August 26, 1960

Messrs. A. J. Eyraud, Chairman
Fred S. Dean, Vice-Chairman
Don Belding, Member
N. (Nat) R. Dumont, Member
Mortimer W. Hall, Member
Carl P. Miller, Member
Arthur J. Will, Member
Los Angeles Metropolitan Transit Authority
1060 South Broadway
Los Angeles 15, California

Re: Rapid Transit Program

Gentlemen:

We are pleased to submit herewith our report on the investigations and engineering we have accomplished for a Rapid Transit System for the Los Angeles Metropolitan Area. This work has been carried out pursuant to the terms of our Agreement of November 3, 1959, which called for a comparative analysis of types of transit systems, recommendations for alignments and station locations within the four transit corridors previously selected, the development of engineering and cost data, and the preparation of planning estimates of construction cost sufficient to indicate the magnitude of the financing problem.

We have been asked to proceed toward a system which would be the most economical to construct and operate, thus attempting to fulfill the requirement of the Authority for a self-liquidating system, which might be built within the limitations of revenue bond financing. In all cases, our recommendations have been made on the basis of the most economic engineering alternate.

This precept has had a significant influence in the choice between subways and overhead facilities.

Section I of this report is the summary of major findings and recommendations which were previously submitted as a separate summary report. The balance of the report reviews in more detail the various alternates of system and route that were investigated during the course of the program. An Appendix, which contains further reports on specialized aspects of the program, will be submitted separately.

We should like to gratefully acknowledge the cooperation and assistance of the many agencies and individuals who have helped us to bring the program to this point. We sincerely appreciate the opportunity to carry out work of such fundamental importance to the future of the Los Angeles Metropolitan Area, and we stand ready to assist in the future work to be done.

Respectfully submitted,
DANIEL, MANN, JOHNSON, & MENDENHALL

Irvan F. Mendenhall,
President

03223

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Consultants

Early Portion of Program

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Harold Otis, Consultant, Transit Equipment
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Los Angeles Metropolitan Transit Authority Report Relating to the Rapid Transit Program

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List of Illustrations

Major Findings and Recommendations

The Los Angeles Metropolitan Transit Authority, before proceeding with the rapid transit program, posed three basic questions and put them to us for answer. These questions, in brief, ask:

What Shall We Build?
Where Shall We Build It?
How Much Will It Cost?

These questions are, of course, highly important to the community and answers were required before the Authority could proceed to establish the over-all feasibility of providing a rapid transit system for the Los Angeles Metropolitan Area.

At the outset of this Summary Report, we present our specific answers to the three questions posed. Thereafter we present, in this section of the report, other conclusions and recommendations of a supplementary nature.

1. What Type of Rapid Transit System Shall the Authority Build?

We recommend to the Authority for main line rapid transit service a system of supported transit vehicles running on rubber tires on concrete tracks. For convenience, we have referred to this equipment as the "Metro" system. This equipment is found to be the most adaptable to the alignments and conditions developed in our engineering investigations. This system would be the first use of rubber-tired rapid transit vehicles in the United States and would be truly unique in its ability to provide large numbers of transit patrons a fast, comfortable, quiet and convenient ride.

The "Metro" system would be one of the first truly *rapid* transit systems in the world, and it would offer important time savings over existing methods of travel. The "Metro" equipment is an advanced concept of a lightweight high speed vehicle of ultra-modern design operating on pneumatic tires with a minimum of sound. The exterior appearance of the vehicle is indicated on the frontispiece and details of the tracks and running gear are shown in the body of this report. The cars would comfortably seat 54 people with ample room for standees and could be coupled together to make up trains of two to six cars or more. Having a completely automatic control and operation system and special safety features, the "Metro" is designed for complete safety at operational speeds, which would reach 80 miles an hour. While the automatic equipment is capable of unattended operation, it is felt that having one attendant per train to serve passengers and to take over in case of emergencies is desirable. The cars are to be air conditioned and powered electrically.

In determining the type of rapid transit system considered most suitable for use here, many types of rapid transit equipment were investigated and the three most suitable types were analyzed in detail. These three systems included two monorail systems (suspended and supported) and the supported "Metro" system. We have concluded that any of the three could be successfully adapted to the Los Angeles Metropolitan Area.

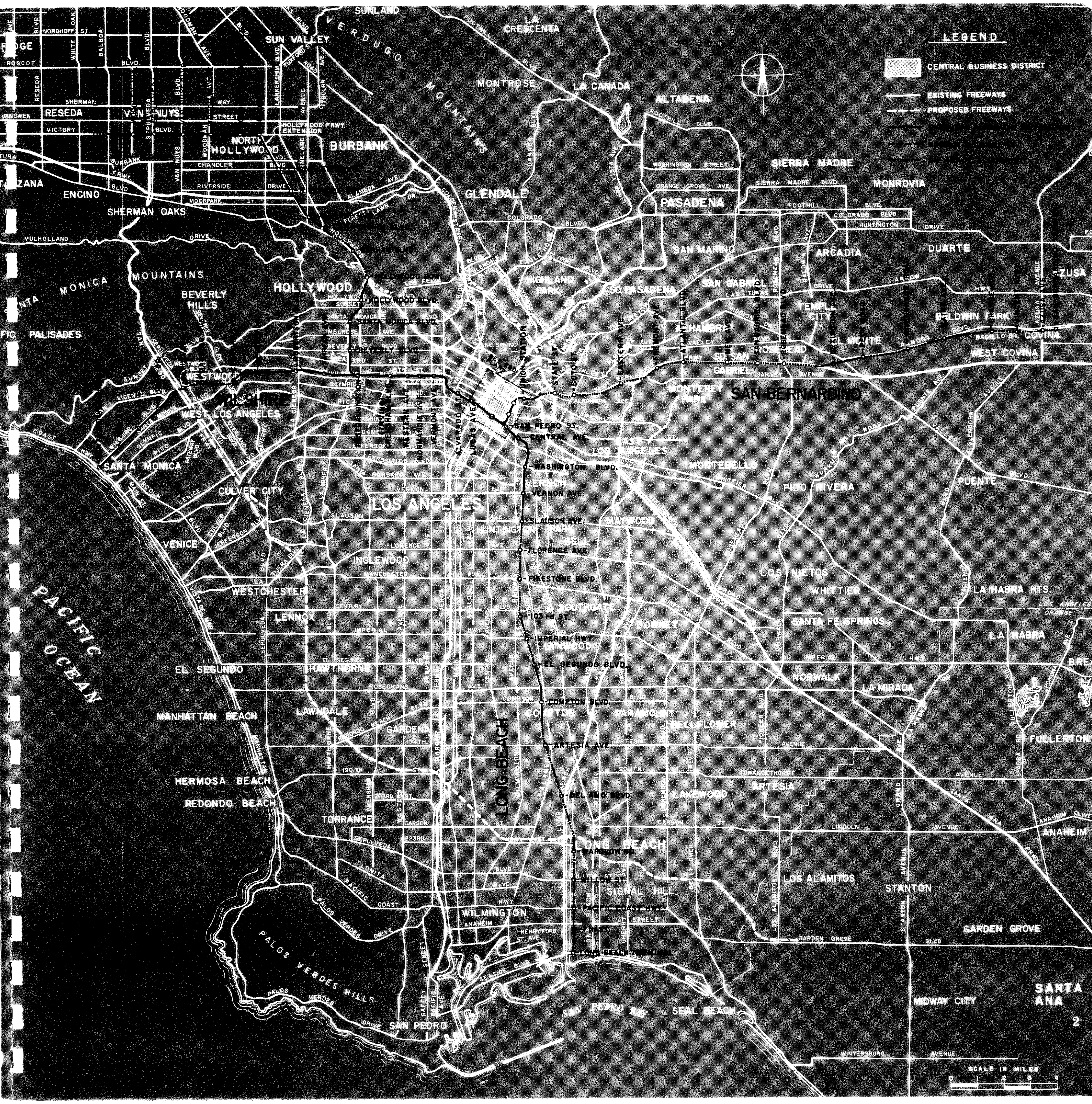
While the suspended monorail is in an early development stage it has a number of interesting advantages. Our cost comparisons, however, indicated the suspended system would be more expensive than the two supported systems. The supported monorail system requires the least overhead structure of the three and for a substantially overhead operation, would be the least expensive in initial capital cost, although higher in maintenance cost. The supported monorail has several problems in switching and car mechanism which present complications, but which we believe can be satisfactorily solved.

The "Metro" system is the least expensive for the recommended alignments, 35 percent of which allow for operation at grade (ground level). The "Metro" has several important advantages, particularly in its ability to run economically not only overhead, but also at grade and underground, thereby providing greater flexibility. Also, with its auxiliary steel wheels, it is capable of running on standard gage steel rail lines. All things considered, we favor the "Metro" type of equipment for the alignments and conditions outlined herein.

For future distribution of passengers within the Central Business District (CBD), several types of systems are available or under development. For the purposes of our analysis and cost estimates, we have projected the use of the Stephens-Adamson Carveyor System operating on an overhead structure. This system utilizes small 8-passenger cars operating at an average speed of 15 miles per hour with cars slowing to pick up passengers on a semi-continuous basis at every station stop. These station stops can be located every 600 feet and can be designed to channel traffic either through adjacent buildings or directly to the sidewalk.

Any permanent secondary system must be grade-separated from pedestrian and vehicular traffic and should be located overhead, probably over sidewalks, to best connect with an overhead main line rapid transit system. The same equipment can also be operated through small subways, although this type of construction is considerably more costly than the overhead. The Lockheed Aircraft Company is also developing a secondary system which offers some advantages and will probably be usable.

The equipment to be used for secondary distribution is entirely independent of the rapid transit system and we



LEGEND
CENTRAL BUSINESS DISTRICT
EXISTING FREEWAYS
PROPOSED FREEWAYS
SUNLAND
LA CRESCENTA
SUN VALLEY
VERDUGO MOUNTAINS
MONTROSE
LA CANADA
ALTADENA
RESEDA
VAN NUYS
NORTH HOLLYWOOD
BURBANK
SIERRA MADRE
MONROVIA
ENCINO
SHERMAN OAKS
GLENDALE
PASADENA
SAN MARINO
ARCADIA
DUARTE
AZUSA
MOUNTAINS
BEVERLY HILLS
HOLLYWOOD
HIGHLAND PARK
SO. PASADENA
SAN GABRIEL
TEMPLE CITY
BALDWIN PARK
COVINA
PALISADES
EL MONTE
ROSEMEAD
WEST COVINA
WESTWOOD
WILSHIRE
UNION STATION
MONTEREY PARK
SAN BERNARDINO
WEST LOS ANGELES
SANTA MONICA
EAST LOS ANGELES
MONTEBELLO
PICO RIVERA
PUENTE
CULVER CITY
LOS ANGELES
VERNON
MAYWOOD
HUNTINGTON PARK
BELL
VENICE
INGLEWOOD
LOS NIETOS
WHITTIER
LA HABRA HTS.
WESTCHESTER
LENNOX
SOUTHGATE
DOWNEY
SANTA FE SPRINGS
PACIFIC OCEAN
LYNWOOD
LA HABRA
EL SEGUNDO
HAWTHORNE
NORWALK
LA MIRADA
MANHATTAN BEACH
LAWNDALE
COMPTON
PARAMOUNT
BELLFLOWER
GARDENA
FULLERTON
HERMOSA BEACH
REDONDO BEACH
LAKEWOOD
ARTESIA
TORRANCE
LONG BEACH
ANAHEIM
LOS ALAMITOS
STANTON
SIGNAL HILL
WILMINGTON
GARDEN GROVE
PALOS VERDES HILLS
SAN PEDRO BAY
SEAL BEACH
SAN PEDRO
MIDWAY CITY
SANTA ANA
SCALE IN MILES

recommend the final selection of secondary equipment not be made until the time the "Metro" system is constructed. Then, advantage can be taken of the latest equipment developments. Alternatively, it is also possible to provide interim distribution service in the Central Business District by using standard motor buses on exclusive bus lanes.

2. Where Should the Rapid Transit System Be Built?

Based on the four broad transit corridors recommended to the Authority by Coverdale & Colpitts (Consulting Engineers for traffic studies) we have developed recommended route alignments and station locations as shown on the map on the preceding page. These four lines extend from the Central Business District radially out to Covina in the San Bernardino Corridor, Santa Monica in the Wilshire Corridor, to Long Beach, and to Reseda.

The routes and configurations were developed as the combinations most economical to build and operate in accordance with basic instructions given us by the Authority.

Included within the recommended alignments are 51.0 miles of overhead in city streets and other rights-of-way, 21.6 miles of line at-grade along Pacific Electric and other rights-of-way, and 2.3 miles of tunnel under private property, making a total initial system of 74.9 miles. The mileage at-grade includes 6.4 miles of converted Pacific Electric line in the San Bernardino Freeway, which has previously been grade-separated from vehicular cross traffic. Also included is 10.5 miles of operation at-grade along the Pacific Electric right-of-way to Long Beach wherein overpasses would have to be built to grade separate important cross streets. Arrangements for the use and development of both of these lines would have to be negotiated by the Authority with the Pacific Electric Company.

The "Metro" would serve passengers during peak hours with average speeds of from 35 to 40 miles per hour including station stops. This compares with the Los Angeles peak hour average freeway driving speed of 25 miles per hour, and with the usual U. S. Mass Transit average speed of 18 miles per hour. During the peak hours, it would take 27.6 minutes to go from 8th & Hill Streets in Los Angeles to Santa Monica, 36.8 minutes to Reseda, 33.4 minutes to Covina, and 31.4 minutes to Long Beach. With a skip-stop type of operation, these travel times could be reduced even further in some cases by as much as 26%.

The recommended alignments make use of city streets and existing rail rights-of-way. "Metro" operation within existing rail rights-of-way will best be achieved by converting the existing ties and ballast rail installation to the dual concrete tracks for the smooth, quiet ride attainable on pneumatic tires. With the exception of the recommended alignment in the median of the San Bernardino Freeway, the transit system cannot make use of existing freeways, particularly because adequate space for construction operations and maintenance is not available.

Within the Los Angeles Central City, we recommend that the "Metro" lines be constructed above the streets with single columns located in a narrow center median. "Metro" lines are recommended to run on 8th Street and on Main Street with supplementary service provided by the secondary passenger distribution system in order to provide for the widest possible transit coverage of this high density area. A permanent secondary system would also relieve present street and sidewalk congestion. The analysis of the movement of people within the Central Business District is a separate problem in itself, and involves the future plans for this area by the responsible planning agencies. However, certain preliminary alignments have been projected in order to establish the probable cost of a secondary distribution system.

Subway construction is entirely possible in Los Angeles, but would cost from two to three times more than overhead facilities which provide the same service. A subway system in the Central Business District and in the Wilshire Corridor would have many advantages, and we have analyzed such installations carefully.

However, the predominantly overhead system would be, by far, the most economical to build and operate, and is therefore recommended. Overhead "Metro" lines would be installed with long span beams and single column construction in order to provide an aesthetically pleasing structure.

3. How Much Will The Rapid Transit System Cost?

The planning estimate for construction of the initial 74.9 mile four-corridor transit system as recommended is $529,700,000 including cost of rights-of-way and allowance for engineering and contingencies. This was prepared on the basis of Southern California construction cost at 1960 price levels. As outlined in the body of this report, these cost estimates must be qualified because factors of time and budget limit the current engineering work to that which would indicate the validity of concepts and magnitude of total costs.

Supplementary Conclusions and Recommendations

The information presented in the following paragraphs and throughout this summary report will further expand upon and support the foregoing basic recommendations and conclusions.

The Trunk Line Rapid Transit Concept: The transit system, in order to be effective, must be capable of transporting sufficient passengers to adequately fulfill the Los Angeles transit needs in the foreseeable future (estimated 30,000 passengers per hour per track). The "Metro" system will definitely meet this criterion.

In addition to the trunk line rapid transit concept as recommended in the previous studies accomplished by Coverdale & Colpitts, we have reviewed proposals for a full coverage system and for a flexible bus system. The full coverage system would provide a network of subways completely covering the Los Angeles Metropolitan area, such that subway stations would be within one-half mile of any location in the entire area. The flexible bus system would use express buses on elevated platforms over streets and freeways to provide the transit service. While these systems each offer some important advantages, neither of them generally suits the criteria and conditions with which we have been faced.

Transit Development Plans will Require Extension to the 150-Mile Eight-Corridor System: The four-corridor 74.9-mile system should be regarded as the initial phase of the rapid transit system. An eight-corridor 150-mile system will be needed in the future, probably within twenty years, in order to keep pace with the projected growth of the Metropolitan Area. A development plan for this 150-mile system is shown within the report. This plan shows that in addition to the first four rapid transit routes, future corridors will be needed to Santa Ana, to Inglewood, to Pasadena, and to San Fernando via Glendale and Burbank. Further mileage can continue to be added to this 150-mile system as user demand to additional areas increases.

Recommended System and Routes Should be Adopted as the Basis for the Remainder of the Program: We recommend adoption by the Authority of the routes and station locations and the "Metro" equipment as the basis for estimates of passenger revenue and operational costs which the Authority needs to determine the over-all feasibility of the program. In proceeding, the Authority should make a determination of how large an initial construction phase will be within the financing capability of the Authority, based on the revenue and cost information. This will form the basis for detailed engineering necessary to secure financing and initiate construction. The engineering work, to date, has generally been limited to that necessary to establish the concept and direction of the program and to provide the initial planning cost estimates.

Technical Recommendations Included in the Detailed Report: During the process of arriving at our basic recommendations, other alternate routes and systems were analyzed in detail. Concept designs and cost estimates were made of the various alternates which enabled cost and functional comparisons to be made. While this summary report deals primarily with the transit system and routes recommended, data on the alternates is being submitted to the Authority separately in the form of a Technical Report along with other detailed technical material.

We have previously mentioned briefly the two monorail systems (supported and suspended) studied in detail. They represent the most highly developed of the many "monorail" types proposed by inventors and proponents. We have indicated in this report some details of the structure and equipment required by the other two systems. In the Technical Report, a great deal more information is being provided along with comparative advantages and disadvantages of applying each of the three systems to Los Angeles requirements. The Technical Report also contains detailed information on conventional steel-wheeled transit vehicles together with a comparison between rubber tires and steel wheels for rapid transit service.

In regard to the routes, a number of alignments were originally evaluated within each of the four corridors. A minimum of two alignments were then selected for a more detailed investigation and comparison. A cost estimate was prepared for each of the two most promising alignments and from this comparison, we developed the recommended routes having the least cost. Plans and profiles are included in the Technical Report for each recommended route, as well as for the other alignment considered. A thorough analysis was made of various means of subway construction in order to make a proper comparison with the cost of overhead facilities. Alternate concept designs for subways and underground stations were developed for the Los Angeles Central Business District and for the Wilshire Corridor utilizing the most suitable modern techniques of subsurface construction.

Data from these analyses together with information on special equipment and acoustic studies, and layouts of stations and facilities, are included in the Technical Report.

The remainder of this summary report elaborates on the more important results obtained during the initial engineering phase of the program, and includes further descriptions of the system and routes recommended.

Transit System Equipment

The drawing on the right illustrates the concept design of the supported dual-track or "Metro" system which is recommended as the system most adaptable to the alignments and conditions existing in the Los Angeles Metropolitan Area. This system consists of supported lightweight transit vehicles running on rubber tires on two concrete tracks. Auxiliary steel wheels of standard gauge spacing would be incorporated as safety wheels. These flanged steel wheels would come into use also for switching operations in conjunction with standard rail switches. While such equipment is not presently used in the United States, it has ample precedent in the rubber-tired equipment used and operationally tested on the Paris subways since 1952.

The design represents a composite of conventional train practice combined with bus and air frame techniques. It is conceived as the fastest and lightest weight transit vehicle in the United States and yet it would be a very quiet system and one which would combine a high degree of operational safety with its high-speed capacity. It would enable maximum speeds of up to 80 miles per hour to be attained and with one-mile station spacings would provide an average speed of about twice the average speed of existing transit systems in the United States and abroad. Such average speed would be at least 40% better than the average speed which can be attained on the Los Angeles freeways during peak hours.

But passengers are needed 'off-peak'. What are speed comparisons then?

Equipment Systems

In arriving at our decision to recommend the "Metro" system, we have conducted a broad search of existing and proposed transit systems in the United States and abroad. After an initial screening of a number of these systems, we chose three for detailed investigation and comparative analysis. These three were:

1. A supported dual-track system similar in some respects to the experimental rubber-tired equipment in use in the Paris subways and elsewhere in Europe, examples of which are shown on page 8. From this evolved the design of "Metro" system.
2. A supported monorail or mono-beam system (saddlebag) similar to the Disneyland ALWEG monorail system in Anaheim, California, and similar to a type proposed by Lockheed Aircraft Company.
3. A suspended monorail or mono-beam or split-rail system similar to the new S.A.F.E.G.E. monorail test installation recently built south of Paris.

The results of this investigation show that any one of the three systems could be applied in Los Angeles. However, the suspended system showed greater cost as compared with the supported systems. It poses some problems in sway control which require further development work and testing. The switching of suspended cars, as with the saddlebag, requires a more complicated solution than with the Metro system, which uses a conventional switch.

The decision as to which of the supported systems should be favored is difficult. The saddlebag system is only slightly more expensive than the Metro system for the recommended alignment and if more overhead operations were included, it would be less expensive. The saddlebag system requires the least cross section of supporting beam (at some penalty in length of clear span) of any of the systems, which would make it the easiest to use in certain locations. However, there are several drawbacks in the mechanical equipment used for this system which have as yet not been entirely overcome.

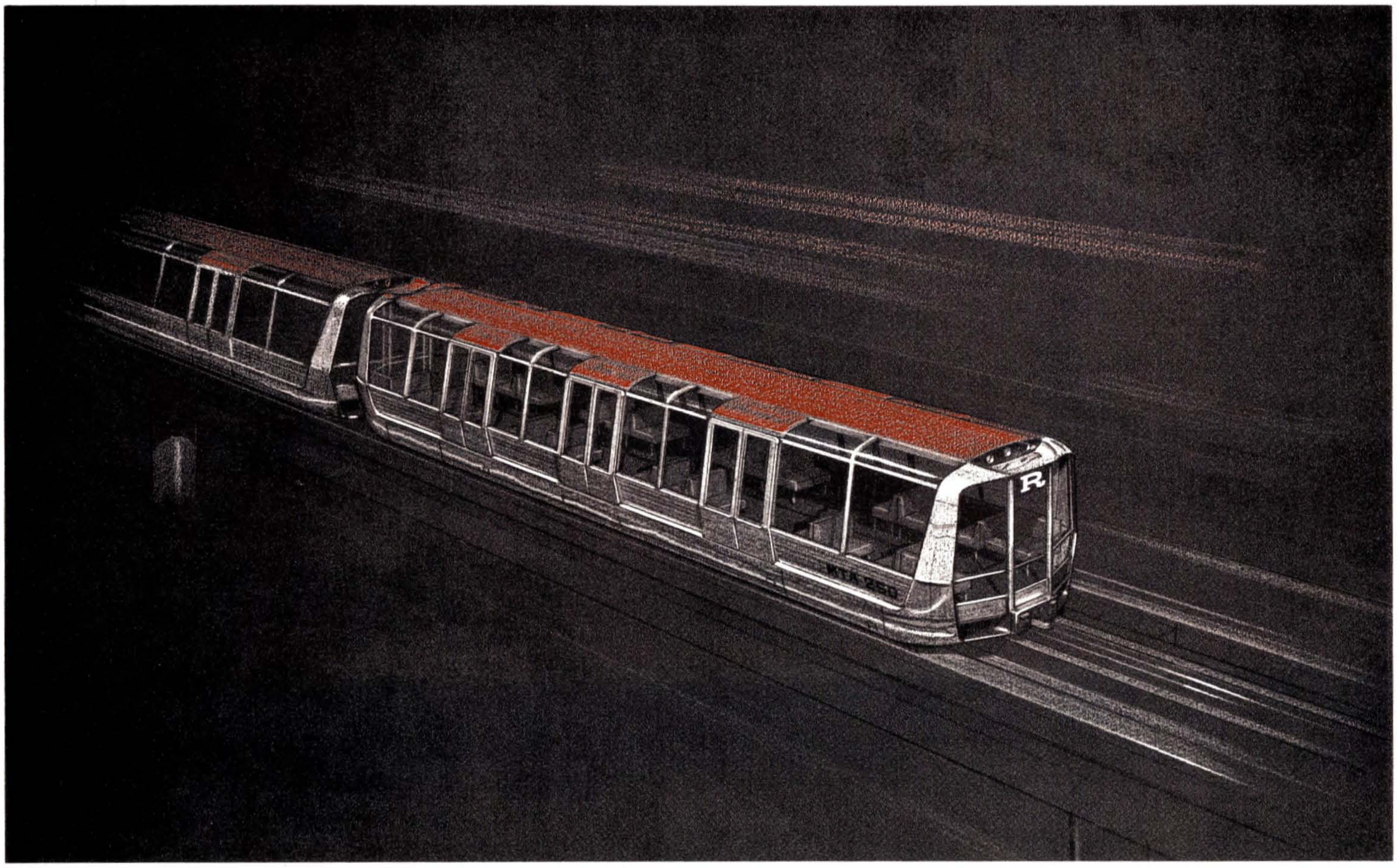
With all things considered, it was felt that while the saddlebag system offers a number of advantages, the Metro system with its more advanced state of development and greater operational flexibility should be favored.

Pneumatic Tires and Air Suspension

It is recommended that the system use pneumatic tires for guidance and support for several basic reasons. Research of the noise control problem indicated that steel wheels would be at least 50% more noisy than rubber tires. Rubber tires would produce sounds not greatly different from those already experienced along most of the routes recommended. In addition, sustained grades of as much as 6% are encountered along some routes and in corridor interchanges, and the increased adhesion of the rubber tire is needed to provide reasonable acceleration and safe braking under these circumstances.

The use of rubber tires will require some additional power over that required by conventional transit vehicles. However, our analysis shows this to be less than 5% before taking into account the savings in power costs resulting from the low weight of the vehicle made possible by the use of pneumatic tires. This savings in weight may amount to as much as 20%. Thus, the difference in power requirement is not regarded as significant, considering the many advantages brought about by the use of pneumatic tires.

Along with the investigation of rubber tires, consideration was given to the potentialities of the new "ground effect" or air suspension vehicles for transit service. While these vehicles offer the challenge of speed without wheels, they are so new and untried that their application and operational characteristics cannot be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evaluated. They must use substantial way structures incorporating support tracks and the jet or propeller propulsion systems generally proposed would be unsuitable for transit service. They would require substantial amounts of power for lift and although a magnetic propulsion system could be devised, it will be some time before the over-all economics of air suspension can be adequately appraised.

Safety

The concept developed for the Metro transit vehicle is based on special design incorporating safety features, many of which are not normally found in transit service. One of these features provides insurance against the vehicle's overturning or leaving the structure. The vehicles are provided with tire pressure indicators to detect any low pressure in the tires, although the European experience has shown that there is little problem with flat tires and no problem with blowouts. The flanged steel safety wheels are provided to be used if tire trouble does develop, at which time the steel wheel would engage a steel running track. They would also be used for switching on conventional switches. The broad width between the rubber tires provides for more stability against wind loads and this is combined with a low center of gravity design of the vehicle which further insures stability. Guidance is provided by horizontal pneumatic tires bearing against a raised center section of the structure. This design is shown in the accompanying illustration. Incorporated into the raised center section will be a positive derailment stop which, while permitting normal movement of the vehicle, would engage a projecting portion of the vehicle undercarriage if any tendency toward overturning or derailment develops. This projecting portion or shoe would also act as an emergency brake under these conditions.

Because of the requirement for maximum safety in the operation of high-speed equipment, a system of automatic control has been conceived, thoroughly investigated and is now recommended. Such a system would enable high-speed operation with headways of as little as 60 seconds and would provide for positive speed control through curves, switches, and other critical points. While such a system would be of new application to transit service, it may be composed principally of standard components already developed and a fail-safe, reliable system is entirely feasible and practical. This combined with the other safety features used will make possible completely safe operation even at the high speeds contemplated.

Vehicle Design

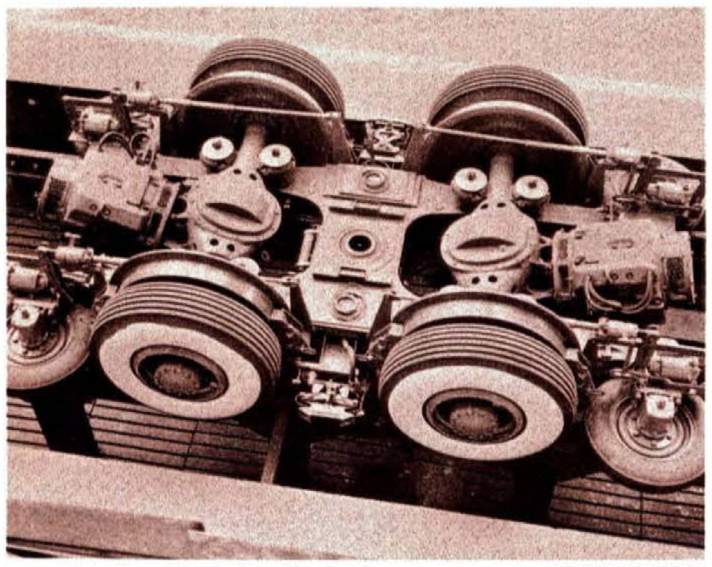
The concept design for the Metro transit vehicle is based on an over-all vehicle length of some 54 feet, seating at least 54 passengers and an approximate empty weight of 30,000 pounds. While this would be regarded as an advanced and unique vehicle by current standards, its practicality has been confirmed by extensive engineering analysis, as well as by representatives of the aircraft industry and transit car builders. Airframe manufacturing techniques may be used to secure this lightweight concept. While the lightweight concept causes some increase in cost, over-all economy would result due to the saving in way structure made possible by the reduction in weight of the vehicle. In addition, the lighter weight affects savings in power consumption.

The vehicle is designed to incorporate the most modern features of appearance and equipment and makes use of large glass areas to provide an appealing view for the passenger and to make the vehicles as pleasing in appearance as possible. The design for the vehicles provides for air conditioning. Easy access in and out of the cars is provided by three sets of double doors on both sides of each car. This will permit either center or side platform loading. The cars have end doors for emergency use. Adequate aisle and door space allows rapid movement of passengers at stations and to accommodate standees. The cars would be semi-permanently coupled together in units of two and operated in trains of 2, 4, 6 or 8 cars.

Dynamic braking would be used, but regenerative braking is not recommended. At lower speeds, disc brakes would be used and special emergency brakes would also be furnished. We recommend that 600 volt direct current traction power be used with four 125 horsepower electric motors per car. Other power systems were analyzed, including the use of alternating current, and were found to be not as economical and advantageous as the conventional 600 volt direct current system. Power would be supplied to trains by means of a contact rail with a negative return which would not be grounded. The power should be purchased from existing sources at specified points but the Authority should construct its own power distribution facilities for best over-all economy.

Summary

The Metro equipment recommended represents the best possible combination of modern design and proven performance. The system is adaptable to use in subways, at-grade level, and on overhead structures. It can operate over existing railroad tracks and can use conven-



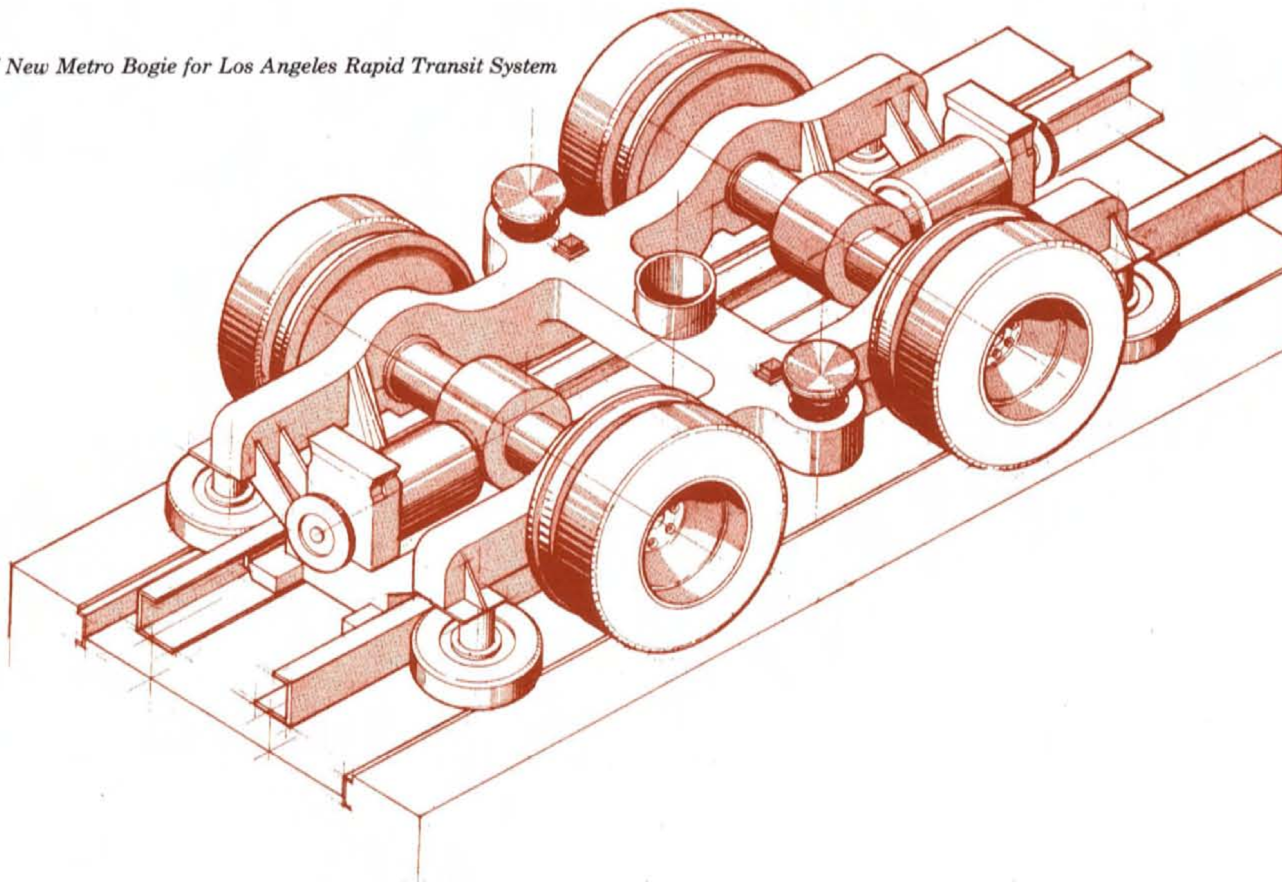
Pneumatic-Tired Bogie Used in Paris BY PERMISSION OF R.A.T.P.

tional switches. The nine years of operation in public transit service of similar rubber-tired equipment in the Paris subway has proven the feasibility of this concept to the point where the entire Paris system is being converted to this type of equipment. The City of Milan, Italy, after an extensive system study, is designing its new rapid transit system to utilize supported rubber-tired vehicles similar in many respects to those used in Paris. While this equipment is not yet in operation, it is indicative of the interest in utilizing the advantages of pneumatic tires.

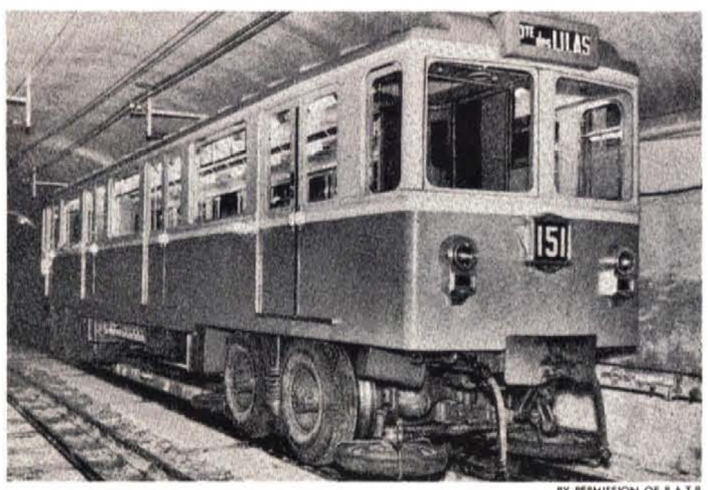
With the attributes of speed, comfort and convenience, offered by the recommended system, it appears to us that the Metro system would be readily accepted by the Los Angeles commuter. The system operation table given elsewhere in the report will indicate to potential patrons the time savings offered by the system.

It is most important to have acceptance by off-peak riders!

Concept of New Metro Bogie for Los Angeles Rapid Transit System



Paris Pneumatic-Tired Car



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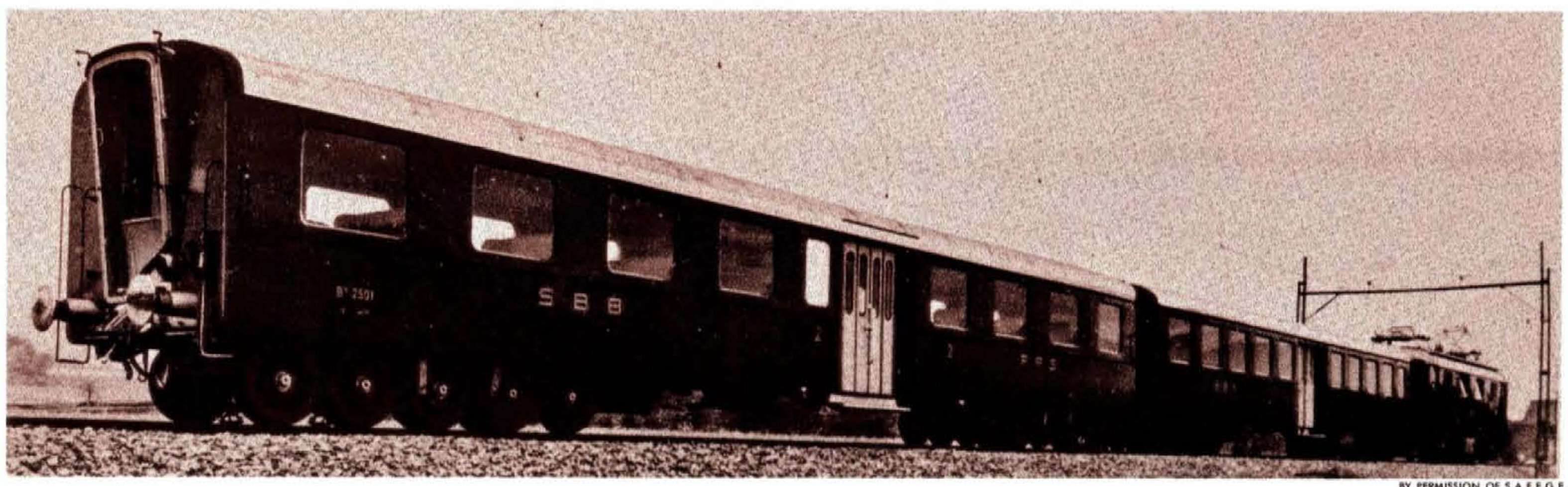
Swiss Federal Railways Pneumatic-Tired Train



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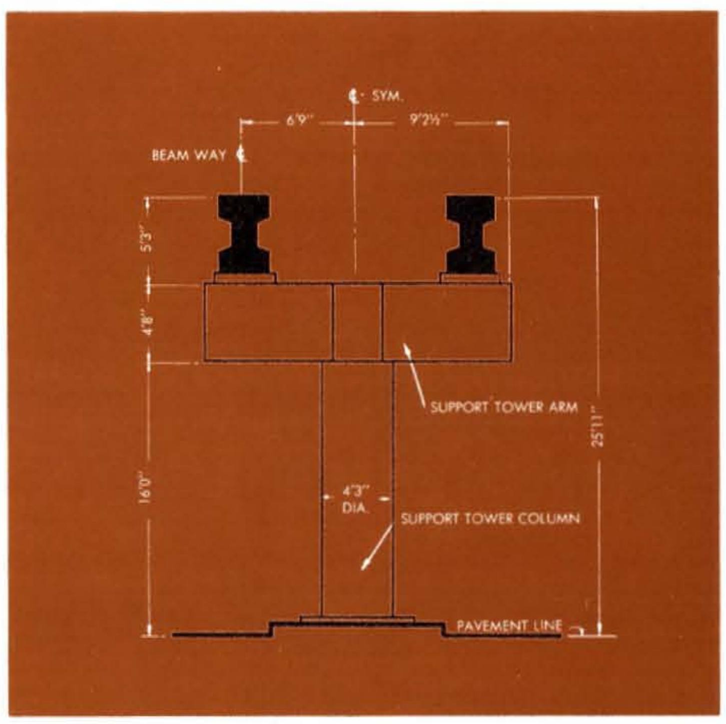
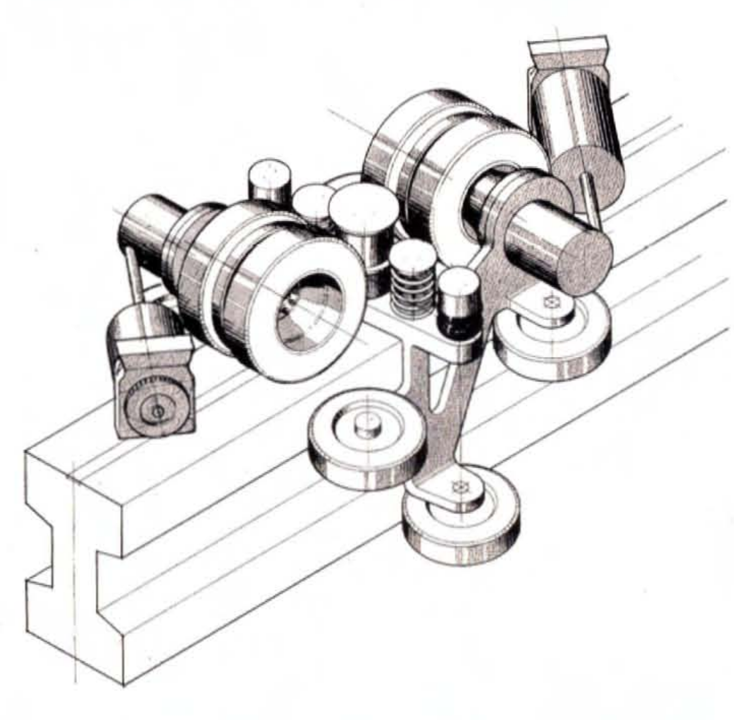
Supported Mono-Beam System Investigated



Typical Structure for Overhead Double Track Operation

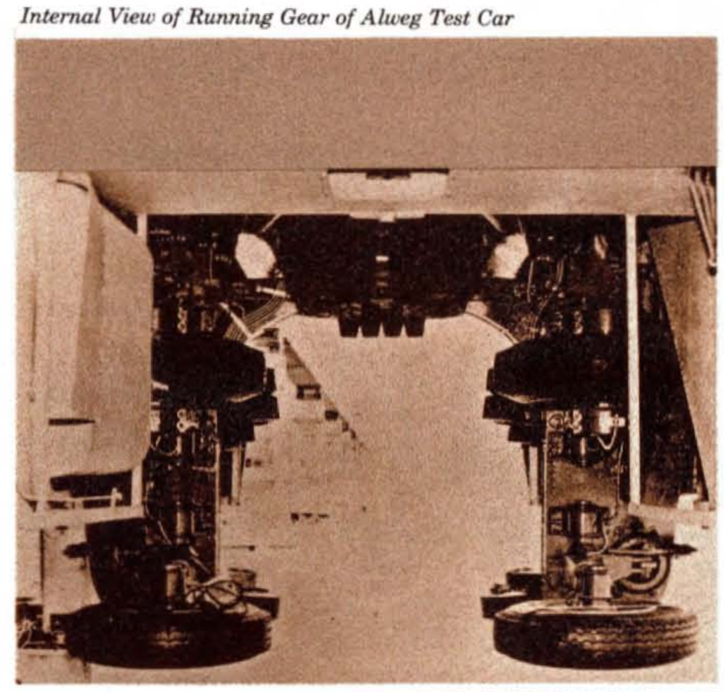
Isometric View of Bogie Concept Design for LAMTA Use



Disneyland—Alweg Installation

BY PERMISSION OF RAPID TRANSIT SYSTEMS OF CALIFORNIA

Internal View of Running Gear of Alweg Test Car



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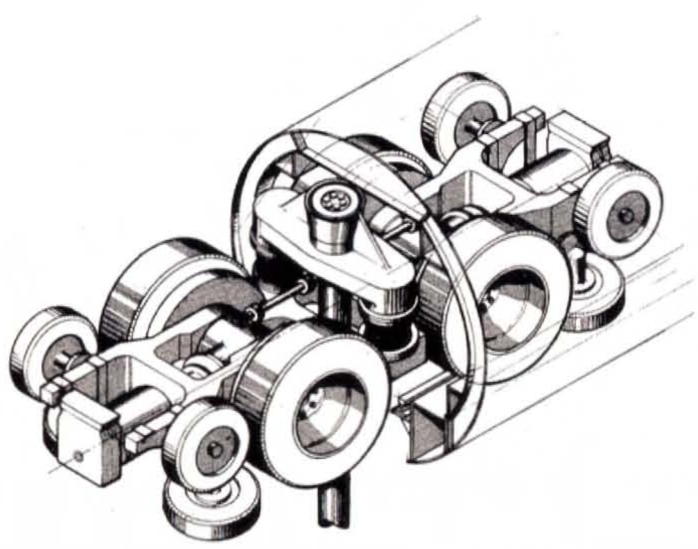
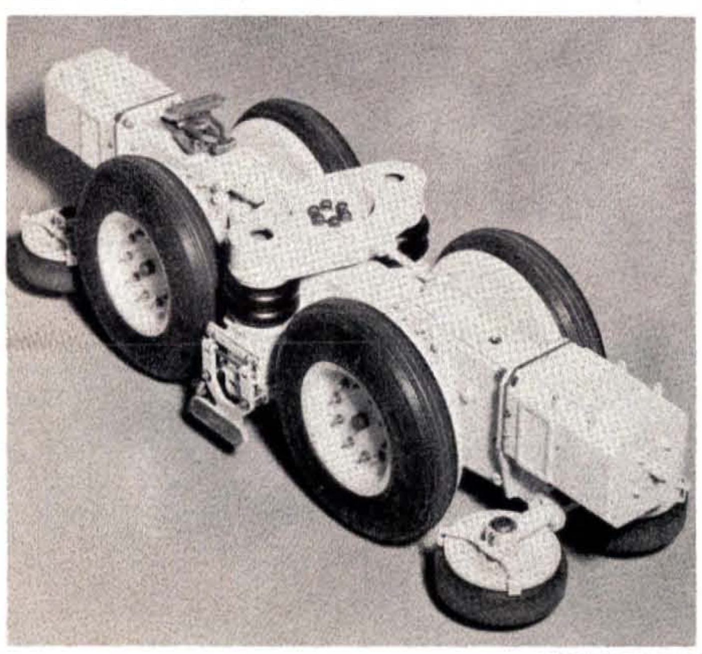
Suspended Mono-Beam System Investigated

Isometric View of Bogie Concept Design for LAMTA Use



Model of Bogie Used by SAFEGE System



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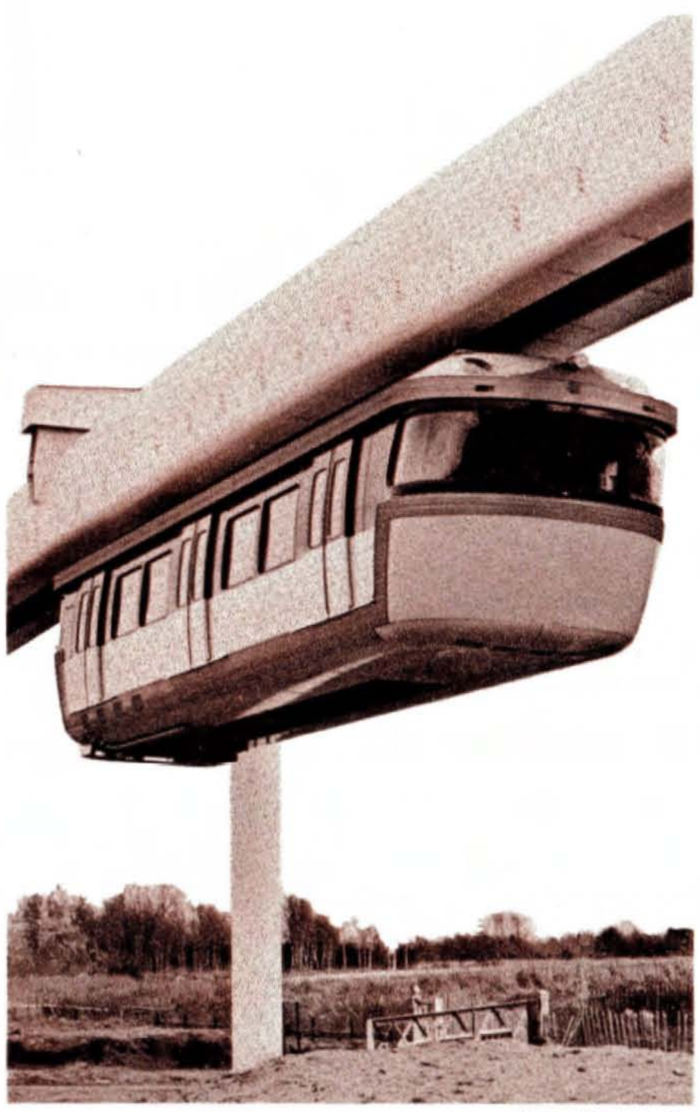
Test Car and Track of SAFEGE System



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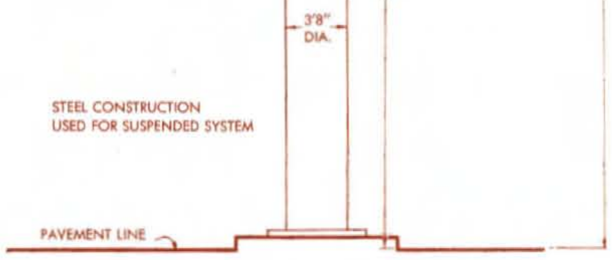
Typical Structure for Overhead Double Track Operation



Transit Facilities

This portion of the transit system includes way structures, stations, storage and maintenance facilities and accounts for a major portion of the cost of the over-all transit system.

The necessity for costly way structures arises from the fundamental need to provide a grade-separated transit system. This is the only way a truly *rapid* transit system can be secured. A transit system, unlike freeways, is quite limited in the choice of available routes. Since it must provide revenue based on service, it must follow routes where maximum patronage can be assured, and therefore must penetrate areas of business, industrial, commercial, and other higher density land uses.

Because of these circumstances, the combining of rapid transit with freeways is not always advantageous. In many cases, the freeways are located away from the better transit service areas in order to minimize right-of-way costs. In addition, the placement of rapid transit in existing freeways not having original provisions for transit creates many problems. Most of the existing freeways have rather narrow medians and although a single column overhead structure could be placed therein, operation upon such a structure would create a dangerous distraction on the freeway. Also, access for construction and maintenance would be difficult or impossible. The San Bernardino Freeway, however, was planned originally to include transit in an extra wide median and therefore provides an existing grade-separated facility ideal for transit use.

Aside from the San Bernardino Freeway and existing Pacific Electric rights-of-way, which are special cases, the existing street system is generally the most logical location for rapid transit. The successful location within street right-of-way provides a most economical solution, not only minimizing the cost of right-of-way acquisition but also maintaining all possible valuations intact (rather than removing property from the tax rolls through costly acquisition of private rights-of-way). The choice to be made then is whether to build the system under the streets (subway) or above them (overhead), since in each case the service provided would be the same. In deciding which configuration to use, the difference in cost between the two becomes a most important factor.

Configuration Analysis

In order to insure that estimated prices of underground facilities were based on the best and most economical construction techniques, as applied to specific conditions to be encountered in Los Angeles, special investigations were conducted. In this respect, the geology of the area was evaluated to determine if subsurface conditions might be especially favorable to one method or another. In addition, tunnel construction techniques were analyzed to ascertain the system most favorable for Los Angeles. This work, conducted in conjunction with our Associate Consultant, Mason & Hanger-Silas Mason Co., Inc. and LeRoy Crandall & Associates, resulted in an actual comparison between conventional tunneling, cut-and-cover methods recently developed for large storm drain and sewer work in Los Angeles, and new European methods of subway construction.

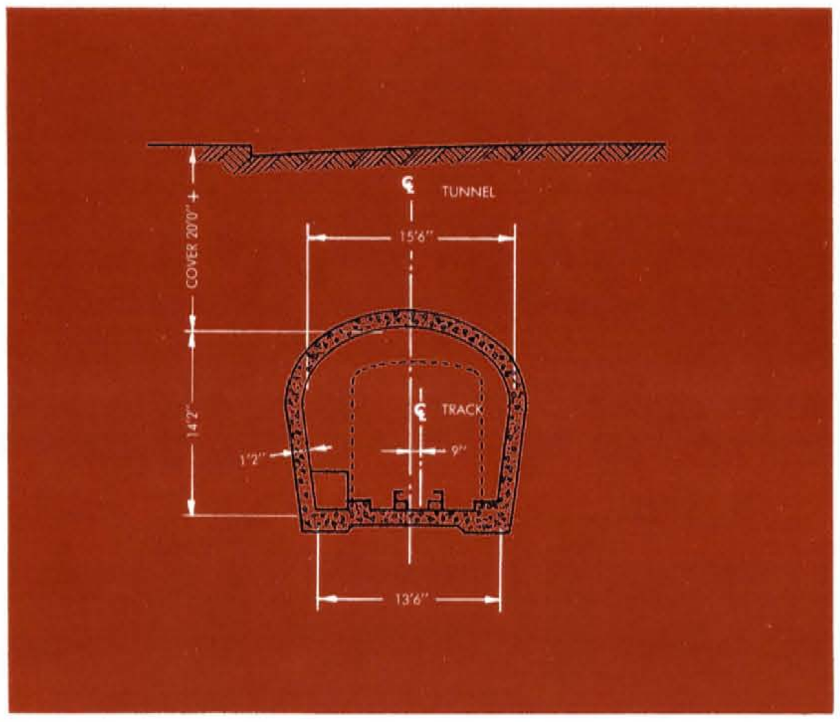
While there is seismic activity in Southern California, this seismic activity is usually not associated with movement in the upper surfaces, and therefore, subways can be built without fear of seismic disruption. However, subways will cost from two to three times as much as the overhead facilities, depending upon the location and subsurface conditions. Regarding construction time and interference with street traffic during installation, the overhead system offers important advantages over the subway.

The Authority, because of its enabling legislation and financing limitations, has sought the configuration most economical to construct and operate. The Authority is vitally concerned with the many effects of the transit system upon the community through which it passes, and also must provide a system with maximum appeal to the user. These criteria indicate the desirability of quiet equipment, running on a graceful, predominately overhead structure, except in areas where operation at grade is possible. A short section of tunnel is used in an area where city streets are not suitably oriented and it is more economical to build underground than to acquire private right-of-way.

Our recommended system includes 2.3 miles of tunnel, 21.6 miles of at-grade and 51.0 miles of overhead. This particular route system was chosen because it appears to provide the best combinations of service and economic feasibility in the light of the information at hand. Further detailed engineering on the routes will be required to finally confirm the choice of various alignment alternates.

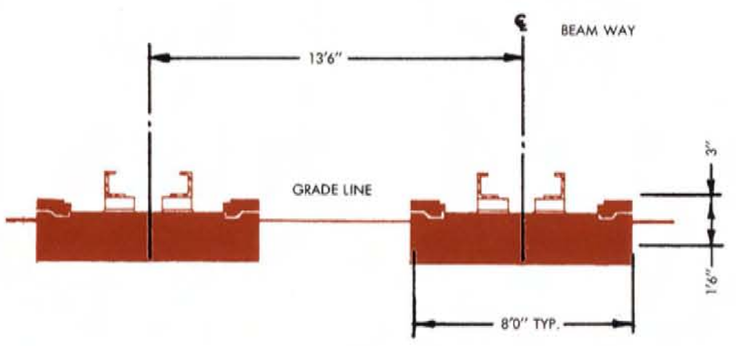
Design Approach

With a system containing a substantial amount of overhead facilities, it becomes particularly important to insure that the design of these overhead facilities meets all the best possible criteria for modern structures. Utilizing modern, lightweight transit vehicles makes it

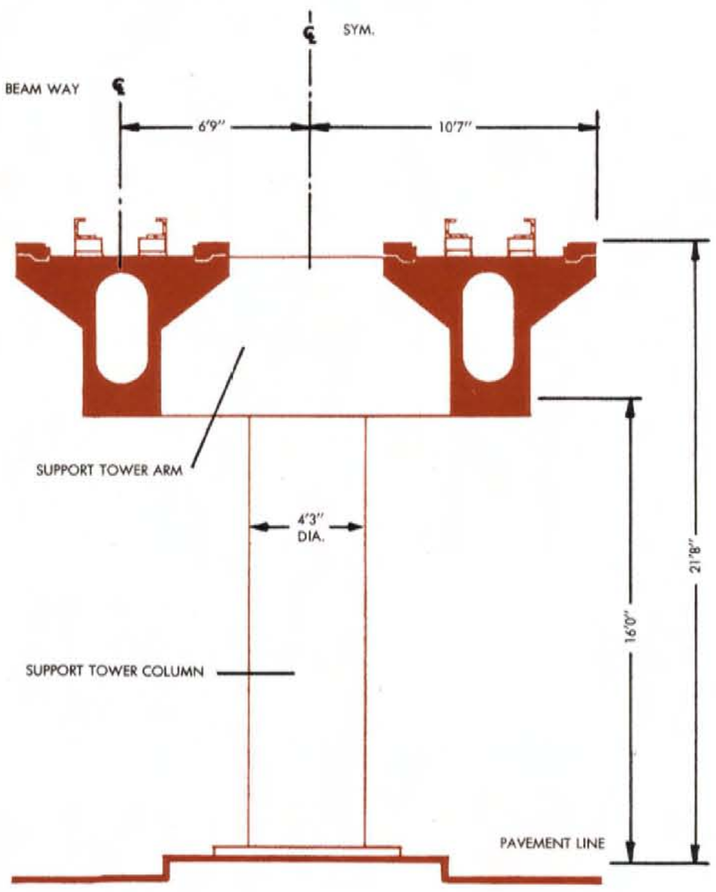


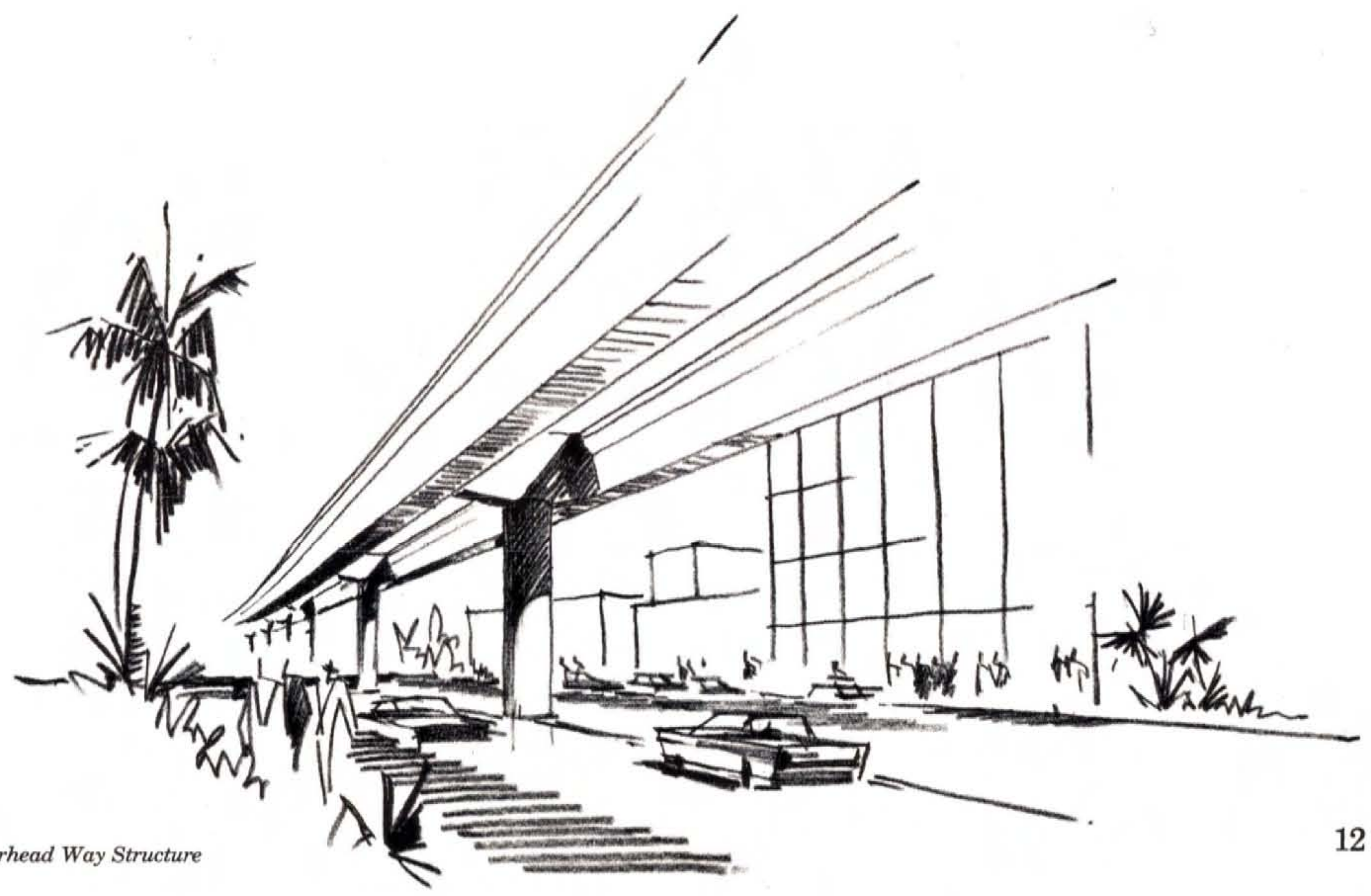
Typical Single-Track Tunnel Structure

Typical Structure for Operation at Grade



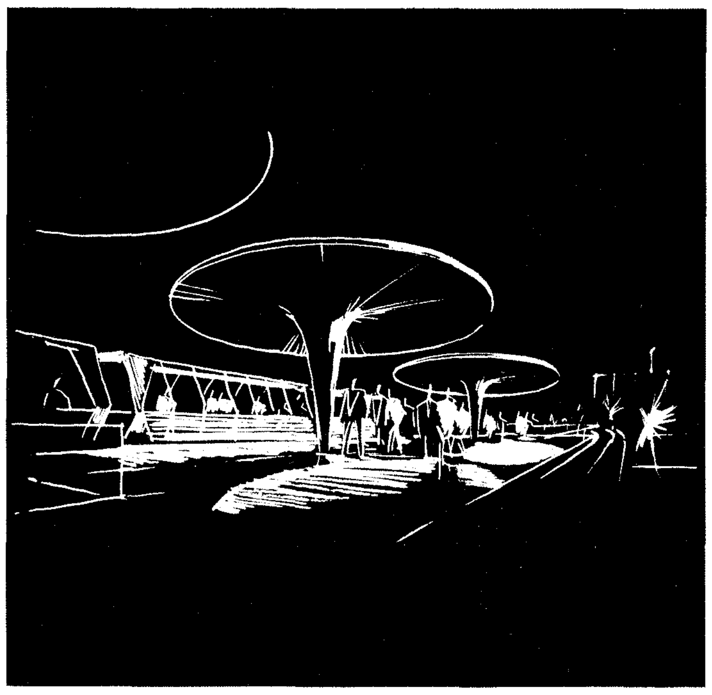
Typical Structure for Overhead Operation





Concept of Overhead Way Structure

possible to design clean, pleasant-looking, long-span structures to carry attractive equipment which will pass virtually unnoticed by pedestrians and neighbors of the Metro.



The design shown for the recommended Metro system uses reinforced concrete construction. For actual construction, it would be desirable to provide additional designs in detail and to take alternate bids on reinforced prestressed concrete and on steel construction. The section shown for use with the Metro system can utilize mass production precasting techniques, and with its single column construction, will occupy a minimum of space within a street. The accompanying illustration shows the outline of the way structure required by the several configurations of overhead, grade, and subway. It is necessary to provide at least 14 feet minimum clearance over public streets for safe motor vehicle operation beneath the transit system and at least 23 feet clearance when crossing over railroads.

Stations

Stations were classified into three major types: (1) Central Business District stations, (2) Medium density stations, and (3) Low density stations. Each of these has separate criteria and requires different treatment. It is recommended that the central platform type of station be used since, in general, it occupies the least space and provides for the most efficient fare collection operation.

Also, the center platform provides flexibility of operation in that transfers may be made directly across the platform, and duplication of access stairs and escalators are not required for peak loads as would be the case for separate side platforms.

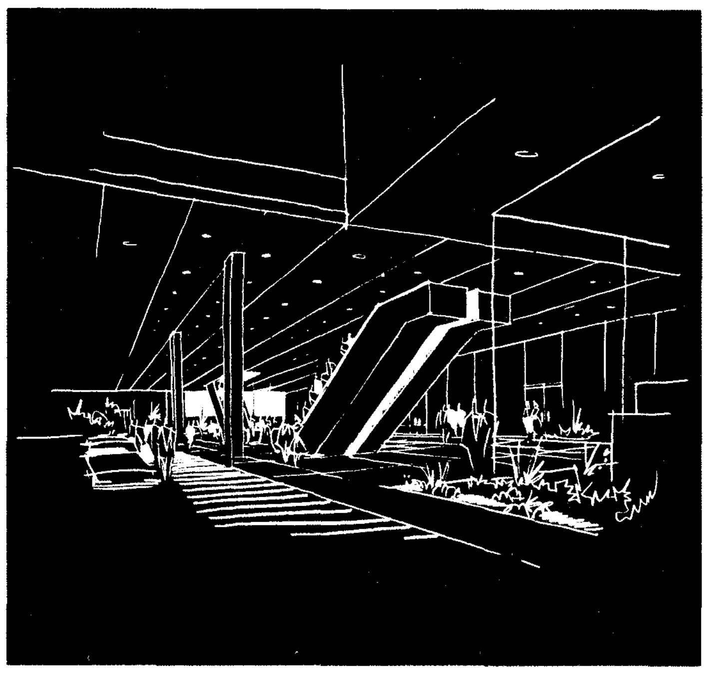
The accompanying concept illustration depicts one solution to the problem of locating a rapid transit station within the Central Business District. This design includes provision for a secondary distribution system for easy transfer of passengers and maximum dispersal of transit traffic, thus minimizing sidewalk congestion in the vicinity of the station.

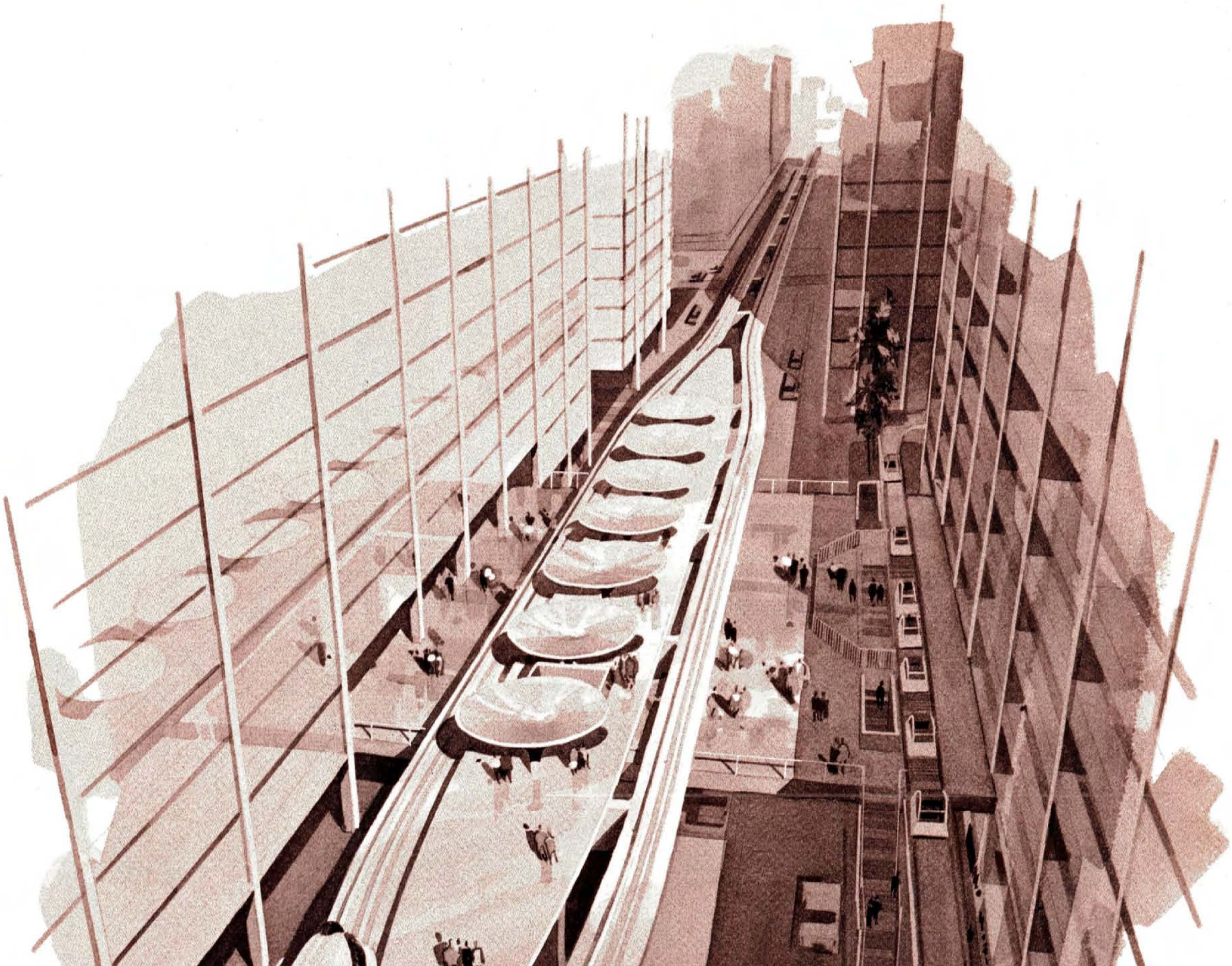
Station platform length has been established at 448 feet for Central Business District stations to accommodate anticipated growth of the system to a maximum length of eight-car trains. This length of station is greater than the normal short city block and therefore the station must be considered as a major feature of the street in which it is located. Medium and low density station platforms will be approximately 336 feet in length with provision for future extension to 448 feet. This provision will permit reasonable growth of the system and yet allow reduced first cost.

Several means of automated fare collection are available and our costs estimates make provision for a satisfactory installation.

Maintenance and Storage Facilities

In order to furnish sufficient data for pricing the over-all system, layouts, preliminary designs and estimates were made for maintenance, and storage facilities for the rapid transit vehicles. These designs provide for terminal storage and light maintenance at the ends of the four corridors with the major maintenance work to be handled at the Macy Street facility of the Transit Authority. It is also recommended that this location be used for the central dispatching and train control functions.





Concept of Station in Central City for Overhead Alignment

Alignments and Station Locations

On May 5, 1959, the firm of Coverdale & Colpitts, Consulting Engineers, submitted a study of public transportation needs in the areas of Southern California served by the Authority. The principal objective of this study was the determination of potential mass rapid transit routes. Upon completion of the study, they reported on twelve travel corridors each approximately 2 miles wide, and recommended to the Authority the following four corridors emanating from the Central Business District (CBD) as the most promising routes for initial rapid transit installations.

1. Wilshire—CBD to Santa Monica
2. Reseda—CBD via Wilshire and Cahuenga Pass to Reseda
3. San Bernardino—CBD to Covina
4. Long Beach—CBD to Long Beach

These four corridors were approved by the Authority and constitute the basis for our detailed alignment investigations.

Long-Range Transit Plan

Before proceeding with detailed route locations, a long-range plan was worked out to insure that initial transit installations would be compatible with the future growth of the city and of the transit system. The basis for this long range plan was the information contained in the Coverdale and Colpitts report previously mentioned. This report considered twelve possible corridor locations. A further analysis was made to determine how to provide service into each of the major passenger generating areas without duplication or overlap of service. This investigation evolved the 150-mile eight-corridor Long-Range Development Plan illustrated in schematic form on the opposite page which indicates the four corridors previously mentioned, and recommends later development of at least four additional corridors as follows:

1. San Fernando via Glendale and Burbank
2. Pasadena
3. Santa Ana
4. Inglewood

Each of these corridors would serve to and through the Los Angeles Central City.

In addition, as traffic builds up in the Wilshire Corridor, an express line will be needed between the Central Business District and the Reseda Corridor. At such time as these additional corridors are developed, the complex of rapid transit facilities to and through the Central Business District would, in effect, produce a full loop system. Thus, a transit patron could travel from any one of the eight corridors to any other corridor with no more than one transfer at any one of three principal interchange stations. With certain corridors, no transfer would be required.

The recommendations for specific alignments, station locations, and other related facilities set forth herein constitute the rapid transit program which is considered to be appropriate for development in the first four corridors of the Los Angeles Metropolitan Area rapid transit program. The following paragraphs will discuss the alignments and set forth certain basic factors involved in station locations.

Central City Area

The Los Angeles Central City becomes, by virtue of its position at the junction of the corridors, the heart of the transit system.

For the purpose of definition, we will define the Central City Area as that section of the city generally bounded by the Harbor Freeway on the west, the Santa Ana-Hollywood Freeway on the north, San Pedro Street on the east, and the Santa Monica Freeway, now under construction, on the south. The Union Passenger Terminal complex is also included.

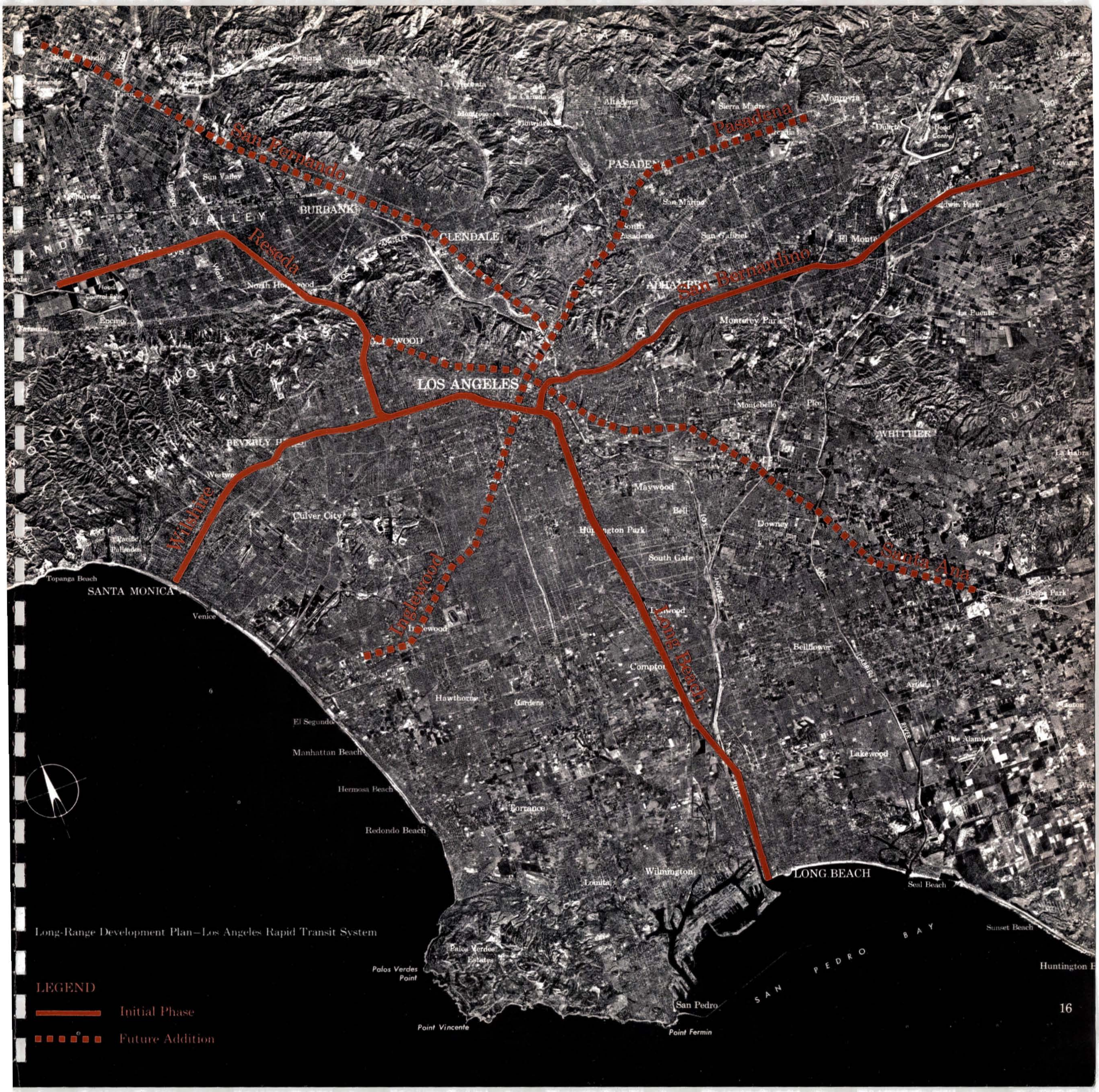
During the course of engineering investigations, many different plans for rapid transit service were analyzed for their adequacy in providing satisfactory service to and distribution of passengers within the Central City Area.

For a multiplicity of reasons, it finally evolved that the main line transit routes of the initial construction phase should follow the alignments shown on the accompanying composite aerial photo. This places rapid transit generally in the middle of the entire Central City Area, and along two sides of the CBD.

Secondary Passenger Distribution

A secondary passenger distribution system is recommended to penetrate the high density CBD and to give closer station coverage than would be possible with the main line facility. While time has not permitted a study of pedestrian and potential passenger movements within the CBD, it is believed that a secondary distribution system will provide important relief to street and sidewalk congestion in the CBD as well as serving the rapid transit system. Fare collection and transfer procedures for such a secondary system will require more study.

What sidewalk congestion?



Long-Range Development Plan—Los Angeles Rapid Transit System

Central City Area—Recommended Rapid Transit Plan

Several choices are available as to the type of secondary distribution system which could be used within the Central Business District.

The system could be a small transit car operating on a fixed grade-separated facility either overhead or in special subways. Several types of equipment are available. At minimum, it could consist of special bus equipment operating at the surface on exclusive bus lanes. On the basis of our preliminary analysis, a fixed type of secondary distribution system would include three loops, each loop connecting directly with one of the three main line rapid transit stations. The tentative alignments for the secondary distribution loops are indicated schematically on the Central City Area—Recommended Rapid Transit Plan.

The fixed type system would be completely automated and would have a capacity of 7,000 to 10,000 passengers per hour in one direction and it would operate at speeds of approximately 15 miles per hour.

The preliminary cost estimates in this report include sufficient allowance to build an overhead secondary distribution system. They have been developed only in sufficient detail to provide a basis for evaluation of the desirability of this means of total service.

Interchange of Corridor Lines at CBD

One of the principal problems encountered in the Central City is developing a suitable junction of the lines serving the various corridors. While it is desirable to provide for full flexibility of operation by enabling trains to proceed from any corridor into any other corridor (full interchange), such flexibility would be very expensive and it is probable that the additional cost would not prove justified. While a partial interchange would require transfers, it is believed that a transit passenger desiring through service would prefer a convenient transfer at the CBD to waiting at the origin extra minutes for a train destined to his specific corridor. However, in order to provide complete information on costs, the full interchange capability has been incorporated in the system.

For a minimum system, a partial interchange would be provided, such that through service is provided from the Wilshire Corridor directly to the Long Beach and San Bernardino Corridors, but a transfer is required between the Long Beach and San Bernardino Corridors. This is based on frequency of passenger movement between the corridors. This interchange would provide a great deal of flexibility of operation at a minimum of cost.

It is anticipated that the Reseda Corridor line would operate primarily through the Central City Area and into the Long Beach Corridor, while the Wilshire Corridor line would operate primarily through the Central City Area and into the San Bernardino Corridor. Transfers from the Long Beach Corridor to the San Bernardino Corridor could be accomplished at the 8th and Hill Streets station and would require no more than an average of a two minute wait during rush periods.

Alignment Description in CBD

The main line transit facility enters the Central City, as illustrated on the opposite page, from the Wilshire Corridor in a two-lane overhead (16-foot average vertical clearance) configuration in the center of 8th Street to a major station located between Olive and Hill Streets. This station would provide for interchange of passengers with a secondary distribution system. The line would proceed to a junction near Broadway and 8th Street. At this point, one leg of the line would proceed easterly along 8th Street and into the Long Beach Corridor, while the other leg would turn north into Main Street. The line would continue north on Main Street to a station located between 5th and 6th Streets. This station would provide the second major loading and unloading point for the rapid transit system in the Central City and would provide for transfer of passengers to a secondary distribution system. A concept of this station is illustrated in that portion of the report dealing with facilities. The line proceeds northerly in the median of Main Street to a station located between First and Second Streets. Secondary distribution transfer should also be provided at this station for access to the Civic Center. The line then proceeds northerly along Main Street to a point just north of First Street where the line swings easterly into a private right-of-way and enters Commercial Street, parallels the Santa Ana Freeway to a station located immediately opposite the Union Passenger Terminal.

A pedestrian walkway would be provided to connect the rapid transit station and the Union Passenger Terminal. The rapid transit line would then proceed easterly and cross the Santa Ana Freeway just west of the Los Angeles River, and thence into the San Bernardino Corridor alignment.

Whenever city streets are followed in the CBD and in the four corridors, the typical construction will utilize a single row of colums spaced in excess of 100 feet would be placed in a narrow center traffic island or median which would separate opposing auto traffic.

Corridor Alignments

The alignments and station locations recommended for the first four corridors are indicated on Page 2. The configuration used in the corridors is generally overhead, except where at-grade operation is feasible. In the Wilshire Corridor, a short section of tunnel is used between the Century City station and Sepulveda Boulevard, where city streets are not suitably oriented. Here the cost of underground construction is estimated to be less than the cost of acquiring right-of-way.

The station locations have been, where possible, coordinated with the Authority bus lines to serve as feeders and distributors. Some re-orientation of these and other lines will undoubtedly take place in order to more efficiently serve the rapid transit facility.

Major "park 'n ride" stations are proposed in each corridor and it is felt that these facilities will be extensively used. All outlying stations would facilitate easy dropping and pickup of Metro passengers from autos and buses.

At the junction of the Reseda and Wilshire Corridors, it is again necessary to provide for an interchange of trains between two corridors. Traffic movement studies indicate that only a partial interchange structure is necessary with a transfer required to go from the Reseda Corridor westward into the Wilshire Corridor.

As has been mentioned earlier, the alignments in the San Bernardino and Long Beach Corridors are recommended in the expectation that an arrangement can be developed by the Authority for the joint use of existing Pacific Electric rights-of-way. The alignment along this right-of-way in the median of the San Bernardino Freeway is already grade-separated and hence is ideal for surface operation of Metro alongside the active Pacific Electric track. The section of transit line from Rosemead Boulevard to El Monte has been projected to be an overhead facility operating above the P.E. track, due to restricted right-of-way width. The wide Long Beach P.E. right-of-way is not now grade-separated, and therefore the Metro alignment would be principally at grade alongside the P.E. tracks but would be overhead at major street crossings. On neither of these lines do we recommend use of the same track by Metro vehicles and P.E. trains.

It should be noted that the detailed alignments are shown out to the end of each of the first four corridors. If financial or other limitations require the initial shortening of these lines for the first phase, the terminal stations would, of course, have to be relocated and the location of the "park 'n ride" stations would have to be reconsidered. Preliminary plans and profiles of the alignments shown are being submitted separately along with other data of a technical nature.

Cost Estimates

Basis of Estimate

The estimate of the cost required to construct the 74.9 mile four-corridor system is based on the information and concept designs developed by us during this initial phase of the program. The concept designs of way structures, stations and other facilities have permitted cost per mile estimates to be made which can then be combined with equipment and right-of-way costs to provide a planning type of construction cost estimate. With additions for engineering contingencies and incidental expenses, the over-all program cost can be approximated. It should be emphasized that these estimates are preliminary in nature and are subject to variation as the detailed engineering required is accomplished. However, it is felt that they will give the required indication of the cost of the rapid transit program.

The estimates reflect Southern California construction conditions and are based on second quarter 1960 construction costs without provision for possible escalation of prices. A contingency factor of 15 percent has been added to the basic estimate of cost of construction and engineering. Right-of-way costs were estimated by methods consistent with accepted theories of land and improvement valuation and the estimates were reviewed with consulting appraisers, but no actual appraisals were made.

The estimate given hereinafter is based on structure configurations and recommended alignments previously shown which provide the following route mileages:

Tunnel	2.3 Miles
On-Grade	21.6 Miles
Overhead	51.0 Miles
Total	74.9 Miles

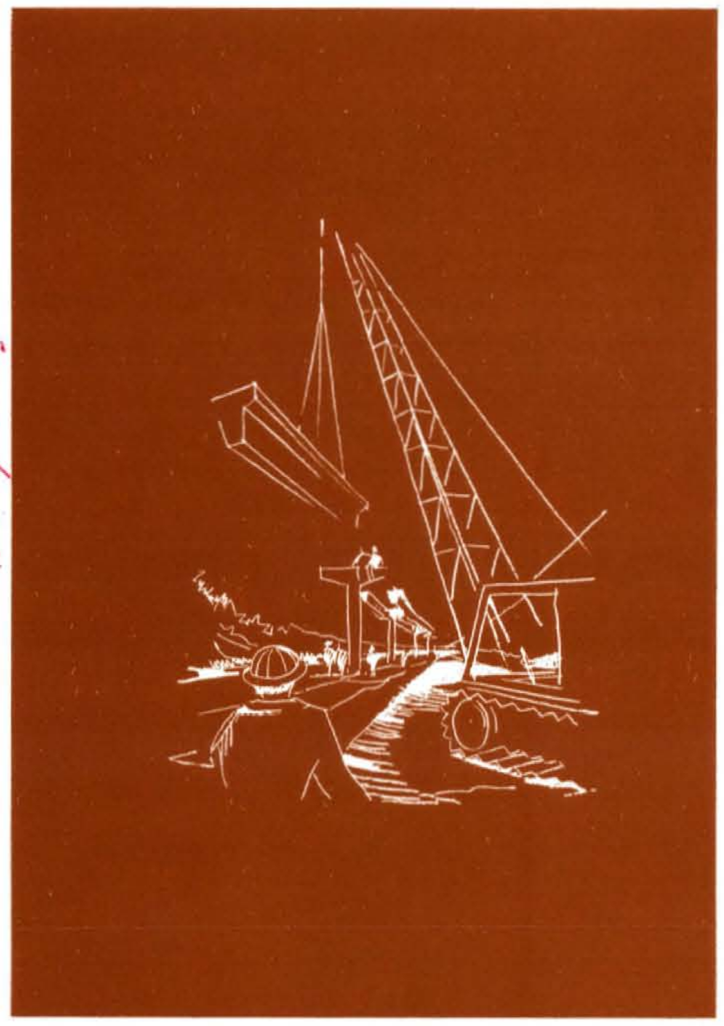
Several other alternates of alignment and equipment were investigated and cost comparisons were made. The combination of the route and system recommended herein provides the least cost of the alternates studied.

System Cost Estimate
74.9 Miles

1. Structure and Road Bed	$155,900,000
2. Stations	41,800,000
3. Electrification	51,900,000
4. Control and Communication	20,600,000
5. Utility Relocation	18,000,000
6. Yards and Shops	7,600,000
7. Secondary Distribution System	20,800,000
8. Land Acquisition and Right-of-Way	26,400,000
9. Rolling Stock	75,900,000
TOTAL (1960) Cost	$418,700,000
Administrative and Professional (Est. 10%)	41,900,000
To include engineering, surveying, subsurface explorations, construction supervision, testing and inspection, management and administrative and Operation Start-Up.	
Plus Reserve for Contingency at 15%	69,100,000
TOTAL SYSTEM COST (1960)	$529,700,000

It should be noted that the development of cost estimates for a complex program such as this is a difficult task at best and at this stage of the program several specific factors make detailed estimation particularly difficult. They are:

1. Detailed engineering designs and construction plans and specifications are, of course, not available.
2. Preliminary structure designs are based only on "average" general conditions. Route layouts were established from small scale area-wide topographic maps.
3. Subsurface and foundation conditions are assumed from only preliminary geology reports and only preliminary utility information was available.
4. Much of the proposed equipment design is unprecedented; some is not yet in the prototype stage of development.
5. As noted previously, appraisals of rights-of-way and other required acquisitions are not available.



Transit System Operations

In Los Angeles where distance is often measured in time rather than in miles, the peak hour schedule which can be maintained by the rapid transit system assumes major importance. The schedule for the recommended system as given below was computed, based on the capability of the equipment proposed and the time required to comfortably load and unload the passengers. The schedules are based on station stops of 20 seconds each, with normal vehicle acceleration and deceleration rates of 3.5 miles per hour per second. Maximum speed attained between stations is 80 miles per hour and generally assumes a slight coasting between acceleration and deceleration. The over-all average speed attained in each corridor is a function of the station spacing, and the conditions of curve and grade existing within each corridor. It should be noted that the average peak hour speeds indicated greatly excel the average peak hour Los Angeles freeway driving speed of less than 25 mph and the U. S. mass transit peak hour average speed of only 18 miles per hour.

Preliminary analysis of time savings that could be accomplished by a skip-stop type of operation was also conducted. It was demonstrated that skip-stopping in outlying areas would result in a saving of time of up to 26 percent to the outer reaches of the several corridors. However, this would of course be at some sacrifice in service frequency to some of the outlying stations.

Wilshire Corridor Time Table Outbound

Station	Miles Between Stations	Accum. Miles	Time (sec.) Between Stations (Start to Start)	Accum. Time (min) (Including Station Stops)
8th & Hill Street		0.0		0.0
Lucas Avenue	0.85	0.85	93.2	1.5
Alvarado Street	0.75	1.60	85.1	3.0
Vermont Avenue	1.00	2.60	95.7	4.6
Normandie Avenue	0.50	3.10	73.6	5.8
Western Avenue	0.50	3.60	73.6	7.0
Crenshaw Boulevard	0.90	4.50	94.2	8.6
Reseda Junction	1.00	5.50	97.1	10.2
Fairfax Avenue	1.25	6.75	110.0	12.1
Robertson Boulevard	1.50	8.25	120.9	14.0
Beverly Drive	1.15	9.40	109.1	15.9
Century City	1.00	10.40	98.3	17.6
Manning Avenue	1.35	11.75	116.5	19.4
Sepulveda Boulevard	0.75	12.50	86.8	20.9
Bundy Drive	1.40	13.90	114.8	22.8
26th Street (Santa Monica)	0.80	14.70	87.8	24.2
14th Street (Santa Monica)	1.00	15.70	98.1	25.9
Santa Monica Terminal	1.00	16.70	96.5	27.6

. . . Average Speed From 8th & Hill—36.4 miles per hour
. . . Average Distance Between Stations—0.82 miles

Reseda Branch Time Table
Outbound

Station	Miles Between Stations	Accum. Miles From 8th & Hill	Time (sec) Between Stations (Start to Start)	Accum. Time From 8th & Hill (min) (Including Station Stops)
Reseda Junction*		5.50		10.2
Beverly Boulevard	0.70	6.20	85.9	11.6
Santa Monica Boulevard	1.00	7.20	100.9	13.3
Hollywood Boulevard	0.85	8.05	93.6	14.8
Hollywood Bowl	0.75	8.80	92.1	16.4
Barham Boulevard	1.35	10.15	112.7	18.2
Lankershim Boulevard	1.15	11.30	107.0	20.0
Vineland Avenue	0.75	12.05	82.3	21.4
Riverside Drive	1.00	13.05	99.5	23.1
Chandler Boulevard	0.85	13.90	93.1	24.6
Victory Boulevard	1.50	15.40	123.2	36.7
Coldwater Canyon Avenue	0.75	16.15	87.4	28.1
Woodman Avenue	1.00	17.15	99.3	29.8
Van Nuys Boulevard	1.00	18.15	99.3	31.4
Sepulveda Boulevard	1.00	19.15	99.5	33.1
Woodley Avenue	1.00	20.15	99.3	34.7
Reseda Terminal	1.50	21.65	120.9	36.8

**For stations and times between Eighth & Hill Streets and Reseda Junction, see Wilshire Corridor Time Table.*

. . . Average Speed From 8th & Hill—35.4 mph
. . . Average Distance Between Stations From 8th & Hill—0.94 miles

San Bernardino Corridor Time Table
Outbound

Station	Miles Between Stations	Accum. Miles	Time (sec) Between Stations (Start to Start)	Accum. Time (min) (Including Station Stops)
8th & Hill Street		0.0		0.0
6th & Main Street	0.50	0.50	73.6	1.2
2nd & Main Street	0.50	1.00	76.4	2.5
Union Terminal	0.80	1.80	89.5	4.0
State Street	1.50	3.30	121.1	6.0
Soto Street	0.60	3.90	79.7	7.3
Eastern Avenue	1.80	5.70	142.4	9.7
Fremont Avenue	1.50	7.20	118.4	11.7
Atlantic Boulevard	1.00	8.20	98.7	13.3
New Avenue	1.50	9.70	117.9	15.3
San Gabriel Boulevard	1.00	10.70	97.3	16.4
Rosemead Boulevard	1.00	11.70	98.3	18.6
Lexington Avenue	2.00	13.70	142.3	20.9
Peck Road	1.00	14.70	99.1	22.6
Rivergrade Road	1.40	16.10	118.0	24.6
Maine Avenue	2.30	18.40	157.0	27.2
Orange Avenue	1.05	19.45	103.4	28.9
Vincent Avenue	1.00	20.45	100.0	30.6
Azusa Avenue	1.00	21.45	100.9	32.3
Hollenbeck Avenue (Covina)	0.50	21.95	69.4	33.4

. . . Average Speed From 8th & Hill—39.5 mph
. . Average Distance Between Stations—1.15 miles

Long Beach Corridor Time Table
Outbound

Station	Miles Between Stations	Accum. Miles	Time (sec) Between Stations (Start to Start)	Accum. Time (min) (Including Station Stops)
8th & Hill Street		0.00		0.0
San Pedro Street	0.65	0.65	83.5	1.4
Central Avenue	0.38	1.03	68.4	2.5
Washington Boulevard	1.30	2.33	113.2	4.4
Vernon Avenue	1.20	3.63	109.4	6.2
Slauson Avenue	1.00	4.53	101.4	7.8
Florence Avenue	1.00	5.53	100.4	9.6
Firestone Boulevard	1.00	6.53	100.4	11.3
103rd Street	1.12	7.65	105.5	13.0
Imperial Highway	1.00	8.65	100.5	14.7
El Segundo Boulevard	1.00	9.65	100.5	16.3
Compton Boulevard	1.50	11.15	123.0	18.5
Artesia Avenue	1.45	12.60	118.9	20.5
Del Amo Boulevard	2.10	14.70	146.7	22.9
Wardlow Road	1.95	16.65	141.5	25.2
Willow Street	1.00	17.65	101.3	26.9
Pacific Coast Highway	1.00	18.65	101.4	28.6
Seventh Street (Long Beach)	1.00	19.65	101.4	30.3
Long Beach Terminal	0.40	20.05	69.4	31.4

. . Average Speed From 8th & Hill—38.4 mph
. . Average Distance Between Stations—1.12 miles

Section II—Transit Equipment Analysis

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LIST OF ILLUSTRATIONS

Transit Equipment Analysis

The evaluation of rapid transit equipment and "system configurations" composed one of the principal efforts during the first three months of this phase of the Rapid Transit Program. A changing pattern of land use, population density, and mass transportation efficiency in the Los Angeles Metropolitan Area indicated need for a complete review of rapid transit technology and the selection of a system configuration to satisfy current and projected transportation and community requirements. The terms "system" or "system configuration" refer to a combination of rolling stock and way structures; for example: a conventional rapid transit car with steel wheels, operating on a way structure composed of steel rails mounted on ties and ballast.

This section of the report will cover the development of criteria for the consideration of the various systems, the initial screening of systems, and a full description of the three systems selected for detailed investigation. These three systems will then be analyzed and compared to the end that a single system can be recommended for adaptation to the needs of Los Angeles. In addition to the material on the transit systems, this section of the report will include a detailed analysis of important system equipment components and will outline the operational features of the recommended system.

INITIAL CONSIDERATION OF SYSTEMS

The Authority, in order to have the most modern possible transit system for this area, has directed the exploration of all recent developments in rapid transit and related fields. Accordingly, an active search has been carried out to find new concepts of mass rapid transportation. From this search evolved a number of systems which were evaluated and then a limited number were selected for detailed investigation.

The first step in the process involved development of basic criteria. This list of minimum requirements covered a broad group of functional factors and was used effectively during the initial screening of transit system proposals. Several points of the criteria were considered particularly applicable to Los Angeles, because of climatic conditions, the lack of precedent setting existing rapid transit facilities and experience of freeway development and use.

CRITERIA

1. Speed Factors
    a. Maximum of 75 to 80 miles per hour.
    b. Average scheduled for 45 miles per hour.
    c. Acceleration rate - 3.5 miles per hour, per second.
    d. Deceleration rate - 4.5 miles per hour, per second - maximum.

2. Capacity Factors
    a. Capable of providing 30,000 seats per lane, per hour.
    b. Capable of 90 second headways.
    c. Maximum station stop - 20 seconds.
    d. Operate on grand-separated rights-of-way.

3. Convenience Factors
    a. Careful design of interchange stations for ease in transfer.
    b. Escalators from lower to higher levels.
    c. Parking areas adjacent to outer limit stations.
    d. Convenient service to the central business district.
    e. Integration with surface bus feeders throughout.

4. Comfort Factors
    a. Adequate seat dimensions.
    b. Internal temperature control. (Air Conditioning ?)
    c. Low noise levels.
    d. Pleasing appearance.
    e. Smooth riding qualities.
    f. Seats for majority of passengers.

5. Safety Factors
    a. Automatic train control with fail-safe features.
    b. Easy evacuation of train in case of emergency.

6. Aesthetic Factors
    a. Stations and way structures pleasing in appearance.
    b. Ultra-modern exterior and interior design of trains.

7. Maintenance and Operation Factors

a. Lightweight equipment.
b. Interchangeability of equipment between lines.
c. Line connections to central maintenance area.
d. No more, or less, than one operator per train.
e. Practical and convenient collection of fares.
f. Efficient and quiet power and propulsion system.

SCREENING PROCESS

The screening and evaluation of transit systems involved hundreds of conferences and hearings, and efforts were made to investigate every potential source of rapid transit technology. A complete listing of system proponents by configuration category is shown as follows. Persons and firms contributing ideas and suggestions on specific items of equipment are also listed.

1. Conventional Rail Systems

a. *Hastings Plane-O-Rail
b. *Norton Aerial Transit
c. General Motors Aero-Train
d. A.C.F. Talgo Train
e. [1]Paris Metro (Rubber Tired Equipment)
f. Lockheed
g. *E.J. Smith Midget Subway
h. St. Louis Car Company

NOTE: Items marked * were formal system proposals made to the Transit Authority; items marked [1] were considerations of equipment presently in operation. The remainder consists of systems or equipment not formally presented or in actual operation.

i. Budd Company
j. Pullman Standard Company
k. General Steel Castings Company
l. Convair
m. North American Aviation

2. Suspended System - Asymmetric

a. Wilbo Industries - MAN
b. *Greene Monorail
c. *Goodell Monorail
d. [1]Tokyo Monorail

3. Suspended System - Symmetric Split Rail

a. *Davino Monorail
b. *S.R.V. Monorail
c. Fussell Monorail
d. A. F. Vinje
e. T. R. Webb
f. Wilbo Industries - MAN
g. *S.A.F.E.G.E.
h. Northrup

4. Supported System - Overhead or Side Stabilized

a. Kearney Monorail
b. *Mono-Tri-Rail
c. U.S. Monorail
d. Lafferty Monorail

5. Supported System - Overriding

a. *ALWEG
b. *Lockheed
c. *Hendrik De Kanter
d. Hawes Monorail

6. Conveyor Belt Systems

a. Turner Moving Walk
b. Stephens-Adamson Carveyor
c. Mathews Moving Walk

7. Miscellaneous Systems

a. *Overhead Duct - L. E. Setzer
b. Ground Effect Vehicle - Ideonics, Inc. and Aeronutronic Division of Ford Motor Company
c. Helicopters - Los Angeles Airways

8. Transit System Ideas

a. E. M. Khoury
b. R. W. Bockman
c. H. E. White
d. A. Opalek
e. R. Swan
f. W. H. T. Holden
g. Mrs. N. Russell
h. Mrs. A. Dickerson
i. W. A. Shannon
j. J. J. Moore

9. Bus Systems

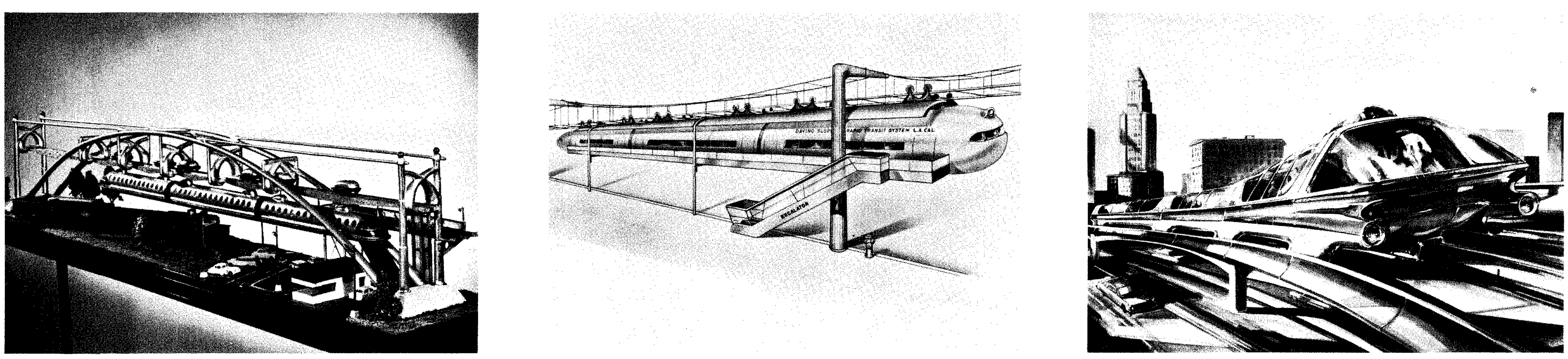
a. General Motors
b. Flexible Coach Company

A comprehensive questionnaire was prepared and distributed to proponents of systems to further explore the extent and validity of their work. Several of the systems investigated are shown on Figure II-1. The details of these investigations appear in a separately bound volume. The result of this work was the elimination of a number of rapid transit system proposals from further consideration, and the selection of three system configurations for detailed study and comparative analysis (See Figure II-2).

Selected for detailed evaluation were:

1. Conventional Two-Rail System (later called Supported Dual Track)
2. Supported System - Overriding (Saddlebag)
3. Suspended System - Symmetric Split-Rail

Figure II-1. Unusual Transit Systems



Throughout the course of the screening process, efforts were made to ferret out new equipment components such as brakes, propulsion devices or suspension systems, which had not previously been applied to rapid transit facilities. This approach was successful in many respects, and one particularly advanced concept in vehicle support was introduced. This was the "ground effect vehicle" proposed by Ideonics, Inc., the Ford Motor Company, and others.

CRITERIA FOR EVALUATION AND COMPARATIVE ANALYSIS

The detailed evaluation of system configurations required development of a detailed criteria, and further, of separating this criteria into items common to all systems, and items where variation between systems could conceivably establish one configuration as most acceptable for conditions existing in Los Angeles

The following items are set forth as basic criteria factors which can be met by any of the three systems:

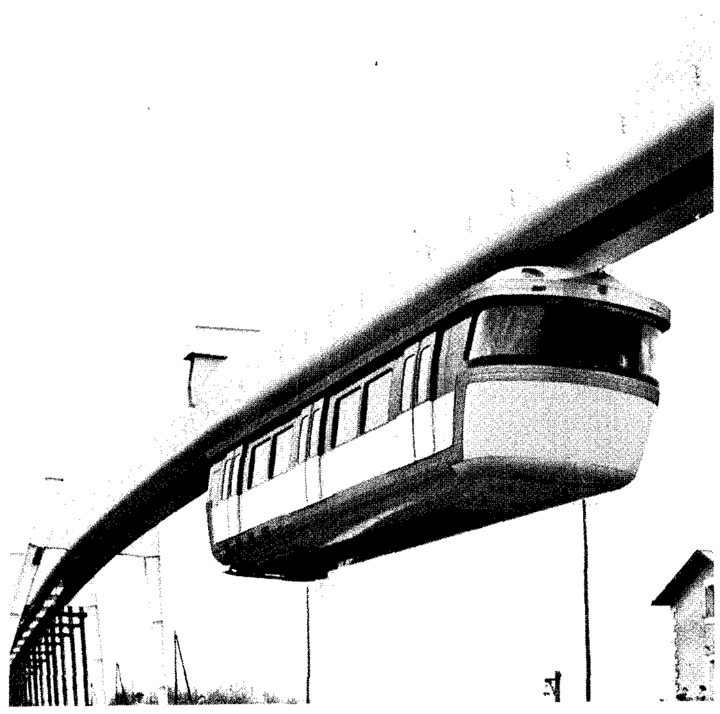
1. Speed - maximum 80 miles per hour.
2. Acceleration and deceleration - 3.5 miles per hour per second.
3. Emergency braking - 4.5 miles per hour per second.
4. Central heating and cooling.
5. Fluorescent lighting in cars.
6. Car length - 50-53 feet.
7. Car width - 10 feet, minimum.
8. Automatic control of operation.
9. Propulsion - D.C. traction motors.
10. Passenger capacity - 50-55 seats per car, 182 maximum design load. Practical total 120 passengers. (should be limited for short haul.)

Further criteria factors more directly affecting the choice of systems are listed as follows:

1. Operational Safety. High speed, close headway operation shall be obtained through use of equipment control devices with fail-safe features.
2. Car Derailment. Positive derail protection shall be provided in all high-speed track sections.
3. Noise Control. Noise levels of operating equipment shall not generally exceed the existing level of background noise in areas through which the line passes.
4. Switching. Switching shall be accomplished with quick-acting, fail-safe, economical devices, which should be of minimum size and easy to maintain.
5. Car Weight. Cars shall be as light as possible, taking into account sound car body and truck design.
6. Stability. Cars shall be stable under side wind loads of 20 pounds per square foot.
7. Pneumatic Tires. Loading shall not exceed recommendations of major tire manufacturers for tested and proven tires.
8. Performance on Grades. Cars shall be capable of full power starts and emergency stop on six per cent grades and capable of negotiating 10 to 12 per cent grades.
9. Car-to-Car Entrance Capability. Car design shall provide for passage between cars when cars are coupled in trains. (Why?)
10. Coupling Device. Cars shall be coupled into trains by devices with fail-safe features and which can be used with automatic coupling operation.
11. Car Seating Arrangement. Seats shall be arranged for maximum economy of space, passenger comfort and efficiency in loading and unloading.
12. Car Height. Over-all car height shall be held to a minimum for reasons of way structure economy, but shall provide adequate headroom for passengers.

Each of the three system configurations has inherent advantages and disadvantages and, as submitted by proponents, required certain modification to meet the recommended criteria. The following material sets forth a review of advantages, disadvantages, adherence to criteria, and modifications required for each of the system configurations.

Figure II-2. Three Configurations Chosen for Detailed Analysis



SUPPORTED DUAL TRACK SYSTEM*

The conventional rail rapid transit system configuration is well-known in the United States with installations in New York, Chicago, Boston, Philadelphia, and Cleveland. The support structure for rolling stock usually consists of two steel rails spaced 4 feet 8-1/2 inches apart, mounted on wooden ties and supported by ballast on grade. Elevated structures and subway construction make use of various modifications of the form of support.

Two formal presentations were made for supported dual-track systems, each of which recommended innovations and improvements in rolling stock and supporting structures. These were: the Hasting's Plane-O-Rail, which would use a modern design car operating on standard gauge rail, specially cushioned with rubber. The second presentation was the Norton Aerial Transit System which recommends use of pneumatic tires for the vehicles. In this system, the trucks are guided by steel flanges which allow for use of conventional switching.

Numerous meetings were held with representatives of firms presently manufacturing conventional rapid transit equipment in order to ascertain the status of the development of conventional rapid transit system components. These firms were: St. Louis Car Company; Pullman Standard Company; Budd Company; General Steel Castings Corporation, and others. Additional investigations were made concerning the Talgo train developed by the American Car & Foundry Company, and also the Aero train developed by General Motors. For examples of existing conventional two-rail equipment, see Figure II-3.

*This system classification was previously termed "conventional two-rail system." In this section of the report, the term "conventional two-rail system" will be generally used to denote existing supported dual track systems using steel wheels.

The following analysis discusses the advantages and disadvantages of conventional two-rail systems using steel wheels:

ADVANTAGES

1. Proven equipment available.
2. Standard inexpensive quick-action switches.
3. Adaptable economically for use overhead, at-grade, or in subway.
4. Minimum way structure required for surface or subway construction.

DISADVANTAGES

1. High noise level with steel wheels.
2. No derail guarantee.
3. Grade limitation (low traction, steel wheel to steel rail).
4. Excessive truck hunting (nature of standard car wheels and rail).
5. Entire car structure subject to high shock loading.
6. Heavy car construction is mandatory to increase car life, due to high shock loading.
7. Requires relatively broad way structure for overhead construction.

ADHERENCE TO CRITERIA

The conventional two-rail system in general use throughout the world, does not meet certain minimum requirements as set forth in the basic criteria for the Los Angeles area.

1. Noise. Steel wheels on steel rails produce sound described as a perceived decibel rating in excess of the recommended allowable.

2. Grade. Steel wheels on steel rails do not permit satisfactory operation on the five and six percent grades included in recommended alignments (with possibilities of 10-12% grades - subway to elevated).

3. Stability. Lightweight equipment as recommended would not be stable under wind loads with standard gage rail equipment.

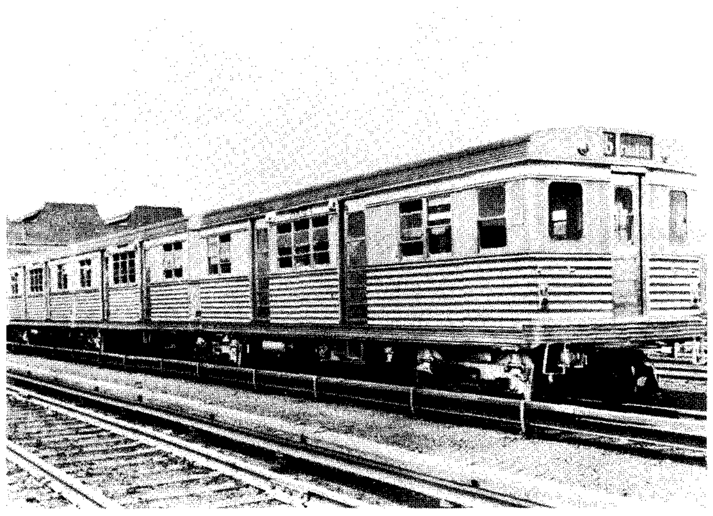
4. Non-Derail. Standard gage rail operation has inadequate protection for derailing.

MODIFICATIONS REQUIRED TO MEET CRITERIA

1. Use rubber tires to reduce noise and vibration, provide satisfactory grade climbing ability, and improve stability. In addition, the use of rubber tires will permit the use of a lighter weight car meeting the weight criteria.

2. Use horizontal guide wheels rolling against raised center flanges for additional stability and the elimination of hunting by conventional trucks. Guidance through conventional switches would be accomplished through use of flanged wheels, which would also act as safety wheels in case of pneumatic tire deflation.

3. Derailing protection would be accomplished by simple restraining devices designed as a part of the center guidance flanges.



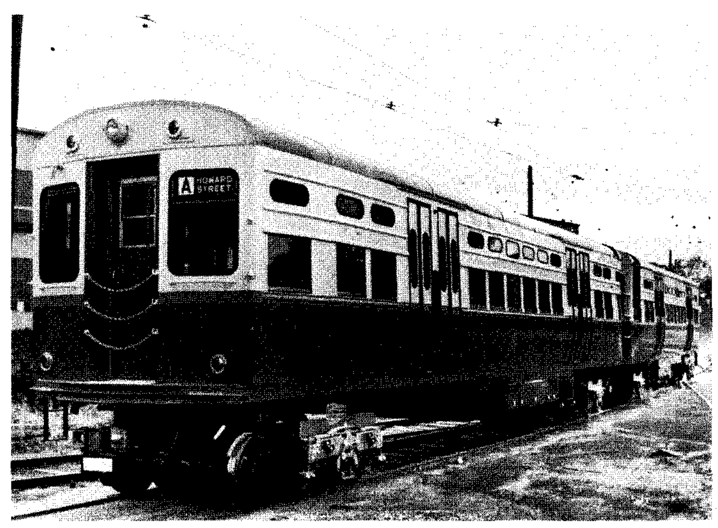


Figure II-3. Conventional Rail Systems

Proponents of dual track supported vehicles on rubber tires are:

North American Aviation
Convair - A Division of General Dynamics Corporation
Norton Aerial Transit
S.A.F.E.G.E.

All of these systems propose the use of rubber tires for support of the vehicle, and with the exception of the S.A.F.E.G.E. design, depend upon the flange of a steel safety wheel for guidance. The Norton system provides derailment protection by extending the wheel axle under an adjacent beam. The other systems have no special derailment provision.

STATUS OF DEVELOPMENT

A system similar in many respects to that meeting the criteria for a supported dual track system has been developed, tested and is in operation on certain lines in the subways of Paris (see Figure II-4). The

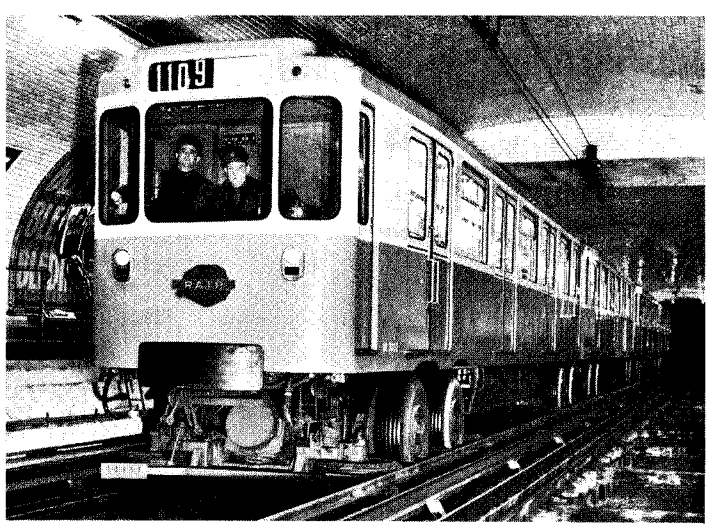


Figure II-4. Rubber-Tired Systems

Paris equipment uses pneumatic tires for support and guidance and also has standard flange wheels for use in switching and as safety wheels, as illustrated by Figure II-5.

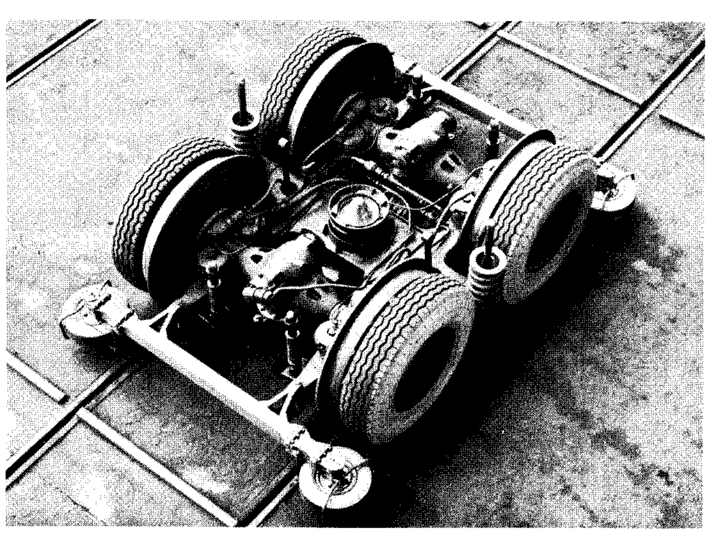


Figure II-5. Rubber Tires and Auxiliary Steel Wheels

This equipment has been operating successfully for some nine years in Paris and certainly provides a degree of operational testing in rapid transit service difficult for any other system to match. However, it must be recalled that the maximum speed in the Paris operation is not more than 40 miles per hour and therefore the ability of rubber tires to stand up to high speed service needs further investigation. Additional discussion on this subject will be given in the paragraphs further on, which discuss rubber tires in some detail. See Page 8 of Section I for further illustrations. The basic design of the Paris subway equipment uses horizontal pneumatic tires against raised sections on both sides of the track. Figure II-6 shows an experimental vehicle using a center guidance which has also been tested in Paris.

In addition to the rapid transit experience in Paris, the City of Milan, Italy has carried out considerable research and development on rubber-tired equipment. Provisions are

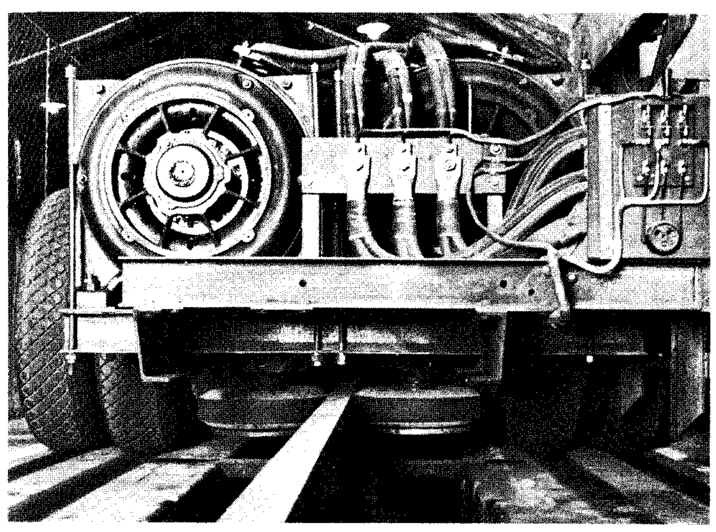


Figure II-6. Experimental Center Guidance System - Paris

being made for the use of rubber-tired vehicles in the new Milan subway. In the United States, both the Convair Division of General Dynamics and the North American Aircraft Corporation have developed designs of transit equipment using rubber tires.

It appears that the supported dual-track system would be able to draw heavily on the experience of the Paris subway equipment. In addition, since the majority of its components would be similar to those in current rapid transit and heavy truck and bus use, it would be able to take advantage of this experience also. Therefore, indications are that a relatively short development and testing program would be required to provide satisfactory equipment of this type.

SUPPORTED MONO-BEAM SYSTEM (SADDLEBAG)

Several types of saddlebag vehicles were proposed during the initial phase of the program. Among proponents were the following:

Rapid Transit Systems of California (ALWEG)
Lockheed Aircraft Corporation
Alan Hawes Monorail System
Henry de Kanter Monorail System

The only proponent that has progressed through design and development to the point of construction and operation of test installations is ALWEG.

The saddlebag system proposed by the Lockheed Aircraft Corporation is shown on Figure II-7. This system uses steel wheels running a steel rail on top of the beam for support and on four rails along the side of the beam for guidance. A single supporting wheel and six guide wheels are provided at each truck. By using a small diameter supporting wheel, the passenger area can have a completely flat floor area. The Lockheed system is still only in the concept stage, not having complete design engineering or any test installations. It provides the only variation of the saddlebag system using steel wheels, but in so doing subjects itself to the disadvantages of increased noise and decreased ability to negotiate steep grades.

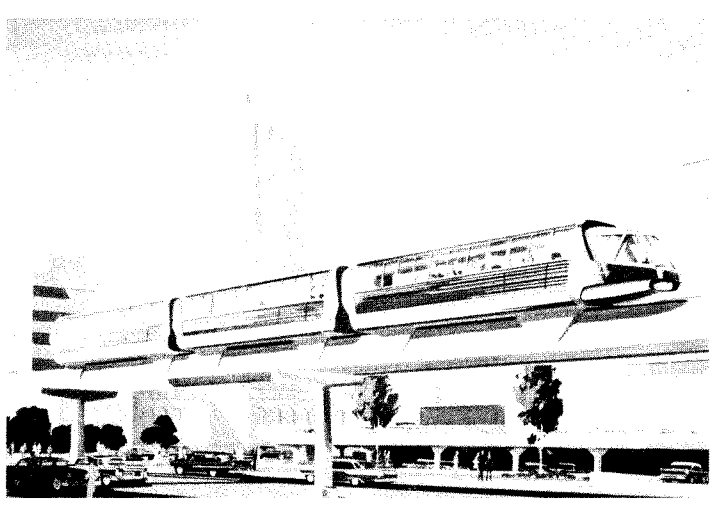


Figure II-7. Lockheed Monorail

The Hawes and de Kanter systems departed from the usual saddlebag design by using a tee beam with the main supporting tires running on the flanges of the tee, instead of on top of the beam, as is the case with the Lockheed and ALWEG designs. While this eliminates some of the problems inherent in the saddlebag, it also loses some of the advantage of minimum structure and introduces several difficult mechanical problems by the use of an eccentrically loaded split axle.

It was decided to base the comparison of systems on the normal saddlebag configuration which has the following characteristics:

The weight of the car is carried by narrow gage wheels riding on top of the supporting beam.

The car is guided and restrained from swaying by horizontal wheels riding on the sides of the beam.

As has been noted previously, the most advanced proponent (in the development sense) of the saddlebag system is ALWEG. The ALWEG train has been under development since 1951. Four reduced scale test trains were built and operated on a developmental basis until July, 1957, when the first full scale two-car train was completed. The proposed ALWEG train is a three-car articulated unit 92 feet long, 10 feet wide, and seating 96 people. The rated capacity is 300 people. Each wheel set consists of dual load-carrying 40-inch wire reinforced tires loaded to 9,000 pounds each (nearly double the manufacturer's rated load). The load wheels are rigidly attached to the car body and cannot pivot. This results in a long wheel base vehicle which must be skidded around corners.

It is understood that ALWEG is currently re-designing the supporting system to eliminate the tire trouble they have experienced on their test track, and to reduce the protrusion of the supporting tires into the car interior. The demonstration line near Cologne was inspected and found to provide a smooth, quiet ride at a maximum speed of about 50 miles per hour. Results of sustained operational testing were not available.

A five-eights scale ALWEG installation was built and installed and is currently in amusement park use at Disneyland. Tire wear has been excessive because the track is a series of curves. It does, however, provide a reasonably smooth and very quiet ride. The principal noise is that of the power shoe on the electrical contact rails. The ALWEG Cologne installation is shown on Figure II-8. The ALWEG Disneyland installation and further details are shown on Page 9 of Section I.

The ALWEG wheels are carried on a hinged stub axle supported at the hinged end only. The hinge is provided to permit tires to be removed from inside the car. Power is transmitted to the wheels through a gear box and long propeller shaft from an electric motor located low in the over-hanging portion of the car. The hinged stub axle is a probable source of mechanical trouble.

The ALWEG wheel housing forms a large box which protrudes into the passenger compartment. It is too high for passenger seating and results in lost floor space amounting to approximately 15% of the total. They are currently redesigning the vehicle and in the process are trying to improve the efficiency of interior use by providing seats on the box.

Since the aesthetics, safety and cost aspects of the system looked favorable, it was decided to investigate the possibility of a modified saddlebag design which more nearly met the criteria established for the Authority's system.

The principal considerations in the new design are outlined in the following paragraphs:

The supporting wheels must intrude into the body of the vehicle in the center of the car at each end. In order to use the space over the wheel wells, longitudinal seats can be placed thereon to do so; however, the car floor must be raised to reduce the intrusion of the wheel well to seat height. This results in raising the center of gravity of the car and places increased torsion on the running beam and increases the over-all height of the car to 15 feet, 5 inches. This requires no structural change of the running beam.

To overcome the problem of excessive tire wear, a four wheel turnable bogie was substituted for the fixed ALWEG running gear. The increased height of floor permitted relocation of the drive motor to a position over the rail and the use of a motor for each axle. No satisfactory way was found to eliminate the single end support of the axle, but it was considered desirable to eliminate the hinge for tire changing. To this end, a fixed axle was considered. It then became necessary to provide for removal of the wheel well cover and seats and a portion of the car floor in order to change the running tires. Tire removal would be through the passenger doors. The wheel wells also interfere with the functional placement of the doors. To overcome this, two double doors have been planned with single doors near each end.

The wheel location prohibits a central buffer beam through the center of the car. The resulting dual beam design requires more steel, hence a heavier car.

The enclosed wheel wells create a hot box which must be ventilated for protection of the tires and for passenger comfort. Thermal insulation would be required on the wheel wells.

The modified design outlined above results in a vehicle 53 feet 8 inches long, 10 feet 0 inches wide, and 15 feet 5 inches high. Twenty-four of the forty-eight seats are placed longitudinally over the wheels. These longitudinal seats are not as desirable as transverse seats, because the back of the seat does not support the passenger during acceleration. However, such seats are in common use in many transit systems.

ADVANTAGES

1. Absolute derail protection.
2. Quiet operation.
3. Minimum way structure required for overhead construction.

DISADVANTAGES

1. Switching operation requires moving entire supporting beam and leaves section of track open.
2. Raised wheel wells in car interferes with seating and door arrangements.
3. Tire change is major shop operation.
4. Wheel well forms a hard to ventilate hot box.
5. Special frame to develop buffing strength increases car weight.
6. Design of suspension system causes excessive tire wear in turns.
7. Expensive beamway required throughout shops and storage areas.
8. Excessive car height requires greater clearance provision.

ADHERENCE TO CRITERIA

The designs submitted by proponents and illustrated by the test line in Cologne, Germany, and the Disneyland amusement ride do not meet the recommended criteria. Principal weaknesses in these designs include overloaded pneumatic tires and inadequate passenger capacity.

MODIFICATIONS REQUIRED TO MEET CRITERIA

1. Complete truck redesign, doubling the number of traction tires per car to eliminate overloading, incorporation of car center bearings in trucks, gear case redesign and elimination of one bevel gear case drive.
2. Car modifications consist of center bearing adoption and raising car floor level to permit seating of 24 passengers on top of wheel wells. Provision is made for tire changes by providing a trap door and removable seats.
3. Increase car length to provide adequate seating capacity.
4. Modify car springing and suspension.

STATUS OF DEVELOPMENT

A test section of the ALWEG saddlebag system is located near Cologne, Germany, and has been in limited operation for three years. This is a full-scale prototype using pneumatic tires and on the one-mile test section achieves speeds of over 50 miles per hour. A small-scale version of the ALWEG system provides an amusement attraction at Disneyland. Results of sustained operational testing of the full-scale ALWEG vehicle have not been made available, although reliable sources report high tire wear.

Indications are that improved designs along the lines recommended herein may make this system acceptable, especially for all overhead installations.

Figure II-8. ALWEG Monorail

SUSPENDED MONO-BEAM SYSTEM - SYMMETRIC SPLIT-RAIL

The suspended mono-beam, or split rail, monorail system is sometimes described as an upside down narrow gage railroad. As a matter of fact, the interior of the car is essentially identical to that used for conventional rail systems. The bogies are quite similar to those used on the Paris rubber-tired equipment, except for the narrow width and provision for suspending the car. The principal physical difference of this system is in the suspension of the split rail car.

Proponents of the split-rail system were:

- Societe Anonyme Francaise D 'Etudes de Gestion et d' Enterprises (SAFEGE)
- Norair (Division of Northrup Corporation)
- S.R.V. Corporation
- Wilbo Industries (M.A.N.)

The most advanced proponent of the split-rail system is the S.A.F.E.G.E. group in France (see Figure II-9). In March of 1960, they completed and are currently testing a suspended vehicle on a 3500' test track located south of Paris. See Page 10 of Section I for further details.

The S.A.F.E.G.E. design incorporates a secondary suspension system which acts to counteract the sway of the car under normal operation, thus creating a restoring force tending to dampen the sway and reduce the torsional effect on the structure. The maximum travel of the primary suspension is 4°20' limited by contact of the suspension rod in the bogie underframe. The secondary suspension provides an additional deflection of 3°10' or a total sway angle of 7°30'. The secondary suspension is controlled on a linear relationship by the primary suspension through the medium of a high pressure hydraulic system.

Upon entering a station, the action of the secondary suspension is locked so as to force the car into alignment and eliminate all sway. This reversed action imposes a torsional load upon the beam. A check of stability shows that under these circumstances, uplift of the bogie wheels will occur on the down-wind side at a wind velocity under 80 miles per hour. Such a condition would result in the car ramming the station platforms unless ample clearances were provided, thereby requiring bridging between the platform and the vehicle.

The S.A.F.E.G.E. engineers state that the response time of the hydraulic system is 3 seconds. The natural period of oscillation of the car appears to be approximately 3 to 4 seconds. Thus, an action of the hydraulic system to correct for sway might come so late as to amplify the motion on the reverse swing. It is understood that further research is now in progress on this problem.

Under normal circumstances, the suspension system should be capable of maintaining alignment of the car and bogie if the response problem is solved. The shift of load on the tires, however, results in an uncompensated deflection of the bogie which is exaggerated in the deflection of the car body. The result is a wider clearance required between the car and station platform as noted before.

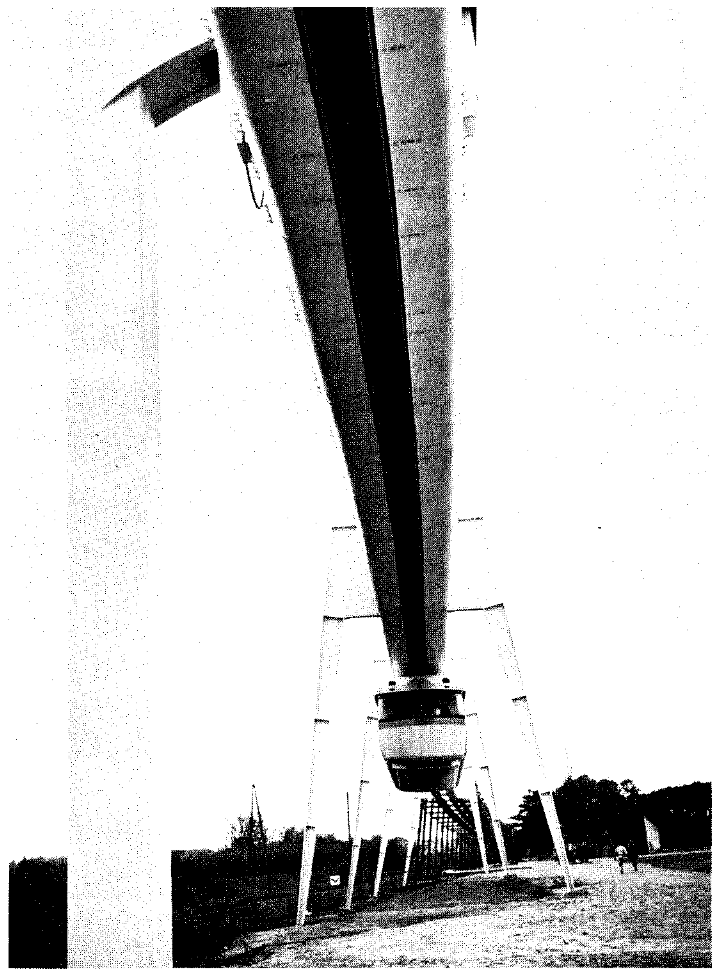


Figure II-9. S. A. F. E. G. E. System

Test and demonstration runs at the S.A.F.E.G.E. track have only just started and there has been as yet little opportunity to work out problem areas which have arisen. The sway control system was out of service undergoing repairs or modifications on our visit to the test track and it is understood that the S.A.F.E.G.E. group is currently developing a new secondary suspension system expected to be in test operation by July of 1960.

The hydraulic system requires a tank, high pressure pumps, pipes, actuating cylinder and control valves. These are items which can be troublesome and require high maintenance. The use of hydraulic fluid becomes a fire hazard if a leak develops.

The running track consists of a steel tube having an open slot in the bottom. A flat running surface is provided and power rails are contained within the tube. The running tube for the French test track appears to act as a reverberation chamber for a loud rumbling sound which emanates from the tube when the car moves. When a section of double walled tube was filled with sand, only slight improvement resulted. The French engineers are currently redesigning the track to provide an open top in an effort to minimize the noise.

Despite these handicaps, the test car provided a smooth ride without objectionable sway in calm weather, even without the secondary suspension system.

Derailment of the enclosed bogie is virtually impossible. However, the possibility of running into overheight vehicles constitutes a collision hazard which must be recognized.

Switching of the split-rail system may be achieved by the use of a transfer table - a heavy, space-consuming item. The S.A.F.E.G.E. switch design utilizes three segments which are rotated through an arc by a hydraulic system to achieve the switching action. The switch operating time is 6 seconds. Safety interlocks prohibiting a train from entering an open switch can be provided. The S.A.F.E.G.E. design affects some reduction on the bulk and weight of the switch compared to a transfer table, but it is still large and expensive. The complication of hydraulic pumps, pipes, valves, cylinders, and a complex of locks and safety switches will be an added maintenance expense.

ADVANTAGES

1. Positive derail protection.
2. Automatic sway compensation at curves.

DISADVANTAGES

1. Suspended configuration requires elevated structure throughout.
2. Requires greatest vertical clearance dimensions and is most costly in tunnel.
3. Sway control under wind conditions not positively solved.
4. Emergency exit from cars is difficult.
5. Switching is cumbersome.
6. Maintenance shops and storage areas are costly.
7. Collision with overheight ground vehicles is possible.
8. Enclosed split-rail beamway creates increased difficulties for maintenance and inspection.

ADHERENCE TO CRITERIA

The principal point of non-conformance to criteria is excessive pneumatic tire loading. This overloading is brought about by use of a relatively heavy car, which is required to produce stability under wind loads.

End doors are not provided for emergency passage between cars.

The existing test installation has produced excessive noise, with the beamway acting as a sounding board resulting in a rumbling sound.

Sway control does not appear to be solved as yet, resulting in hazardous conditions at station appraoches.

MODIFICATIONS REQUIRED TO MEET CRITERIA

1. Redesign bogie to provide uplift safety wheels. The uplift wheels would give positive control to excess sway, and make possible a lighter car.
2. Redesign way structure to reduce noise. This can be accomplished through the use of reinforced concrete beamway.
3. End doors for emergency passage should be provided.

STATUS OF DEVELOPMENT

The suspended split-rail system has had a test section operating since March, 1960. This system, developed by SAFEGE, includes one test car and 3,500 feet of overhead beamway. Difficulties have been experienced in sway control and noise factors. Sustained test results are not available. The bogies for this test installation were manufactured by the same firm as the rubber-tired bogies used in the Paris Metro, hence the testing of this component is well advanced.

Indications are that adequate development and testing of this system can be accomplished in a relatively short time.

EQUIPMENT ANALYSIS

In making the comparative evaluation and analysis of the several transit systems, there are several factors which need to be explored in detail. These factors are: 1) air bearing; 2) steel wheels vs. rubber tires; 3) acoustical considerations; 4) switching; and 5) safety. These factors have received special investigation which will be summarized in the paragraphs following.

AIR BEARING

Consideration was given to the potentialities of the "ground effect" or air bearing vehicles for transit service. This newest entry in the transportation field presents the challenging possibility of high speed operation without wheels. The principle of these vehicles involves the support of the vehicles above a track by the use of air jets. Ideonics, Inc., Convair, Curtiss Wright and the Ford Motor Company are among the United States firms presently conducting research on this transportation concept.

A great deal of interest has been expressed in the "Hovercraft" version of this concept from the standpoint of its ability to provide service without the necessity of having grade separation structures. However, it was found that in so doing, serious problems of noise, guidance and power consumption would be created. For the version using tracks, a magnetic propulsion system was proposed which offered interesting possibilities. However, it was decided that the over-all concept is so new and untried that application and operational characteristics cannot be adequately evaluated. While this system offers a great deal of promise for really high speed operation, it will be some time before research has been carried to the point where the over-all economics of the concept can be adequately appraised.

STEEL WHEEL VS. RUBBER TIRES

The desire to reduce noise levels to the lowest practical level provided the first incentive to use pneumatic-tired vehicles on the rapid transit system.

As the studies progressed, it became apparent that the 5% to 6% grades encountered at Cahuenga Pass in the Reseda Corridor presented a traction problem to the steel-wheeled vehicle, and corridor interchange facilities would be less cumbersome if steeper grades could be used.

The theoretical adhesion coefficient required for emergency braking at 4.5 mphps is 0.21 on level track and 0.26 on 5% downgrade. Some safety margin should be available so 0.30 is used as the minimum traction coefficient required for safe uninterrupted operation during all weather conditions. Available data indicates that adhesion coefficients for steel wheels will be in the range of 0.12 to 0.35 and for rubber on concrete in the range from 0.30 to 0.9.

Trouble with wheel slipping has been repeatedly encountered with steel rail systems with grades of 4% and over whenever an unfavorable condition such as wet rails is encountered. It is apparent that if safe operation is to be achieved with steel wheels, acceleration rates (and braking) must be reduced and/or track sanding equipment must be provided. Sanding will increase the adhesion coefficient to approximately 0.25. However, since sanding equipment adds considerable weight to the car, its use should be avoided if possible. Reduced acceleration on grades and reduced speed on down grades will result in slower operations.

The studies have also revealed that reduction in vibration of the car body may be achieved by the use of pneumatic tires. The operators of the Paris Metro and the designers of the Milan equipment state that up to 20% reduction in weight of the car can be made because the structural fatigue considerations associated with vibrations permit higher working stresses. Results on the Authority system may not be as appreciable but should be significant. However, the desire to reduce weight of the transit vehicles to the order of 30,000 pounds empty weight creates a condition where a conventional rail vehicle is subject to overturning by wind. To avoid this condition, either the wheel spread must be increased to a non-standard wide gauge or the weight must be increased. The use of rubber tires with auxiliary steel wheels permits the use of lightweight cars and satisfies the wide gauge-non-overturning requirements while still allowing operation of the vehicle on standard gauge rails under emergency conditions.

Vibration of the structure and of the ground when in subways, has also been considered. Nearly every city which has subways has experienced complaints from nearby residents because of the ground vibration experienced when trains pass. Pneumatic tires also offer a solution to this problem.

An evaluation of load, speed and size factors has confirmed the feasibility of the use of rubber tires for train operations. This idea of trains using rubber tires is not a new one, such trains having been tested on the French and Swiss National Railways for a number of years. The Paris Metro has been operating rubber-tired transit vehicles on a test line for nine years and this experiment has been so successful that it is planned to undertake the conversion of the entire Paris Metro to rubber-tired operation. Rubber-tired vehicles are presently under design in Italy as prototypes of cars to be used for the new Milan subway. In considering the application of tires to the system under consideration here in Los Angeles, it was realized that certain of the operating conditions would be more severe than are encountered in Paris. For this reason, exploratory discussions were conducted with several of the major United States tire manufacturers.

The Firestone Tire & Rubber Company has conducted extensive tests on 11-20 12-ply Nylon casing heavy duty truck tires which could be used for Los Angeles rapid transit vehicles. These tests accounted for most of the conditions of loading and speed variations which would be encountered in Los Angeles transit system operations. These tests included repeated speed cycling having 15 second runs at 80 miles per hour, 20 second stops at 91-second cycle at loads approximately those contemplated for Los Angeles. These tests showed that tire temperature is the controlling factor when operations under high loads and speeds are considered, but that with proper tire design the maximum temperature would not reach the critical range.

The results of the tests are conclusive in demonstrating the feasibility of using rubber tires for lightweight rapid transit equipment under Los Angeles conditions. Either the nylon cord tires or the steel cord tires should be capable of running for at least 100,000 miles before recapping, and the tires could be recapped several times. The operating experience in Paris has been excellent, with the tires only half worn at 140,000 miles and no trouble with flat tires. It should, of course, be borne in mind that the Paris operation is in a subway with a maximum speed of less than 40 miles per hour.

For comparison, the Authority's experience with PCC rubber sandwich steel wheels shows a life of approximately 150,000 miles with returning operations every 50,000 miles. This amounts to a cost of approximately 0.2 cents per mile per wheel for steel wheels. Current rubber tire costs for the Authority buses are approximately 0.14 cents per mile per tire.

ROLLING RESISTANCE The normal rolling resistance for rubber tires is greater than for steel wheels. However, this situation is reversed at curves because of the increased flange resistance of steel wheels during curve passage. The over-all effect of rubber tires, however, is dependent on the average station spacing which determines how much of the power must be expended in achieving high acceleration and how much goes into overcoming rolling resistance. In the instance of commuter or suburban railroads with station spacings in the range of two to five miles, the effect of the increased rolling resistance is appreciable. However, for the recommended system with station spacing averaging only one mile, this difference is not so significant. One further factor difficult to evaluate is the effect of the savings in weight brought about by the use of rubber tires. This would further decrease the power consumption attributed to rubber tires. It is estimated that the use of rubber tires will result in an increase of total power consumption of less than five percent, and it is felt that this is a small price to pay for the advantages gained by the use of rubber tires.

ACOUSTICAL FACTORS

With a system including substantial mileages of overhead construction, the problem of transit system noise becomes acutely important. Even with subway configurations, where noise affects primarily the passenger, noise must still be controlled. To assist with the evaluation of this problem, the firm of Bolt, Beranek & Newman, Consulting Sound Engineers, was retained to study the acoustical factors in rapid transit system operations. Their work consisted of the preparation of a report(1) giving methods for evaluating the effect of the various noise levels on different types of community areas. The important questions to be asked in the study of transit system noise include:

How much noise will be produced by various vehicle configurations and routings?

What can be done to minimize the noise produced in community areas by the system?

How much noise will be produced inside the transit vehicles?

How much noise is permissible inside the transit vehicles?

ACOUSTICAL EVALUATION PROCEDURE. Figures II-10 and II-11 provide a basis for evaluation of perceived noise level at any point in

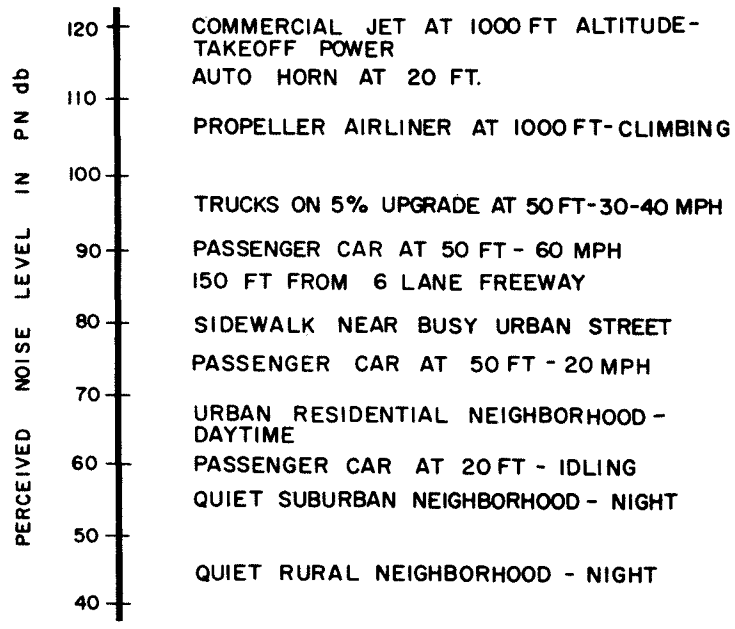


Figure II-10. Figure 1 of BB&N Report

the community. Note that perceived noise level, (PNdb), is a number adjusted for source frequency to indicate sound intensity as judged by the average person. It is not the same as the physical measure of sound in decibels. The reader should note that an increase of 10 PNdb in perceived noise level is essentially a doubling of noise level due to the logarithmic variation of sound intensity.

The use of charts on Page 34 is best explained by an example: consider an urban residential area, with houses set back approximately 100 feet from the street center line. From Graph B-2, Figure II-11, we would expect the continuous background noise to be approximately 65 PNdb at the houses. Assuming that PCC type of street cars run down the middle of the street, Graph B-1 suggests a 76 PNdb noise level for the street cars. Thus, they exceed the continuous background by more than 10 PNdb. For relaxation inside the homes with partially open windows, the design goal of 75 PNdb is noted. Thus, the noise level which is intermittently received from passing street cars is approximately equivalent to the design goal, and the continuous background noise is below the design goal. If a transit system with pneumatic-tired vehicles on an elevated track with no shielding other than shrouded wheels is installed, the noise levels estimated from Part A would be about 77 PNdb for 20 miles per hour speed, and 87 PNdb for 40 miles per hour speed. Thus, at 20 miles per hour, the transit system would produce levels comparable to the existing street cars, while at 40 miles per hour, they would exceed the street car and the design goal by only 10 PNdb.

At 80 miles per hour, however, the noise levels would exceed the design goals by 20 PNdb. It would probably be the noisiest single intrusion in the neighborhood unless trucks appeared on the street. At 80 miles per hour, the noise intrusion into houses would last for 10 to 15 seconds.

The design goal obtained from Part C represents the highest level of intruding noise (outdoors) that will still permit continuous activity of the specified kind without interference. This design goal should not necessarily be interpreted as the maximum allowable noise intrusion. The levels of intermittent noises can be allowed to rise above the design goal without serious consequence in most instances, inasmuch as the activities are not really continuous and interference can be accommodated by momentary interruption, raised voice, repetition, etc. The "decision rules" suggest amounts by which the noise from transit trains may be allowed to exceed the design goals.

CONCLUSIONS OF ACOUSTICAL STUDIES

Study of the many conditions encountered throughout the rapid transit system reveals that there are many areas where noise will be a serious problem. The foregoing example shows one of the problem areas. Shielding techniques are, in general, equally applicable to the steel-tired or pneumatic-tired vehicle. The 6 PNdb difference in noise level represents approximately 60% increase for steel - a difference which offers little hope of solution. The difference in character of the sounds might impose a penalty of another 5 PNdb on the steel-wheeled vehicle in areas where the background noise is entirely from passenger car traffic.

Psychological factors greatly affect community acceptance of the transit system. The noise from pneumatic tires is one that most people are used to in Los Angeles and it would have a tendency to be lost in the general background noise. The opposite would be true of the use of steel-wheeled trains which would introduce sound of an entirely different character into the neighborhood and which would be disrupting.

The data and analysis provide sufficient information for the initial system choice and design. It will be necessary to undertake more detailed noise studies and analyses for the final system. This is especially true in cases of track shielding, shrouding of running gear, track or roadbed surface choice, and structural support of track or roadbed. It is also important in the design of the cars to provide satisfactory noise environments and low vibration levels in the interior. These problems are common to development of any vehicle.

(1) "Considerations of Noise Control For the Proposed Los Angeles Mass Rapid Transit System". Report by Bolt, Beranek and Newman, May 1960.

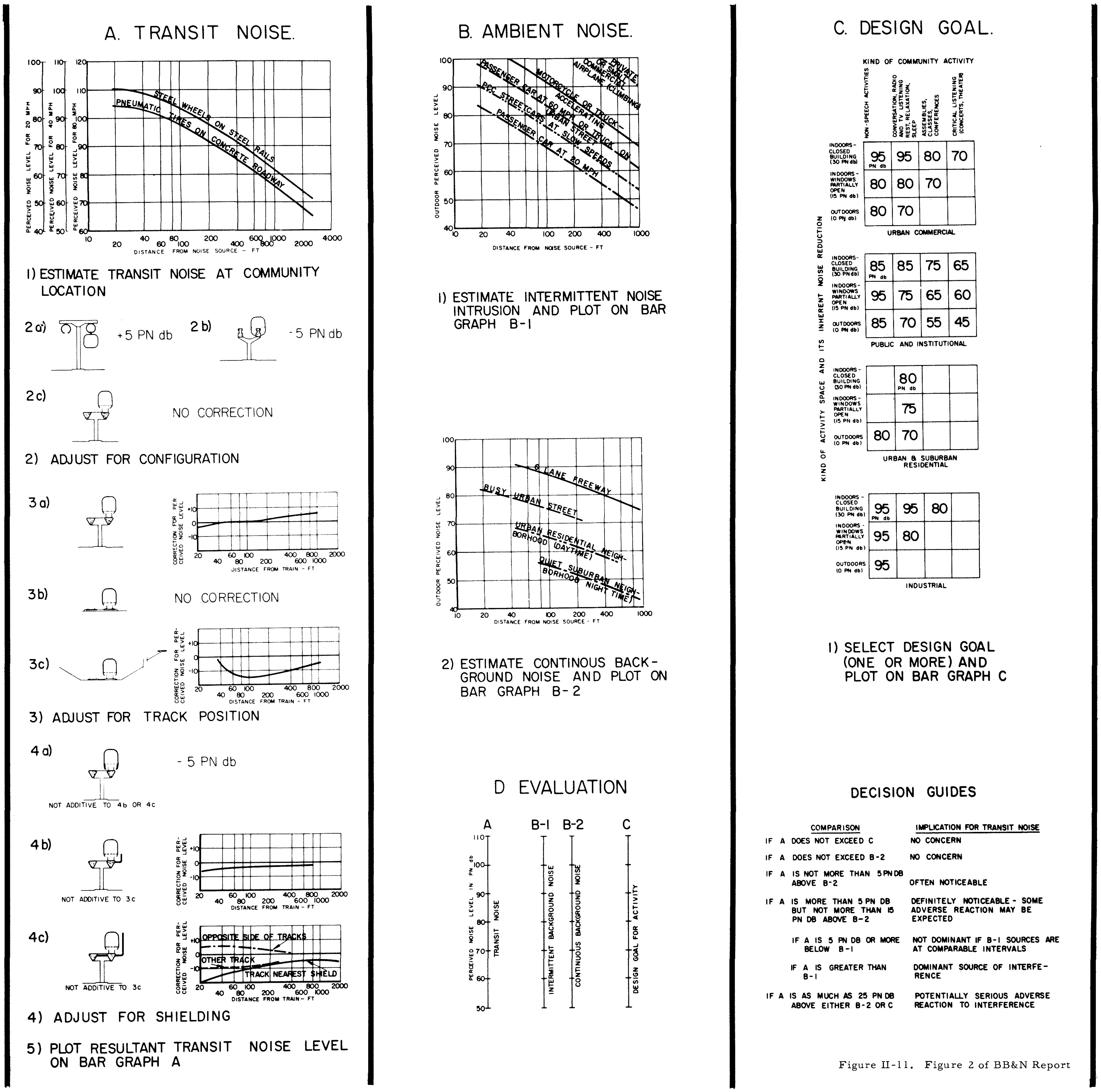


Figure II-11. Figure 2 of BB&N Report

SWITCHING

For rapid transit service, the capacity for economical and rapid switching is extremely important especially in storage yards and maintenance areas. A system requiring long switching cycles for main line switches substantially reduces operational flexibility. The ALWEG System has developed a flexible beam switch for main line service as exemplified by their test installation at Cologne as shown on Figure II-12. This, they claim,

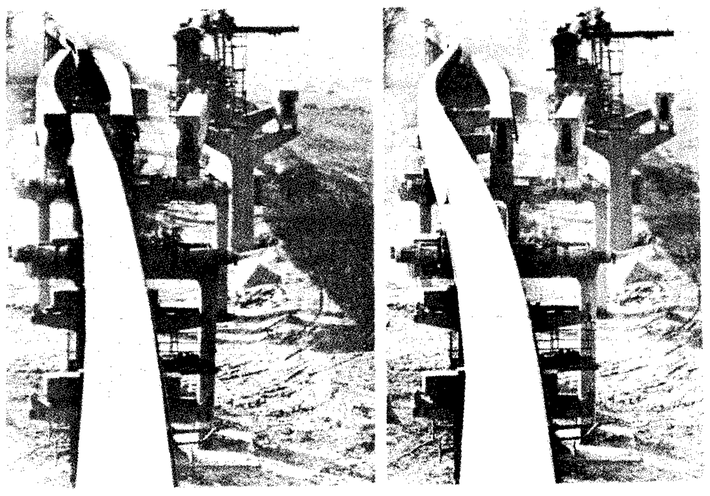


Figure II-12. ALWEG Switch

has an operating cycle of six seconds. A pivoted beam switch similar to the one used for the maintenance track at the Disneyland installation would be satisfactory for yard service, however both of these designs are expensive.

The suspended split rail system uses a transfer table or a three-segment pivoted switch developed by the S.A.F.E.G.E. group in France (see Figure II-13). This

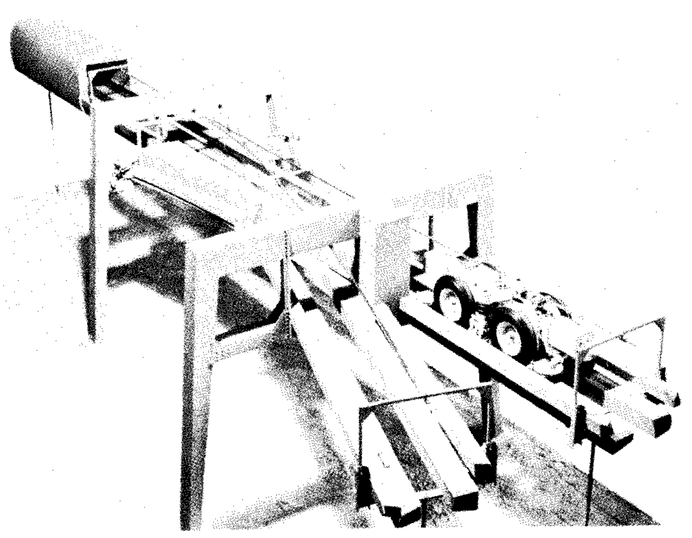


Figure II-13. S. A. F. E. G. E. Switch

switch operates on a six-second cycle but the design is complex and the switch expensive. Switches become particularly important at interchanges between corridors where main line switching must be done on overhead facilities.

Conventional railroad switches are fast and inexpensive, giving a distinct advantage to the modified conventional system in its ability to use conventional rail switches.

SAFETY COMPARISONS

Derailment is usually the first concern when discussing safety of trains. By the basic concept of the saddlebag and split-rail systems, derailment is virtually impossible. The desire to achieve equal assurance of safety in the supported dual track system leads to the concept of using uplift shoes and a safety rail which is a feasible solution to the derailment problem.

Safe emergency escape from a stalled suspended vehicle on overhead structure is impossible without special provisions. Escape from the saddlebag vehicle is possible, but extremely dangerous via the 26" wide track. Escape from the supported dual track vehicle is also possible, but dangerous due to track obstructions, the electrical contact rail, and the height of structure. It is likely that an unmovable vehicle failure would be so infrequent that the provision of escape equipment would not be warranted. Rather, dependence upon emergency trucks or fire department equipment would be in order.

Failure of the secondary suspension of the split-rail system could result in the car striking a station platform or other way structures. The other systems are not subject to this problem.

Striking of a track obstruction is most likely with the supported dual track system because of the large exposed surface. The Saddlebag beam is safer because of its small top surface and the split-rail beam is inherently protected by the enclosed structure.

Redesign of the Suspended Split-rail structure to open the top will result in increased hazard from this source.

All of the switches contemplated depend upon electrical interlocks to assure safe and complete operation. Careful inspection and maintenance should make them all safe.

Collision with overheight ground vehicles is possible with the Split-rail system, less likely with the Saddelbag car and virtually impossible with the Dual Track.

The contact rail presents a moderate safety problem in the yards with all systems. The overhead position of the rail on the Split-rail system affords little protection since access for inspection and maintenance must be provided. From a safety viewpoint, the Saddlebag design seems to have a slight edge. The Dual Track would rate second and the Split-rail third, because of its dependence on a powered mechanical system for sway control. However, all should provide adequate safety.

EVALUATION AND COMPARISON OF SYSTEMS

In making an evaluation and comparison of the three transit systems, both functional and cost factors are used. The systems were analyzed on a comparable basis with the specific application to Los Angeles principally in mind. Table II-1 provides a summary of the comparative analysis of the three systems. In Section V, COST ESTIMATES, further information on comparative costs are presented. The cost analysis shows that for the recommended alignment alternate the modified version of the Supported Dual Track System is the least expensive of the three systems.

When an all overhead system is used, the Supported Mono-Beam system presents a more competitive cost picture although its increased maintenance cost still makes it more expensive than the Dual Track System on a capitalized cost basis. The functional analysis of the systems shows that any one of the three could be adapted to the transit needs of the Los Angeles Metropolitan Area. The status of development of the Supported Dual Track System is better than the other two and, therefore, it could probably be put into operation quicker. The Supported Dual Track System is more easily adaptable to different way structure configurations. The Supported Mono-Beam System provides the least structure for overhead configuration which would enable a slightly more aesthetically pleasing structure. However, with all things considered, the Supported Dual Track System is recommended as the least expensive system and the system best adaptable to the needs of the Los Angeles Metropolitan Area.

TABLE II-1 COMPARATIVE ANALYSIS OF THREE CONFIGURATIONS

COMPARISON PARAMETERS	SUPPORTED DUAL TRACK*	
	PRESENT STATUS	MODIFIED (METRO)
1. First Cost of Way Structure	Not pertinent to evaluation	$155, 900, 000 (75 miles)
2. First Cost of Equipment	Not pertinent to evaluation	$75, 900, 000
3. Annual Maintenance Cost of Equipment and Structures (10th year level)	Not pertinent to evaluation	$2, 360, 000
4. Status of Development and Use	Fully developed and in general use in Chicago, New York, Philadelphia, Boston, etc.	Similar system tested for nine years in Paris Metro. Considered well developed and tested except for modifications.
5. Equipment Mechanisms	Fully developed, but do not adhere to recommended criteria.	Standard components available for motors, drives, rubber tires, brakes, etc.
6. Switching	Proven conventional railroad switches. Quick acting, dependable, safe, low cost.	Proven conventional railroad switches. Quick acting, dependable, safe, low cost.
7. Aesthetics of Line and Station Structures	Generally considered unacceptable in present form for overhead structure. Good for at-grade or underground.	Minimum structure of precast reinforced concrete for overhead structures, excellent for at-grade or underground construction.
8. Requirements for Storage and Maintenance Facilities	Minimum requirements for special structure or other facilities. Conventional switching advantageous.	Minimum requirements for special structure or other facilities. Could operate on steel wheels with conventional railroad switches.
9. Adaptability to Grade, Overhead or Underground Operation	More adaptable to at-grade and underground than to overhead.	Fully adaptable to overhead, at-grade or underground.
10. Positive Derail Protection	No positive protection. Debris on track can cause derailment.	Positive derail device recommended. Would not be in effect through switch areas.
11. Safety	Record of operation is excellent.	Added safety devices should improve the already excellent safety status of the conventional system.
12. Noise	Not considered acceptable for recommended alignments.	Estimated to be entirely acceptable in all areas of recommended alignment.
13. Passenger Appeal	Does not have adequate passenger appeal.	Estimated to be entirely acceptable to public.

*Previously termed "Conventional Two-Rail (Modern Design)"

SUPPORTED MONOBEAM (SADDLEBAG)		SUSPENDED MONOBEAM (SPLIT-RAIL)	
PRESENT STATUS	MODIFIED	PRESENT STATUS	MODIFIED
Not pertinent to evaluation	$136, 600, 000 (75 miles)	Not pertinent to evaluation	$240, 500, 000 (75 miles)
Not pertinent to evaluation	$85, 000, 000	Not pertinent to evaluation	$82, 100, 000
Not pertinent to evaluation	$3, 040, 000	Not pertinent to evaluation	$2, 740, 000
Test section results not available. Needs redesign.	Recommended modifications not yet in plan phase. Development and testing may take considerable time.	Test section results not available. Redesign is required.	Recommended modifications not yet in plan phase. Development and testing may take considerable time.
Standard components can be used. Present prototype required special equipment components.	Can be made up of standard motors, drives, brakes, rubber tires, etc.	Bogie is adapted from rubber tired Paris Metro bogie. Suspension system is special and requires attention.	Can be made up of standard motors, drives, brakes, rubber tires, etc.
Flexible beam switch developed. Leaves main line track open during operation. Expensive, slow acting, high maintenance.	Flexible beam switch developed. Leaves main line track open during operation. Expensive, slow acting, high maintenance.	Transfer table switch developed. Expensive, slow acting, high maintenance, bulky structure.	Transfer table switch developed. Expensive, slow acting, high maintenance, bulky structure.
Considered most acceptable structure for overhead construction.	Considered most acceptable structure for overhead construction.	Structure would be at higher level than for other overhead systems. Provides advantages at stations.	Modified structure not as pleasing in appearance and would be at higher level than other overhead systems.
Requires special beam way structure throughout. Extra cost for maintenance facilities. Difficult yard operation.	Requires special beam way structure throughout. Extra cost for maintenance facilities. Difficult yard operation.	Requires special structures and fully elevated yard and shop facilities. Expensive switching poses problems.	Requires special structures and fully elevated yard and shop facilities. Expensive switching poses problems.
Satisfactory adaptation to at-grade and underground. Best adapted to overhead.	Satisfactory adaptation to at-grade and underground. Best adapted to overhead.	Not advantageous to operate at-grade or underground where costs are comparatively higher. Designed for overhead.	Not advantageous to operate at-grade or underground where costs are comparatively higher. Designed for overhead.
Configuration of Saddlebag precludes derailment.	Configuration of Saddlebag precludes derailment.	Configuration of Suspended Split-rail precludes derailment.	Configuration of Suspended Split-rail precludes derailment.
Overloaded rubber tires reduce safety factor. Emergency exit poses problem.	Emergency exit poses problem, but otherwise safety aspects appear excellent.	Overloaded rubber tires reduce safety factor. Potential of collision with overheight surface traffic is problem.	Potential of collision with overheight surface traffic and emergency exit remain as safety problems.
Acceptable in all areas of recommended alignments.	Acceptable in all areas of recommended alignments.	Not considered acceptable as developed in test section.	Modifications should reduce noise to acceptable levels.
Indicated to have excellent public appeal.	Indicated to have excellent public appeal.	Undetermined public appeal--term monorail is attraction.	Undetermined public appeal--term monorail is attractive.

CREATIVE ENGINEERING

After arriving at the recommended Supported Dual Track System, as the one best adaptable to the local needs, the next step is to apply the creative engineering process and to develop equipment and structure designs. This process has resulted in the equipment and structure shown in Section I. This adaptation of the Supported Dual Track System has been called the "Metro" system to signify its advanced concept of a lightweight high speed vehicle of ultramodern design.

Such equipment with optimizing and final design could be used as the basis for competitive bidding by transit equipment and aircraft manufacturers. Design details of the system are shown on Figure II-14 and the overall concept is shown on the Frontispiece and on Page 8 of Section I.

SUMMARY DESCRIPTION OF "METRO" SYSTEM

The vehicle is conceived as having a conventional body of modern, functional, comfortable design. It will be supported on two rubber-tired bogies having horizontal guide wheels riding on a center guide rails. The adjoining figure will serve to illustrate this concept.

A steel safety rail permits continued operation at reduced speed to the end of the line in case of a flat tire.

The addition of an anti-derail uplift channel along the central way structure will provide a positive derailment feature.

Power is received from an outside electrical contact rail and the current return is through the anti-derail uplift channel. Guide rails are used for negative return current.

Safety items of concern here are those features associated with the method of supporting the vehicle. The inherent ability of the vehicle to resist derailment (wheels leaving the normal running surface) must be provided. Derailment on conventional systems can result from switch failure, excess speed, obstacles on the track and/or track failure. The last two can be overcome only by adequate maintenance. However, because of the grade separation contemplated little problem with track debris should occur.

The signal or automation systems will effectively prevent excess speeds on curves but the addition of an anti-derail device serves to provide added insurance. The use of conventional rail switches in yards and shops is contemplated. They can also be used for main line service. Development of a flexible beam center rail switch appears feasible and would permit continuity of the anti-derail angle. Mechanical failures of conventional switches occur rarely. To date, the only preventive measures available are a high level of maintenance and automatic speed limiting devices. A rubber-tired, supported vehicle depending on conventional switches and steel wheels will be subject to these failures. Interlocks will, of course, be provided to insure against a partially operated switch.

In the event of prolonged train stoppage which would leave passengers stranded in the cars, it would be necessary to evacuate the cars. With the Metro system, it would be possible to leave through the end door and walk the track to the nearest station.

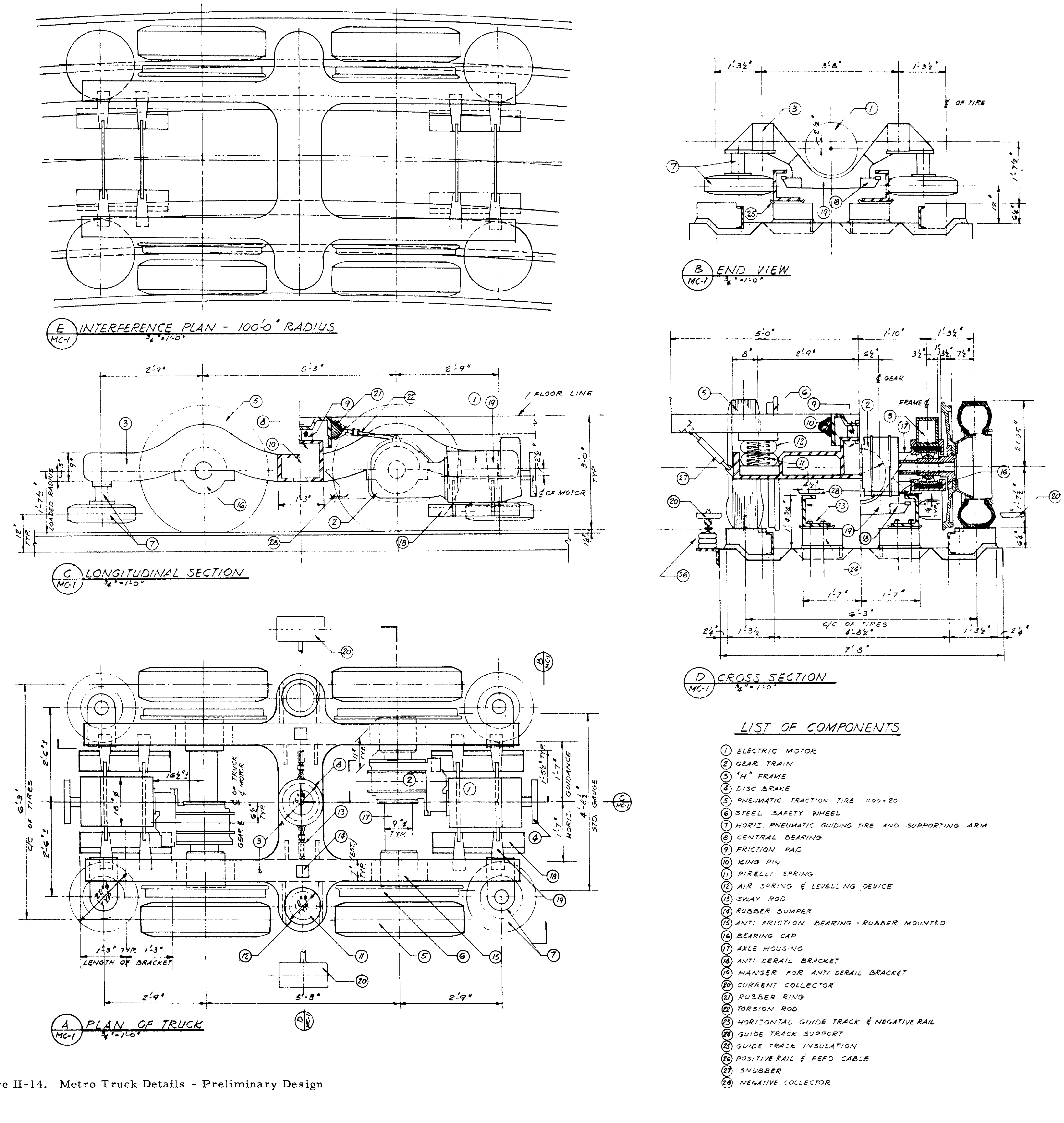


Figure II-14. Metro Truck Details - Preliminary Design

EQUIPMENT COMPONENTS

POWER AND PROPULSION

In complying with the high-speed, frequent-stop performance required of the system, a rapid transit six-car train weighing approximately 172 tons with full passenger load requires 5230 Kw (7000 horsepower) of power for a short time (about 6 seconds) during acceleration at a rate of 3.5 miles per hour per second until the speed is about 40 miles per hour. After this, the train's speed continues to increase, but at a lesser rate of acceleration and power consumption until a speed of 75 to 80 miles per hour is reached, depending on the length of run, when the speed must be decreased and the train brought to a stop at the next station. A smaller power demand in addition to traction power exists continuously because of electric lights, air compressors, etc., on the train. Longer trains would have proportionally larger power requirements. It is estimated that on a heavy traffic line, when trains follow one another on a 90-second headway, the total power required would average more than 3,000 Kw per double-track mile.

Both prime movers (self-contained power generators) and power-collecting electrical systems were considered for the Los Angeles Metropolitan Transit Authority's rapid transit system.

NUCLEAR AND CONVENTIONAL POWER PLANTS Experience in other cities has shown the load factor of a transit system to be low compared to that of a large public utility power system serving many customers. Therefore, a central power plant, whether nuclear or conventional, which supplies power to only a transit system would be uneconomical.

The use of a nuclear power package for propelling an individual car or train is out of the question from the safety standpoint. In the event of collision between trains, contamination of perhaps the entire city could occur. Further, the United States Atomic Energy Commission will not permit civilian use of a mobile nuclear unit.

INTERNAL COMBUSTION ENGINES The use of diesel and gasoline reciprocating engines to power rapid transit trains with high accelerating rates is impractical because of the size of the engine necessary to furnish sufficient power for frequent high acceleration to high speeds.

Gas turbines using kerosene as fuel have been developed with sufficient horsepower and small size to furnish the requisite power, one turbine to a two-car unit. The high temperature, heat losses, fumes, smog, noise and a danger of fire from fuel tanks make all internal combustion engines impractical for multiple-unit passenger service, especially if long subways are to be traversed.

ELECTRIC MOTORS Direct current traction motors are very well suited to rapid transit service with high acceleration rates. This type of motor is well developed and successful. If alternating current is used, the a-c traction motors for direct application have not been developed except for low frequency (25 cycles per second or less), which is unsuitable and uneconomical for rapid transit, or for wound-rotor 3-phase motors which are bulky, more costly and require 3-phase conductors.

An a-c electro-magnetic propulsion system has been suggested which does not utilize rotating motor armatures but visualizes a 3-phase squirrel cage motor laid out longitudinally and flat with the wound armature on the car arranged to move, with the car, alongside the stationary squirrel-cage winding in the form of a rigid slotted aluminum plate fixed to the track in a vertical plane. With a 3-phase a-c 60-cycle excitation on the armature, a strong tractive effort is created and the car accelerates to a balancing speed corresponding to the synchronous speed minus the slip caused by the air gap which is large compared to a round squirrel-cage motor.

While the round squirrel-cage motor is unsuitable for the frequent accelerations of rapid transit service, the flat squirrel motor is suitable because the heat of the stator ("squirrel-cage") during acceleration is readily dissipated as the train moves along the track. However, such a system would be very expensive.

Another single-phase a-c system, using high voltage (11,000) current collection at 60 cycles, with this voltage stepped down and rectified to d-c on the cars, has been successfully tested on conventional railroads. But it would not be applicable to systems where limited space precludes the high-voltage current collection. Other serious disadvantages are the high cost, space requirements and the weight of control equipment (including transformer and rectifier) on each car. This a-c system, therefore, was rejected.

LOW VOLTAGE (600-VOLT) D-C SYSTEM The 600-volt d-c system has been highly developed and is in successful operation in thousands of miles of rapid transit and surface lines. It is well suited to the high accelerations of rapid transit service. Also, it is adaptable to dynamic braking which saves wear and tear of the wheels and trucks.

One objection to it is the frequent spacing of the substations required for power distribution, but this feature has a redeeming characteristic because it increases the reliability of the power supply. Adjacent substations share the load between them and one can be out of service for a time without seriously affecting the operation of trains. Dynamic braking of trains is an important advantage of the 600-volt d-c system, and higher d-c voltage systems do not generally possess it because of design difficulties. The low-voltage contact rail would occupy much less space than overhead contact wires of a high-voltage system.

The 600-volt d-c power collection system is therefore recommended for the new rapid transit system and its future extensions in the Metropolitan Area.

SCHEDULE SPEEDS AND TRACTION MOTOR SELECTION The design scheduled speeds of the rapid transit trains were determined from the speeds set up as desirable for riders who would have the choice of driving their private automobiles or riding the rapid transit system. These desirable speeds then were modified where necessary to meet the practical considerations of safe and comfortable acceleration and braking rates together with the service requirements of frequent station stops for the pick up and discharge of passengers at intervals of 0.38 to 2.1 miles (average 1.1 miles on the 74.9-mile system). The minimum goal of 35 miles per hour average speed between outlying neighborhoods and the Central City Area was then set.

In order to obtain this speed from the train equipment, described elsewhere in this section of the Report, the horsepower of the traction motors was selected to perform under various loading conditions with the following characteristics:

- Maximum acceleration rate:	3.5 miles per hour per second
- Normal braking rate:	3.5 miles per hour per second

- Average length of stop: 20 seconds
- Time margin over highest speed capability: 3% (ability to make up time)

Figure II-15 shows the calculated typical speed-time and distance time curves for performance on the average run on level straight track resulting in 38.8 miles per hour average speed from start to start.

This average run is not a sufficient basis, however, for determining the motor rating from the heating incurred which is the true measure of motor capability and endurance.

From inspection of routes, it was evident that the rush-hour trip of a loaded train from the Central City Area to the vicinity of North Hollywood, including severe up-grades, would be a safe indication of the maximum motor endurance required. The heating calculations were made for motors in this service, operating up to their momentary capability during the high accelerations required and running without coasting, a condition which would be possible when the train is late and is making up time. This trip was calculated using motor speed and tractive effort characteristics, and gear ratio selected for the acceleration, speeds and other criteria as required.

The root-mean-square current (effective heating current) per motor for this trip, was found to be 333 amperes which corresponds closely to 125-horse-power (nominal one-hour rating) 300-volt (two motors in series on 600 volts). The maximum current during acceleration was found to be within the commutating limit for a motor of this horsepower.

The motor control equipment would be specified to include constant automatic 3.5 miles per hour per second acceleration, as desired, for all conditions of loading and grades, except that on very severe grades, the acceleration rate will be limited so that the commutating limit of a 125-horsepower motor will not be exceeded. The study showed that 3.5 miles per hour per second acceleration would be practical for this motor performance, except on grades over 4% when the acceleration rate must be reduced slightly (2.5 miles per hour per second on 5% up-grade) to stay within the motor commutating limit. These various computations result in recommendation that each transit car be equipped with four 125-horsepower d-c traction motors.

BRAKING

Dynamic brakes will be used at all speeds down to 8 to 10 mph. Final braking will be accomplished with a mechanical disc brake. Normal braking will decelerate the car at 3.5 mphps. Emergency braking would use both brakes with deceleration at 4.5 mphps (2,100 feet stopping distance from 80 mph to 525 feet from 40 mph). The disc brakes will be capable of a full emergency stop in case of failure of the dynamic brakes. Disc brakes require only one half of the parts of the more conventional clasp brake and are considerably lighter.

Disc brakes cost less and last many times longer than clasp brake shoes in comparable service. Disc shoe does not have to be reversed for even wear. There are fewer parts to maintain, almost half the usual number of parts are eliminated, with weight saving of approximately 2,000 lbs. per each car.

The disc brake design eliminates lost motion (back-lash) and no slack adjuster is required. Today more than 550 railway passenger cars have been equipped with the disc brake and on one train 2-1/4 million train miles of service have been registered.

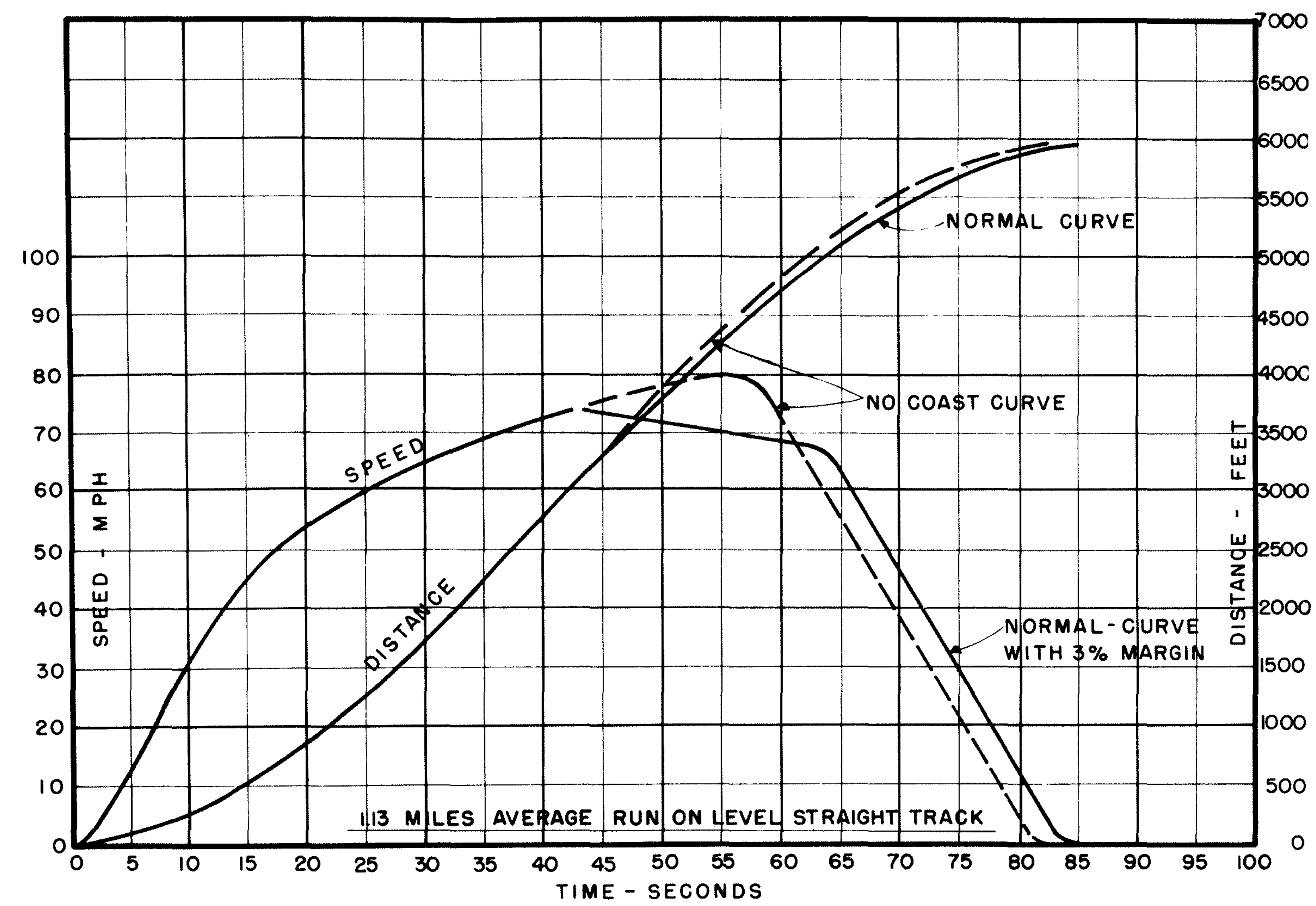


Figure II-15. Typical Speed-Time-Distance Curve

VEHICLE DESIGN

A complete design of the transit vehicles could not, of course, be undertaken at this time. However, certain design features have been established and they will be described in the following paragraphs.

VEHICLE UNITS The use of semi-permanently coupled two-car units may reduce the duplication of auxiliary equipment such as compressors, generators, batteries, and controls and thereby lower vehicle costs. While the savings in first cost are highly desirable, a penalty in the form of increased operating costs will be paid whenever traffic density would justify single car operation. Since the evaluation of this problem is dependent on train headway and traffic studies yet to be conducted, no recommendation can be made at this time. The cost estimates assume two-car units. The use of both two and three car units may prove to be advantageous. Each car would be 53'-8" long, 10'-0" wide, and 11'-10" high. Each car will seat a minimum of 52 passengers. The concept of the interior layout is shown in Figure II-16.

CAR WEIGHT FACTORS The weight of rapid transit cars has great importance in its effect upon the cost of supporting structures and electric power requirements.

For the Authority, electric power costs will be approximately $275 per ton of vehicle, per year. For the next twenty-five years at 5% interest, this cost has a present worth of $3,875.00 per car ton. Thus, it becomes apparent that a lighter car is worth more in long-range investment; provided that quality is not sacrificed.

It should be noted that vehicle development costs would not be incurred on future equipment additions. Structural savings would be made on future extensions to the overhead system.

It seems reasonable to assume that approximately half of the apparent savings could thus be paid out in the premium cost for lightweight vehicles; i.e., the Authority would be better served to pay $180,000 for a 30,000 pound car than to pay $150,000 for a 45,000-pound car. On the recommended 456-car purchase, the builder would thus have a $13,680,000 incentive to reduce weight.

On a recent purchase of new transit cars for the City of Philadelphia, a bonus of $3,000 per ton of negative weight (weight under specific maximum) was offered.

A rough estimate indicates that savings in costs on overhead structures made possible by lighter weight cars might approach 1% per ton of vehicle weight. This would amount to approximately $23,000 per mile in initial cost, or $1,700,000 per ton on an all-overhead 74-mile system. This savings amounts to $3,700 per car per ton for the estimated 456 cars that are required for the system. Combining the present worth of future power costs and initial structural savings results in a total savings of $7,575 per car per ton. The current standard for lightweight cars of the size proposed here is approximately 45,000 pounds. By the use of selected aircraft techniques and rubber-tired bogies, a 30,000 pound vehicle seems feasible. Recalling that $7,575 per car per ton can be saved, it is apparent that as much as $56,800 premium per car could be paid for this "negative weight" to obtain a 30,000 pound vehicle.

STABILITY UNDER WIND LOADS Design loads for horizontal wind forces have been selected to permit operation under the most critical conditions to be anticipated in the Los Angeles Basin. Winds up to 80 miles per hour may be expected. For this condition, the wind pressure is estimated to be 20 lbs per square foot on the vertical projected car surface and 10 lbs. per square foot uplift on the horizontal projected surface.

When detail design is undertaken, the effect of aerodynamic configuration of the car body must be considered. The design may permit some reduction in the loads indicated.

DOORS Fast loading of passengers is essential in a rapid transit operation. To achieve the required speed, three four-foot doors on each side of the cars are desirable. Folding doors are preferred for this fast action and sliding doors will also render satisfactory service. The use of a soft rubber non-sensitized leading edge is preferred. In operation, a buzzer will sound approximately two seconds before the doors close. The doors will close with a force of approximately twenty pounds. A person caught in the doorway will be able to forcibly push the door back open and step clear but the doors would not automatically spring back. The doors will, of course, be interlocked with the train controller so as to prohibit operation until all doors are closed.

The use of sensitized leading edges on the doors is undesirable because it becomes too easy for passengers to hold up the entire train.

End doors are considered desirable to permit evacuation of the train in case of emergency. The passage of passengers between two car units would be allowed but would be prohibited between train units. The small advantage of passenger movement between cars does not warrant the cost and labor required to provide additional safety devices for through passenger movements. Experience with other transit operations has shown little desire for passenger movement between cars.

WINDOWS AND AIR CONDITIONING Maximum use of fixed window glass providing good visibility for both seated and standing passengers is desirable.

Heat resisting glass will be used where necessary to minimize solar heat load on the passengers. The use of a refrigerated air conditioning and heat unit is desirable. A high capacity heating and forced air ventilating unit is the minimum requirement.

PNEUMATIC TIRES The pneumatic tires should be 11 x 20 - 12 ply tires. The tires will be a mixture of natural rubber and synthetic compound, and being subject to full-time sunlight and high ozone for long periods of time, a neoprene skin should be applied to the tires to prevent deterioration of rubber.

The tires can either be tubeless or with tube. The tubeless tires will operate at higher temperatures than tube tires, and for this reason, the tube tires are preferred. A black carbon mixture shall be added to the tire compound for draining the static electric discharge. This addition of carbon black does not affect the tire life in any way.

It is recommended that no inert gas such as nitrogen be used for tire inflation, but rather regular air inflation should be used.

The small amount of water which may be introduced with air is actually beneficial. It has been determined by the various rubber tire manufacturers and manufacturing companies that up to a quart of water per large tire will affect a cooler running tire. Since heat destroys rubber and reduces the tire life, some small amounts of water are beneficial to the tire life. The water in tires distributed heat more uniformly.

Steel cord tires of equal dimensions will operate at lower temperatures than the nylon cord tire under identical circumstances.

The steel cord tire has much higher "cornering power", a higher resistance to deviation from the tangent and both types are equal in load carrying capacity.

The next phase of the Metro vehicle development should include further laboratory and field research of tires.

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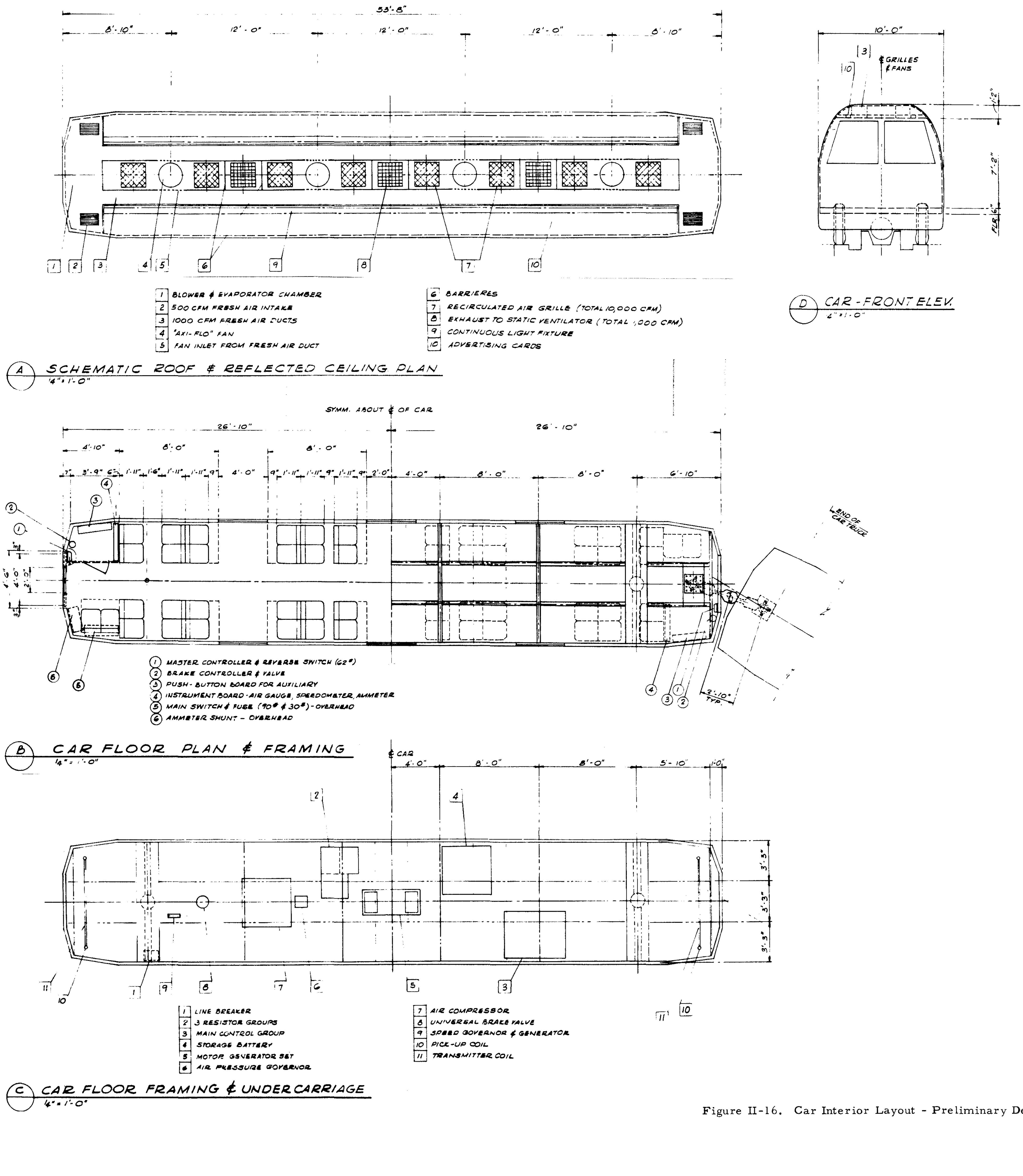


Figure II-16. Car Interior Layout - Preliminary Design

POWER SUPPLY AND DISTRIBUTION

The problem of obtaining power economically in a large urban area can be solved by purchasing electric power from one or more of the local power utilities which have, or have planned, ample capacity for the territory served without building special generating stations to supply the new load. The cost of the purchased 3-phase A-C 60-cycle power for the initial 74.9-mile system would be approximately 1¢ per kilowatt hour when delivered to the Authority at six widely distributed locations and then transmitted over the Authority's cables to the traction substations.

VOLTAGES

The decisions on number of traction substations and their spacing, the size of the current collection wires or rails, depend on the voltage selected for the current collection systems - the higher the voltage, the fewer the substations that are needed.

The total cost of the substations can, therefore, theoretically be reduced by making the current collection voltage as high as possible There are certain technical considerations, however, which limit the current collection voltage.

Higher voltages require greater clearances because the insulators are larger and the arcing distances are greater. Most urban rapid transit systems, where overhead clearances would be costly because of long tunnels and frequent overhead street crossings which are required, now use 600-volt D-C contact rails at the side of the track and in tunnels with small clearances in congested areas. The 600-volt D-C substations are approximately two miles apart.

The rapid transit lines now being considered for the Los Angeles Metropolitan Area will also have close clearances for their contact systems, and, therefore, must use a fairly low voltage current collection system.

A-C VS. D-C SYSTEMS FOR TRACTION POWER

The question of whether to use a -c (alternating current) or d -c (direct current) was carefully considered from economic and technical standpoints.

The power purchased from the local power utilities will be a -c 3-phase at a frequency of 60 cycles per second and at a voltage of 34,500 volts or 16,500 volts which can be transmitted economically over the distances involved. This purchased 3-phase power will be transformed or converted in the traction substations to the voltage selected for current collection. It would simplify the substations if this 60-cycle a -c power could be merely stepped down by transformers for use by the trains. However, this is not possible except through the use of heavy and expensive torque converters which are not considered feasible. Direct current voltage has an advantage over the a -c voltage for use on rapid transit trains.

The 600-volt d -c power will be conducted to the trains through steel contact rails reinforced by bare copper cables clamped along the rails and tapped into them at frequent intervals.

The contact rails will be supported and insulated from the track structure by insulators spaced approximately every 8 feet. The cars in the trains will each be equipped with hinged collector shoes on each side of each truck. The current will return to the substations through the anti-derail channels.

TRACTION SUBSTATIONS

The 600-volt d -c power in the current collection system will be obtained from traction substations spaced approximately two miles apart. The substations will convert the high-voltage a -c power to 600-volt d -c by means of rectifiers. Each substation will require an enclosed space of approximately 1600 square feet.

HIGH-VOLTAGE POWER DISTRIBUTION

The traction substations will be supplied with power through a high voltage power distribution system. It was found to be economical to purchase the high-voltage power at six widely distributed points, one on each corridor, then distribute it through high-voltage cables to the traction substations.

The following economic comparison is based on power consumption of 17,500,000 Kwhr per month which is estimated for the initial system after two to five years of operation:

- Cost of purchased power with separate billing at each traction substation (based on utility company estimate):	$3,720,000 per year (1.6¢ per Kwhr)
- Cost of purchased power at only six points of supply (based on utility company estimate):	$2,320,000 per year (1.0¢ per Kwhr)
- Savings in annual cost	$1,400,000 per year
- Cost of the Authority's high voltage distribution system for six purchased power points to traction substations:	$11,900,000
- Fixed charges 10% of this cost per year plus maintenance:	$1,235,000 per year

Therefore, it is evident that the cost of the Authority's high voltage distribution system will be justified by the savings in power cost.

TRAIN CONTROL AND COMMUNICATION

The high peak speeds which the rapid transit train must attain in order to achieve the goal of high average speed with frequent stops will require precise control backed up by extremely reliable safety features. The following systems of train control were studied to determine whether they will satisfy these requirements.

1. Wayside Signals

   Manual control by a motorman-operator on each train observing illuminated wayside signals located at the beginning of each track block, to inform him of the track occupancy ahead. The back-up safety features consist of mechanical devices at the side of the track which stop the train if it fails to observe a stop signal.

2. Cab Signals

   Manual control similar to "One" above, but with the illuminated signals located in each operating cab, instead of along the track. The track blocks are usually made shorter, and the back-up safety device is built into the car control equipments and includes compulsory slowdown as well as stop functions.

3. Automatic Control

   Automatic programmed train control and operation with fail-safe features to prevent collisions and excessive speeds in case of failure of programmed control circuits. No comparable system is in existence.

Each of these three systems would be supplemented by human supervisors and voice communication between them and with the chief train dispatcher. Due to recent advances in communications methods, voice communication channels can be maintained between supervisors and moving trains for the information of motormen on the trains or to make announcements to the passengers when necessary. These systems will be further discussed in the following paragraphs.

WAYSIDE SIGNALS

Most of the existing rapid transit systems in large cities, including New York, Chicago, London, etc., are operated manually with the motorman observing the wayside signals to enable him to operate at high speeds with adequate signals to slow down, stop or proceed, depending on where the train ahead is located, and without knowing the speed of the leading train but assuming it is stopped.

A frequently applied fail-safe feature of this signal system is the use of mechanical trippers which raise into the trip position when the red (stop) signal is shown and which, if a train fails to observe the stop signal, will trip an emergency track valve under the passing train which applies the emergency brake to stop the train as quickly as possible and thus prevent the train from entering the occupied block.

The normal safe operation of the train depends on the motorman obtaining information from the wayside signals which are spaced for normal braking distances, including the human reaction time, plus a margin of safety. The trains must be operated far enough apart for the following train to get a green (full speed) signal when the preceding train is also in a green block. The maximum train frequency, therefore, cannot usually exceed about 30 trains per hour, while the Los Angeles ultimate requirement has been set at 40 trains per hour, or 90 seconds headway.

CAB SIGNAL AND SPEED CONTROL

In the Stockholm, Sweden subways, and on several main line railroads in the U.S.A., the cab signal system is used in place of the wayside signals. Illuminated signals in the motorman's cab indicate safe speeds so that he does not have to wait for a signal until the train reaches the next track block. Use of the cab signal system makes the use of short blocks economically feasible. The signals can include two or more variations in allowable train speeds as well as the stop, clear, and caution signals possible with the longer-block wayside signals.

Because of the additional signals calling for speed variations and also because of the shorter blocks for these additional signals, the trains can operate closer together with the same safety as with wayside signals.

Both systems have, or can have, the fail-safe features of stopping or slowing down the train automatically and in a safe distance, in case the signal is not obeyed by the motorman or in case of power failure on the signal system.

This cab signal and speed control system permits operations approaching 90-second headway of trains safely with speeds up to 70 or 80 miles per hour, while the wayside signal system with automatic emergency stops permits operation at approximately 120 seconds headway. Both systems have designed-in delays to allow for the human factor requiring an elapsed interval for the motorman to become cognizant of a change in signal and then for him to act on it.

In order to shorten delays at route junctions, where the signals are usually controlled by switchmen or towermen who route the trains in accordance with pre-arranged time tables or by dispatcher's orders, an automatic programmer and controller has been designed. Such a device is in successful use on the London Transport system at each important junction. It automatically throws the switches and changes the signals in accordance with train identifications remotely obtained from the distant check points on the tracks leading to the junction. This programmer would improve the schedule speeds through junctions on either the wayside-signal or cab-signal system.

AUTOMATION

The signal systems described above depend on prompt response by human operators on the trains, or delays will result. Automatic operation would eliminate these possibilities for delays.

Since a complete transit system has never been fully automated before, the question of technical feasibility must be resolved. Reliability is the important consideration in any system that involves the transportation of people, especially in an automatic system where all basic decisions and actions are made by an impersonal device rather than human.

A set of system requirements was developed and distributed among some of the leading companies in the control and signal fields, outlining preliminary functional specifications for an automatic control system for the Los Angeles rapid transit system. The approach taken at this time in determining the technical feasibility consisted primarily of a review and survey of proposals submitted by these companies.

In all cases the proposals definitely stated that the automation of the system is not only feasible but that it can be developed with existing knowledge and components. No new "technical breakthrough" will have to be made to perform the task. It is well to repeat here, that the companies who submitted these proposals are the leaders in the fields of electronic controls and railway signalling

The ideal type of automation would provide an "electronic brain" that can adapt to any abnormal situation which might arise, and take the necessary corrective action to relieve the abnormality, just as a human operator could. For normal operation, the automatic system would control all trains according to a master schedule.

In addition to maintaining a schedule, use of an automatic control system will result in a more economical and safer operation.

The economy is realized by having the speed control operated automatically according to a predetermined optimum speed-time program. The precise control of an electronic system can result in sizeable power savings. With the high speeds and close headways that the ultimate schedule calls for, automatic control appears to be mandatory if the schedule requirements are to be met with complete safety.

Increased safety is realized because of the multiplicity of safety circuits utilized in an automatic operation. The system has the normal safety equipment (described under Cab Signals) which operates when one train is too close behind another, or when there is a signal failure. In addition, the central computing equipment can sense an unsafe condition and also send out a corrective command. Wayside equipment is provided for positive speed control at curves, switches, and other places where hazardous conditions could occur.

In all cases, the automatic system can be provided with a manual override, so that an on-board attendant can take over control of the train in emergencies. However, the wayside speed control provisions cannot be overridden.

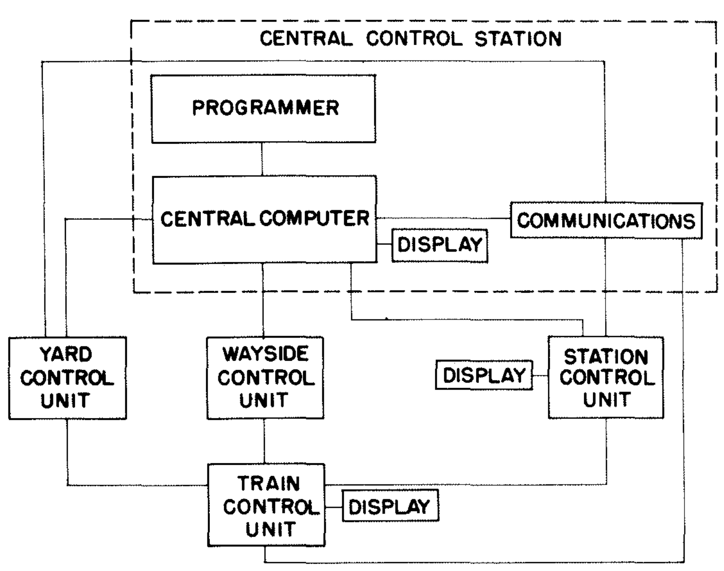


Figure II-17. Automatic Control Block Diagram

The block diagram of the automatic train operation system is shown on Figure II-17. The components of the system are described as follows:

PROGRAMMER

The Programmer is the unit which stores train schedules and feeds the schedule information to a computer. It is a magnetic tape or drum recorder and various schedules can be installed in the recorder conveniently and interchanged if conditions on the transit system require a new schedule.

It is also possible to make minor changes in a pre-programmed schedule while it is in use, without disrupting service. The Programmer would be located in the Central Control Station.

CENTRAL COMPUTER

The Central Computer is the so-called "electronic brain" of the system. It is a high-speed digital unit specifically designed for this purpose. The computer receives data inputs from the various control units located along the wayside, in stations, and in yards. These data signals reflect train status regarding speed, location and loading. The computer compares these signals with those from the Programmer, which indicates the desired status and detects impending hazardous conditions. If the actual status of the train is not the same as the desired status, the computer will send out correction commands to the train via the various control units, to bring the train back into the schedule. The computer would be located in the Central Control Station.

YARD CONTROL UNIT

The Yard Control Unit controls the train when it is entering or leaving any of the five yards. The control of the train by this unit is only in effect when the train is on the entrance or exit tracks of the yards. At all other times when the train is in the yard, it will be controlled manually. The Yard Control Unit will automatically send trains onto the main track from the exit track upon command from the central computer. There would be a Yard Control Unit located at each of the five yards.

WAYSIDE CONTROL UNIT

The Wayside Control Unit is the equipment that controls the speed of a train when the train is between stations or between a station and a terminal. This unit receives instructions from the central computer by electrical signals carried in wires and transmits these commands to the train by electrical signals using inductive coupling. The Wayside Control Unit has fixed maximum speed limits for its own sector, in line with safety requirements, so that these safety limitations can override any computer commands in case of malfunction or excessive schedule requirements. Included in the Wayside Control Unit circuits are fail-safe provisions so that lack of a signal will bring the train to a stop. These units would be spaced along the tracks as required by the particular section of the track.

STATION CONTROL UNIT

The Station Control Unit controls the speed and stopping position of a train as it enters a station. The unit receives information from the train by an inductive loop that indicates train identification, destination, loading, number of cars and speed. With this information, the Station Control Unit will stop the train in the desired locations in the station and announce the destination and stopping position of the incoming train to the waiting passengers. The Station Control Unit will automatically open the train doors and station gates for a pre-determined time, close them again, and upon completion of this function, it will send a start command to the train.

Interlocking circuits are provided to prevent starting of any train if the doors and gates are not in a locked position. One of these units would be required for each track at each station.

TRAIN CONTROL UNIT

The Train Control Unit receives commands from the various control units and actuates the proper elements of the train's motor control system to achieve the desired effect. The unit also transmits, to the various receiving units, the train's identifications, destination, number of cars, loading, and speed. The Train Control Unit is mounted on the train and only one of these units would be required for each train although difficulty of removal may force a unit for each minimum train unit.

DISPLAY

There would be visual and aural displays indicating train status in the Central Control Station, stations, and trains. The display in the Central Control System would consist of a panel showing the position of all trains and switches by the use of colored lights. The display of stations would be a visual and aural indication of the destination and stopping position of incoming trains. The train display would consist of a speed indication in the motorman's cab similar to that of a standard cab control system. There would be loudspeakers in all the cars which would automatically announce the identity of the next station.

Summarized comparisons of Cab Signals vs. Automation:

Item	Cab Signals	Automation
Average Speed	36 mph	38 mph
Minimum Headway	Approach 90 sec.	90 sec. & less
Operational Experience	Excellent	None
Safety	Good	Excellent
Personnel	Operator	Attendant
Public Acceptance	Good	Good
Reliability	Excellent	Excellent
Estimated First Cost	$14,900,000	$20,600,000
Estimated Annual Maintenance	$ 48,000	$ 66,000

COMMUNICATION

A metropolitan rapid transit system, as proposed, with stations, junctions, terminals, storage yards, traction substations, maintenance headquarters, supervisors' offices, etc., must have adequate and reliable communication equipment, with both normal channels and emergency channels.

The train operating staff would have its own channels for the chief dispatcher to communicate with the operating supervisors and with each train in service. The normal channel would be combined with the signal circuits, which can be accomplished without interference with each other. The emergency channels would be the wayside emergency telephone at each passenger station, substation, and other locations as required.

The maintenance crews would have normal telephone service between their various headquarters and also would have radio communication with their supervisors when crews are on their automotive repair vehicles in the field.

The traction substations and high-voltage distribution switching stations would normally be unattended and would be controlled and supervised remotely through a special supervisory control system using a pair of telephone wires for their coded control impulses. When electrical maintainers are in the remote stations, they can use this control channel for telephone communications with the central power supervisor, temporarily interrupting the control channel only at times when the channel is not being used to open and close circuit breakers or transmitting an alarm.

The visual train announcing system at each station and the audio or visual station announcing system on each train in service are important communication functions which would be incorporated in the signal and train control systems.

CONCLUSIONS

The application of automation to a rapid transit system is new. Functional inquiries for automation systems have resulted in a wide range of prices. This wide range of prices occurs because of the diversity of conceptual solutions and the lack of specific development. The technical feasibility of automation remains unquestioned. The economic feasibility can only be decided on the basis of pricing specific designs. There are some indications that automation may prove to be less costly than even a cab signal system. This question must be answered by definitive design.

For the optimum system, the inclusion of an automatic control system is recommended. The minimum system would have the cab signal system with speed control. Adequate communications, as described, should be installed.

Wayside signals with automatic stops do not seem to have sufficient operating capability to meet the transit system's requirements of train frequency and speed.

An automatic control system is included in the system cost estimates.

SECONDARY DISTRIBUTION SYSTEMS

With the development of the concept of secondary distribution of passengers within the Central Business District, it became necessary to give initial consideration to equipment systems which could perform this important function. Because of the limitations of time, it was not possible to perform the detailed analysis as was done on the main line systems. However, sufficient work was done to investigate the feasibility and to determine the approximate cost.

The first step in this process consisted of the development of preliminary criteria which is given as follows:

1. Capacity 7,000 to 10,000 passengers per hour in one direction.
2. Average speed 15 miles per hour with reasonable accelerations and decelerations.
3. Grade separated system requiring a minimum of structure.
4. Small cars of attractive design completely automated and as quiet as possible.

As may be seen, these criteria are considerably different from those given for the main line rapid transit system and thus a different type of system is indicated.

TYPES OF SYSTEMS

Since an exhaustive search for secondary distribution systems was not possible at this time, it was decided to concentrate initial consideration on several systems for which at least some engineering had been done. Two such systems are the Stephens-Adamson Carveyor and the Lockheed-Fussell system.

CARVEYOR SYSTEM This system is based on a continuous belt which carries a series of small cars (see Figure II-18). Turns are negotiated on motorized tapered rollers. The belt transfers the cars to the rollers and another belt receives the car on the exit end of the roller track. All belt and curved taper roller tracks operate at synchronized speed which prevents collisions and automatically provides a uniform car spacing along the track. At the stations, the platforms are provided with moving sidewalks, moving at 1-1/2 miles per hour in the direction of the main line for the length of the platform. The main line traction belt is terminated at a given distance before entering the station area, and the cars are transferred to a series of decelerating power driven rollers. These rollers are driven by an electric motor at constant speed, but the roller diameter is reduced progressively, thereby reducing the car speed from 15 miles per hour to 1-1/2 miles per hour through the stations. Since the moving walk is traveling at the same speed, passenger entry to and exit from cars is made at zero relative speed.

The main line car spacing is such as to allow ample time for preceding cars to decelerate, discharge and load passengers before coming to the end of the moving walk. At the end of the walk, the car automatically engages a series of accelerating propulsion rollers and is accelerated to main line speed.

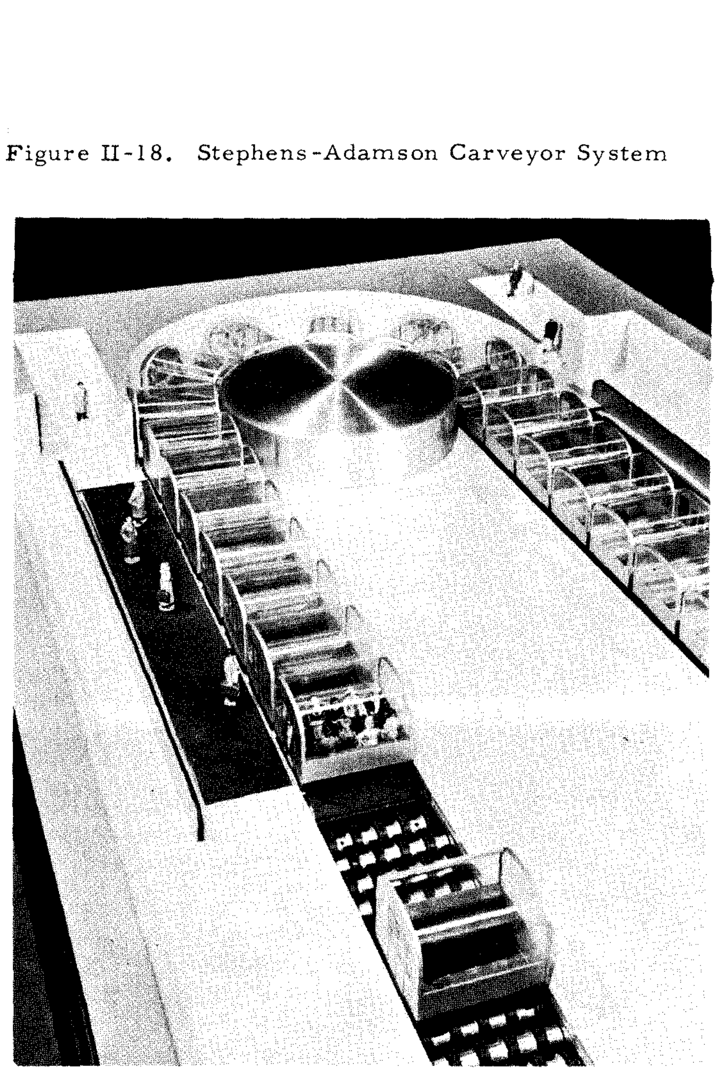
The operation of the system is completely automatic and the cars do not require either controls or attendants. A test installation of the system was constructed in Aurora, Illinois, and several small demonstration models have been built. The carveyor system was selected by the New York Transit Authority for use at the Time Square Shuttle but it was never built.

LOCKHEED-FUSSELL SYSTEM This system consists of a network of overhead tracks and small electrically powered symmetrically suspended passenger cars. The stations are simple sidings from the main line, but are in the vertical plane, which permits passenger loading and unloading at the sidewalk level. The system provides for empty cars to be stored at sidewalk level until needed. The cars have a capacity of from two to four passengers and are completely automated. The passenger upon entering selects a destination button which activates the trip cycle and carries the passenger onto the main line and to his particular destination station. The body of the car hangs by two hangers from a single truck. Each truck is provided with four main support wheels which will be of solid rubber. Guidance of the vehicle is obtained by the support wheels running in a concave or channel track. As yet there are no test installations and the final design engineering has not been done.

CONCLUSIONS For the purposes of our analysis and estimates of cost, we have projected the use of the Stephens-Adamson Carveyor System. However, the Lockheed-Fussell System offers several advantages and it is felt that further investigation would be in order before actually selecting the type of secondary distribution system. It is recommended that the final selection of the secondary equipment system not be made until such time as the "Metro" system is constructed. By postponing the decision, full advantage can be taken of the latest equipment developments. It is also possible to provide an interim distribution service in the Central Business District by using standard motor buses on exclusive bus lanes.

Not necessary.

Figure II-18. Stephens-Adamson Carveyor System



The competition is not speed but time. Speed must be such as to compete with TIME and CONVENIENCE of auto.

TRAIN OPERATIONS

The rapid transit system must operate at average speeds which are at least competitive with private automobiles being driven to and from the Central City Area and outlying residential areas. Since the trains must stop at intermediate stations to pick up and discharge passengers, the speeds between stations must be high to compensate for the time lost stopping. Acceleration and braking rates must also be in high.

The study of traction motor power requirements included a consideration of the specific routes and grades to be encountered. Four 125-horsepower motors per car were found adequate for all conditions of operation up to 1% grade. For grades in excess of 1%, acceleration rates must be reduced slightly (2.5 miles per hour per second on 5% grade) to stay within the commutating limit of the motor when carrying the maximum design load. Consideration of power system's ability to make up time and of savings in power consumption prompted the decision to include a coasting period during each run which results in a 3.0% increase over the no-coast running time.

The small increase in running time will save approximately 20% in power and afford a margin for making up time when necessary. (See Figure II-15).

The Figure II - 15 shows the no-coast and normal speed time and distance time curves for an average run (station spacing 1.1 miles) resulting in a 38.8 miles per hour schedule speed, including 20 second stops.

Train system operations factors which form the basis for the estimate of the number of the vehicles required are as follows:

- Four 125-horsepower motors
- Rubber tires
- 20-second station stop
- Four-minute rush hour headway in each corridor (2 minutes on Wilshire Common Section)
- 3.5 miles per hour per second acceleration and deceleration
- 1.75 miles per hour per second impact
- 3% time allowance for coasting
- Maximum speed 80 miles per hour
- 5% maintenance out-of-service time (will increase as cars age)
- Approximately 54 persons seated and 73 standing. (Note that seats for as many as 72 people can be provided by certain interior layouts)

54
73
127

Vehicle weight empty - 30,000 pounds

The tabulations presented on pages 21 and 22 of Section I give the estimated normal running time and elapsed time, including stops, of a rapid transit train in the four corridors of the recommended system.

A computation of theoretical running time using a skip-stop operation has also been made. The following tabulation is a comparison of schedule times of rapid transit trains skipping alternate stations in outlying areas with the schedule times of trains making all stops. The times shown include 20-second stopping time at each station stop.

SKIP-STOP SCHEDULE TIMES COMPARED TO LOCAL TRAIN TIMES

8th & Hill Street to Santa Monica	"A" Trains	"B" Trains
Time to Reseda Junction (No Skips)	10.2 Min.	10.2 Min.
Reseda Junction to Santa Monica (Skip-Stops)	13.6 Min.	12.6 Min.
TOTAL	23.8 Min.	22.8 Min.
Time of local run, for comparison	27.6	27.6
% TIME SAVED	13.8% 3.8 Min	17.4% 4.8 Min.
8th & Hill Street to Reseda		
Time to Reseda Junction (No Skips)	10.2	10.2
Reseda Junction to Reseda (Skip-Stops)	20.4	19.2
TOTAL	30.6 Min.	29.4 Min.
Time of local run, for comparison	36.8	36.8
% TIME SAVED	11.9% 6.2 Min	20.0% 7.4 Min
8th & Hill Street to Covina		
Time to Union Terminal (No Skips)	4.0	4.0
Union Terminal to Covina (Skip-Stops)	23.1	22.1
TOTAL	27.1 Min.	26.1 Min.
Time of local run, for comparison	33.4	33.4
% TIME SAVED	18.8% 6.3 Min	21.8% 7.3 Min
8th & Hill Street to Long Beach		
Time to San Pedro Street (No Skips)	1.4 Min.	1.4 Min.
San Pedro Street to Long Beach (Skip-Stops)	21.8	21.9
TOTAL	23.2 Min.	23.3 Min.
Time of local run, for comparison	31.4	31.4
% TIME SAVED	26% 8.2 Min	25.8% 8.1 Min

Section III—Transit Facilities Analysis

Table of Contents Section III

LIST OF ILLUSTRATIONS

Transit Facilities Analysis

The facilities portion of the transit system includes way structures, stations, maintenance and storage yards, shops, and other structures necessary to the installation and operation of a rapid transit system. These facilities and in particular the way structures account for a major portion of the cost of the transit system.

It has been established that a rapid transit system must have complete grade separation from other traffic to insure safe, fast, and reliable service. This fact eliminates "at-grade" operation except in those areas where no streets or crossings exist. Grade separation is inherent in subway or in overhead configuration which is essentially a continuous bridge structure.

When surface operation is possible, a suspended transit system would require structures similar to that for overhead operation. Supported systems, on the other hand, would utilize ground supported track and secondary way structures such as vehicle and pedestrian bridges. Subsurface operation may take the form of open cut and utilize a track system of the same type as surface alignment with secondary way structure providing grade separation, or tunnel which is constructed as primary way structure with appropriate track integrally installed.

One of the principal choices to be made relates to the selection of the configuration of way structure to be used. This section will discuss this question along with other aspects of the design of transit facilities.

DESIGN APPROACH

Investigations first established functional and aesthetic criteria as goals for each facility item. Preliminary designs were then made to determine the extent to which this criteria could be met. Materials for way structures were selected which appeared most advantageous to each system for aesthetics, maintenance, economy and functional capability. Safety, cost and appearance are of prime concern. Designs were advanced to a point which insured functional compatibility with equipment and operating conditions, but not to the degree required for final design of an operating system.

The first step in development of way structures must be the establishment of criteria in conjunction with local and state Building Code groups and other agencies involved with public safety. Particular consideration will be required to establish dynamic, torsional and seismic load conditions within the allowable stresses of material. Presently accepted standards for structures are not specifically applicable for design of a rapid transit system because of the departure from conventional concepts.

CONDITIONS FOR DESIGN

The initial step in developing designs of way structure for the three systems under study was to establish critical loading conditions based on possibility and probability of load application. Basic working stresses were assigned and appropriate increases established for combinations of dead, live, impact, torsion, wind, seismic, temperature, and acceleration loads. Allowance was made for long term loading as well as repetitive loads of several million cycles.

Loading values were developed from preliminary designs of lightweight car equipment with allowance made to include maximum possible passenger load. Acceleration loads assumed the extreme condition of two trains from opposite directions making an emergency stop in adjacent spans of the structure, thus producing the maximum condition for torsion on column and foundation.

The design philosophy of facilities for the rapid transit system must balance factors of economy, aesthetics, maintenance and safety. To arrive at the preliminary designs, a series of investigations were undertaken to determine the feasibility of various combinations of materials, shapes of members, support systems, etc. The following paragraphs expand on investigations leading to designs, described for elevated and subway facilities.

MATERIALS

Selection of materials for construction of way structures caused the weighing of factors of first cost, maintenance, adaptability, appearance, equipment characteristics, in addition to safety and construction feasibility. Reinforced concrete was selected for dual track and supported mono-beam systems as the material best suited to meet this criteria. Structural steel was used for the suspended mono-beam system due to size and shape requirements dictated by equipment.

Concrete structures in general have the advantage of cost, adaptability and low maintenance. Cost and adaptability are coupled since moderate changes in span length may be economically made by increasing or reducing reinforcement and concrete strength without changing external dimensions. Maintenance of way structures is primarily a function of appearance and may be solved by cleaning procedures at nominal expense.

Mass fabrication techniques limit variation of material changes. Shape of the members also has an important effect on cost, due to fabrication techniques. To maintain a pleasing appearance, a steel structure will require washing at regular intervals and periodic painting.

Materials investigated for overhead structures include reinforced concrete, prestressed concrete and structural steel. Physical dimension limitations of equipment indicated at an early date that only small variations in member size could be anticipated with changes in materials of construction. For example, only nominal reduction in depth is feasible when structural steel or prestressed concrete is used in place of reinforced concrete for supported systems. Due to the flexible characteristics and fatigue limitations of prestressed concrete and the fact that no significant reduction in depth would result from its use, it was decided that preliminary designs for dual track and supported mono-beam systems would be developed using conventional reinforced concrete.

Studies of beamways for the suspended system established dimensions using structural steel which minimized bulk and weight. Preliminary investigations of concrete, both reinforced and prestressed, produced sections of large bulk, weight and difficult construction. Feasibility of composite construction was also studied and ruled out for further study at this time as having limited adaptability.

High-strength low-alloy steel has a resistance to corrosion from 2 to 6 times that for carbon steel, depending primarily on the exact composition specified. Strength can be 2 to 3 times greater than carbon steel. In the specific application to the suspended system, cost may be 50% more than for carbon steel; however, additional strength for the minimum beam configuration is not required and therefore high-strength steels were not used.

Support structures, in addition to presenting a pleasing appearance, must occupy minimum space at ground level and be adaptable to variations in height. Several forms of structures were considered but the "Tee" shaped support offered a pleasing appearance and possesses great adaptability.

FABRICATION AND ERECTION

Designs developed for the three equipment systems under study may be fabricated and erected by conventional construction techniques. Member dimensions approach the limit of size for present mass production and transportation capabilities of the construction industry; however, no major problem is anticipated in the handling of 110-foot long beamways. Concrete beamways and support columns have been designed as precast units. Tower arms are designed as cast in place concrete.

APPEARANCE

Acceptance of the addition of rapid transit facilities in the community will require these structures to be of pleasing appearance and minimum size. Support columns will have to be of sufficient size to assure confidence, yet spaced at intervals which will not seriously impair the field of view of the neighboring public. To this end, beamway spans in the range of 100' have been explored and member shapes selected for each system which satisfy equipment needs and reduce bulk to a minimum. "Tee" shaped columns and support arm structures have been used for all systems, as this configuration satisfies all criteria and has extreme adaptability to height variation and super elevation of beamways.

SOUND CONTROL

Sound control is sufficiently significant to influence material selection and design approach. Mass associated with concrete construction, provides good characteristics for restraining noise emission from a rapid transit system to a low level. On the other hand, steel structures with large surface areas have poor characteristics for noise reduction. If steel structures are used in areas of critical noise control, it may be necessary to use additional material of sound deadening nature to develop a composite structure of acceptable characteristics. Sound baffles or similar appendages to beamways may be desirable to solve the problem of noise control. However, this solution is in conflict with appearance criteria for maintaining bulk of way structures to a minimum. Noise reduction and control should generally be accomplished as much as possible within the limits of vehicle and minimum structure configuration, with external control methods reserved for critical conditions.

GEOLOGY AND FOUNDATION CONDITIONS

Preliminary investigations[1] of geologic and foundation conditions existing along the proposed routes have been carried out by LeRoy Crandall and Associates, Foundation and Geology Consultants. A review of logs of test borings taken in the general vicinity of the corridors was made and correlated with surface geologic information. The purpose of this work was to provide a general guide as to the soil conditions likely to be encountered within the specified areas, thus permitting a more realistic estimate of the cost of underground and foundation construction.

The soils underlying the proposed routes are generally well consolidated alluvium - a mixture of sand, gravel, silt and clay. Only local areas of "poor" (unstable) ground are anticipated.

In the downtown area, the alluvium recently deposited by the Los Angeles River bed extends to a depth exceeding 100 feet. This soil, predominantly sand and gravel, fills the river gorge eroded from the older, underlying shale and sandstone.

Bunker Hill, north and west of the center of the downtown area, is an outcropping of Puente Shale. The subsurface slopes of the firm shale extend to encompass part of the downtown route along Main Street and the Wilshire Corridor line west to Vermont Avenue. Localized alluvium-filled drainage channels are cut through the shale at several places.

Westward from Vermont, the shale and other rock is overlain to a considerable depth by continental deposits and more recent alluvium.

(1) Preliminary review of Foundation Conditions in the Los Angeles Central Business District and in the Four Transit Corridors, January 22, 1960 Report by LeRoy Crandall & Associates.

Again, the more recent alluvium fills natural north-south drainage channels for run-off from the Santa Monica Mountains. A major filled channel at La Cienega may be so extensive as to require special consideration for any subway structure to be constructed at that location.

Ground water level is generally in excess of 50 feet below grade. However, the previously mentioned drainage channels will periodically contain seepage water at subway elevation. Also, local perched water exists on some shale strata. A prime example of both of these conditions is the lake at MacArthur Park, where water, held by a dam across a drainage channel, rests on the impervious shale.

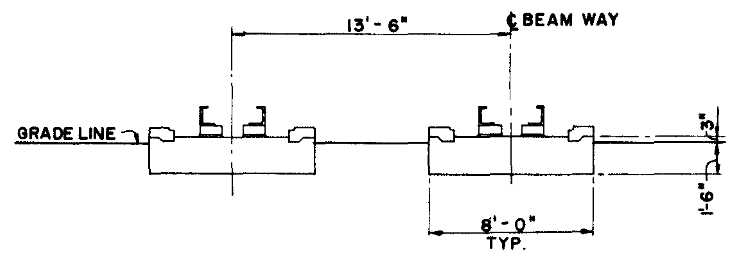
Seismically, all of the Los Angeles Basin is an active area. However, the only recognized fault located in the areas studied is the Cherry Hill fault, which intercepts the Long Beach Corridor roughly 1-1/2 miles south of Del Amo Boulevard. Although this and other lesser faults may cross the proposed system, normal seismic design criteria will be sufficient since the chances of a slip across the line are extremely remote, and could not be protected against in any event.

FUTURE DESIGN CONSIDERATIONS

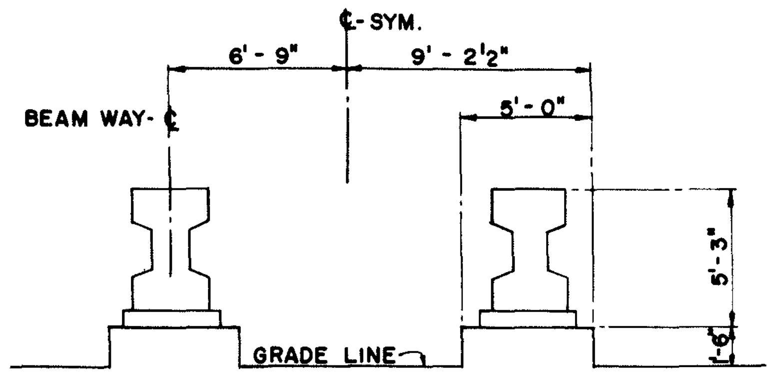
When final design is undertaken, it is recommended that alternate designs be developed in structural steel, reinforced concrete, and prestressed concrete for the selected system way structures to insure maximum economy of construction. Detailed design may show economic and other advantages which were not apparent in preliminary designs. Consideration must be given to every facet of the structure to insure the best combination of materials and techniques. Of major importance will be development of specifications for testing and inspection of materials and fabrication as well as dimensional tolerance in construction.

At the time of final design for the operating system, it will be necessary to have detailed physical data of the selected system operating equipment from which structures may be engineered. This information coupled with specific right-of-way conditions will permit precise appraisal of the many possible configurations of way facilities. Preliminary designs shown on Figures III-1, III-2, and III-3 in this report are possible solutions to the problem which meet established criteria and are considered "typical" examples of way structures for evaluation purposes.

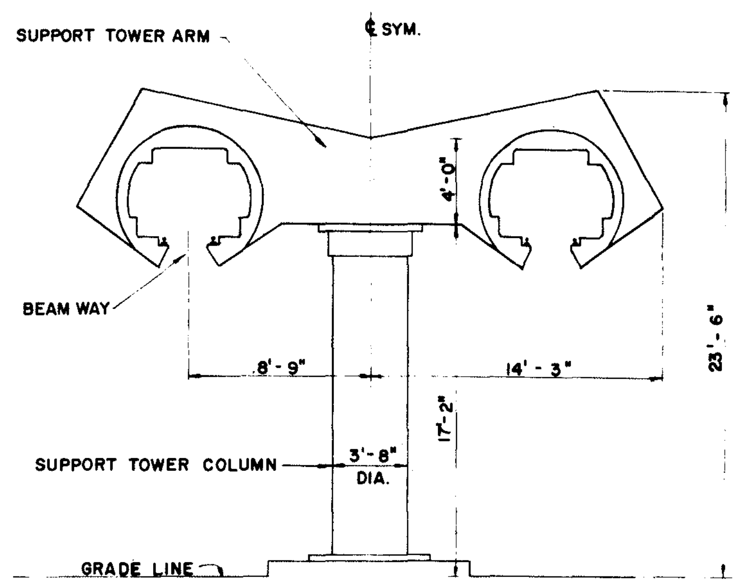
Figure III-1. Typical support and beamway structures for surface operation of rapid transit system.



(a) Dual track system

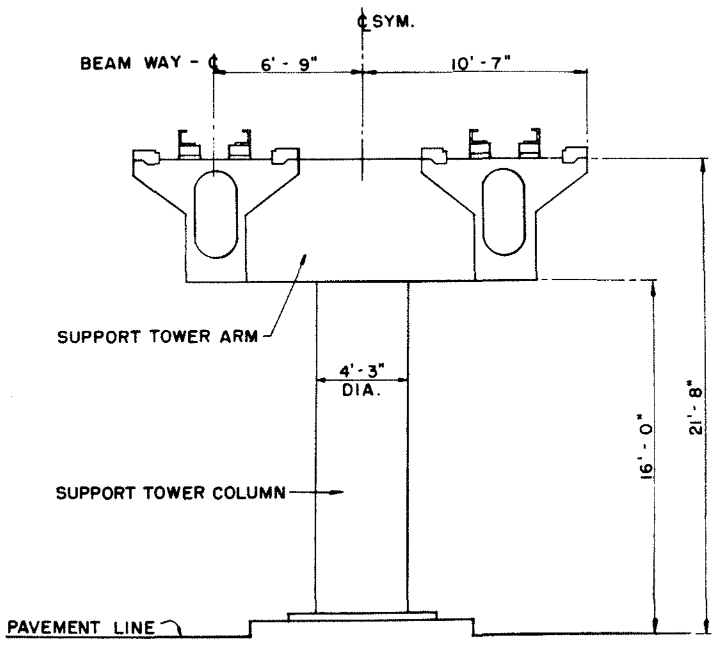


(b) Supported mono-beam system

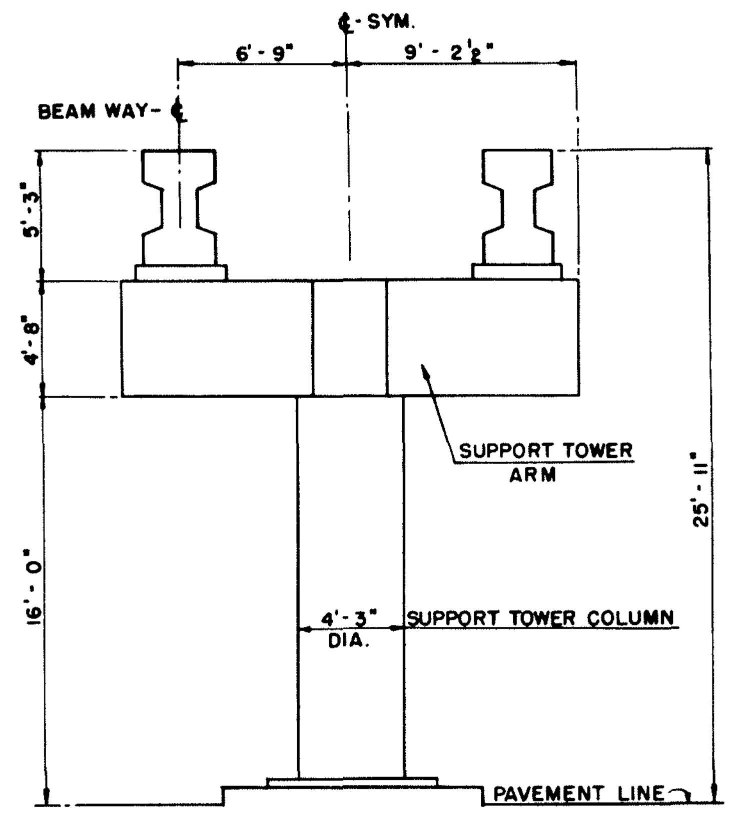


(c) Suspended mono-beam system

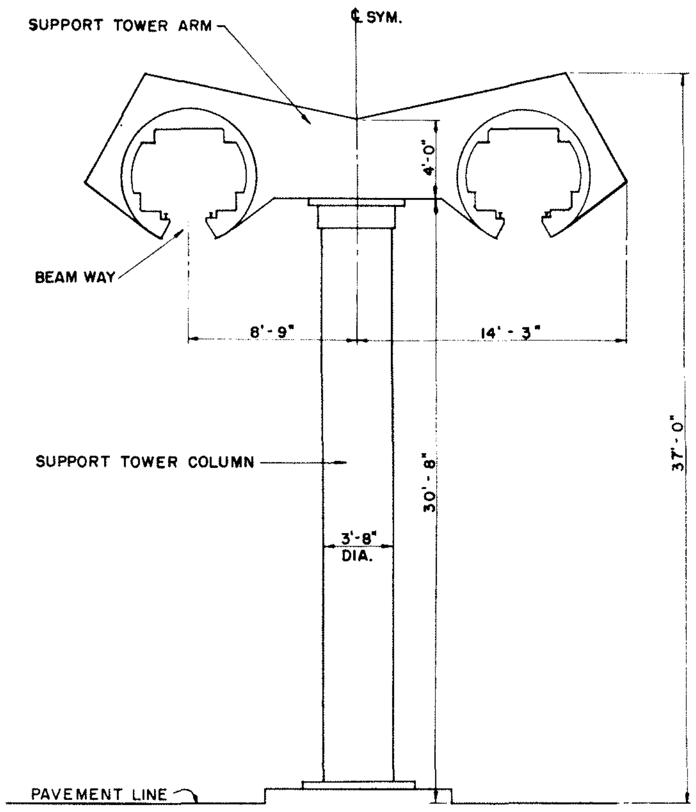
Figure III-2. Typical support and beamway structures for overhead operation of rapid transit system.



(a) Dual track system



(b) Supported mono-beam system



(c) Suspended mono-beam system

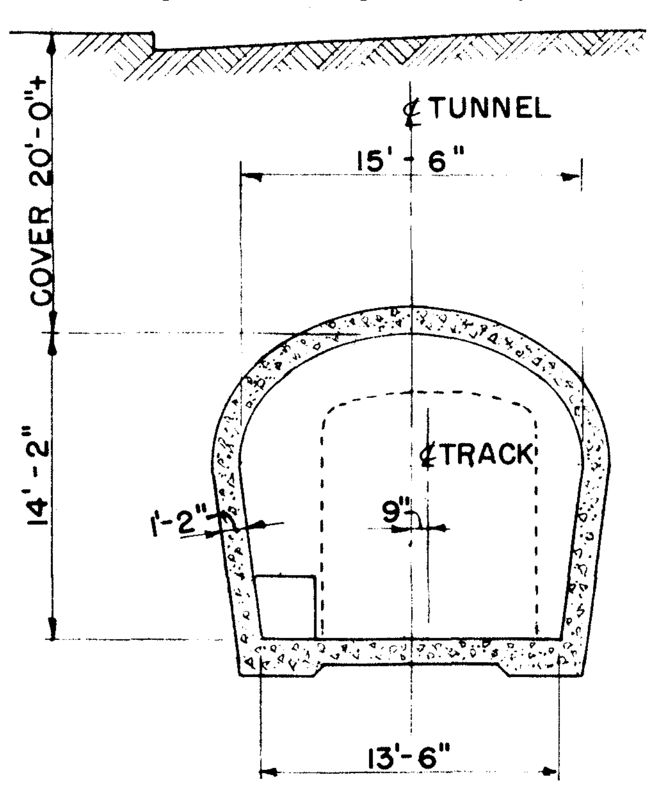
OVERHEAD FACILITIES

From studies of land subdivision in areas in which the rapid transit system may be installed, spans of 110 feet were established as best meeting all criteria. This dimension would promote economical design in that a maximum of "typical" spans could be used with a minimum of special conditions required for clearing wide street rights-of-way.

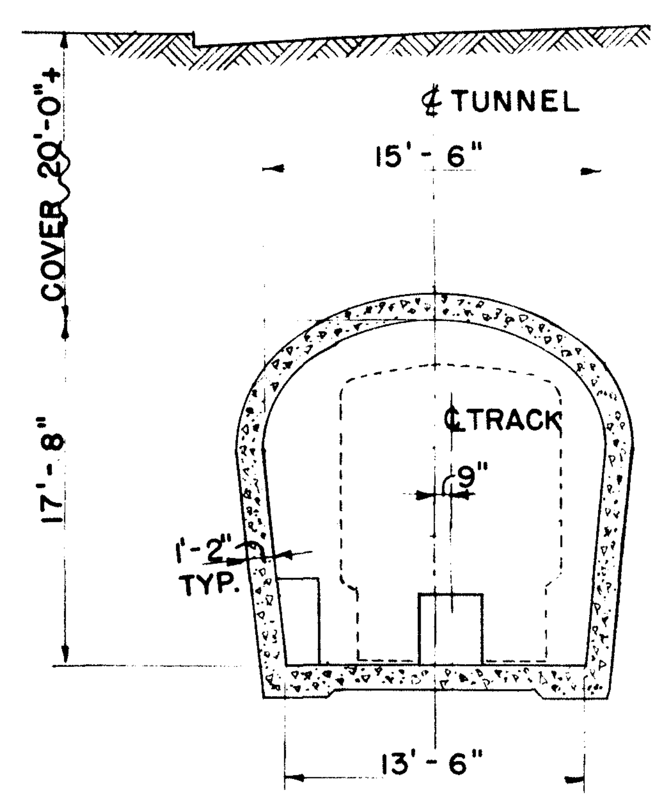
"Typical" spans for supported mono-beam system are limited to 92 feet as this is the greatest span permissible due to stability of structure limited by dimensions of the running gear. Where non-typical conditions dictate longer spans, typical beam systems were changed or special supporting methods provided for cost estimating purposes.

For estimating purposes, span lengths were reduced at stations and on short radius curves. Similarly, at locations requiring unusual heights, the structure was proportionately increased for estimating costs. Heights of way structures and clearances for grade separation were established in accordance with standards presently established by the California Division of Highways, California Public Utilities Commission and similar agencies having jurisdiction over transportation and safety.

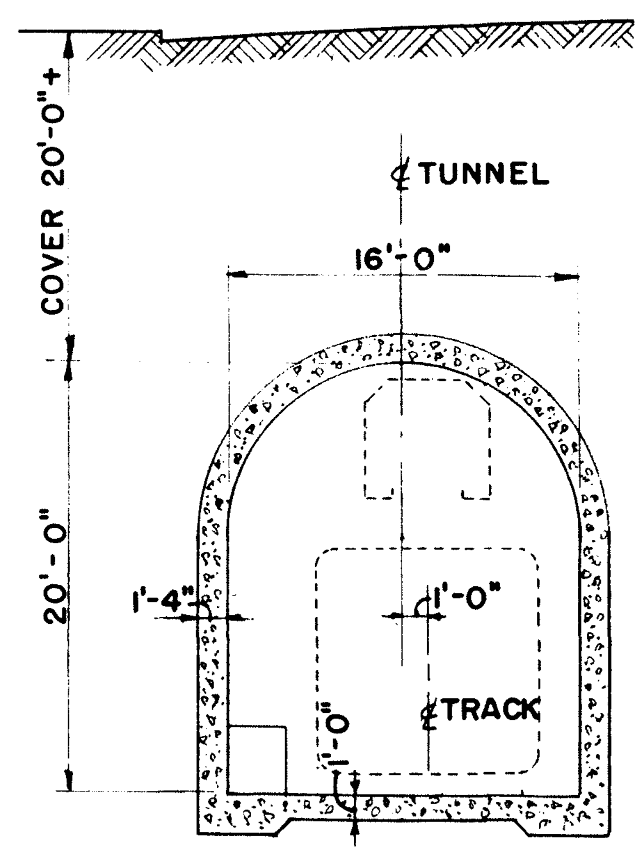
Figure III-3. Typical tunnel structures for subsurface operation of rapid transit system.



(a) Dual track system



(b) Supported mono-beam system



(c) Suspended mono-beam system

In general, average ground clearance was established at 16 feet due to the fact that minor variations in ground elevation would not be followed and thus provide relatively uniform grades for vehicle operation. Minimum clearance over public streets is 14 feet. Design details of the beamways for the several equipment systems are shown on Figure III-4.

DUAL TRACK CONFIGURATIONS

The reinforced concrete beamway for this system has been designed in a Tee-shape and is formed with a continuous void throughout its length to reduce dead weight. Width of the beamway is established at a minimum to accommodate the running gear.

Depth and shape of this member were determined from design. Running surfaces for load-bearing wheels are removable precast concrete plank. Horizontal guide wheels bear on continuous steel angles anchored to main beams.

Support structure for this system consists of a Tee-shaped reinforced concrete column and cross beam. A bracket type connection is provided on tower arms to receive track beams. In this manner, bulk is reduced to provide minimum silhouette and improve appearance, as well as lowering the entire structure to minimum ground clearance level. Provision has also been made for longitudinal movement of one end of the track beam, thus minimizing stresses due to temperature variations.

SUPPORTED MONO-BEAM

Dimensions of the track beam for this system are established primarily by the transit car and running gear configuration. Gross depth may be varied, however, minimum depth is set by running gear of the vehicle. The beam is a reinforced concrete modified "I" shape which, due to the limited width, is limited in span. Where spans in excess of 92 feet are required, it is necessary to use a steel beam or develop a structure similar to the Tee girder used on the dual track system beneath the running beam for primary support.

Support towers for this system are similar to those of the dual track system, except support arms must be below the running beam to clear running surfaces of stabilizing wheels.

SUSPENDED MONO-BEAM

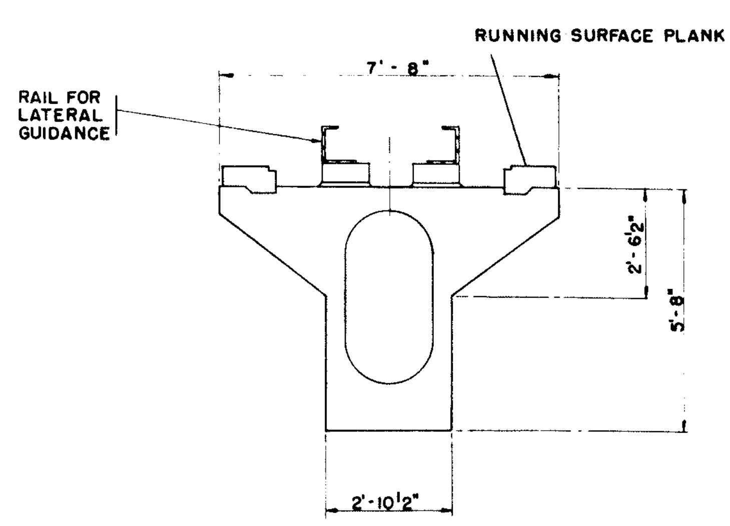
Support beam of circular shape for the suspended mono-beam system is dictated by bogie configuration, silhouette and economy of fabrication. Size, basically, is minimum to enclose bogies and power rail. Continuous steel running surfaces have been provided for vertical safety wheels and for vertical and horizontal running wheels.
The "Tee" support tower arm is a fabricated steel structure with rail beam connection at one end having provision for longitudinal movement due to temperature variation. A bracket type connection, again, is used to minimize silhouette. Reinforced concrete columns are used to provide stiffness, ruggedness, and minimize maintenance. Connections of cross arms to column are bolted to permit maximum erection adjustment.

FOUNDATION DESIGN

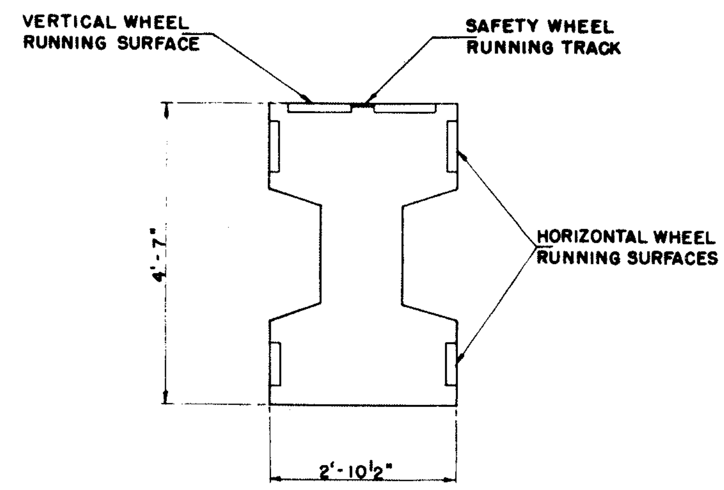
Preliminary foundation designs for each of the three equipment systems have been based on soils information provided by LeRoy Crandall & Associates.[1] The tower structures for the overhead facilities will develop large downward, upward, torsional and overturning forces. Drilled cast-in-place concrete friction piles will be the type of foundation used for the majority of the soil conditions encountered. This foundation should be economical for roughly 60 to 80 percent of the tower locations, and will be reasonably representative of the average costs at the remaining locations. Where soil conditions are poorer than those of the typical condition, driven piling could be readily substituted; where better foundation conditions exist, drilled-and-belled caissons

[1] Characteristics of Typical Foundation, Rapid Transit System, Letter Report by LeRoy Crandall & Associates, May 9, 1960.

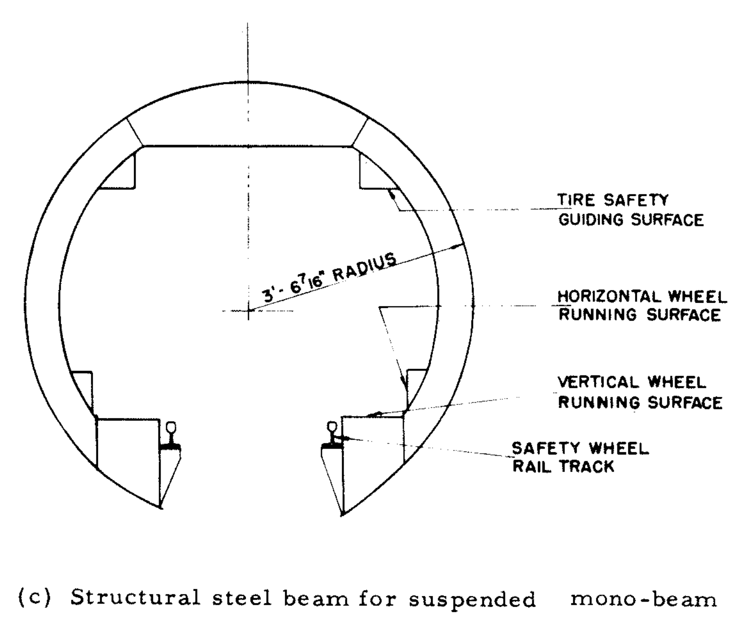
Figure III-4. Typical beamway sections.



(a) Reinforced concrete beam for dual track system



(b) Reinforced concrete beam for supported mono-beam system



(c) Structural steel beam for suspended mono-beam system

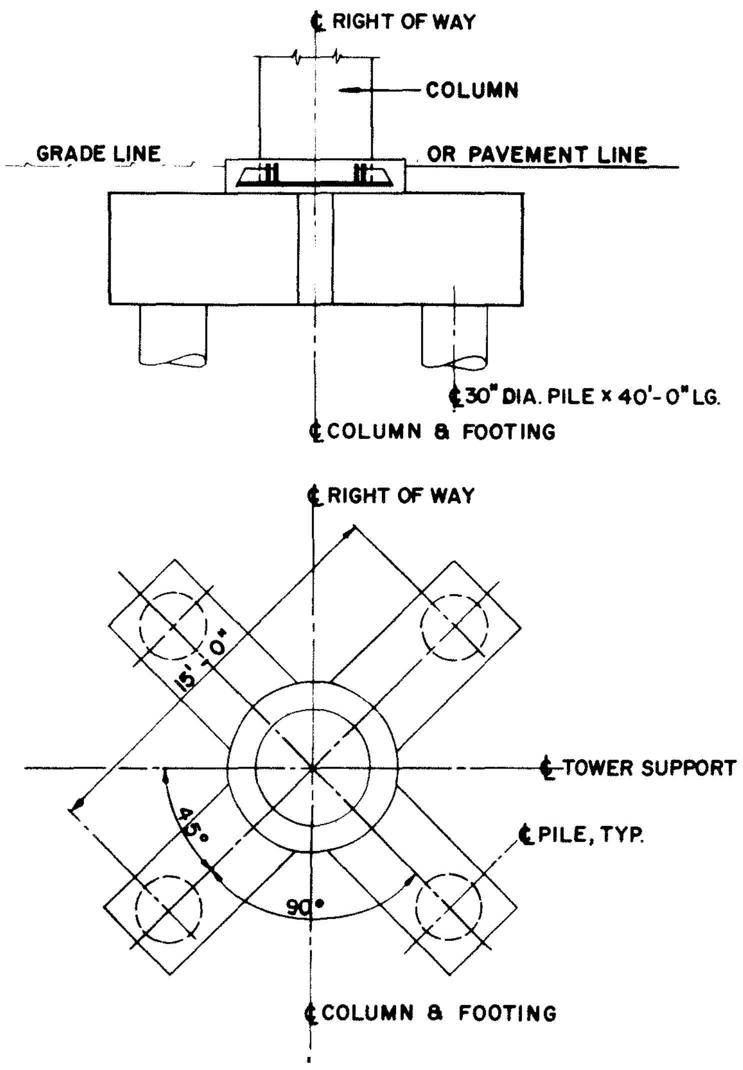


Figure III-5. Typical foundation plan for overhead way structure.

could be used. Details of the typical foundation are shown on Figure III-5. This shows two reinforced concrete beams at right angles to each other, forming an "X" with each beam set at 45° to the transit line. Beams bear on 30-inch diameter drilled pile, penetrating roughly 40 feet into undisturbed soils. Since a large portion of design loadings will be of a momentary nature, settlement and deflection of the foundation is anticipated to be of negligible magnitude from live loads.

The above information is an estimate of typical conditions based on the preliminary soils and geologic information. The information is adequate for preliminary estimates of cost. Specific information for design will, of course, require investigation of the soils at the specific locations finally chosen.

SURFACE WAY STRUCTURES

Way structures required for surface operation of rapid transit vehicles vary widely depending on the system used. Common to all systems, however, is the need for private property for operation "at grade". Community acceptance and safety again dictate requirements for security fencing and landscaping. Planting of marginal sections of private right-of-way will improve appearance, aid in sound control, and provide erosion control. This treatment is similar to practice employed by the State Division of Highways on freeways.

Secondary way structures such as vehicle bridges and underpasses are familiar structures of concrete and steel construction which require no elaboration here. Estimates for surface right-of-way include costs of primary and secondary way structures, grading, fencing, drainage structures, landscaping and land. An artist's concept of at grade operation in the San Bernardino Freeway is shown in Figure III-6.

DUAL TRACK CONFIGURATION

A concrete runway with concrete plank and steel angle running surfaces of the same type used for overhead operation is provided for surface operations.

The structure is a simple reinforced concrete continuous mat foundation and slab which supports the transit vehicle. This configuration is analogous to ties and ballast used for conventional rail operations.

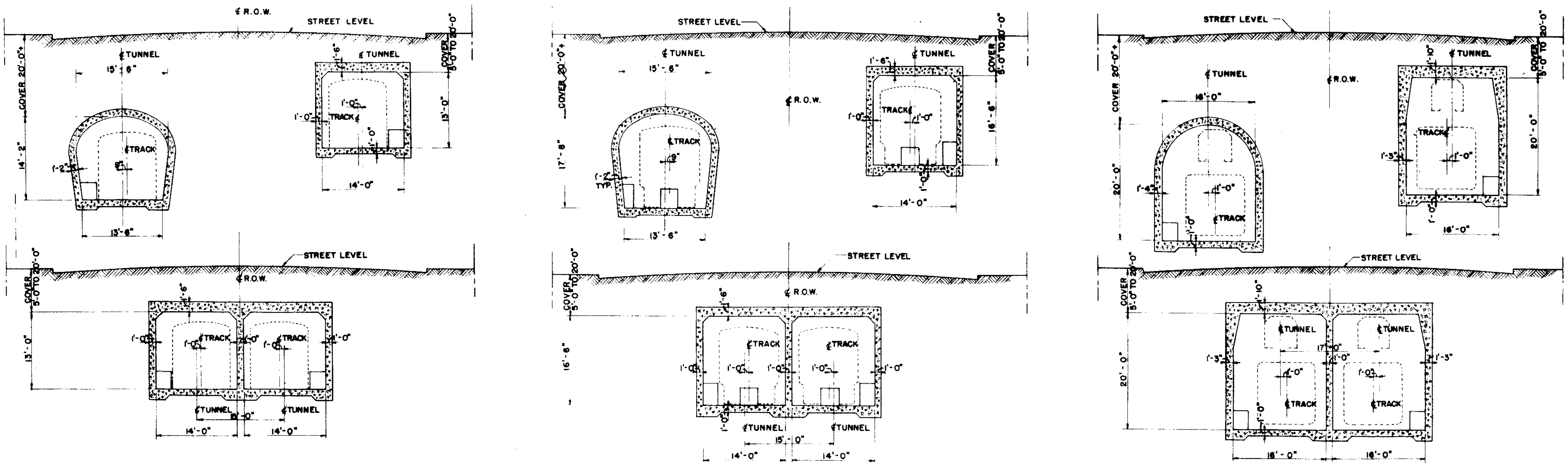
SUPPORTED MONO-BEAM CONFIGURATION

Due to the high degree of precision required in alignment and shape of the beamway necessary for this system, it is necessary to use beam sections similar to those of the "typical" overhead configuration. Reinforced concrete pedestals support beams at minimum ground clearance elevation.

SUSPENDED MONO-BEAM CONFIGURATION

Requirements of this system are the same for operation "at grade" or overhead, except that ground clearance is reduced to about two feet below the vehicle. Therefore, way structures are the same for all practical purposes. A slight reduction in support column diameter is the only change in this structure.

Figure III-6. Photo rendering of operation in San Bernardino Freeway.



(a) Dual track system

(b) Supported mono-beam system

(c) Suspended mono-beam system

Figure III-7. Typical subway structure cross sections.

SUB SURFACE WAY STRUCTURES

The advantages of subway transit - minimum surface space usage, minimum interruption of light and air to street level, and minimum disturbing noise are gained only at great expense. Subway facility dimensions are determined by the rights-of-way clearance necessary for the transit system operation. The dual track concept of the Metro system is best adapted to underground alignments because the compact car-truck configuration permits the smallest, least expensive tunnels. The suspended mono-beam system is least efficient for underground construction due to the large vertical clearance necessary for track beams. Subway configuration is a function also of construction methods employed. Special investigations(1) of subway construction methods and costs were carried out by Consultants, Mason & Hanger-Silas Mason Company, Inc.. Configuration requirements for the several construction methods are shown on Figure II-7.

Subway alignments that were investigated are primarily located beneath public streets. This routing is desirable for several reasons: minimum property acquisition costs, ease of access during construction, and station location on main thoroughfares. It is necessary however to deviate from exclusive use of public streets at junctions of transit routes, and at natural barriers to economic tunnel construction such as MacArthur Park Lake. It is also desirable in some cases to follow a direct path under private property where street orientation would result in a longer, more circuitous route. In these instances, particularly in "high rise" areas, tunneling is a practical requirement. Protection of building foundations by underpinning or by deep tunnel alignment is a far more reasonable approach than acquisition and demolition of the properties as required by cut-and-cover methods.

(1) "Underground Construction for Mass Rapid Transit in Los Angeles", Report by Mason & Hanger-Silas Mason Company, Inc., May 16, 1960

A high level of passenger safety and comfort must be maintained underground. Adequate ventilation is important. Vent shafts at stations and at short intervals along tunnels are required to provide fresh air, and reduce the discomforting rush of air pushed ahead by moving trains. Walkways adjacent to each track, with frequent access to the surface, are provided to assure safe passenger escape from any tunnel location where an emergency condition might occur. Pumping stations must be installed at system low points to remove any water entering the subway network. Installation of sound absorbent material on the lower wall areas is recommended to reduce high noise levels inside passenger cars.

Open cut alignment way facilities are identical with surface operation structures with the addition of extensive excavation and in confined areas, retaining walls of major proportion. This construction configuration is applicable only at tunnel approaches, and where localized sharp variations occur in terrain which preclude at grade or overhead alignments.

SUBWAY STRUCTURES

Primary interest in selection of subway structure configuration is that of cost. Cost factors in addition to direct labor and material for the subway structure are protection of existing buildings, property acquisition, easement costs, utility maintenance or relocation, and disruption of surface traffic.

Choice of construction method is limited to tunneling or cut and cover procedure. The tunnel method requires minimum surface access for construction which may be provided at station locations. Cut and cover, on the other hand, requires access from the surface throughout the length of right-of-way with attendant disruption of normal surface activities for an extended period of time. Surface traffic may be restored to near normal circulation by placing temporary decking over partially excavated work; however, noise, dust and general nuisance may exist for several months with cut and cover methods.

TUNNEL METHODS

There are many tunneling procedures in common usage. The method most applicable for size, shape and geology of the three systems under study is the one developed in Southern California primarily for large storm drain and sewer work.

This method uses a horseshoe-shaped open bottom shield, which supports the peripheral earth at the tunnel heading, protects the workers, and provides easy erection of a steel rib and temporary lining. As tunneling progresses, the shield is propelled forward by hydraulic jacks supported on the previously erected temporary lining. The horseshoe shape of this lining allows vertical jacking, after passage of the shield to minimize surface subsidence. A permanent concrete lining is later cast inside the temporary one. Tunneling progresses from work shafts through which construction materials are supplied and spoil removed. In many places, parts of the open cut excavation for stations may be used as shafts.

CUT AND COVER METHOD

The cut and cover method has advantages only in "bad ground" which cannot be tunneled easily, and for station sections as well as approach and transition structures at shallow depth. The sequence of operations for this method of construction are:

1. By-pass gas mains in the area to avoid possible leaks in work space.
2. Underpin adjacent structures as required to protect building foundations from possible damage during and after subway construction.
3. Drive soldier beams (Steel H piles) along excavation outline for lateral support. Preboring for piles may be substituted for pile-driving in areas where noise and vibration are objectionable.
4. Remove pavement and excavate from surface to a depth sufficient to expose utilities and to support them as required; set heavy transverse beams supported by soldier beams and hang utilities from them; set timber decking on transverse beams at street surface level. This work may be done in successive patches or at night or both to minimize interruption to street traffic.
5. Complete excavation under decking.
6. Construct structure.
7. Backfill, replacing or relocating subsurface utilities.
8. Repave.

MILAN METHOD

Recently an alternate subway construction method was developed in Europe. Pile driving and most underpinning are eliminated by excavating tunnel walls in a series of pits which are supported during construction by filling with a bentonite slurry. The walls are constructed by setting reinforcing steel frames down into the bentonite slurry and placing concrete by tremie to displace the slurry. Excavation between the walls is then carried to the grade of the tunnel roof. The roof concrete is placed, and only then is the tunnel cross-section itself excavated. A short section of the new Toronto subway was constructed by this method. No appreciable cost savings have been experienced with this method and quality of sidewall concrete, tremied into the bentonite slurry is still in question. In addition, the method is difficult to apply in areas of extensive utilities.

SUMMARY OF SUBSURFACE WAY STRUCTURES

Obviously, no one method of underground construction can be efficient for all underground conditions encountered. However, construction of parallel single-track, horseshoe shaped tunnels constructed by means of open-shield mining methods has been determined to be the most economical for the major portion of the routes investigated. Flexibility of alignment and minimum surface traffic and utilities disruption are also factors inherent in this method. Cut and cover methods would be used at stations where shallow depths would be maintained.

STATIONS

The purpose of a rapid transit passenger station is to provide service to the transit rider and occupants of adjacent property. The primary function of this service is the accumulation of transit riders at their origin of travel and dispersal at destination with minimum effort, annoyance, delay and confusion.

The impact of this single item on the acceptance of the rapid transit system should not be minimized. More attention will be focused on the stations after the system is built than any other single feature of the system. This is the part people walk through everyday. Because of the size, this is the part the adjacent property owner will "live with". It is, therefore, necessary to make the station as attractive, functional, and aesthetically pleasing as possible.

Preliminary designs of passenger stations have been developed to determine space requirements, access conditions, functional layout and costs of these facilities. Passenger volumes were established for stations by Coverdale & Colpitts, Consultants to the Authority on traffic and revenue. These passenger volumes resulted in three sizes of stations; low, medium, and high density. Concept drawings of these stations, as they may apply to the various systems and conditions of rights-of-way, appear as Figures III-8 to III-24. It should be borne in mind that stations, like all properly designed buildings, must be adapted to the individual sites selected to insure performance of their intended function. For this reason, the term "concept" has been used in station layouts illustrated.

Passenger traffic volume data has been translated into platform width, access stair and escalator width, and lobby space requirements. It was determined at an early date that single platform loading was preferable to "through" loading (entry from one platform exit another platform) for passenger volumes anticipated for this system.

The layout of a station platform and fare collection lobby is practically independent of the requirements of the right-of-way for overhead or surface operation or of the system. Access to streets does vary, however, and such access will have to be solved for each station location in final design. A general solution to the most common condition, that of an overhead system in a public street, has been used for preliminary design and illustration of station concepts.

TYPICAL MEDIUM DENSITY STATION FOR OVERHEAD OPERATION

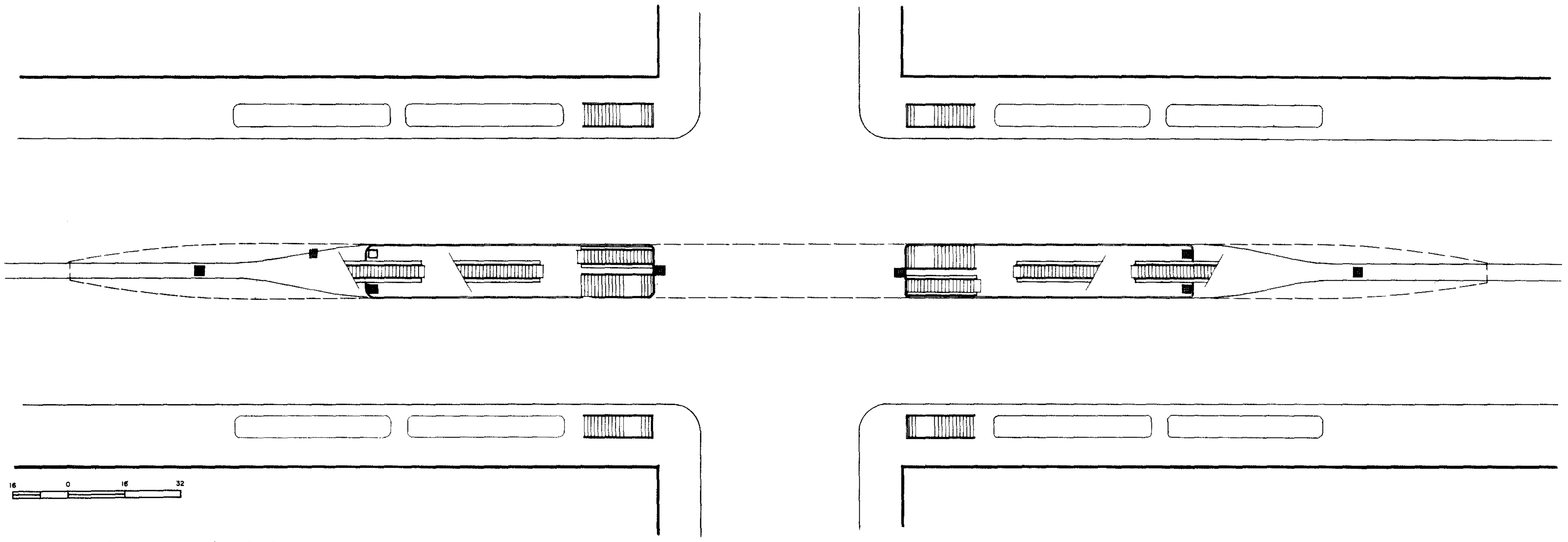


Figure III-8. Street level plan

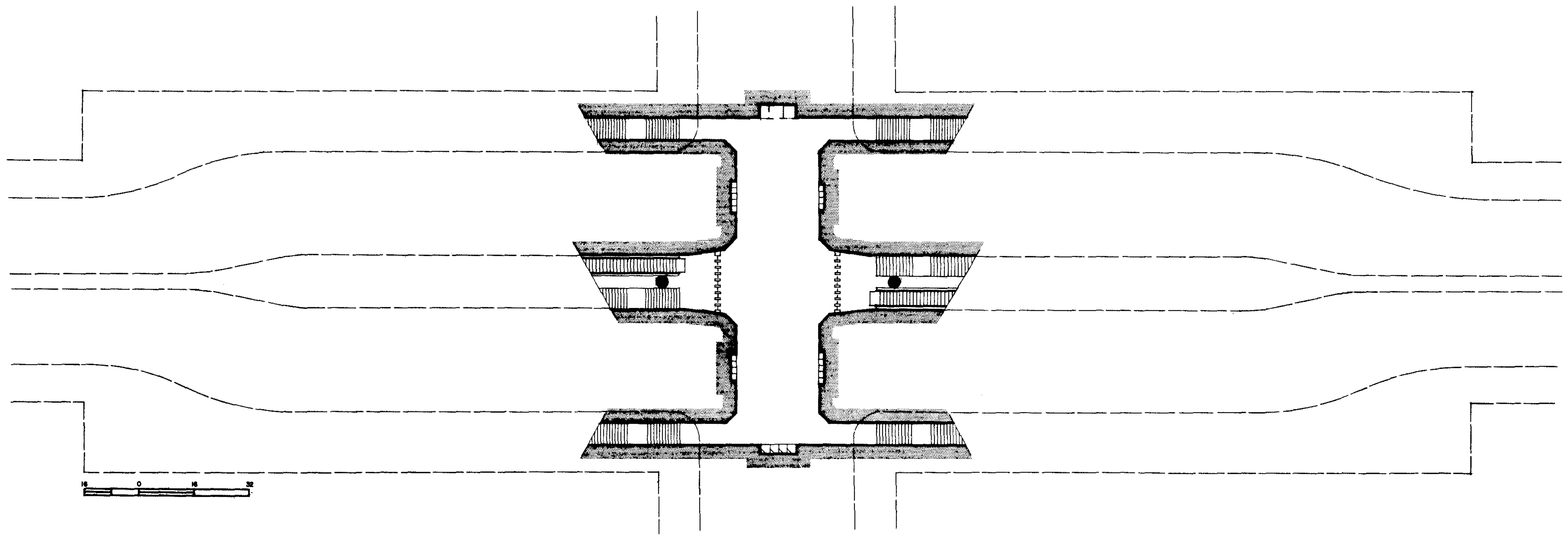


Figure III-9. Lobby plan (subsurface)

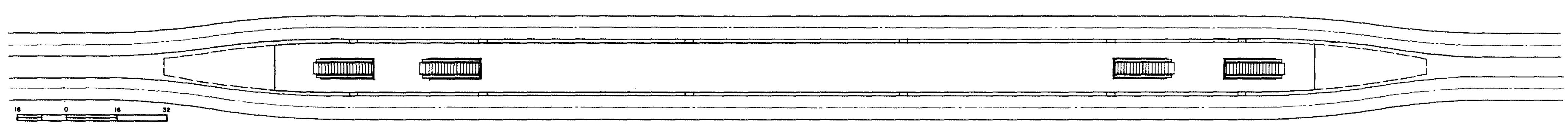


Figure III-10. Platform plan

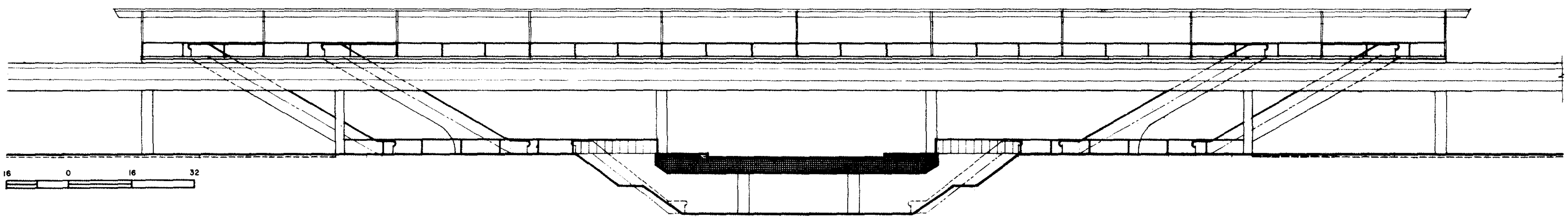


Figure III-11. Longitudinal elevation Medium density station

STATION CRITERIA

After station traffic volumes were established in cooperation with Coverdale & Colpitts, traffic and revenue consultant to the Authority, it was determined that access to low density stations elevated in the median of public streets may be gained by passage from sidewalks via crosswalks at signalled intersections.

Medium- and high-density (Central City Area) station volumes are of such magnitude that passage from adjacent sidewalks to stations must be positively separated from surface traffic through bridges or subways. This requirement for passageways also affords excellent opportunity to disperse transit passengers over a larger area of adjacent sidewalks, thereby reducing potential congestion and annoyance to all concerned.

Space required for passageways, stairs, escalators, fare collection and platform were assigned as follows:

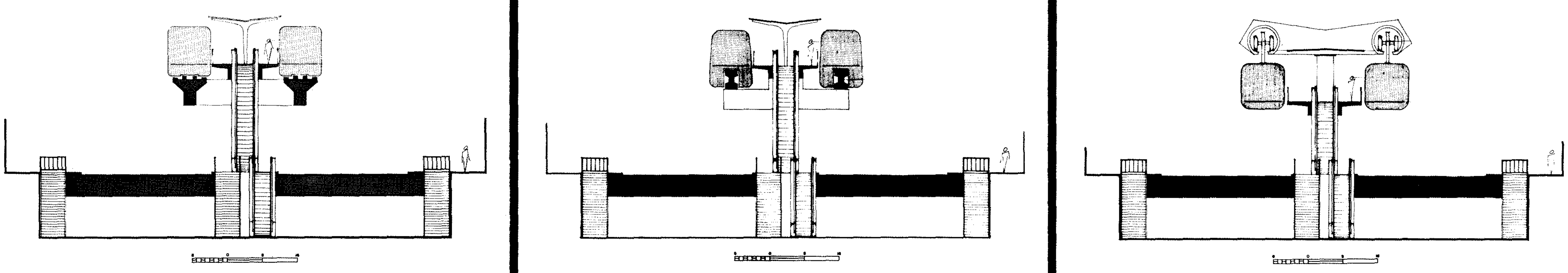
Station	High Density	Medium Density	Low Density
Platform length	336'	336'	336'
Platform width: Island Side	20' (net) 12'	15'(net) 10'	12'(gross) 8'
Stairs	4	2	2
Escalators	4-4'	2-4'	2-2'-8"
Turnstiles	36	18	6

The above figures are based on maximum train length of six cars. The potential long-term growth of the system indicates possible demand for eight-car trains.

Therefore, space has been allowed for future extension of platforms to 448' in medium and low density stations. Central City Area stations have been extended to 448' in preliminary designs due to the extreme impact on adjacent property development and high cost which may result should the additional length be required in the future.

In all cases except medium density subway stations, it was determined that central platforms would best meet all criteria. Maximum functional capability exists for fare collection, transfer, operational control, passenger access, aesthetics, and economics of operation. Designs incorporate escalators in all configurations for upward traffic when the rise is in excess of 12 feet. This limit was set to insure maximum appeal to potential riders of the system and to expedite movement within the station. This does not, however, preclude a person from using stairs if desired.

Figure III-12. Typical cross sections of medium density station



(1) Dual track system

(2) Supported mono-beam system

(3) Suspended mono-beam system

Why MILEAGE? This system has been used for years and years! Why not use TIME? The shorter the time the higher the fare!

FARE COLLECTION

Fare collection methods have been investigated sufficiently to establish that an automatic system is practical and adaptable to the needs of the Los Angeles rapid transit system. The system which is based on mileage traveled rather than arbitrary zoning, consists of a cash sale ticket vending machine and a ticket reading turnstile operation. Tickets are inserted into the turnstile upon entry which unlocks the turnstile and the ticket is returned to the patron. At the destination, the ticket is reinserted in a turnstile where it is retained and exit is permitted. If the fare paid is overridden, the turnstile will return the ticket to the patron and summon the station attendant for collection of the additional fare. Space for fare collection within the stations has been proportioned for the above system, but it is not limited to this system should more conventional means be used.

OVERHEAD STATIONS

Designs for all three systems resolve to the same solutions except for heights of platforms and slight differences in width of platforms to accommodate support columns for the suspended system. Illustrations of station plans are based on the use of supported equipment.

Two factors to be accounted for in developing stations and in selection of right-of-way are available space and adjacent land use. To elevate a station in a public street, a median width of approximately 10 feet is required for passenger movement and surface vehicle clearance. The loss of this width in the paved street would require a complete change in motor vehicle traffic using this street. To retain existing paved width for vehicular use, removal of approximately 6 feet of space presently devoted to sidewalks on each side of the street would be required. Loss of sidewalk width which in most cases is already classified as minimum is difficult to justify. Very true. Therefore, some changes in present

Typical high density (Central City Area) station for overhead operation.

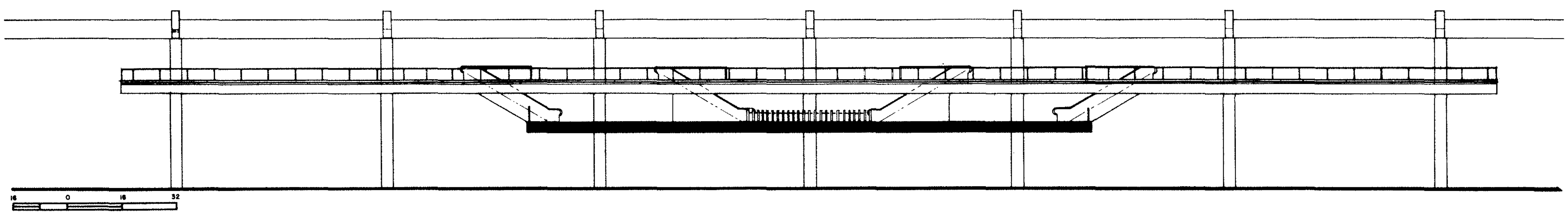


Figure III-13. Longitudinal elevation - suspended mono-beam system

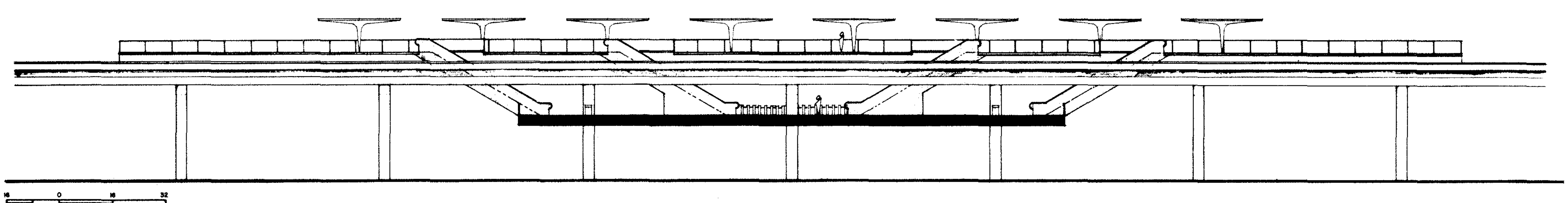


Figure III-14. Longitudinal elevation - supported system

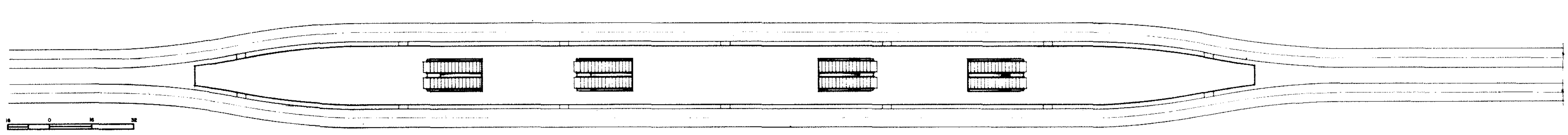


Figure III-15. Platform plan

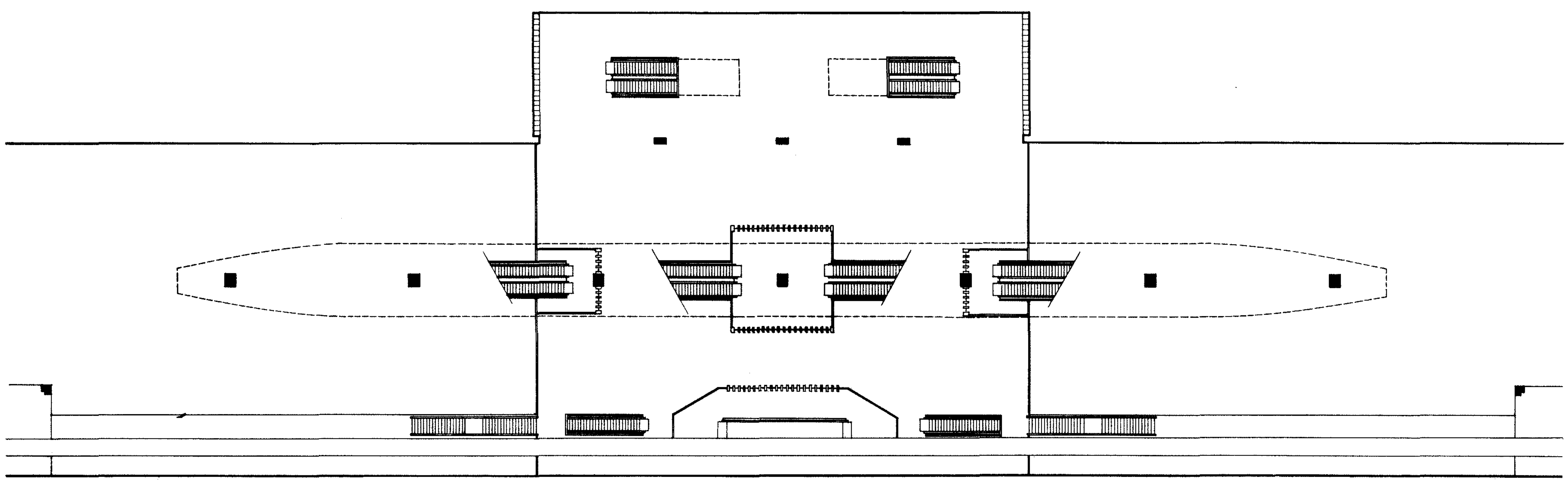


Figure III-16. Mezzanine plan with secondary distribution system High density station

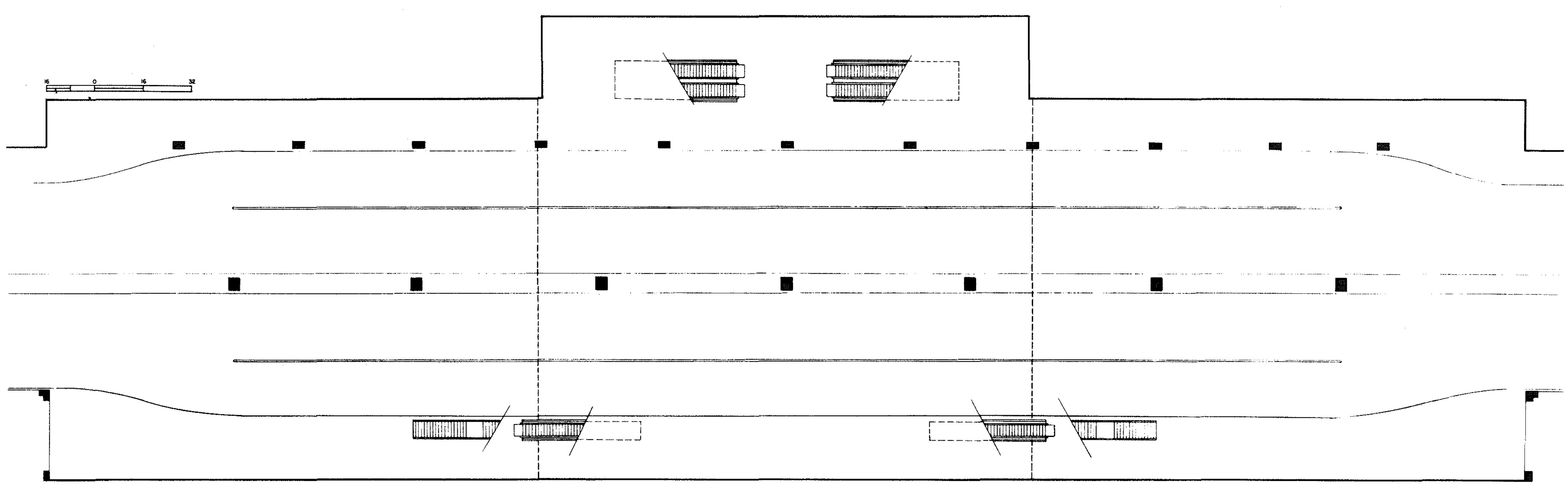


Figure III-17. Street level plan - High density station

Sidewalks "congestion" is important to retailers!

vehicle traffic circulation may be necessary on some of the streets chosen for transit alignment. One partial solution is to relocate presently installed utilities, such as lighting, power and telephone lines which are mounted on poles, to an integral installation with transit way structures and stations. Sufficient width, presently lost to these facilities would be available to widen streets for normal way structures, but would be insufficient to accommodate the conditions occurring at stations. A bonus feature of this method of widening streets would be the removal of the forest of poles presently cluttering the skyline.

Further expansion of factors of available space and adjacent land use should consider space occupied by station platforms for the three systems under investigation.

Obviously, the smallest overhead beamway structure will be the most acceptable to the general public, assuming it is of pleasing appearance. The supported mono-beam system requires the smallest structure. The apparent bulk at a station, however, is not as strongly emphasized due to the size of the platform and weather shelter proportions. By referring to previously tabulated platform width requirements, it is easily seen that the central platform arrangement will produce a condition of least bulk.

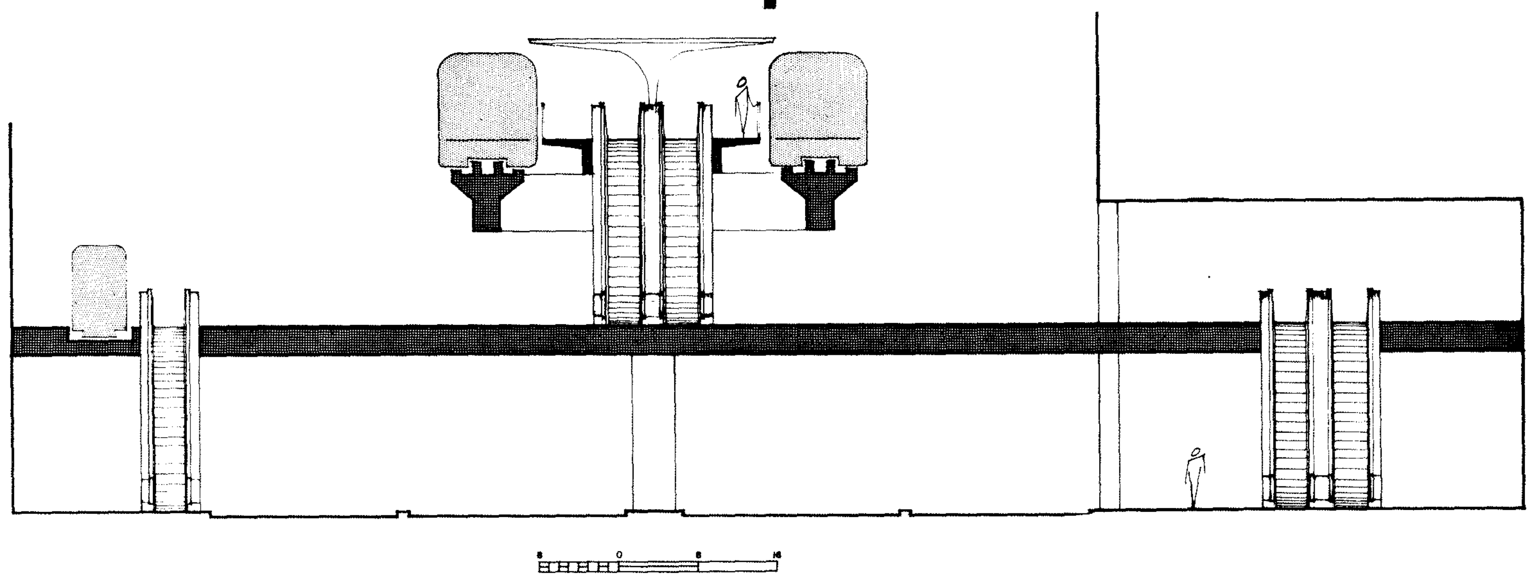
Another advantage of the central platform is that the intruding eye of the transit patron on the platform is removed as far as possible from adjacent property. Although this difference in distance is small, it may be significant in some locations.

Nominal weather protection has been included in all designs. It is reasonable to assume that wind screens and rain or sun shelters are sufficient protection for the transit patron during the brief period between trains. Lighting of this area should be attractive and inviting without annoyance to adjacent property.

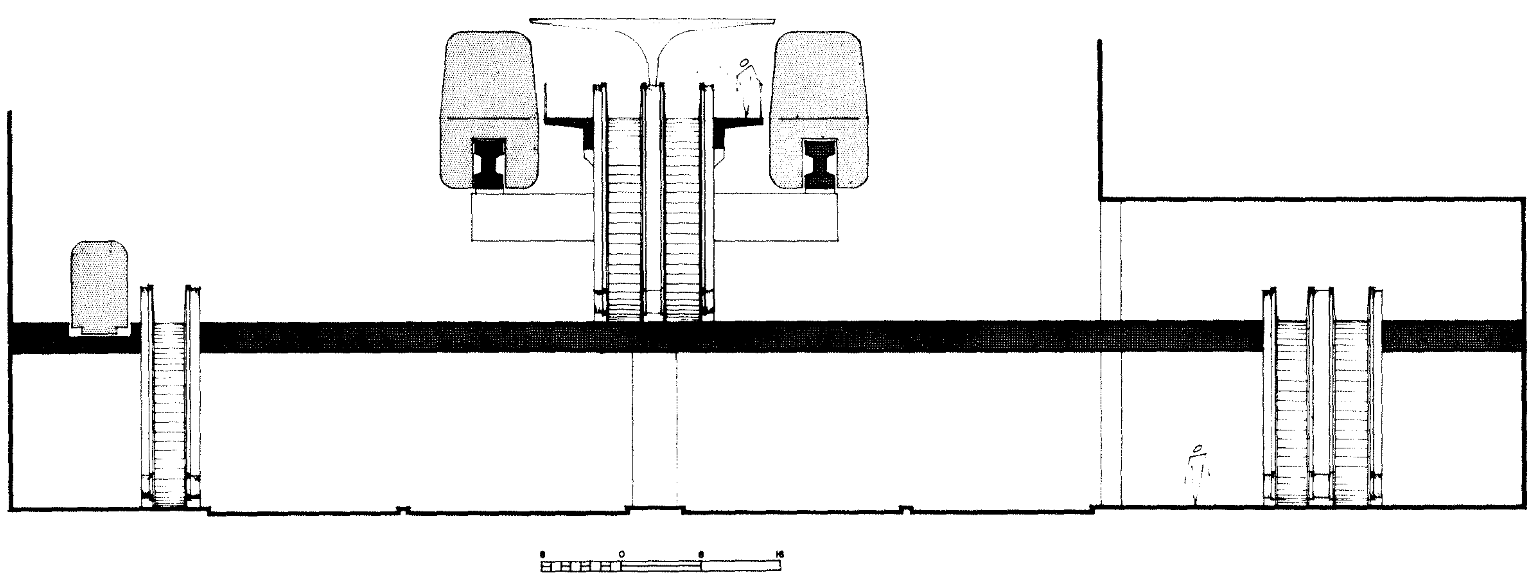
Low density stations have not been illustrated due to their similarity to medium density stations. Differences consist of narrower platform and escalators, and the omission of ticket lobby and street passage area. Fare collection is easily accomplished as space requirement is minimal, for this type of station.

SECONDARY DISTRIBUTION SYSTEM

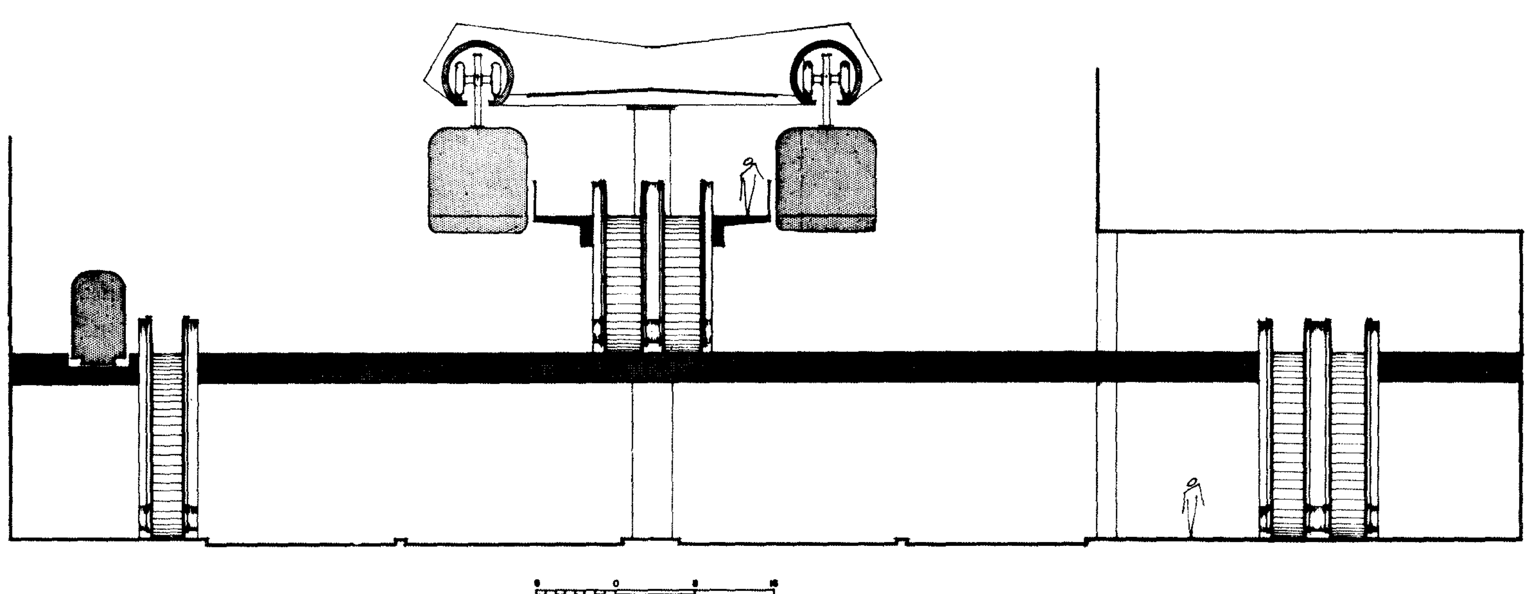
A secondary distribution system for the movement of persons within the Central Business District has been included in the concept of high density stations. A system of secondary distribution in conjunction with the rapid transit system will reduce congestion of sidewalks considerably below that which may be anticipated adjacent to stations if only the rapid transit system is installed. Very little change in station layout will occur if the secondary distribution system is not included.



(1) Dual track system



(2) Supported mono-beam system



(3) Suspended mono-beam system

Figure III-18 Typical cross sections of high density station

TYPICAL MEDIUM DENSITY STATION FOR SUBWAY OPERATION

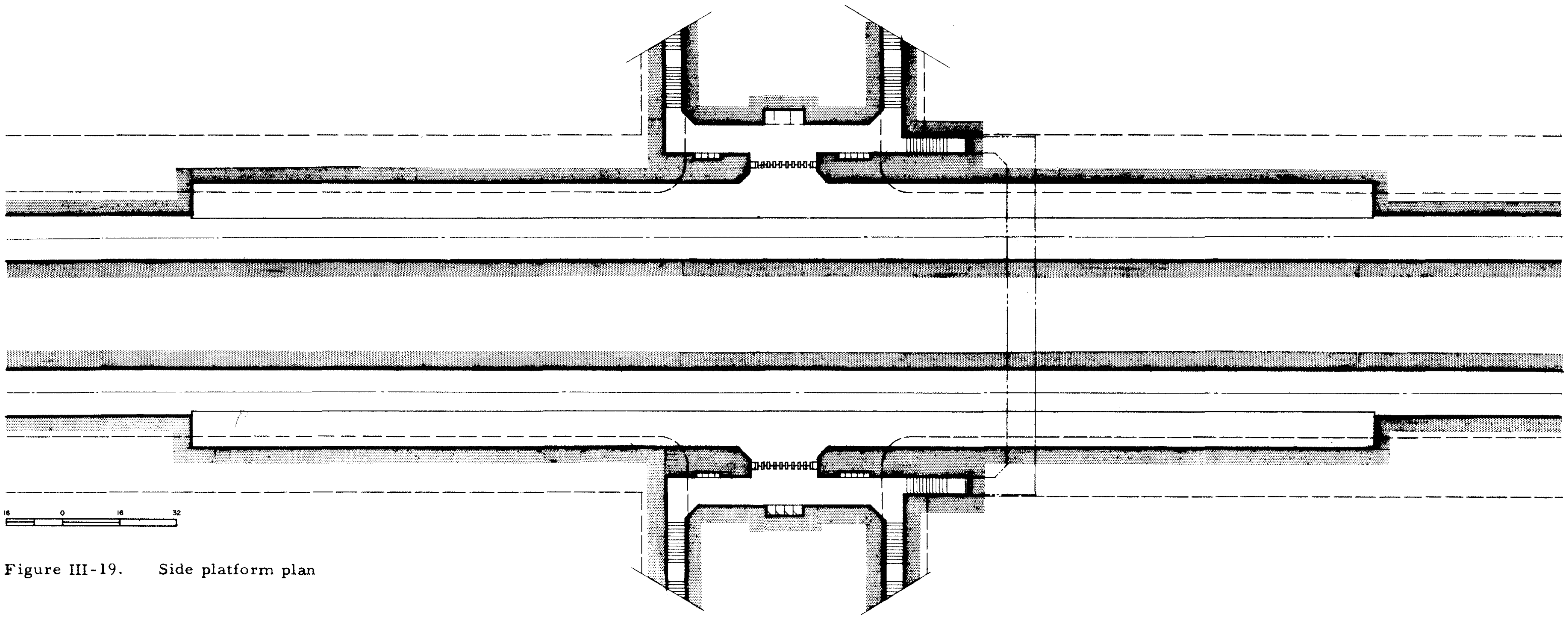
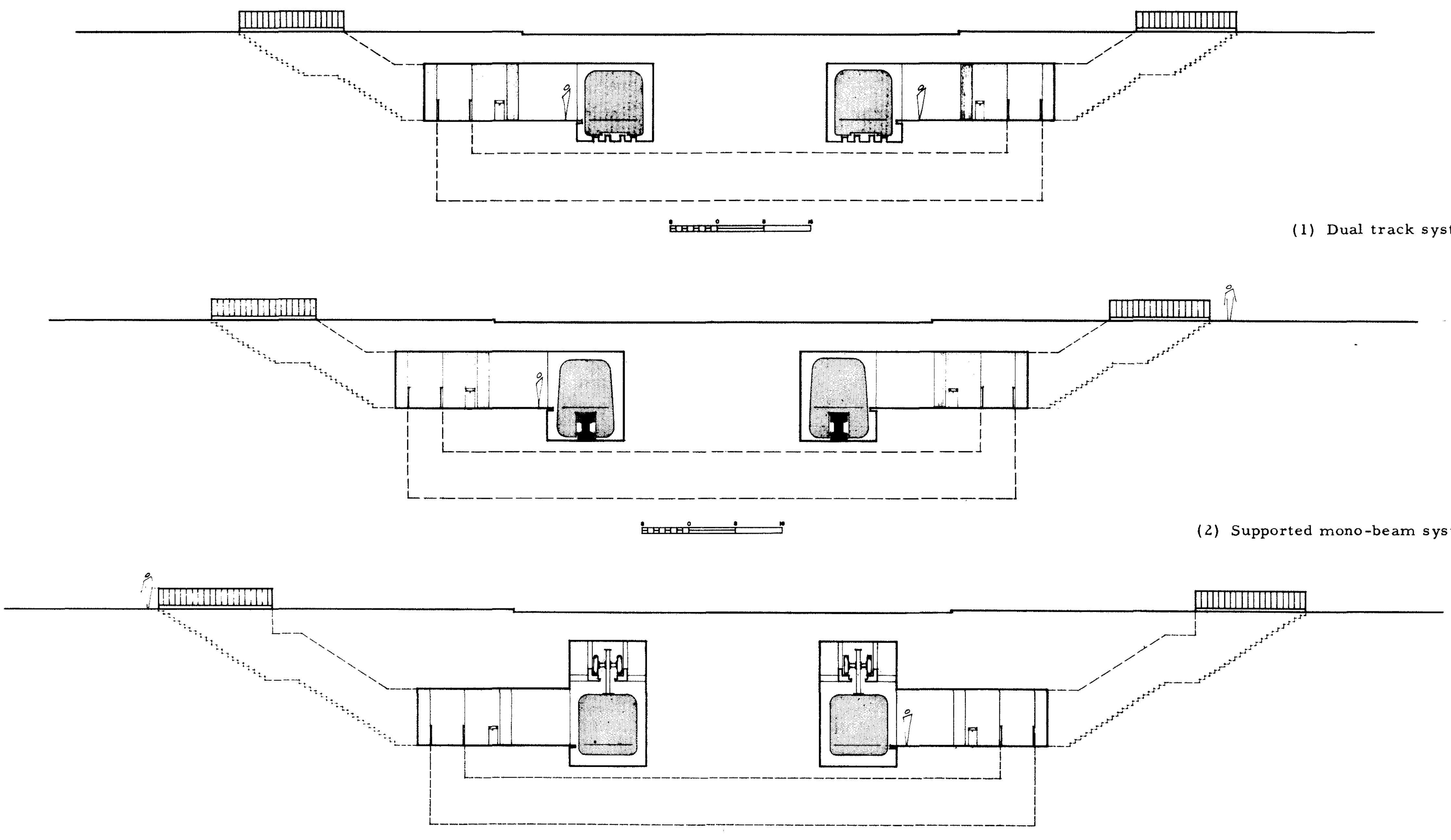


Figure III-19. Side platform plan



(1) Dual track system

(2) Supported mono-beam system

Figure III-20. Typical cross section of station

(3) Suspended mono-beam system

TYPICAL HIGH DENSITY (CENTRAL CITY AREA) STATION FOR SUBWAY OPERATION.

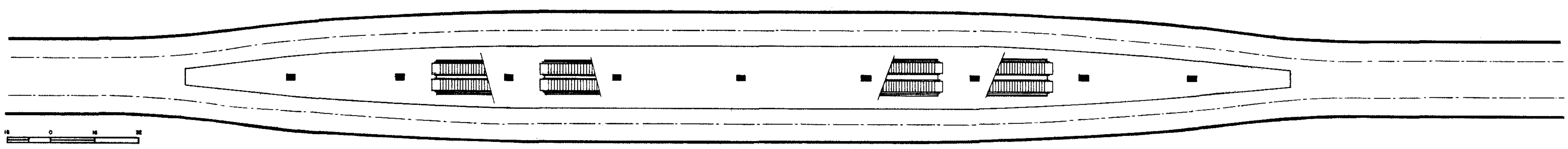


Figure III-21. Central platform plan

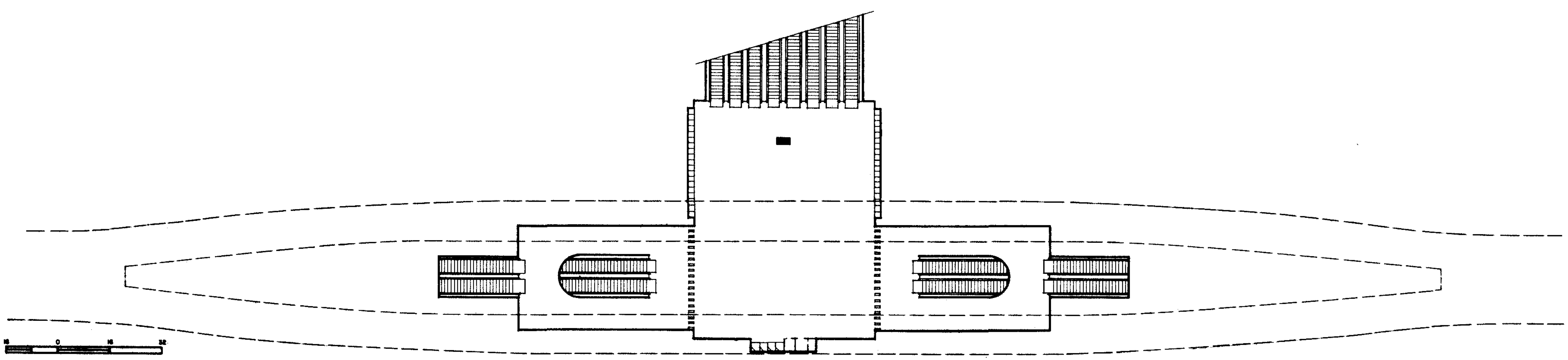


Figure III-22. Mezzanine plan

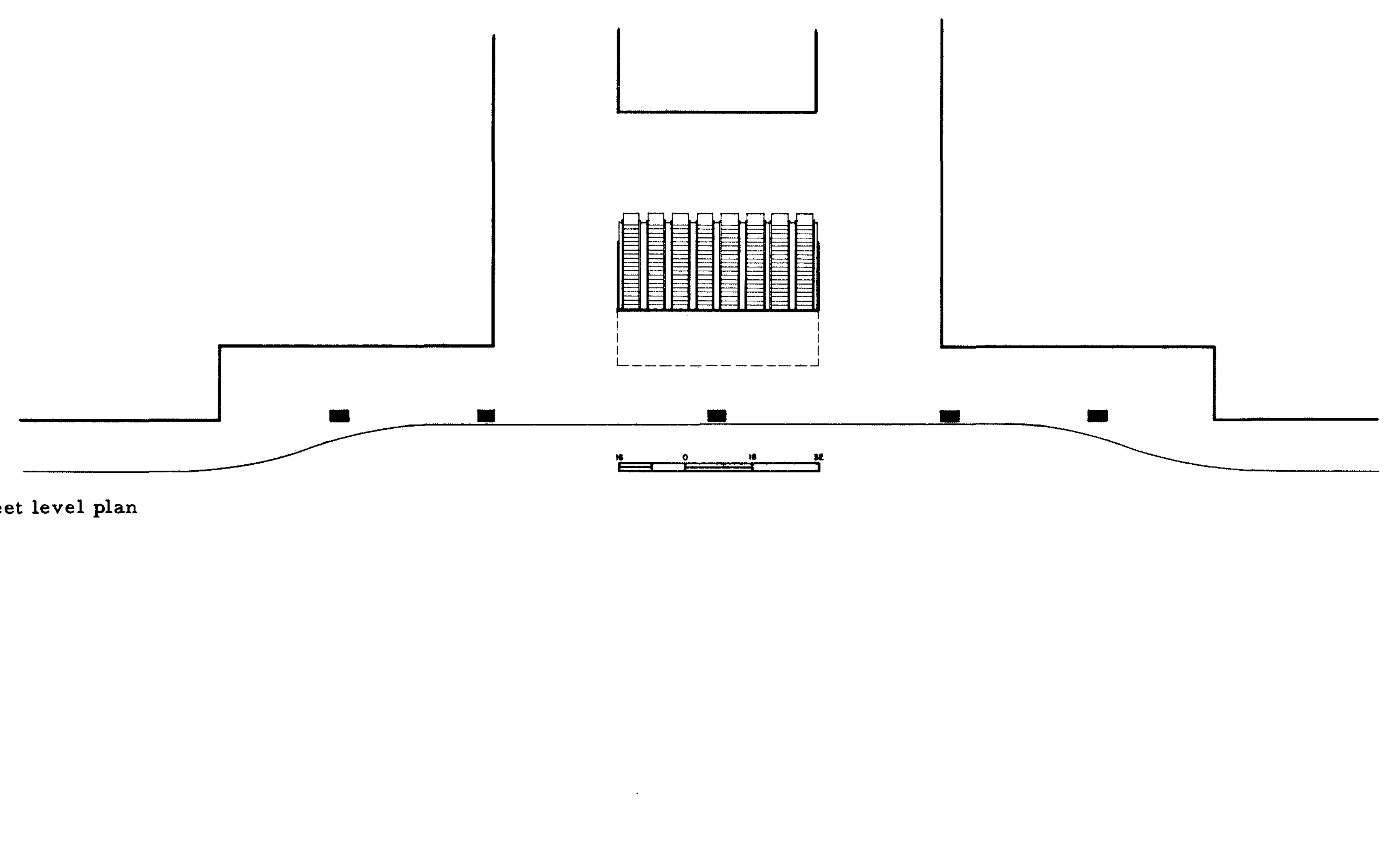


Figure III-23. Street level plan

SUBWAY STATIONS

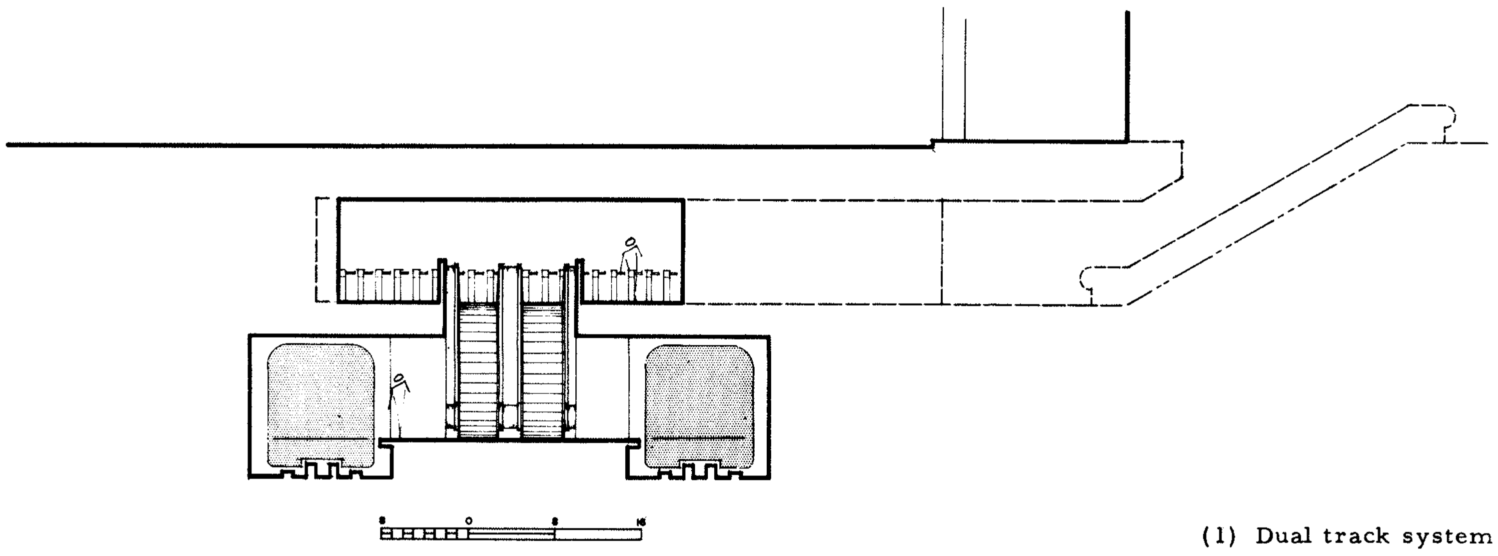
High density (CBD) stations differ from medium density stations in platform arrangement. Central platforms are used in the CBD, primarily to facilitate transfers and provide maximum flexibility in passenger handling. Due to traffic volume, a large ticket lobby is required and a means of gaining maximum traffic dispersal is desirable. These functions are best served by a mezzanine and central platform. The medium density station can function adequately from two platforms and takes advantage of the lower cost of construction. A mezzanine is not required. The resulting shallower stations reduce operating as well as first costs.

A pleasant and safe passenger environment is most difficult and expensive to attain underground. Profuse use of easily maintained tile in light colors may be advantageous to improve psychological conditions.

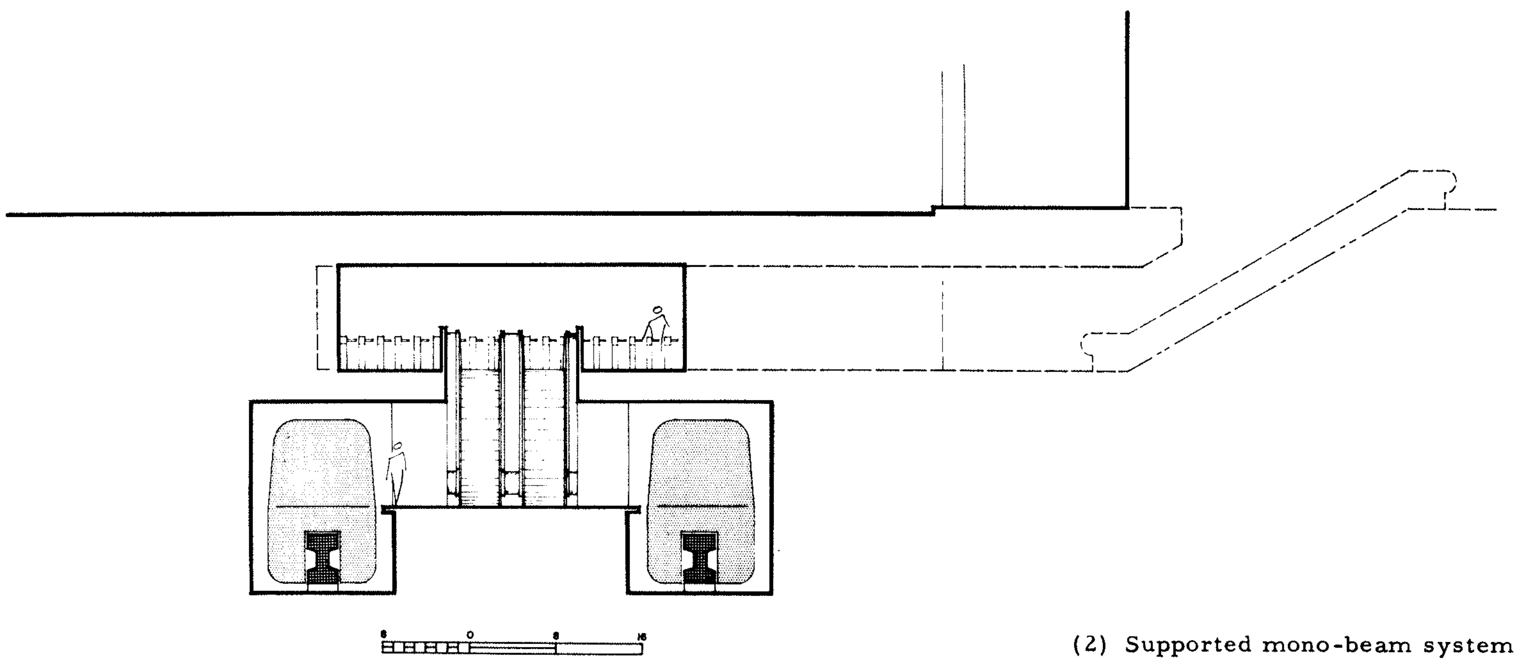
Adequate station and tunnel ventilation is another significant factor effecting passenger health and comfort. The "piston effect" of train operation moves sufficient air for health considerations, but it also creates a rush of air ahead of incoming trains, which is uncomfortable to station platform and lobby occupants. Vent shafts in station entry tunnels and in station ceilings, reduce this discomfort and provide fresh air inlet: shafts spaced at short intervals between stations are required to provide fresh air throughout the length of the tunnels.

Sound control within stations will also improve conditions for passenger appeal. Proper use of sound deflecting baffles in conjunction with strategically located sound absorbing materials should produce the desired result.

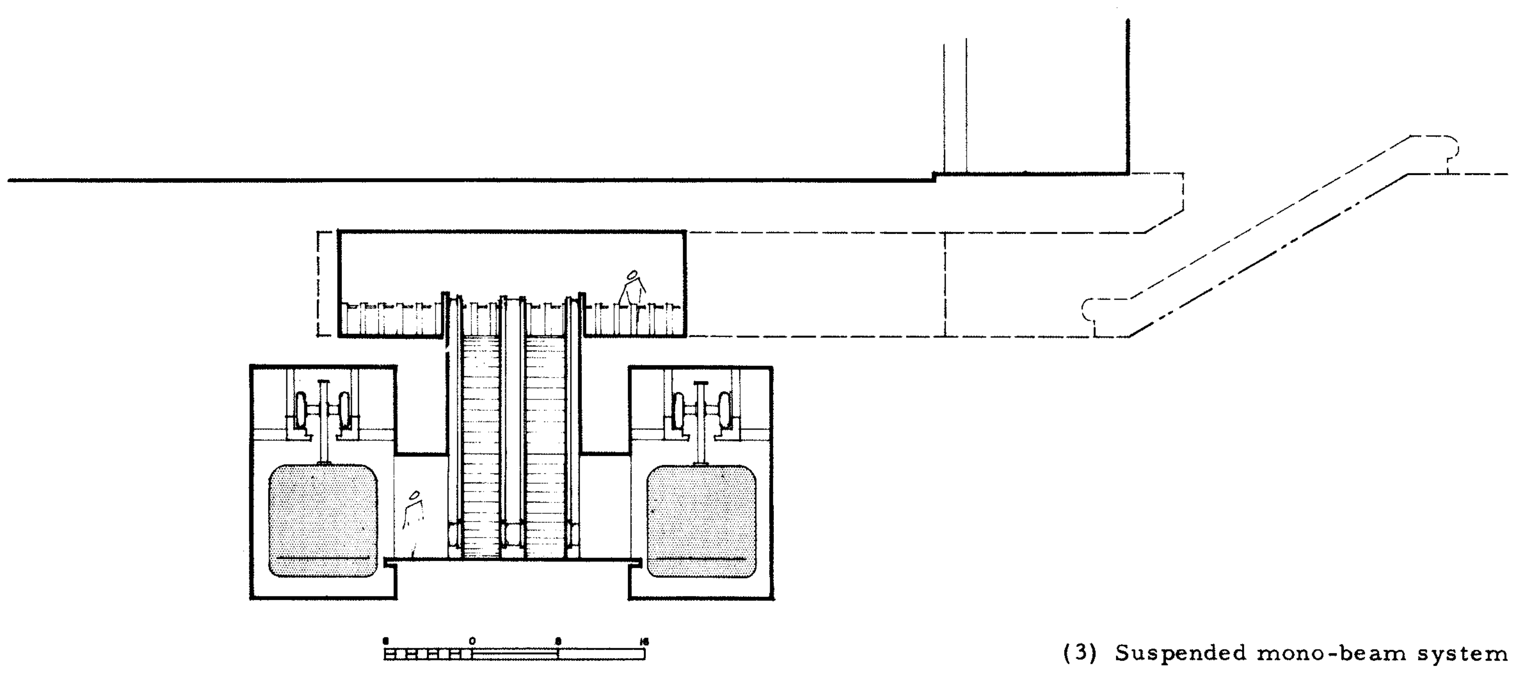
Proponents of underground construction have emphasized the possibility of using subway structures as fall-out shelters. It must be pointed out that structures designed for efficient transit operations will not make effective shelters against weapons of war as are now being produced. An important shelter design feature involves complete and immediate sealing of all portals correlated with blast proof filtered air inlets. The large, easily accessible station entries and numerous direct ventilation facilities in stations and tunnels are incompatible with these requirements. Also, shelters must embody all provisions for prolonged occupancy during periods of hazard. It is reasonable to coordinate shelter and transit construction, but only on the basis of contiguous, rather than identical structures.



(1) Dual track system



(2) Supported mono-beam system



(3) Suspended mono-beam system

Figure III-24. Typical cross section of station

MAINTENANCE AND STORAGE FACILITIES

Facilities required for the maintenance, inspection and storage of rapid transit vehicles are relatively simple structures of a functional nature.

The concept layout of the maintenance shop and central storage yard shown on Figure III-25 is suitable for servicing the needs of any one of the three systems studied. It has been assumed, for purposes of cost estimating, that no existing buildings are available or adaptable to perform the function of maintenance on rapid transit vehicles. It may be possible, however, depending on the system chosen, that buildings do exist which could perform these functions and that such buildings are reasonably accessible from the rapid transit system. A preliminary layout of the dispatchers building to be included in the Macy Street facility of the Authority is shown on Figure III-26.

To minimize operational costs, a storage yard is planned at the end of each of the branch corridors and at the Macy Street facility. It is expected that only the routine inspection, lubrication, cleaning and washing would be performed at end of line storage yards. All vehicles requiring repairs or major maintenance will be scheduled into the Macy Street shop facility. See Figure III-27. This shop will be equipped to do all necessary work to replace components and to do body work and painting. Major machine tools, which would duplicate the existing South Park Shop facilities, will not be provided. Components such as traction motors and air compressors, will be sent to the South Park Shops of the Transit Authority for reconditioning as required.

Based on this operational plan, applicable to all systems, we may discuss the yard requirements for each.

DUAL TRACK SYSTEM - YARDS AND SHOPS

Cars for this conventional system would operate on grade with their steel safety wheels on standard gage track in yards, using conventional switches. Yard requirements will not be greatly different from street car and other rapid transit systems now in existence.

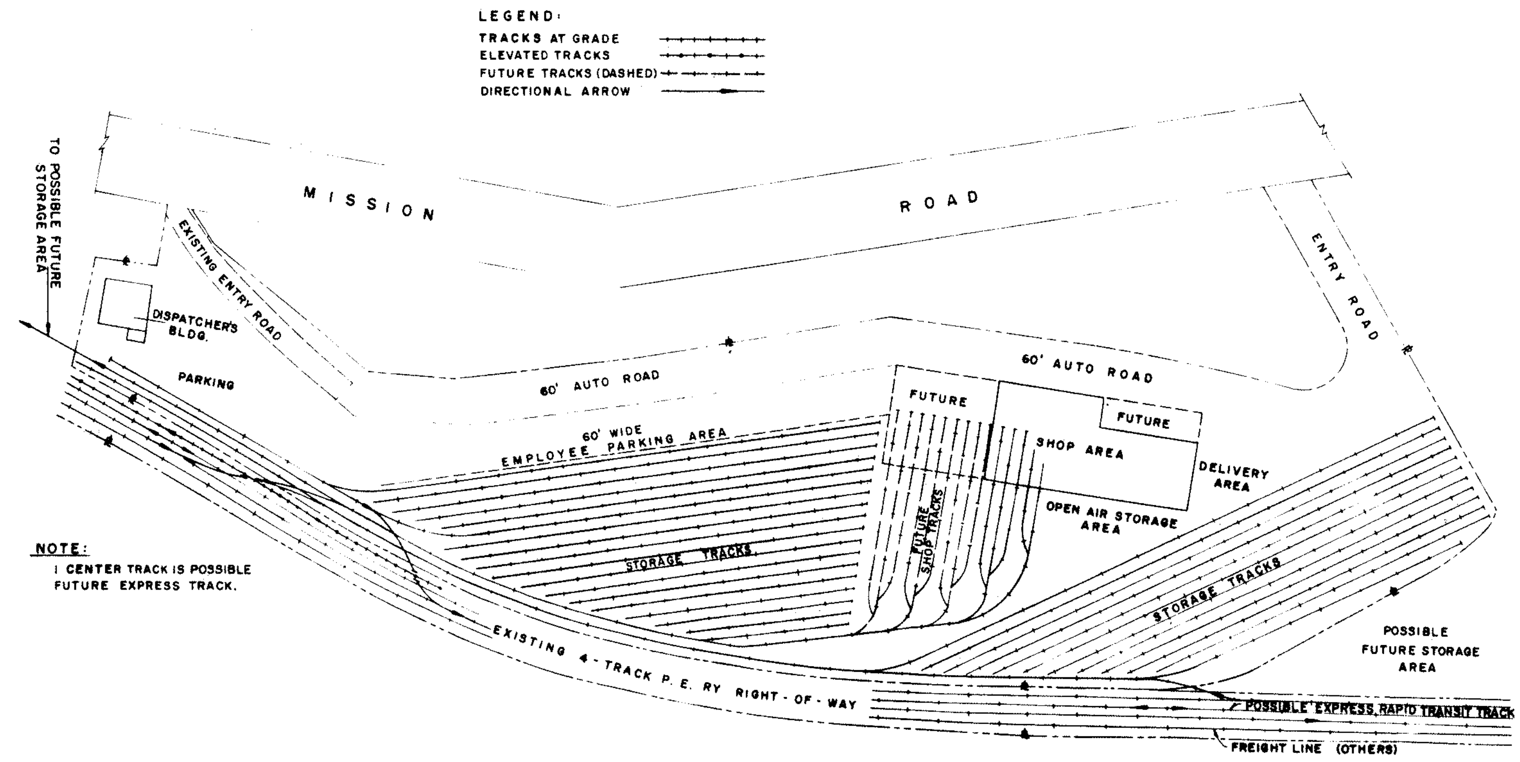


Figure III-25. Plot of suggested maintenance shops and storage yards at Macy Street.

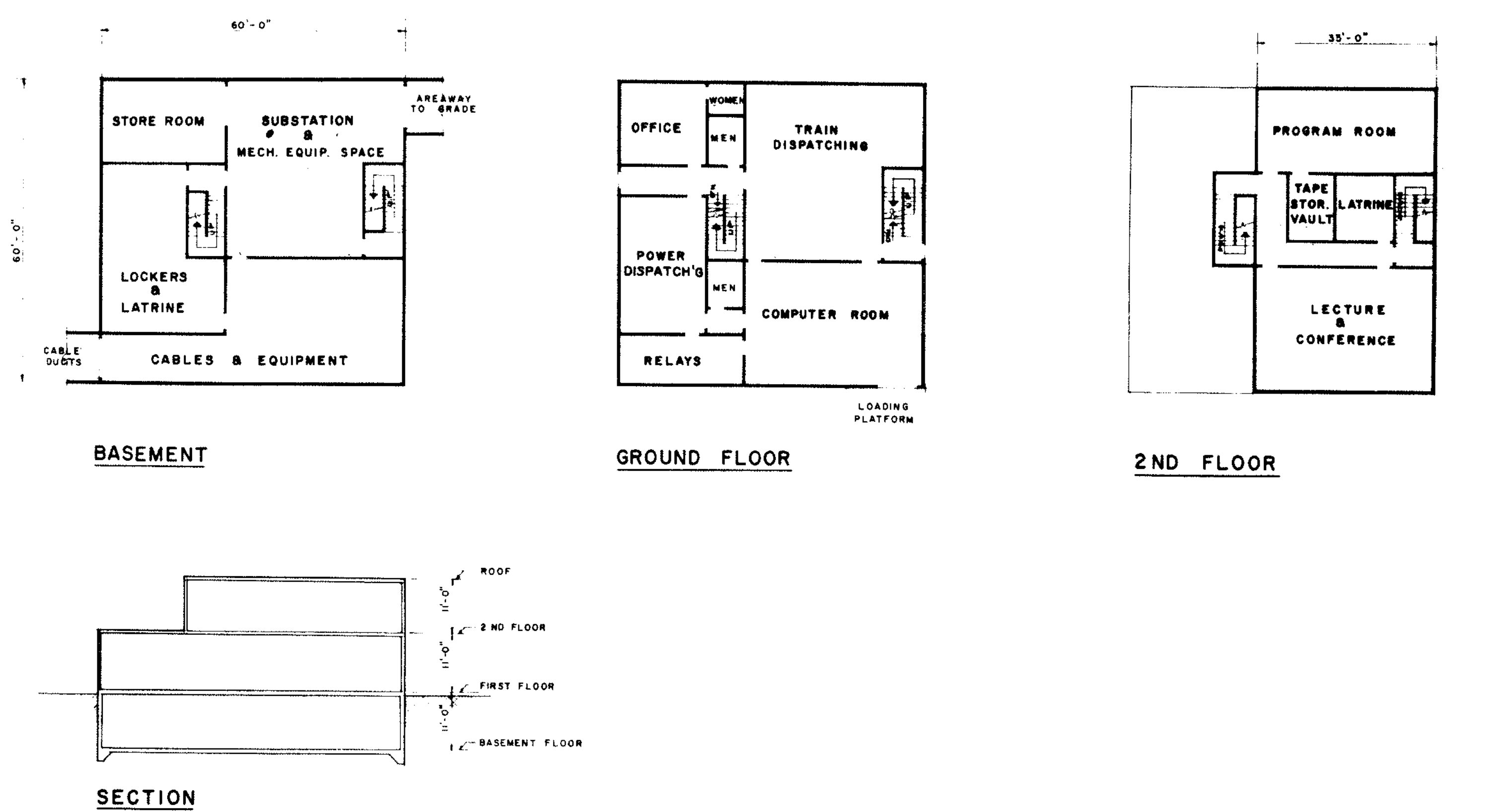


Figure III-26. Preliminary layout of dispatchers building including space-function relationships to be performed for automatic train control system.

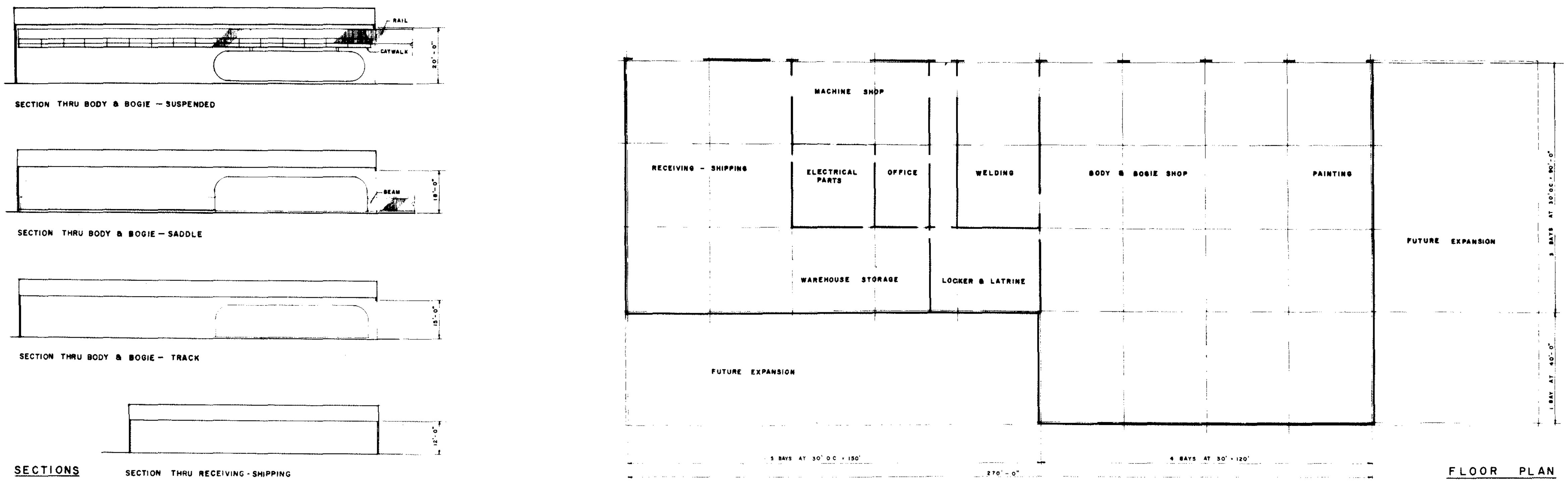


Figure III-27. Concept of central maintenance shop - Initial installation may be expanded as needed to provide additional facilities as the system is expanded in the future. Heights shown on sections indicate openings necessary for equipment to enter the building. Total building height may vary greatly depending on type of equipment selected and manner in which servicing is to be performed.

It should be noted that tracks must be raised above grade by approximately 2 inches even in paved areas. A bonus feature of this operational concept is the elimination of need for vehicle jacks for tire changing since the tires are clear of the ground in storage. Removal of tires will permit cars to be moved over any standard gage track.

An electrical contact rail will be utilized in storage areas but not in shops because of the hazard to personnel. A shop mule on overhead rail and pigtail will be used to move cars as required when away from the contact rail.

SUPPORTED MONO-BEAM - YARDS AND SHOPS

The supported mono-beam system cannot abandon its supporting beam. Since economics force yards and shops to be on grade, the riding beams will form a series of barriers to cross traffic.

Shop and yard layout are restricted by track beams and the need to provide motor vehicle access. Pedestrian cross-overs will be required for access by maintenance and operating personnel in the yards.

The bulky, slow operating, high cost switches force consideration of other means of achieving the switching objective. Round tables and transfer tables are physically able to achieve the transfer, but are so slow as to prohibit making up trains when operating on a short headway. They do, however, offer a possible way of diverting cars going into the shops, since the need then is to move one car when time is not critical.

Since there is no apparent simple solution to this switching problem, it becomes mandatory that the system be designed to utilize the fewest possible number of switches. This, in turn, suggests that the storage tracks be few in number and very long. In the extreme case, this might be just an extension of the main line track or a third track along the main line. However, use of an elongated third track for storage may result in complaints from nearby residents because of the nature of the facility.

Major overhauls requiring removal of the bogie will require the car body be raised from the running gear by an overhead crane. The raised track in shop areas will require passageways below beams to enable mechanics to move throughout the shop. The track at the same time places running gear in an accessible location. Track sections with hydraulic lifts may be desirable.

Since the track beams obstruct other vehicles, shielded power rails in the shop will be required to permit cars to move under their own power. These power rails will be de-energized when not in use.

SUSPENDED MONO-BEAM - YARDS AND SHOPS

Suspended vehicles can come down to ground level, but must always have an overhead structure.

Switches are bulky, slow operating and expensive leading to the long, narrow storage yard concept.

Shops must also have the overhead structure although this may be used to advantage by providing open top tracks and a mezzanine platform for servicing the bogies.

The mezzanine platforms with suspending rails will require heavy framing supporting roof structure to permit open floor space and the use of a shop tug for moving cars. Powered hoists will be used for removing bogies for major repair.

MAINTENANCE OF FACILITIES

If an overhead structure is of pleasing appearance when construction is complete, a regular program of maintenance will be required to retain such appearance. Cleaning at regular intervals by washing steel and brushing concrete structures must be anticipated. A method may be devised which will include a special vehicle operating on the transit system track which will be capable of performing the necessary cleaning task. Painting of steel structures presents a more serious problem from the standpoint of economics. However, with proper specification of materials and workmanship, and proper periodic cleaning, a painting cycle of two years or more may be expected to provide the level of appearance desired.

SUMMARY - MAINTENANCE AND STORAGE FACILITIES

The shop building layout indicates variation anticipated in building for the three systems under consideration.

Gross building height has not been established due to the close relationship of final equipment design to operational practice. Space allocation for indicated functions has been established from current practice and anticipated needs for the new system.

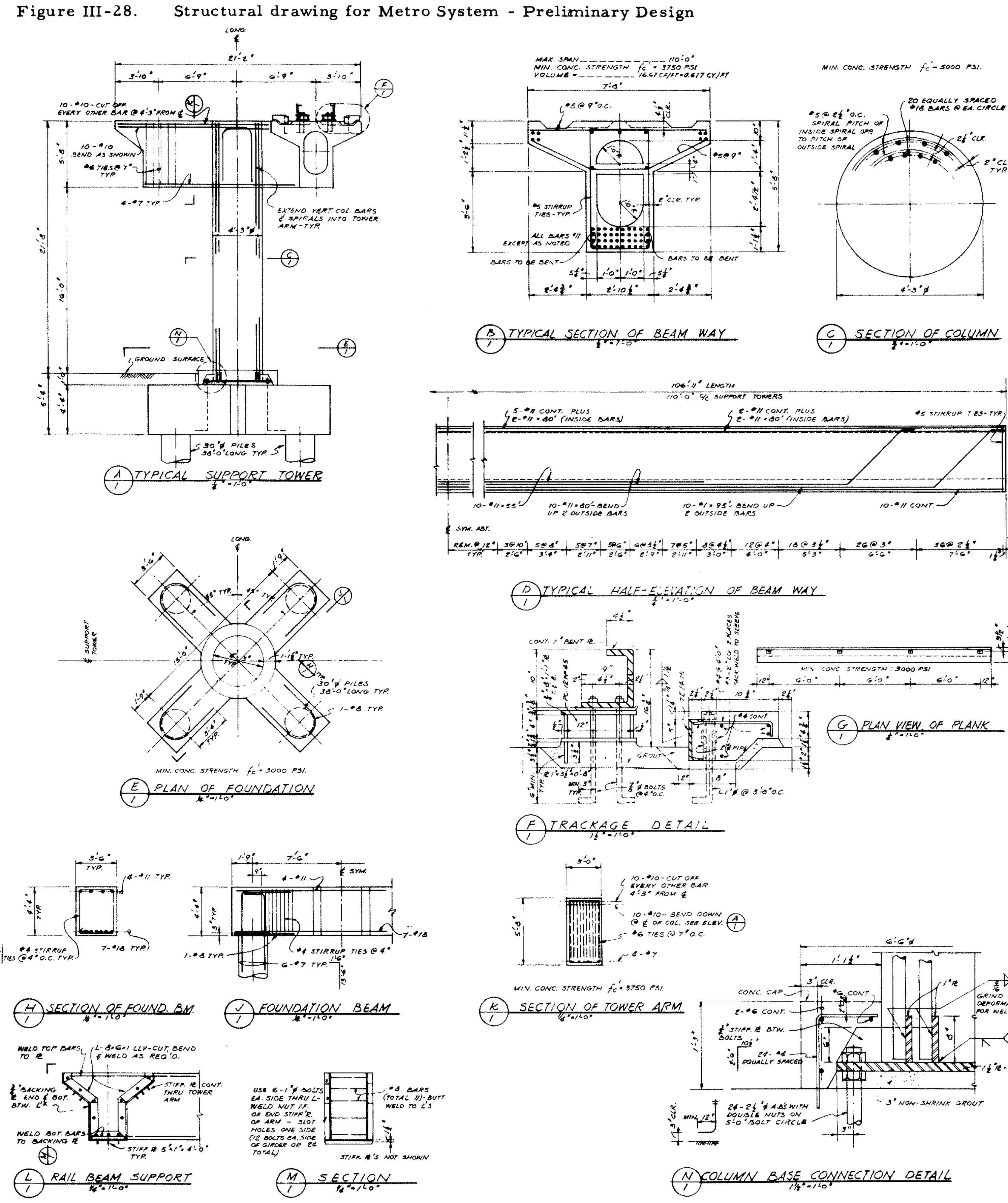
Storage track layout is based on the dual track system. Either of the other systems would follow a similar pattern with the addition of at least one transfer table.

COMPARISON OF SYSTEM FACILITY REQUIREMENTS

In determining the influence the facility requirements of the several equipment systems will have on the over-all selection of the system, it is necessary to select certain parameters. The Authority, because of its enabling legislation and financing limitations, has sought the configuration most economical to construct and operate. The Authority is vitally concerned with the many effects of the transit system upon the community through which it passes, and must also provide a system with maximum appeal to the user. Those criteria indicate the desirability of quiet equipment, running on a graceful, predominately overhead structure, except in areas where operation at grade is possible. A short section of tunnel is used in an area where city streets are not suitably oriented and it is more economical to build underground than to acquire private right-of-way.

The comparative analysis included in Section II of this report covers many aspects of the differences in facility requirements. In addition, a further comparison of the difference in facility requirements will be found in the estimates of the cost of the several systems found in the COST ESTIMATES Section of this report, since the facility portion of a transit system amounts to such a large proportion of the over-all cost. It is felt that this cost comparison is the most significant comparison which can be made, for while the systems each have certain advantages and disadvantages in each configuration, they can be adapted to any of them, and thus the selection from the facilities standpoint is primarily a matter of cost. Preliminary structural details of the three systems were developed for cost estimating purposes. Figure III-28 shows the drawing of details for the recommended overhead "Metro" system.

Figure III-28. Structural drawing for Metro System - Preliminary Design



Subway construction is entirely possible in Los Angeles, but would cost from two to three times more than overhead facilities which provide the same service. A subway system in the Central Business District and in the Wilshire Corridor would have many advantages. However, a predominately overhead system would be, by far, the most economical to build and operate, and is therefore recommended. Overhead "Metro" lines would be installed with long span beams and single column construction in order to provide an aesthetically pleasing structure. An example of this type of construction is shown on Figure III-29.

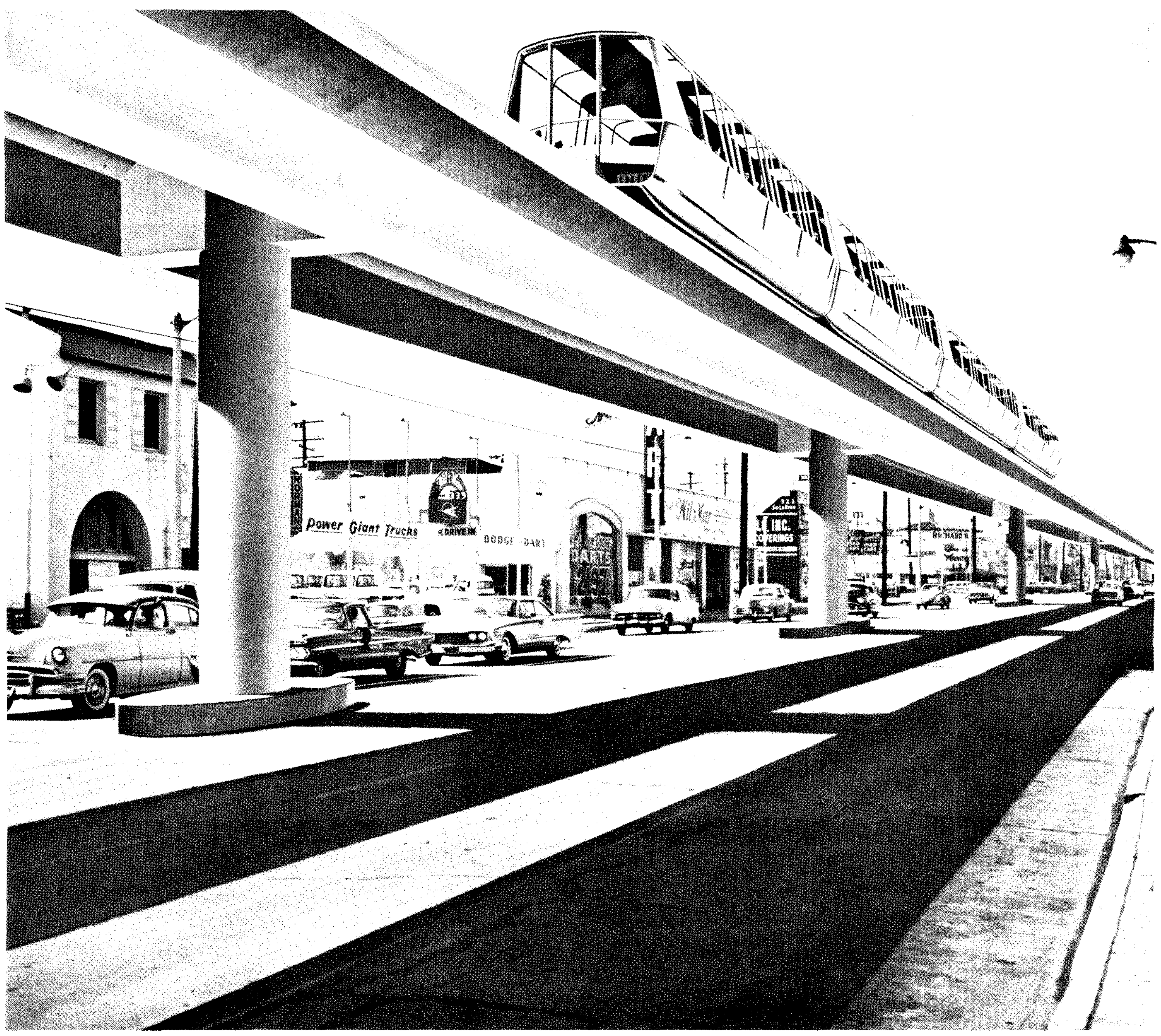


Figure III-29. Photograph rendering of La Brea Boulevard overhead.

Section IV–Alignments and Station Locations

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LIST OF ILLUSTRATIONS

Alignments and Station Locations

ALIGNMENTS AND STATION LOCATIONS

The report of Coverdale & Colpitts, covering their study of public transportation needs in the areas of Southern California served by the Authority was submitted on May 5, 1959. The principal objective of this study was the determination of potential rapid transit routes. Upon completion of the study, they reported on twelve travel corridors, each approximately two miles wide, and recommended to the Authority the following four corridors emanating from the Central Business District (CBD) as the most promising routes for initial rapid transit installations.

1. Wilshire - CBD to Santa Monica
2. Reseda - CBD via Wilshire and Cahuenga Pass to Reseda
3. San Bernardino - CBD to Covina
4. Long Beach - CBD to Long Beach

These corridors are shown on Figure IV-1. The selection of the corridors was approved by the Authority with the stipulation that further engineering investigations be carried out prior to the selection of specific alignments within the corridors. This section of the Report will review the various factors influencing the selection of alignments and station locations, and will analyze and compare the several most suitable alignments available within each corridor. The position of the Los Angeles Central City at the junction of the corridors makes it the hub of the transit system and service to it will be considered separately from the corridors.

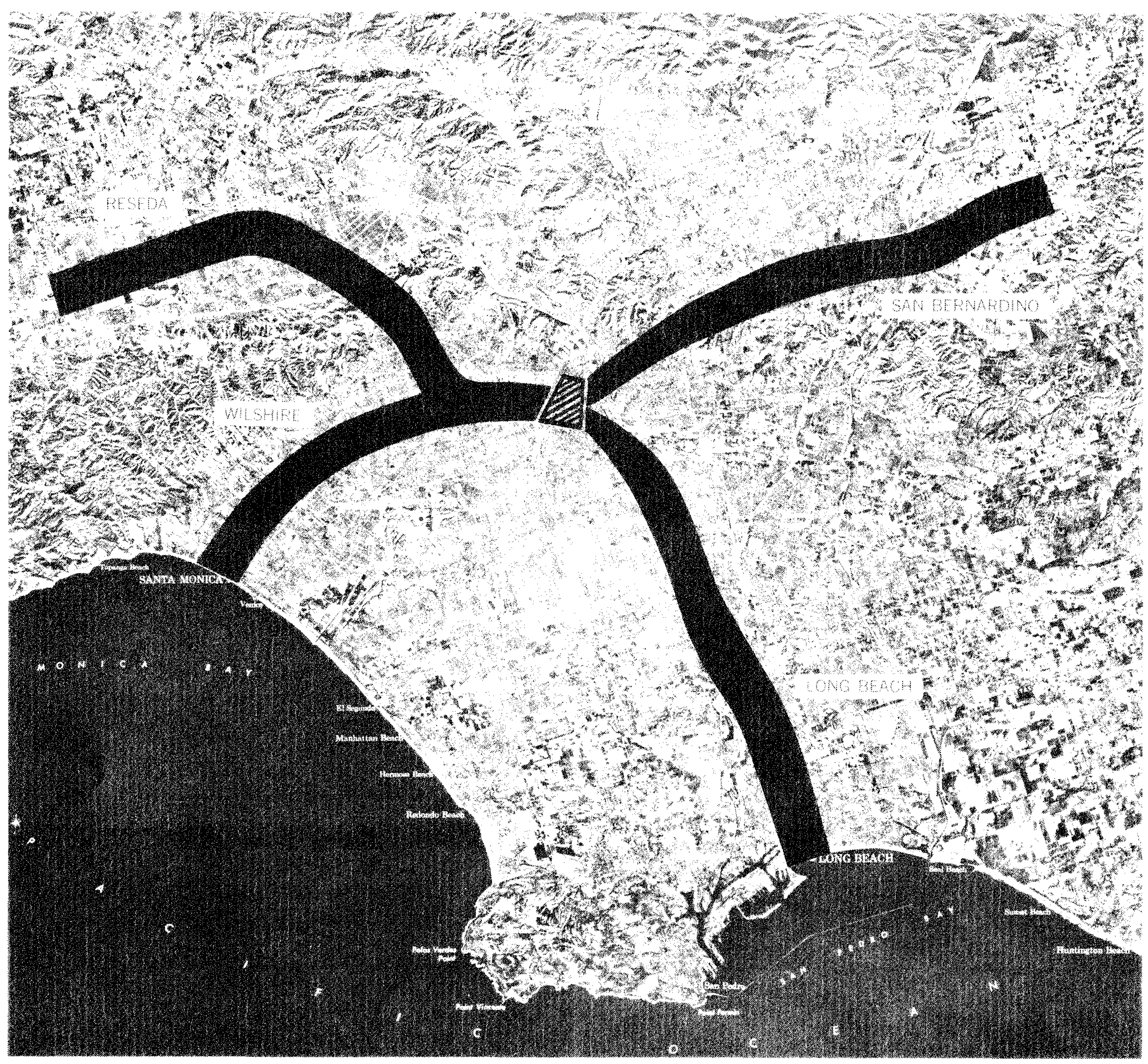


Figure IV-1. Map Showing Four Travel Corridors Recommended for Initial Consideration

LONG-RANGE DEVELOPMENT PLAN

While the initial phase of rapid transit development in the Los Angeles Basin would be confined to the four corridors previously stated, it is apparent that service to additional corridors will be required. Before proceeding with detailed route locations in the initial four corridors, a Long-Range Transit Development Plan was worked out to insure that initial transit installations would be flexible and compatible with the future growth of the city and of the transit system. The basis for this Long-Range Plan was the information contained in the Coverdale & Colpitts Report previously mentioned. This report considered twelve possible corridor locations. Of these, two were variations of the San Fernando and Reseda Corridors; one, designated Pico, closely paralleled the Wilshire Corridor. Another corridor, designated the San Gabriel, was between the San Bernardino and Pasadena corridors.

This investigation evolved the 150-mile eight corridor Long-Range Development Plan illustrated in schematic form on Figure IV-2. This figure indicates the four initial corridors along with the recommended plan for the development of at least four additional corridors as follows:

1. San Fernando via Glendale and Burbank
2. Pasadena
3. Santa Ana
4. Inglewood

In addition, as traffic builds up in the Wilshire Corridor, an express line will be needed between the Central Business District and the Reseda Corridor. Final selection of the eight corridors was determined to provide service into each of the major passenger generating areas without duplication.

Recognizing that each of the eight corridors must pass through the Central Business District, a careful and detailed analysis was made of possible alignments and interchange points. Several alternates were considered and are discussed elsewhere in this report. At such time as the additional corridors are developed, the complex of rapid transit facilities to and through the Central Business District would, in effect, produce a full loop system. Thus, a transit patron could travel from any one of the eight corridors to any other corridor with no more than one transfer at any one of three principal interchange stations. With certain corridors, no transfer would be required.

Secondary distribution in the CBD was also considered in selecting route alignments. On the initial phase, using an off-side main line, secondary distribution could readily be incorporated to bring transit passengers within two blocks of any destination in the CBD. This system would also serve future San Fernando and Pasadena lines running along Figueroa providing easy access to the downtown area from all transit lines.

ALIGNMENT AND STATION LOCATION COMPARISON FACTORS

In making a comparison between alignment and station location alternates, certain parameters and factors must be considered.

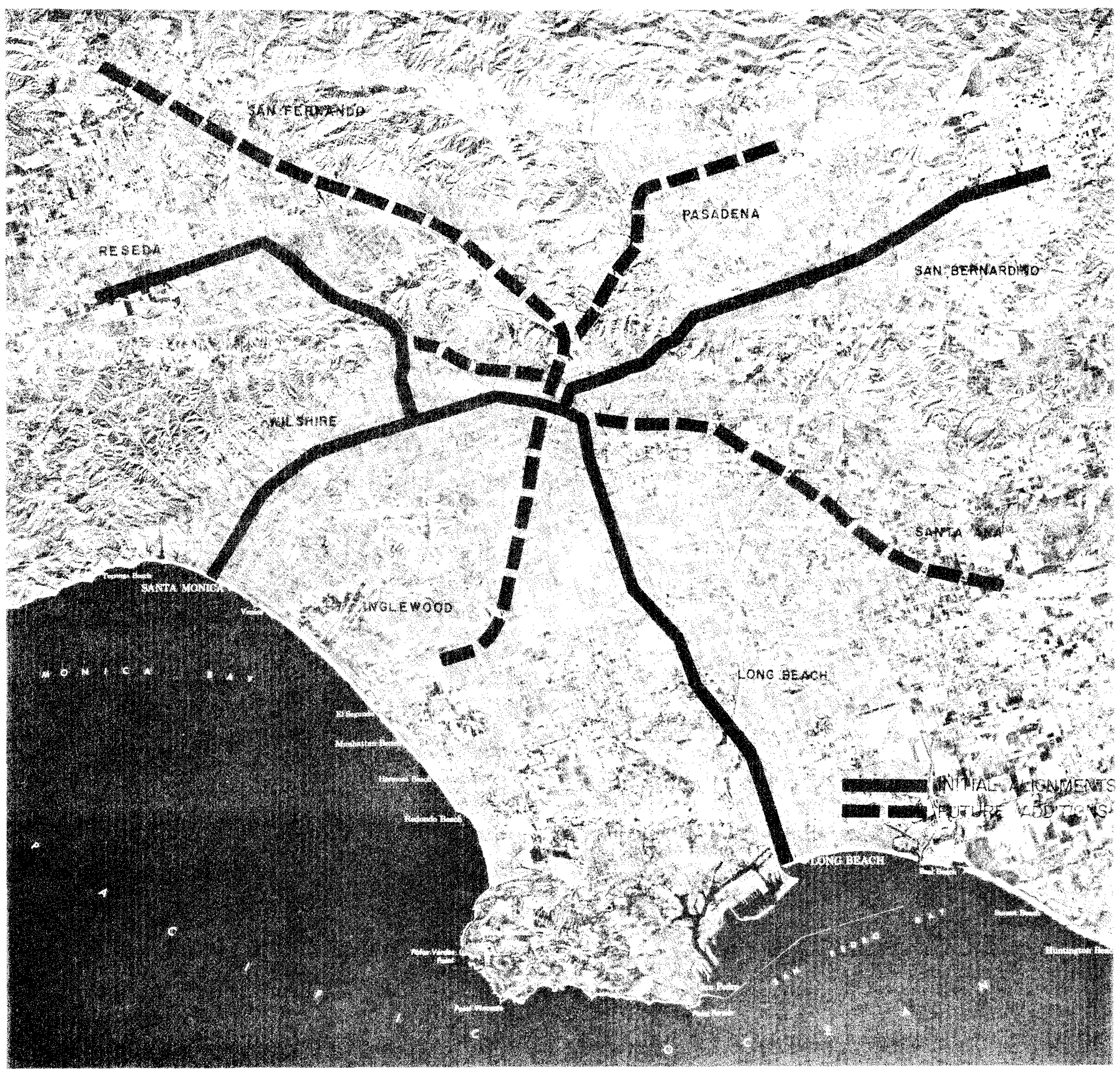
In general, the goal is to provide the most service for the least construction cost and the least community disruption. The following paragraphs will review the factors influencing the choice of alignments and station locations and, in addition, will briefly discuss community acceptance factors.

ALIGNMENT FACTORS

The selection of specific alignments in each of the four corridors has been based on the following factors:

- Service
- Community Acceptance
- Land Use
- Physical Obstacles
- Available Right-Of-Way
- Comparative Cost

Figure IV-2. Long-Range Development Plan



These factors were applied to the several possible alternates in the preliminary selection of the two or three alignments to receive detailed comparison in each corridor.

The same procedure was followed in the Central Business District. However, the higher density of the Central City required a greater emphasis of secondary distribution of passengers. Therefore, service considerations became a dominant factor in alignment selection.

STATION FACTORS

The selection of rapid transit station sites was based on several basic considerations:

- Expected passenger volume densities as obtained from the Coverdale & Colpitts reports.
- Spacing requirements needed to maintain desired speeds and headways.
- Proximity of site to major surface streets and freeways that would provide adequate access to established bus routes and to passengers arriving by automobile for "park 'n ride" or "kiss 'n ride" service.
- Adaptability of site for construction of stations and facilities.

COMMUNITY ACCEPTANCE FACTORS

During the evaluation of alternate alignments within each of the four initial system corridors, community acceptance factors were given primary considerations. Basically, these factors were divided into two main categories: Internal, which pertains to transit vehicle and station design comfort features affecting the transit system passenger; and External, which includes noise, traffic interference, neighborhood disruption, utility interference and aesthetics affecting the transit system neighbor.

The criteria used during the evaluation of alternate alignments for the four recommended corridors from the community acceptance standpoint, were developed with the assistance of Victor Gruen Associates, consulting planners who conducted special investigations[1] in community planning.

These criteria factors are:

- Traffic Interference - System must be grade-separated throughout.
- Neighborhood Disruption - Reasonable frequency of access must be made across the system to maintain continuity of neighborhood areas.
- Utility Interference - Unreasonable disruption must be avoided during construction of system.
- Aesthetics - Transit vehicle, way structure and station design must have a high degree of visual attractiveness.

[1] "Community Planning Considerations", letter report by Victor Gruen Associates, June 1960.

STATION PLANNING - EXTERNAL FUNCTIONS

Rapid transit stations are planned to provide an efficient fare collection system, maximum comfort and pleasing aesthetics, and whenever possible, to facilitate important external functions such as:

- Bus connections
- "Park 'N Ride" operation
- "Kiss 'N Ride" traffic
- Pedestrian flow
- Transferring
- Relation to streets and sidewalks
- Access to buildings

Layouts of two typical stations incorporating many of these features are shown on Figure IV-3.

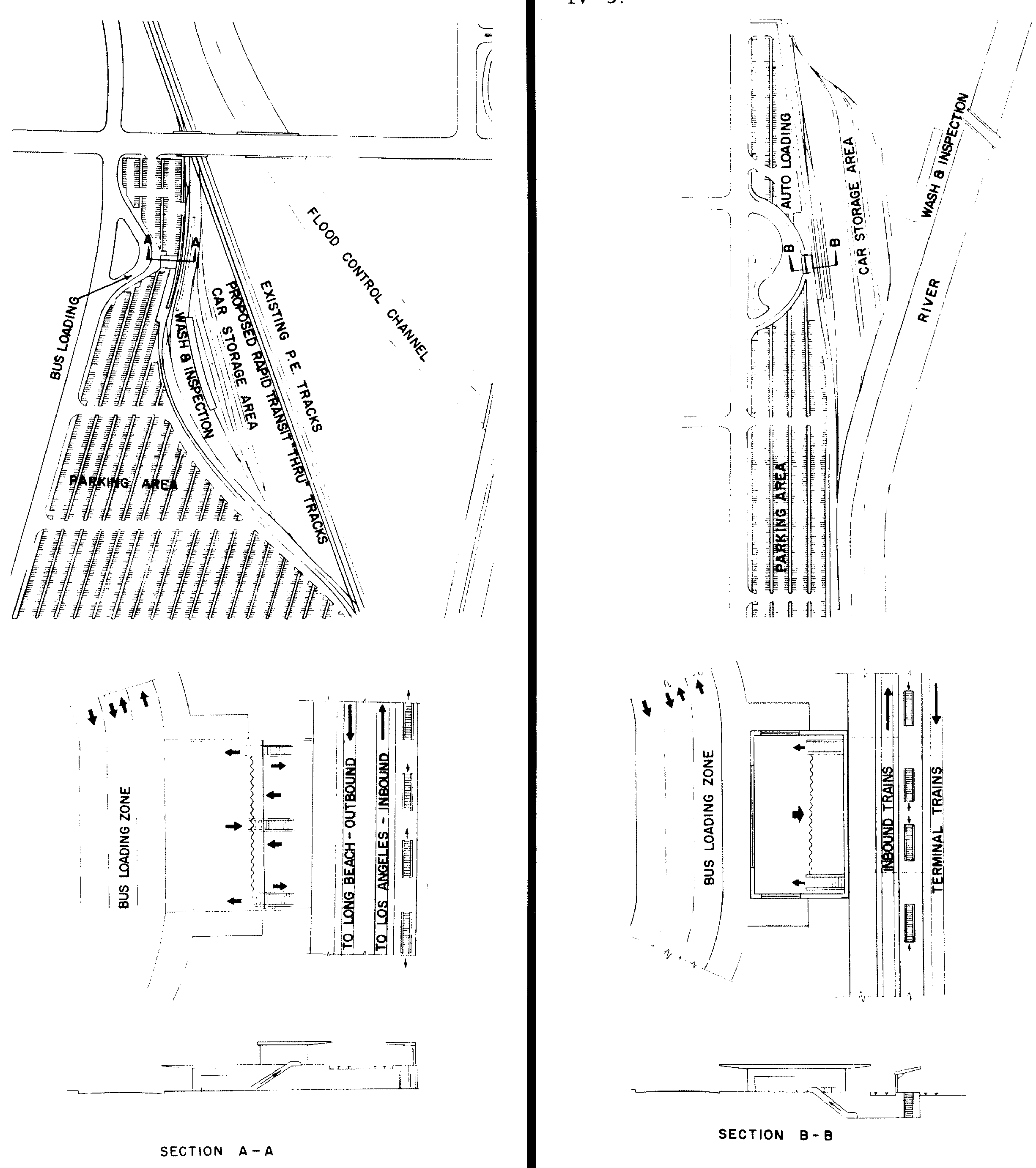


Figure IV-3. External Layouts of Outlying Stations

BUS CONNECTIONS

Integration of surface transit service with the proposed rapid transit system is highly essential in order to offer a well coordinated mass transportation plan. Such surface transit service, buses or trolleys, will deliver passengers to rapid transit stations and stimulate the overall patronage of the transit system. Bus loading facilities at major stations would be provided by special ramps or turnout lanes. At other stations, similar provisions should be considered or curb loading zones provided as a minimum facility.

"PARK 'N RIDE" OPERATION

Certain stations have been designated as "park 'n ride" stations for the initial system. Provisions have been made for approximately 1800 automobiles spaces in the Wilshire Corridor, 3000 spaces in the Reseda Corridor, 4000 in San Bernardino, and 1500 in the Long Beach Corridor.

It is reasonable to expect that the parking demand in each corridor will appreciably exceed these figures. However, the lack of sufficiently large parcels made it necessary to provide parking only at key locations and limit the number of spaces to the size of the lot which may be available at a reasonable cost. The Wilshire Corridor, for example, is expected to carry the highest number of transit riders exclusive of the Central City Area. Estimates indicate the probable parking demand may exceed 6000 spaces in the initial phase. Yet the high cost of land along this alignment limits consideration to areas providing 1800 spaces at this time. Further investigation seems warranted on this problem after a more precise determination of traffic and revenue estimates.

"KISS 'N RIDE" TRAFFIC FLOW

In addition to providing parking facilities at major stations, it is important that short-term loading zones be established for those commuters whose wives or friends provide automobile rides to and from stations.

Many proposed rapid transit stations are located along streets where no off-street parking or loading facilities are available. It may be desirable to request local authorities to provide parking areas, or curb loading zones, and it may be possible to construct special off-street loading areas or access driveways for such traffic.

PEDESTRIAN FLOW

Regardless of the conveyance to the station area, the passenger must reach the platform by foot. His approach must be made direct and safe.

This means that at all stations special provision must be made to allow the pedestrians to reach the platform with a minimum of effort and conflict. Should the station be located in the median of a street, direct connection between the sidewalk and platform will be necessary. This will be done by a walkway connected by stairs or escalators, rising above the trainway, crossing over, and then back to street level; through adjacent buildings; or by pedestrian underpass.

TRANSFER FACTORS

In the recommended initial phase, we have given careful consideration to the desires and convenience of passengers whose trips will necessitate a transfer movement. There will be four transfer points or stations in the initial system; three in the Central City Area, and one at the junction of the Reseda and Wilshire Corridors. In each case the transfer from one line to another could be made conveniently by a cross-platform movement.

Convenient physical transfer features alone cannot accomplish the job of providing the rapid transit rider with the kind of fast, efficient service he demands. The system must have the maximum frequency of service physically and economically possible.

During rush periods, the time interval between units may approach the generally accepted minimum safe operating headway of 90 seconds; at other times headways could vary up to 15 minutes, depending on fluctuations of passenger volume demands and the time of day. With this kind of service, riders transferring from one line to another may leave one transit vehicle, and after a minimum wait at the station platform, board another transit vehicle to a destination.

Further review of frequency of service and scheduling will have to be made after more detailed estimates of passenger loads are made by others.

Interchange features or transfer between rapid transit vehicles and supplementary equipment will also be part of the overall mass transportation plan. As mentioned heretofore, feeder buses must be considered an important branch of the plan bringing passengers from areas not within reasonable walking distance of rapid transit stations. Each station, therefore, must be designed to provide easy, direct transfer of bus passengers onto rapid transit vehicles. This has already been discussed elsewhere in this report in more detail. Scheduling of feeder bus lines must, of course, be coordinated with the rapid transit system to offer an optimum service.

In addition to bus interchange facilities, it has been recommended that a secondary distribution system be incorporated into the Central City Area plan. This system is described more fully in the section covering the Central City Area. However, mention should be made here that this is also considered as a transfer feature of the overall transportation plan.

Direct transfer facilities will be provided at Central City stations between rapid transit vehicles and secondary system equipment.

RELATION TO STREET AND SIDEWALKS

Where rapid transit stations are located along streets, there must be certain minimum standards established to avoid the creation of undesirable aesthetic features, unsafe conditions, and characteristics detrimental to the efficient and expedient flow of automobiles and trucks along the street. In general, means for direct access of pedestrians between the sidewalk and station platforms by an underpass, overpass or an abutting building will be provided.

Should the rapid transit structure be overhead, vertical and horizontal clearance and safety requirements have been reviewed and clearly established.

Where special bus access driveways for loading and unloading of rapid transit passengers are required, establishment of an ordinance usually will be necessary.

If the rapid transit line is below grade, the problem of clearances will generally apply only to the sidewalk areas where stairs or escalators will be constructed. In general, a minimum clear sidewalk width of five feet must be maintained unless otherwise approved by the governing public agency.

In the matter of maintaining safe flow of vehicular traffic, the space required by way structure columns and street median must not reduce the remaining street width to a point where substandard lane widths results. Such lane widths should be kept at 11 to 12 feet. However, in some instances, a minimum of 10 feet may be used if approved by the public agency which has jurisdiction over the street. Additional features such as guard rails, lighting, signs, etc., must be provided at pedestrian underpass entrances.

UTILIZATION OF BUILDINGS FOR ACCESS

In many instances, in the Central City and other high or medium density areas, it would be advantageous to utilize buildings for providing direct access to the rapid transit station platforms. Regardless of system configuration (underground or overhead), this station concept would provide the best service in areas where it is desirable to maintain maximum unobstructed sidewalk widths.

In future years, as the rapid transit system gains greater patronage and demand for parking will increase, "park 'n ride" garages incorporating direct passenger access features seem probable.

ALIGNMENT AND STATION LOCATIONS WITHIN THE CENTRAL CITY

The Los Angeles Central City becomes, by virtue of its position at the junction of the transit corridors and the freeways, the heart of the metropolitan transit and transportation system.

The Central City Area is defined as that section of the city generally bounded by the Harbor Freeway on the West, the Santa Ana-Hollywood Freeway on the north, San Pedro Street on the east, and the Santa Monica Freeway, now under construction, on the south. The Union Passenger Terminal complex is also included. A land use plan, as developed by the Los Angeles City Planning Department, was carefully reviewed and became a significant influence in planning rapid transit service concepts in the CBD.

During the course of engineering investigations, many different plans for rapid transit service were analyzed for their adequacy in providing satisfactory service to, and distribution of, passengers within the Central City Area.

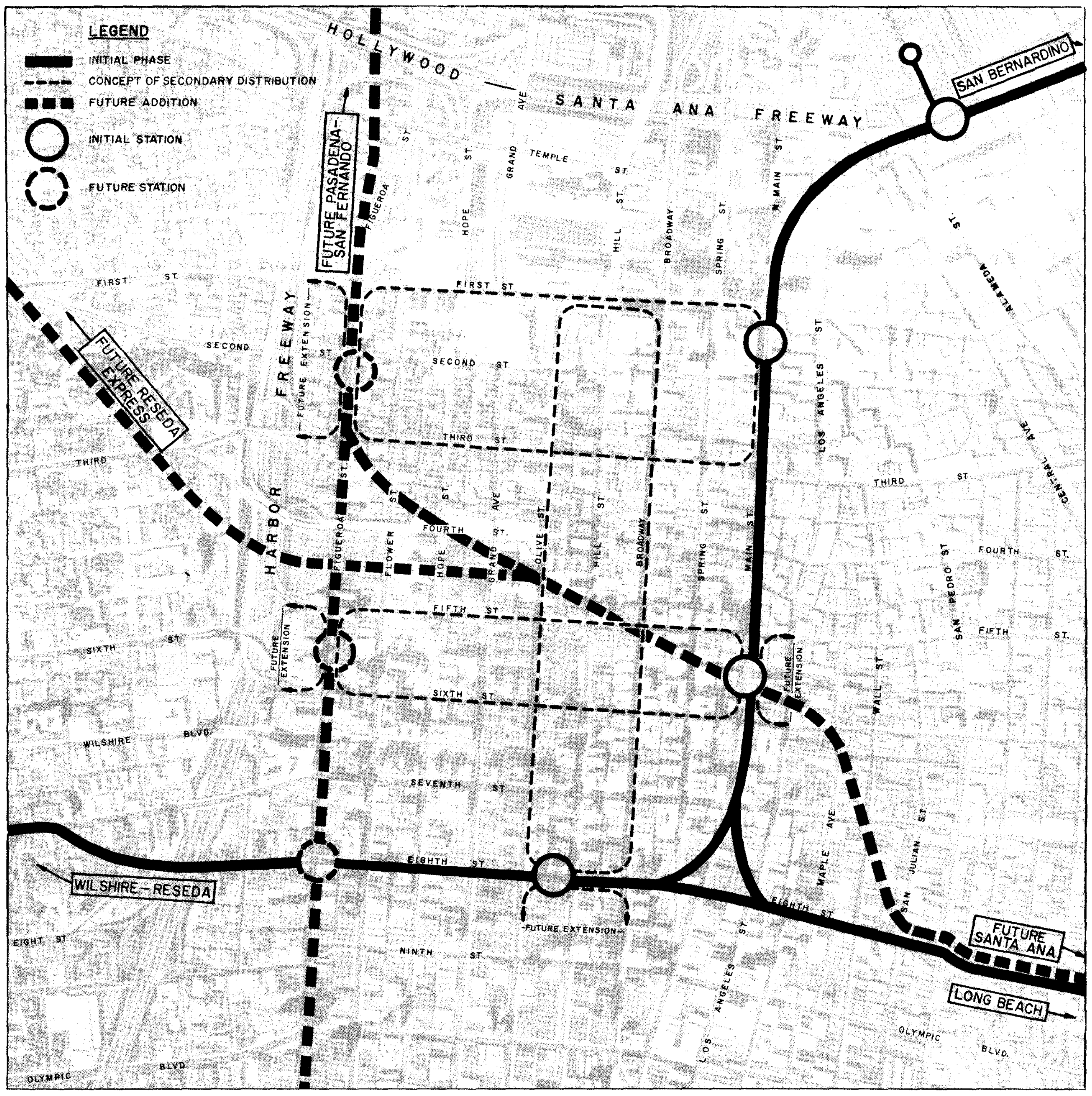
CENTRAL CITY SERVICE

The several alternate alignments selected for study fall into one of four basic concepts of transit service to the Central City Area. For convenience of discussion, three basic concepts have been defined as: 1) major center terminal; 2) inner loop; 3) outer loop (freeways); and 4) off-side main line and secondary distribution.

Each of the basic concepts demonstrates certain advantages. The concept of the major center terminal finds advantage in simplicity and ease of comprehension for potential transit passengers.

An inner loop would provide for passenger distribution in the Central City Area without a secondary distribution facility. The outer freeway loop lends itself to the use of an economical elevated way structure throughout. It is the concept of an off-side main line with a secondary passenger distribution that derives a certain portion of the advantages of the other three and most readily integrates itself into the future development of mass rapid transit for the Los Angeles Metropolitan Area. The recommended plan is shown on Figure IV-4 and this conforms with requirements for the eight-corridor plan, as shown previously on Figure IV-2.

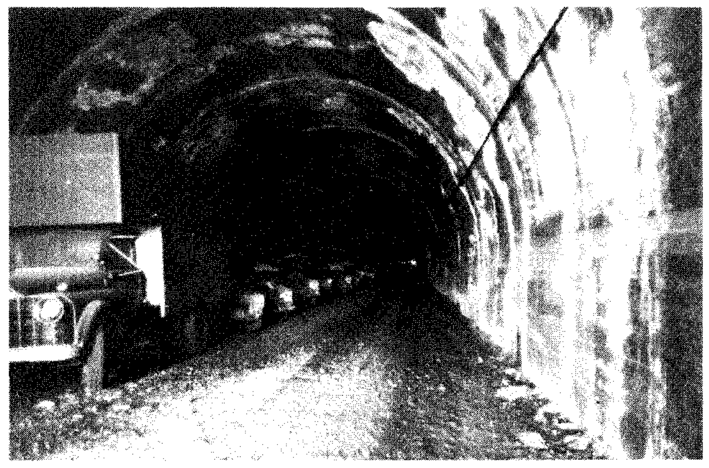
Figure IV-4. Central City Plan



CENTRAL CITY ALIGNMENT ALTERNATES

Large areas in the Central City have been cleared to provide parking for an automobile oriented population. Utilization of air rights over such areas could provide suitable private rights-of-way for overhead rapid transit. In other areas, both in Central City and in the corridors, new improvements such as apartment houses, large office buildings, and fine homes make a private right-of-way excessively expensive.

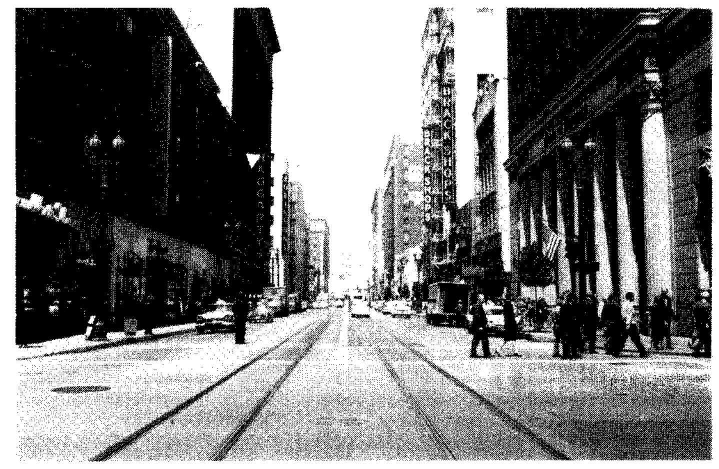
The subway tunnel from Glendale Boulevard near Beverly Boulevard to the Hill Street terminal was utilized by the Pacific Electric Railway for many years. This facility illustrates the advantage of subway in private right-of-way making possible passage of transit lines through areas of dense population by the most direct route.



Land use and basic geometrics of the street are two important factors dictating feasibility of appropriately designed overhead way structures.

In addition, stations could be in some cases incorporated with existing buildings. The above photos show existing facilities potentially usable in future developments of rapid transit in the Central City Area.

In the Central City Area, there are streets which would derive some economic advantage from the proposed system of mass rapid transit. Better transportation could accelerate needed redevelopment in many areas of the Central City Area as illustrated by the accompanying photographs.



The subway alternates were designed to fit in with the same concept of off-side main line service as planned for an overhead facility.

Plans and profiles and specific alignment descriptions of the several alternates are given later in this section.

INTERCHANGE OF CORRIDOR LINES AT CBD

One of the principal problems encountered in the Central City is the development of a suitable junction of the lines serving the various corridors. While it is desirable to provide for full flexibility of operation by enabling trains to proceed from any corridor into any other corridor (full interchange), such flexibility is expensive to provide.

While a partial interchange would require transfers, it is believed that a transit passenger desiring through service would prefer a convenient transfer at the CBD to waiting at the origin extra minutes for a train destined to his specific corridor.

There will be two basic transit movements, one between the Wilshire-Reseda Corridors and the San Bernardino Corridor; the other is between the Wilshire-Reseda Corridor and the Long Beach Corridor. It is contemplated that a passenger on the Long Beach line could travel directly to a destination in the San Bernardino Corridor without transferring, but with a limited number of trains providing such service.

SECONDARY PASSENGER DISTRIBUTION

Rapid transit service to the Central City Area can generally be classified according to the ability of the system to deliver riders within easy walking distances (two or three blocks) of their destinations. The cost of main line rapid transit construction makes impractical the development of a network of such facilities to provide the desired service in the Central City Area.

The recommended plan for the initial phase of the rapid transit development sets forth the concept that three principal main line stations would be most appropriate for main line service. However, three stations, no matter how they might be placed within the Central City Area, cannot adequately distribute passengers throughout the whole area.

During the course of our review of proposed rapid transit systems, proposals were made for transit facilities and equipment, which although not meeting the criteria for speed, passenger handling capacity, etc., for the main line system, could be developed for use in a secondary distribution plan. The secondary distribution system would be keyed to the three stations from the main line rapid transit system and would provide for three service loops, two oriented east and west and one oriented north and south within the Central City Area. This would make it possible to utilize the combination of main line and secondary distribution systems to distribute passengers within approximately two blocks of any destination within the Central City Area. This assumes that stations in the secondary distribution system would be spaced at approximately 600-foot intervals. While no attempt has been made to assess the economic feasibility of the secondary distribution facility, there are indications that such a facility might be almost entirely self-sufficient from use by pedestrians traveling from one section of the Central City Area to another. Estimates indicate that speed would be in the order of 15 miles per hour; capacity would be 7,000 to 10,000 passengers per hour in one direction; size of cars would be for eight to ten people, and equipment would be, for all practical purposes, noiseless.

The supporting structure required for such facilities would be relatively lightweight and, if located along a sidewalk alignment, would occupy no more space than existing street light poles.

It is further anticipated that existing street light facilities could be incorporated with such structures.

Approximately five miles of the secondary distributer would be required as an adjunct to the main line rapid transit facility. Present planning indicates that the most desirable facility would be an overhead configuration at approximately second or third-floor level. It would also be desirable to locate stations in a manner to integrate with existing buildings, thereby providing direct access for transit passengers or other persons desiring to utilize the facility.

The principal desirable aspects of the combination of main line rapid transit and secondary distribution facilities are as follows:

- Minimum number of expensive main line rapid transit stations.
- Minimum mileage of main line rapid transit structure in the Central City Area.
- Maximum service provided to the entire Central City Area.
- Delivery of passengers to points closer to the center of gravity of projected Central City Area population.

Should initial funding be insufficient to provide a grade-separated, fully automated secondary distribution system, the minimum consideration for secondary distribution of passengers would be through the use of surface buses, possibly operating in exclusive bus lanes.

The preliminary cost estimates in this report include sufficient allowance to build an overhead secondary distribution system. They have been developed only in sufficient detail to provide a basis for evaluation of the desirability of this means of total service.

CORRIDOR SERVICE

As outlined by contract, the scope of work covering detailed alignment evaluations was limited to the four corridors. The task then was to select the best alignment within each corridor. While one alignment may most closely meet service requirements, the cost or community acceptance factors may be prohibitive. Conversely, the least costly line may be too far removed from the service center to fulfill transit needs adequately, or physical obstacles may require reduced speed and detract from system desirability. The purpose of the alignment studies is to determine a "best" route in each corridor based on engineering comparisons. A complete discussion of the selection is found hereinafter.

SERVICE CONSIDERATIONS

Basically, all rapid transit riders can be classified into one of the following categories: 1) persons who reside or work within a short distance from stations and in most cases will walk to the station; 2) persons who will drive their automobile to and from the station; and 3) persons who will use supplementary surface vehicles, such as buses, streetcars, and taxies as a means to reach the station.

In order to attract a fair share of each category, the rapid transit system must be not only fast and comfortable but the service line and station location must be conveniently oriented for as many types of activity as is practical.

The ideal transit alignment should achieve a good balance of origin and destination trips by penetrating and connecting areas with high density land use characteristics, including commercial, industrial, recreational, and residential.

From a point of view of practicality, it is difficult to acquire a right-of-way which taps to a maximum degree each of these activities or land uses. However, it is highly desirable that the alignment selected approach as closely as possible the prime service areas. In order to accomplish this, alignments have been selected along or adjacent to major strips of commercial and residential activity. In each corridor, the recommended alignment provides excellent service to at least two of the four basic activities. In addition, service to industrial and recreational areas is accomplished by "park 'n ride" facilities. Extension of the Wilshire and Long Beach lines to tap beach areas is also considered advantageous.

Evaluations of service and passenger generation were analyzed in conjunction with the studies of Coverdale & Colpitts on this subject. Victor Gruen Associates were consulted on factors of community acceptance and land use.

REDUCTION OF POTENTIAL ALIGNMENTS TO THOSE GIVEN DETAILED STUDY

As was mentioned previously, there are, generally speaking, six factors to be considered in alignment selection. These factors together with a detailed field investigation along each of the corridors provided a series of possible alignments for study. At this point, the process of elimination commenced by the development of estimated costs for the several possible way structures applicable to each alignment.

A list of the various alternatives, types of right-of-way, and way structure configurations shows the extend of their diversity:

A. Street Right-Of-Way

1. Overhead - Street median

2. Overhead - Street devoted to landscaped mall with diagonal auto parking.
3. Overhead - Along parking lanes at side of street.
4. Street subway.

B. Private Right-Of-Way

1. Overhead
2. Open-cut, utilizing retaining walls
3. Open-cut, with no retaining walls
4. Subway

C. Rail Right-Of-Way

1. Overhead with land purchase
2. Overhead with air rights easement purchase
3. At-grade, with arterial streets under all tracks
4. At-grade with arterial streets over all tracks
5. At-grade, elevating only rapid transit lines over arterials at crossings.

D. Freeway Right-Of-Way

1. Median at grade
2. Median, overhead
3. Shoulders, overhead along side slopes

E. Land Adjacent to Drainage Channels

1. At grade
2. Overhead

The cost estimates were developed so that alignments could be analyzed for application of supported dual track, supported mono-beam or suspended mono-beam transit systems.

With the basic cost data developed, it became possible to follow a logical elimination process. Other factors such as passenger service and community acceptance were then analyzed with respect to the costs of each of the alignments. For example, alignment "1" would be favored where two alignments - "1" and "2" have equal costs but with alignment "1" demonstrating distinct advantages to passenger service. Alignment "2" could then be logically eliminated.

By repeating the elimination process at intervals, the several potential alignments were ultimately reduced to two in each of the four corridors and in the Central City Area. These two alignments which were given detailed analysis and study are depicted by the alignment plan and profile maps later in this section.

WAY CONFIGURATION ANALYSIS

To evaluate each corridor fully, several possible alternates were selected. In general, at least one alignment was selected to utilize each basic type of right-of-way. However, subway was considered only in the CBD, Wilshire Corridor, and through the Cahuenga Pass.

One of the most apparent alignment possibilities for a rapid transit system would follow freeway routes either in the median or along the shoulder. However, in the case of existing freeways, medians are generally too narrow to permit at-grade operation and freeway bridges become difficult obstacles to overhead transit line construction. The use of freeway shoulders would be possible in some areas but in many instances would require purchase of additional property. In other areas, depressed freeway construction results in steep side slopes and insufficient space for transit lines. In those areas where freeways are proposed but not designed and where such alignments coincide with proposed rapid transit routes, provisions for joint use of right-of-way could be made.

Other public lands which could be used in developing transit lines can be found adjacent to river or flood control channels. While affording clear right-of-way and possibility of at-grade operation, they would generally be outside the desired service area. In certain areas, such as the Long Beach Corridor, a flood control right-of-way closely parallels the service area and is, therefore, given more consideration.

In the case of public street right-of-way, either subway or an overhead system must be employed to afford grade operation. Consideration of street median would generally be confined to those streets with sufficient right-of-way width to allow a median divider while maintaining at least four lanes of traffic with parking. However, in some areas, notably Sixth Street in the Wilshire Corridor, streets with less right-of-way widths can be utilized with some special treatment such as one-way traffic or restricted parking.

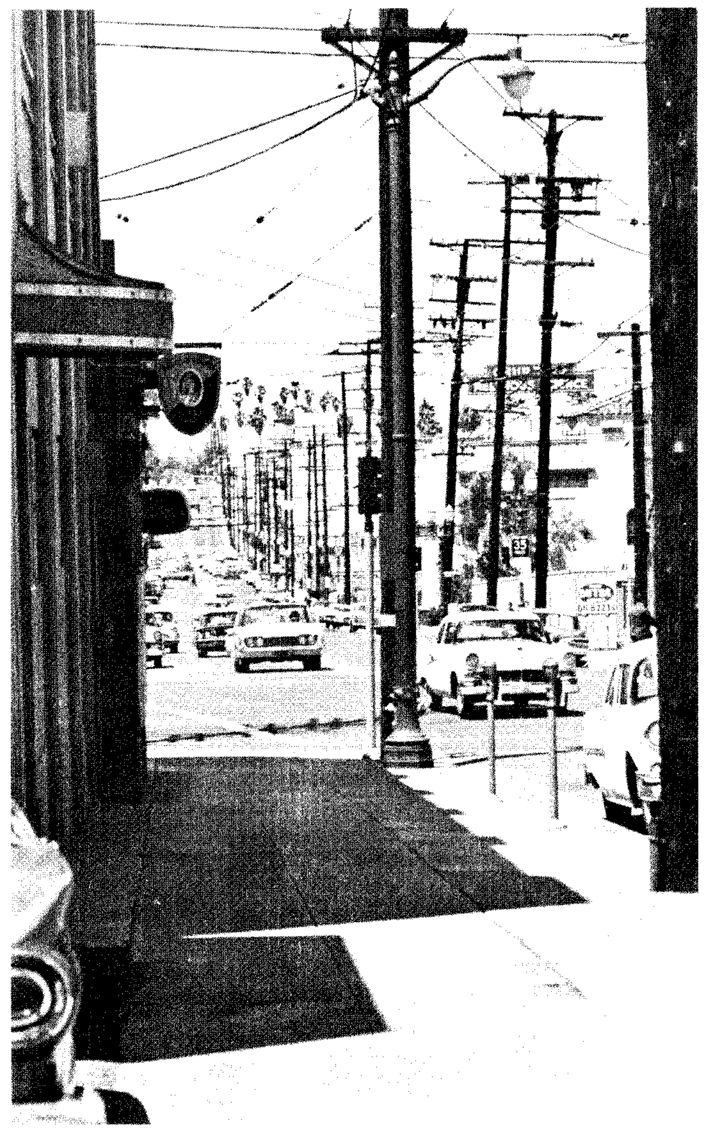
Private right-of-way considerations generally fit into two categories: 1) public utility lines such as railroads or lands along freeway rights-of-way; and 2) privately-owned properties through mid-block, in residential or commercial areas.

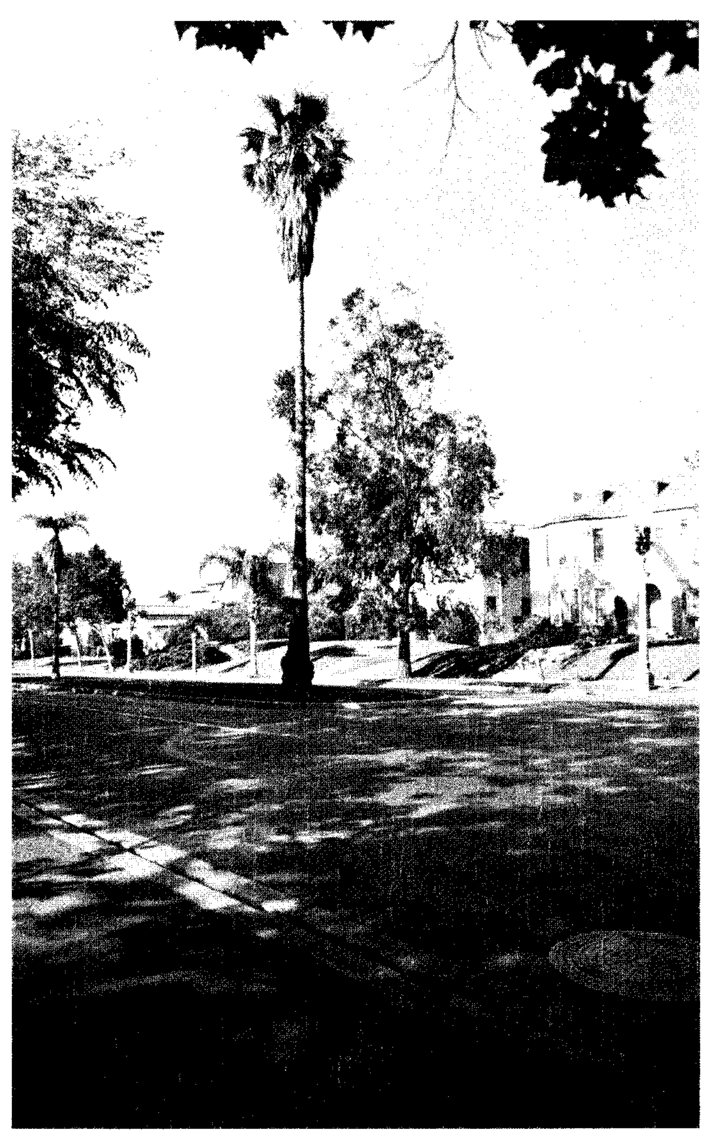
Evaluation of the potential advantages of railroad rights-of-way indicates that at-grade or overhead rapid transit configurations or a combination of both could be employed. Consideration of use of railroad right-of-way must assume that current rail operations could not be disrupted.

Where private right-of-way in mid-block is considered, either overhead, subway or open-cut configurations could be employed. Generally, overhead and open-cut construction methods were applied to each alignment of this type to provide a cost comparison. Basic problems in open-cut configurations are found in utility relocation at crossing streets and in transition to at-grade or elevated configuration. One major advantage to mid-block right-of-way is close proximity to principal service areas.

As a further aid in the analysis of alignments, the following outline of the advantages and disadvantages of the several choices of way configuration has been compiled.

PUBLIC STREET





ADVANTAGES

The right-of-way is presently available and is now dedicated to transportation in many forms. Judicious combining of various elements such as power lines, telephone lines, and street lighting with an overhead rapid transit structure would improve the vista of the street pictured on the left, since all existing poles could be removed.

Direct access to commercial areas would also be possible. Disruption of street traffic during construction would be at a minimum, with single columns spaced approximately 110 feet apart. Direct access to commercial buildings could be obtained from station areas, thereby providing an ideal transportation service to such buildings.

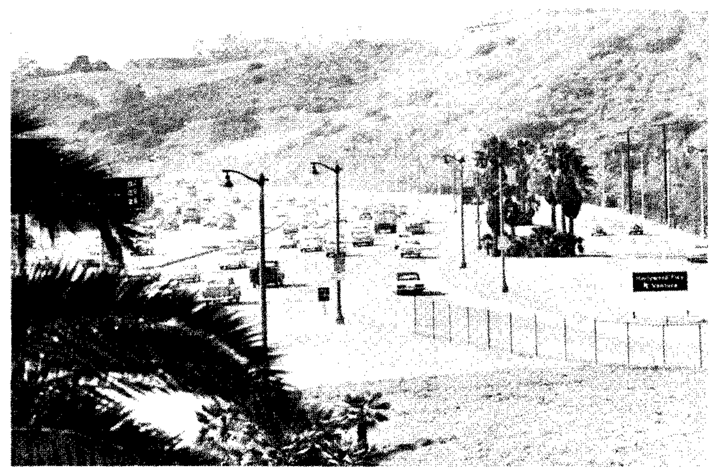
DISADVANTAGES

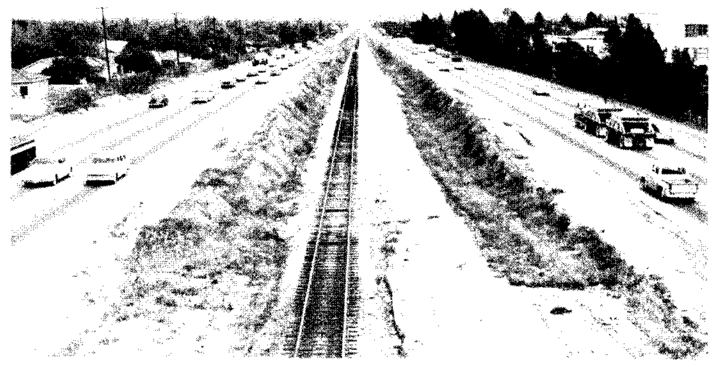
Since a city street is rarely homogeneous throughout its length, a rapid transit line conceivably could traverse a street section ideally suited to overhead line construction, then enter an exclusive residential area where there are presently no man-made obstructions to a pleasing tree-lined vista. Such sections of city streets should be avoided where physically and economically possible. A rapid transit line would gain no passenger service advantage by passing through exclusive single family dwelling areas illustrated by the accompanying photograph.

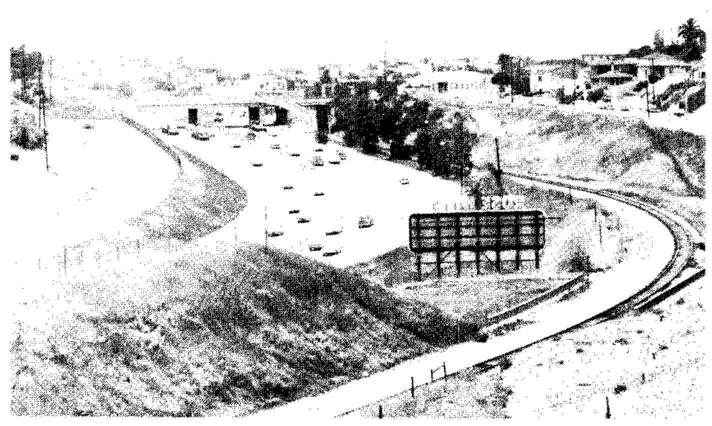
USE OF FREEWAY

ADVANTAGES

Where major transportation rights-of-way are provided, maximum utilization should be obtained. In some of the existing Los Angeles freeways, surplus rights-of-way are available in sections either in adjacent side slopes or in the median. They could be developed for rapid transit.



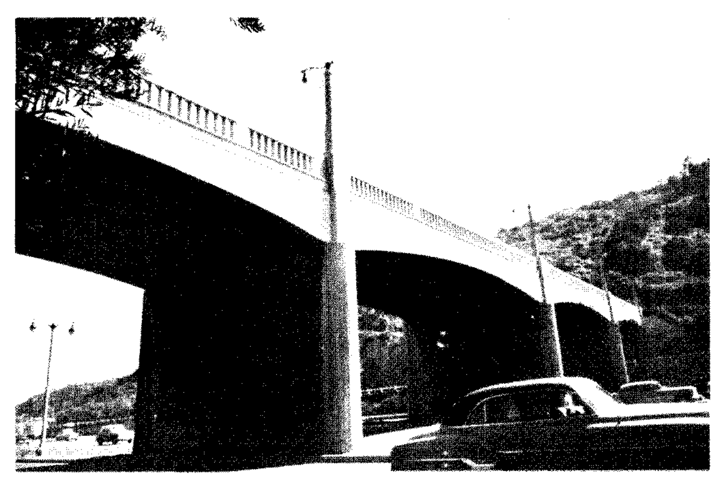




The various studies of origin and destinations of persons in the area indicate that in most cases a rapid transit line would be properly oriented by paralleling the freeway. Illustrations of logical areas for transit use are shown above.

DISADVANTAGES

Multiple bridges, narrow medians, and full utilization of freeway rights-of-way contribute to the shortcomings of most of the present Los Angeles freeway mileage as a location for rapid transit lines. Planning for combined freeway-rapid transit development should start even before property acquisition, and long before detailed plans are drawn.



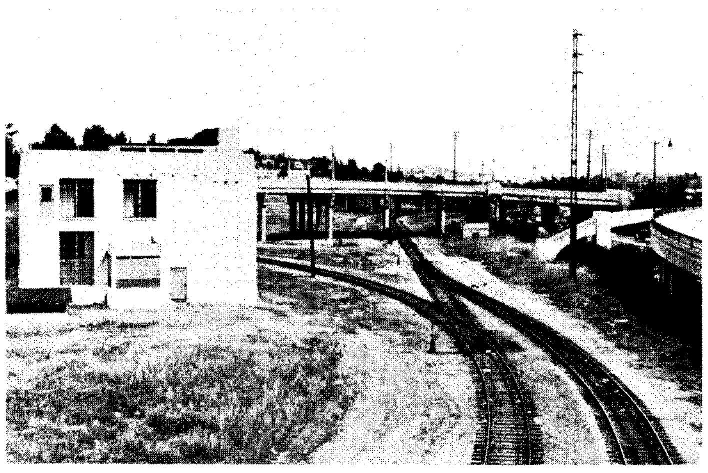
A principal factor against locating overhead rapid transit in existing narrow freeway medians would be the problem of maintaining and servicing rapid transit structures and equipment. Maintenance vehicles would be hazardous obstructions on an overloaded freeway and during several hours of the day would probably be banned, creating an impossible situation. Construction costs would be higher than in most other locations due to severe limitations on the periods of the day when construction would be permitted.

RAILROADS

ADVANTAGES

The rights-of-way owned by the railroads are attractive from several standpoints.

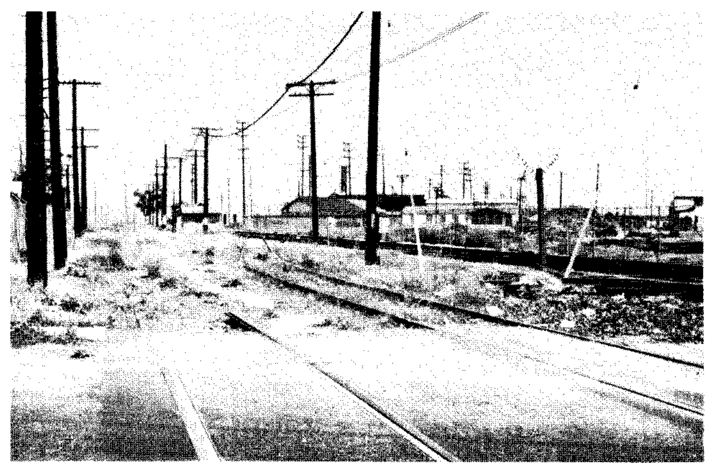
Such rights-of-way are usually straight, relatively wide, and due to the important role the railroads played in the development of the Los Angeles area, they connect the major population centers. Reduction of

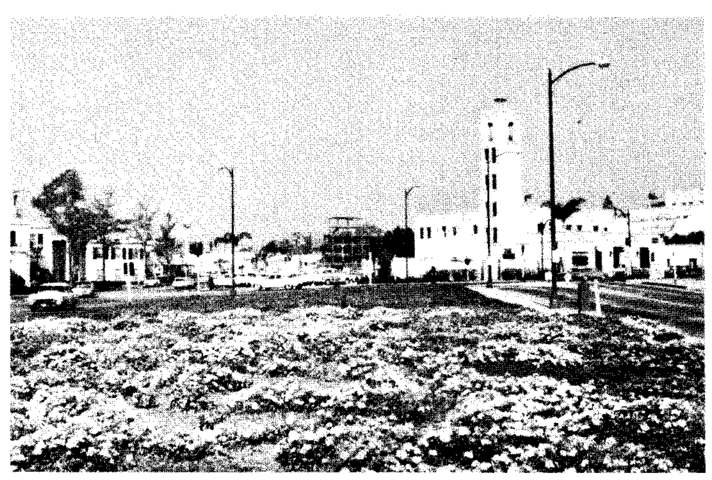


passenger service in recent years has also left certain of the rail lines in a surplus status. The increasing use of motor trucks for local and long distance hauling of freight has further reduced the use of certain major rail lines. Joint use of rail rights-of-way appear to be desirable, although joint use of trackage does not appear practical. Rapid transit must be grade separated from all cross traffic, but should not be required to stand the cost of grade separation for the existing rail lines.

DISADVANTAGES

Rail rights-of-way frequently do not traverse the best passenger service area due to the emphasis on freight handling. Congestion of rail rights-of-way by standing freights restrict usability, and industrial spur lines require special treatment. Special grade separation structure with grades of up to seven or eight percent can be tra-



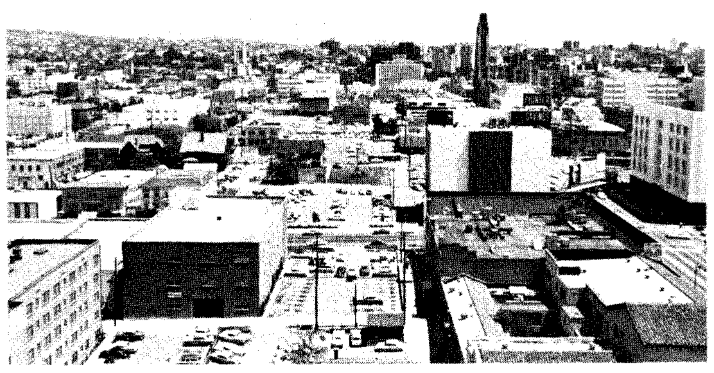


versed by rapid transit, but not by freight trains, thereby introducing partial grade separation - a hazardous factor. Many parts of the old Pacific Electric rights-of-way still exist and could be utilized, but they are now separated by stretches that have reverted to cities and private owners. Such properties now have little use potential for rapid transit.

ACQUIRED LANDS

ADVANTAGES

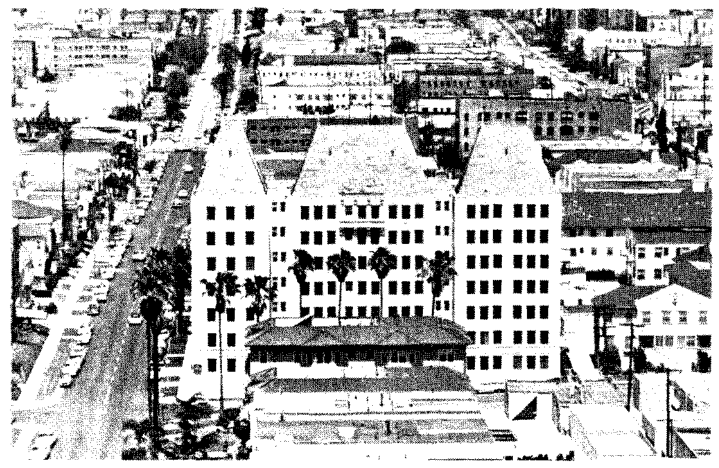
The purchase of private rights-of-way permits close approach to principal service areas and also provides the potential for recapturing such right-of-way costs through resale. Usually the private right-of-way provides easier construction procedures



than in a city street due to the absence of underground utilities. The potential of a combined project of clearing substandard buildings and transit line construction is also present.

DISADVANTAGES

The availability of a continuous strip of private right-of-way which is economical to acquire is unusual. The desirability of producing a relatively straight alignment also adds to this problem, since it may be necessary to curve past a building that is

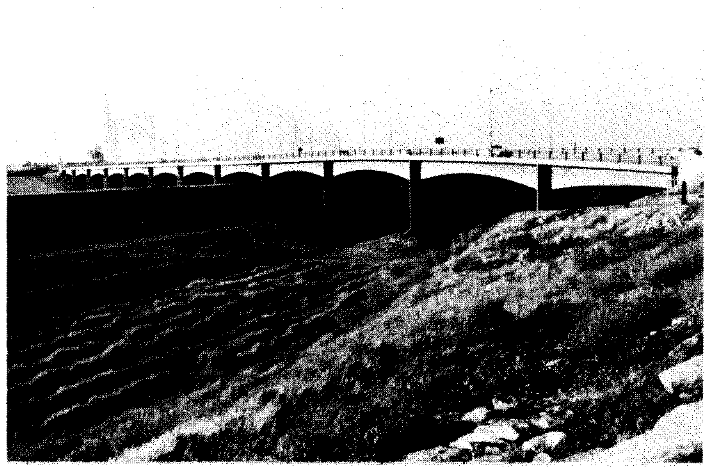


considered too expensive to acquire. Private right-of-way is usually difficult to purchase, even with condemnation powers. The photographs indicate typical buildings which make private rights-of-way unusually expensive or create the necessity for producing a winding alignment, which reduces speeds and impairs the attractiveness of the schedule.

FLOOD CONTROL

ADVANTAGES

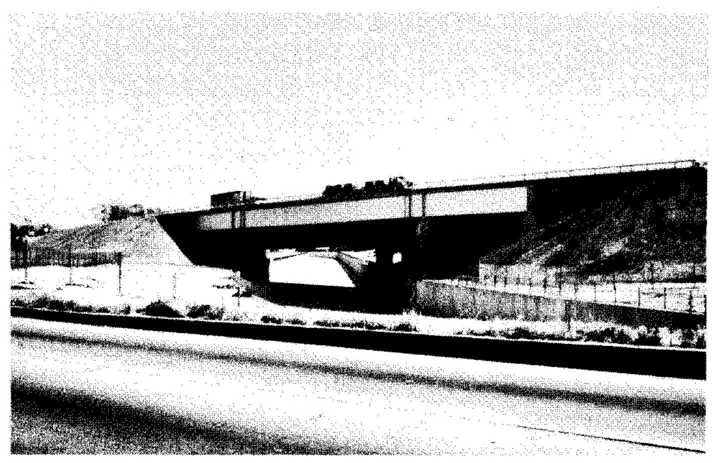
Flood control channels provide many stretches of unobstructed right-of-way ideally suited for transit use from a purely physical standpoint. Advance planning of



bridge crossings also improve such alignments by providing grade separation. The photographs illustrate typical situations where these advantages occur.

DISADVANTAGES

Due to the attractive right-of-way many sections of flood control channels are already utilized for railroads, power lines, etc. Such rights-of-way also are usually removed from areas generating passenger

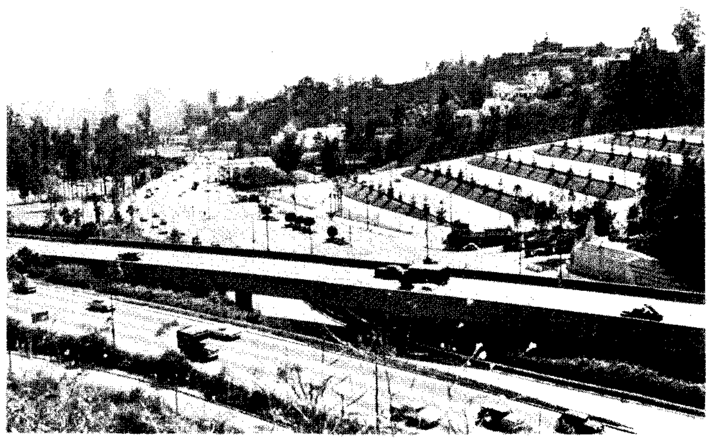


origin or destination. Adequate protection from flood conditions must still be provided. The photographs illustrate conditions of extensive use and obstruction to continuous transit line development.

PARKS AND RECREATION

ADVANTAGES

The development of rapid transit facilities near parks and recreation areas is advantageous because they provide direct access to major sporting events. The parking areas can also be utilized in a reverse process for



"park 'n ride" facilities during normal week days. In certain types of strip park development adjacent to freeways, rapid transit lines could be incorporated successfully.

DISADVANTAGES

The fine parks and recreation areas illustrated below would undoubtedly suffer damage if a high-speed rapid transit line were superimposed across them. Even though a relatively noiseless system were introduced,

the very existence of a fast moving vehicle would disrupt the serenity of the park area. Such areas should be avoided except for necessary short sections of a transit line where no economic alternate is available.

Alternate Plans and Profiles

The alignment and profile drawings shown on the following pages represent two alternate rapid transit routes considered to have the most merit within each corridor and the Central City Area, and were selected for detailed investigation and analysis.

For the purpose of description, one alignment is referred to as "A" and is shown in color; the other is designated as "B" and appears as a black line.

Alternate "A" is recommended as being the most economical for use with the "Metro" transit equipment. A summary of the recommended alignments for the four corridors is shown on Page 2 of Section I of this report.

CENTRAL CITY

Within the Central City, designated by the shaded area, three major transit stations would be located along either alignment "A" or "B". Each of these stations would be 448 feet long and would be capable of handling 30,000 passengers per hour. Transfer facilities between rapid transit vehicles and a secondary distribution system would be planned in each case. The figure on Page 14 of Section I illustrates one concept of a typical Central City station. In addition to these three major stations, provisions for a pedestrian connection between a medium density rapid transit station and Union Railway Terminal is recommended.

N/S Streets: 660' E/W Streets: 330'

Why?

Both alignments conform to the "off-side" concept of Central City rapid transit passenger distribution, whereby the routes are located immediately adjacent to the heart of the Central City Area providing excellent and efficient service with minimum disruption to property and current business activity. Along either alignment trains would operate on a through basis and provide for direct travel between corridors.

ALIGNMENT "A"

Alignment "A" would utilize an overhead way structure in the center of two Central City thoroughfares, 8th Street and Main Street. This structure will have single support columns located on a center street median approximately 6 feet in width.

Beginning at 8th Street just east of the Harbor Freeway, Alignment "A" proceeds easterly along 8th Street to a station located between Olive and Hill Streets. This station would serve as a transfer point for passengers not taking through trains between the Long Beach and San Bernardino Corridors. It would provide excellent service to the several retail stores along 7th and Hill Streets. From this station, the line continues along 8th Street to a junction in the vicinity of Broadway where one leg turns north into Main Street and the other leg proceeds east along 8th Street and joins the Long Beach line (described under the Long Beach Corridor Section).

Continuing north along Main Street, Alignment "A" would have two stations, one located between 5th and 6th Streets; another between 1st and 2nd Streets. The latter station is located close to the Civic Center. From this point, the line proceeds along Main Street to a point near Temple Street where it turns east into a short section of private right-of-way and then enters Commercial Street.

Why not at Civic Center - between First and Temple?

The line would continue east along the center of Commercial Street on an overhead structure to a point opposite the Union Passenger Terminal where provisions for a pedestrian connection would be made to permit direct service between the rapid transit system and Union Terminal. From this point, Alignment "A" continues east to join the San Bernardino Corridor.

ALIGNMENT "B"

Alignment "B" would be in two single track deep tunnels throughout the Central City Area.

Commencing at 7th Street and a point near Grand Avenue, this alignment proceeds east along 7th Street to a station between Olive and Hill Streets which, as in the case of Alignment "A", would serve as a transfer point between Long Beach and San Bernardino Corridor trips. It then proceeds along 7th Street to a junction near Spring Street where one leg would continue east along 7th Street and joins the Long Beach Corridor, while the other leg turns north into Main Street.

Following along the Main Street Leg, two stations would be located at the same points as in Alignment "A"; one between 5th and 6th Streets; the other between 1st and 2nd Streets. Leaving the latter station, the line continues under Main Street to a point near Sunset Boulevard where it turns east, passing just north of the Union Passenger Terminal into Macy Street and joins the San Bernardino Corridor.

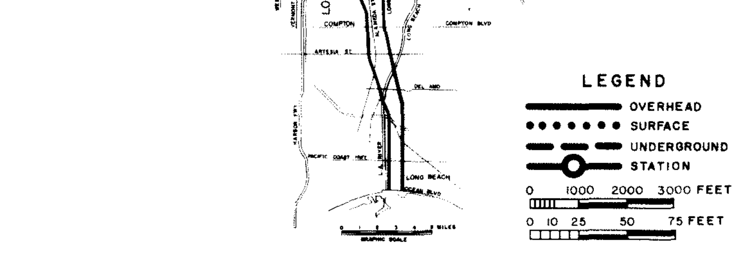
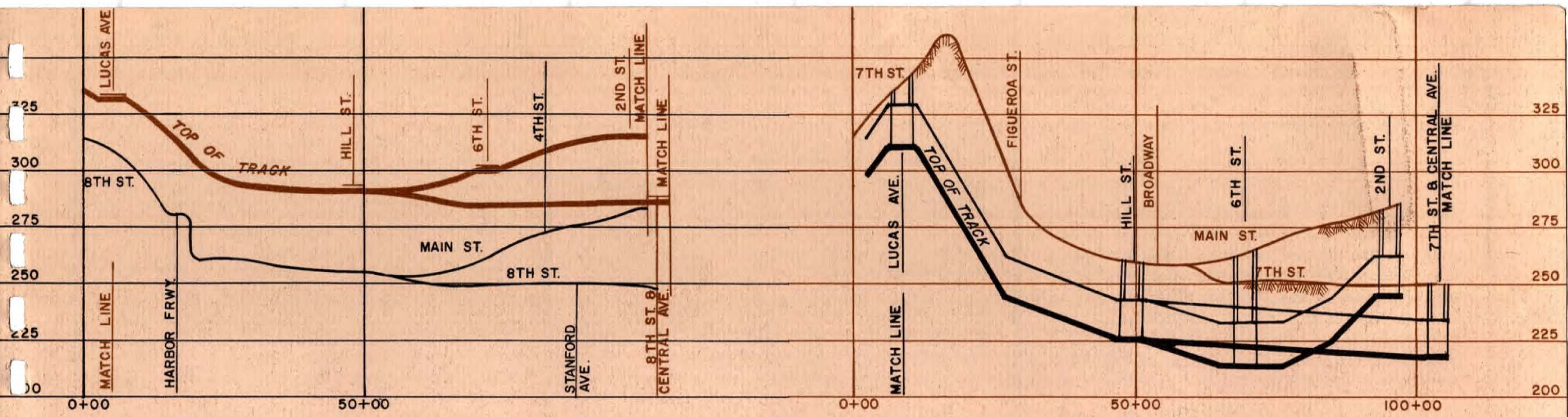
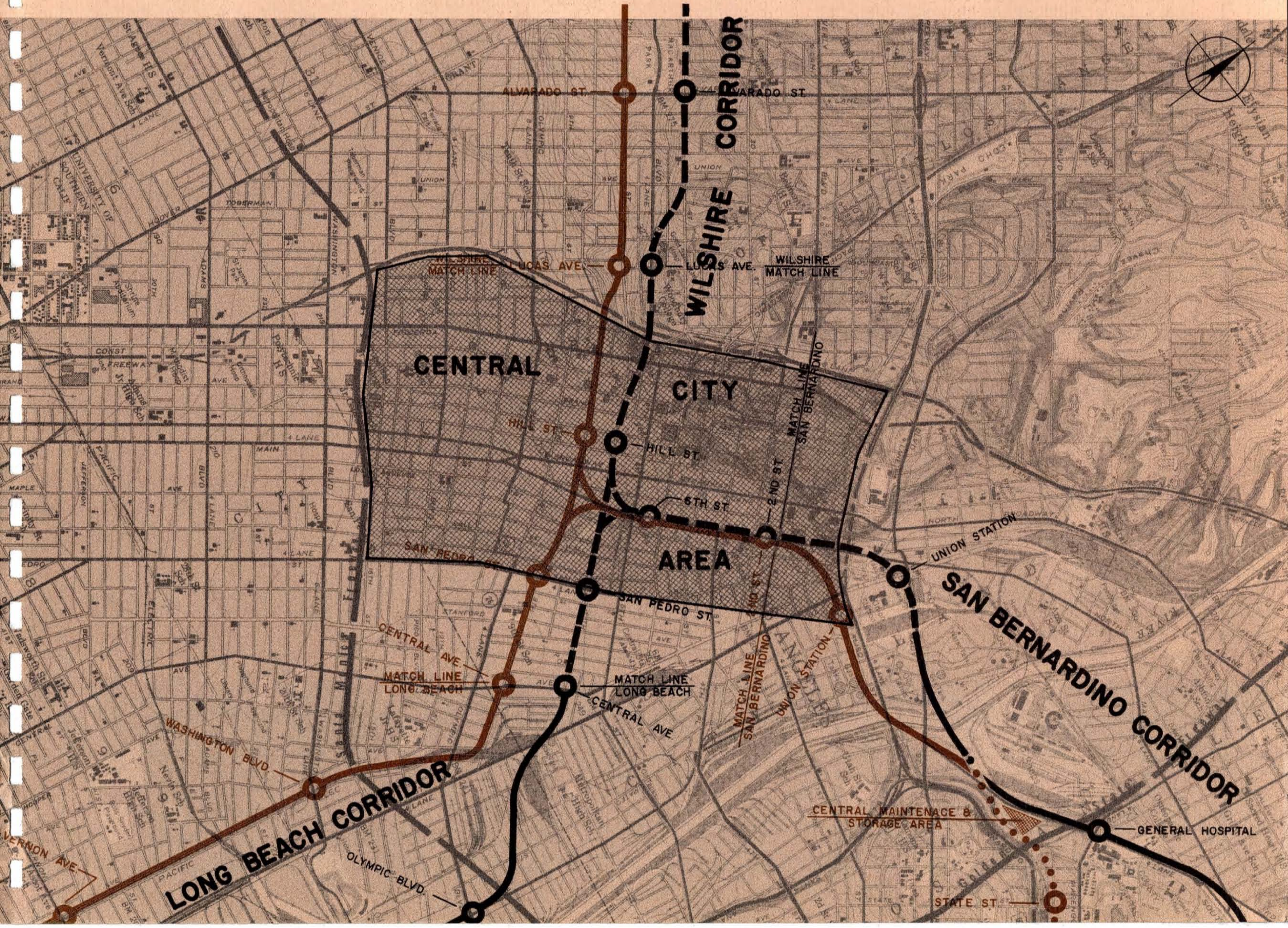


Figure IV-5. Key



LUCAS AVE
TOP OF TRACK
8TH ST.
HILL ST.
6TH ST.
4TH ST.
2ND ST.
MATCH LINE
MATCH LINE
MAIN ST.
8TH ST.
MATCH LINE
HARBOR FRWY.
STANFORD AVE.
8TH ST. & CENTRAL AVE.
7TH ST.
FIGUEROA ST.
LUCAS AVE.
TOP OF TRACK
MATCH LINE
HILL ST.
BROADWAY
6TH ST.
MAIN ST.
7TH ST.
2ND ST.
7TH ST. & CENTRAL AVE. MATCH LINE
325
300
275
250
225
200
0+00
50+00
100+00



ALVARADO ST.
WILSHIRE CORRIDOR
LUCAS AVE.
WILSHIRE MATCH LINE
CENTRAL CITY AREA
HILL ST.
6TH ST.
2ND ST.
MATCH LINE SAN BERNARDINO
UNION STATION
SAN BERNARDINO CORRIDOR
SAN PEDRO ST.
CENTRAL AVE
MATCH LINE LONG BEACH
WASHINGTON BLVD
LONG BEACH CORRIDOR
OLYMPIC BLVD.
CENTRAL MAINTENACE & STORAGE AREA
GENERAL HOSPITAL
STATE ST.
VERNON AVE.

WILSHIRE CORRIDOR

ALIGNMENT "A"

Leaving the Central District from a point on 8th Street just east of the Harbor Freeway, Alignment "A" continues westerly over the Harbor Freeway and then into a private right-of-way. The private right-of-way is used to accommodate the rapid transit way structure to its intersection with 7th Street and consists, for the most part, of open land.

The line then continues along 7th Street on an overhead way structure using a center median to a point just west of Rampart Boulevard. Presently, 7th Street is used as a four-lane roadway with curb parking permitted and with streetcar tracks in the two center lanes. To accommodate the six foot median required for rapid transit structure supports, without reducing capacity for street traffic, it would be necessary to restrict curb parking or widen the street. Through this section of Alignment "A", two stations would be located, one at Lucas Street, serving the Good Samaritan Hospital; another at Alvarado Street, where transfer to bus line number 41 could be made.

Beyond Rampart Boulevard, Alignment "A" would execute a 600-foot radius curve and turn north into Hoover Street to Wilshire Boulevard. From there, it would then cross the Lafayette Park area to a point near 6th Street and Commonwealth Avenue. Continuing on an overhead way structure, Alignment "A" would proceed westerly along a proposed median in 6th Street to a junction with the Reseda Corridor.

Stations through this section would be located at Vermont Avenue, where transfer to surface transit lines, R and V, would be made; at Normandie Avenue, where service to the many multi-story office buildings along Wilshire Boulevard and 6th Street would be accomplished; at Western Avenue, where transfer to bus line number 84 could be made and at Irving Boulevard, serving the Crenshaw-Wilshire District and where transfer to bus line number 85 could be accomplished. In the Reseda Junction Area, there would be two possible alternate station locations, each of which could be developed as a "park 'n ride" facility to utilize excess right-of-way in the interchange area. One would be near Las Palmas Avenue where connection to the Reseda Corridor via Highland Avenue (described under Reseda Corridor, Alignment "B") would be made; the other would be at a site near Orange Drive where connection to the Reseda Corridor via La Brea Avenue (described under Reseda Corridor, Alignment "A") would be accomplished. In each case, it would be necessary to utilize some private right-of-way required for construction of a 600-foot radius curve in the transition from 6th Street to Highland Avenue or La Brea Avenue.

As in the case of 7th Street, curb parking would need to be restricted or street widening accomplished along 6th Street in order to maintain adequate vehicular street capacity. Between Western Avenue and Highland Avenue, there are two winding segments of 6th Street which would require realignment.

Throughout Alignment "A" where use of 7th Street and 6th Street is planned, overhead utilities, such as power and telephone lines, street lighting and traffic signals, could be incorporated within the proposed rapid transit way structure.

Should such facilities be combined in one well designed structure, it would create a more aesthetically pleasing street appearance.

ALIGNMENT "B"

Alignment "B" would be in subway between the Central City Area and the Reseda Junction. Beginning at a point near 7th Street and Grand Avenue, the line would proceed in a northwesterly direction through private easement to intersect Wilshire Boulevard approximately at Figueroa Street. From there, Alignment "B" would continue in Wilshire Boulevard westerly under the Harbor Freeway to a point near Witmer Street where it would then turn northeasterly through private easement to a point near 6th Street and Union Avenue in order to avoid construction problems in MacArthur Park. It would continue along under 6th Street to a point at approximately Coronado Street where it would turn west through private easement to intersect Wilshire Boulevard in the vicinity of the Lafayette Park Area. From there, the subway would follow Wilshire Boulevard to the Reseda Junction.

Stations along Alignment "B" would be located near the same cross streets as in the case of Alignment "A" and with the same transfer facilities.

With respect to the Reseda Junction area, there would be two alternate station locations, one in the vicinity of Tremaine Avenue, the other at approximately Orange Avenue. In either case, "park 'n ride" facilities would be planned to utilize excess right-of-way from interchange development.

The shifting of the subway alignment from Wilshire Boulevard to 6th Street and back to Wilshire Boulevard would be required to avoid the need for an excessively deep tunnel underneath MacArthur Park Lake for which construction costs and grade problems would be severe.

Throughout Alignment "B", careful consideration has been given to utility interference and relocation, particularly with respect to the storm drain boxes across Wilshire Boulevard. Recommended construction procedures would place the subway at sufficient depth so that in general utility problems would be confined to the more shallow station areas.

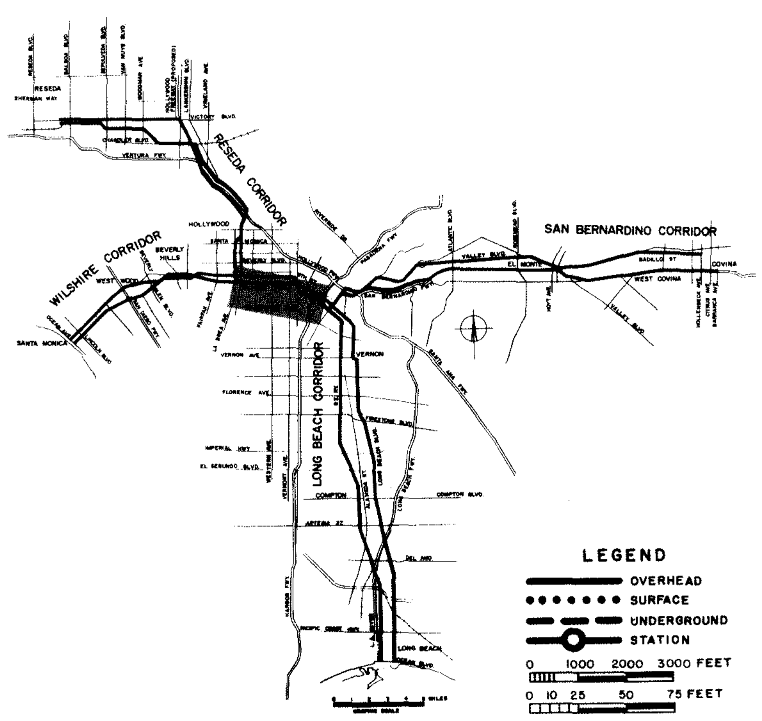


Figure IV-6. Key


MATCH LINE
RESEDA JUNCTION
ROSSMORE AVE.
CRENSHAW BLVD.
WILTON PL.
WESTERN AVE.
IDENTICAL
NORMANDIE AVE.
VERMONT AVE.
HOOVER ST.
TOP OF TRACK
ALVARADO ST.
LUCAS AVE.
250+00
200+00
150+00
100+00
50+00
0+00
225
250
275
300
325
350
RESEDA JUNCTION
CRENSHAW BLVD.
WESTERN AVE.
NORMANDIE AVE.
VERMONT AVE.
ALVARADO ST.
LUCAS AVE.
MATCH LINE
BEVERLY BLVD.
MATCH LINE
RESEDA JUNCTION
ROSSMORE AVE.
CRENSHAW BLVD.
TOP OF TRACK
WESTERN AVE.
MARIPOSA AVE.
NORMANDIE AVE.
VERMONT AVE.
IDENTICAL
ALVARADO ST.
UNION AVE.
LUCAS AVE.
175
200
225
250

WILSHIRE CORRIDOR

ALIGNMENT "A"

Alignment "A" proceeds westerly along 6th Street, utilizing an overhead way structure supported by columns on a center median to a point near Shenendoah Street in the City of Beverly Hills. In this section of Alignment "A", there would be two stations to provide service to the Miracle Mile district as well as other traffic generators such as the Parklabrea Towers development. One station would be at Hauser Boulevard, and another at Fairfax Avenue where transfer to the bus line number 89 serving the west Hollywood area would be accomplished.

From Shenendoah Street, the line would enter a private right-of-way proceeding over Wilshire Boulevard and then following a line along an alley between Wilshire Boulevard and Charleville Boulevard utilizing sections of existing parking lots and buildings where property and/or easements would be required. Stations through this section would be located at Robertson Boulevard and at Beverly Drive where connection to bus line number 91 could be made. These two stations would provide direct service to the heart of downtown Beverly Hills where many multi-story office buildings and high-quality retail stores are located.

It is expected that the demand for parking will continue to increase as the City of Beverly Hills grows and as additional multi-story buildings are constructed.

It is, therefore, conceivable that auto parking facilities could be integrated with the rapid transit overhead way structure, particularly in conjunction with station buildings.

The line would then proceed westerly along the alley to Santa Monica Boulevard where it would swing into the Pacific Electric right-of-way at which point the alignment would then make transition from an overhead structure to tunnel. Continuing below Santa Monica Boulevard, Alignment "A" would proceed to a station at the proposed Century City development. This station would provide a connection with bus line number 75 operating along Santa Monica Boulevard. The line would then proceed westerly in tunnel through a private easement beneath Beverly Glen and to an underground station at Manning Avenue on Wilshire Boulevard where service to U.C.L.A. would be available.

ALIGNMENT "B"

Beyond the Reseda Junction station, Alignment "B" would continue as subway below Wilshire Boulevard to Santa Monica Boulevard in Beverly Hills. At this point, the subway would turn into Santa Monica Boulevard to a station serving the proposed Century City development. Just west of this station, transition would be made to an overhead structure using part of the existing Pacific Electric right-of-way. Except at Overland Avenue, all other stations would be located at the same cross streets as along Alignment "A" and the same transfer facilities would be planned.

The California State Division of Highways is presently studying alternate routes for a proposed Beverly Hills freeway. One of these routes would utilize sections of Santa Monica Boulevard where the proposed rapid transit line would be located.

It is, therefore, anticipated that the alignments described here would be changed to allow for either separate freeway and transit rights-of-way or integration of both through the relatively narrow section between Wilshire Boulevard and Beverly Glen Boulevard.

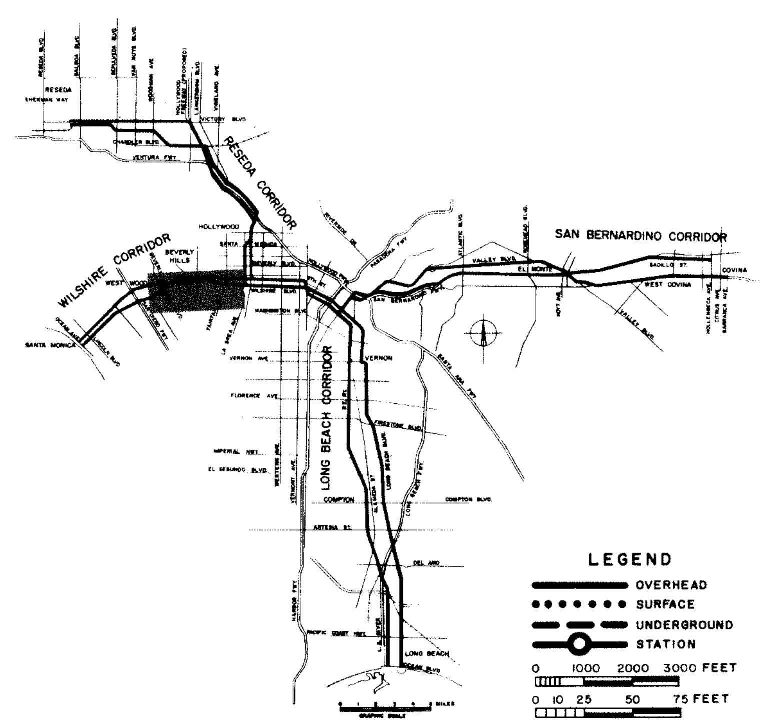
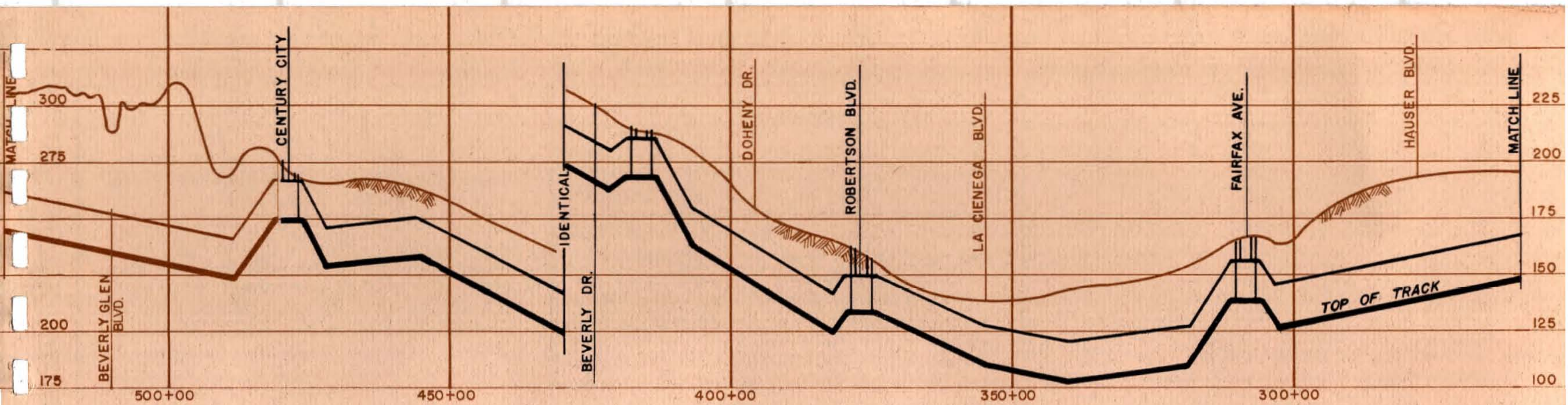
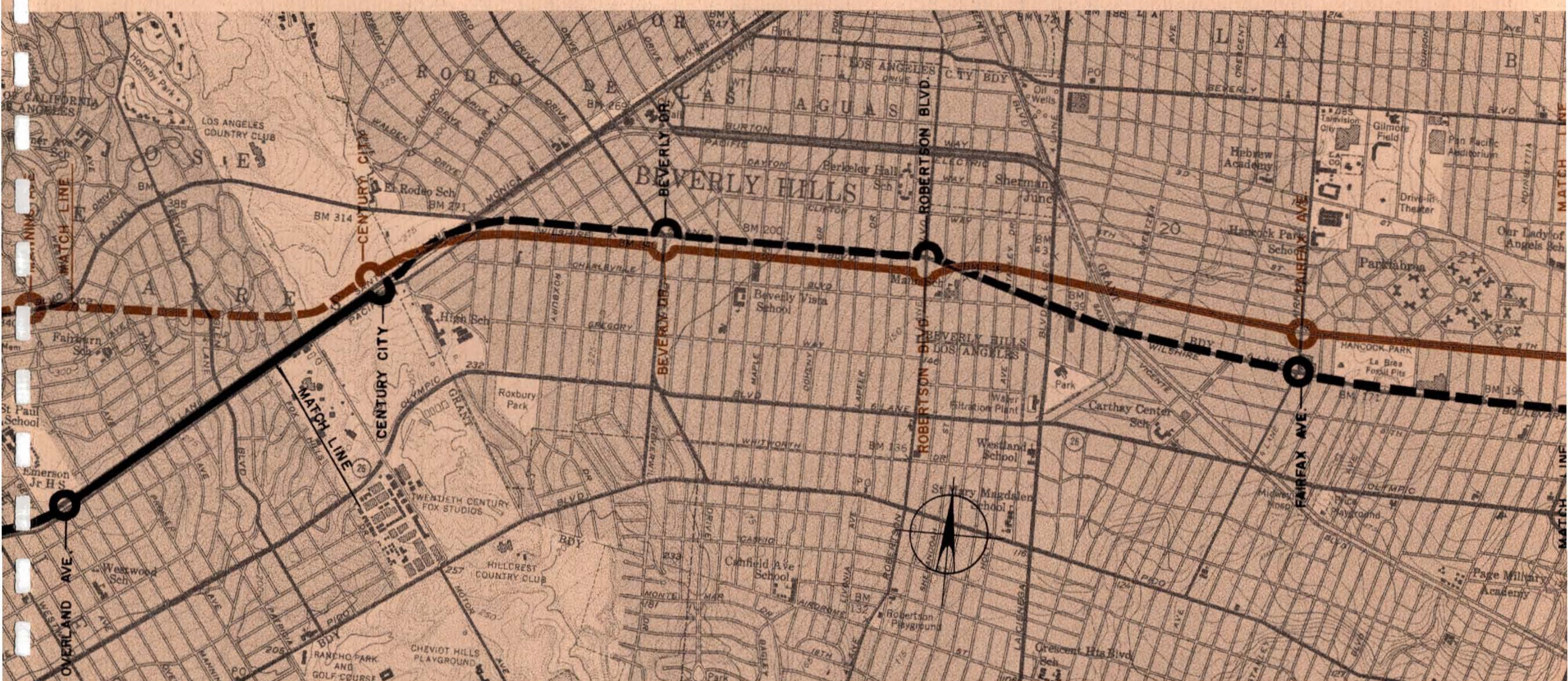
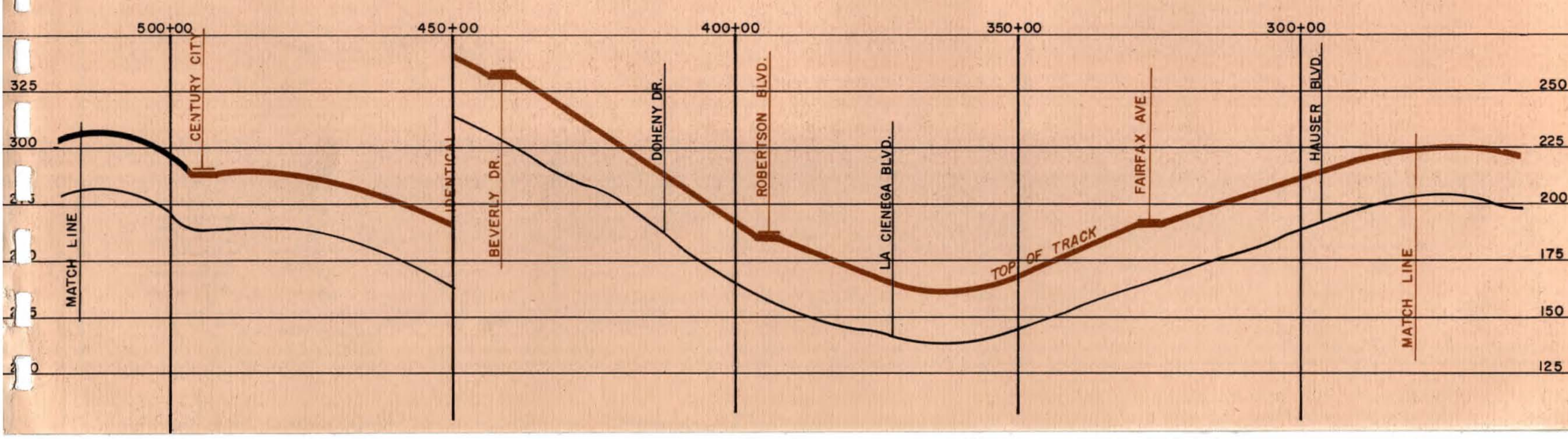


Figure IV-7. Key


MATCH LINE
300
275
200
175
BEVERLY GLEN BLVD.
CENTURY CITY
IDENTICAL
BEVERLY DR.
DOHENY DR.
ROBERTSON BLVD.
LA CIENEGA BLVD.
FAIRFAX AVE.
HAUSER BLVD.
MATCH LINE
TOP OF TRACK
225
200
175
150
125
100
500+00
450+00
400+00
350+00
300+00


MATCH LINE
OVERLAND AVE.
CENTURY CITY
CENTURY CITY
MATCH LINE
BEVERLY DR.
ROBERTSON BLVD.
FAIRFAX AVE.
BEVERLY HILLS
LOS ANGELES COUNTRY CLUB
TWENTIETH CENTURY FOX STUDIOS
HILLCREST COUNTRY CLUB
RANCHO PARK AND GOLF COURSE
CHEVIOT HILLS PLAYGROUND
Roxbury Park
Beverly Vista School
Hebrew Academy
Hancock Park School
HANCOCK PARK
Carthay Center Sch
Page Military Academy
Pan Pacific Auditorium
Gilmore Field


500+00
450+00
400+00
350+00
300+00
325
300
MATCH LINE
CENTURY CITY
IDENTICAL
BEVERLY DR.
DOHENY DR.
ROBERTSON BLVD.
LA CIENEGA BLVD.
FAIRFAX AVE
HAUSER BLVD.
MATCH LINE
TOP OF TRACK
250
225
200
175
150
125

WILSHIRE CORRIDOR

ALIGNMENT "A"

Continuing westerly in a subway along Wilshire Boulevard, Alignment "A" would proceed to a station east of Sepulveda Boulevard and the San Diego Freeway where major "park 'n ride" and transit vehicle storage facilities would be provided. This station would also serve Westwood Village and the Veterans Administration Center. The line would then continue under the San Diego Freeway and through the Veterans Administration property to a point near the intersection of Wilshire Boulevard and San Vicente Boulevard. At this point, Alignment "A" would change from a subway to an overhead line and would proceed westerly on a proposed median along Wilshire Boulevard to a station at Bundy Drive.

Between Bundy Drive and Ocean Avenue, there would be three stations which would serve the City of Santa Monica, one would be at 26th Street, another at 14th Street, and a third near Ocean Avenue. The latter would be a terminal facility and would be developed for major "park 'n ride" operation as well as transfer connections to surface bus lines. Service to the beach recreational areas as well as the Central Business District of Santa Monica would be provided from this station.

Wilshire Boulevard through most of this section is relatively wide and placement of a center median for the rapid transit way structure would not appreciably reduce the vehicular capacity of this street, or require the elimination of curb parking.

ALIGNMENT "B"

Leaving the Overland Avenue station, Alignment "B" proceeds westerly over the Pacific Electric right-of-way to a point just east of Sepulveda Boulevard. Beyond this point, the line continues over the San Diego Freeway and then follows an alignment in the center of Santa Monica Boulevard where a median would be constructed. Alignment "B" then proceeds westerly to a point east of Cloverfield Boulevard where it turns northwesterly into a private right-of-way strip paralleling Santa Monica Boulevard and south of Wilshire Boulevard. Following this route, Alignment "B" proceeds to its terminal near Ocean Avenue in the City of Santa Monica.

Stations along Alignment "B" would be located at Sepulveda Boulevard where transit vehicle storage and "park 'n ride" facilities would be available; at Bundy Drive; 26th Street; 14th Street; and the terminal station, where "park 'n ride" and transfer facilities would be provided.

Santa Monica Boulevard, between Sepulveda Boulevard and Cloverfield Boulevard is sufficiently wide to accommodate a transit median without seriously affecting the vehicular capacity of the street; however, beyond Cloverfield Boulevard the street is narrow and would require elimination of curb parking, or extensive widening. For this reason, the line in this area has been routed through private properties where acquisition costs are not expected to be excessively high.

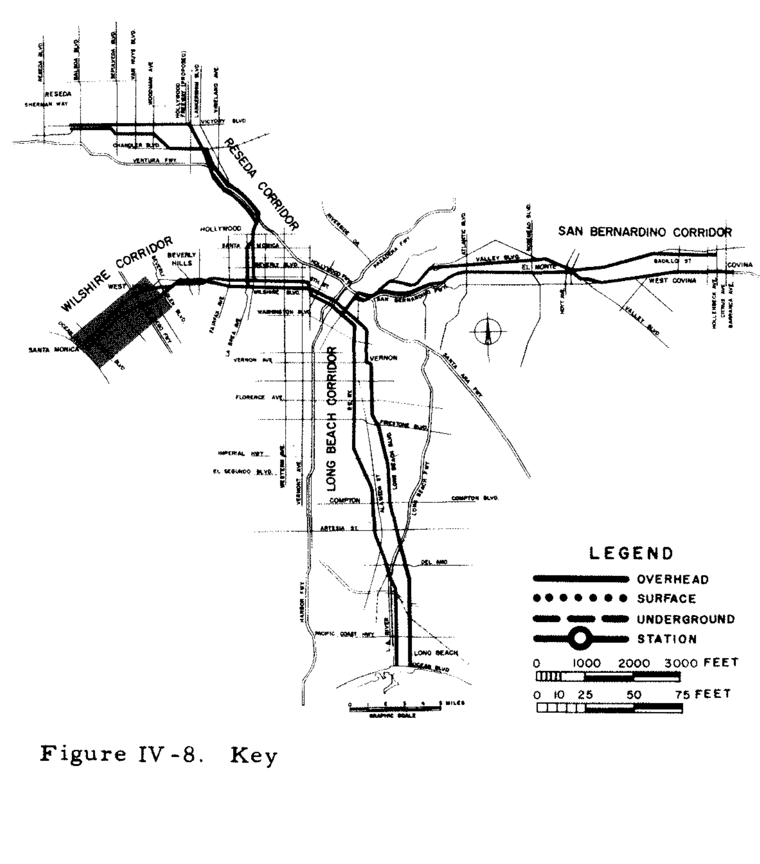
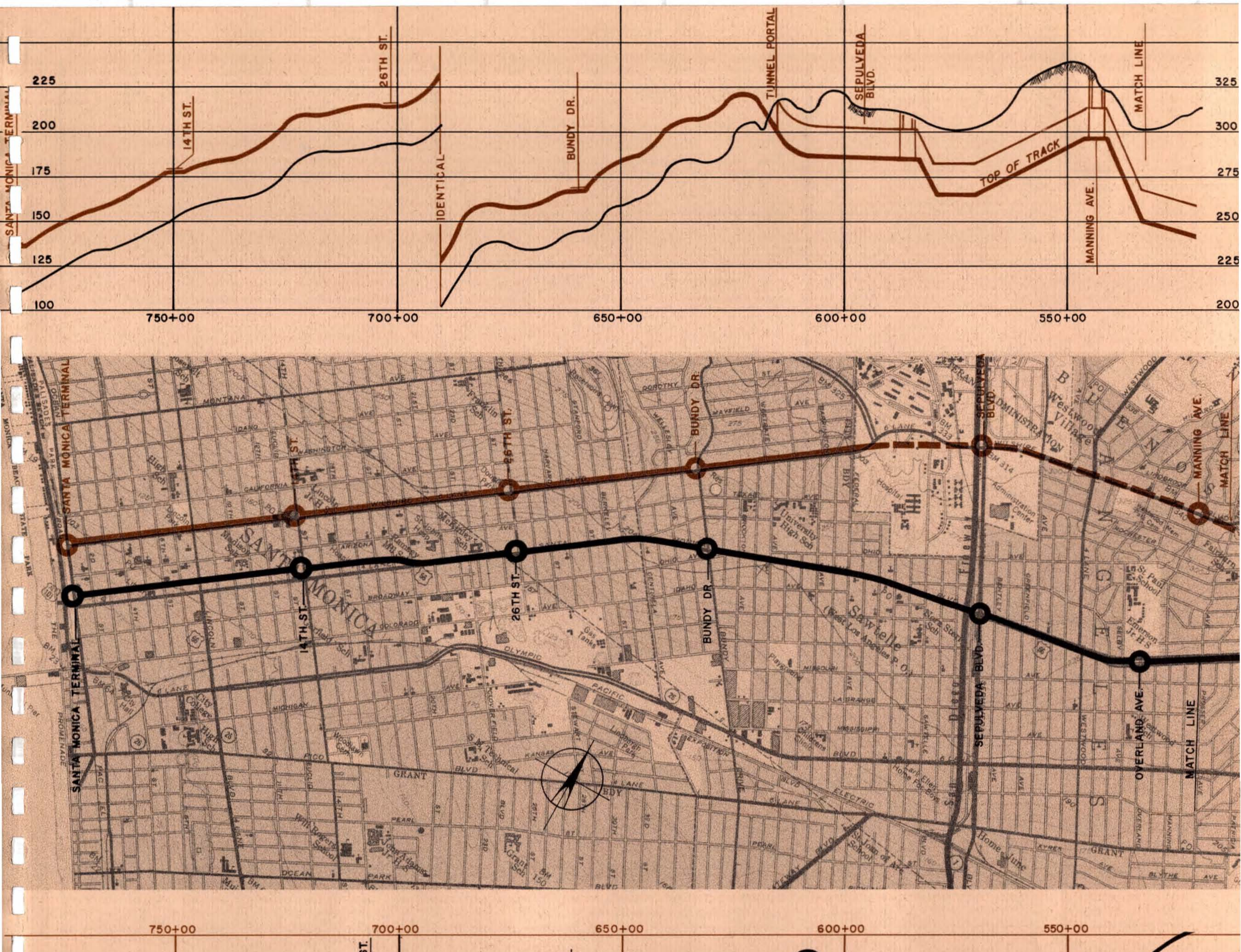


Figure IV-8. Key


SANTA MONICA TERMINAL
14TH ST.
26TH ST.
IDENTICAL
BUNDY DR.
TUNNEL PORTAL
SEPULVEDA BLVD.
TOP OF TRACK
MANNING AVE.
MATCH LINE
225
200
175
150
125
100
325
300
275
250
225
200
750+00
700+00
650+00
600+00
550+00
SANTA MONICA
Sawtelle
Westwood Village
OLYMPIC
PICO
GRANT
OCEAN PARK
SEPULVEDA BLVD.
OVERLAND AVE.
TOP OF TRACK
SAN DIEGO FREEWAY
75
175
150

RESEDA CORRIDOR

ALIGNMENT "A"

The rapid transit line serving the Reseda Corridor uses that section of the Wilshire Corridor between the Central City Area and the Reseda Junction as a common line and is described under the Wilshire Corridor.

Beginning at the Reseda Junction, Alignment "A" swings north from 6th Street on a 600-foot radius curve utilizing an overhead way structure to a proposed median strip in La Brea Avenue. The line proceeds northerly along La Brea Avenue to a station at Beverly Boulevard where transfer connection to bus lines numbers 44 and 76 could be made. The existing width of La Brea Avenue is adequate to provide a median for the rapid transit support structure without seriously affecting present traffic and parking conditions. Alignment "A" continues along the median on La Brea Avenue to a station at Santa Monica Boulevard where connection could be made with bus line number 94.

Immediately beyond the Santa Monica station, the line swings northeasterly into a private right-of-way to a point just south of Sunset Boulevard on Highland Avenue. The line then continues overhead in a proposed median strip in Highland Avenue to a station at Hollywood Boulevard where transfer to bus lines numbers 81, 85 and 89 could be made. The line then proceeds northerly in the median of Highland Avenue to a station opposite the Hollywood Bowl parking lot which is recommended for use as a "park 'n ride" facility. Interchange with buses operating on the Hollywood Freeway could be accomplished at this station.

ALIGNMENT "B"

Beginning at Wilshire Boulevard and a point near Tremaine Avenue, Alignment "B" turns north through private easement in subway under existing properties and into an overhead structure which would be constructed in the existing center median of Highland Avenue.

The line continues north on Highland Avenue to a station at Beverly Boulevard where transfer to bus lines numbers 44 and 76 could be made, and then to Melrose Avenue where the existing median ends. North of Melrose Avenue, construction of a median to accommodate the rapid transit facilities would be required.

Alignment "B" proceeds along the center of Highland Avenue to stations at Santa Monica Boulevard, Hollywood Boulevard and the Hollywood Bowl. Similar transfer and parking facilities would be available as along Alignment "A".

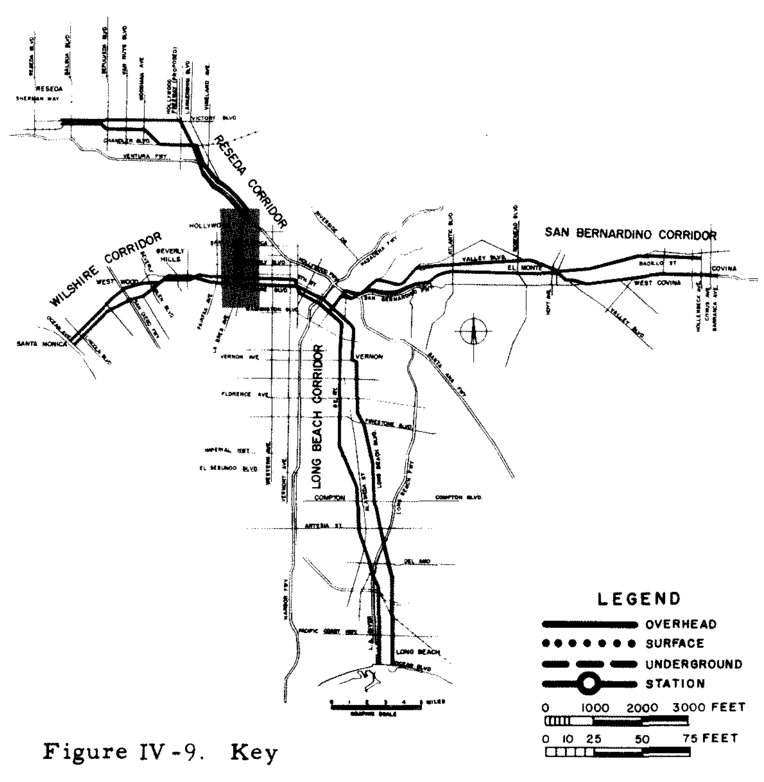


Figure IV-9. Key

MATCH LINE
HOLLYWOOD BOWL
HOLLYWOOD BLVD.
IDENTICAL
SUNSET BLVD.
SANTA MONICA BLVD.
TOP OF TRACK
BEVERLY BLVD.
4TH ST.
RESEDA JUNCTION
=STA.245+50 6TH ST.
RESEDA JUNCTION
WILSHIRE BLVD.
6TH ST.
TUNNEL PORTAL
RESEDA JUNCTION
=STA. 251+50 WILSHIRE BLVD.
200+00
150+00
100+00
50+00
0+00

RESEDA CORRIDOR

ALIGNMENT "A"

Beyond the Hollywood Bowl station, Alignment "A" would proceed through Cahuenga Pass in a private right-of-way immediately adjacent to and on the west side of the Hollywood Freeway crossing over the Mulholland Drive Bridge and to a station located at Barham Boulevard where transfer to bus line number 21 would be possible. A portion of this section would be constructed at grade, while the remainder would be overhead. The line then proceeds north over the Barham Boulevard Bridge and along the west side of the Hollywood Freeway utilizing private right-of-way to a station at Lankershim Boulevard providing service to Universal City and Studio City. This section also would be partly at grade and partly an overhead structure. Alignment "A" would then proceed northerly along an alignment adjacent to and west of the Hollywood Freeway to a station located at Vineland Avenue where transfer connection to bus line number 6 would be possible. The line would then proceed to a station at Riverside Drive near the interchange area of the Ventura and Hollywood Freeways.

ALIGNMENT "B"

Alignment "B" would be located on the east side of the Hollywood Freeway with stations located at the same general locations as for Alignment "A" and with the same transfer connections.

The Cahuenga Pass with its many bridges across the Hollywood Freeway constitutes one of the most difficult and expensive stretches of the entire rapid transit system. The vertical rise in excess of 300 feet between Hollywood Boulevard and the pass summit at Mulholland Drive would require grades of slightly over 5% with critical points occurring where the system crosses over the Mulholland Drive and Barham Boulevard bridges. In the case of Alignment "B", an additional problem occurs where the line crosses over the Hollywood Freeway just beyond the Hollywood Bowl. Because of the required rise in the line, the station serving the Hollywood Bowl would be constructed higher than normally necessary. Utilities located in Cahuenga Pass are mostly underground and in only a few instances would relocation be required in connection with rapid transit line construction.

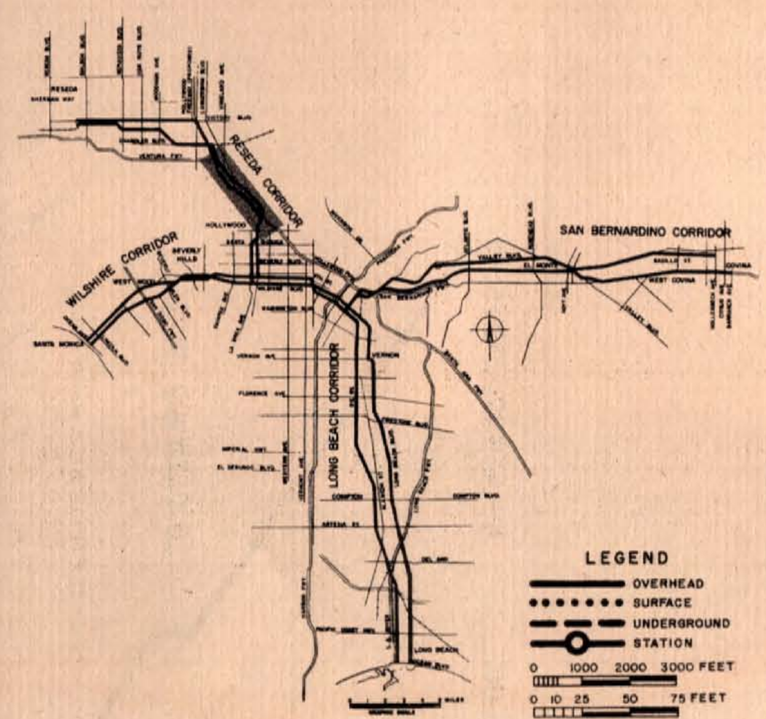
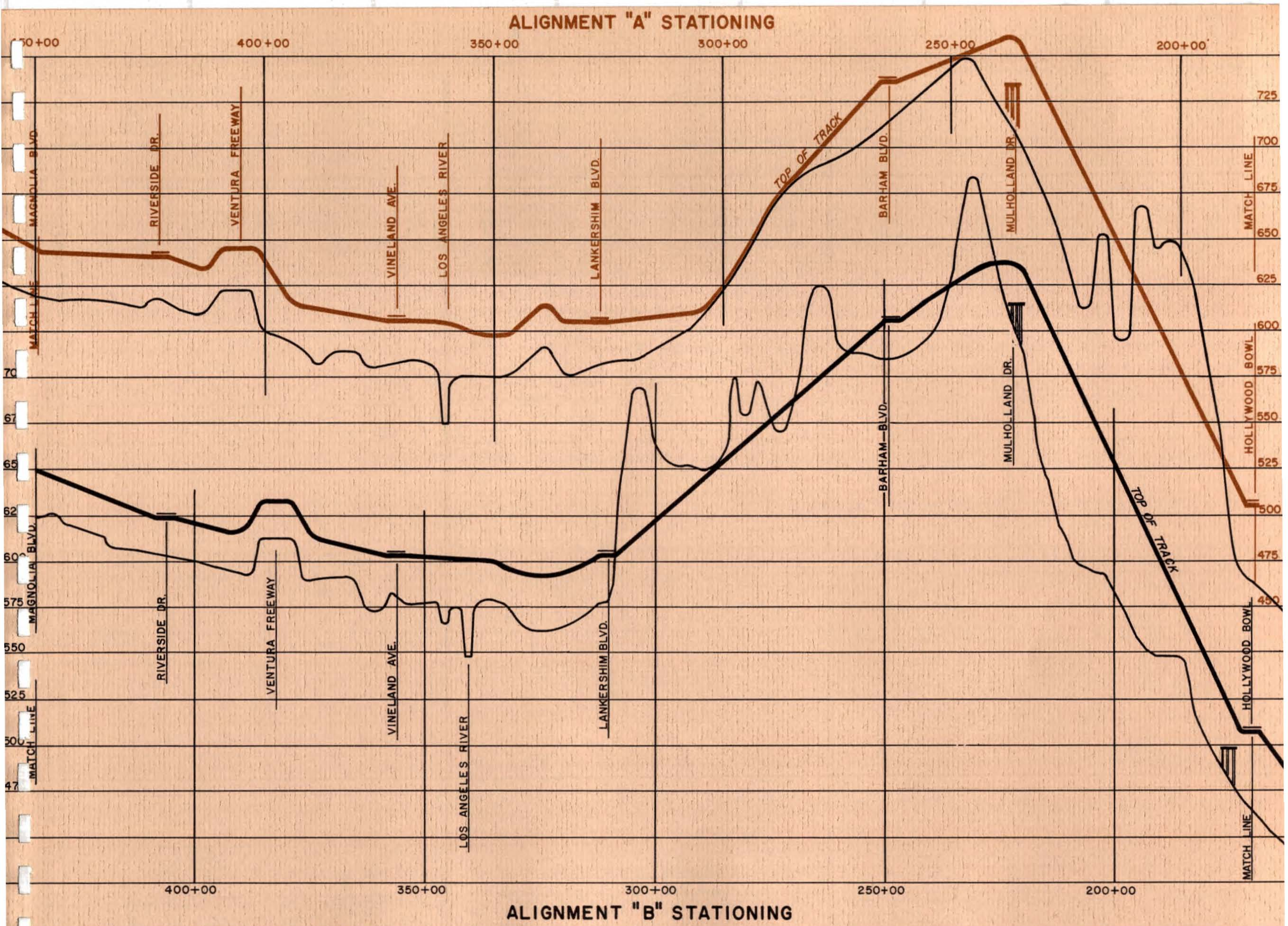
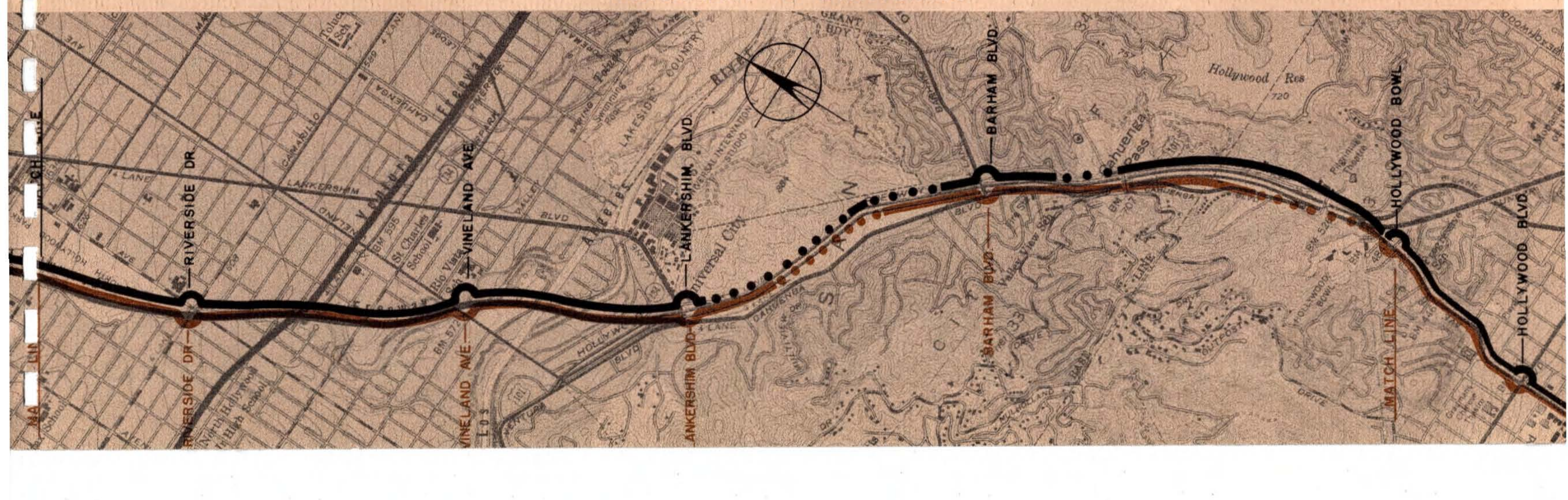


Figure IV-10. Key


ALIGNMENT "A" STATIONING
400+00
350+00
300+00
250+00
200+00
MATCH LINE
MAGNOLIA BLVD.
RIVERSIDE DR.
VENTURA FREEWAY
VINELAND AVE.
LOS ANGELES RIVER
LANKERSHIM BLVD.
TOP OF TRACK
BARHAM BLVD.
MULHOLLAND DR.
HOLLYWOOD BOWL
725
700
675
650
625
600
575
550
525
500
475
450
ALIGNMENT "B" STATIONING


RIVERSIDE DR.
VINELAND AVE.
LANKERSHIM BLVD.
BARHAM BLVD.
HOLLYWOOD BOWL
HOLLYWOOD BLVD.
MATCH LINE
Hollywood Res

RESEDA CORRIDOR

ALIGNMENT "A"

Alignment "A" continues along the west side of the Hollywood Freeway to a station located at Chandler Boulevard in the North Hollywood area where transfer to bus line number 93 would be possible. Continuing north, the line proceeds in an overhead structure to Victory Boulevard where a station would be located just east of Whitsett Avenue. Transfer connections to bus line number 86 operating along Victory Boulevard could be accomplished at this point. This station would serve the Valley Plaza and May Company Shopping centers. A major "park 'n ride" facility would be planned at this site.

Alignment "A" would then continue west along the center of Victory Boulevard utilizing an overhead structure on a median and would connect to stations at Coldwater Canyon Avenue, Woodman Avenue and Van Nuys Boulevard. The Van Nuys Boulevard station would serve the important retail shopping strip along Van Nuys Boulevard and the Civic Center planned for the San Fernando Valley. Transfer connections to bus line number 90 could be made from this station. Future feeder bus facilities could be provided at both the Woodman Avenue station and the Coldwater Canyon station as conditions warrant.

ALIGNMENT "B"

Alignment "B" parallels the east side of the Hollywood Freeway to a point just north of Magnolia Boulevard where it crosses the freeway into the Southern Pacific right-of-way located in the center of Chandler Boulevard.

This line would continue westerly as an overhead structure utilizing the Southern Pacific right-of-way to Van Nuys Boulevard.

Stations would be located along this line at Laurel Canyon Boulevard and at Burbank Boulevard serving the San Fernando Valley Junior College. Stations would also be located at Woodman Avenue and at Van Nuys Boulevard serving the central part of Van Nuys.

This line would need to be constructed on overhead structure in the existing Southern Pacific right-of-way since many sections are relatively narrow and do not provide sufficient space for a rapid transit facility to parallel the tracks, particularly in that portion between Burbank Boulevard and Van Nuys Boulevard.

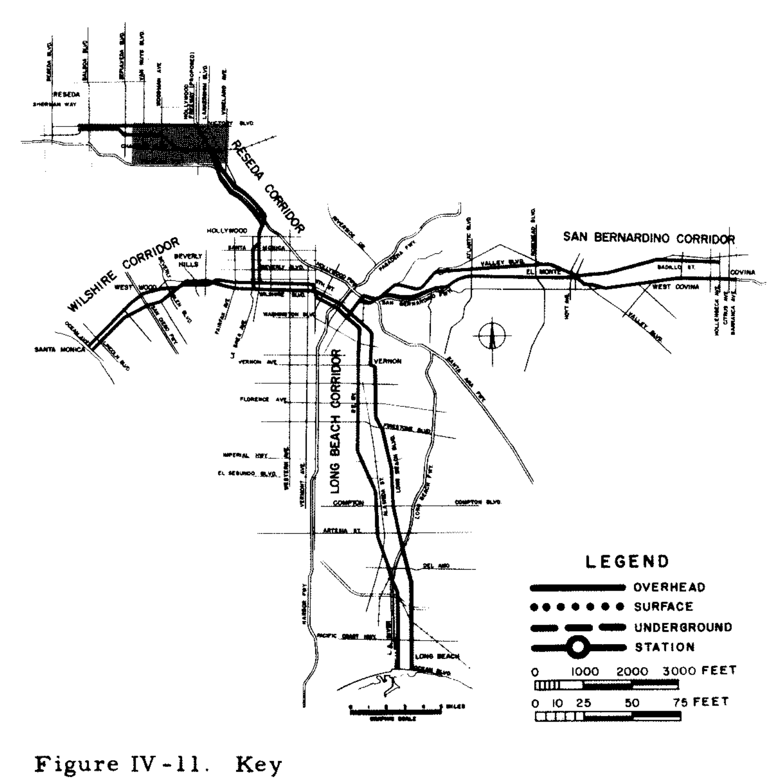
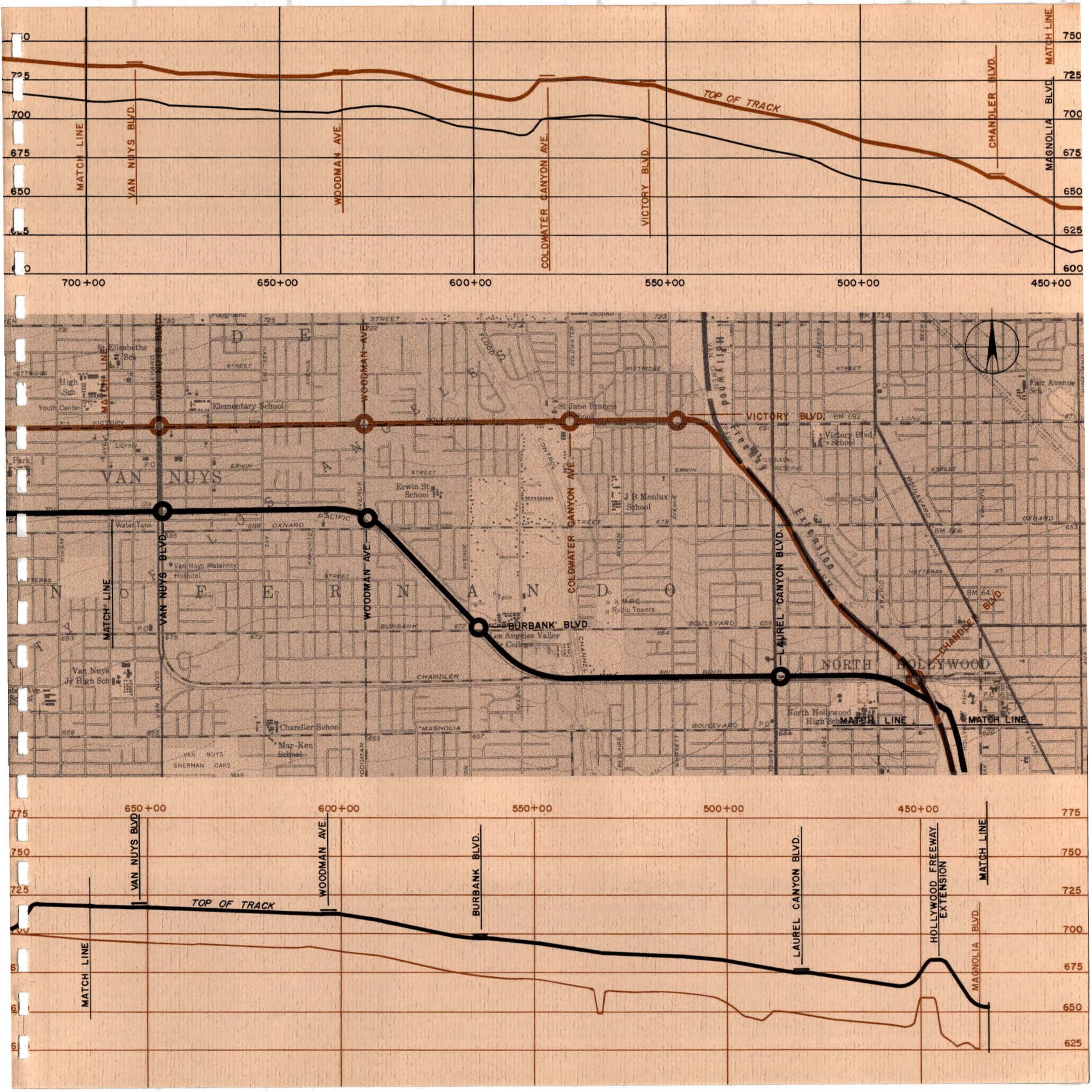


Figure IV-11. Key


750
725
700
675
650
625
600
MATCH LINE
VAN NUYS BLVD.
WOODMAN AVE.
COLDWATER CANYON AVE.
VICTORY BLVD.
TOP OF TRACK
CHANDLER BLVD.
MAGNOLIA BLVD.
MATCH LINE
700+00
650+00
600+00
550+00
500+00
450+00
VAN NUYS
NORTH HOLLYWOOD
MATCH LINE
VAN NUYS BLVD.
WOODMAN AVE.
VICTORY BLVD.
COLDWATER CANYON AVE.
BURBANK BLVD.
LAUREL CANYON BLVD.
CHANDLER BLVD.
Hollywood Freeway Extension
St Elizabeths Sch
Elementary School
St Jane Francis School
Victory Blvd. School
Erwin St School
J B Monlux School
Van Nuys Maternity Hospital
KMPC Radio Towers
Los Angeles Valley College
Van Nuys Jr High Sch
Chandler School
Mar-Ken School
North Hollywood High Sch
Fair Avenue Sch
MATCH LINE
MATCH LINE
775
750
725
700
675
650
625
650+00
600+00
550+00
500+00
450+00
MATCH LINE
VAN NUYS BLVD
WOODMAN AVE
TOP OF TRACK
BURBANK BLVD.
LAUREL CANYON BLVD.
HOLLYWOOD FREEWAY EXTENSION
MAGNOLIA BLVD.
MATCH LINE

RESEDA CORRIDOR

ALIGNMENT "A"

Leaving the Van Nuys Boulevard station, Alignment "A" continues overhead in the median of Victory Boulevard to a station located at Sepulveda Boulevard where transfer to bus line number 74 would be possible. The line then proceeds to stations at Woodley Avenue, Balboa Boulevard, and then to a terminal station located near Louise Avenue. At this terminal station, major "park 'n ride" facilities would be provided and the main transit vehicle storage area for the Reseda Corridor would be planned. It is anticipated that a feeder bus line serving the western section of the San Fernando Valley would be developed to connect with this terminal station.

Victory Boulevard in this section is of sufficient width to allow for construction of an adequate rapid transit median without appreciably affecting the traffic and parking characteristics of the street.

ALIGNMENT "B"

Alignment "B" continues to utilize an overhead structure from Van Nuys Boulevard over the existing Southern Pacific tracks to Kester Avenue. The line then proceeds at grade to the Reseda Terminal, except for overcrossings at Sepulveda and Balboa Boulevards. Stations would be located at the same cross streets with bus connections similar to those along Alignment "A". Parking and storage facilities would also be developed at the Reseda Terminal to serve this line.

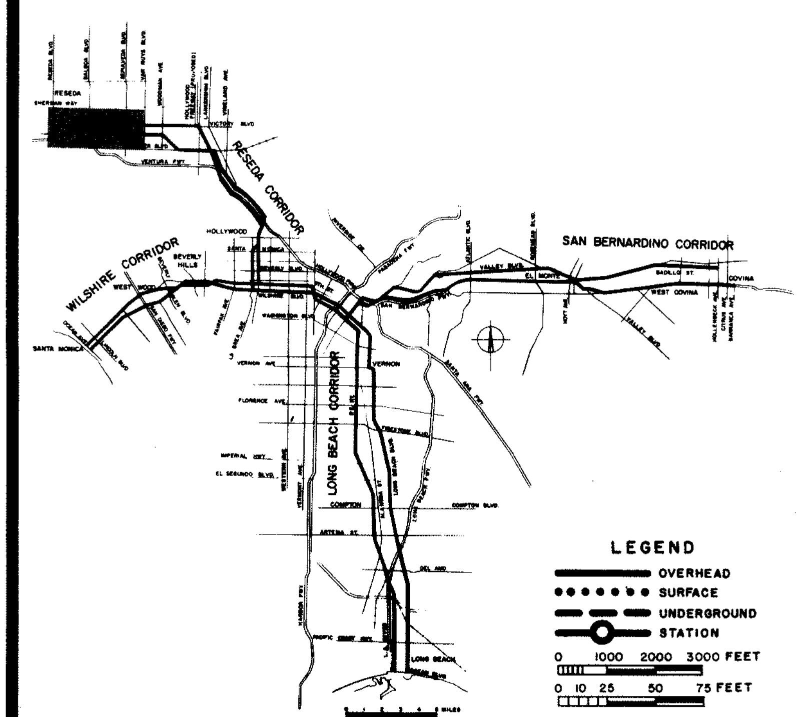
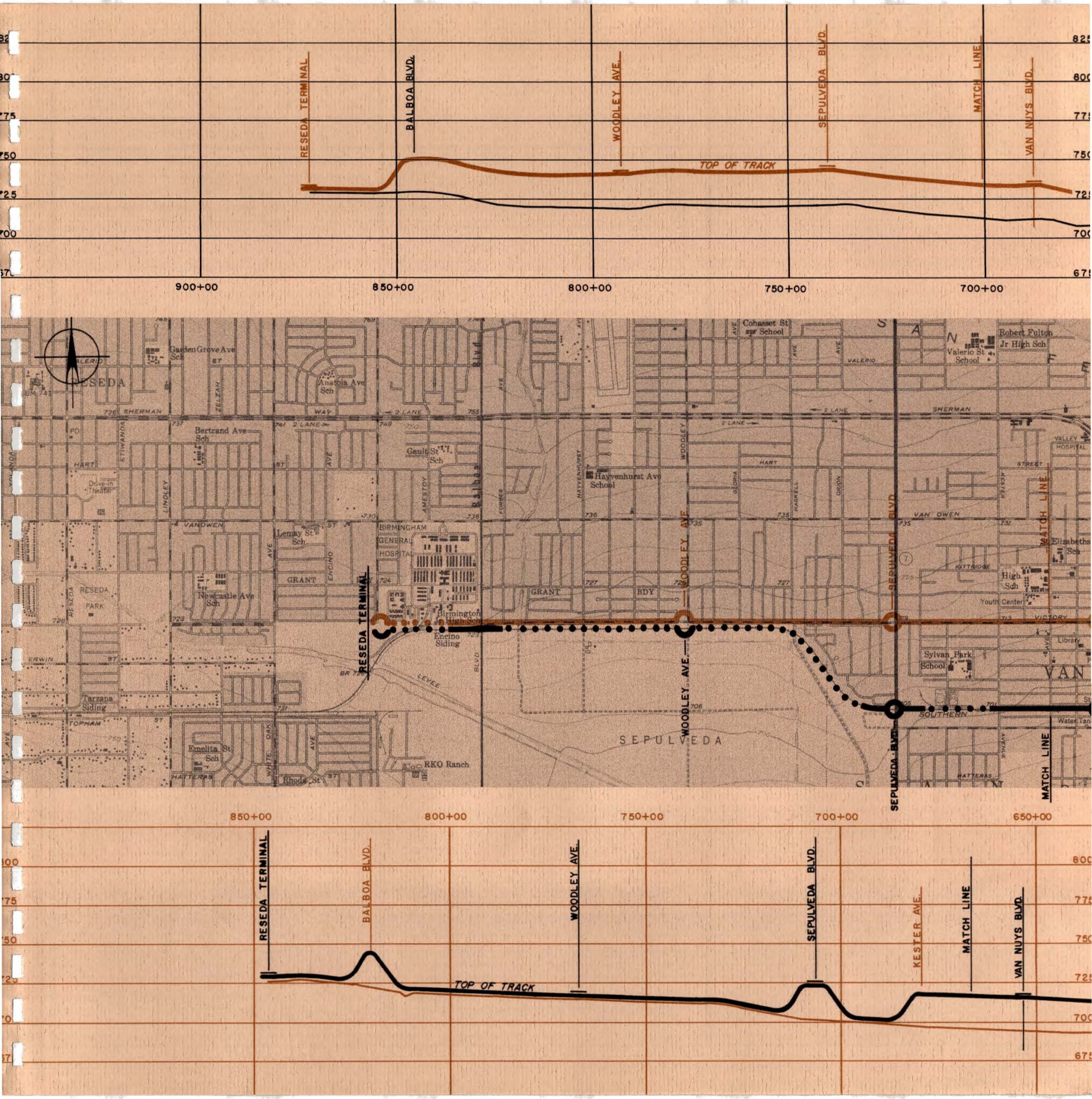


Figure IV-12. Key



RESEDA TERMINAL
BALBOA BLVD.
WOODLEY AVE.
SEPULVEDA BLVD.
MATCH LINE
VAN NUYS BLVD.
TOP OF TRACK
825
800
775
750
725
700
675
900+00
850+00
800+00
750+00
700+00
RESEDA
SHERMAN
2 LANE
Bertrand Ave Sch
Garden Grove Ave Sch
Anatola Ave Sch
Gault St Sch
Hayvenhurst Ave School
Cohasset St School
Valerio St School
Robert Fulton Jr High Sch
VALERIO
HART
VANOWEN
VAN OWEN
GRANT
BIRMINGHAM GENERAL HOSPITAL
Birmington High Sch
Encino Siding
Lemay St Sch
Newcastle Ave Sch
RESEDA PARK
Drive-in Theater
ERWIN
Tarzana Siding
TOPHAM
Emelita St Sch
HATTERAS
Rhodes St
RKO Ranch
LEVEE
SEPULVEDA
SOUTHERN
Sylvan Park School
VAN
VICTORY
KITTRIDGE
Youth Center
Library
VALLEY HOSPITAL
WHITE OAK
WOODLEY
HASKELL
ORION
ENCINO
AMESTOY
LINDLEY
ETIWANDA
ZELZAH
850+00
800+00
750+00
700+00
650+00
RESEDA TERMINAL
BALBOA BLVD.
WOODLEY AVE.
SEPULVEDA BLVD.
KESTER AVE.
MATCH LINE
VAN NUYS BLVD.
TOP OF TRACK
800
775
750
725
700
675

SAN BERNARDINO CORRIDOR

ALIGNMENT "A"

Beginning with the Union Passenger Terminal Station, Alignment "A" continues easterly along Commercial Street using an overhead way structure to a point just west of the Los Angeles River where the line then crosses over the Santa Ana Freeway. Alignment "A" then proceeds over the Los Angeles River to a point about 600 feet east of Macy Street where transition to at-grade operation is made. Just beyond this point, the line joins the Pacific Electric Railway right-of-way paralleling the San Bernardino Freeway to a connection with the recommended Macy Street Central Maintenance Yard.

Leaving the Yard, Alignment "A" continues at grade along the Pacific Electric right-of-way to a station at State Street where service to the Los Angeles County General Hospital would be provided. The line then proceeds along the Pacific Electric right-of-way to stations located at Soto Street and Eastern Avenue. At the Soto Street station, transfer to bus lines numbers 50 and 92 would be possible. The Eastern Avenue station would provide service to the Los Angeles State College and would have transfer facilities to bus lines numbers 2 and 3.

The potential use of the Pacific Electric right-of-way in this section is regarded as an important factor for selecting Alignment "A" as one of the two recommended rapid transit routes.

Between the porposed Macy Street Yard and a point just beyond Eastern Avenue, where the Pacific Electric Railway enters the San Bernardino Freeway, there is sufficient width to provide space for four parallel tracks, two for passenger trains and two for freight service.

ALIGNMENT "B"

Leaving the Union Passenger Terminal, Alignment "B" changes from subway to an overhead line at a point just east of the Terminal railway yard. The line then enters Macy Street on an overhead structure along a proposed center median to a point just west of the Los Angeles River. At this point, Alignment "A" would leave Macy Street, bridge over the river and enter Mission Road near Gallardo Street. A connection to the Macy Street Central Maintenance Yard would be made from Mission Road about 1000 feet east of Gallardo Street.

The line would then continue as an overhead structure along the center of Mission Road crossing over the Golden State Freeway and to a station just east of Marengo Street providing service to the Los Angeles County General Hospital. Continuing to the intersection of Valley Boulevard and Mission Road near the west end of Lincoln Park, Alignment "B" would swing into the center of Valley Boulevard and proceed easterly to stations located at Soto Street and Eastern Avenue. Transfer to bus line number 92 would be possible at the Soto Street station.

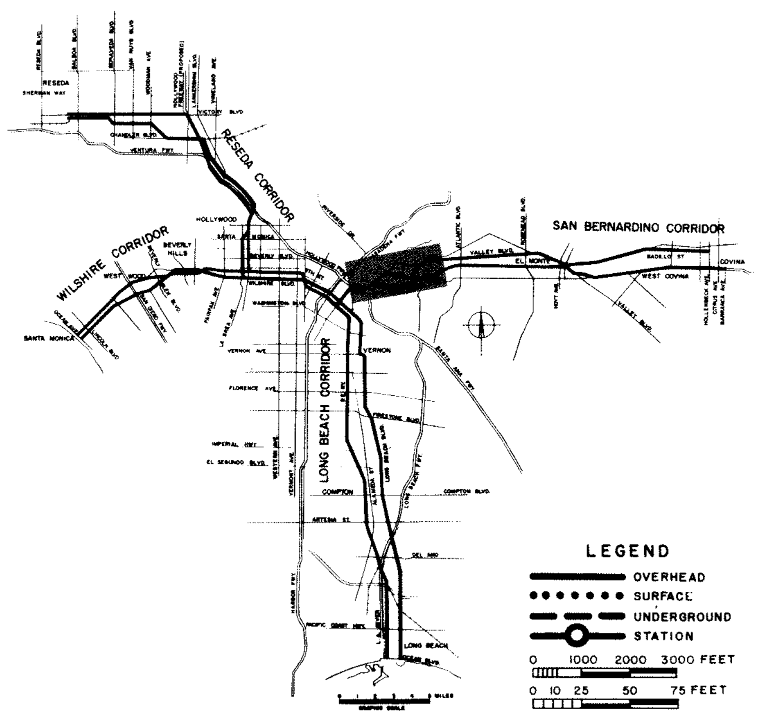


Figure IV-13. Key

UNION STATION
TUNNEL PORTAL
L.A. RIVER BRIDGE
MISSION ROAD
GOLDEN STATE FWY.
STATE ST.
SOTO ST.
TOP OF TRACK
EASTERN AVE.
MATCH LINE
50+00
100+00
150+00
200+00
250+00
400
375
350
325
300
275
250
FIRST & MAIN ST.
MATCH LINE
UNION STATION
GENERAL HOSPITAL
SOTO ST.
EASTERN AVE.
MATCH LINE
GENERAL MAINTENANCE & STORAGE AREA
UNION STATION
STATE ST.
SOTO ST.
EASTERN AVE.
MATCH LINE
LOS ANGELES
Lincoln Heights
El Sereno
Freeway
UNION STATION
SANTA ANA FREEWAY
GOLDEN STATE FREEWAY
GENERAL HOSPITAL
TOP OF TRACK
SOTO ST.
IDENTICAL
EASTERN AVE.
MATCH LINE
450
425
400
375

SAN BERNARDINO CORRIDOR

ALIGNMENT "A"

Continuing easterly in the median of the San Bernardino Freeway at grade, Alignment "A" would provide stations at Fremont Avenue, Atlantic Boulevard and New Avenue. At the Atlantic Boulevard station, it is anticipated that feeder bus facilities would be made available to serve the communities of Alhambra and Monterey Park. The station located at New Avenue would be planned with "park 'n ride" facilities.

Current plans of the California State Division of Highways indicate that construction of an additional traffic lane on both sides of the San Bernardino Freeway median between the Long Beach Freeway and Rosemead Boulevard would be accomplished during the next year, and thereby reduce the median width from 80 feet to approximately 50 feet. Based on this 50 foot width, there would be space for three tracks at grade. It is anticipated, therefore, that two rapid transit tracks and one freight track, at grade, would be planned through this section.

Although this alignment does not follow a major commercial street, such as Valley Boulevard, it is still located relatively close to the center of the communities of Alhambra, Monterey Park, San Gabriel, and Rosemead, and would provide excellent rapid transit service.

ALIGNMENT "B"

Alignment "B" continues easterly along the center of Valley Boulevard to the overhead way structure with stations located at the same cross streets as along Alignment "A", and with the same transfer and "park 'n ride" facilities.

Valley Boulevard is of sufficient width through this section to accommodate a rapid transit median while still maintaining satisfactory traffic and parking operations. Due to an existing sharp curve between Borland Road and Cabrillo Avenue, the rapid transit line would need to be realigned through a private right-of-way strip north of Valley Boulevard.

In addition to physical advantages, Valley Boulevard is recommended as an alternate rapid transit alignment because of its excellent service location. It is one of the most important commercial thoroughfares in the San Gabriel Valley providing direct service to the communities of El Sereno, Alhambra, San Gabriel, and Rosemead.

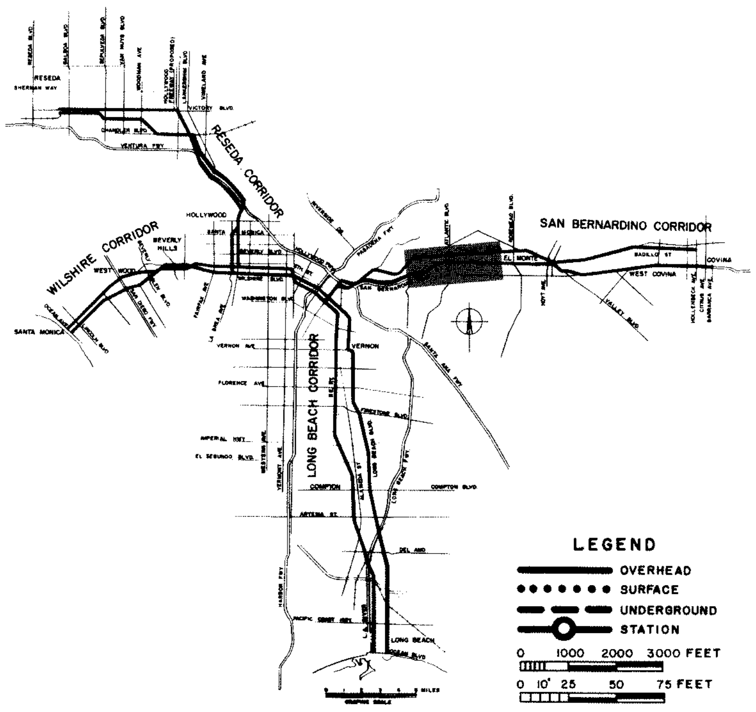
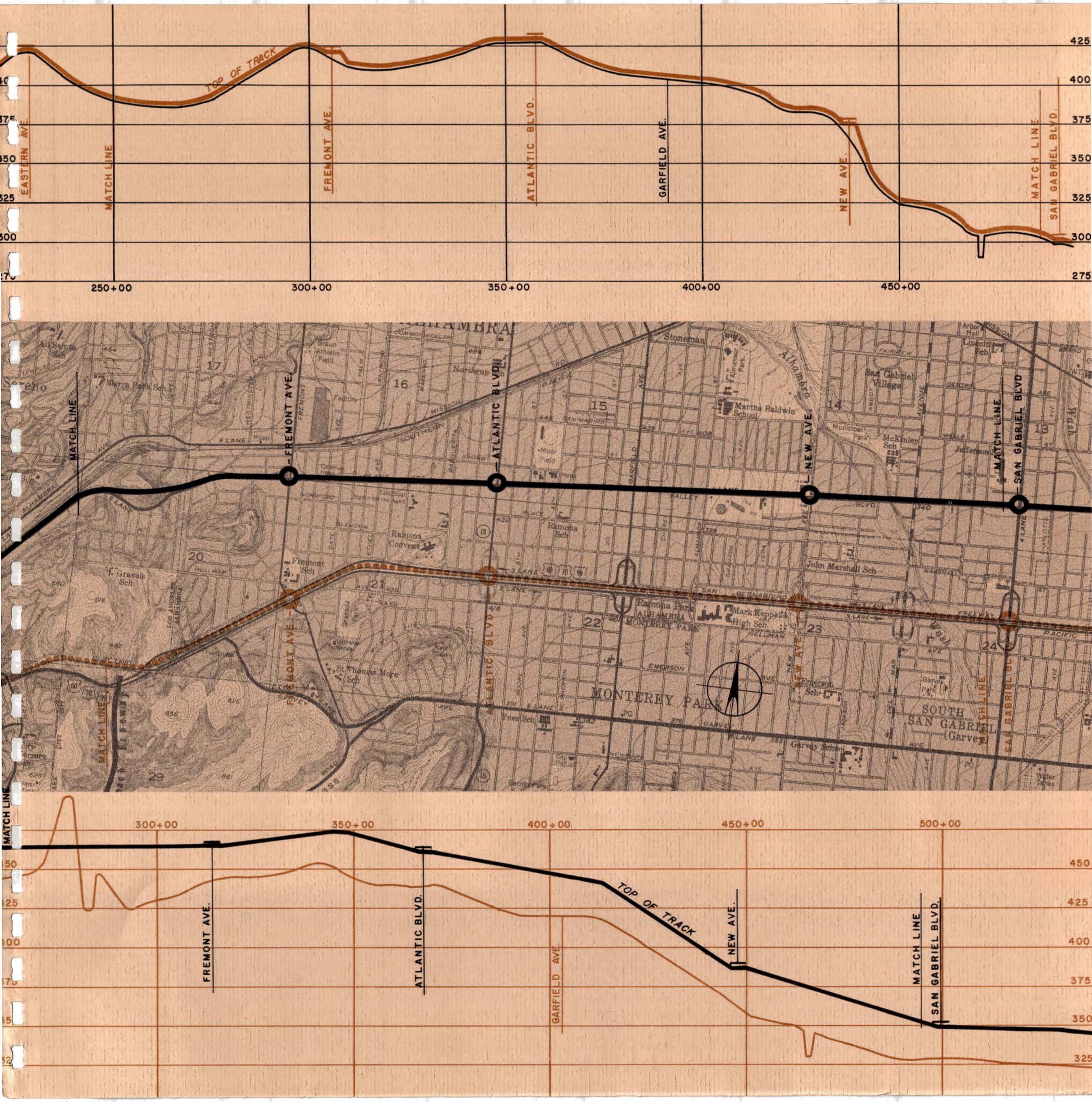


Figure IV-14. Key


TOP OF TRACK
EASTERN AVE.
MATCH LINE
FREMONT AVE.
ATLANTIC BLVD.
GARFIELD AVE.
NEW AVE.
SAN GABRIEL BLVD.
425
400
375
350
325
300
275
250+00
300+00
350+00
400+00
450+00
ALHAMBRA
MONTEREY PARK
SOUTH SAN GABRIEL (Garvey)
San Gabriel Village
Martha Baldwin School
John Marshall Sch
Ramona Convent
Mark Keppel High Sch
Ramona Park
Thomas More Sch
Fremont Sch
Gravois Sch
Sierra Park Sch
Garvey School
Emerson Sch
McKinley Sch
Jefferson
Ramona Sch
Northrup
Stoneman
SOUTHERN PACIFIC
FREEWAY
GARFIELD AVE.
500+00
450

SAN BERNARDINO CORRIDOR

ALIGNMENT "A"

Beyond New Avenue, Alignment "A" proceeds along the median of the San Bernardino Freeway to stations at San Gabriel Boulevard and Rosemead Blvd. Just east of Baldwin Avenue, the Pacific Electric Railway leaves the median of the San Bernardino Freeway using a narrow underpass of approximately 35 feet in width. The proposed rapid transit line would utilize one of the two existing Pacific Electric tracks through this underpass while the other passenger track would need to be constructed over the freeway. Beyond this point, Alignment "A" proceeds at grade along the Pacific Electric right-of-way over the Rio Hondo River and then changes from at grade to an overhead line near Hoyt Avenue in the City of El Monte. The line then would continue on an overhead structure to a station at Lexington Avenue. This station would be developed as a major "park 'n ride" facility and would provide for transit vehicle storage. Excellent service from this station to downtown El Monte would be provided. Leaving the Lexington Avenue station, Alignment "A" continues over the Pacific Electric Railway to a station at Peck Road.

ALIGNMENT "B"

Alignment "B" continues on an overhead structure in a proposed median along Valley Boulevard to stations at San Gabriel Boulevard, Rosemead Boulevard, and Hoyt Avenue. At the Hoyt Avenue station, provisions would be made for major "park 'n ride" facilities as well as storage for transit vehicles. Beyond this station, Alignment "B" would follow Monte Vista Street which bypasses the downtown El Monte area, re-entering Valley Boulevard just south of San Bernardino Road. From here, the line would continue easterly to a station at Peck Road. As in the previous section of Valley Boulevard, the route is of sufficient width to allow for construction of a rapid transit median while maintaining adequate street capacity for surface traffic.

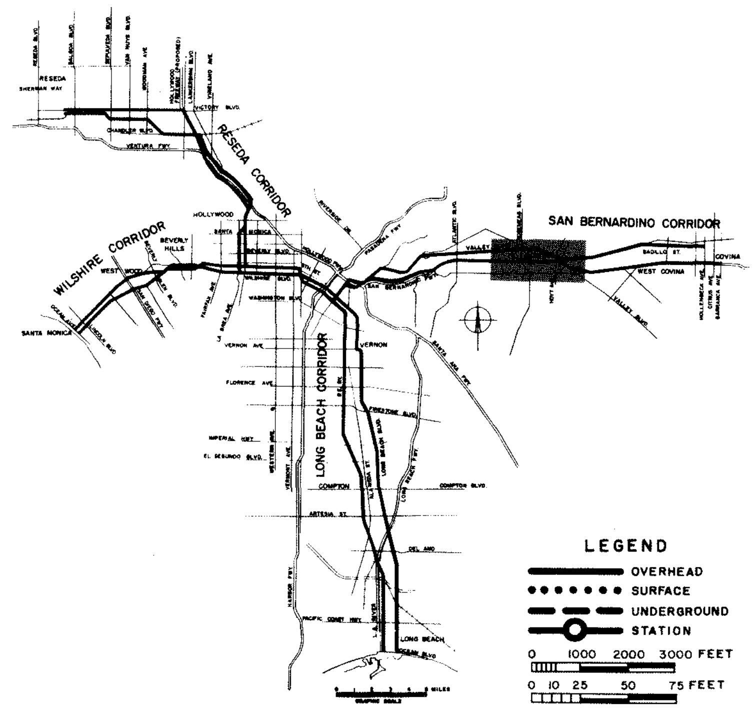
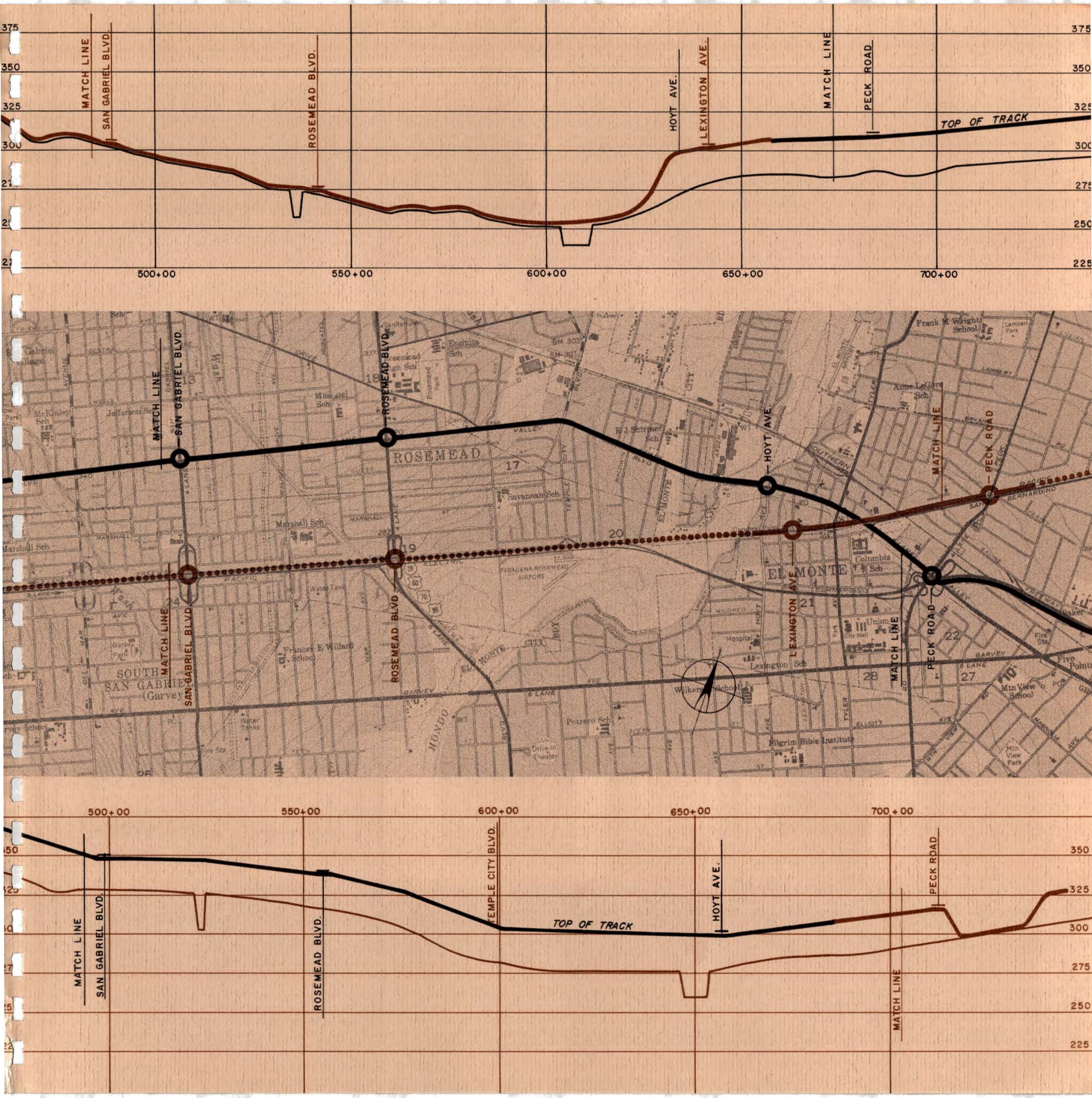


Figure IV-15. Key



MATCH LINE
SAN GABRIEL BLVD.
ROSEMEAD BLVD.
HOYT AVE.
LEXINGTON AVE.
MATCH LINE
PECK ROAD
TOP OF TRACK
375
350
325
300
275
250
225
500+00
550+00
600+00
650+00
700+00
ROSEMEAD
EL MONTE
SOUTH SAN GABRIEL (Garvey)
PASADENA-ROSEMEAD AIRPORT
SAN GABRIEL BLVD.
ROSEMEAD BLVD.
HOYT AVE.
LEXINGTON AVE.
PECK ROAD
MATCH LINE
TEMPLE CITY BLVD.
TOP OF TRACK
HOYT AVE.
PECK ROAD

SAN BERNARDINO CORRIDOR

ALIGNMENT "A"

Just east of Peck Road, Alignment "A" changes from overhead to at grade operation except at crossings over Cogswell Road, Maxson Road and the San Gabriel River to a station at Rivergrade Road. Leaving the station, the line returns to grade along the Pacific Electric Railway to a point just west of Harlan Avenue. The line then crosses Harlan Avenue and continues easterly over the Pacific Electric Railway to a station at Maine Avenue in Baldwin Park.

The station at Rivergrade Road would be developed as a major "park 'n ride" facility. In addition, when the proposed San Gabriel River freeway is developed, it is possible that feeder buses running along the freeway could service between this station and the communities of Azusa, Irwindale, Baldwin Park, Bassett, and La Puente.

ALIGNMENT "B"

Leaving El Monte and just beyond the Peck Road station, Alignment "B" would cross over the San Bernardino Freeway, utilizing portions of relatively wide fill slopes along the south side of the freeway, crossing over the San Gabriel River to a station at Rivergrade Road. As in the case of Alignment "A", this station would be developed as a major "park 'n ride" facility with connections to the future San Gabriel River Freeway and to feeder bus lines. The line would continue as an overhead facility along the south side of the freeway to a station location at Francisquito Avenue.

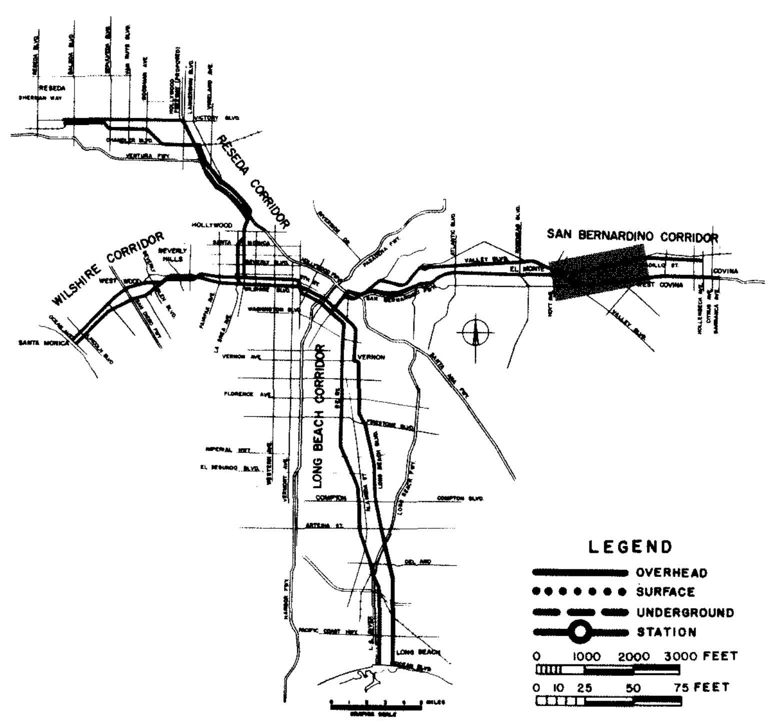
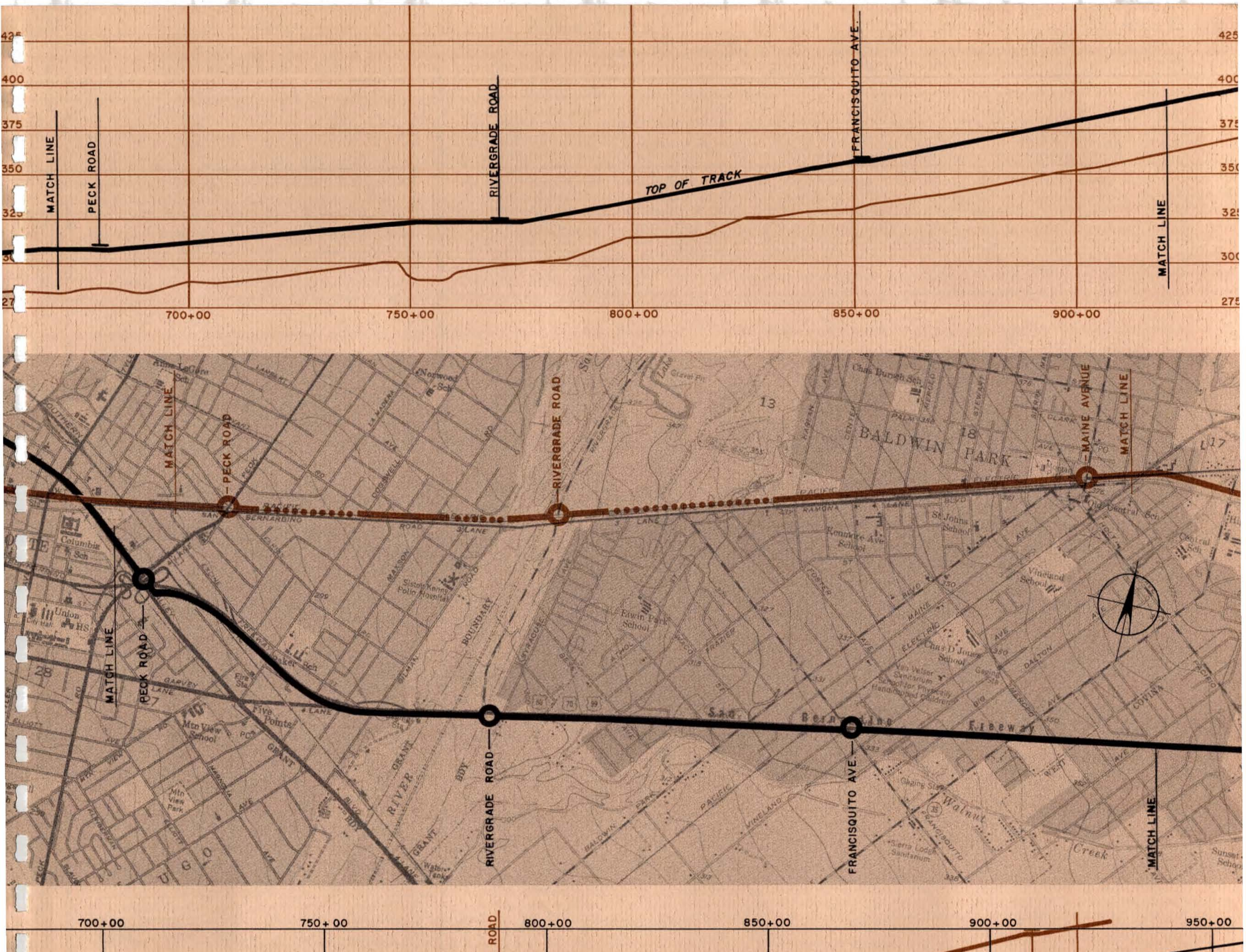


Figure IV-16. Key



425
400
375
350
325
300
275
MATCH LINE
PECK ROAD
RIVERGRADE ROAD
FRANCISQUITO AVE.
TOP OF TRACK
MATCH LINE
700+00
750+00
800+00
850+00
900+00
MATCH LINE
PECK ROAD
RIVERGRADE ROAD
MAINE AVENUE
MATCH LINE
BALDWIN PARK
MATCH LINE
PECK ROAD
RIVERGRADE ROAD
FRANCISQUITO AVE.
MATCH LINE
700+00
750+00
800+00
850+00
900+00
950+00
MATCH LINE
PECK ROAD
RIVERGRADE ROAD
TOP OF TRACK
MAINE AVENUE
MATCH LINE
COGSWELL
MAXSON RD.
HARLAN AVE.
375
350
325
300
275
250

SAN BERNARDINO CORRIDOR

ALIGNMENT "A"

Alignment "A" crosses over the Pacific Electric right-of-way to El Monte Street. At this point, the line leaves the railway and turns east into El Monte Street to a station at Orange Avenue. Just east of Orange Avenue, where El Monte Street changes its name to Badillo Street, the line returns to grade, except for overcrossings at stations and at Irwindale Avenue and Lark Ellen Avenue. Stations through this section would be located at Vincent Avenue, Azusa Avenue and the San Bernardino Terminal at Hollenbeck Street.

"Park 'n ride" and transit vehicle storage facilities would be provided at the Terminal Station.

ALIGNMENT "B"

Alignment "B" proceeds in overhead structure easterly along the south side of the San Bernardino Freeway and would have stations at Pacific Avenue, Vincent Avenue, Azusa Avenue and the San Bernardino Terminal at Barranca Street. Parking and transit vehicle storage facilities would be provided at the terminal station.

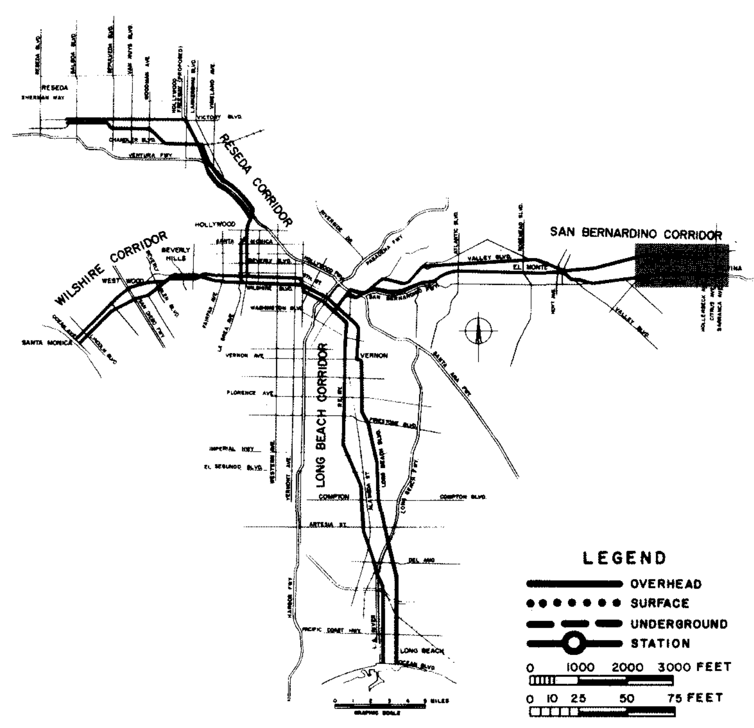
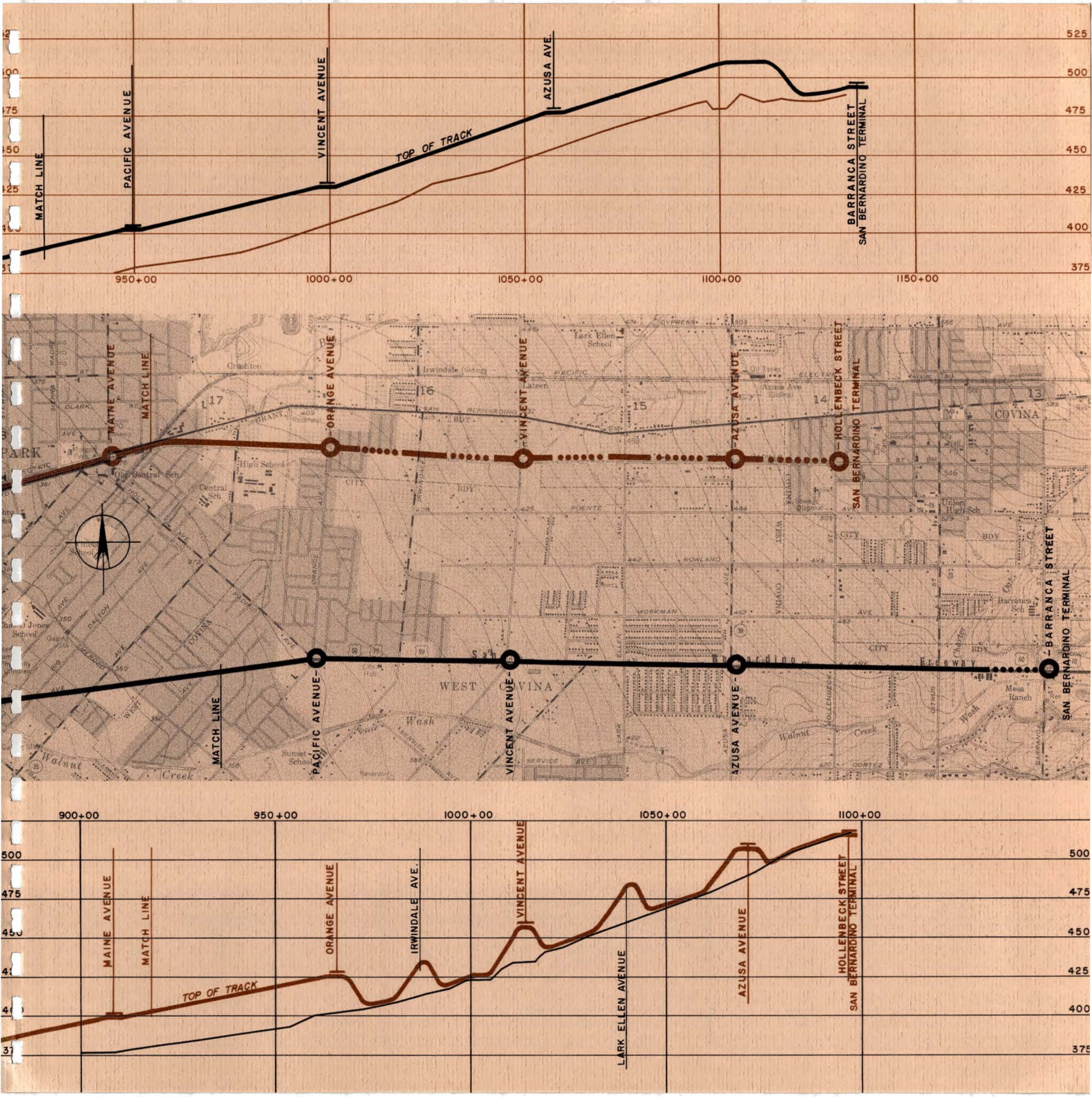


Figure IV-17. Key



MATCH LINE
PACIFIC AVENUE
VINCENT AVENUE
AZUSA AVE.
TOP OF TRACK
BARRANCA STREET
SAN BERNARDINO TERMINAL
525
500
475
450
425
400
375
950+00
1000+00
1050+00
1100+00
1150+00
MAINE AVENUE
MATCH LINE
ORANGE AVENUE
VINCENT AVENUE
AZUSA AVENUE
HOLLENBECK STREET
SAN BERNARDINO TERMINAL
COVINA
WEST COVINA
PACIFIC AVENUE
VINCENT AVENUE
AZUSA AVENUE
BARRANCA STREET
SAN BERNARDINO TERMINAL
MATCH LINE
900+00
950+00
1000+00
1050+00
1100+00
MAINE AVENUE
MATCH LINE
TOP OF TRACK
ORANGE AVENUE
IRWINDALE AVE.
VINCENT AVENUE
LARK ELLEN AVENUE
AZUSA AVENUE
HOLLENBECK STREET
SAN BERNARDINO TERMINAL
500
475
450
425
400
375

LONG BEACH CORRIDOR

ALIGNMENT "A"

Leaving the junction at 8th and Main Streets, Alignment "A" proceeds on an overhead way structure in the center of 8th Street to stations located at San Pedro Street and Central Avenue where transfer to bus line number 3 would be possible.

Beyond the Central Avenue station, the line would turn south into the existing Pacific Electric Railway right-of-way and to a station at Washington Boulevard. Continuing southerly over the Pacific Electric tracks, Alignment "A" would connect with stations at Vernon Avenue, where transfer to surface transit line V could be made; at Slauson Avenue and at Florence Avenue, where transfer to bus lines numbers 72 and 50 is possible.

As indicated in the plan on the opposite page, Alignment "A" through this section would be at grade between 48th Place and 55th Street and between 65th Street and 70th Street requiring the closing of 68th Street.

ALIGNMENT "B"

Alignment "B" continues as subway beyond the junction at 7th and Main Streets and transitions to an overhead way structure in the vicinity of 7th Street and San Julian Street north of San Pedro Street.

Beyond this point, the overhead line proceeds along the center of 7th Street to a station at Central Avenue where transfer to bus line number 3 could be made.

The line then proceeds over an area of extensive trackage including the Alameda Street yards, crossing over the Santa Monica Freeway now under construction, and into Santa Fe Avenue. The line would then continue on an overhead way structure along a proposed center median on Santa Fe Avenue to a station at Olympic Boulevard where transfer to bus line number 47 could be made.

Continuing southerly along Santa Fe Avenue, Alignment "B" would proceed to a point just north of Vernon Avenue where it could turn easterly through private right-of-way, crossing over Vernon Avenue and then into Pacific Boulevard. A station would be provided at Vernon Avenue where transfer to transit lines, V, J, and number 23 could be made. The line would then follow the center of Pacific Boulevard on an overhead structure to stations located at Slauson Avenue and Florence Avenue.

Santa Fe Street is approximately 60 feet wide and may require the restriction of curb parking on at least one side of the street to accommodate the proposed rapid transit median while still maintaining normal vehicular traffic capacity.

Pacific Boulevard is of sufficient width to allow placement of a rapid transit median without adversely affecting existing traffic operation.

The alignment along Santa Fe Avenue and Pacific Boulevard, an important retail shopping street, would offer excellent service to the heart of the cities of Vernon and Huntington Park.

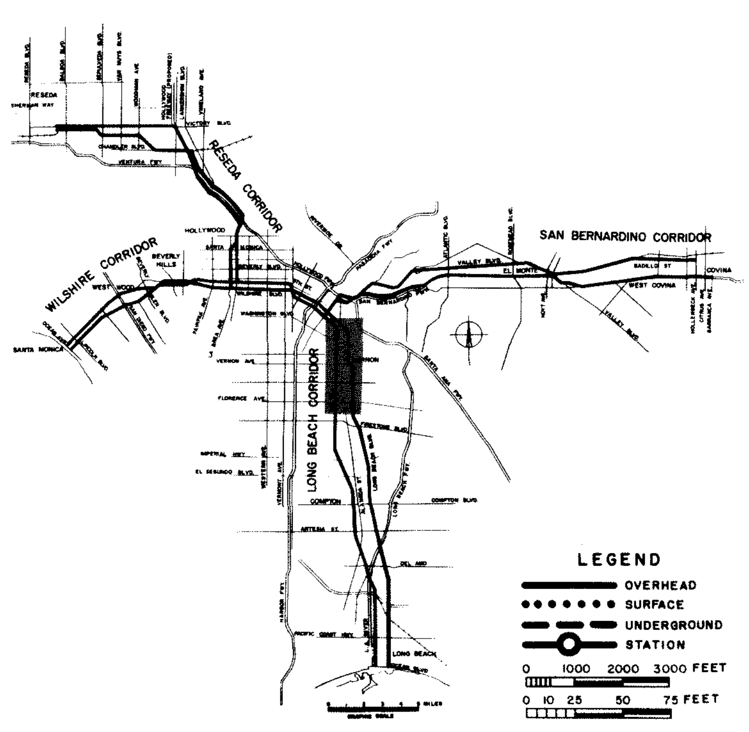
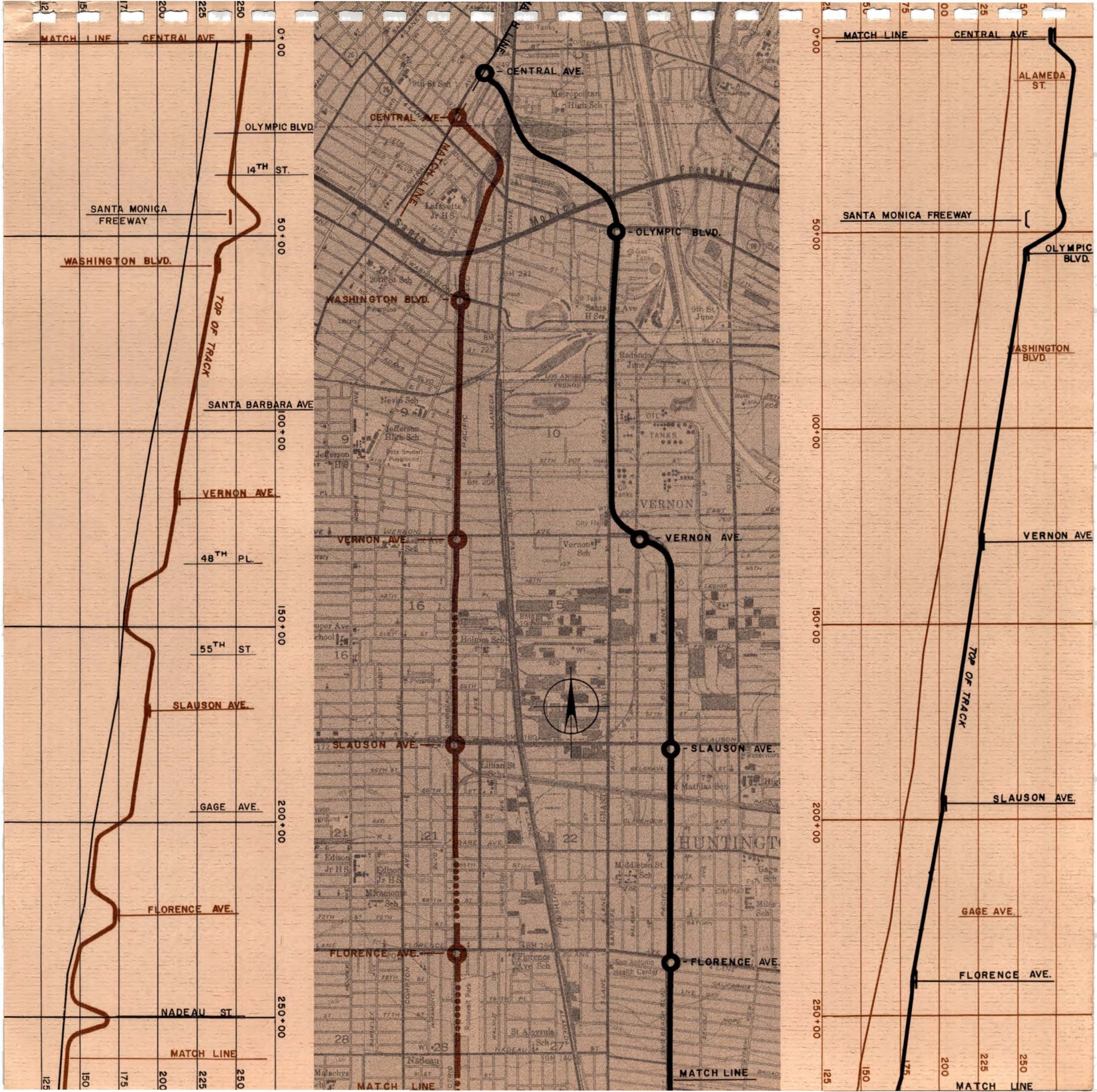


Figure IV-18. Key



MATCH LINE
CENTRAL AVE.
OLYMPIC BLVD.
14TH ST.
SANTA MONICA FREEWAY
WASHINGTON BLVD.
TOP OF TRACK
SANTA BARBARA AVE.
VERNON AVE.
48TH PL.
55TH ST.
SLAUSON AVE.
GAGE AVE.
FLORENCE AVE.
NADEAU ST.
MATCH LINE
0+00
50+00
100+00
150+00
200+00
250+00
125
150
175
200
225
250
CENTRAL AVE.
MATCH LINE
OLYMPIC BLVD.
WASHINGTON BLVD.
VERNON AVE.
VERNON
SLAUSON AVE.
HUNTINGTO
FLORENCE AVE.
MATCH LINE
MATCH LINE
CENTRAL AVE.
ALAMEDA ST.
SANTA MONICA FREEWAY
OLYMPIC BLVD.
WASHINGTON BLVD.
VERNON AVE
TOP OF TRACK
SLAUSON AVE.
GAGE AVE.
FLORENCE AVE.
MATCH LINE

LONG BEACH CORRIDOR

ALIGNMENT "A"

Beyond the Florence Avenue Station, Alignment "A" continues southerly along the Pacific Electric right-of-way to Compton with a station located at Firestone Boulevard, where transfer to bus line number 54 could be made. Stations would also be provided at 103rd Street, Imperial Highway, El Segundo Boulevard, and Compton Boulevard.

Except at stations and over major streets, Alignment "A" would be at grade through this section.

ALIGNMENT "B"

Alignment "B" continues as an overhead structure in a proposed median in the center of Long Beach Boulevard. Stations are recommended for location at Firestone Boulevard, where transfer to bus lines numbers 53 and 54 could be made, and at Tweedy Boulevard, Imperial Highway, and Burton Avenue.

Long Beach Boulevard is of sufficient width to accommodate the rapid transit median without major changes in the traffic and curb parking characteristics.

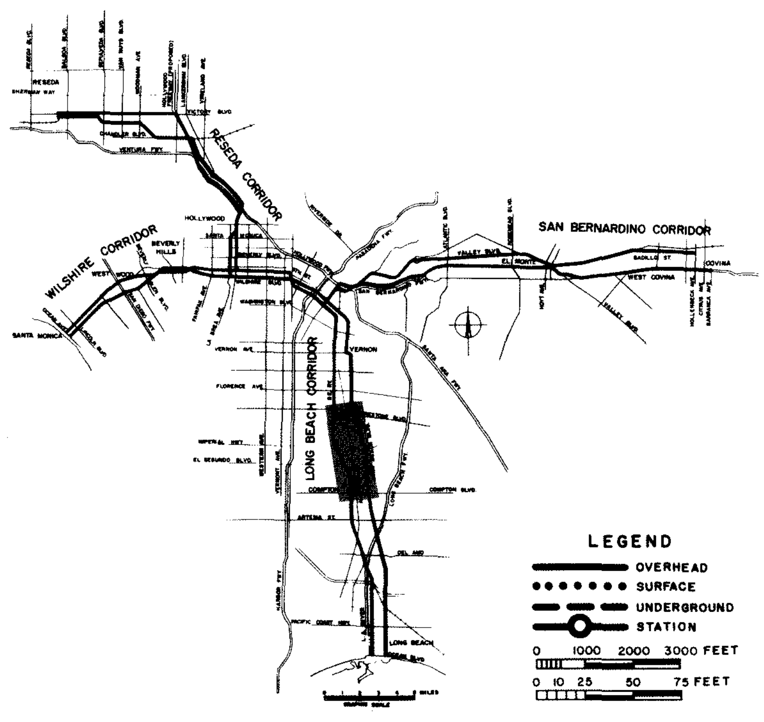
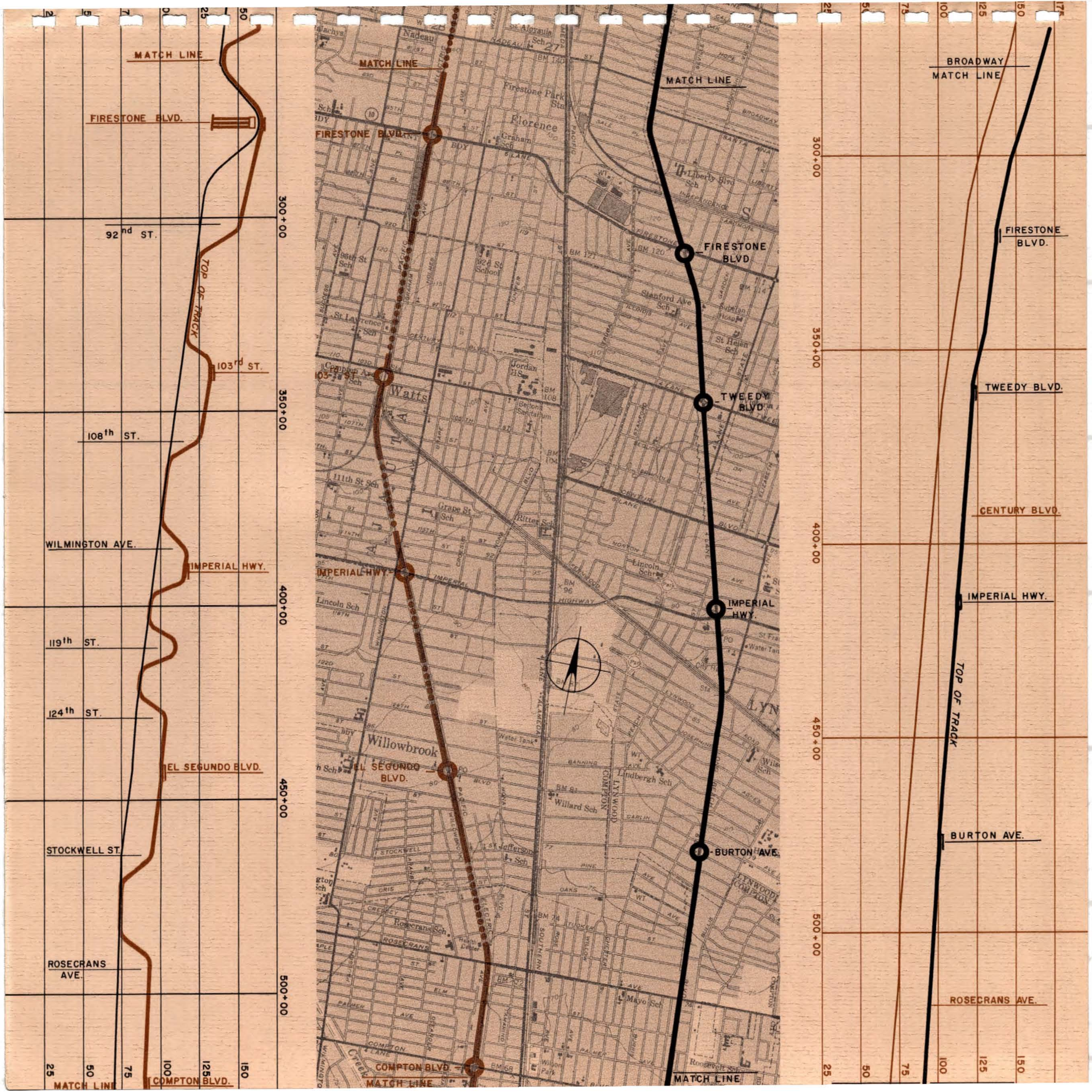


Figure IV-19. Key



MATCH LINE
FIRESTONE BLVD.
92nd ST.
TOP OF TRACK
103rd ST.
108th ST.
WILMINGTON AVE.
IMPERIAL HWY.
119th ST.
124th ST.
EL SEGUNDO BLVD.
STOCKWELL ST.
ROSECRANS AVE.
COMPTON BLVD.
300+00
350+00
400+00
450+00
500+00
25
50
75
100
125
150
MATCH LINE
FIRESTONE BLVD.
103rd ST.
Watts
IMPERIAL HWY.
Willowbrook
EL SEGUNDO BLVD.
COMPTON BLVD.
MATCH LINE
FIRESTONE BLVD
TWEEDY BLVD
IMPERIAL HWY.
BURTON AVE.
MATCH LINE
BROADWAY
MATCH LINE
FIRESTONE BLVD.
TWEEDY BLVD.
CENTURY BLVD.
IMPERIAL HWY.
TOP OF TRACK
BURTON AVE.
ROSECRANS AVE.
175

LONG BEACH CORRIDOR

ALIGNMENT "A"

Alignment "A" proceeds southerly along the Pacific Electric right-of-way to stations at Artesia Avenue and Del Amo Boulevard where "park'n ride" facilities would be developed. It is anticipated that local feeder bus service connections would be made at the Del Amo Boulevard station which would provide service to Lakewood and North Long Beach. Beyond the Del Amo station alignment "A" continues over the Long Beach Freeway and the Los Angeles River and then into a private right-of-way strip alongside the east bank of the River.

Both stations (?) have "parkin ride"

Between Olive Street in Compton and the east bank of the Los Angeles River, Alignment "A" would be at grade, except for grade separation at the stations and at Alameda Street, the Union Pacific Railroad, and the Los Angeles River.

ALIGNMENT "B"

Alignment "B" would proceed along the center of Long Beach Boulevard to a station at Compton Boulevard and then continues southerly in an overhead structure crossing over the Long Beach Freeway and to proposed stations at Artesia Avenue and Del Amo Boulevard. South of Del Amo Boulevard, the line would cross the Union Pacific Railroad tracks with a vertical clearance of 23 feet.

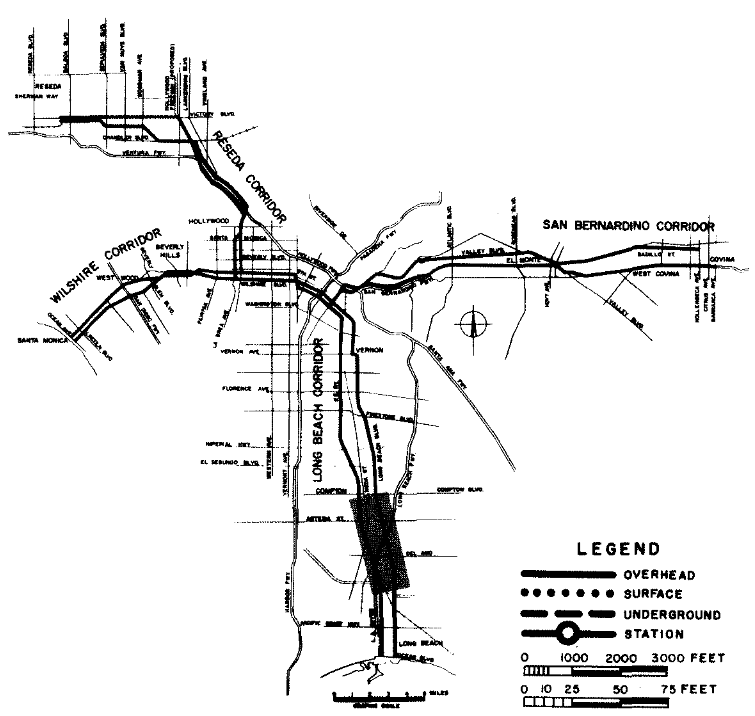
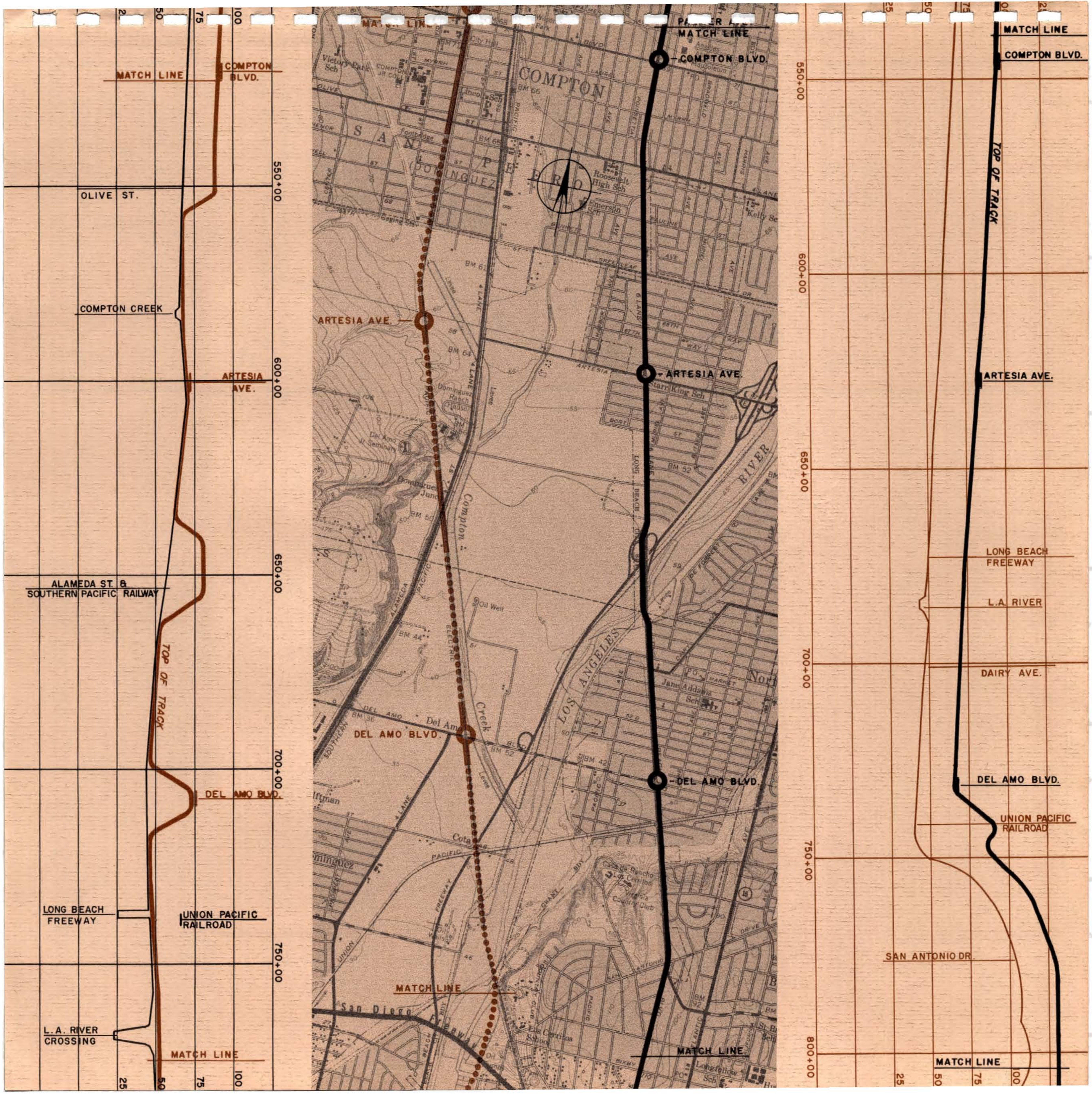


Figure IV-20. Key



MATCH LINE
COMPTON BLVD.
550+00
OLIVE ST.
COMPTON CREEK
ARTESIA AVE.
600+00
650+00
ALAMEDA ST. & SOUTHERN PACIFIC RAILWAY
TOP OF TRACK
700+00
DEL AMO BLVD.
LONG BEACH FREEWAY
UNION PACIFIC RAILROAD
750+00
L.A. RIVER CROSSING
MATCH LINE
25
50
75
100
MATCH LINE
COMPTON
ARTESIA AVE.
DEL AMO BLVD.
LOS ANGELES RIVER
Compton Creek
MATCH LINE
MATCH LINE
COMPTON BLVD.
ARTESIA AVE.
DEL AMO BLVD.
MATCH LINE.
MATCH LINE
COMPTON BLVD.
550+00
TOP OF TRACK
600+00
ARTESIA AVE.
650+00
LONG BEACH FREEWAY
L.A. RIVER
700+00
DAIRY AVE.
DEL AMO BLVD.
UNION PACIFIC RAILROAD
750+00
SAN ANTONIO DR.
800+00
MATCH LINE
25
50
75
100

Why? The best "park'n ride" location on L.B. line has been Los Cerritos for years. This is north of Wardlow.

LONG BEACH CORRIDOR

ALIGNMENT "A"

Alignment "A" continues at grade along the east bank of the Los Angeles River and would connect with stations at Wardlow Road, Willow Street, Pacific Coast Highway, 7th Street and the Long Beach Terminal. Transfer connections to local bus lines running along Willow Street and Pacific Coast Highway would be possible. The Long Beach Terminal Station would be planned as a major "park'n ride" facility.

An important factor in the selection of this route through Long Beach is that in most instances existing bridge structures over the Los Angeles River would provide adequate clearance to accommodate an at grade rapid transit line, resulting in lower construction costs.

ALIGNMENT "B"

Alignment "B" would proceed southerly along a median in the center of Long Beach Boulevard with stations located at the same cross streets as along Alignment "A". Similar transfer facilities to local bus lines would be provided along this alignment. The Terminal Station would also be developed as a "park 'n ride" facility.

The City of Long Beach is currently studying plans for redevelopment of the shoreline area and it is conceivable that the Terminal Station of either Alignment "A" or "B" could be integrated as part of that area.

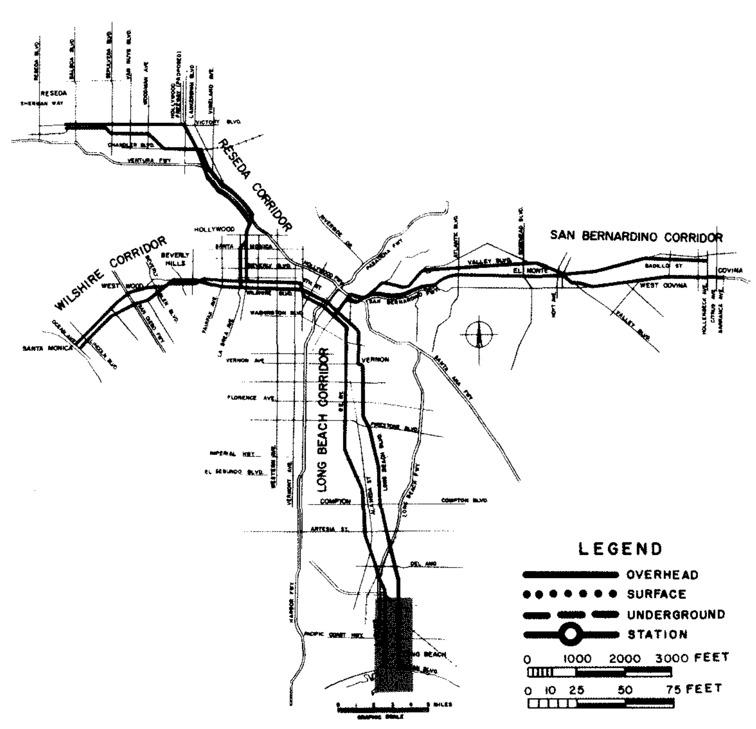
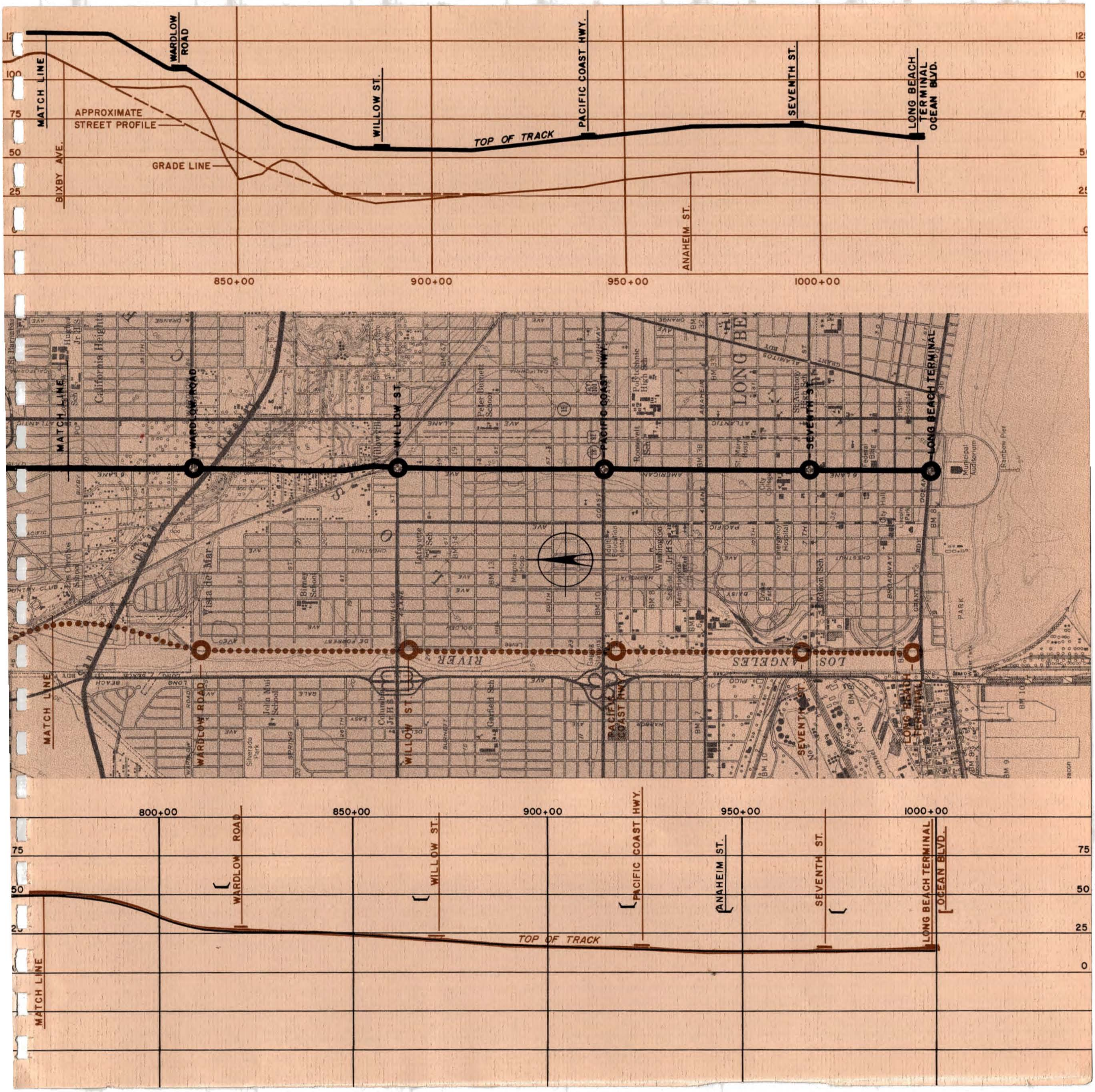


Figure IV-21. Key



MATCH LINE
BIXBY AVE.
WARDLOW ROAD
WILLOW ST.
PACIFIC COAST HWY.
SEVENTH ST.
LONG BEACH TERMINAL OCEAN BLVD.
APPROXIMATE STREET PROFILE
GRADE LINE
TOP OF TRACK
ANAHEIM ST.
125
100
75
50
25
0
850+00
900+00
950+00
1000+00
MATCH LINE
WARDLOW ROAD
WILLOW ST.
PACIFIC COAST HWY.
SEVENTH ST.
LONG BEACH TERMINAL
California Heights
Vista del Mar
LOS ANGELES RIVER
Rainbow Pier
Municipal Auditorium
PARK
MATCH LINE
WARDLOW ROAD
WILLOW ST.
PACIFIC COAST HWY.
SEVENTH ST.
LONG BEACH TERMINAL
800+00
850+00
900+00
950+00
1000+00
MATCH LINE
WARDLOW ROAD
WILLOW ST.
PACIFIC COAST HWY.
ANAHEIM ST.
SEVENTH ST.
LONG BEACH TERMINAL
OCEAN BLVD.
TOP OF TRACK
75
50
25
0

Section V—Comparative Cost Estimates

Table of Contents Section V

LIST OF ILLUSTRATIONS

Comparative Cost Estimates

BASIS OF ESTIMATES

The estimates of cost given herein were developed in order to provide information for cost comparisons between the several system and route alternates investigated in detail. The first major comparison to be made is between the types of systems, and since construction cost is not the only cost which might affect the choice, a further estimate of capitalized maintenance cost is required in order to provide a true economic comparison. The next comparison involves choices of routes and route configurations. Cost estimates were prepared for both of the route alternates shown on the plans and profiles included in the previous section. For the Wilshire Corridor and the Los Angeles Central Business District, alternates of subway and overhead structure were laid out and cost estimates developed.

The estimates of cost are based on information and concept designs developed by this firm during the initial phase of the program. Estimating prices based on preliminary designs for the cars and equipment were secured from reputable manufacturers. The concept designs of way structures, stations, and other facilities have permitted cost per mile estimates to be made, which are combined with the equipment and right-of-way costs to provide a planning type of construction cost estimates. With additions for engineering, incidental expenses and contingencies, the overall program cost can be approximated. The concept designs and initial work indicate that the normal procedure of competitive bidding by general contractors and manufacturers can be followed.

It should be noted that the development of cost estimates for a complex program such as this is a difficult task at best, and at this stage of the program several specific factors make detailed estimation particularly difficult. They are:

1. Detailed engineering designs and construction plans and specifications are, of course, not available.
2. Preliminary structure designs are based only on "average" general conditions. Route layouts were established from small scale area-wide topographic maps.
3. Subsurface and foundation conditions are assumed from only preliminary geology reports and only preliminary utility information is available.
4. Much of the proposed equipment design is unprecedented; some is not yet in the prototype stage of development.
5. As noted previously, appraisals of rights-of-way and other required land acquisition are not available.

It should, therefore, be understood that these estimates are preliminary in nature and are subject to variation as more detailed engineering is accomplished.

EQUIPMENT ALTERNATES

Three equipment systems were investigated in detail as noted hereinbefore. In order to develop cost estimates of these three systems, it was necessary to prepare concept designs of the equipment, way structures, stations and storage and maintenance facilities required by each of the systems.

These concept designs were based on criteria developed specifically for the Los Angeles Program and the designs, therefore, required modification to the systems submitted by proponents. A considerable amount of creative engineering was done in order to effect improvements to the designs and to adapt them to the requirements and criteria. In this manner, the systems could be analyzed on a comparable basis and advantage taken of local conditions.

The cost of rolling stock for the three systems was estimated on the basis of preliminary information submitted by transit car builders and local aircraft manufacturers who are also interested in building the vehicles. The concept designs of the vehicles were reviewed with them and the difference in cost of manufacturing rolling stock for the three systems is reflected in the cost estimates.

The cost estimates then actually bring out the importance cost-wise of the advantages and disadvantages of the systems.

The recommendations for the transit system best adaptable to the Los Angeles needs are based, not only on the comparative cost analysis outlined in this section, but also on the comparative functional analysis included in the Transit Equipment Section of this Report.

ALIGNMENT ALTERNATES

Estimates have been prepared for four alternates of alignment and way structure. The purpose of these estimates is to show the difference in cost between the two basic route alternates and to bring out what the additional cost would be for subway along portions of the two routes. In addition, estimates are also included for each of the alternates on the basis of providing initially a shortened 49-mile transit system, rather than the full 74.9 mile system. These additional estimates are provided in order to give the Authority information which may be helpful in financing the rapid transit program. In arriving at the estimates for the shortened system, layouts of new terminal stations and storage facilities were made and further details of significance which would change in the shortened system have been taken into account.

The following tabulations indicate what is included in each of the alternates:

ALTERNATE NO. 1
(Recommended Alternate)

Route Mileage	Full System	Shortened System
Overhead	51.0	32.5
Grade	21.6	14.9
Tunnel	2.3	2.0
Subway	0	0
Total	74.9 Miles	49.4 Miles

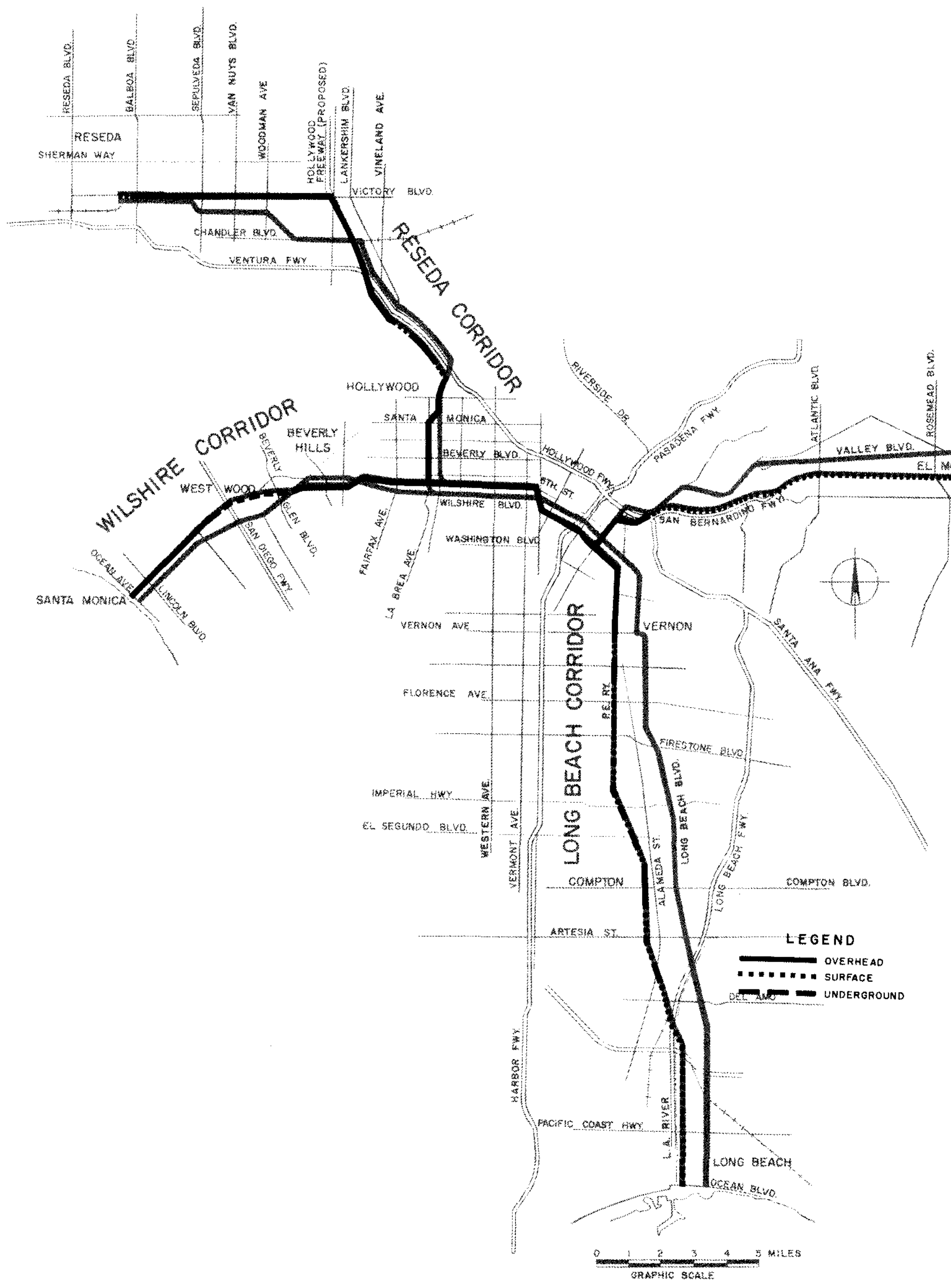


Figure V-1 Map of Alternate Alignment No. 1

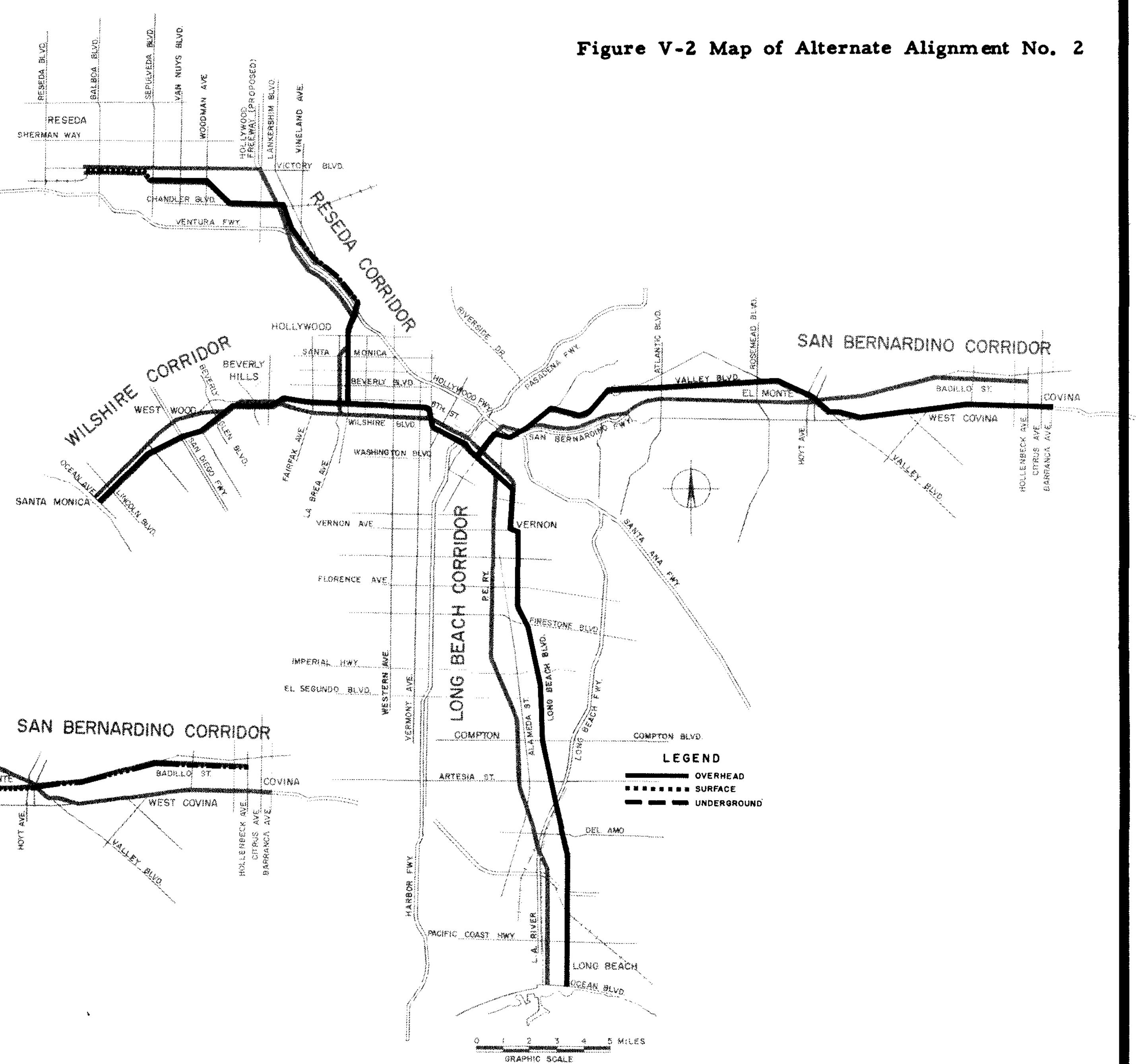
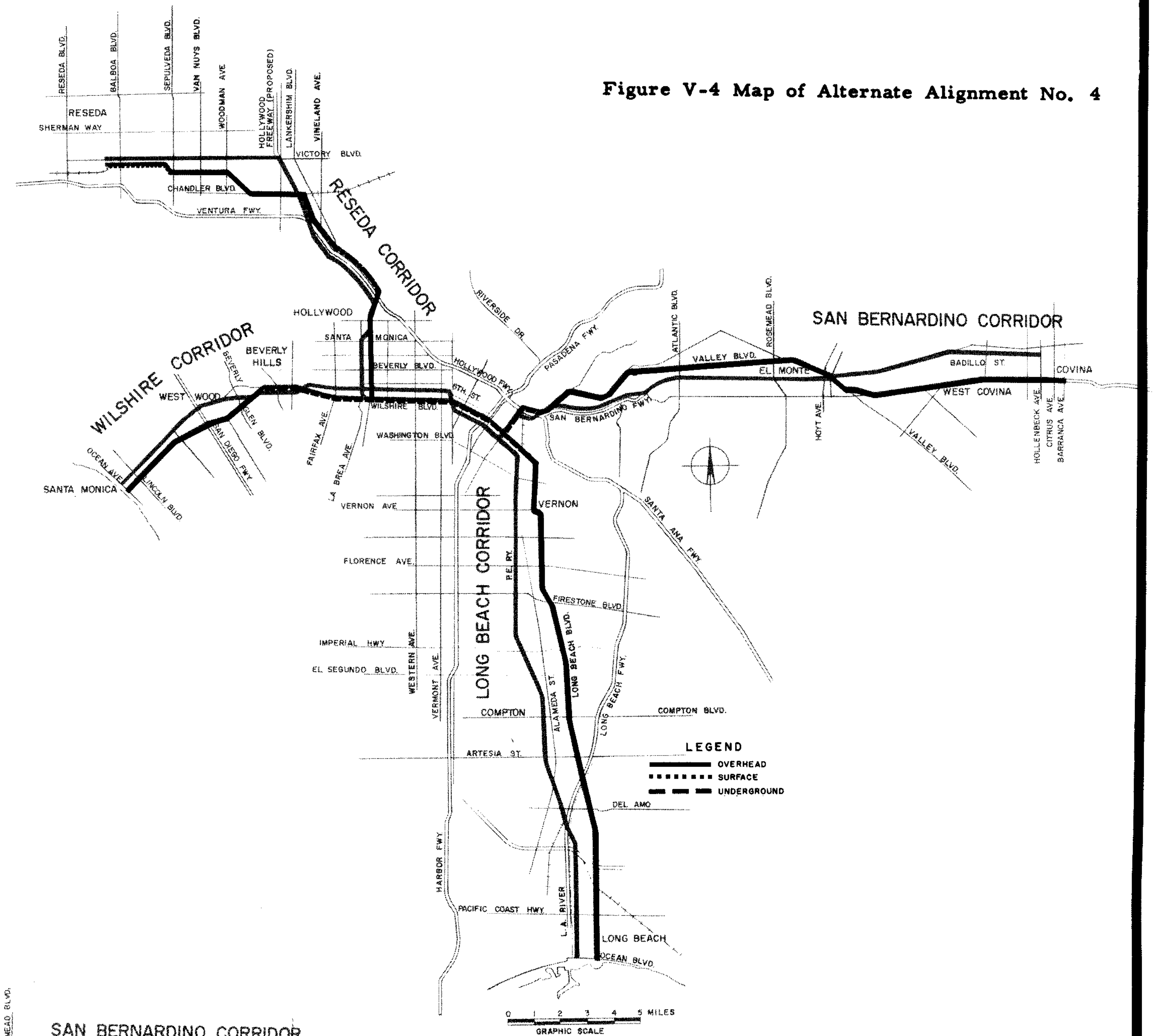


Figure V-2 Map of Alternate Alignment No. 2

ALTERNATE NO. 2

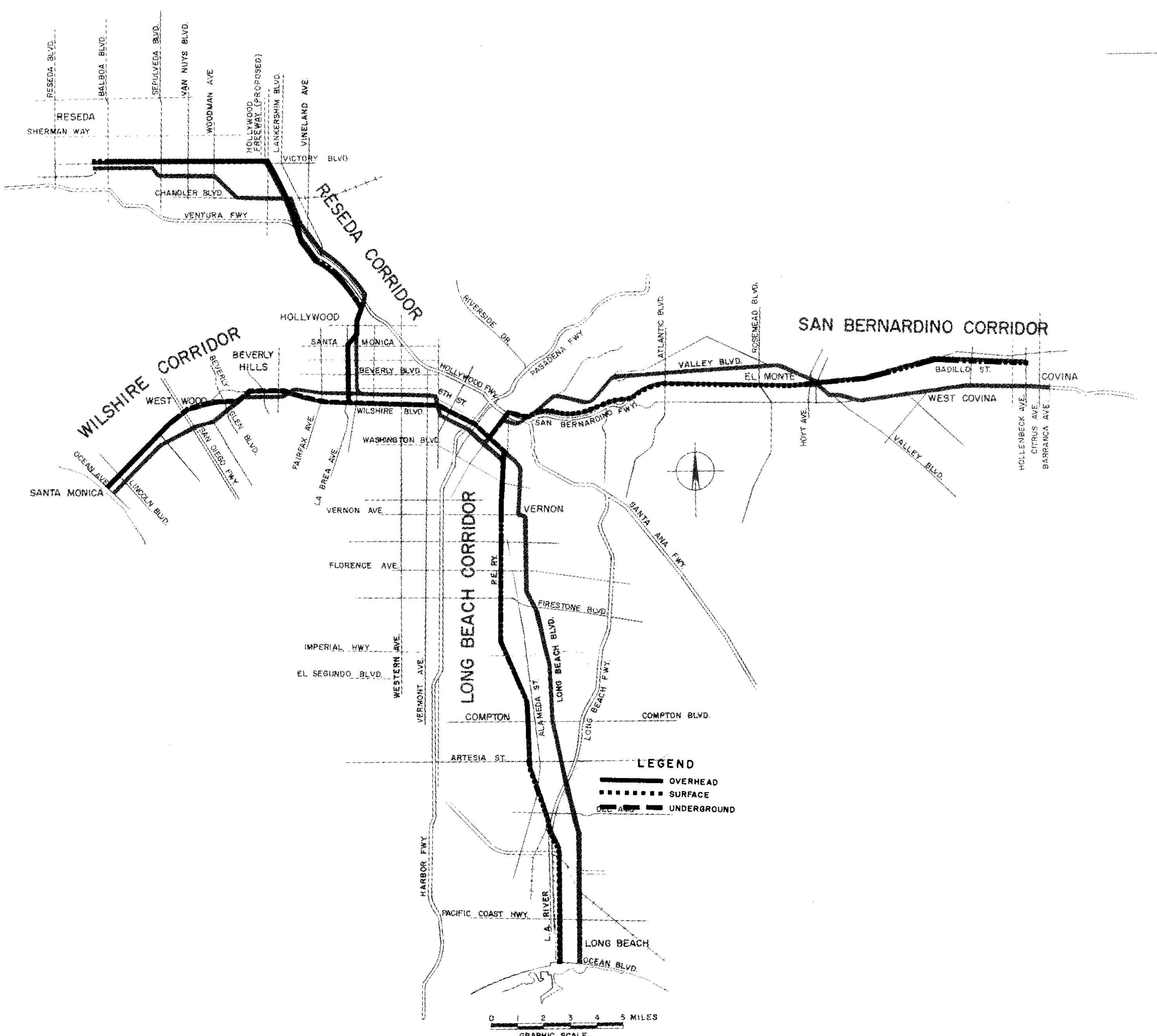
Route Mileage	Full System	Shortened System
Overhead	69.3	48.2
Grade	4.6	1.3
Tunnel	0	0
Subway	0	0
Total	73.9 Miles	49.5 Miles

Figure V-4 Map of Alternate Alignment No. 4



ALTERNATE NO. 3

Route Mileage	Full System	Shortened System
Overhead	38.4	19.9
Grade	21.6	14.9
Tunnel	2.3	2.3
Subway	12.3	12.3
Total	74.6 Miles	49.1 Miles



ALTERNATE NO. 4

Route Mileage	Full System	Shortened System
Overhead	56.7	35.6
Grade	4.6	1.3
Tunnel	0	0
Subway	12.3	12.3
Total	73.6 Miles	49.2 Miles

Figure V-3 Map of Alternate Alignment No. 3

Rights-Of-Way

Since the alignment investigations were of a preliminary nature, the comparisons of alternates were made on the basis of small scale planimetric and topographic maps and the estimates of right-of-way cost generally used cost per mile allowance figures. Actual appraisals of specific parcels could not be made. However, the cost per mile allowances were made by methods consistent with accepted theories of land and improvement valuation. Railroad land acquisition was evaluated on the basis of the value of the adjacent land areas through which the railroad alignment passes.

No damages were assumed and no allowances for damages were incorporated in the cost estimates. All real estate values reflect the current market value of land in improvements, and no allowance has been made for any increase in value.

Cost Items

The estimates reflect second quarter 1960 Southern California construction costs without provision for possible escalation of prices. A contingency factor of 15 percent has been added to the basic estimate of cost of construction and engineering.

Major cost items have been divided into nine categories as defined below:

1. Structures and Roadbed

This item includes all structure and track cost elements for overhead, at grade, or underground right-of-way. Costs of site preparation, excavation, grading, paving, landscaping, construction of secondary structures, street restoration, and protection of existing buildings are incorporated.

2. Stations

Station costs include building construction and finish costs of the stations and parking areas. Station furnishings, stairways, escalators, ticketing equipment, and standard utilities - plumbing, ventilation, and lighting - are included. Way structures and track through the station are included in Structures and Roadbed above rather than here.

3. Electrification

Costs of power distribution and control are included herein. Switchgear and cable,

CONSTRUCTION COST ESTIMATES

	Supported Dual Track "Metro" System				Supported Mono-Beam System				Suspended Mono-Beam System			
FULL SYSTEM	ALT. I	ALT. II	ALT. III	ALT. IV	ALT. I	ALT. II	ALT. III	ALT. IV	ALT. I	ALT. II	ALT. III	ALT. IV
Structure & Road Bed	155.9	170.9	223.5	238.5	136.6	126.6	234.3	224.3	240.5	224.9	336.5	320.9
Stations	41.8	42.4	42.2	42.8	42.1	42.9	42.8	43.6	41.2	41.5	41.3	41.6
Electrification	51.9	51.1	51.7	50.9	57.0	56.1	56.8	55.9	48.9	48.3	48.8	48.2
Control and Communication	20.6	20.4	20.6	20.4	20.6	20.4	20.6	20.4	20.6	20.4	20.6	20.4
Utility Relocation	18.0	21.9	16.3	20.2	20.1	24.6	17.5	22.0	18.2	21.9	16.5	20.2
Yards & Shops	7.6	7.6	7.6	7.6	13.5	13.5	13.5	13.5	26.7	26.7	26.7	26.7
Secondary Distribution System	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8
Land Acquisition & Right-of-Way	26.2	26.7	8.1	8.6	26.2	26.7	8.1	8.6	26.2	26.7	8.1	8.6
Rolling Stock	75.9	75.9	75.9	75.9	85.0	85.0	85.0	85.0	82.1	82.1	82.1	82.1
TOTAL	418.7	437.7	466.7	485.7	421.9	416.6	499.4	494.1	525.2	513.3	601.4	589.5
Administration & Professional (10%)	41.9	43.8	46.7	48.6	42.2	41.7	49.9	49.4	52.5	51.3	60.1	59.0
Reserve for Contingency (15%)	69.1	72.2	77.0	80.1	69.6	68.7	82.4	81.5	86.7	84.7	99.2	97.3
TOTAL SYSTEM COST	529.7	553.7	590.4	614.4	533.7	527.0	631.7	625.0	664.4	649.3	760.2	745.8

COSTS IN MILLIONS OF DOLLARS

substation structures and control equipment, contact rails, supports protecting structures, negative feeders and bonding make up the high voltage distribution system. Low voltage auxiliary power distribution at passenger stations and dispatching areas is covered.

4. Control and Communication

Signal and control equipment are included herein. Installation costs include wayside, train-carried, central display, and switch equipment units of a cab-signal system. Costs include all equipment located in the Central Control Station, wayside, stations, terminals, and trains. Fail-safe devices for control system malfunction are included.

5. Utility Relocation

Included in this item are costs required to revise known existing utility facilities to accommodate the transit system. Power, telephone, water, gas, sewer, storm drain, and street lighting installations have been considered.

6. Yards and Shops

Shop buildings, maintenance equipment, switches, and car storage track are priced here. Land acquisition costs for these facilities are placed with other real estate costs below.

7. Secondary Distribution System

Approximately 5 miles of secondary distribution way structure, and sufficient equipment for operation is included in this item.

8. Land Acquisition & Right-of-Way

This item covers costs of real estate acquisition necessary for right-of-way, stations, parking facilities, maintenance shops, and train storage yards.

9. Rolling Stock

The total cost of engineering development, fabrication, and supply of sufficient rolling stock to serve the total system is included here. Quantities are based on headways established by traffic requirements and anticipated maintenance schedule. Each car is complete with furnishing and equipment, except control and communication gear which is included elsewhere.

10. Administrative and Professional

This item includes fees for engineering, construction supervision, management and administration and the costs of subsurface explorations, surveying, testing and inspection, and operation start-up.

CONSTRUCTION COST ESTIMATES

	Supported Dual Track "Metro" System				Supported Mono-Beam System				Suspended Mono-Beam System			
SHORTENED SYSTEM	ALT. I	ALT. II	ALT. III	ALT. IV	ALT. I	ALT. II	ALT. III	ALT. IV	ALT. I	ALT. II	ALT. III	ALT. IV
Structure & Road Bed	104.0	115.8	171.6	183.4	93.4	84.2	191.1	181.9	172.4	149.9	258.0	245.9
Stations	31.2	32.4	31.6	32.8	31.5	32.9	32.2	33.6	31.2	31.5	30.7	31.6
Electrification	34.4	34.4	34.2	34.2	37.8	37.8	37.6	37.6	33.3	32.6	32.4	32.5
Control and Communication	14.9	15.0	14.9	15.0	14.9	15.0	14.9	15.0	14.9	15.0	14.9	15.0
Utility Relocation	12.3	17.5	10.6	15.8	13.9	19.5	11.3	16.9	13.2	17.5	10.8	15.8
Yards & Shops	6.3	6.3	6.3	6.3	11.2	11.2	11.2	11.2	21.9	21.9	21.9	21.9
Secondary Distribution System	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8
Land Acquisition & Right-of-Way	25.4	21.6	7.3	3.5	25.4	21.6	7.3	3.5	25.6	21.6	7.3	3.5
Rolling Stock	52.2	52.2	52.2	52.2	57.8	57.8	57.8	57.8	56.0	56.0	56.0	56.0
TOTAL	301.5	316.0	349.5	364.0	306.7	300.8	384.2	378.3	389.6	366.8	452.8	443.0
Administration & Professional (10%)	30.2	31.6	35.0	36.4	30.7	30.1	38.4	37.8	39.0	36.7	45.3	44.3
Reserve for Contingency (15%)	49.8	52.1	57.7	60.1	50.6	49.6	63.4	62.4	64.3	60.5	74.7	73.1
TOTAL SYSTEM COST	381.5	399.7	442.2	460.5	388.0	380.5	486.0	478.5	492.9	464.0	572.8	560.4

COSTS IN MILLIONS OF DOLLARS

MAINTENANCE COST ESTIMATES

In addition to the estimates of cost of construction of the system, it is necessary to review other possible costs to insure that the comparison between systems is complete. The other cost factors considered are operation and maintenance cost. Our analysis shows that the cost of operation of any of the equipment systems would be substantially the same and, therefore, this cost need not be taken into account in the choice between the systems. However, our comparison does show a difference in the cost of maintenance between the three systems as given below:

Estimated Annual Maintenance Costs
(Includes inspections, scheduled services, repairs, cleaning, batteries and tires)

Total Number of Cars - 456
Average Miles Per Year, each car - 60,000
Total Car Miles Per Year - 27,400,000

75 Mile System	Metro System	Supported Mono-Beam System	Suspended Mono-Beam System
1st Year (Millions of $)	$1.67	$2.11	$2.08
¢/mile	6.1	7.7	7.6
10th Year (Millions of $)	2.36	3.04	2.74
¢/mile	8.6	11.1	10.0

In order to determine the influence of these differences in maintenance costs, it is necessary to compute the present worth of these future costs. This procedure then converts the annual cost of maintenance to a capitalized cost which can be added to the construction cost to provide an overall comparison. A twenty-five year period is assumed and an interest rate of five percent. Since the construction costs are computed on the basis of 1960 prices without provision for escalation, the present worth is converted to a 1960 base also. This results in the following:

Worth in 1960 of Maintenance Costs From 1965 to 1990

Metro	Supported Mono-Beam	Suspended Mono-Beam
$26,000,000	$37,500,000	$30,100,000

The important significance of these figures lies in their difference.

COST ANALYSIS AND COMPARISONS

While the cost estimate figures are largely self-explanatory, it is pertinent to summarize the important cost comparisons which should be made. It will be recalled that there are three basic comparisons for which recommendations must be made. These are:

1. The choice of the type of system.
2. The choice of the route.
3. The choice between underground and overhead way facilities.

These three comparisons will be discussed in the following paragraphs.

Type of System

For the recommended Alternate I route and way structure plan, the comparison of cost between the three types of transit equipment system is given as follows:

FOR ALTERNATE I	Metro	Supported Mono-Beam	Suspended Mono-Beam
Cost of Construction:	$529,700,000	$533,700,000	$664,400,000
Capitalized Cost of Maintenance:	$ 26,000,000	$ 37,500,000	$ 30,100,000
Total*:	$555,700,000	$571,200,000	$694,500,000
Comparison:	0	+ 15,500,000	+138,800,000

This comparison shows that the Metro System is the least expensive of the three for the recommended route and configuration.

An inspection of the cost estimates for the other alternates reveals that for Alternate No. II, the Supported Mono-Beam System has a construction cost less than that of the Metro System.

Therefore, the same analysis as above will be performed for Alternate No. II.

FOR ALTERNATE II	Metro	Supported Mono-Beam	Suspended Mono-Beam
Cost of Construction:	$553,700,000	$527,000,000	$649,300,000
Capitalized Cost of Maintenance:	$ 26,000,000	$ 37,500,000	$ 30,100,000
Total*:	$579,700,000	$564,500,000	$679,400,000
Comparison:	+ 15,200,000	0	+114,900,000

This comparison shows the Supported Mono-Beam to be the least expensive for Alternate No. II, which is of predominantly overhead construction. However, in comparing Alternate II with Alternate I, it will be noted that the use of the Metro System with Alternate I is less expensive than the use of the Supported Mono-Beam System with Alternate II. Alternates III and IV provide for more extensive use of subways and for these alternates, the Metro system is the least expensive.

*Economic comparison total, not total construction cost.

Choice of Route

For the recommended Metro system, the comparison between the route alternates is given as follows:

	Alternate I	Alternate II
	$529, 700, 000	$553, 700, 000
Comparison	0	+ 24, 000, 000

This comparison shows that Alternate No. I (which makes extensive use of existing Pacific Electric rights-of-way for grade operation) is the least expensive of the four alternates. Alternate No. II, an almost exclusively overhead system, is next but would cost an additional $24, 000, 000.

Choice Between Underground and Overhead

The comparison of the cost of underground and overhead way facilities is brought out by examining Alternates III and IV which include a substantial mileage of subway, with the predominantly overhead Alternates I and II. As may be seen from the maps of the various alternates,

Alternate III is basically the same as Alternate I except for the substitution of 12. 3 miles of subway for overhead in the CBD and in the Wilshire Corridor. Alternate IV is basically the same as Alternate II except for the substitution of 12. 3 miles of subway for overhead in the CBD and in the Wilshire Corridor. The comparison is as follows:

	Alternate I	Alternate II
	$529, 700, 000	$553, 700, 000
Comparison	0	+ 24, 000, 000
	Alternate III	Alternate IV
	$590, 400, 000	$614, 400, 000
Comparison	+ 60, 700, 000	+ 84, 700, 000

Thus it may be seen that Alternate III would add $60, 700, 000 to the cost in order to provide subways in the Central Business District and in portions of the Wilshire Corridor.

Alternate IV reflects the additional cost of the subway together with the extra cost of using the Alternate II alignments, making a total extra of $84, 700, 000.

SUMMARY

While factors in addition to cost have been taken into account in the analysis and comparison of the systems and routes, the basic requirement of the Authority was for the system least expensive to construct and operate. The system recommended to meet this requirement would use the Metro equipment operating over the routes in Alignment Alternate No. I. This is the least cost combination and, in addition, provides the most highly developed of the three types of equipment systems and the type of route and structure which could be constructed and put into operation in the least time.

The comparisons have been made on the basis of the costs of the full system in order to include the overall long-range factors. However, if they were made on the basis of the costs of the shortened system, the comparisons would even more strongly point to the recommended routes and equipment.

The preliminary nature of the estimates should again be emphasized. However, it is felt that they are adequate for the selection of the system and they furnish, with appropriate contingency factors, the required indication of the overall cost of the rapid transit program.