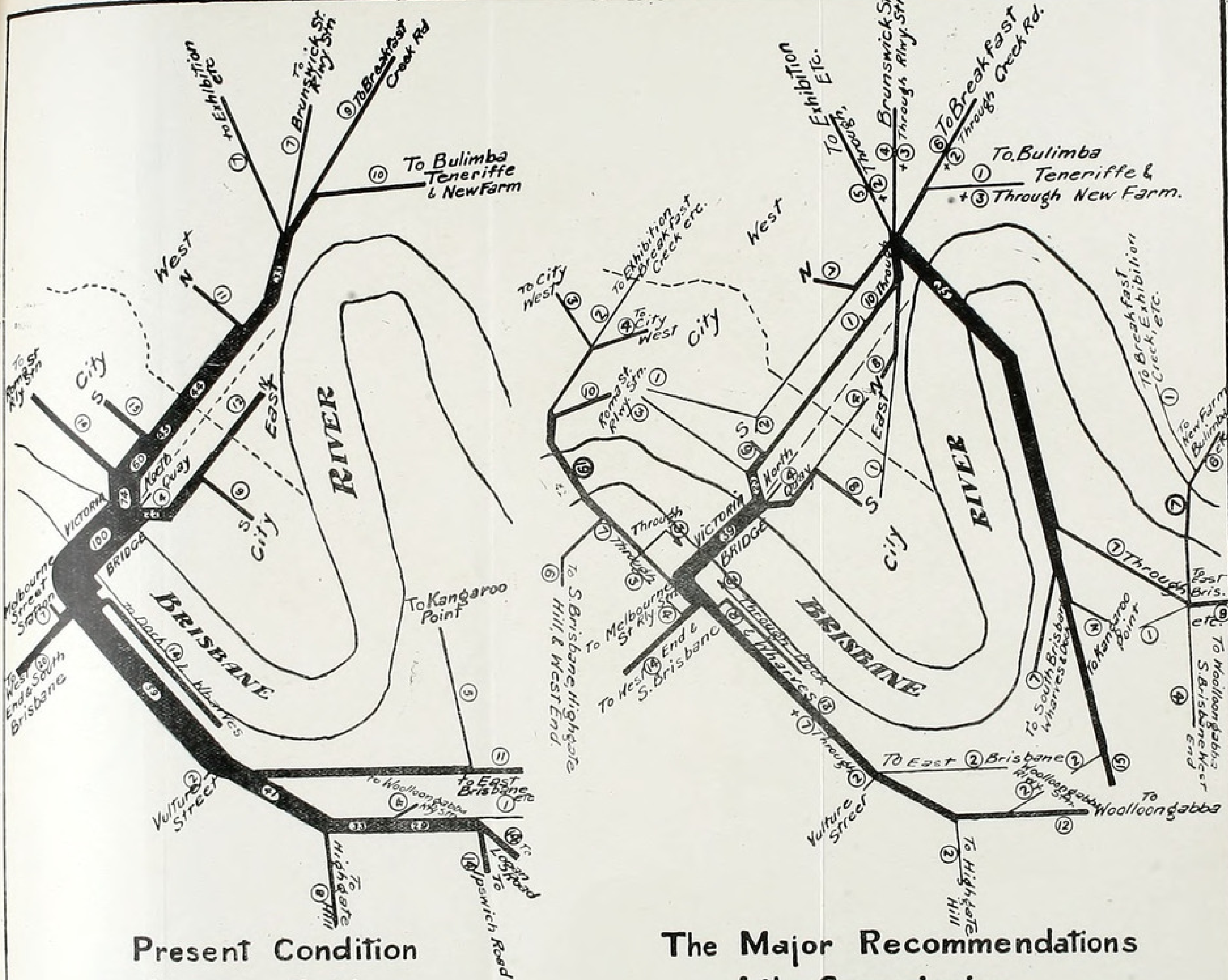
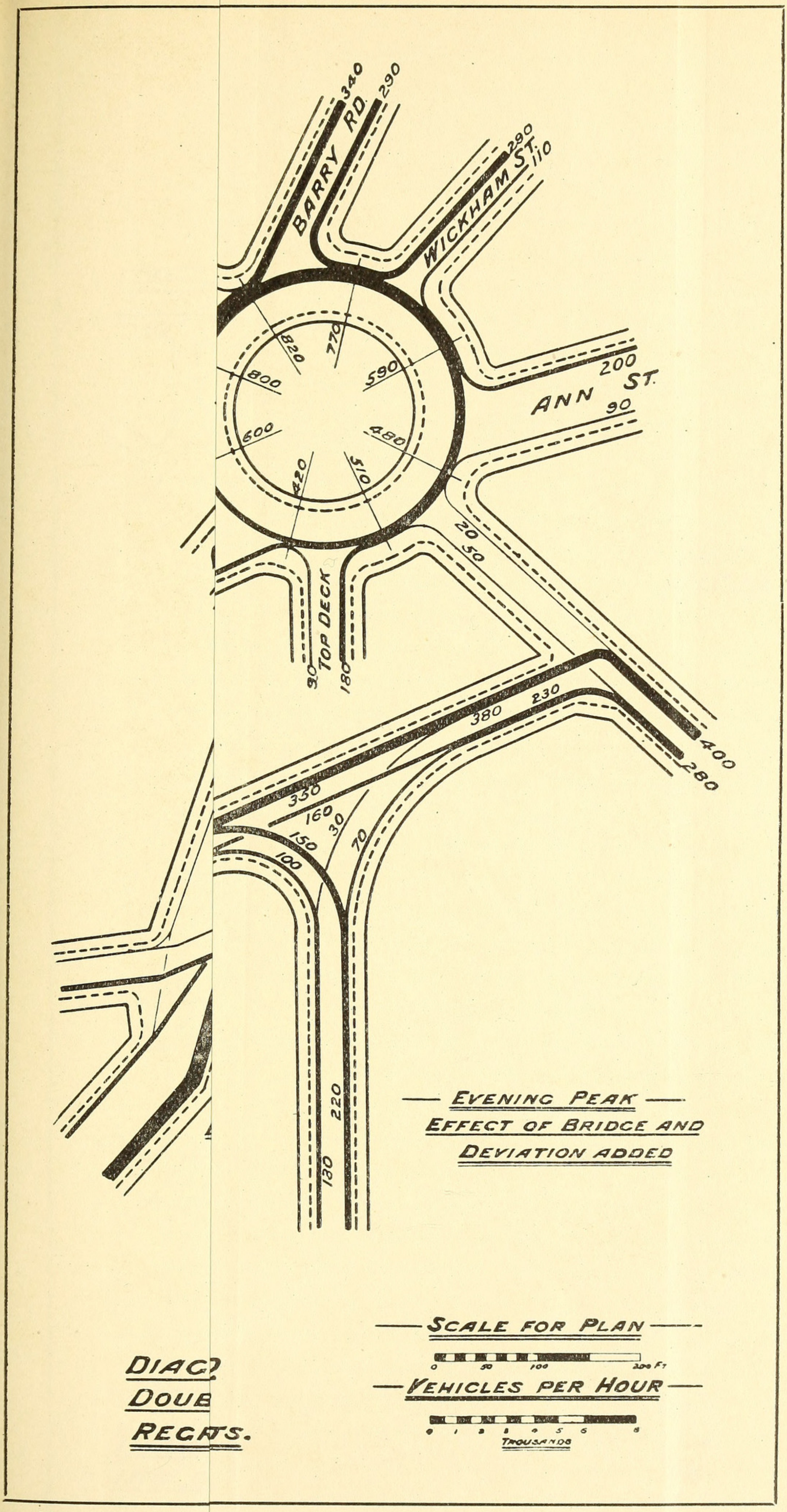


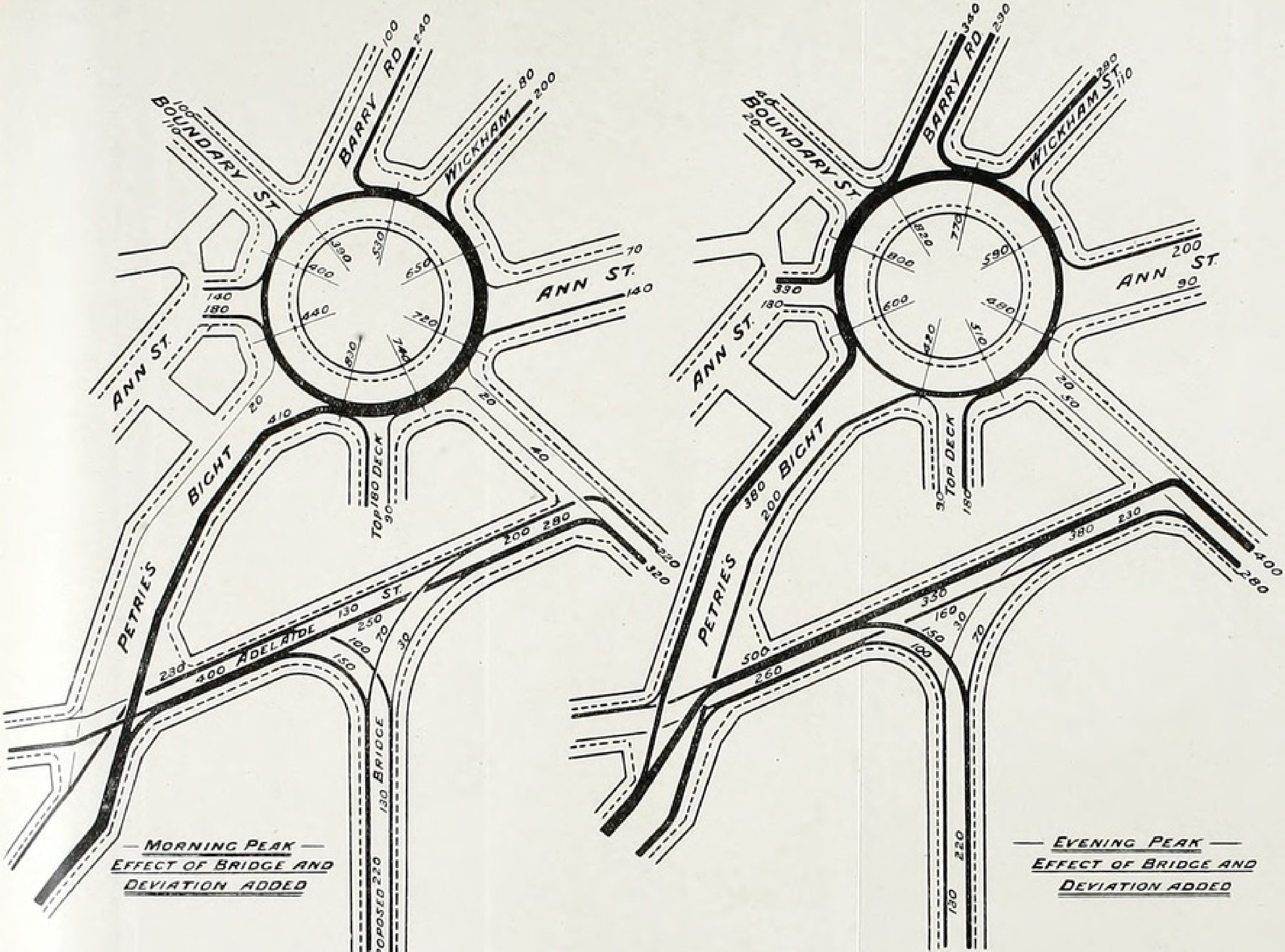
Present Condition Victoria Bridge

The Major Recommendations of the Commission

DISTRIBUTION OF CROSS RIVER TRAFFIC

[Face page 22.]


BARRY RD.
340
290
WICKHAM ST.
290
110
ANN ST.
200
90
820
770
590
800
600
480
420
510
TOP DECK
90
180
20
50
380
230
400
280
350
160
150
30
70
100
220
130
EVENING PEAK
EFFECT OF BRIDGE AND
DEVIATION ADDED
SCALE FOR PLAN
0 50 100 200 FT
VEHICLES PER HOUR
0 1 2 3 4 5 6 8
THOUSANDS
DIAG?
DOUB
REGTS.



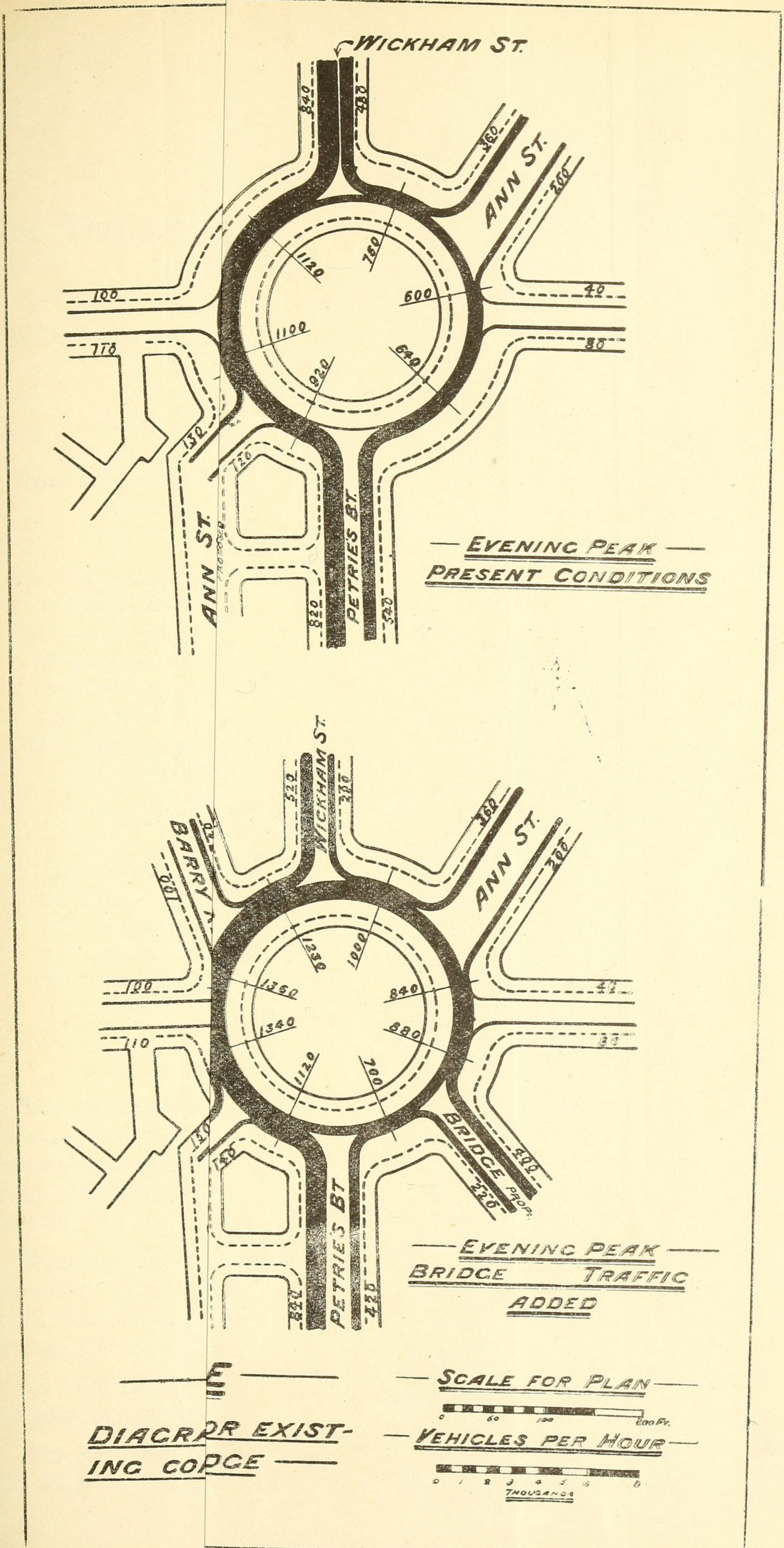
— Proposed Traffic Circle —

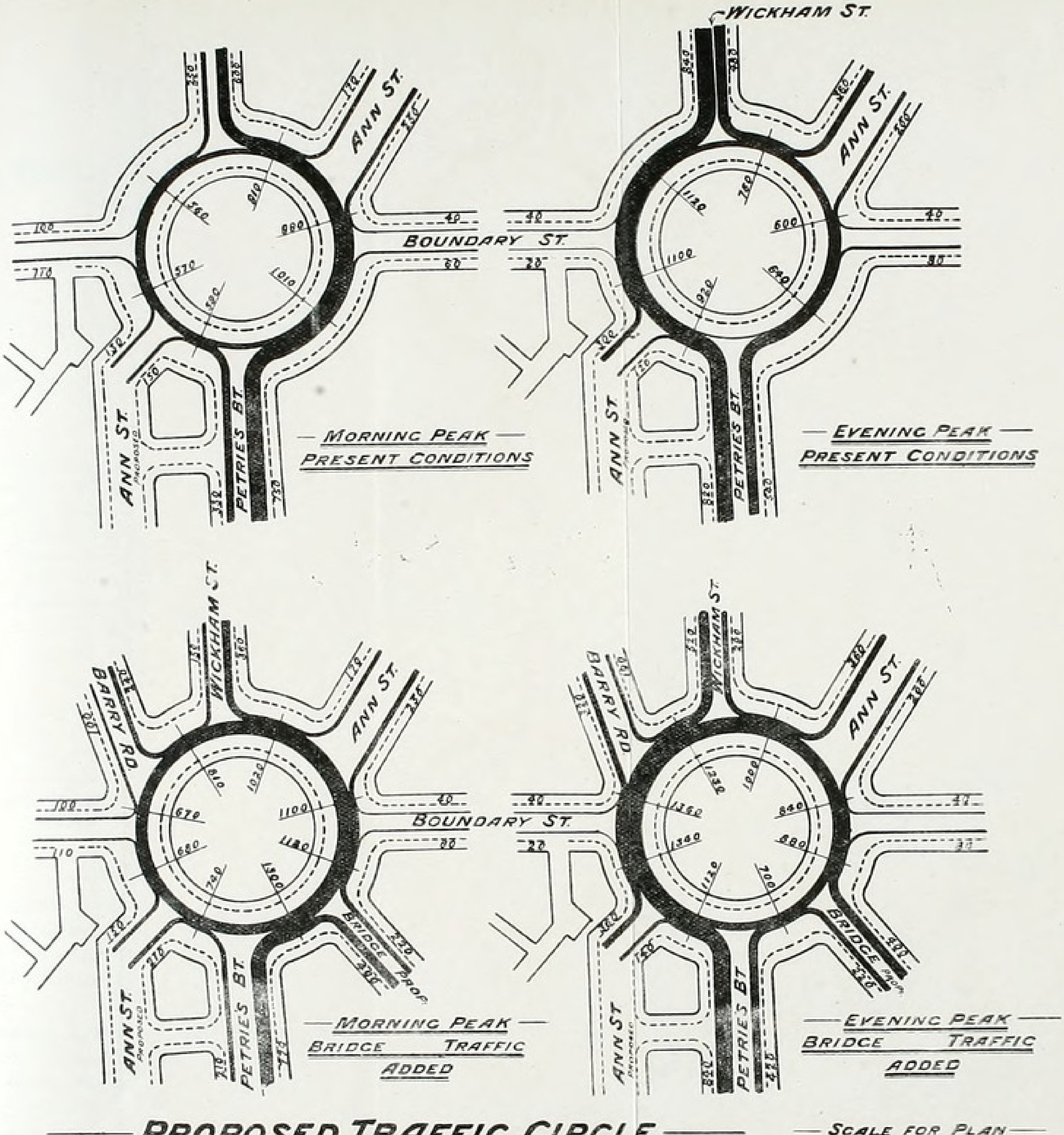
Diagram of Hourly Traffic Intensities with Proposed Double Deck Bridge — Recommendation I — Added and Regrading parts of Ivory, Boundary, and Adelaide Sts.

— Scale for Plan —

— Vehicles per Hour —

[Face page 22.]


WICKHAM ST.
ANN ST.
PETRIES BT.
ANN ST.
— EVENING PEAK —
PRESENT CONDITIONS
WICKHAM ST
BARRY
ANN ST.
BRIDGE PROP.
PETRIES BT
— EVENING PEAK —
BRIDGE TRAFFIC
ADDED
— SCALE FOR PLAN —
— VEHICLES PER HOUR —
THOUSANDS



PROPOSED TRAFFIC CIRCLE

DIAGRAM OF HOURLY TRAFFIC INTENSITIES FOR EXISTING CONDITIONS AND WITH SINGLE DECK BRIDGE (ALTERNATIVE B2) ADDED