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Report on proposed Belle Isle bridge by the Consulting board, Bell ...

Detroit (Mich.). Dept. of public works. Belle Isle ...

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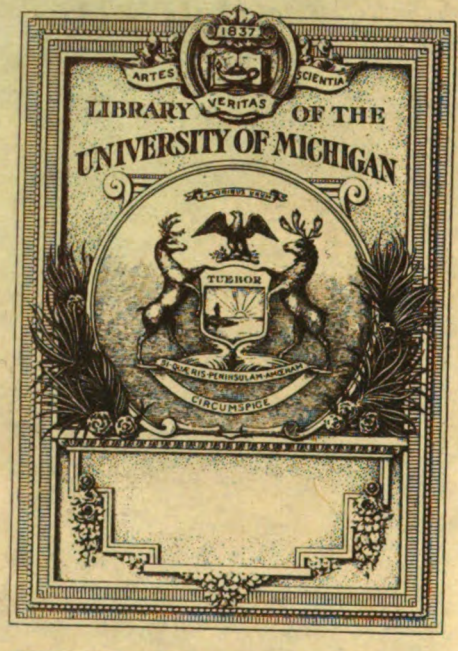

THE GIFT OF
Detroit Dept. of Pub. Works

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REPORT ON

PROPOSED BELLE ISLE BRIDGE

BY THE CONSULTING BOARD

Belle Isle Bridge Division of Engineering
and Construction

Department of Public Works

CITY OF DETROIT

1918

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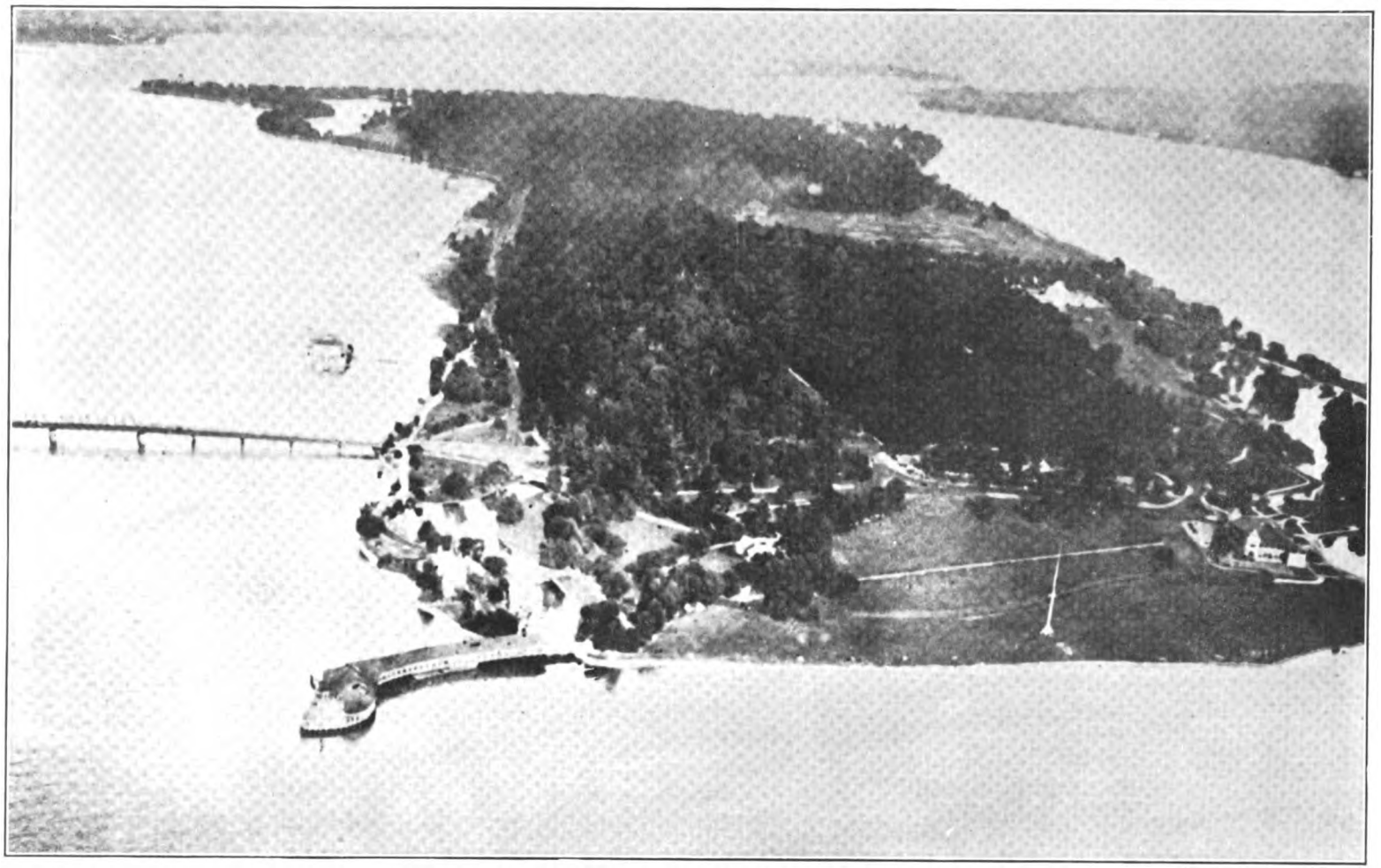

From the Detroit News

BIRD'S-EYE VIEW OF BELLE ISLE

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Detroit Dept. of Public Works.
9-8-1925

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LIST OF ILLUSTRATIONS

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Detroit, May 1, 1918.

To the Honorable,

The Common Council,

City of Detroit.

Gentlemen:—

In pursuance of a resolution adopted by you on June 13, 1916, authorizing me to proceed with the preparation of plans, etc., for the construction of a new permanent bridge to Belle Isle, I created the "Belle Isle Bridge Division of Engineering and Construction," and appointed a Consulting Board consisting of Messrs. Mortimer E. Cooley, (Chairman), Francis C. McMathWilliam R. Kales, Emil Lorch and Henry E. Riggs.

Offices of the Division were equipped in the old Wayne County Savings Bank Building on Congress Street and the work started early in July, 1916 by a force of engineers, draftsmen and clerical help, under the active supervision of Emil Lorch as Architect and Lewis M. Gram as Engineer. On February 1, 1917 the offices of the Division were removed to an unused court room and connecting rooms in the New Municipal Court Building.

The work was actively carried on until October 1, 1917, meetings of the Consulting Board being held from time to time to review what had been done and to direct further progress of the work. On December 5, 1916 a public meeting was held in the office of Mayor Marx at which a report of progress on the plans was made.

On May 12, 1917 further progress was reported to a joint meeting of the Committees on Ways and Means and Bridges and at their suggestion another public meeting was held in the Council Chamber on May 25, 1917. For several days prior to this meeting sketches and plans of the bridge as proposed were on exhibition in the Council Chamber.

The final report of the Consulting Board including plans and estimates prepared under date of November 5, 1917 is transmitted herewith.

Respectfully yours,

GEORGE H. FENKELL,

Commissioner, Board of Public Works.

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Detroit, November 5, 1917.

Mr. George H. Fenkell,
Commissioner, Board of Public Works,
Detroit, Michigan.

Dear Sir:—

The Consulting Board appointed by you, to direct and assist in the preparation of plans for a new permanent Belle Isle bridge, begs to submit their report herewith together with the plans which have been developed.

The report is divided into two general divisions, the first consisting of historical notes and a description of various important portions of the bridge as proposed. The second division deals with technical features of the proposed structure, containing also a summarized statement of cost.

The appendix is divided into five sections consisting of tabulated data and conclusions which are referred to in the body of the report.

Very respectfully yours,

MORTIMER E. COOLEY, *Chairman*
FRANCIS C. McMATH
WILLIAM R. KALES
EMIL LORCH
HENRY E. RIGGS
Consulting Board.

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REPORT ON
PROPOSED BELLE ISLE BRIDGE

HISTORICAL

The earliest suggestion, of record, for a bridge to connect Detroit with Belle Isle, was made in February, 1885. At this time the island was almost entirely undeveloped and was used largely as a picnic ground, visitors being transported to the island by boat.

In December, 1885, a resolution, for building a bridge to the island, was adopted by the City Council, and a site for the proposed bridge was purchased soon afterward. Plans and specifications for this bridge were approved in February, 1886; the contract for construction was awarded in September, 1887, for $295,000 and the bridge was completed and accepted on June 25, 1889.

It was located at the end of East Grand Boulevard and was a steel truss bridge, with plank floor and timber stringers. There were twelve 156-foot through spans, one 318-foot swing span, and five 88-foot pony truss spans, making a total length between abutments of 2,628 feet. The width of the roadway was 26 feet, and that of the sidewalks 9 feet, making the total width of the bridge 44 feet. The height above ordinary water level was about 19 feet 9 inches to the bottom of the vertical posts, or clearance line, and 22 feet to the top of the bridge floor.

With the increase in population of the city of Detroit and the development of Belle Isle the structure became inadequate to the demands made upon it. The design moreover was out of keeping with the further development of Belle Isle.

These facts resulted in agitation for replacing the old bridge with one adequate for the traffic needs and architecturally suitable as a connecting link between the City of Detroit and its finest park. As a result, a small appropriation was made in May, 1914 for the purpose of making a preliminary study for a new bridge.

In April, 1915 the timber floor of the then existing bridge was destroyed by fire, resulting in the collapse of the major portion of the steel superstructure. This was followed by an appropriation, made in May, 1915, for the construction of a temporary bridge to the island, and during the following month a special election was ordered for the purpose of authorizing a $2,000,000.00 bond issue to construct a new bridge. At this election which was held July 9, 1915 the proposition failed to carry.

The present temporary bridge was completed in August, 1916 under the appropriation of May, 1915. This structure is located about 175 feet down-stream from and practically parallel to the old bridge. It is a pile trestle with I-beam stringers and plank floor. A swing span is located about 500 feet from the Detroit end. The over-all width is 36 feet,

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including two sidewalks each 7 feet and a roadway 22 feet in width. The floor at the Detroit side is 25 feet above mean water and slopes down to the swing span at a two per cent grade. On the Belle Isle side of the swing span the grade is one per cent for about 500 feet and level for the remainder of the distance to the island.

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THE PROPOSED BRIDGE

General

The present design for the proposed Belle Isle Bridge has been developed by comprehensive study of the conditions fundamentally affecting it. The conclusions relative to site, general dimensions, appropriateness of structural type and design are based therefore upon practical requirements, with due regard to the aesthetic features of the proposed structure which will be a connecting link in the municipal system of parks and boulevards.

The value of the region between East Grand Boulevard and the water works for manufacturing and shipping is limited by the depth and width of the river channel, there being insufficient space for turning large boats, and by the lack of railroad facilities. This region contains one of Detroit's finest groups of residences whose well-kept gardens greatly enhance the interest of the river shore and are among the most beautiful features of the city.

The river basin between the island and the mainland above the site of the bridge ranks with the best for boating to be found in American cities. It is the only portion of the river near the city where small boats can move with freedom and safety, and is one of Detroit's greatest assets. Few foreign cities have a more attractive water front and its beauty and availability depend on the retention and development of the present character of its shores.

The proposed bridge has an unusually favorable setting. The site at the end of East Grand Boulevard is a conspicuous one, making a bridge at this point visible from all boats and from the Detroit and island shores, as well as from part of the Canadian shore. The city's property known as the Detroit approach is 200 feet wide and is 800 feet in length from Jefferson Avenue to the harbor line. The center line or axis of this property does not coincide with that of the Boulevard which is 150 feet wide. The river channel, used primarily by tugs, scows and yachts, is near the Detroit shore which is considerably higher than the level of the island. At the island end of the old bridge is an open space beyond which are canals, bridges, roads and fine high trees.

The direction of river current as indicated by government records makes an angle of about 86 degrees with the axis of the old bridge. Using the old location as that for the new structure, it would probably be necessary to use skewed spans in order to keep within the displacement considered allowable for the bridge piers. In that case the piers would not be normal to the bridge axis and if a bascule span were required the satisfactory design of the bascule piers would be practically impossible. A survey of the direction of river current made by the Consulting Board verifies the above angle in the channel near the mainland end of the bridge but shows angles of more nearly 90 degrees near the island end. The most desirable arrangement of the piers would be to make them normal to the axis of the bridge, and this can be done provided the island end is moved

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somewhat up-stream. Since, moreover, additional space is needed at the island approach and will be provided by such a change in the bridge axis without destroying any of the trees, the island end of the proposed bridge is placed 150 feet further up-stream than that of the old one and the approach is extended to the harbor line.

Other Sites

Consideration has been given other sites. The situation of the city, however, with respect to the island is favorable to a bridge at the lower end of the island not too far from the ferry landing. At this point East Grand Boulevard is a well established and natural approach to the bridge from various parts of the city. By retaining approximately the old site there would also be preserved for boating purposes direct access to Lake St. Clair from the splendid body of water between the bridge and the head of the island.

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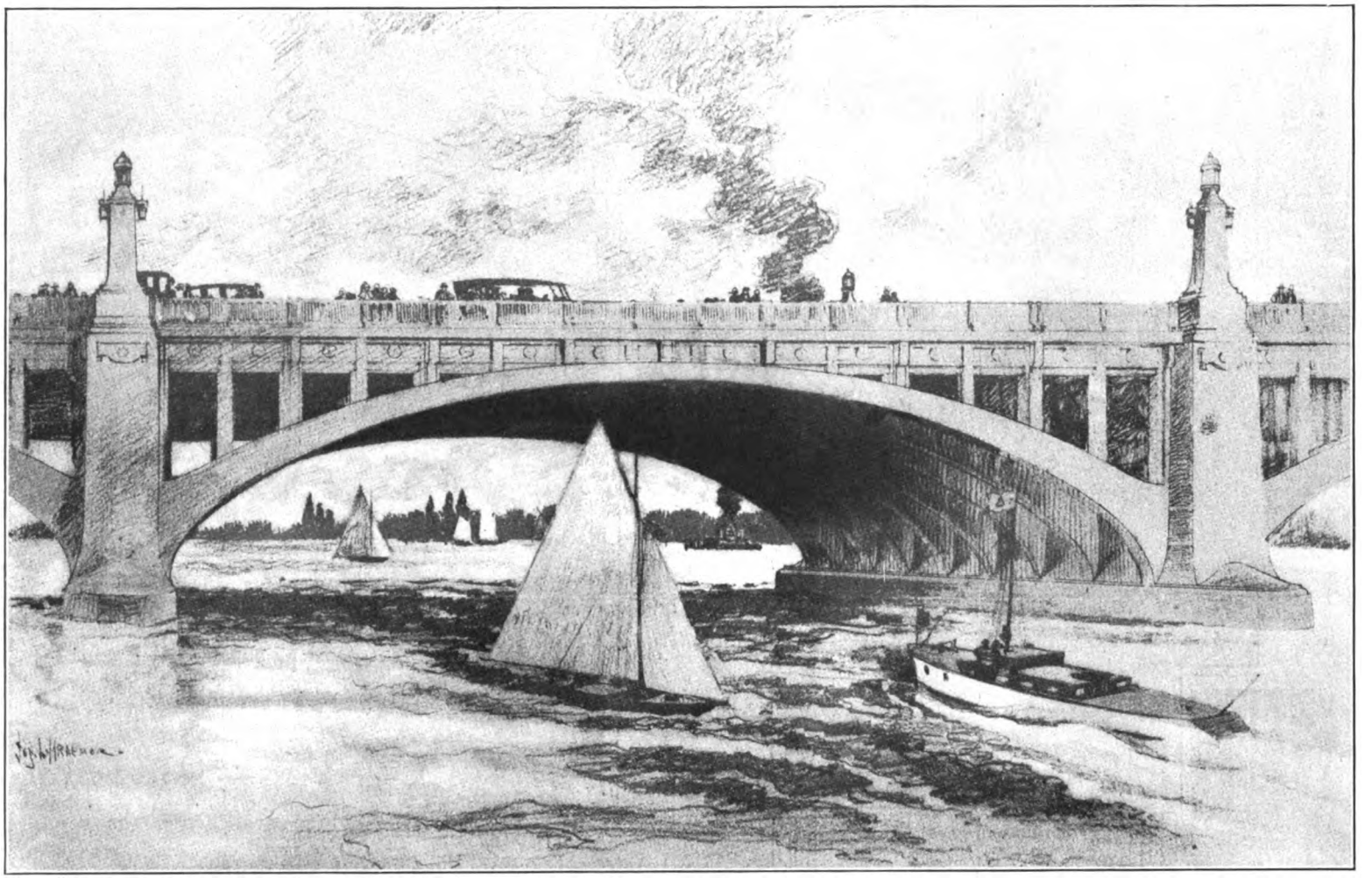

From The Detroit News

A TYPICAL SPAN

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General Description

The initial problem and indeed the fundamental one from the standpoint of service to the public is to decide upon the width of the bridge so that every kind of traffic may have ample and equitable space. In this instance an estimate of present requirements is based upon surveys of traffic over the temporary bridge and ferries during the summer of 1916 on Sundays and holidays when heavy traffic occurred. (See Appendix I.) As a result of the survey referred to it has been concluded that a bridge having a width of roadway of fifty-nine feet including space for street car tracks, should these be used, and two sidewalks each of twelve feet width, would amply provide for present needs as well as for reasonable growth of traffic in the future. Such width of sidewalks, it is estimated, will accommodate pedestrians at the rate of 28,000 per hour in both directions on two walks, or 14,000 per hour in the same direction on one walk. The width of roadway contemplated would provide easily for four lines of vehicular traffic, two lines in each direction, besides two tracks for street cars, so that the rate of passage might be 3,200 vehicles per hour. The traffic survey shows a maximum rate of passage on the temporary bridge of 800 automobiles and 4,000 pedestrians per hour.

The allowable obstruction to flow of water and interference with shipping is under complete control of the War Department, through its engineers. The piers must not in number and size seriously prevent the flow of water and ice, and the interests of navigation must be considered in determining clearances above the water line. After careful study of the situation during which the government engineer in charge of this district and the largest shipping interests were consulted, it has been tentatively assumed that a bridge twenty-two hundred feet long and consisting of nineteen fixed spans varying from 74 to 135 feet each, with a maximum clearance of 30 feet above mean water-line in three channel spans, would provide sufficient water-way and equitable service for the traffic over and under the bridge. The preliminary plans have been prepared accordingly, but whatever changes are dictated by the War Department after the plans are submitted to them, must of course be made. (See Appendix I for data relative to use of draw in present bridge.)

The bridge floor is of reinforced concrete supported on spandrel columns and walls carried by nine rows of cantilever arms, which are thoroughly braced laterally and merge into the piers at the springing line. Below the springing line each pier is a solid mass of concrete extending the entire width of the bridge. The outer ends of the cantilever arms are tied back to the pier superstructure by steel I-bars encased in concrete. This concrete, in the case of the outside ribs, is panelled and continues with a belt course marking the floor level throughout the length of the bridge, tying together the entire composition. At the middle of each span, where the cantilever arms meet, a shield is placed and this forms one of

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the few purely decorative features of the bridge. There is indeed very little ornament, the emphasis being placed rather on the architectural treatment of essential features. These shields are to bear symbols which represent the various industries and some of the significant historial events associated with the city.

The light posts are placed outside the clear width of the walks and carry out the vertical lines of the pier design. The balustrade is of iron and steel, of ample strength and comparatively light in weight. It should be painted a light gray-green color.

At the Detroit end, stairs on each side of the bridge lead from the approach level to a boat landing and serve to break the effect of height of the concrete retaining walls of the bridge approach, also unifying the bridge with the approach. There is also provision for passage at the boat landing level below the last span of the bridge. At the island the bridge is kept as low as possible, again allowing free passage along the shore beneath the bridge where a landing is provided for small boats.

Structural Type

Data obtained from surveys, borings and pile loading tests at the site of the proposed bridge indicate that a structure designed upon cantilever principles would best fit the natural conditions. Other structural types were carefully considered but the great distance to rock and the plastic condition of the overlying soil was the most important eliminating factor. Moreover the curved arms of the cantilever construction give pleasing lines consistent with the character of the bridge as a civic and park structure. The water level is subject to slight changes, hence the curved arms can spring from the piers at a low point and an open spandrel treatment is practicable, giving an effect of lightness without sacrificing that of strength and dignity. The advantages with respect to appearance as well as permanence were deciding factors in the selection of reinforced concrete as the most suitable material. A more detailed discussion of the structural type will be found under "Technical Features," page 53.

As a Memorial Bridge

It would be most appropriate to build such a structure as a memorial to those who have gone from Detroit into the service of the Government. If this were decided upon some minor modifications could be made in the design to help express this thought. Many structures, hospitals, schools and bridges have been erected as commemorative monuments. Among bridges thus erected the Alexander Bridge in Paris is a well-known example, while some years ago it was proposed to build a memorial bridge across the Potomac, from Washington to Arlington.

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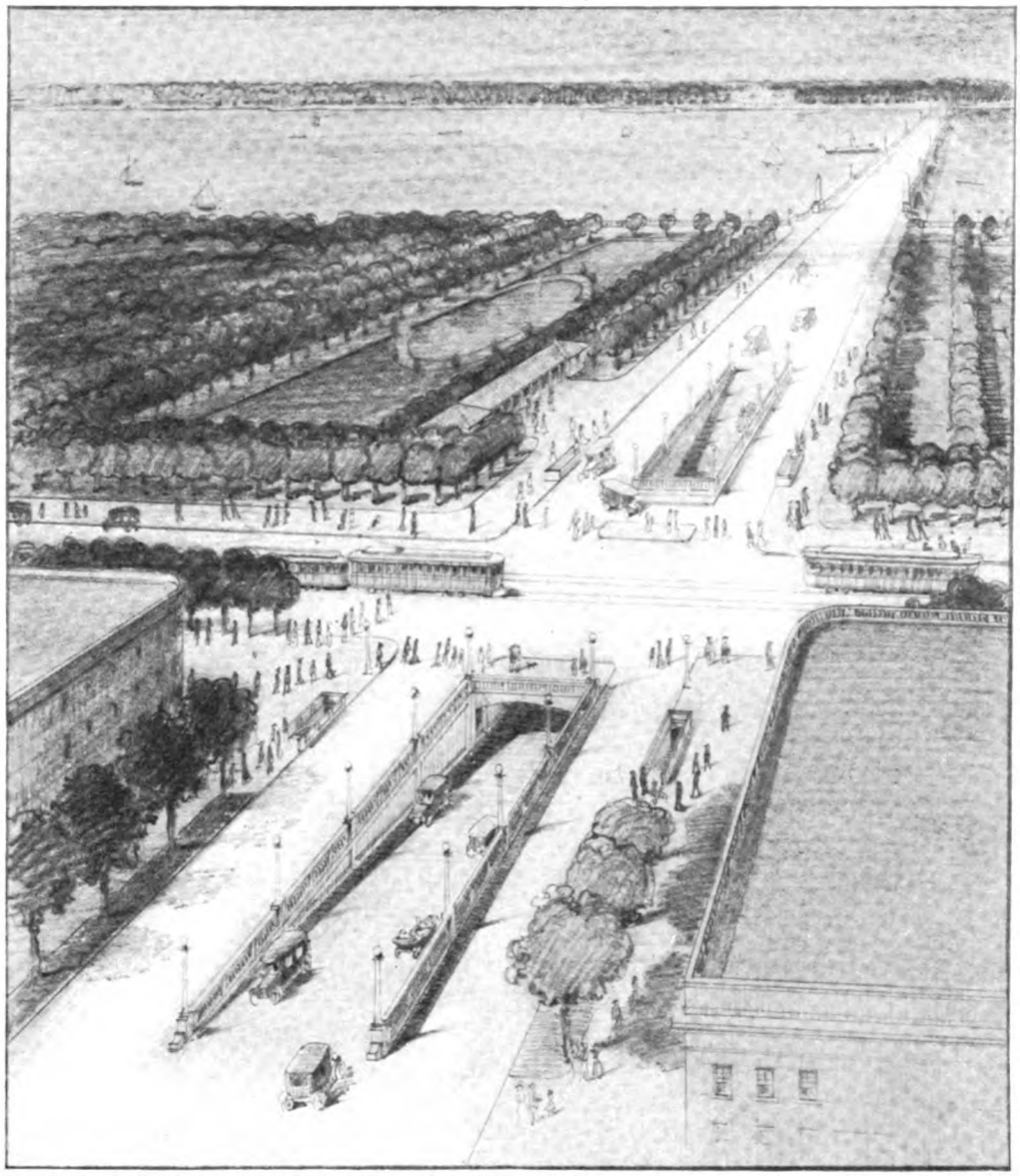

THE DETROIT APPROACH AS SEEN FROM MAINLAND
Vehicles to and from the Island will use the Subway, and thus will not be stopped by traffic on Jefferson Avenue.

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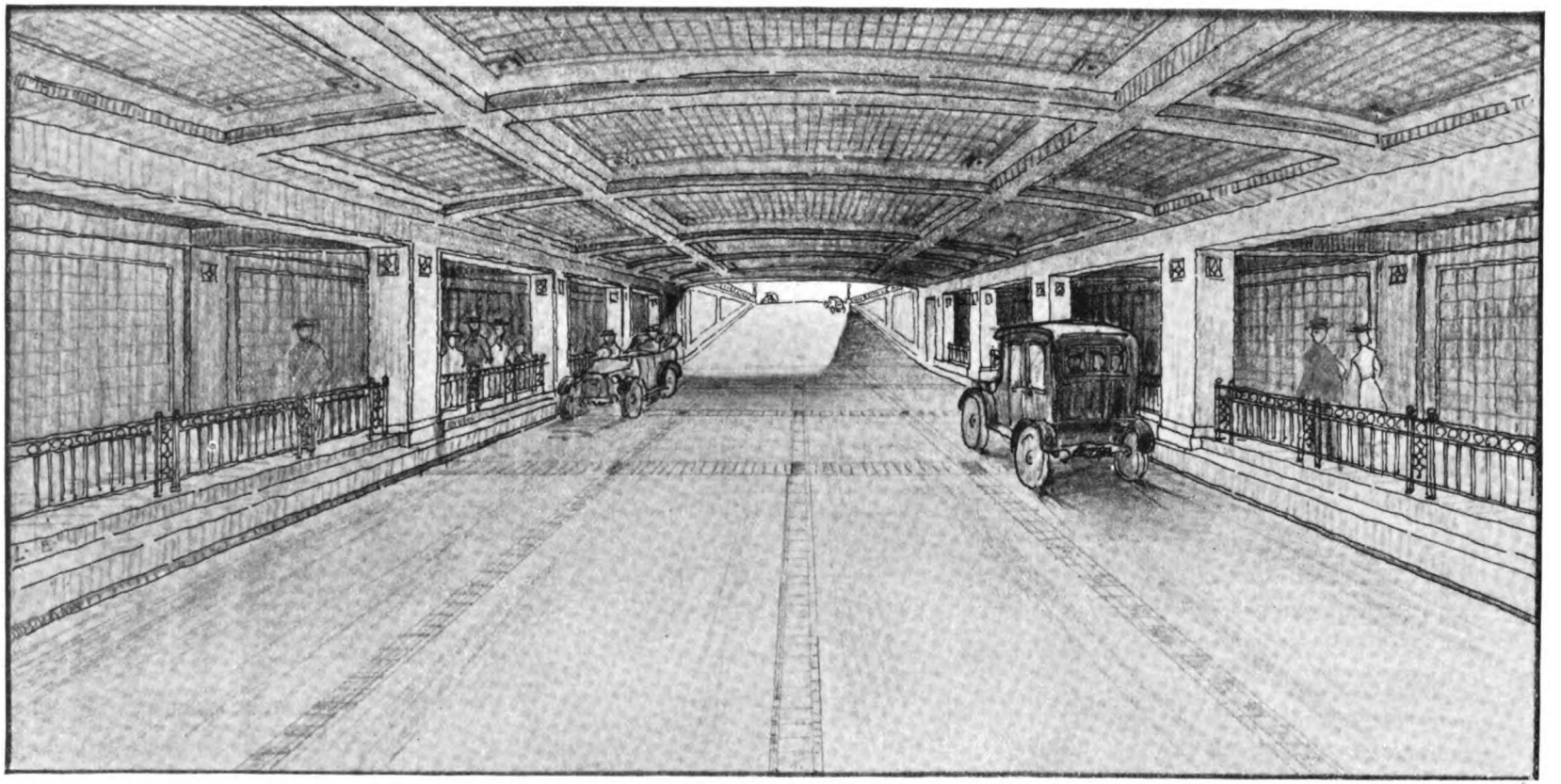

SUBWAY BELOW JEFFERSON AVENUE

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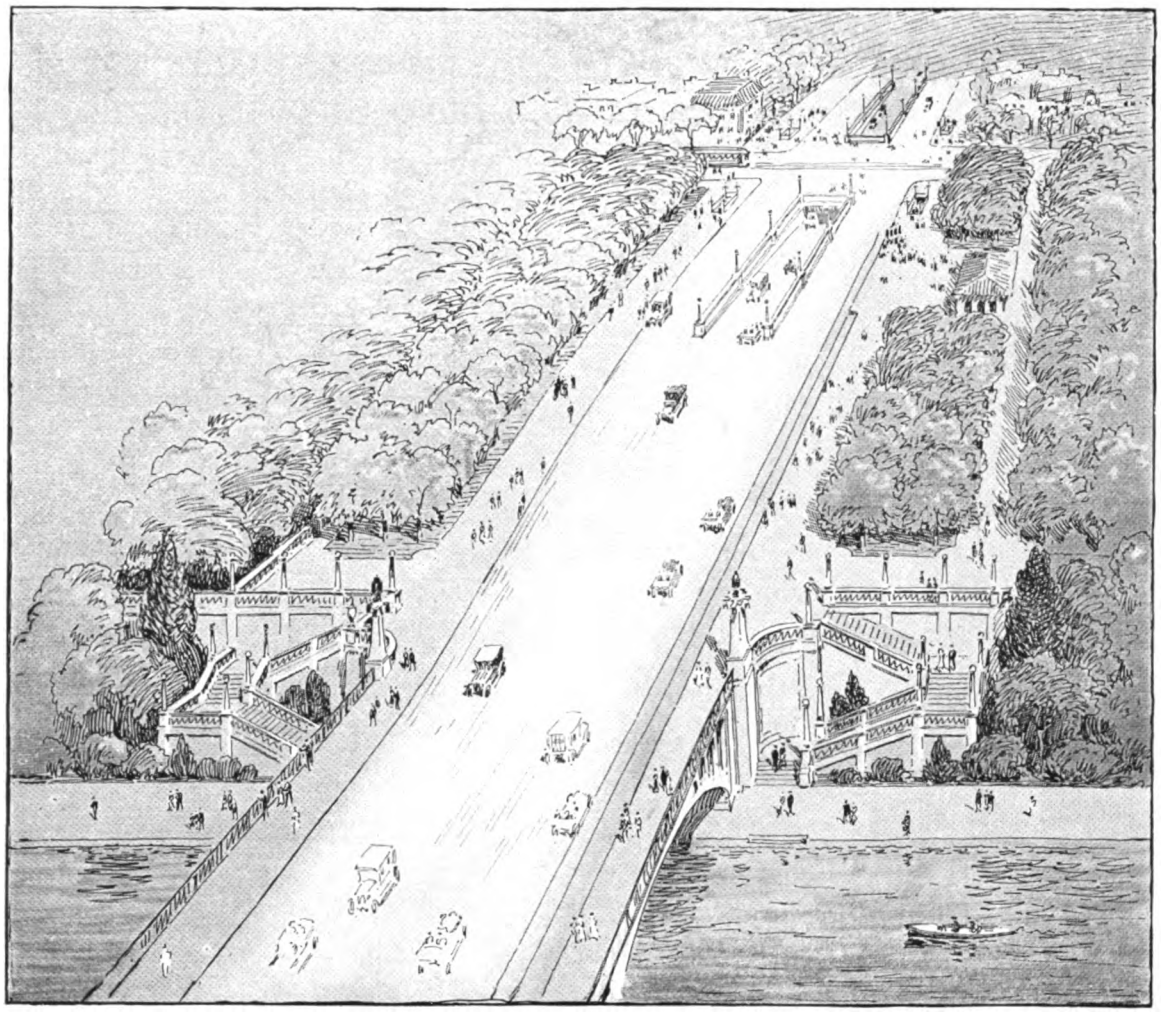

THE DETROIT APPROACH WITH SUBWAY

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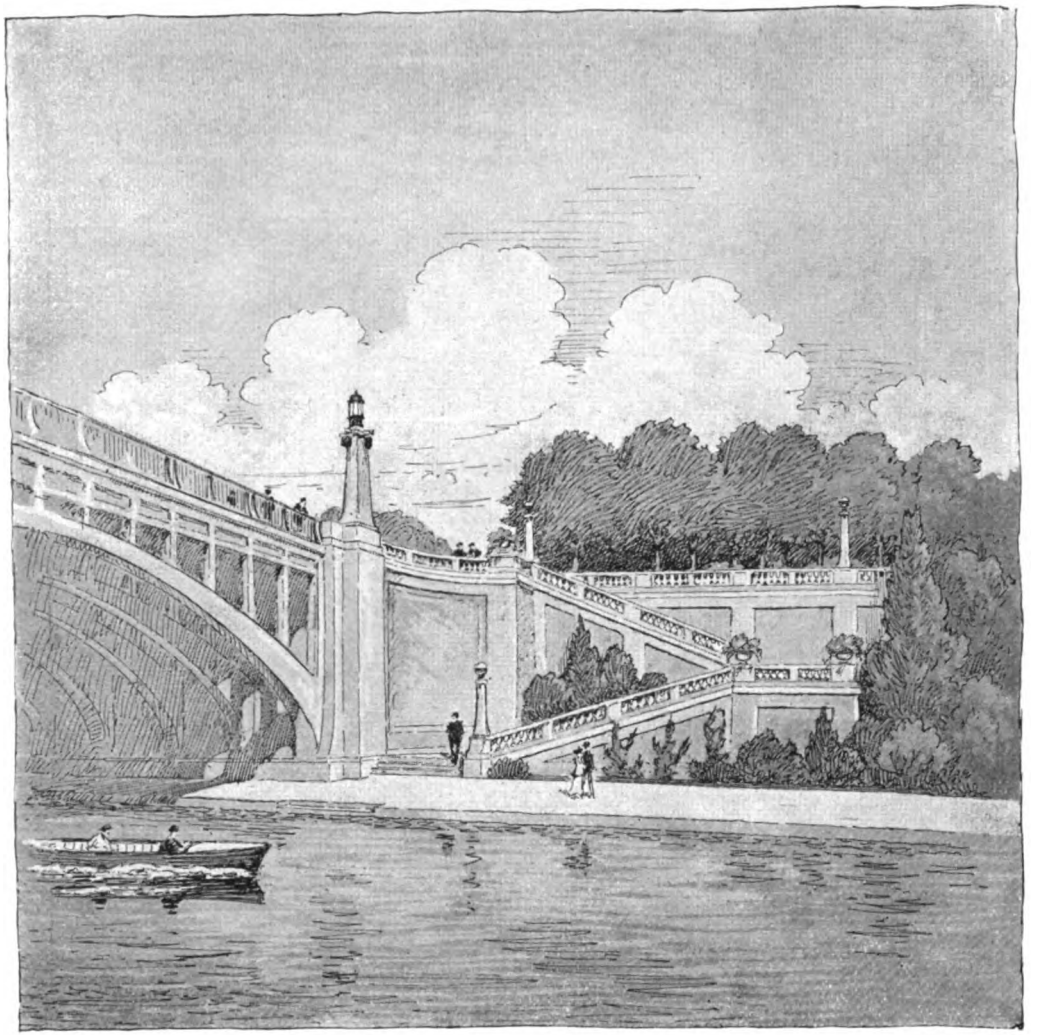

STAIRS AND BOAT LANDING AT DETROIT APPROACH

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THE APPROACHES

The effectiveness of the bridge as above described will depend largely upon the facilities for safe and rapid distribution of traffic at both ends. To obtain continuity of traffic movement has therefore been one of the aims of this study. Accordingly provision has been made for the separation of pedestrian and vehicular traffic, thus safeguarding pedestrians and permitting rapid, continuous movement of vehicles to and from each end of the bridge, as well as up and down Jefferson Avenue.

The Detroit Approach

The seriousness of the congestion at East Grand Boulevard and Jefferson Avenue, due to the conflict of through Jefferson cars and vehicular traffic with that bound for the bridge, is generally known. It is unusual in that it is seasonal, taking place very largely during the summer months, being most severe on holidays and during but a few hours on other days and thus not justifying as large an outlay as would a similar problem down town where congestion might be a daily occurrence. With the growth of the city this problem will become more and more troublesome.

Various forms of grade separation were studied, the straight-away subway shown in the plans appearing as the most direct, economical and inconspicuous, and therefore best adapted to the present and probable future conditions. Vehicles from Grand Boulevard can reach the bridge approach without delay by means of this broad subway under Jefferson Avenue. When traffic is light, vehicles can cross or turn into Jefferson Avenue on the surface, there being a roadway 18 feet wide on each side of the subway. These roadways also give ample access to Boulevard property adjoining the subway. A heavy parapet and curbing separates the subway from these roadways. Sidewalks are also provided in the subway making it possible for pedestrians to reach the bridge approach from the Boulevard side of Jefferson Avenue without crossing the car tracks, thus facilitating street car movement during the rush hours.

Between Jefferson Avenue and the River the roadway on the north side of the subway is made wide enough to allow for the loading, unloading and handling of automobile busses. The south subway portal is far enough from the Jefferson Avenue walk to provide passage for vehicles, thus allowing the bridge busses after reloading to return to the island without delaying pedestrian traffic on the south side of Jefferson Avenue across the approach.

The assumption is made that the present auto-bus system for carrying people across the bridge, or some analagous plan will be used. If a special bridge street car system were installed the space allowed would also be sufficient for a car terminal.

The roadway of the subway approaches is 36 feet in width between curbs and has a five per cent grade. This width provides for four lines of automobiles. The width of roadway in the subway is also 36 feet, with a

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clear height of 12 feet. Pedestrians reach the walks in subway by stairs from each side of Jefferson Avenue and adjoining the roadways of the Boulevard and approach. These stairs are 8 feet in width and are four in number. Inclines could be used in place of stairs.

Stairs on each side of the roadway and at the ends of the subway, leading from the roadway up to the subway walk, provide ready egress in case of necessity. Each walk has 11 feet 6 inches clear width and an overhead clearance of 8 feet 3 inches.

The roadway of Jefferson Avenue is carried over the subway on cantilever reinforced concrete beams. These beams are in turn carried by longitudinal girders supported on columns. Along the edge of the sidewalk sufficient clearance is allowed under the girder and between columns to give ample ventilation and light to the walks.

The property between Jefferson Avenue and the river is utilized in such a way as not to require the immediate purchase of additional land and yet to permit coordination with any development that may take place due to the acquisition of more land or the installation of special transportation over the bridge. Grass plots are left on each side of this approach with space for trees and shrubbery. A satisfactory approach being thus possible it does not seem justifiable at this time to make the acquisition of additional land an essential part of the project, however desirable a larger area would be at this point. There is, however, no doubt that additional space on each side is very desirable to keep certain amusement features at some distance, to give a larger parked area, to allow more space for the distribution of people, as well as to form a more attractive approach to the bridge. Once the bridge has been built the cost of this land will be greatly increased. The Consulting Board therefore believes that additional land should be acquired on each side of the present property.

The creation of such a parked area should carry with it protection against undesirable encroachments. The right of excess condemnation used so effectively in the interests of the public in London and Paris would enable this and other American cities to control the immediate environment of areas given extraordinary value by reason of the expenditure of public funds.

By placing the island end of the bridge slightly further up-stream than in the case of the original bridge, the Detroit end can begin at the centre of the city's property and thus permit giving a symmetrical treatment to the stairs and retaining walls at that end. The change in direction is taken up by a slight curve in the approach roadway in such a way that an automobile going to the island upon emerging from the subway is about on the axis of the bridge.

An alternate design of this bridge head was also developed to accommodate a river front boulevard should this most desirable feature later become possible.

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A new shelter and comfort station is shown to replace the present inadequate red brick building. The proposed building is kept low so as to make it inconspicuous and is set back from the walk to give more space and freedom of movement at the point where crowds turn on and off the approach.

From the level of the approach, stairs lead down to the boat landing which continues below the first span of the bridge. The government harbor line changes in direction at the bridge but for convenience in landing with launches and other pleasure craft the dock line is made a continuous flat curve in plan. Space is allowed at this level for some planting to carry out the park character of the project.

Broad panels relieve the plain surface of the retaining walls. The balustrades are moulded in a manner appropriate to the material, to lend interest to and contrast with the walls. If at the time of construction it is possible to do so stone should be used for the balustrades of the approaches.

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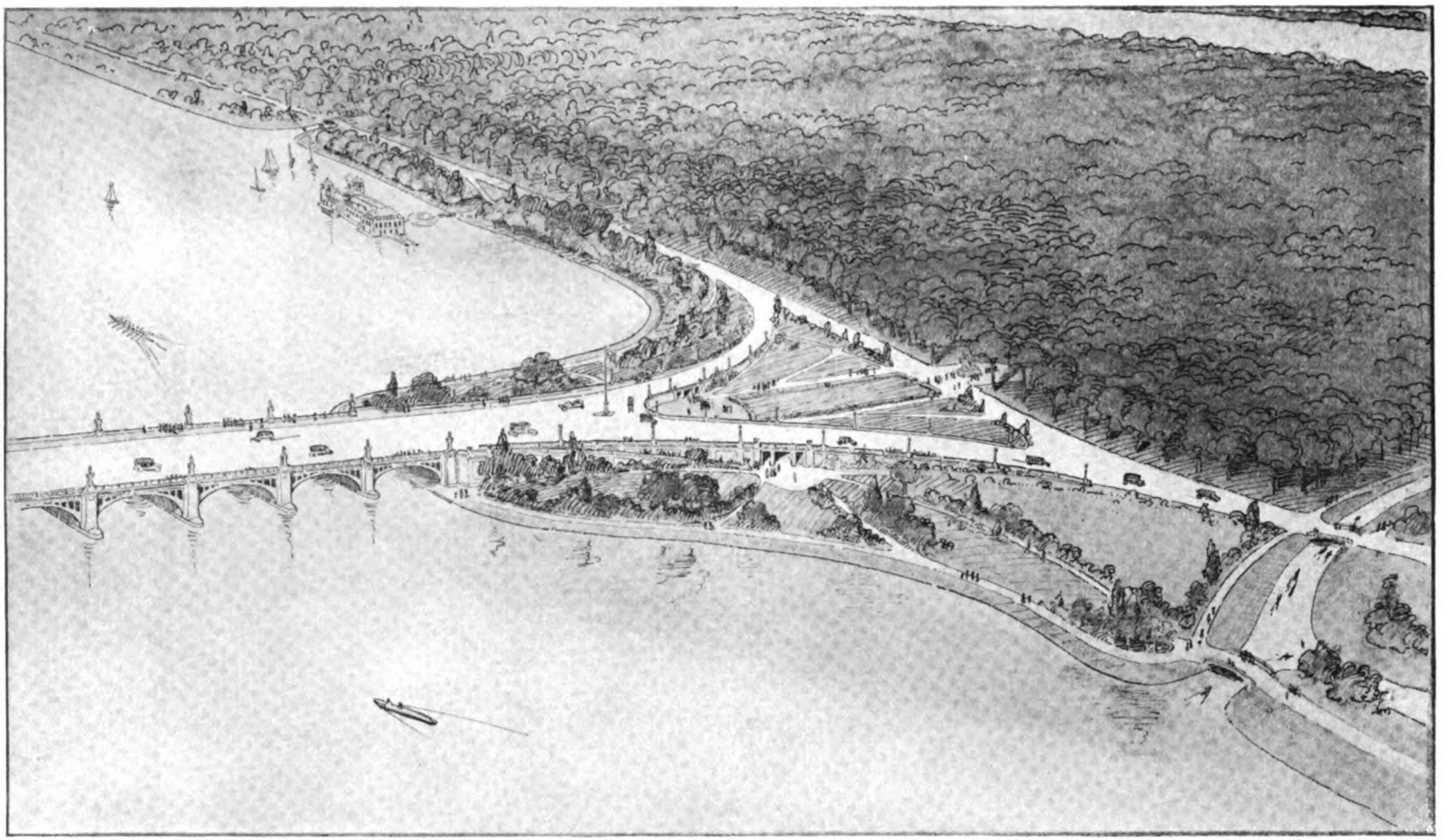

GENERAL VIEW OF BELLE ISLE APPROACH

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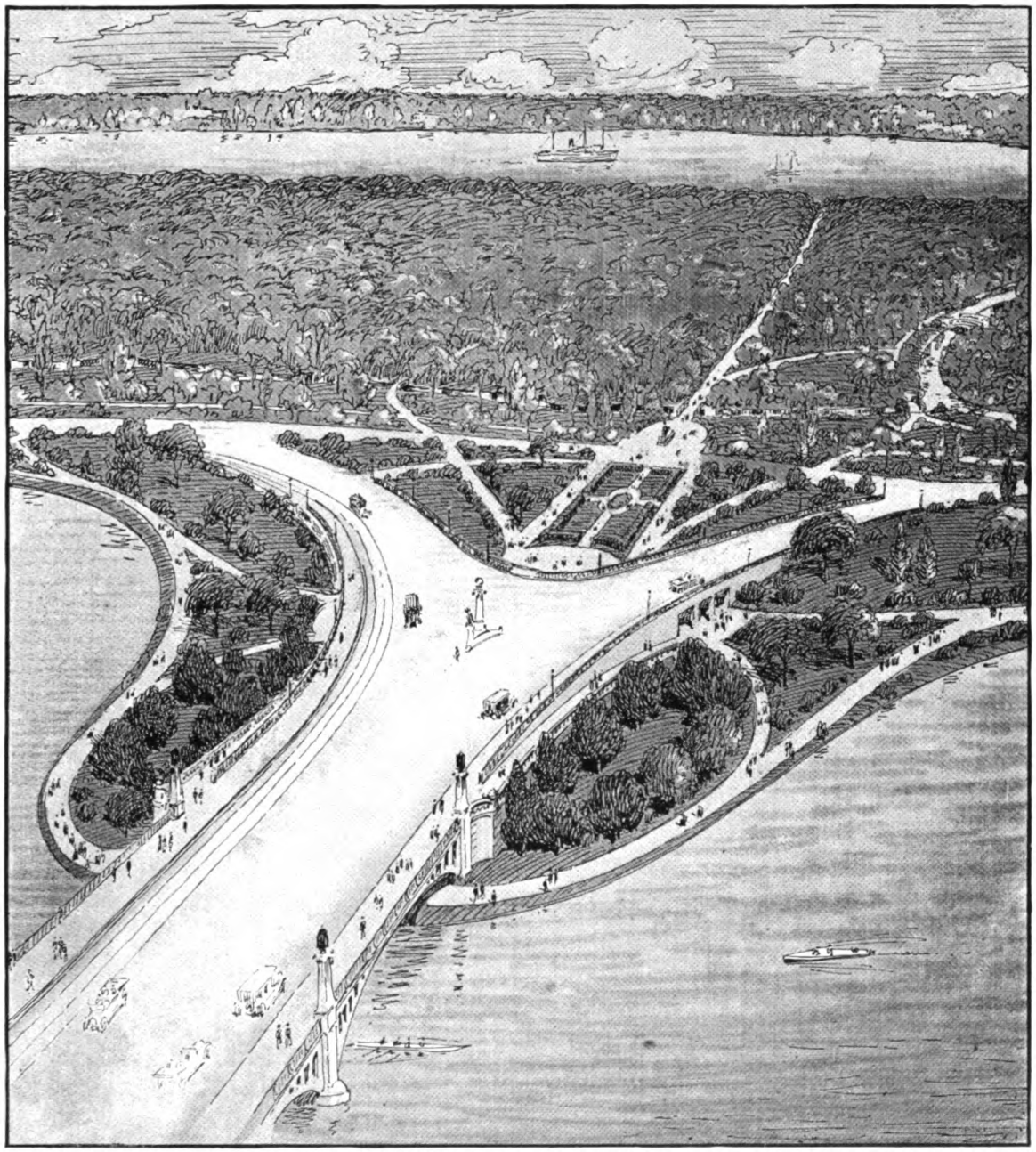

THE BELLE ISLE APPROACH

On each side the Inclines lead to ground level and to Passages below arms of Approach.

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The Belle Isle Approach

The problem at the island end of the bridge was more complex than that at the other. The lower end of the island is an important distributing center for visitors arriving by ferry boat, vehicle and on foot, and most of the permanent features in this section have been located or developed accordingly. Because of the heavy steamboat traffic and the current of the Canadian channel it will never be advisable to have the ferry boat landing on the Canadian side of the island. The Boulevard acts as a natural collecting element for traffic and the bridge as a discharging unit at the island approach. The Casino, a permanent and costly building, was located with reference to the bridge, boat landing and the river view, as were also the roads. The picnic grounds lie just beyond and to the left of the bridge approach with the bath house and various other attractions farther on. The use of these features as well as traffic movement to and from them, will be affected by the Scott Memorial Fountain, the setting of which will be largely created by filling in the middle ground or flats just below the island, a development which will bring the bridge more nearly midway between the chief attractions of the island, or at least those most readily reached on foot.

At the present time traffic delays occur at the end of the bridge. At this point pedestrians moving along that side of the island cross the bridge approach on the surface. Even with further restriction of automobiles this approach would always be a source of traffic interruption which should be eliminated if full advantage is to be taken of the subway at Jefferson Avenue and other plans to attain continuous movement of traffic.

A plaza at this point with circular traffic movement, similar to some of the foreign plazas, means as many points of delay and danger to pedestrians as there are roads to cross. A road straight across the island from the bridge would again involve delay where roads cross it, the continuous stream of vehicles cutting off pedestrians moving up and down the island and necessitating the destruction of many of the finest trees in that section, also keeping vehicles away from points near the Scott Fountain.

The present effective one-way movement of vehicles allows them to use the outer roads as a loop about the lower portion of the island, thus keeping the entire lower central part of the island free of vehicles. Even with this simplification of control it might prove desirable to keep vehicles off the island altogether on certain occasions. It therefore seemed best to continue the present one-way traffic movement and devise a plan to bring pedestrians within the vehicle loop without delay, while allowing them freedom of movement along the shore as in the case of vehicles. No form of mere surface traffic control seems adequate to solve this problem and hence the proposed approach was developed to separate pedestrians and vehicles in such a manner as to make uninterrupted and safe movement possible for both, and particularly to allow pedestrians to leave and reach

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the bridge as well as move below it without crossing a heavy traffic roadway. This was brought about by a "Y" shaped approach, the arms of which, made up of roadways and walks, reach the island at practically its present grade.

During hours of heavy traffic pedestrians can reach the ground level directly from the bridge by means of inclined walks or ramps on the outer side of each arm of the approach, passing thence at ground level, by means of a passage or an underpass, through one arm to within the approach court, from this point having unrestricted access to the inside of the island; or, by going through a similar passage opposite the first they can reach shore points beyond the bridge. Pedestrians can also move along the shore below the last bridge span which with the underpass will be of even greater importance should the island ever be developed to the harbor line, as has been proposed. When traffic is light pedestrians and vehicles can reach and leave the level of the island at the end of the arms. Unimpeded movement by pedestrians is thus possible under various conditions, in all essential directions about the approach.

This approach with its passages also makes possible the elimination of traffic delays which take place at that point where ferry boat passengers cross the main drive which will lead to the lower end of the island. After the construction of the Scott Fountain these delays will become even more serious. The avoidance of delays would be further facilitated should the ferry dock, whenever its reconstruction becomes necessary, be moved somewhat further up-stream.

The underpasses are large enough to accomodate 40,000 persons per hour, while half that number could pass below the end of the bridge at the harbor line. These underpasses could thus accommodate all passing over the bridge as well as those on the island likely to move along the shore. The ramps are made the full width of the bridge walks, since at certain times practically all pedestrians would use them.

The walls and balustrades of the approach and its arms will be similar in treatment to those at the Detroit end of the bridge, except that the walls are considerably lower, being further broken in height by the ramps, grading and the planting of trees and shrubbery. Indeed they have been kept as low as possible consistent with retaining the advantage of separating the two principal classes of traffic. Suitable planting is also to be used inside the approach. In the space or court included between the arms, wide walks are shown to distribute pedestrians in various directions. It may be pointed out that those using these walks must cross Riverbank Road, where they would seemingly come in conflict with vehicles which are re-circling the island; but this difficulty is overcome by the approach which permits re-circling traffic to use its road-ways during hours when there is need for such diversion of vehicles.

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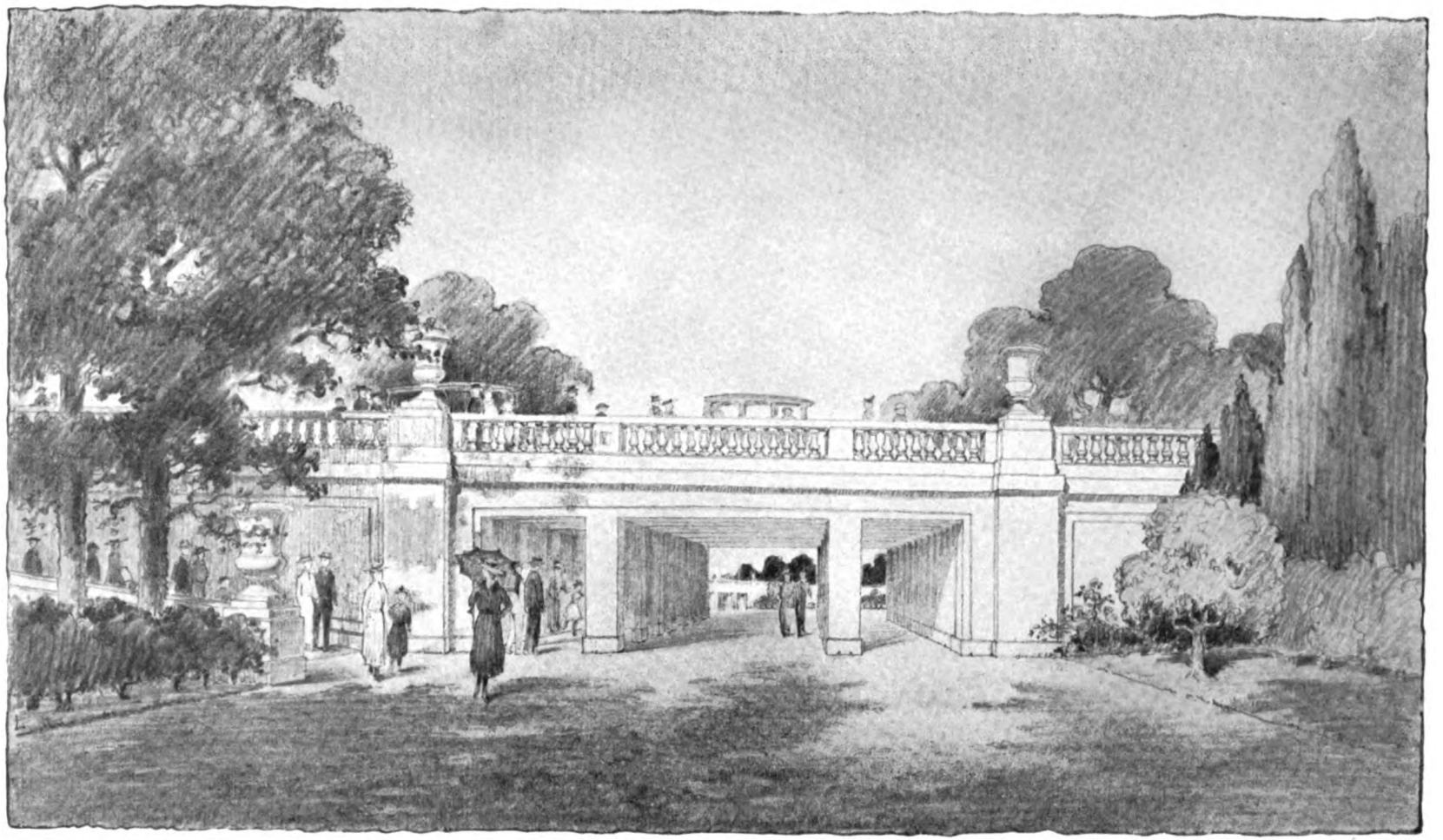

PASSAGE BELOW BELLE ISLE APPROACH

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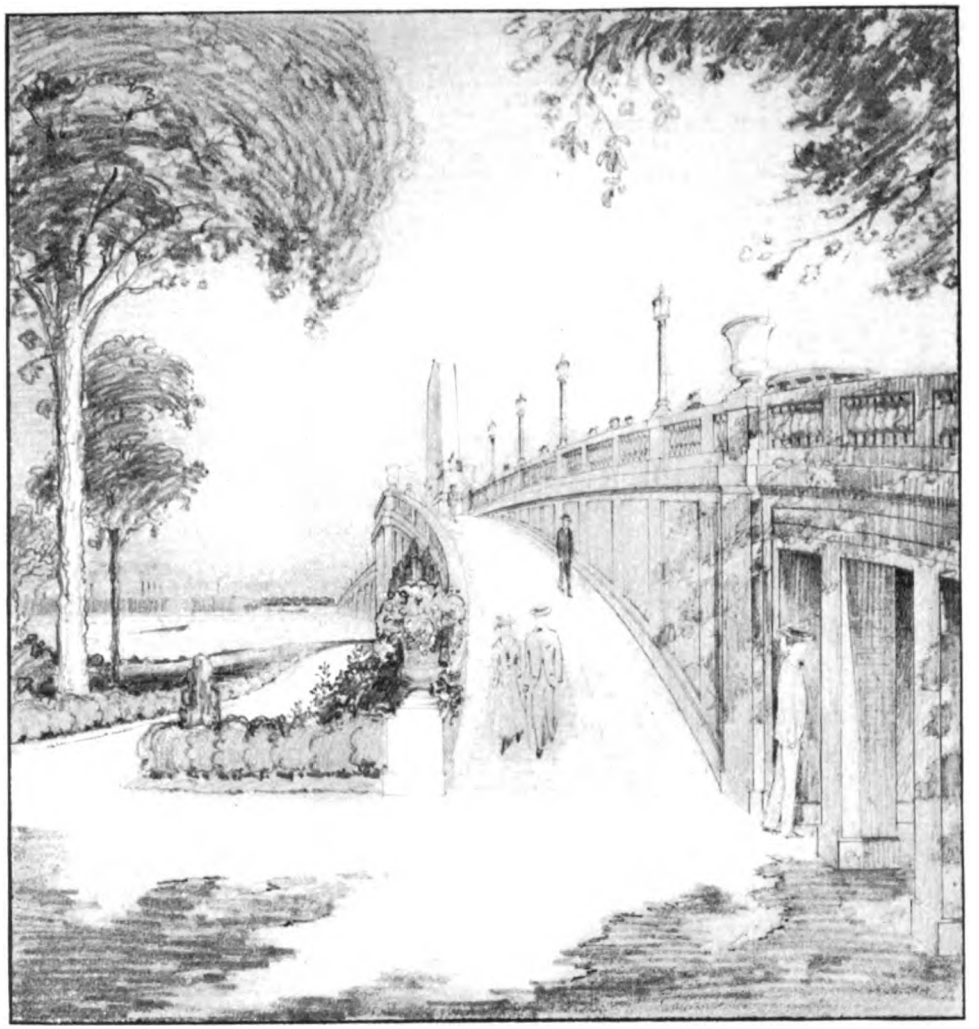

AN INCLINE AT THE ISLAND APPROACH

By means of Inclines and the Passages below Approach. Pedestrians can reach island without crossing and stopping a line of vehicles.

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OMISSION OF DRAW

Continuity of traffic movement being assured at the approaches, it should if possible be maintained on the bridge itself by omitting the draw. In addition to avoiding delays and accidents, a saving in cost of construction and in cost of maintenance and operation would be effected, and the appearance of the bridge would be improved. The clearance of thirty feet given the three channel spans was based upon an actual study of the boats using this channel, that height being adequate for the ordinary river traffic on this side consisting of tugs, scows and small yachts. The unusually wide and deep channel on the Canadian side of the island is regarded as ample for all possible developments of freight and passenger traffic, and for this reason the Lake Carriers' Association after a study of the situation stated that no objection would be offered by them to the omission of the draw.

However, if valid objections are raised a bascule could be made a part of the design without disturbing its other essential features the proposed clearance being retained in order to minimize the number of times the draw must be opened. Owing to the size of the piers required, the necessity for an operator's tower and that of building the arms of the bascule of steel, a bridge placed as this would be seriously marred in appearance by incorporating such a feature for which moreover there is not enough practical justification.

The large and costly Charles River Bridge between Boston and Cambridge, almost identical in length with this proposed bridge, was built without a draw upon authorization of Congress. Attention might also here be called to the fact that in many foreign cities lying on both sides of navigable rivers and having but a single channel the bridges do not have a greater clearance than that proposed for this bridge.

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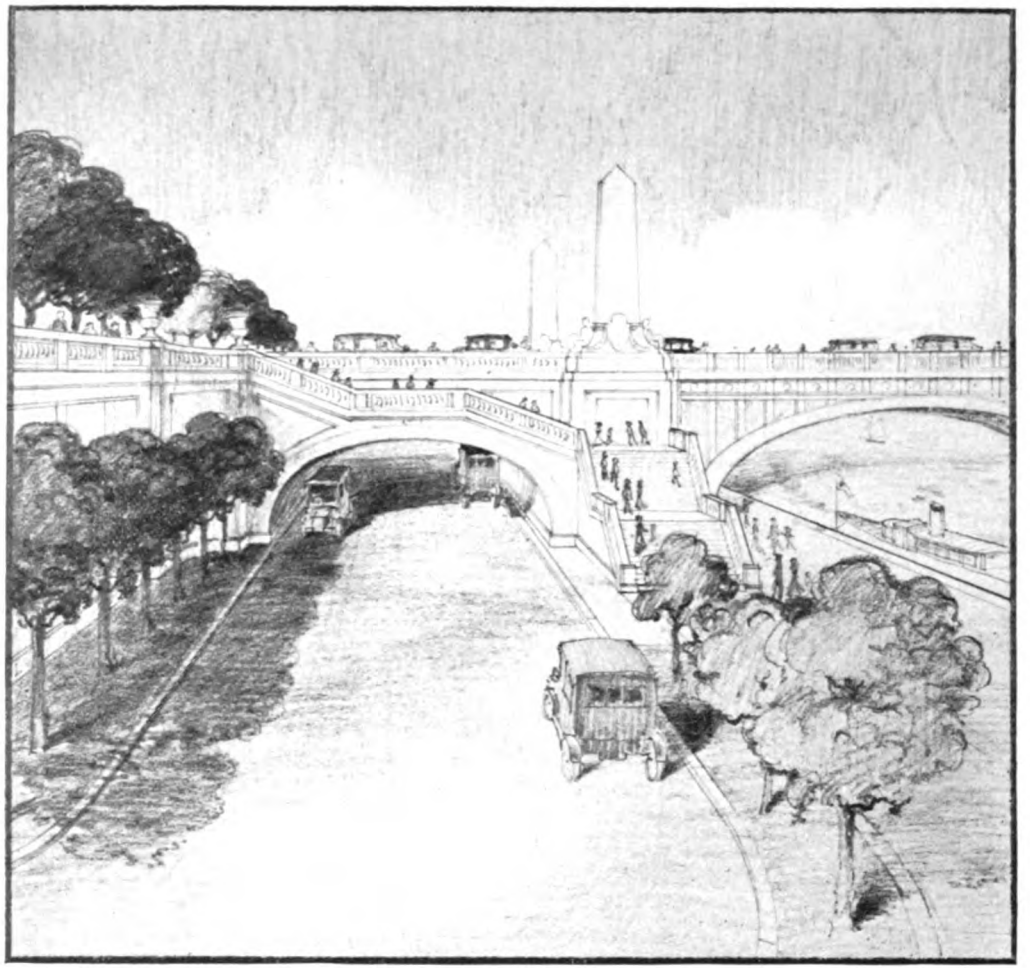

ALTERNATE STUDY FOR DETROIT END OF BRIDGE

This provides for the enlargement of the Approach, the extension of Helen Avenue to the River connecting there with a River Drive, and permits reaching the Boat Landing without crossing the Drive.

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TRANSPORTATION OVER THE BRIDGE

Such transportation is now carried on by means of auto-busses which load and unload on the up-stream side of the Detroit approach and discharge and receive passengers at various points on the island.

Since the installation of street cars on the bridge may become a necessity, and is strongly urged by some advocates of the bridge, a study has been made of car service on the bridge as compared with auto-bus transportation. The design of the bridge and approaches is such that street cars can be installed.

The conclusions reached in this connection are as follows:

1. That an auto-bus system should be used until such time as a change to another form of conveyance becomes necessary.

2. That the bridge should be built in such a way as to permit the future installation of street cars.

3. That when car tracks are installed, either during construction of the bridge, or later, they should be placed on the up-stream side of the bridge.

4. That a shuttle system with storage battery cars, thus requiring no trolley, would seem to be best suited to the conditions.

5. That the car tracks be not depressed at the terminals.

The reasons are as follows:

A. Such a system has the advantage of an unbroken roadway on the bridge; of flexibility, in that it can be readily adjusted to any new conditions that may arise, as routes can be easily changed and stations readily established wherever needed; a large number of passengers can be carried past the terminals and thus avoid congestion at those points. On the Detroit side such busses could owing to the subway load and unload on both sides of Jefferson Avenue, relieving the approach and leaving passengers on that side of the avenue from which a desired street car can be most readily reached.

A disadvantage of the bus system is the relatively low number of passengers that can be carried across the bridge in proportion to the cost of equipment and its operation. Such busses are limited in speed to that of the vehicles using the bridge, the latter speed limitations being of course very desirable on the island proper. In this connection it should be remembered that this is not a railroad structure whose function is to expedite the transfer of passengers during business hours, and that a reasonably effective though more leisurely system would answer the purpose.

B. It is possible that with the continuous growth of the city it may later become necessary to install cars in order to accommodate a large number of passengers and to develop the full effectiveness of the bridge. It is therefore good economy to provide for this possibility when building.

Cars on the bridge do not add to its attractiveness. On the other hand cars are not very conspicuous on so large a structure as is shown by many bridges bearing car systems.

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C. If car transportation is installed it might be a local system which is used only on the bridge from terminal to terminal.

Another possibility is the combination of local car service on the bridge with auto-bus service from the Detroit approach to points beyond the Belle Isle approach. This would utilize both systems each in a way best suited to the ground covered by them.

Another form of car transportation would involve through service from down-town over the bridge to the island terminal. With such a system loops would be required on the island. One objection to the through car system is that every car going to the island must turn off at the bridge approach and in so doing delays street cars and vehicles going out Jefferson beyond this point. The chief advantage of such a plan would be the minimizing of transfers down town and the avoidance of transfers at the Detroit approach of the bridge. It would however be very difficult to route cars from the various city lines satisfactorily. If such through service were used it would probably be best to use one line as a feeder, as in the case of Woodward Avenue cars to the Michigan Central station, passengers transferring to the feeder line at various points down-town, thus scattering transfer points and reducing congestion.

By placing the car tracks on one side of the bridge adjoining one of the walks, the remainder of the roadway can be used to greater advantage, since the peak load in vehicular traffic going to the island comes at an earlier hour than that returning. At certain times there would be two or three lines of vehicles going as against one returning, while later the reverse would be true. An unbroken roadway is thus more serviceable. The tracks should be shut off from the roadway as a safeguard and to permit rapid service.

D. Of the various terminal treatments and forms of car operation that known as the shuttle system seems best adapted to the requirements of space, service and appearance. Sufficient space for loops would be available at the island but not at the Detroit approach, hence the loop system does not seem to be as desirable. By the shuttle plan cars would unload at one point, proceeding to a point just beyond for loading, then switch to the returning track and repeat this operation at the other terminal. A plan of an appropriate terminal with loading and unloading platforms and its capacity is shown in Appendix IV.

Storage battery cars would be most desirable to avoid the use of overhead equipment. Such cars can be low, should load from the side at the end of each row of seats and should be controlled from each end.

Another system worthy of consideration and in some ways adapted to bridge service is the trackless trolley. It makes possible a road unbroken by tracks but its low cost of installation is balanced by a lower efficiency.

E. By keeping the tracks on the same level with vehicles and having the island car terminal on one arm of the bridge approach it is possible to

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separate pedestrian and vehicle movement and to keep the end of the bridge reasonably low. Upon leaving cars the passengers can proceed up-stream along shore, or by using the passages below arms of approach they can reach the interior of island or its lower end without crossing a roadway. If the car tracks are depressed, the bridge must be raised and all the advantages of separating vehicle and pedestrian traffic would be lost, no cross communication would be possible below the end of the bridge, and traffic delays could not be avoided.

Car Storage

If a car system is installed on the bridge it will be necessary to connect the tracks with those on Jefferson Avenue to provide for getting the bridge cars on the bridge and for returning them to some nearby point of storage.

Cars and the Detroit Approach and Terminal

A transportation system would increase the efficiency of the structure but would ultimately congest this approach through the loading and unloading of large numbers of passengers at the car terminal. The proposed subway would absorb vehicles going to and from the island and thus keep traffic moving on Jefferson Avenue, making practically the entire area of the approach available and large enough for some years to come as a distributing area. With the continued rapid growth of the city a larger approach would however presently be necessary.

Cars and the Belle Isle Approach

In the design of the island approach the primary consideration has been to solve the traffic problem in as many of its aspects as possible. If cars are installed, the island car terminal should be on the up-river arm of the approach.

There are those who fear that the installation of a car system on the bridge would presently mean its extension over the island. Ample facilities on the bridge proper would probably check such a tendency. It is hardly likely that any particular form of approach would prevent the building of tracks on the island later if sufficient demand arose for it, however undesirable and unthinkable such tracks now appear.

Plan of City Contiguous to Detroit Approach

The study of the bridge and the Detroit approach has naturally involved a consideration of the various streets and car lines which must act as feeders to the bridge and at the same time serve the needs of ordinary communication throughout the year of this rapidly growing city. In this connection as in that of any large project in a great city there appears the need of a well worked out city plan with provision of ample authority to carry out its essential features. Among the fundamental requirements to be borne in mind constantly are those having to do with distribution of traffic to avoid congestion, and the widening and cutting through of streets.

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The location of Elmwood and Mt. Elliott cemeteries restricts traffic going to the northeastern part of the city to a comparatively few streets and of these Jefferson Avenue and Lafayette Avenue East alone continue unbroken from down town to points beyond the Boulevard. During certain hours Jefferson Avenue is so crowded with vehicles that steps should before long be taken to relieve it possibly by extending Congress Street to the Boulevard. This street now stops at Mt. Elliott Avenue; it again begins at the Boulevard and continues to Baldwin Avenue. It is the street most likely to relieve Jefferson Avenue because of its width and its relation down town to Cadillac Square and Randolph Street for receiving and distributing traffic. It could be carried through at less cost than either Fort or Larned Streets. A grade separation would be necessary at Dequindre Street and at the Belt Line for this or any other street chosen. Whatever street is extended some obstacles would be met but none of these seem insuperable.

New Car Loop

Another source of congestion is due to the crossing of Grand Boulevard by those car lines which going out Lafayette Avenue East, loop back over Field, Jefferson and Concord Avenues, and force the loading of cars on Field Avenue and on Jefferson Avenue beyond Field. This situation would be greatly improved by routing these car lines to turn off Lafayette before reaching the Boulevard, using Helen Avenue to Jefferson and thence to Concord Avenue. The principle is that which has been applied to the region about the City Hall. This proposed new loop would multiply convenient points of loading and would expedite car handling. The regular Lafayette Avenue cars which run to Baldwin Avenue need not be interfered with.

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TECHNICAL FEATURES

One of the important problems from a technical standpoint was to select a type of structure which would economically fit the natural conditions at the proposed site, and at the same time lend itself to proper architectural treatment. Therefore, surveys were undertaken at the outset for the purpose of gathering data which would help in reaching a conclusion on this point.

Foundations

Thorough study of foundation problems being of fundamental importance in the design of a bridge whatever its type, special investigation of underlying soil conditions in the vicinity of the proposed site was made by means of borings and pile tests, the results of which were verified by data obtained from others who have made similar surveys.

In 1903, for example, an examination of soil conditions under the Detroit River was made for the Michigan Central Railroad in connection with the design of a proposed bridge over the Detroit River, and the records of this survey are available through the courtesy of the engineering department of that company. Borings were made at two crossings, the upper location being at the foot of Dequindre Street and the lower one approximately at the site of the present Michigan Central railroad tunnel. Foundations on rock were considered, consequently the soil was investigated to that depth, rock being found at thirteen points on the upper site and at sixteen on the lower. According to this survey the soil is quite uniformly soft clay with traces of fine sand and gravel, and the rock is generally overlain with from five to ten feet of hardpan. The rock at the upper site was found at a distance of from 105 to 110 feet below the water surface and at the lower site was practically level at a depth of about 100 feet below the water surface.

Preliminary to the actual construction of the Detroit River tunnel two lines of holes were bored, 100 feet down stream and 100 feet upstream respectively, from the center line of the structure. On these lines ordinary "wash" borings in a 2½-inch steel casing were made 100 feet apart to bed rock. Within the region of the tunnel the material was found to be a coarse blue clay, of varying consistency, with occasional seams of sand and gravel and scattered boulders. Bedrock was found at about 90 feet below the water surface. In addition to the borings, two test-pits were sunk on each side of the river, and these seemed to verify in every particular the character of the material as disclosed by the borings. The deepest of these test-pits was carried to a point approximately 10 feet above bed-rock, and the section of this test-pit revealed stiff blue clay with very little sand.

The Detroit Edison Company has made soil borings at the sites of the Delray and Connor's Creek power plants and at some of the local substations. A number of holes put down to rock at Delray show alternate

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layers of soft yellow and blue clay with occasional streaks of hardpan; rock was found at an elevation corresponding very closely with the results of the Michigan Central tunnel borings. At Connor's Creek the soft blue clay is over 100 feet thick, underlain by 5 to 15 feet of clay, pebbles and boulders. The limestone rock, generally at a distance of 125 to 130 feet below the water surface, is covered by a thin layer of marl and shale. These were core borings made with special equipment, driving a 4-inch casing, and the results are very reliable.

In connection with the design of the Detroit Water Works tunnel a number of auger borings were carried down 40 to 60 feet below the river bottom. Two borings, one at the land shaft and the other at the intake were put down to what was supposed, at the time, to be rock, but presumably the hard material encountered was shale some distance above the solid limestone. In the first hole this hard material was found at about 98 feet and at the intake 117 feet below the water surface. The material above was uniformly soft blue clay containing varying amounts of sand and sharp pebbles.

The excavations for many large buildings in the City of Detroit disclose substantially the same kind of material as was found in the borings described above. The soft yellow or blue clay encloses pockets of sand and varies in hardness from a soil capable of supporting three tons per square foot to a very plastic material which tends to flow when not confined. In and above Detroit the clay is fairly stiff; in Windsor it is more or less soft throughout. In the vicinity of the Conner's Creek Power House the material is somewhat softer and piles have been driven 100 feet into it with a gradually increasing resistance to driving.

During July, 1916 borings were made at the site of the temporary bridge under the direction of the Consulting Board. (See Appendix II. for Drill Report.) Four holes were put down to rock, two from the temporary bridge, one on Belle Isle and the fourth near the old mainland abutment. These borings were made with an ordinary well driver's equipment, driving a 2½-inch casing, and were essentially "wash" borings, although it was frequently possible to withdraw the drill and obtain a core of the material practically in its original state. Samples of the soil were obtained at intervals of approximately 10 feet. (See Location Map, Sheet 13 of Plans in Appendix V.) The material for a distance of about 90 feet below the water surface, as shown by this survey, is a light blue clay of nearly uniform hardness, containing fine sand in spots. At hole No. 2 near the middle of the river, quicksand was found at a depth of 90 feet below the water surface. The thickness of the quicksand layer is about 7 feet and the extent laterally is indefinite; it was not encountered however in any of the other holes. The pile driving records for the temporary bridge also indicate a softer material near the middle of the river. Hardpan was found at 100 to 110 feet below the water surface, and about 10 feet of sand and gravel seemed generally to cover the rock. Rock was found at a depth of 103 feet at Belle Isle, 108 feet at the Detroit abutment

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and at 123 and 125 feet respectively at the two holes in the river, all dimensions referring to mean water level. It will be noted that the contour of the rock approximates that of the bottom of the river bed.

Notwithstanding some difficulties peculiar to the methods employed, it was believed that the results of these borings, corroborated by such a large amount of evidence, did not warrant further exploration; also that the data obtained may be considered as fairly representing the various soil conditions that would be encountered in the construction of bridge foundations at or near the site of the temporary Belle Isle bridge.

In view of the situation as above described with respect to soil conditions, it would be impracticable in the judgment of the Board to extend foundations of the proposed structure through 30 feet of water and 90 feet of more or less plastic clay to bed-rock.

A reinforced concrete bridge, recently constructed over the Maumee River at Toledo, for which foundations were built on rock through a similar material, furnishes comparable data as to the difficulties that might be encountered and the cost that might result from such an undertaking. The thickness of clay overlying the rock in that case was only about two-thirds of the thickness of similar material at the Belle Isle Bridge site and the cost of the foundation alone, with about one-third of the number of piers required at Belle Isle, amounted at normal prices to over $500,000.00.

Hazard to the life of workmen is another factor entering into the advisability of deep foundation work in the vicinity of Detroit, on account of the presence of sulphur gas in the clay.

It is recommended therefore that the bridge structure be terminated at some level above the rock. It is common practice in the vicinity of Detroit to found buildings and other structures directly on the more or less compressible clay, allowable intensities of pressure depending upon the depth of foundation; and when the area covered by the structure is relatively small and a slight uniform settlement is not objectionable, the results are generally satisfactory.

The proposed bridge, however, stretches over a length of nearly half a mile, and on account of the fact that the soil conditions are not uniform throughout, there would be danger of unequal as well as excessive settlement if the structure were founded directly on the compressible material. It is further recommended therefore in order to reduce this danger to a minimum, consistent with least cost, that the foundation material be reinforced. This is usually done by means of wooden or concrete piling, and hence a careful study was made with respect to the use of piling in this locality. The Michigan Central Railroad Company and the Detroit Edison Company have used piling extensively; the Board has been courteously given the benefit of their data in this connection, and the information obtained from them as well as from other sources has been verified by observations on a pile which was driven near the site of the proposed bridge

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and loaded with pig iron. This pile was 15 inches and 8 inches in diameter at the upper and lower ends respectively, and was driven to a penetration of 51 feet, the records of the test being given in Appendix III.

It is assumed from the above investigation relative to the carrying capacity of piles, that piles of size and penetration comparable to the test pile would carry 18 to 20 tons without serious progressive settlement. In actual construction the length of piles required for given capacity could be adjusted to conform to the varying soil conditions by reference to the data of the test pile. The piles should be cut off below the bottom of the river so as to eliminate danger of scouring or damage from ice.

Selection of Type

A comprehensive study of the whole foundation problem in the light of information as described, led to the following conclusions relative to the type best adapted for the proposed structure.

1. That it should be as light as possible.
2. That the foundation reactions should be entirely vertical.

The problem was thus narrowed down to consideration of the relative merits as to cost and appearance of a comparatively few types.

Arches and cantilevers are types which economically follow pleasing lines, and therefore investigation of their relative adaptability was made by means of sketches and estimates of costs. Two-hinged, three-hinged and hingeless arches were considered, and while each has its advantages, all are dependent for stability upon lateral resistance of the soil. Furthermore, an intelligent analysis of stresses must be based upon assumed and uncertain displacements of the piers. For these reasons and in view of the soil conditions as described above, a structure based upon the cantilever principle with vertical reactions is considered preferable. Accordingly, the design contemplates the construction of a series of spans consisting of curved cantilever arms extending in both directions from each of the piers to which they are rigidly connected. The arms are joined near the centers of the spans by simply supported units. The advantage of the latter arrangement instead of using a shear joint connecting the cantilever arms, as is sometimes done in structures of this sort, is to avoid damage which might result from unequal settlement of the piers. The cantilever arms are constructed of concrete reinforced with structural steel, the latter being so designed that it may be completely fabricated in the shops, erected in advance of the concrete work and used to carry the forms for the concrete.

Live Loading

The roadway is designed to carry two 50 ton loaded cars on each car track, the dimensions of wheel bases being as shown on page 97 with 100 pounds per square foot uniformly distributed over the remaining area of the roadway; or 100 pounds per square foot over the entire area.

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The lateral distribution of the concentrated street car loads as used in the computations is based upon the relative stiffness of the cantilever arms and lateral distributing members. The sidewalks are designed to carry 100 pounds per square foot uniformly distributed.

Allowable Working Stresses

STRUCTURAL STEEL—

Tension—16,000 pounds per square inch.

Compression—
- 16,000 pounds per square inch when effectively stiffened by concrete,
- isolated columns $16{,}000 - 70\frac{l}{r}$, pounds per sq. inch

CONCRETE, Mix 1:2:4—650 pounds per square inch at the extreme fibres in flexure.

REINFORCING STEEL—16,000 pounds per square inch in tension.

WOODEN PILES—18 tons per pile.

Analysis of Stresses

The proposed bridge is designed so that each pier with its projecting arms and ties is an elastic unit entirely independent of adjacent units. The internal stress functions in the projecting arms are statically indeterminate on account of the rigid connections at the piers, therefore the method of least work has been used for the analysis of stresses in those members. It is assumed that the steel reinforcement will serve as falsework, the concrete in the arms being placed from the piers outward. After the concrete in the arms has set sufficiently to withstand stresses, forms for the remainder of the superstructure may be erected and the concrete placed. The computations of stresses in the projecting arms and ties are based upon loadings which accord with details of construction as outlined above.

Starting with an assumed design of arms the analysis was made as follows:

1. Considering combined action of structural steel and concrete in arms, in the usual manner as for reinforced concrete construction, the required area of ties was determined for the completed structure with live loading.

2. With area of ties determined as above the structural steel arm was analyzed for erection loads, and maximum stresses computed in all members, considering the concrete for arms poured outward from the piers in successive stages. Stresses in steel members were also determined for arm completely poured, concrete considered plastic, and as these stresses remain in the steel after the concrete sets, they were termed permanent initial stresses in the steel.

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3. Moments, thrusts and fibre stresses were then computed for the structure as completed, neglecting weight of arm concrete in dead load as this is carried by permanent initial stresses in steel.
4. Combination of unit stresses determined in steps two and three to obtain maximum intensities of stress in ties, arms, concrete and structural steel. Stresses in steel members as determined in usual manner for reinforced concrete, were algebraically added to permanent initial stresses as determined in step two to obtain final stresses.
5. Revision of area of ties and sections of arms to keep stresses within prescribed limits and re-calculation where changes were of such magnitude as to require it.

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ESTIMATE OF COST

A detailed estimate of cost has been made for the structure as recommended without bascule span. On account of the fact that the War Department has not yet approved a fixed bridge, an estimate of cost has also been made for a structure with a bascule span. The summaries are given below:

Bridge Without Bascule Span

Bridge Proper—	
Substructure	$969,225.00
Superstructure	976,035.00
Detroit Approach	281,042.00
Island Approach	332,005.00
Jefferson Avenue Subway	192,809.00
Grand Total	$2,751,116.00

Bridge With Bascule Span

The cost of Detroit approach, subway and island approach will remain the same as for the bridge without the bascule span.

Bridge Proper—	
Substructure	$1,019,225.00
Superstructure (exclusive of bascule span)	886,035.00
Bascule Span	287,000.00
Detroit Approach	281,042.00
Island Approach	332,005.00
Jefferson Avenue Subway	192,809.00
Grand Total	$2,998,116.00

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APPENDICES

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APPENDIX I.

TRAFFIC SURVEY

In this appendix is given the results of a count made of traffic over the temporary bridge on a typical Sunday, (August 20, 1916), and of river traffic in the American channel between August 29, 1916 and October 16, 1916.

Tables 1 and 2 give the number of pedestrians and automobiles to and from the Island during 20 minute periods. The curves on page 66 are plotted from data in Tables 1 and 2 and give the rate of movement at different times of day.

Notes On Traffic Count

HORSE vehicles went to the island at fairly uniform intervals throughout the day, and about fifty per cent of them remained on the island until after 7:00 P. M. They invariably delayed automobile traffic.

BICYCLES as a rule were in groups of three or four. Their speed was about the same as automobiles.

MOTORCYCLES did not delay traffic. About one third of the motorcycles carried side cars and took the place of automobiles in the traffic, but were not so counted.

AUTOMOBILES went at a uniform rate of speed of about 10 miles per hour throughout the day. After 7:00 P. M. this speed was somewhat increased, until at 10;00 P. M. the average rate of speed was about 14 miles per hour.

PEDESTRIANS were held to the one-way rule, and throughout the day the automobile traffic had to be stopped frequently to allow pedestrians going to the island to cross over to the west sidewalk at the Detroit end of the bridge. Returning pedestrians moved more slowly than those going to the island. After 8:00 P. M. many of those returning from the island used the left-hand side of bridge to good advantage.

DELAYS: Jefferson Avenue automobile traffic was diverted at points above and below the Boulevard. The street cars on Jefferson Avenue caused several stoppages of traffic on the bridge especially after 7:00 P. M. Two delays were caused by accidents to automobiles. There were three or four openings of the draw each delaying traffic. Boats which went through were small, and a few feet more clearance would have allowed them to pass without opening the draw.

ISLAND BUSSES carried approximately 5,100 to the island. The average service was 4 minutes and the average capacity 22.

SIGHT-SEEING CARS carried approximately 850 to the island. The average service in the morning was 15 minutes and in the afternoon 25 minutes. Average capacity 25.

GENERAL INFORMATION: Width of sidewalks temporary bridge, 6 feet. Width of roadway temporary bridge, 22 feet.

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TABLE No. 1

TRAFFIC COUNT

August 20–1916

These tables give the number of Automobiles and Pedestrians passing a point on Temporary Bridge during 20 minute intervals. (By actual count)

MORNING TRAFFIC 8:00 A.M. to 1:00 P.M.

Direction of Traffic	Kind of Traffic	Time 8:00	8:20	8:40	9:00	9:20	9:40	10:00	10:20	10:40	11:00	11:20	11:40	12:00	1:00 P.M.
Toward Detroit	Pedestrian	3	10	4	5	16	18	22	48	50	52	88	110	399	
	Automobile	22	19	30	40	50	70	49	94	113	133	135	161	306	
Toward Belle Isle	Automobile	44	57	66	101	135	136	137	156	181	206	167	161	306	
	Pedestrian	80	121	146	123	274	250	343	427	563	700	556	531	2094	

AFTERNOON TRAFFIC 1:00 P.M. to 6:00 P.M.

Direction of Traffic	Kind of Traffic	Time 1:00	1:20	1:40	2:00	2:20	2:40	3:00	3:20	3:40	4:00	4:20	4:40	5:00	6:00
Toward Detroit	Pedestrian	156	224	139	174	170	245	320	345	425	550	695	895	2916	
	Automobile	85	94	72	77	53	83	112	157	152	172	192	174	657	
Toward Belle Isle	Automobile	127	141	139	213	148	231	215	275	121	171	221	201	579	
	Pedestrian	865	1131	1134	1416	1328	1212	1096	1055	749	749	750	448	972	

EVENING TRAFFIC 6:00 P.M. to 11:00 P.M.

Direction of Traffic	Kind of Traffic	Time 6:00	6:20	6:40	7:00	7:20	7:40	8:00	8:20	8:40	9:00	9:20	9:40	10:00	11:00
Toward Detroit	Pedestrian	1050	1268	1204	1028	1000	1366	1406	1446	1241	1036	674	612	1800	
	Automobile	264	269	262	133	145	260	260	261	262	278	294	300	900	
Toward Belle Isle	Automobile	185	179	175	166	206	170	165	160	154	148	143	135	400	
	Pedestrian	200	280	520	524	392	406	348	288	228	220	210	200	600	

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TABLE 2.
HOURLY TRAFFIC.
August 20-1916

This table gives the number of pedestrians and Autos passing a given point in one hour. The total on bridge is the sum of numbers passing given point in both directions during one hour. This data is taken from Table No. 1.

Direction of Traffic	Kind of Traffic	TIME															
		Morning					Afternoon					Night					
		8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00
Toward Detroit	Pedestrian	17	39	120	250	399	519	589	1090	2140	2916	3522	3394	4093	2322	1800	
	Automobiles	71	160	256	429	306	251	213	421	538	657	795	538	783	872	900	
Toward Belle Isle	Automobiles	167	372	474	534	306	407	592	611	593	579	539	542	479	426	400	
	Pedestrian	347	647	1333	1787	2094	3130	3956	2900	1947	972	1000	1322	864	630	600	
Total on Bridge	Pedestrian	364	686	1453	2037	2493	3649	4545	3990	4087	3888	4522	4716	4957	2952	2400	
	Automobiles	238	532	730	963	612	658	805	1032	1121	1236	1334	1080	1262	1298	1300	

Total Automobiles to Belle Isle from 8:00 A.M. to 11:00 P.M. = 7,021
Total Automobiles to Detroit from 8:00 A.M. to 11:00 P.M. = 7,190
Total Pedestrians to Belle Isle from 8:00 A.M. to 11:00 P.M. = 23,529
Total Pedestrians to Detroit from 8:00 A.M. to 11:00 P.M. = 23,210

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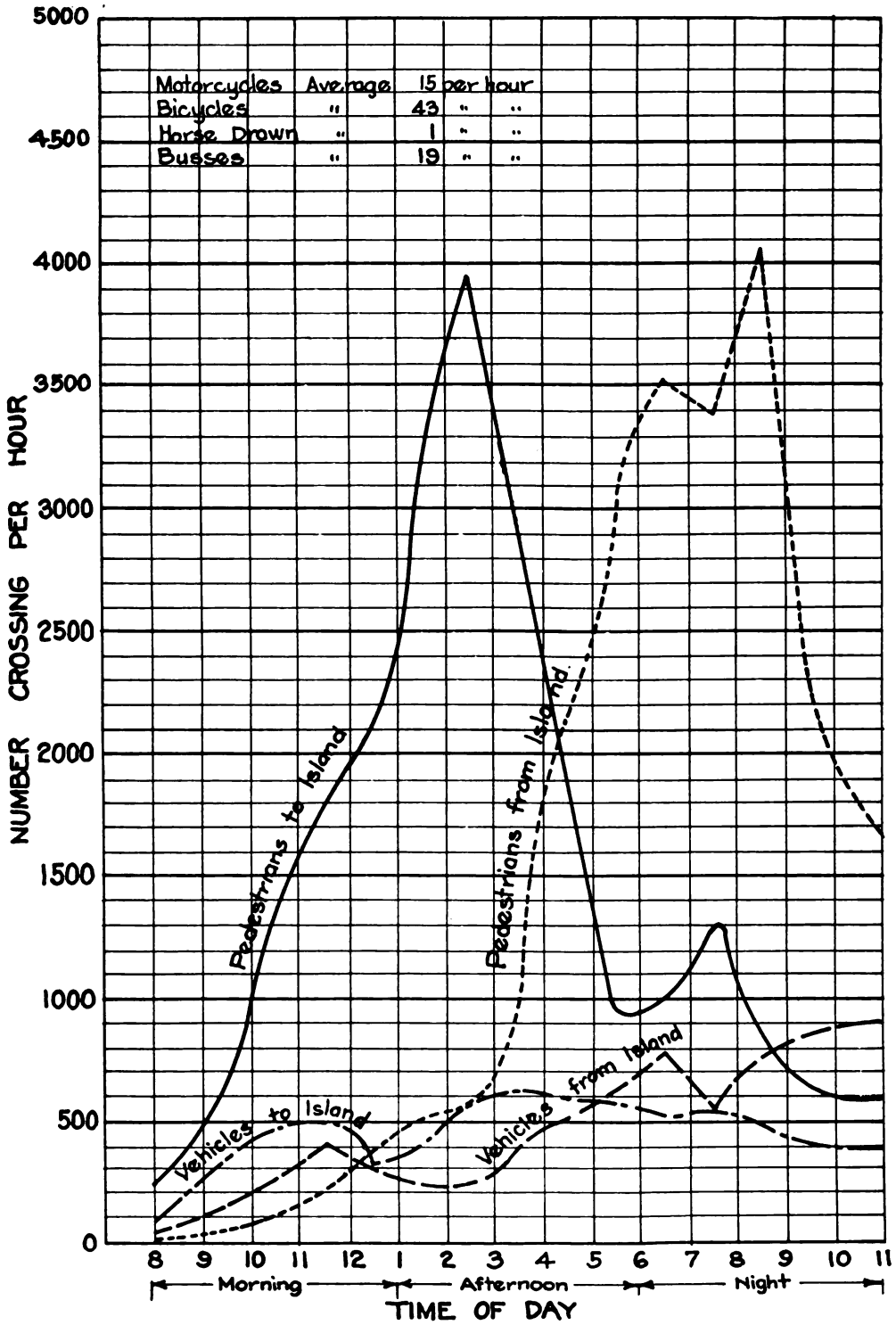
TRAFFIC RATE CURVES

These Curves are plotted from data in Table 2 and show rate of traffic each way.



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River Traffic

A census of river traffic past the temporary bridge from August 29th to October 16th, 1916 was made, the results of which are as follows:

Total number of passages of boats over 50 feet in height	Commercial	8	Total 35
	Pleasure and others	27	
Total number of passages of boats 41 to 50 feet inclusive	Commercial	3	Total 24
	Pleasure and others	21	
Total number of passages of boats 31 to 40 feet inclusive	Commercial	3	Total 8
	Pleasure and others	5	
Total number of passages of boats 21 to 30 feet inclusive	Commercial	16	Total 48
	Pleasure and others	32	
Total number of passages of boats 11 to 20 feet inclusive	Commercial	113	Total 161
	Pleasure and others	48	
Total number of passages of boats up to 10 feet inclusive	Commercial	4	Total 18
	Pleasure and others	14	
Total passages			294

The draw in temporary bridge was opened 230 times between August 9 and September 26, 1916. It will be noted that there were 294 passages during the census period, of which 147 or exactly one-half were commercial boats, the other half being pleasure and miscellaneous boats; also that 133 passages, or 91 per cent of the commercial traffic, and 94 passages, or 64 per cent of the pleasure traffic, could have passed *under* a span with 30 feet clearance.

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APPENDIX II.

REPORT AND DESCRIPTION OF BORINGS MADE NEAR SITE OF PROPOSED BELLE ISLE BRIDGE DRILL REPORT

The equipment consisted of a complete well-driving outfit, the machine being run by a four horsepower gasoline engine and operated by two men. The hammer weighed approximately 300 pounds and was usually given a fall of from 18 to 24 inches, although in very hard material the fall often amounted to 4 feet. In drilling, the fall was never over two feet.

The drill was hollow, having a half inch hole closed by a ball valve. Due to this the maximum size stone in the samples is half inch. However, there were larger stones present as some became wedged between the drill rods and casing on several occasions.

In drilling a hole the general procedure was as follows:

From 30 to 60 feet of 2-inch casing were driven down into the clay and then drilled out. This was very easy driving, (less than 100 blows per foot.) After that the casing was drilled out after every 10 feet of driving. Driving became harder after passing through clay and gravel into a sand and gravel layer at an average depth of 90 feet, but the driving of the casing necessarily preceded the drilling as the sand would cave in and back up into the casing when drilling ahead was attempted. In driving and drawing the slush rods in this layer the casing was kept full of water to prevent any back filling.

Below the clay came hardpan at a depth of 90 to 99 feet. This was very hard driving (300 to 800 blows per foot) and better progress was made by drilling ahead, the hole holding very well. In all cases driving of the casing was stopped after penetrating the hardpan for some distance so as to cut off the inflow of the sand layer above. The drilling was then continued until rock was reached, as indicated when the drill penetration did not exceed one foot in 4000 to 7200 blows.

Description of Soils

See Profile, Page 103

(A) Clay

In all holes clay was found at the surface and continued down to a sand and gravel layer at a depth of 82 to 93 feet. The clay contained increasing amounts of gravel down to within 10 feet of the bottom of the layer, when it almost entirely disappeared. The gravel was found in particles up to half inch size, but practically all would pass a quarter inch mesh screen. The clay was light blue and very plastic and water had to be freely used to insure effective drilling.

The penetration of the 2-inch casing into the clay varied up to 150 blows to the foot, being very easy driving. However, on standing any length of time the clay had a setting action which decreased the penetration one-third to one-eighth the distance per blow. This layer was very much the same for all holes.

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(B) Sand and Gravel

This layer was found directly below the clay at a depth of 90 to 98 feet and it varied in thickness from 3 to 16 feet. The quality of material also varied greatly.

The material graded from sand to a fine gravel with some stone particles up to three-eighth inch in size. The percentage of stone varied, but in no case was it very great.

This layer was not uniform across the bed of the stream, there being a great variation in material and penetration.

The penetration of the casing in this layer varied from 0 to 300 blows per foot.

In hole number 2, seven feet of quicksand was struck and at this point the drill dropped without resistance. This material back filled 40 feet of the casing over night and had to be kept down by a head of water while passing this point. The lateral extent of the pocket was not ascertained.

(C) Hardpan

The hardpan layer of from 4 to 15 feet in thickness lies below the sand and gravel layer at an elevation of 98 to 110 feet below water level at the river borings and 97 to 102 feet at the shore borings.

It consists of a very compact mixture of clay, gravel and sand and is uniformly very hard. Gravel stones up to half inch in size were found which was the maximum obtainable with the drill.

The 2-inch casings were driven down into hardpan until penetration became less than one inch per 100 blows. In drilling through this layer, the drill rebound indicated a very hard surface.

(D) Gravel and Sand

Gravel and sand were found below the hardpan in all holes. This layer is from 3 to 19 feet in depth, being thicker under the river than under the shore.

The material was found to be quite uniform, fine gravel with some particles up to half inch in size and containing coarse sand. There was little, if any clay.

As the casings did not penetrate this layer no penetrations were found for it. However, the drilling here was very slow.

(E) Bed Rock

Bed rock was assumed to have been reached when the drill rebounded as much as 6 inches and made practically no progress during an hours driving.

Samples indicated very little concerning the true nature of the rock. The last sample taken in each case was a coarse sand and gravel. The particles had rough edges and sharp corners. There were some small rough particles of this stone in the samples, but as to whether they were chips from bed-rock could not be stated as limestone appeared all through the borings, one sample of boring, number 4, contained two three-eighth pieces of limestone with some coarse sand and fine gravel. These stones appeared to be loose stones from top of the bed-rock.

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APPENDIX III.

NOTES ON TEST PILES DRIVEN NEAR SITE OF PROPOSED BELLE ISLE BRIDGE

Four test piles were driven near one of the low piers of the old bridge as indicated on page 73. They tapered from 15 inches in diameter at the large end to 8 inches at the small end and were not sharpened. Observations were made of the penetration increments during driving, the distances moved under last blow at 40 and 50 feet penetrations being recorded in Table I. The head of Pile 1 was slightly broomed by driving but the heads of the others remained in good condition. According to the soil survey none of the piles extended below the stratum of blue clay, but the driving record indicated that they passed through a stratum of soft material of about 8 feet in thickness, the top of which was about 16 feet below the river bottom.

The pile driver used was a double acting steam hammer, the specifications of which are as follows: Total weight, 5,500 pounds; weight of ram, 890 pounds; cylinder bore, 7¼ inches; 16 inches stroke; total downward force (ram and steam pressure—3,300 pounds) computed on 60 pounds mean effective pressure at cylinder; 130 blows per minute.

The safe loads in tons on the test piles at 40 and 50 feet penetrations are recorded in Table I, according to both impact and friction formulas in practical use.

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TABLE I.

Safe Load in Tons

	Pile Number	*Penetration under last blow inches*	*Eng. News formula**	*Friction formula***
For 40 feet penetration	1	0.36	9.6	14.5
For 40 feet penetration	2	0.38	9.2	14.5
For 40 feet penetration	3	0.27	11.9	14.5
For 40 feet penetration	4	0.29	11.3	14.5
For 50 feet penetration	1	0.05	29.4	18.0
For 50 feet penetration	2	0.18	15.7	18.0

$$* \text{ Safe Load} = \frac{2\,W\,h}{S + 0.1}$$

W = Force of blow in pounds = 3,300 pounds.

H = Height of fall in feet = 1.33.

S = Penetration under last blow in inches.

** Safe Load = P + fs.

P = Bearing resistance of soil = 5,000 pounds per square foot.

f = Frictional resistance of pile against soil = 250 pounds per sq. foot.

S = Area of pile surface; average diameter = 11 inches.

It is interesting to observe from the above table the discrepancy in capacities of Piles 1 and 2 as computed by the impact formula for 50 feet penetration. This is due to the well known tendency of piles in clay soil to increase in resistance to driving after rest. In the case of Pile 1 there was a lapse of about twenty hours after the 40 feet penetration was reached before driving was continued; Pile 2 was driven continuously.

After about two weeks a test load of 42 tons was placed progressively on Pile 1; a record of its settlement is given in Table II.

TABLE II.

Number of days loaded	*Settlement in feet*	*Load in tons*
1	.015	18.5
14	.023	20.
18	.026	20.
21	.027	20.
24	.030	20.
29	.034	20.
32	.035	20.
15	.074	42.
58	.124	42.

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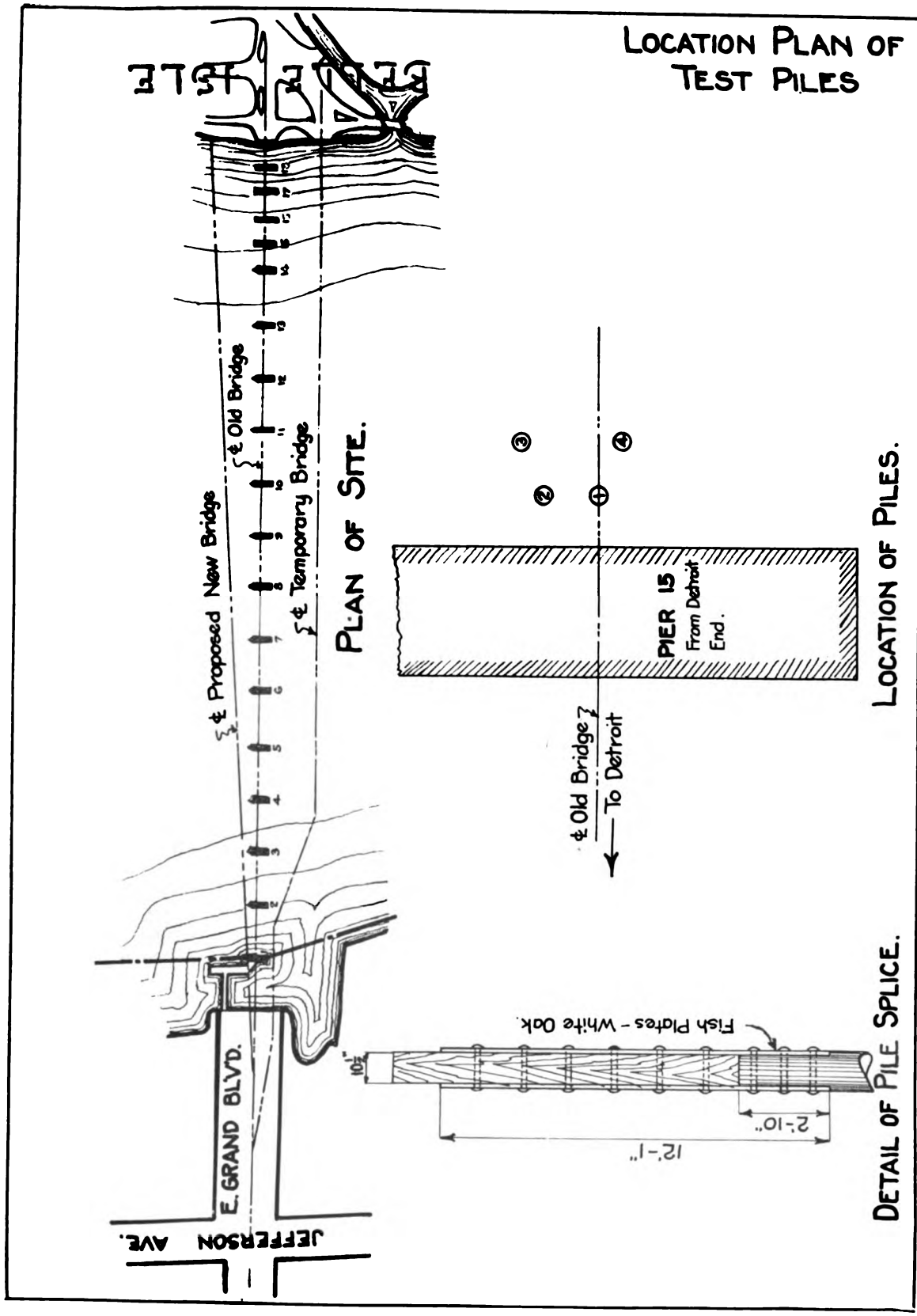

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APPENDIX IV.

DISCUSSION OF CAR SYSTEMS WITH PARTICULAR REFERENCE TO A SHUTTLE CAR SYSTEM

Possibilities of a Car System on the Bridge

The demand for transportation to the island is irregular, varying with weather, day and occasion; hence a flexible system is needed. The most efficient system for this traffic would be a loop system with loading and unloading stations at both ends. The next best system is a shuttle system with loading and unloading stations at both ends.

Type of Cars

The cars could be special ones with through benches, running across the car, with a door at the end of each seat for easy and rapid loading and unloading. A good size would be 45 feet long overall and 10 feet wide, with a carrying capacity of 90 passengers.

Operation and Carrying Capacity

The loading and unloading platforms could be as in the accompanying sketch. Six trains might be operated under rush conditions; two trains en route at a rate of 15 miles per hour, (one going to island, one returning), one train at each of the four stations. This system would give a service of great elasticity and would furnish a train service of not over two minutes, based on the following estimates:

Loading	40 seconds
Unloading	1 minute
Time in transit	3½ minutes
Total	5 minutes 10 seconds going.

Round trip per train 10 minutes 20 seconds.

Time one train one-sixth of 10 minutes 20 seconds or one minute 43 seconds.

With a car capacity of 90 passengers six cars or units would convey 6,264 passengers per hour. Six trains of six units would carry 37,584 passengers per hour.

Clearance

These cars would require a clearance of three feet outside of outside rails, 6 feet between center rails or a total clear space for car service of 22 feet. For trolley cars a clear space of at least 15 feet is necessary from top of rail to lowest point of ceiling. Standard 5.1 feet between center of rails; for a storage battery car 12 feet would be sufficient clearance.

The maximum grade at which this system could be operated to advantage should not exceed three per cent.

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Loading Platforms

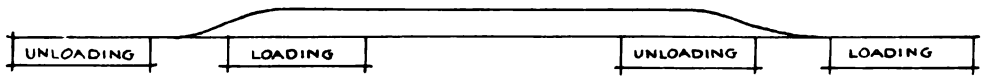
The loading platforms should be on grade with car floor and should be divided into as many sections as there are cars in train. Each section should be divided by a rail with registering turn-stile in same, which will allow as many passengers to pass to the actual loading platform as the car will carry, in this way avoiding crowding.

Unloading Platforms

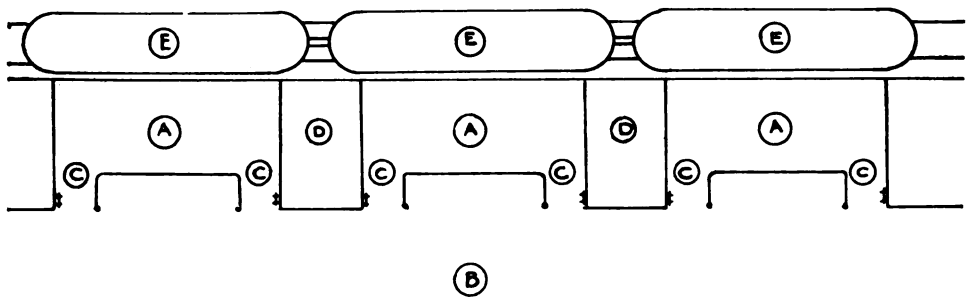
The unloading platforms should be of similar construction as regards level and communicate with the street by means of one-way turn-stiles.

The accompanying sketch gives location of loading and unloading platforms in relation to the switches on a track designed for a shuttle system.

Cars to operate on this system would load and unload from the same side at all times if desired.



Distance between loading and unloading stations to be determined by conditions at the distributing points.



Loading Stations

(Showing three units.)

A. Actual loading platforms from which cars "E" are loaded.

B. Ticket office from which turnstiles "C" are operated. When enough passengers have been admitted to platform "A" to load car "E" the turnstiles "C" are automatically locked, thus avoiding crowding and jamming.

D. Platform to hold passengers when crowds exceed carrying capacity.

Unloading Stations

Unloading stations on island at least, should be of same design as loading station in order that the station might be used as a loading station at times when traffic is leaving the island, in this way accommodating twice as many people.

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APPENDIX V.

SCALE DRAWINGS

1. General Plan and Profile.
2. Plan and Elevation of Bridge and Belle Isle Approach.
3. Plan and Details of Detroit Approach and Subway.
4. Elevation of Maximum Span.
5. Belle Isle Approach and Subway Details.
6. Stairs and Balustrade at Detroit Abutment.
7. Pier and Light Post Details.
8. Plan and Details of Detroit Abutment.
9. Plan and Details of Island Abutment.
10. Structural Steel Details of Typical Span.
11. Structural Steel Details of Detroit Abutment Cantilever.
12. Plan and Details of Jefferson Avenue Subway.
13. Location Maps, Profile and General Plans.

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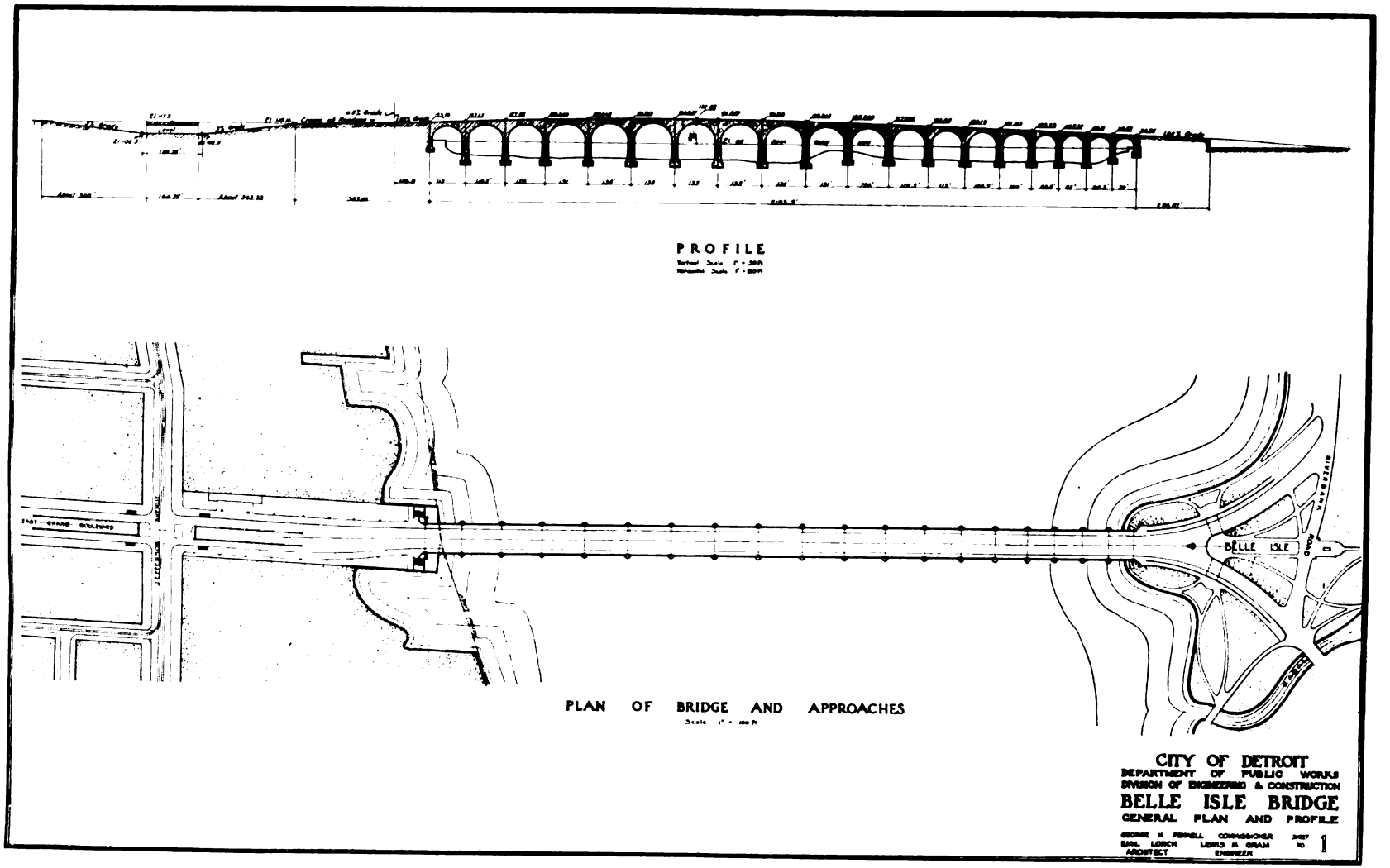

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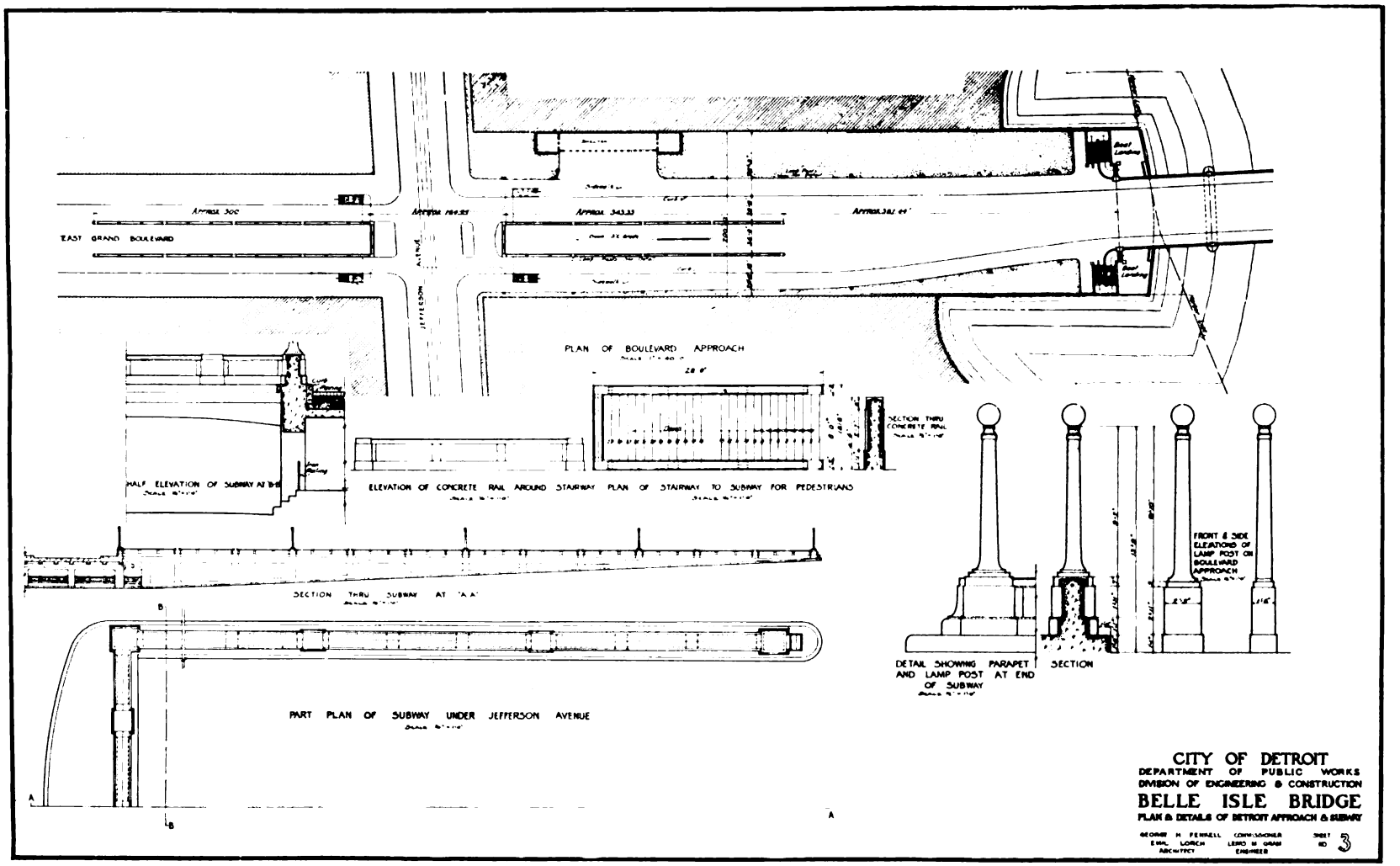

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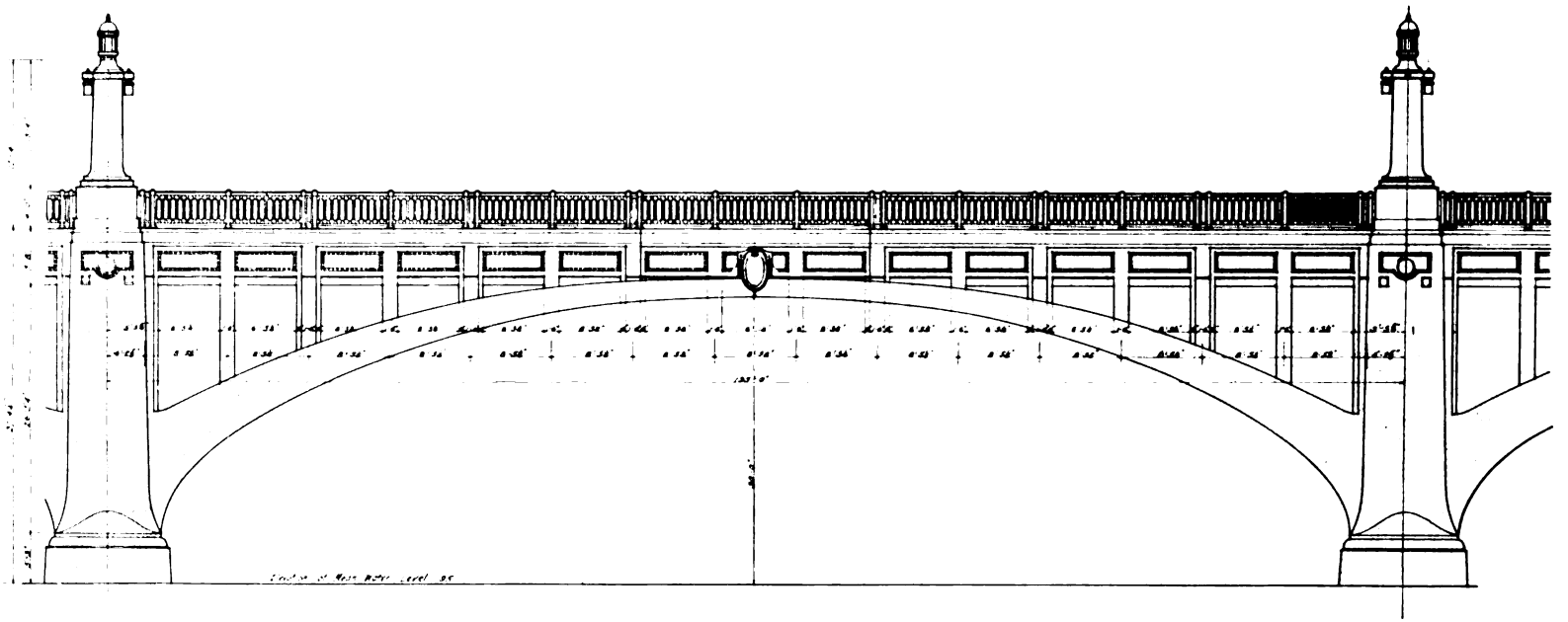

ELEVATION OF MAXIMUM SPAN

SCALE 1/8" = 1'0"

CITY OF DETROIT
DEPARTMENT OF PUBLIC WORKS
DIVISION OF ENGINEERING & CONSTRUCTION
BELLE ISLE BRIDGE
ELEVATION OF MAXIMUM SPAN

GEORGE H. FERNELL COMMISSIONER
EMIL LORCH ARCHITECT
LEWIS H. GRAM ENGINEER
SHEET NO. 4

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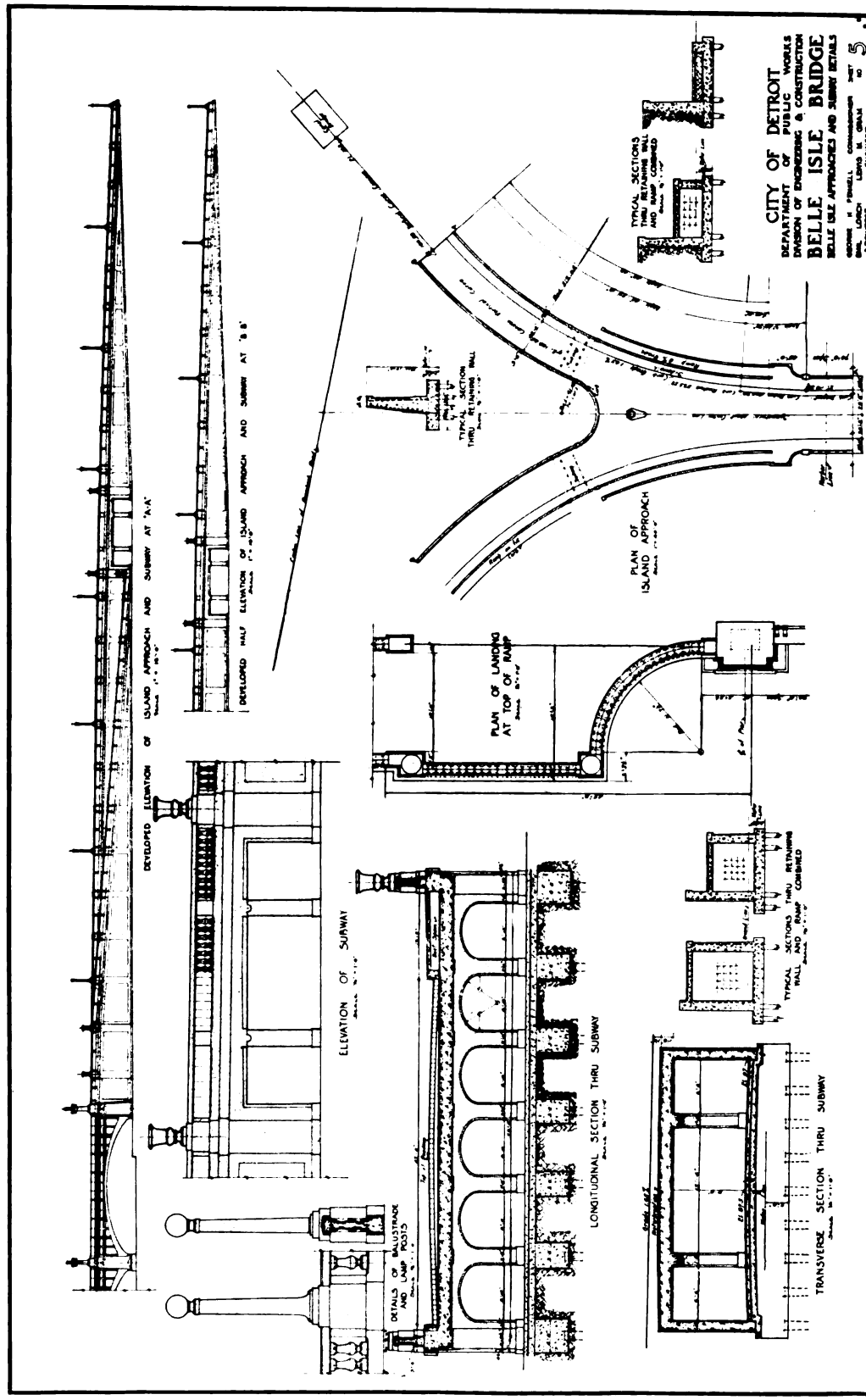

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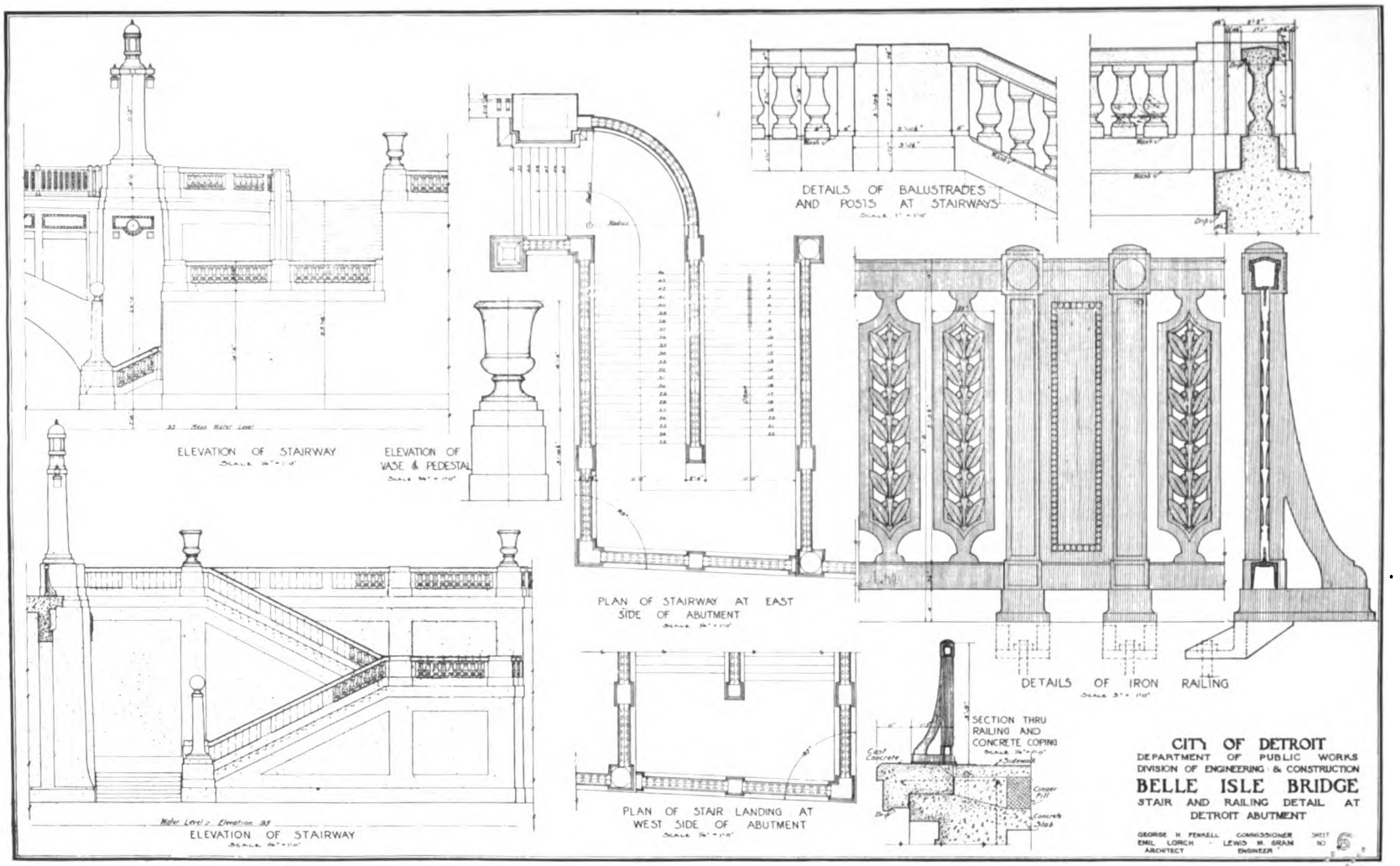

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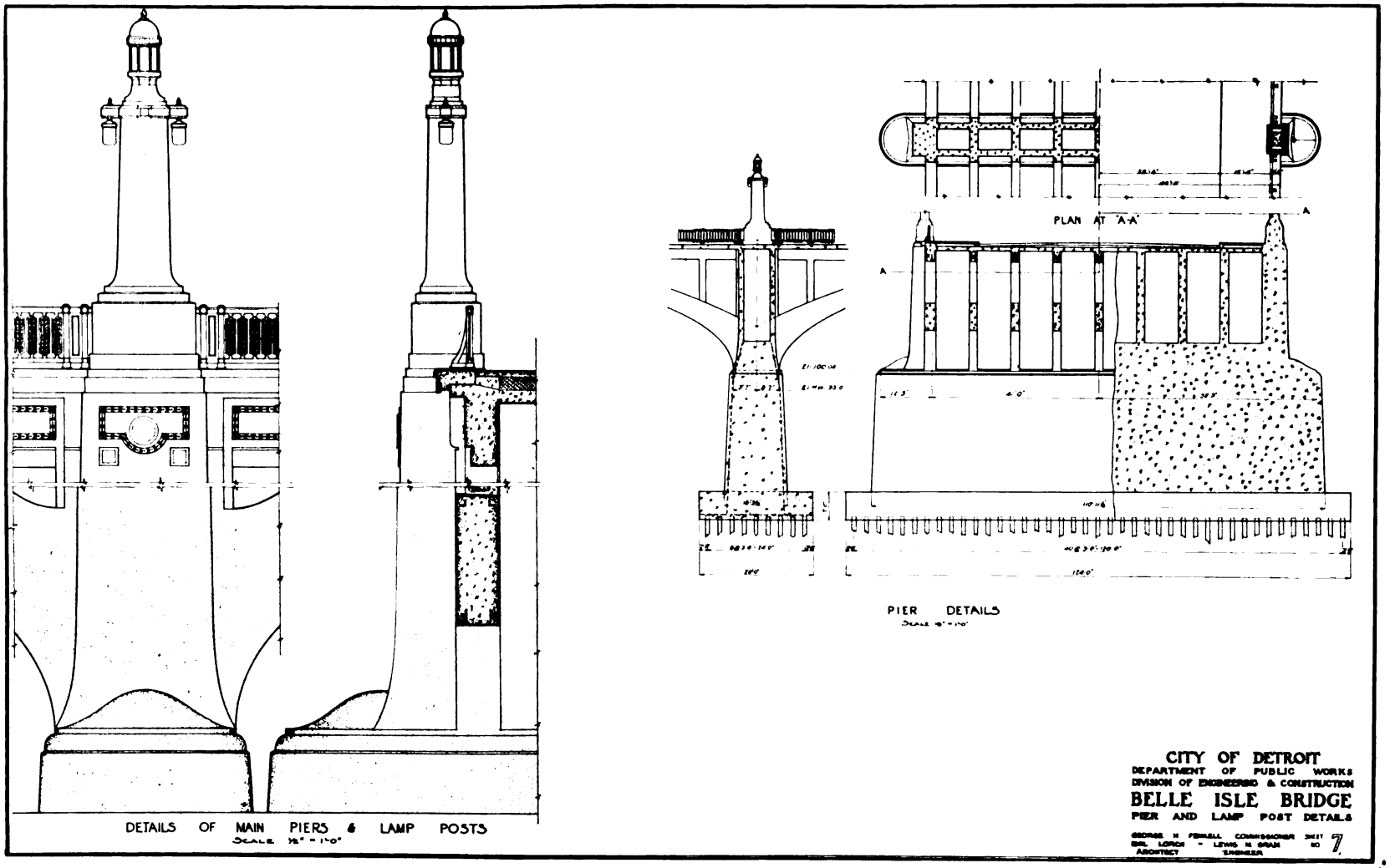

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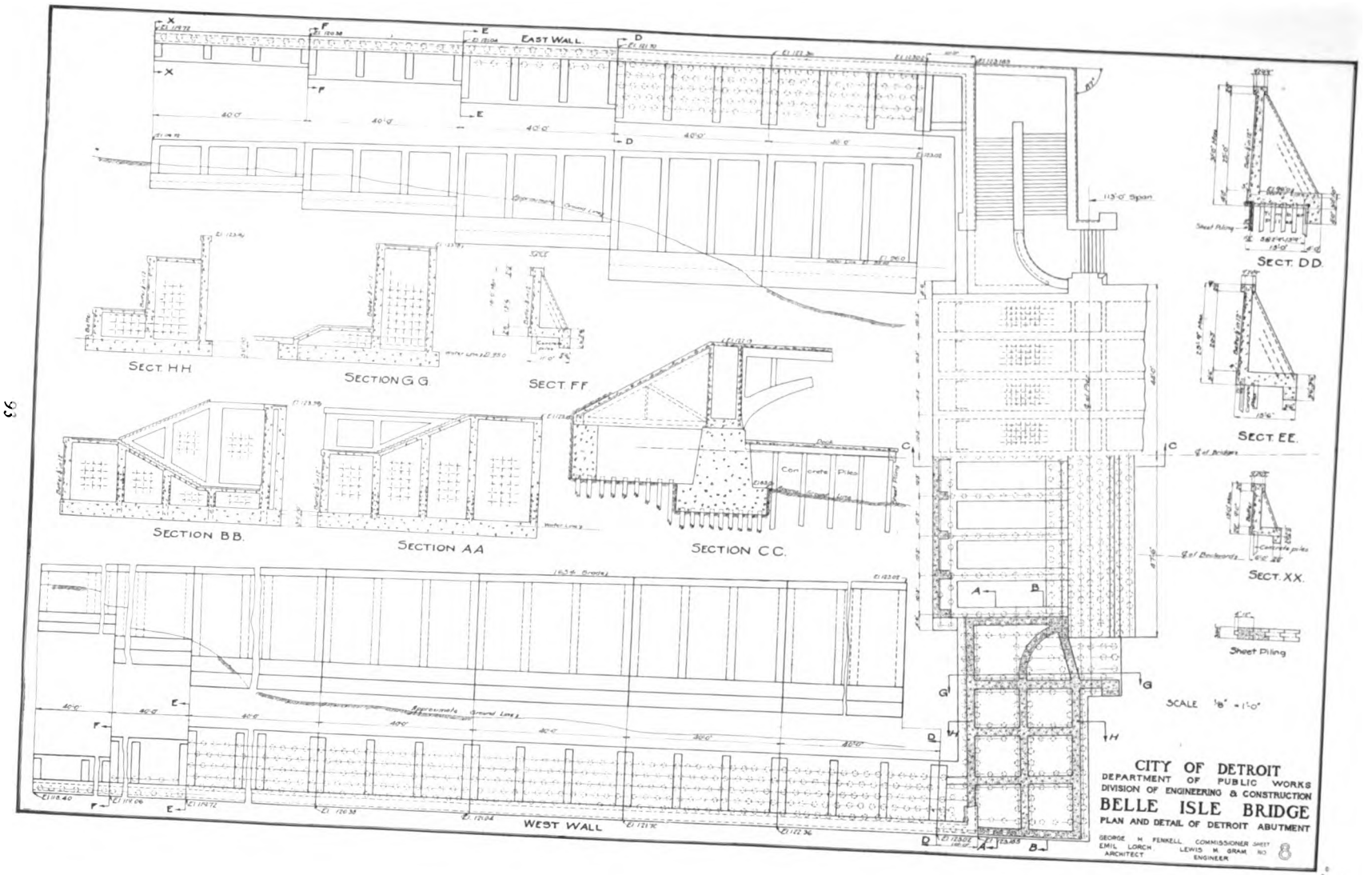

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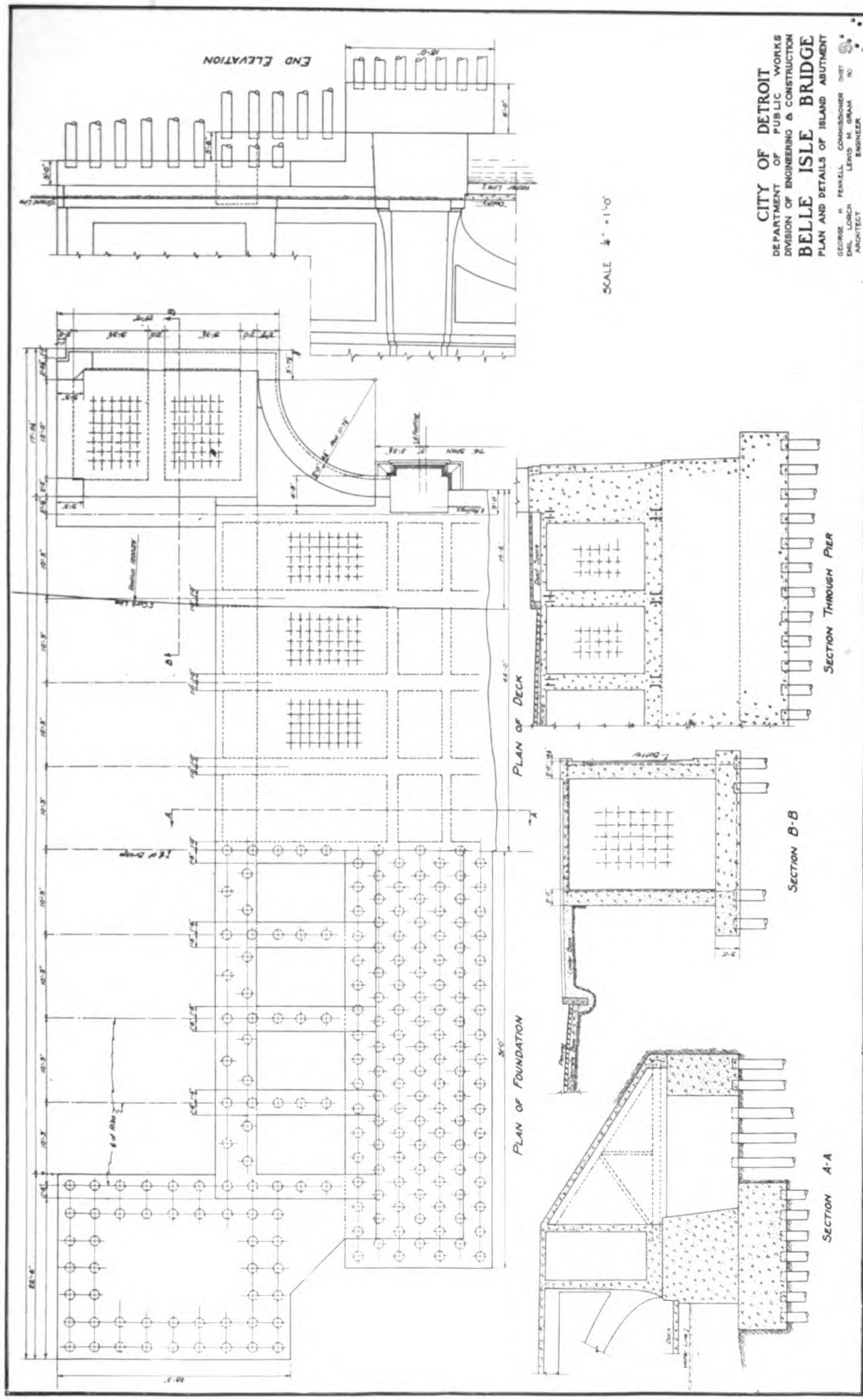

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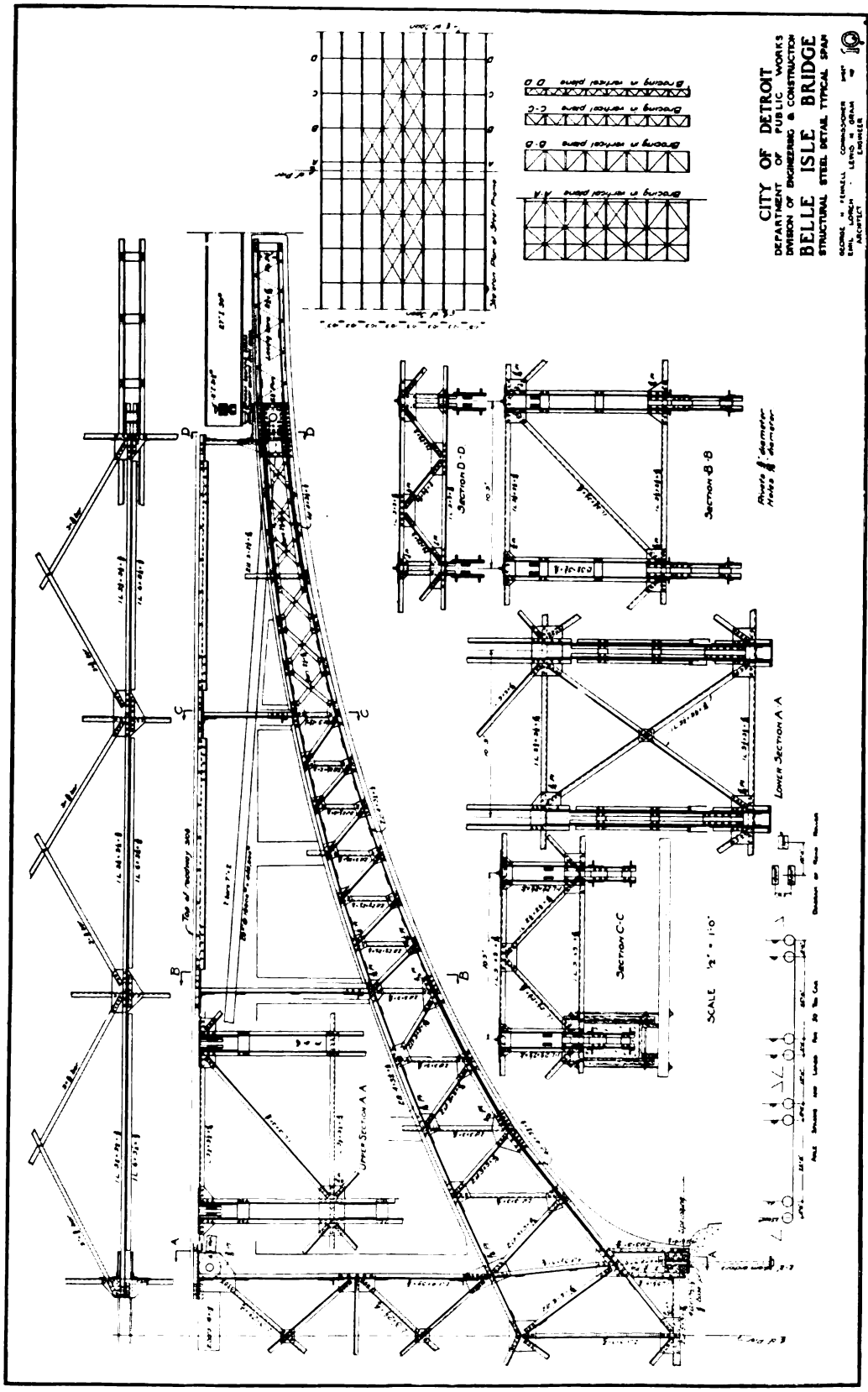

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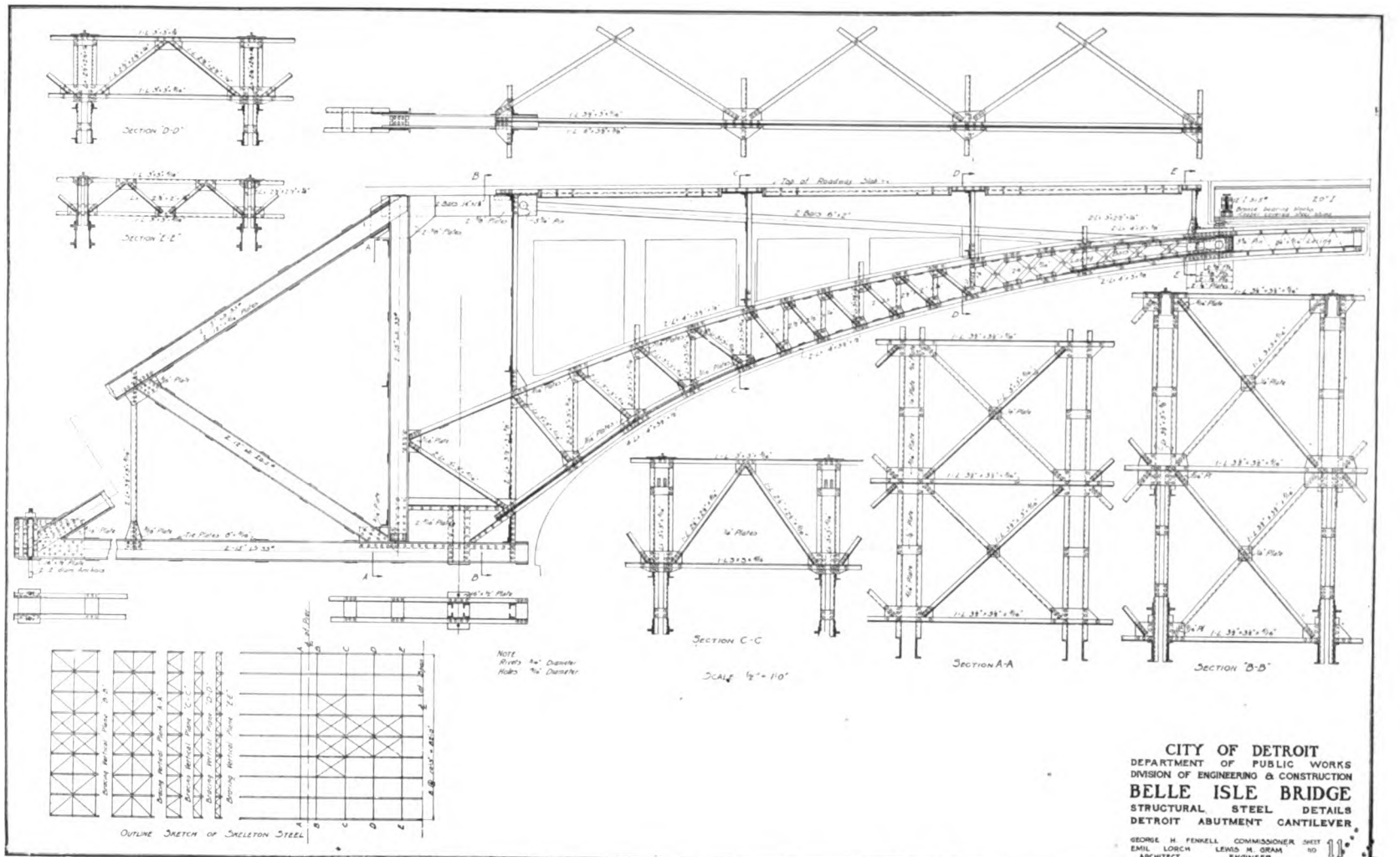

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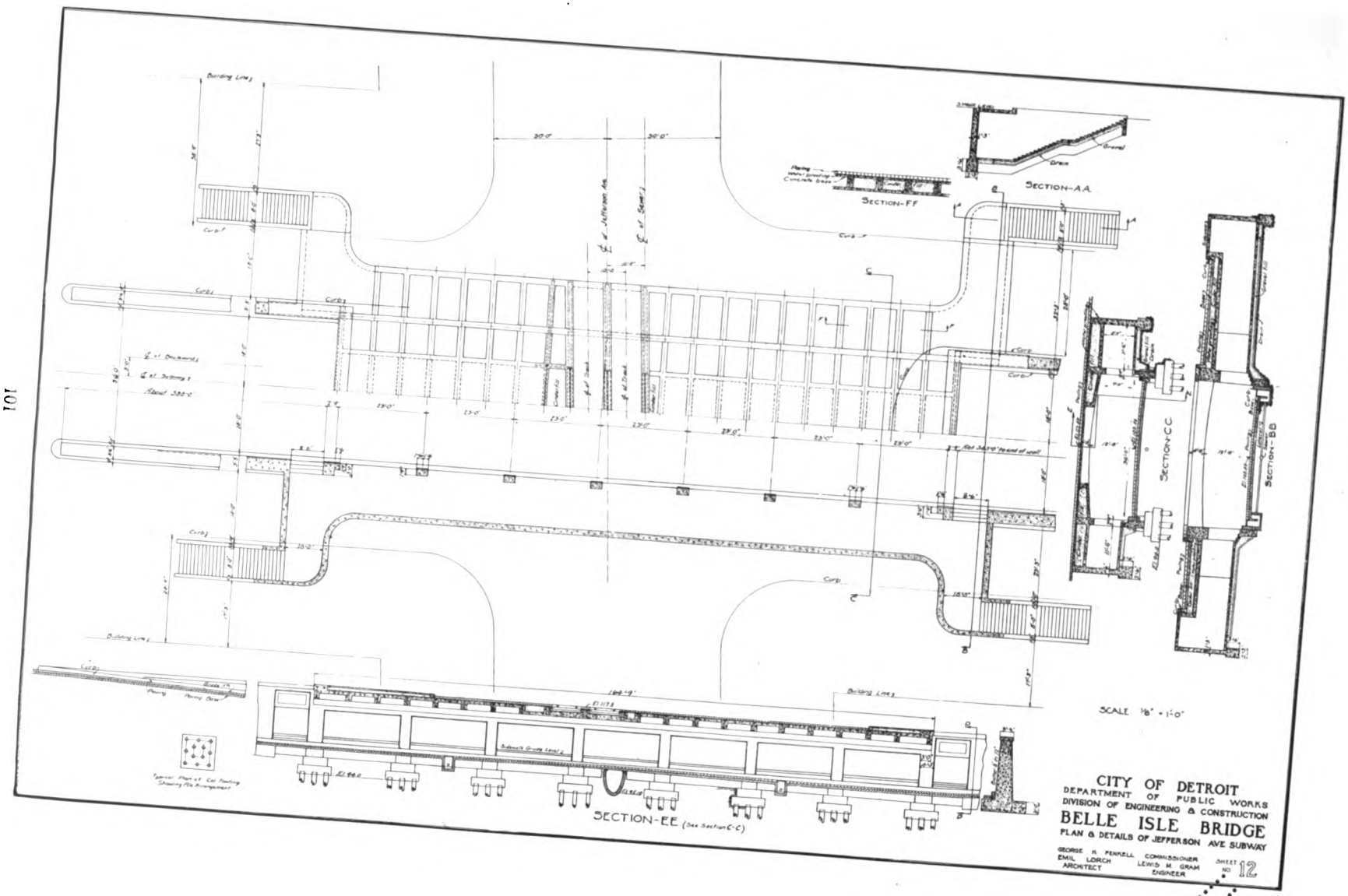

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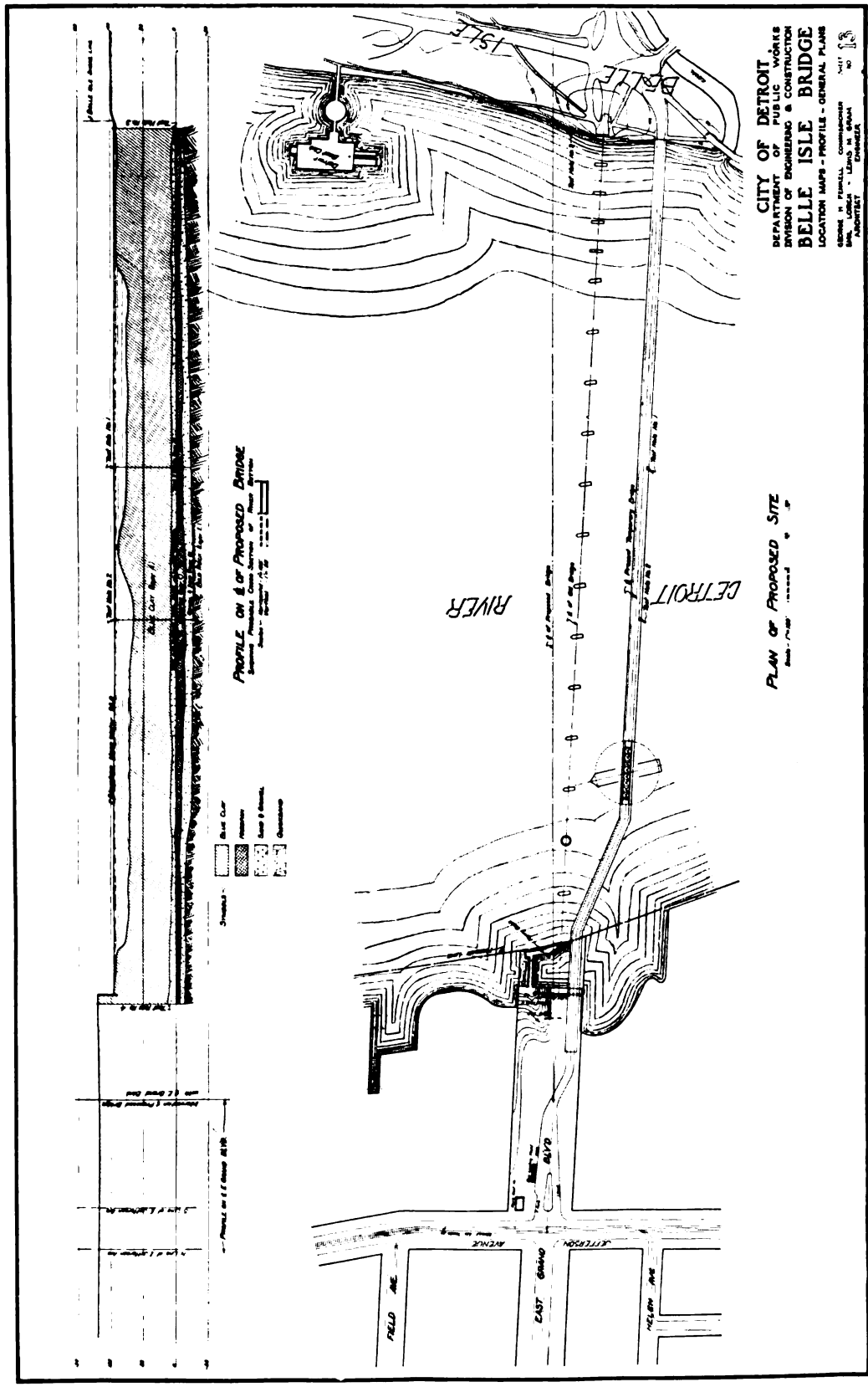

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