CALIFORNIA
HIGHWAYS AND PUBLIC WORKS

MARCH-APRIL 1950

California Highways and Public Works

Official Journal of the Division of Highways, Department of Public Works, State of California

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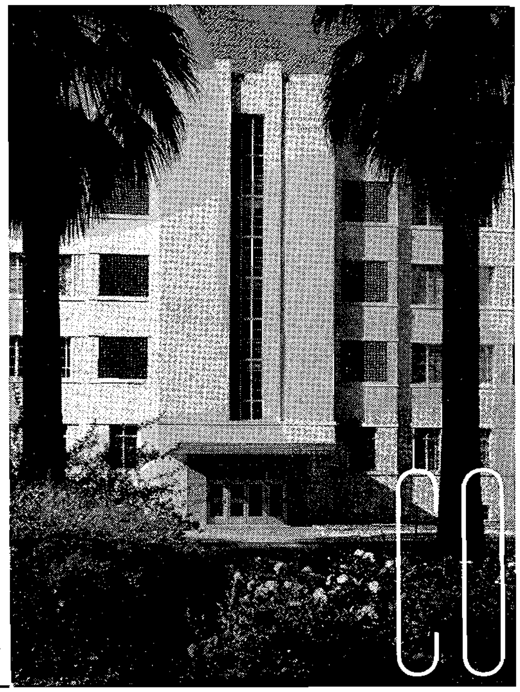
Address Communications to

CALIFORNIA HIGHWAYS AND PUBLIC WORKS
P. O. Box 1499
Sacramento, California

Vol. 29 | March-April | Nos. 3, 4



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The Concluding Article of a Series by G. A. Tilton, Jr., Supervising Highway Engineer, "Prison Labor—Story of Highway Road Camps in the State of California," Will Appear in the May-June Issue of This Magazine.

Roseville Underpass Opened on April 1 at Cost of $1,485,000

By G. A. GREENE, Associate Highway Engineer

THE ROSEVILLE UNDERPASS was opened with appropriate local ceremonies on April 1st. It is another important step in the relief of bottlenecks and congested urban areas along Route US 99E. This project, having a total cost of about $1,485,000, is in the heart of the City of Roseville, Placer County, running from Vernon and Grant streets through the center of town and two miles north of town toward Marysville.

Southern Pacific freight yards in which freight trains are made up for the trip over the mountains going east, divide the City of Roseville. In the past these yards formed an effective barrier to highway traffic. Owing to the very large number of switching operations in progress in the yards, the grade crossing at Lincoln Street was customarily blocked for long periods of time and the delays to highway traffic were very severe. The fact that there are 17 railroad tracks at this location made the construction operations difficult and separation of the crossing required a project of major magnitude.

BLANDLY OBLIVIOUS

"Blessed be the bridge that carries me over"
Said the sage of ages past,
When bridges were weak and crudely built
And each crossing might be the last.
They blessed the road that guided them:
Our forbears plodding along;
Though wearied by the rough, faint trail,
Their hearts beat a grateful song.
The bridge today is strong and sure,
A thing of beauty and grace,
Leaping safely o'er road and river,
Gladly bearing one on apace.
The road today is marked and smooth,
Delighting the traveler's eye,
Like the rug of a giant magi,
Through the valleys and mountains high.
But who today gives time or thought
As he rushes from dawn to dawn,
To contemplate the blessings of
These fruits of brain and brawn

S. R. OFFUTT
District VII, Division
of Highways

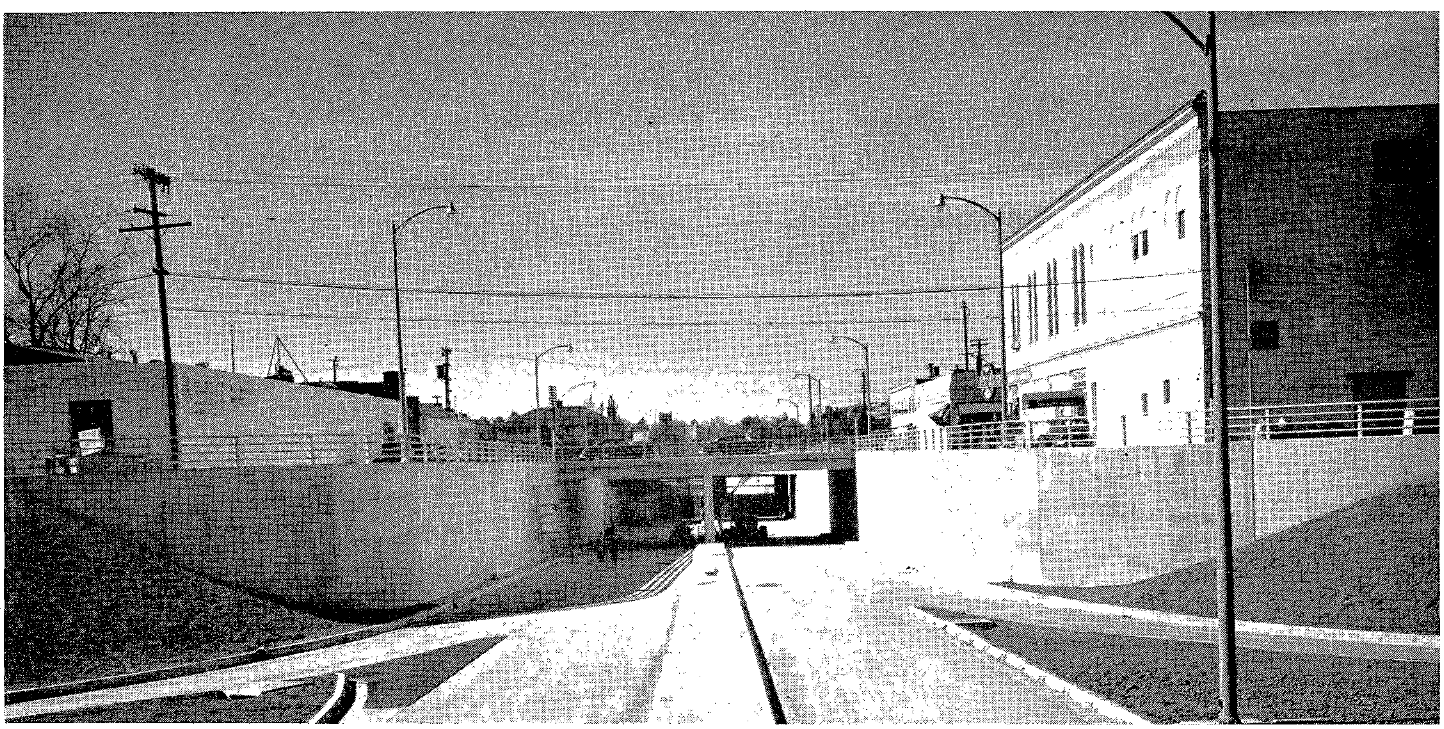
Dedicated to Spencer V. Cortelyou, Assistant State Highway Engineer, Retired

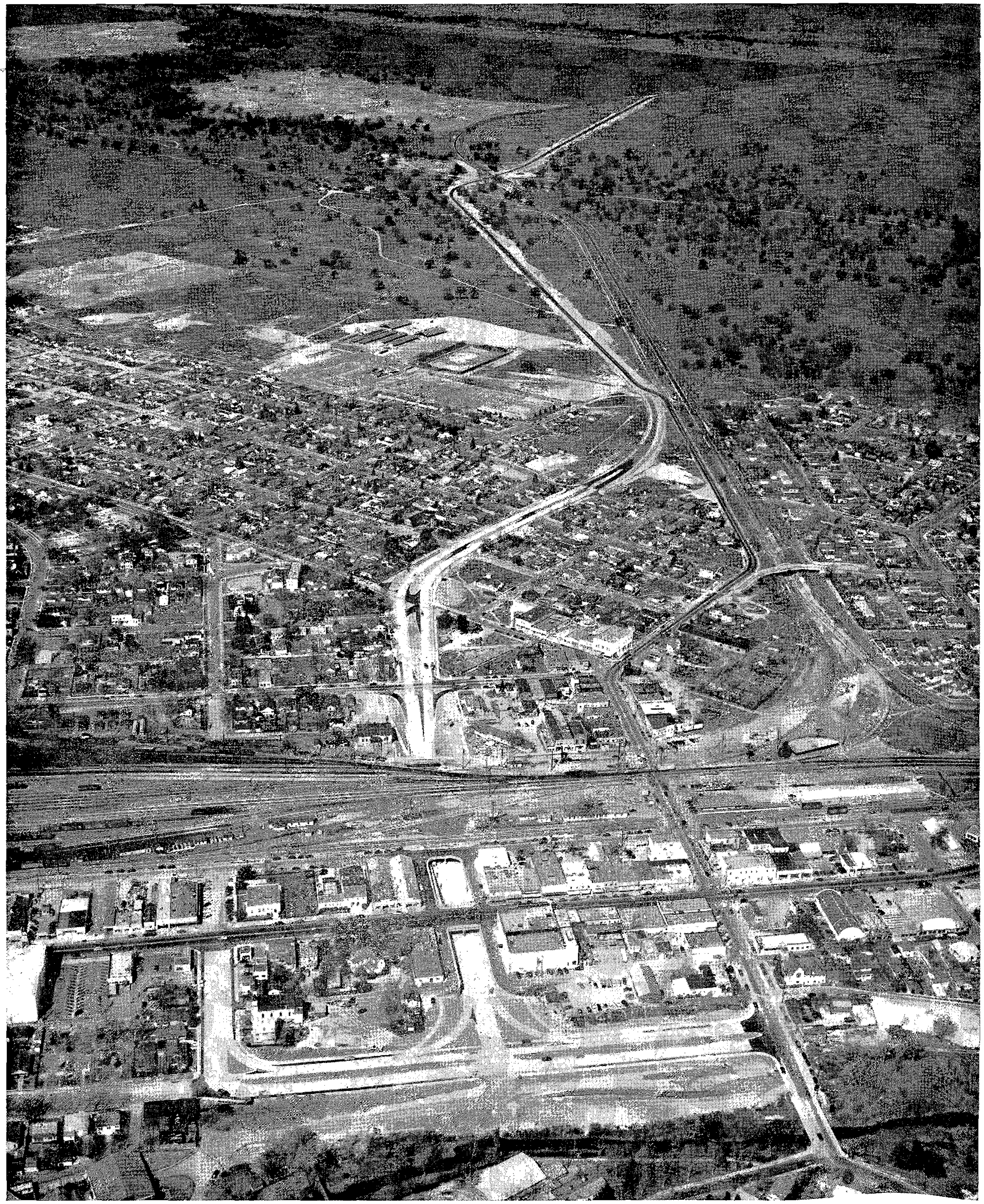
Underpass Has Four Lanes

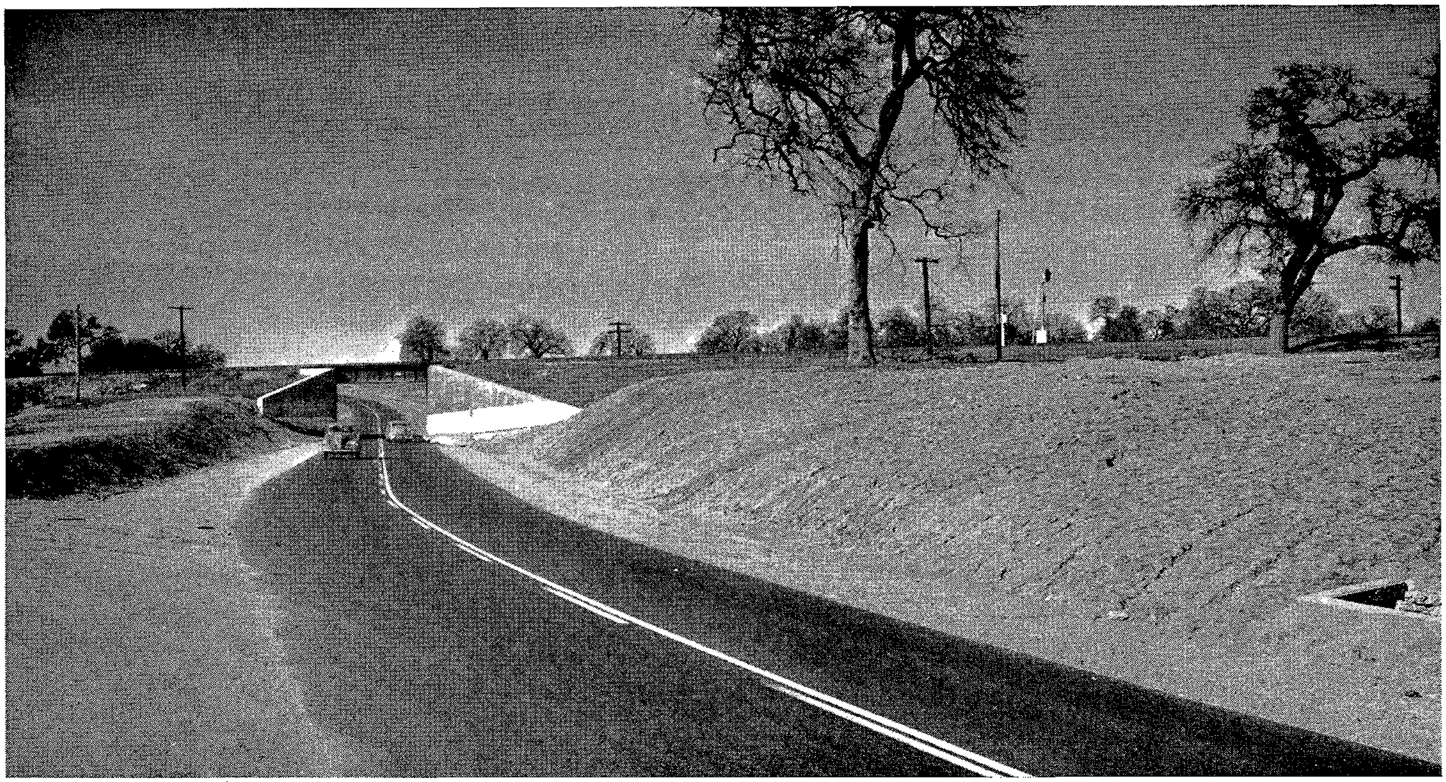
The south end of the work begins at the intersection of Vernon and Grant Streets. Traffic will be temporarily routed around one block to come on to the four-lane divided section of the underpass at Washington Street. The underpass itself, which will be a continuation of Washington Street, provides four lanes of divided highway underneath the railroad yards. The crossing at Washington Street is parallel to and one block south of the old grade crossing on Lincoln Street.

The portion of the structure under the railroad tracks is 360 feet long, the railroad being carried on steel rolled beams. Coming out of the underpass,

Close-up view of Roseville underpass which carries traffic under railroad tracks to and from U. S. 40 and U. S. 99E







Widening of U. S. 99E gives sight distance at Andora subway one mile north of Roseville, previously a traffic hazard

the highway continues in a northeasterly direction on Washington Street which was rebuilt and widened to provide four lanes with a center dividing strip. About 2,000 feet from the subway the four lanes are decreased to two lanes which extend to the end of the project about two miles north of town.

Andora Subway Approaches

Another major feature of the new alignment is the elimination of the dangerous curves adjacent to the Andora Subway about one mile north of Roseville. The old road approached this narrow subway with a sharp curve on each end of the underpass. The new alignment making a considerably wider swing on each end, approaches the underpass on a tangent and by eliminating the dangerous curves, gives the traffic a straight approach to the opening.

The underpass itself has a reinforced concrete deck on steel beams. The spans are 31 feet and 39 feet, supported on reinforced concrete abutments with a steel center bent between the two lanes of traffic. This provides two 24-foot roadways in each direction with a six-foot center dividing strip. A seven-foot elevated sidewalk is provided along the west side.

Owing to the length of the structure and its tunnel-like aspect, it is necessary that continuous lighting be provided for both pedestrian and vehicular traffic. It was also necessary to provide a pump house with sump pumps to remove the runoff which will accumulate in the depressed portion.

Problem of Railroad Tracks

The major problem of constructing the underpass beneath 17 active railroad tracks without disrupting the railroad's use of its facilities was accomplished by doing the construction in three separate operations. The railroad tracks were moved sufficiently to provide working room for approximately one-third of the structure. After this portion was completed, the tracks were moved back to their original position except that they now are supported by the new structure. After three such shifts and three stages of construction of the underpass, all of the railroad tracks were replaced approximately in their original locations. All of the track work, moving, and reconstruction of the railroad appurtenances was done by the Southern Pacific Company's forces.

In addition to the underpass under the railroad, two overcrossings were provided over the depressed section to carry Vernon and Atlantic Streets across the highway. Both of these structures are of reinforced concrete slab construction with center bents in the dividing strip.

Concrete Pavement

The concrete portions of the pavement are uniform thickness eight-inch slabs placed on four inches of cement treated base which over-laid a base course of selected material. The plant-mixed portions of the road consist of

. . . Continued on page 8

←Aerial view of the improvement included in the Roseville Underpass project. The old route entered from Sacramento on Vernon Street at the lower left, thence to Lincoln Street and a left turn across the railroad tracks near the end of the yard at right center. The old route then followed the railroad to the Andora Underpass in the center distance where, with two sharp curves it ducked through under the railroad.

The new layout envisions a connection to the new freeway from Sacramento in the center foreground. For the present, traffic going north will make a right turn off Vernon Street and then two left turns to lead into the underpass and under the railroad yard.

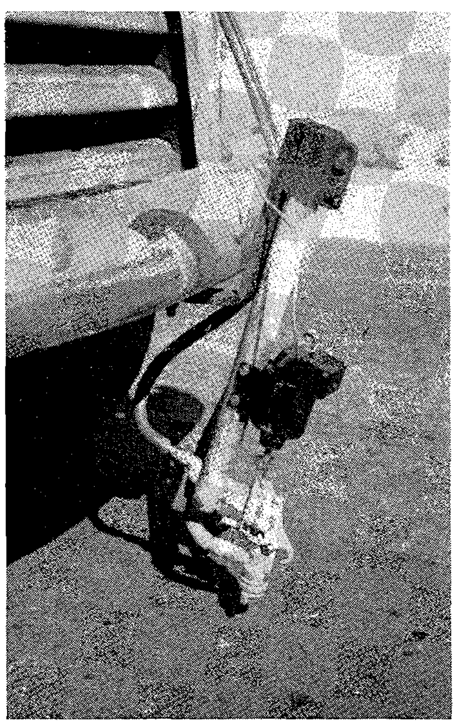
Through town the highway is divided, reducing to two lanes at the north edge of town. The alinement is improved at the Andora Underpass, eliminating the hazardous curves. The new line joins the old in the right distance.

Traffic Striping

New Idea for Laying Out Highway Traffic Stripes

By DON WIEMAN, Highway Superintendent

UPPER LEFT—Transit, set up near the end of existing center stripe, ready to control spotting adjacent unpainted section. LOWER LEFT—Spotting device in operating position, showing the actuating mechanism coupled to the control trigger of the spray gun



THE PRACTICE of painting lines and other markings on highway surfaces, generally referred to as traffic striping, is probably the greatest single contribution in many years to highway safety. The placing of this traffic stripe, however, is not only one of the most hazardous of highway maintenance operations but is a costly process as well.

In studying the problem of lowering costs and reducing hazards it is at once apparent that the materials used are standardized and their costs are not very flexible. Neither is there much allowable variation in the actual applying of the paint which is done by means of spray guns mounted on a lightweight striping machine. This machine is pushed ahead of a truck which carries the supply of paint and an air compressor. Both paint and compressed air are delivered to the striping machine through hoses. The operator of the striping machine steers it along the established course while the spray guns apply the paint either as dashed or solid, double or single lines.

Hazardous Job

The repainting of existing stripe is relatively simple where there is enough of the old paint remaining on the pavement to serve as a guide for the striping machine. The possible saving in cost and the greatest possible reduction of hazard lies primarily in the work preliminary to painting new stripes. This has always been an awkward and inefficient procedure. The practice has been that of "pig tracking" which consisted of painting spots by hand along a rope stretched tightly between previously established points—these spots or "pig tracks" being used as a guide for the striping machine. This method was slow and particularly hazardous to those so engaged because of their exposure to vehicles travelling along the highway.

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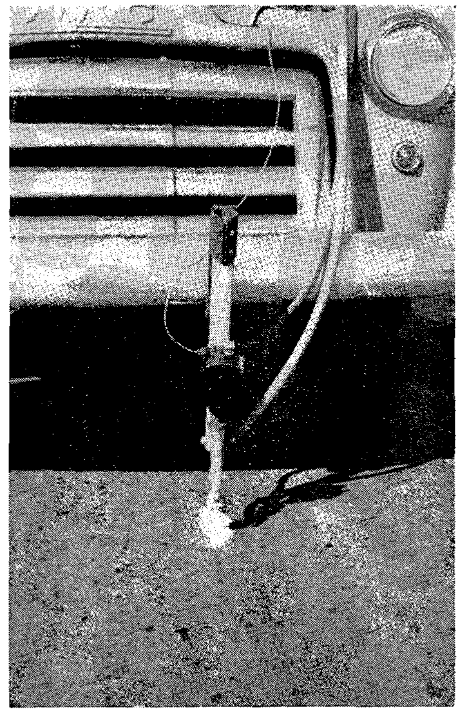
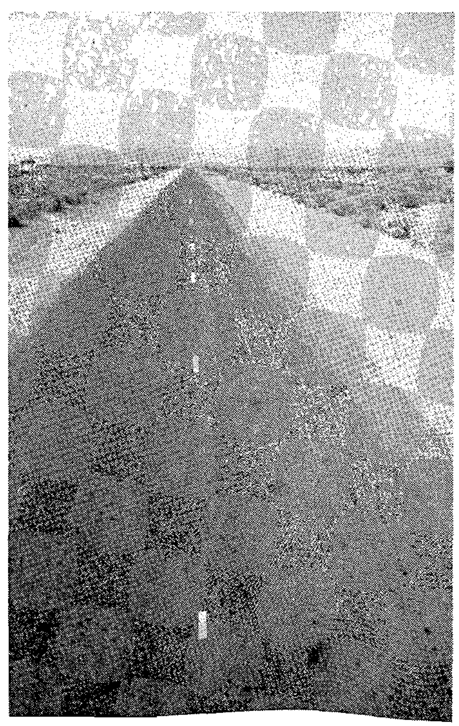


UPPER RIGHT—The last spot of a run. Equipment remained in this position to serve as a back sight for next transit setting
LOWER RIGHT—Line of spots produced by spotting device



Expressway

Thirteen Miles of Limited Freeway Completed on U. S. 40 During 1949

By M. C. FOSGATE, District Construction Engineer

DURING 1949, District X of the State Division of Highways opened to traffic as an expressway (limited freeway) a total of 12.95 miles of four-lane divided highway on U. S. 40, extending from Vacaville, by-passing Fairfield, through the American Canyon to a connection with the existing four-lane road near the Napa county line.

All two-lane road is eliminated between Sacramento and the Bay area with the exception of that portion which lies between Ledgewood Creek and Cordelia, a distance of 5.24 miles, and a short section betwene Ulatis Creek and Alamo Creek, 1.4 miles. It is hoped both of these remaining sections will be under contract before July 1st of this year.

The section between Ulatis Creek and Alamo Creek will require the construction of a separation structure over a county road and the Southern Pacific Railroad branch leading into Vacaville. A railroad underpass structure is also included in the plans for the Ledgewood-Cordelia unit.

American Canyon Section

The most important section of this construction, as far as the traveling public is concerned, is probably that section known as the American Canyon, which, when originally opened to traffic in 1936, eliminated the old winding road through Vallejo up the Napa Valley to the Napa Wye, then winding back through the Jamison Canyon to the Cordelia Wye, now the easterly terminus for the American Canyon section of U. S. 40.

When the American Canyon section was first opened to travel, it was considered one of the outstanding revisions of highway routing in Northern California. However, as traffic volumes increased, along with rising vehicle speeds and continual expansion of truck transportation, the long grades and curves made passing extremely hazardous. By 1940 traffic conditions were such that four lanes were necessary, but the war caused postponement of any construction. In 1942 the department widened a section from near the Napa county line on the east through Rindler Creek and over the two major summits in the American Canyon to a four-lane undivided highway. This revision eliminated the high, dangerous, wooden structure across Rindler Creek by filling from slides on the two summits. This was all the work that it was possible to do during the war years for relief to traffic on this section.

The present four-lane improvement has made it possible for the faster-moving vehicles to pass the trucks throughout the canyon, and this section is no longer a hazard or a hindrance to fast-moving vehicles.

Smoothest Pavement

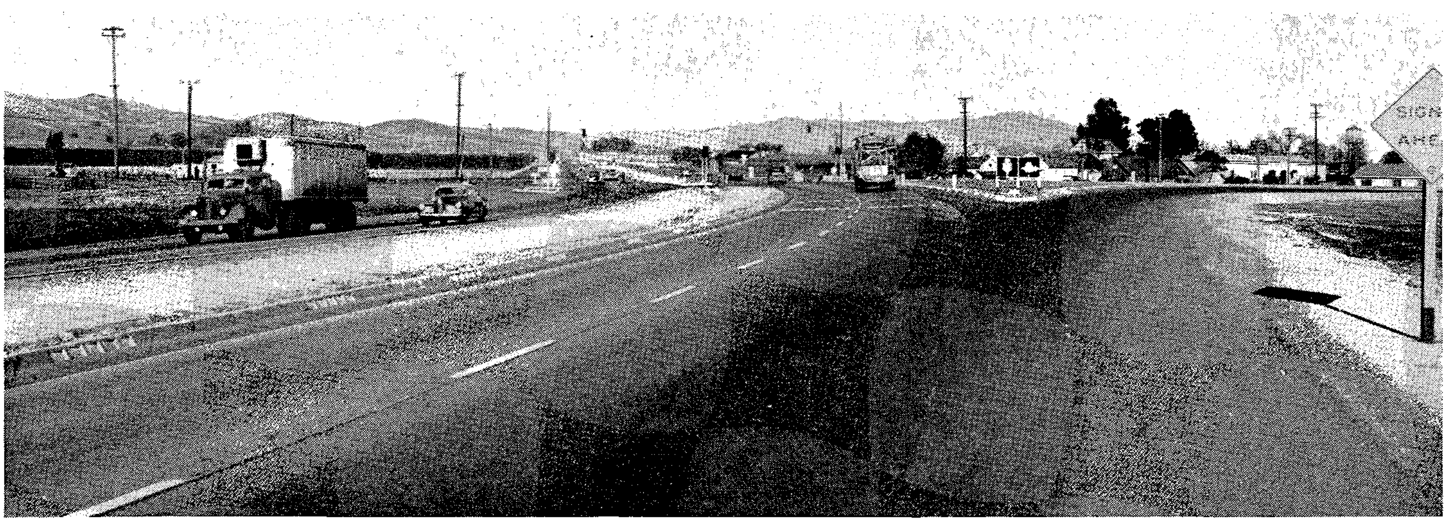
The added lanes on the section from Vacaville to the commencement of the Fairfield By-pass were placed to the north of the present traveled way, utilizing the present traveled way for eastbound traffic. This is also true in the American Canyon. The section from 3.5 miles east of Fairfield to Ledgewood Creek, a distance of 4.7 miles, is on new alignment, consisting of two 24-foot concrete roadways.

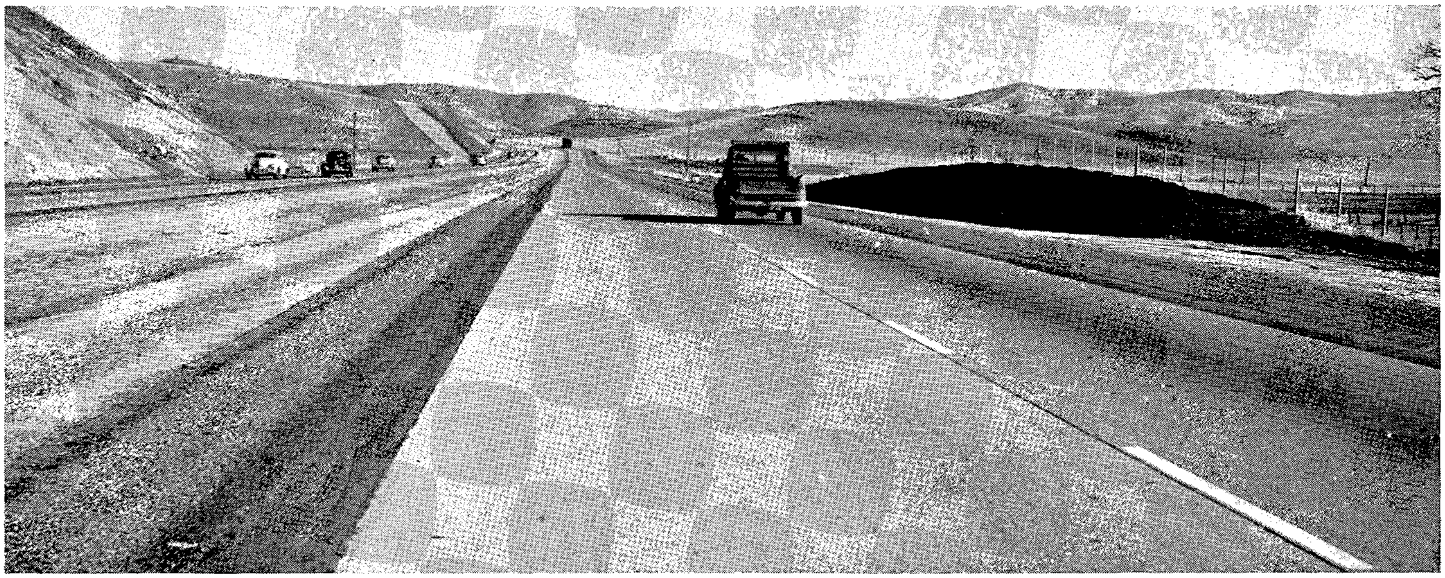
The section of U. S. 40 past Fairfield was measured for roughness by a machine perfected at the University of California and found to be the smoothest pavement so far measured.

Heavy Grading

Due to the heavy grading necessary on the Vacaville end as well as through the American Canyon, the dividing strip between the two traveled ways varied in width, and in some cases is as narrow as 16 feet, which is considered

View on the Fairfield by-pass section of U. S. 40, showing the westerly approach to Fairfield





Section of Fairfield by-pass with the eastbound lane to the right near the east entrance to Fairfield

the least that is desirable on a divided highway. Where these narrow medians exist, it is necessary that the difference in elevation of the two roadways be held to a minimum. In such locations, particularly around curves, guard railing was considered necessary to prevent cars from going over the grade and into opposing traffic. This guard rail also partially deflects headlight glare at night. A total of 13,000 feet of guard rail was placed on these three projects. To delineate the roadways in locations where guard railing was not used, reflectorized sight posts were placed. At night these reflectorized sight posts give the effect of illumination, and it is believed that these three projects are delineated as well as any project not using artificial lighting.

Many Cuts

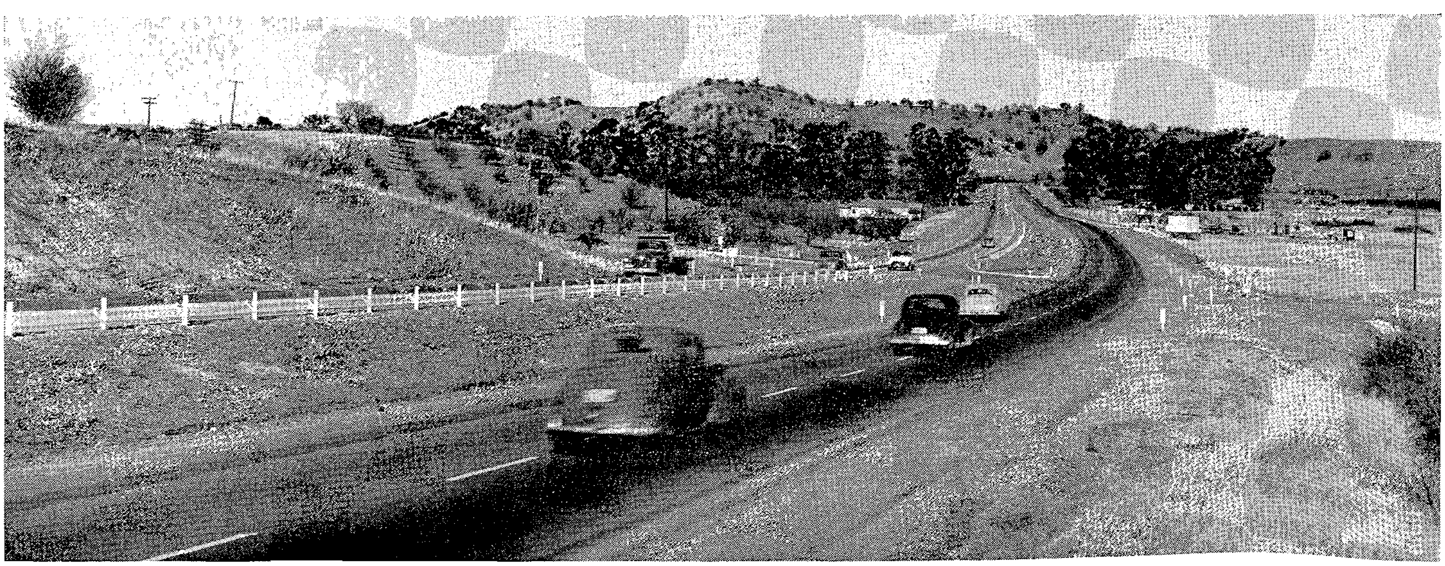
The three projects consist of five-sack-per-yard concrete pavement, eight inches thick, each roadway 24 feet wide with plant-mixed borders, the remainder of the shoulders outside of the borders being covered with a Class "C" seal coat. Under the concrete slabs is a four-inch subbase. All cuts, of which there were many, were sloped 1½:1, which should preclude any heavy sliding of material in a locality where the formation tends to slip at the least provocation.

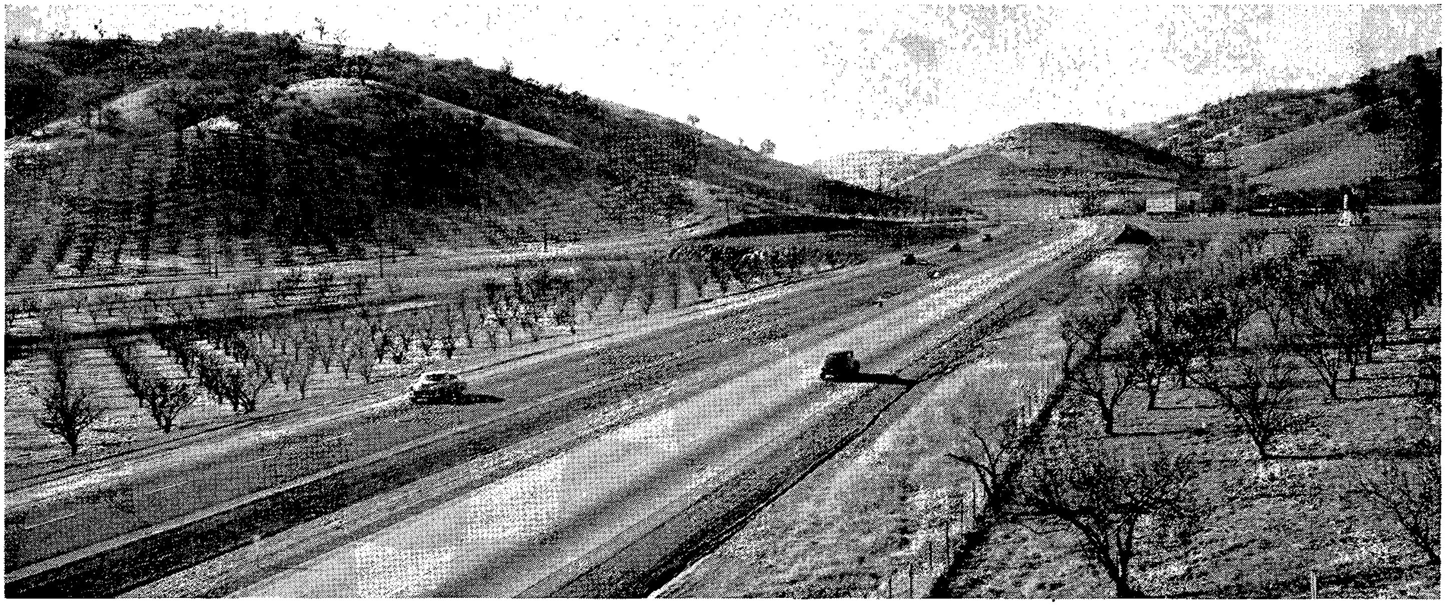
There was but one heavy slide on these projects and it included the removal of only 20,000 cubic yards. There was one cut on this project 200 feet high. This cut was about half out when a spring developed at the bottom of a layer of sandstone. This spring was not extensive; however, a considerable area of the bank was saturated. To stabilize the saturated area, willow sticks were planted, and at the present time are growing rapidly, apparently having accomplished their purpose as no slides or slipouts have developed in this area.

Drainage Problems

There was one major spring area in the American Canyon where the material was saturated by flows of water

View on Vacaville project facing east, showing the new lane on the left at the intersection of the old state highway routing now known as the Cherry Glen Road





View facing west with new lane showing on the right about 2.5 miles west of Vacaville

from the hills to the north. This condition had previously been encountered in the original construction of the American Canyon section and considerable effort was expended in draining the area under the original grading contract. However, approximately two years after this section was under traffic the designed system of drainage became plugged, the highway fill collapsed and moved out, necessitating detouring traffic around the area.

A study was made by drilling test wells to determine the depth to embedded shale and the water stratum. The fill was then removed and the ground stripped to the embedded shale area. Drainage systems were installed and drain rock was placed. The fill was then reconstructed and the traffic was rerouted over the original alignment.

The presence of the spring was the reason for placing the added lane over this section on the west side of the existing traveled way, thus placing the new lane into the hill and avoiding overloading the spring section. It was necessary to remove the soil under the new road to a depth of 45 feet, where the embedded shale was again found, and a new drainage system installed. It was planned to jack pipes through the existing highway. It was, however, found that the fill underlying this highway was not of sufficient stability to allow the jacking of the pipes, and it was necessary to cut this road in two places in order to drain the water encountered under the new construction.

Major Contract Items

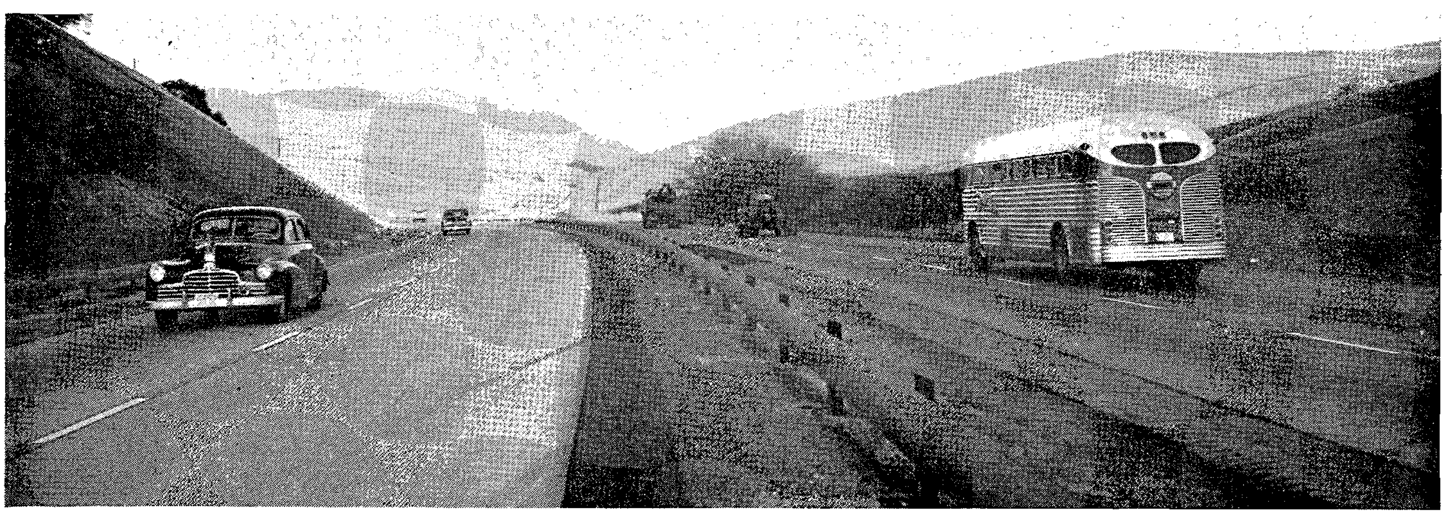
The major items on these three contracts make quite imposing figures. They include the following totals:

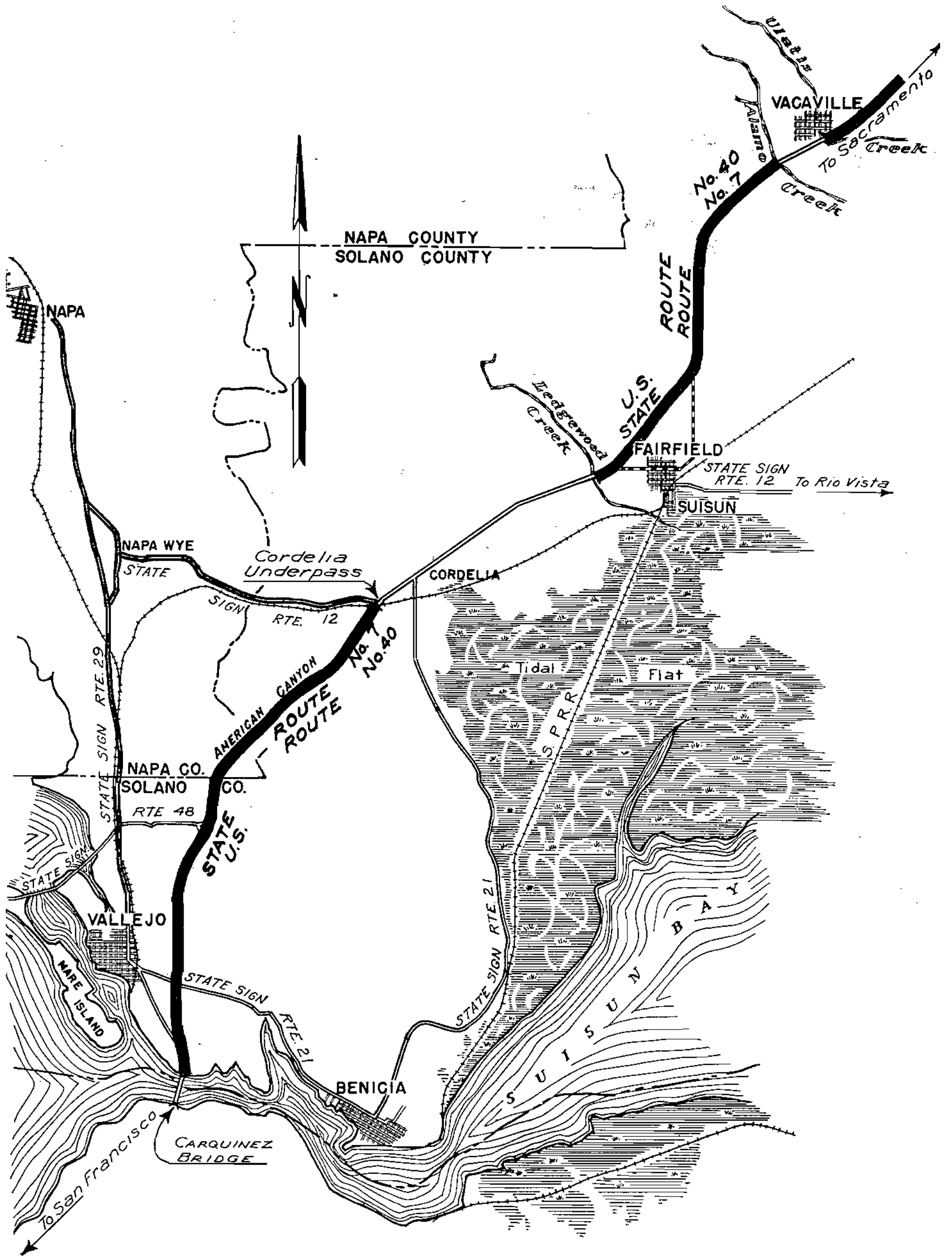
1,010,688 cubic yards roadway excavation
35,857,495 station yards overhaul
268,706 tons imported borrow
232,504 square yards cement-treated subgrade
54,167 tons untreated rock base
26,902 tons plant-mixed surfacing
55,076 cubic yards portland cement concrete
520,000 pounds reinforcing steel

In addition to the grading and paving the projects included construction of three bridges.

Under a separate contract, a traffic-actuated signal system was installed just west of Fairfield and lighting was

View on the American Canyon section with the new lane on the left





13 MILES EXPRESSWAY COMPLETED ON U.S. 40

DISTRICT X

placed at the east entrance of Fairfield. Illumination has also been placed at the transition to two-lane pavement west of Ledgewood Creek, and also at the transition to the two-lane pavement near Vacaville.

The total money involved in actual construction was $2,914,000.

The contractor on the 4.1-mile section near Vacaville was Harms Bros. and the Resident Engineer was E. L. Craun.

The other two sections were contracted to Parish Bros., and the Resident Engineer on both projects was Wm. L. Hurd. All work was supervised by M. C. Fosgate, Construction Engineer, under the general direction of C. E. Waite, District Engineer, and, after his transfer to Headquarters Office, J. G. Meyer, District Engineer.

Roseville Underpass

Continued from page 3 . . .

three inches of plant-mix surfacing on six inches of crusher run base and 15 inches of imported borrow.

Also in connection with the work, a large storm sewer was constructed and irrigation facilities were installed in the slopes and center dividing strips within the city to provide for watering of future planting and landscape developments.

As a part of the project, traffic actuated signal lights were installed at the intersection of Vernon and Grant Streets and all of the roadway within the city limits is lighted by means of mercury vapor and incandescent units. At some future date, it is anticipated that an approach will be provided to the south which will eliminate the present necessity of three right-angle turns to get on and off of Washington Street from the south.

Collier-Burns Act Funds

The Roseville Underpass became a reality as a result of the Collier-Burns Highway Act. During the war when state highway construction was at a very low ebb, plans were made by Governor Warren for a postwar highway program. Legislation was sponsored appropriating $12,000,000 for the preparation of plans and the acquisition of rights of way for postwar construction. The Roseville Underpass was one of the many projects included in this program.

At the 1947 Special Session of the Legislature, the Collier-Burns Highway Act was passed which increased highway revenues and provided for the development of a long-range highway construction program. From this program came the Roseville Underpass on which work was finally started October 27, 1948, after 20 years agitation by its local sponsors.

The project was designed and constructed by the Bridge Department, Division of Highways, under the direction of F. W. Panhorst, Bridge Engineer. The Guy F. Atkinson Company of San Francisco was the contractor, and the author acted as Resident Engineer for the Bridge Department.

Cooperation

Community Planning Spurs Freeway Progress in Alameda County

By NEWELL A. GROVER, Senior Right of Way Agent, District IV

As you speed along a new freeway through an urban area you probably do not realize the background of cooperative planning which has preceded the location and clearance of the right of way to be used in the development of the modern express highway which so well serves all people and which is so appropriately designated by California as a "freeway."

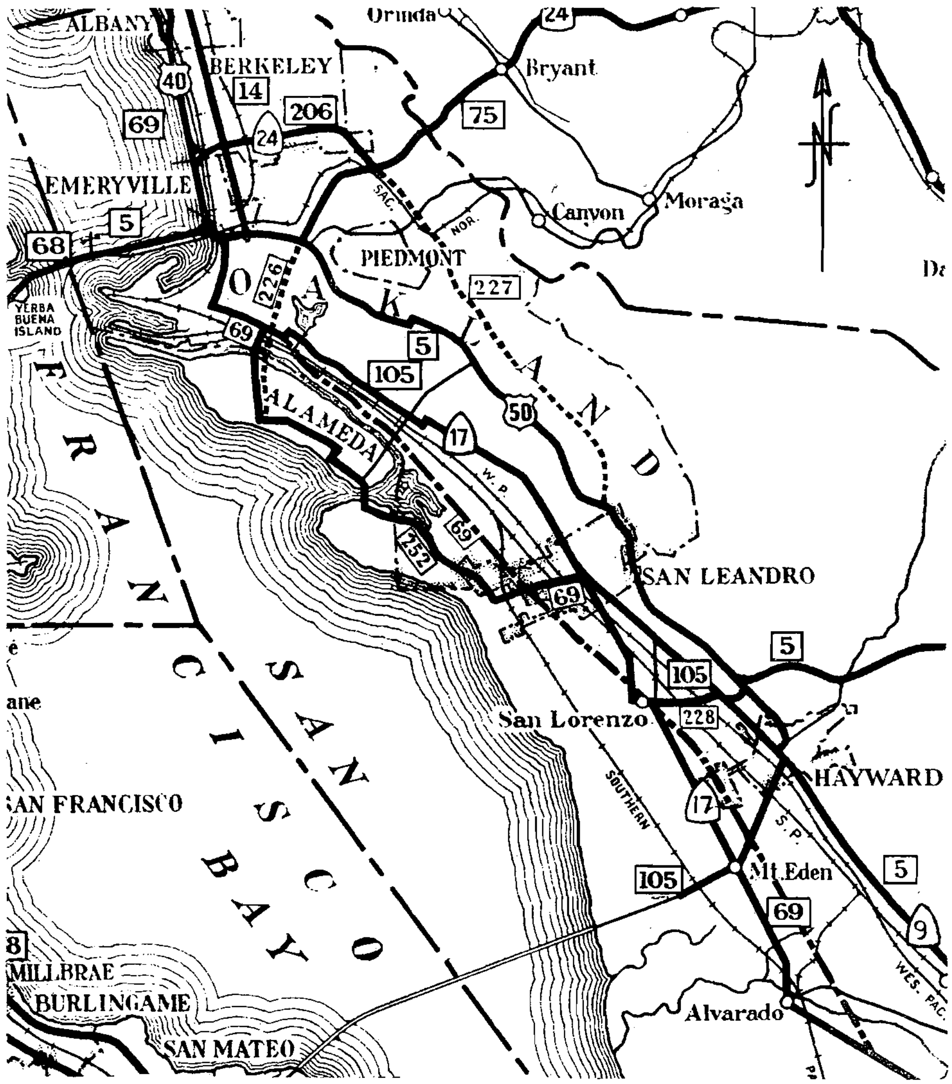
An outstanding example of the results of such planning may be seen along the East Shore Freeway through Alameda County, the first section of the Oakland portion of which was opened to traffic last summer.

During the middle 30's, state, city and county officials realized the necessity of looking forward to a fast, through artery to carry a large volume of motor traffic from the northerly to the southerly limits of the city and thence to the southerly county line.

Congested Areas

The metropolitan area of Oakland had its beginning along the level waterfront areas, with business enterprises developing near rail and water facilities and the early homes located not too distant from the centers of business and industry. By 1930, however, the city had built up so that there were very few sizeable vacant areas left between the bay and the foothills running parallel thereto. Existing sections of state highways serving north- and southbound traffic ran along MacArthur Boulevard, Foothill Boulevard and East 14th Street, respectively, carrying through-traffic along congested city streets with interference at each intersection in spite of boulevard stops and signals.

Early studies for Route 69 through Oakland explored the possibility of improving one of the existing city streets into a freeway, but it was finally decided that, as had been done in the case of the Bayshore Highway along the westerly side of San Francisco Bay, a new location should be provided through the Oakland area, which, insofar as practicable, would pass through the lesser developed areas between the easterly shore of the bay and the existing industries along the railroad lines.



State highway route through Oakland and vicinity with portion of Route 69, or East Shore Freeway, shown by broken line

Freeway Planned

After further extensive study a location was agreed upon for what was finally to develop into a portion of the East Shore Freeway, starting toward the bay from a point at Sixth and Fallon Streets, a short distance westerly of Lake Merritt, and then crossing over the the main line tracks of Western Pacific Railroad Company and those of Southern Pacific Company so as to run parallel with the shore of the bay to a point near 23d Avenue.

The route selected then crossed 23d Avenue to run approximately parallel with the Southern Pacific right of way until it again approached the shore area

Air view northerly along East Shore Freeway from point near Davis Street, San Leandro, showing built up subdivisions on each side of the freeway right of way reserved several years ago when the residential development started, and now being utilized for the advancing freeway construction. Brookfield Village and the 98th Avenue and Hegenberger Road overcrossings show in middle distance, San Leandro Creek marking the southerly city limits of Oakland in center, and subdivision near Davis Street in near portion of picture

in the vicinity of 50th Avenue, where the outline of the waterfront referred to as San Leandro Bay returned to a position not too far distant from the proposed freeway. Leaving 50th Avenue the location was across tide marsh areas until the shore line again swung southwesterly in the vicinity of the Oakland airport.

Not only did this route pass close to the industrial, business, and county office sections of the metropolitan county seat but it provided the advantage of a water-level location except where it was necessary to carry the freeway over railroad grade separation structures or across bridges requiring some clearance above water courses.

City Cooperation

The City of Oakland, in addition to its cooperation in the matter of planning for this freeway, set aside the first large parcel of right of way required for the project, made up of approximately 22 acres of industrial waterfront property under the jurisdiction of its Board of Port Commissioners, and located between the so-called Low Tide Line of 1852, near Lake Merritt Canal, and 19th Avenue. The clearance of this parcel required the complete removal of several waterfront industries and the major rehabilitation of several other large plants with marine ways, warehouses, etc., as well as the construction of a new belt line railroad track between the southwesterly side of the freeway and the waterfront to replace the existing rail service furnished to the waterfront industries from a track on the Southern Pacific Company's right of way adjacent to but on the northeasterly side of the freeway.

Between 19th and 50th Avenues the acquisition and clearance of the right of way for the freeway, which was carried on over a period of several years, involved the complete removal of one large chemical plant, the rehabilitation of several other large industries, the removal or rehabilitation of numerous smaller industrial and commercial developments, as well as the removal or rehabilitation of many homes.

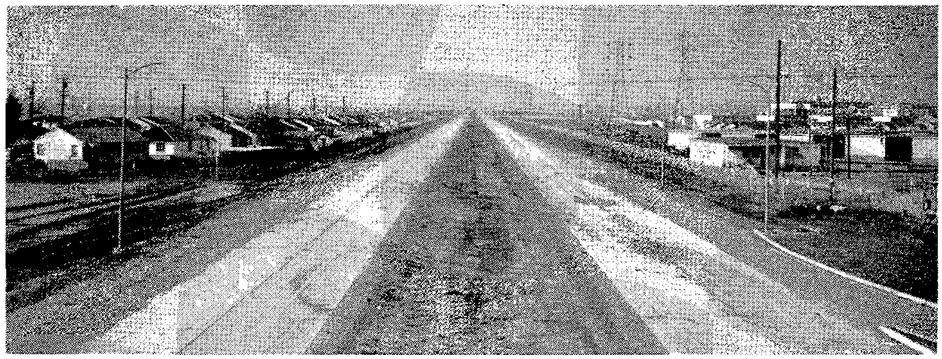
San Leandro Expansion

After leaving 50th Avenue the projected location ran across what was then practically undeveloped country area. This country section, however, between Hegenberger Road and the environs of Hayward has since been subject to an expansive development of industries and homes so as to make it, from the planning point of view, one of the most interesting portions of the entire project.

Vacant industrial area closer to the center of Oakland had become quite scarce, with the result that more and more industries sought the larger locations available near San Leandro, and more and more workers turned in that direction for their homes. This resulted in a rapid growth, both industrial and residential, of the southerly portion of the City of Oakland, as well as the adjoining City of San Leandro. The residential expansion, accentuated by war conditions, spread to San Lorenzo where an entire new community known as San Lorenzo Village was grafted onto the south side of the trunk of the old village, with a resulting growth which is rightly a matter of pride to the developer, David D. Bohannon Organization, as well as to the entire area.

Brookfield Village

The first major subdivision effort along this vacant section of the East Shore Freeway was the development known as Brookfield Village. Tentative maps for this residential project had been prepared prior to the time that the freeway location was established,

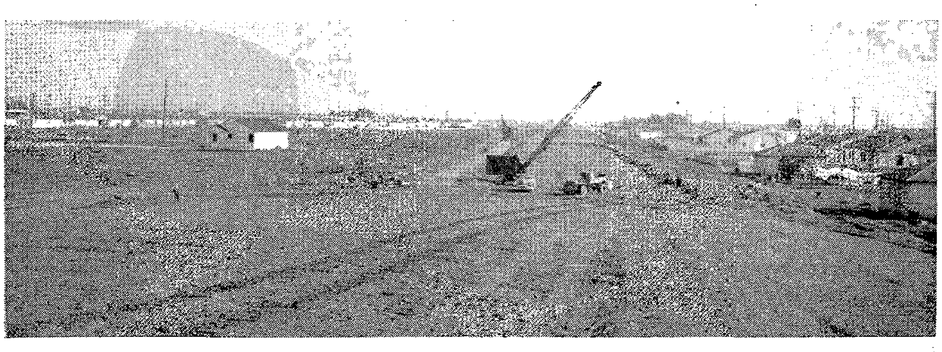


Recently completed section of East Shore Freeway just north of 98th Avenue, Oakland, with Hegenberger Road overcrossing in distance and Brookfield Village homes, built several years ago, on each side of freeway right of way

and so when these maps were presented to the City Planning Department, it immediately became necessary to redesign the subdivision in order to coordinate it with the future freeway. The subdivision streets were built parallel to the freeway with one tier of lots intervening, the rear of which abuts upon but has no access to the through highway, in accordance with the generally accepted design. The main cross artery to serve the subdivision, both before and after the freeway development, was 98th Avenue, and a sizeable commercial area of stores, service stations, etc., started to build up between the freeway location and San Leandro Street, which is a county road forming the present north and south artery just westerly of the Southern Pacific Company tracks.

The homes in the Brookfield Village on both sides of the freeway right of way were constructed and occupied during the war period to take care of workers in the growing industries throughout the East Bay area. The freeway right of way remained vacant, however, until 1949 when the construction project of the Division of Highways proceeded with the building of the freeway paving and the separation structure necessary to carry 98th Avenue over the freeway.

Construction of San Leandro Creek bridge and approaches proceeds in 1950 on reserved section of East Shore Freeway right of way north of Davis Street, San Leandro, where homes bordering the freeway were built several years ago



Other Subdivisions

Several other subdivisions went forward during this period in the vicinity of Davis Street, San Leandro, which is the next east-west artery south of 98th Avenue. Here also efficient planning by the County Planning Commission and the subdividers resulted in the development of residential areas located on both sides of the freeway right of way, which was set aside as a part of the cooperative master plan and which remains vacant today, although early freeway construction is now on the program of the State.

The next major subdivision to the south was the San Lorenzo Village, and here again the developers have cooperated by setting aside a wide vacant swath along the easterly side of the project to accommodate the ultimate East Shore Freeway.

Although the growth of San Lorenzo has been mainly residential, the area along the freeway location through San Leandro has witnessed the establishment of many large industrial and commercial plants, several of which were relocations required by the clearance of the freeway right of way through Oakland proper and the right of way for the Bayshore Freeway through San Francisco.

These industries are attracted to San Leandro by the readily available land, rail facilities, the fine surrounding residential area in which workers may

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New Route

Expressway Around Stockton Will Be Completed in June

By JOHN G. MEYER, District Engineer

JUNE, 1950, will see the completion of a contract awarded to United Concrete Pipe Company in June, 1949, for the paving and completion of the expressway project located on the eastern fringes of the City of Stockton.

Its location met with the approval of the Stockton City Council, a large majority of the business men of this area, and the San Joaquin County officials. The finish of this contract will complete the project which was described in more detail in an article published in the July-August, 1949, issue of this magazine and which was started by a previous contract held by Lord and Bishop and M. J. B. Construction Company in June of 1948.

This expressway is a portion of Rt. U. S. 99 and begins at the Mariposa Road one and one-half miles south of Stockton. It extends thence in a northerly direction over new right of way to the Calaveras River where it joins an eight-mile piece of four-lane divided expressway between the Calaveras River and Lodi. The rerouting saves through traffic 1.57 miles in distance as well as a tedious drive through a business area in Stockton.

Avoids Congested Area

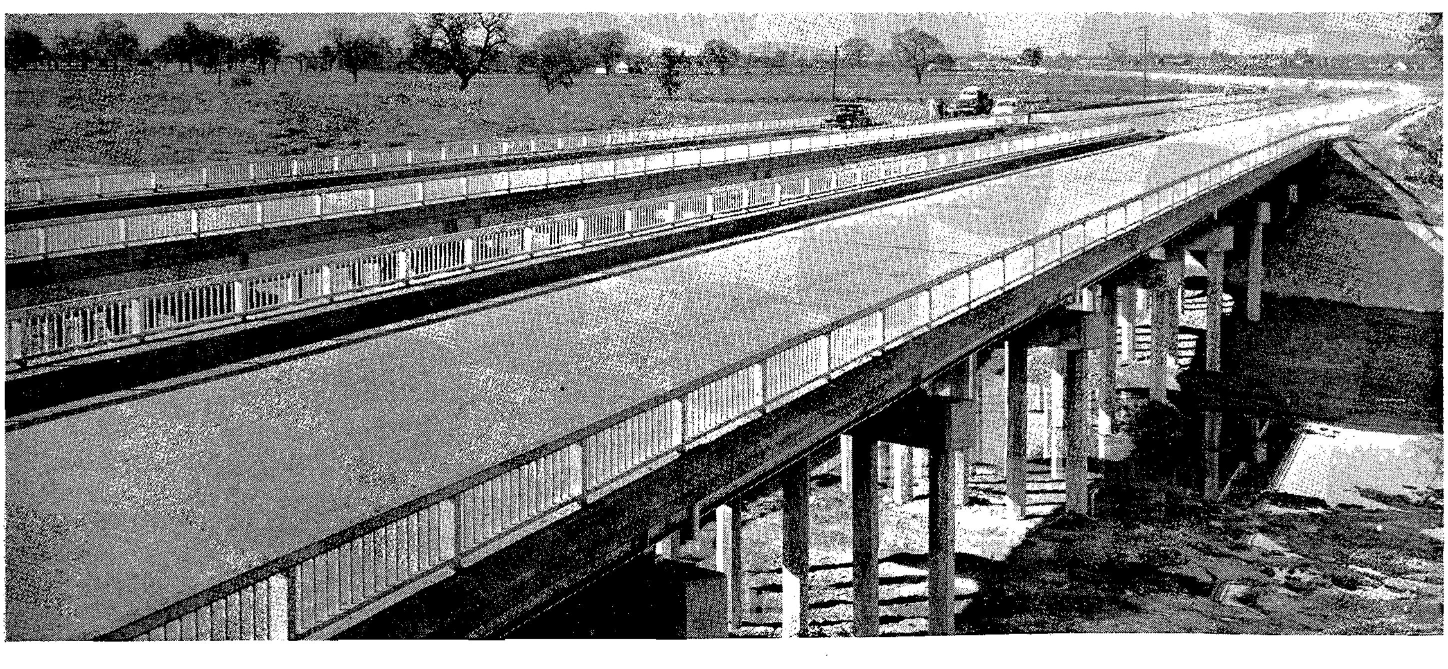
The project also includes a two-mile extension of U. S. 50, locally known as Charter Way, from Wilson Way in Stockton to join the expressway at a point 300 feet south of Main Street. The U. S. 50 portion includes a structure over Mormon Slough as well as an underpass under the Santa Fe Railroad. In making its connection with U. S. 99, an overhead separation is constructed which allows north-bound traffic to cross the expressway and then blend in with through traffic near the south entrance of the Main Street overhead or with local streets.

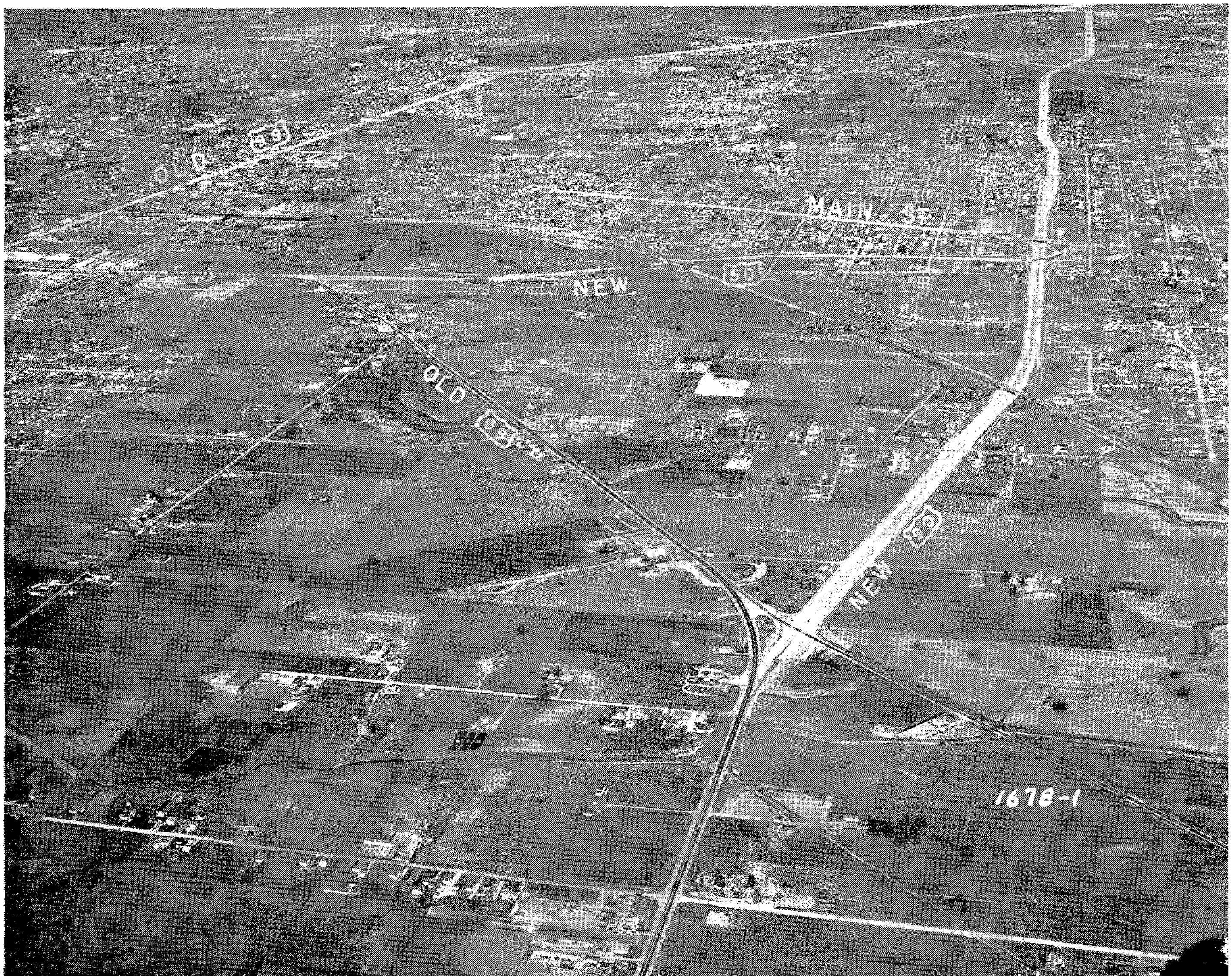
The two traveled ways from Mariposa Road to Calaveras River are of Portland cement concrete, each consisting of one 11-foot lane and one 12-foot lane. The outside and inside shoulders consist of plant-mix surfacing three feet and two feet in width, respectively, adjacent to the pavement edges, with bituminous surface treatment applied to the remaining five-foot and three-foot widths. The speed change lanes and the inlet and outlet ramps consist of plant-mix surfacing on either untreated rock base or Portland cement concrete base.

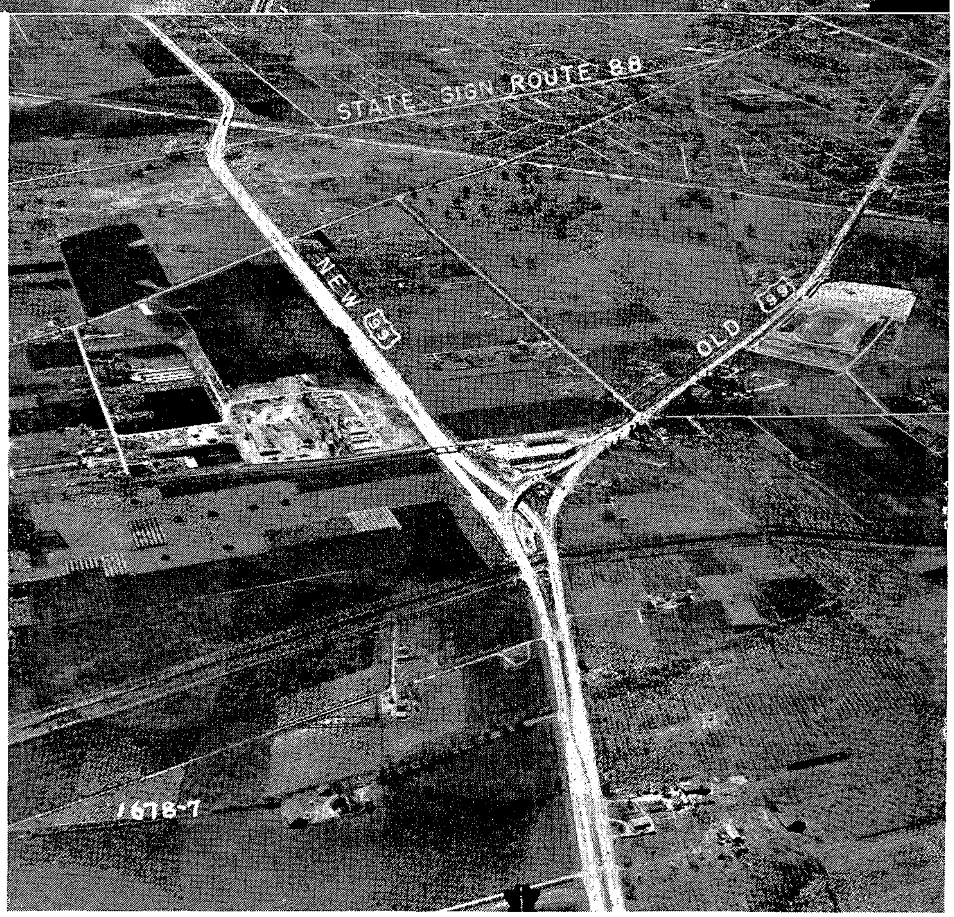
Four-lane Divided Highway

On U. S. 50 there is a four-lane divided highway from Wilson Way to D Street, a distance of approximately 3,600 feet, where the northbound traffic to Stockton uses a new 23-foot Portland cement concrete traveled way and the southbound traffic uses the existing pavement which is being resurfaced. From D Street on to the expressway the construction consists of a two-lane 23-foot Portland cement concrete traveled way with combination shoulders of three-foot plant mix adjacent to the edges of the pavement and bituminous surface treatment on the outer five feet. Right of way for Route 50 has been acquired for future development to four-lane throughout.

New twin bridges for north and southbound traffic at diverting canal across Mormon Slough on U. S. 99







These aerial views show old and new locations of U. S. 50 and U. S. 99 in area covered by new Stockton Expressway

The structures on U. S. 99 were a major item of work, there being an underpass under the Santa Fe Railroad, twin bridges across Mormon Slough, an overhead for the connection of U. S. 50 and the overhead at Main Street, a pedestrian underpass at Miner Avenue, twin bridges across the diverting canal, an underpass under the Central California Traction Company Railroad, an overhead to connect northbound traffic leaving Stockton to the expressway as well as a bridge across the Calaveras River and an extension and widening of the original Calaveras River Bridge.

Flat Curvature

The terrain through which this project is located is level and while there are eight curves in the project,

. . . Continued on page 50

Truck Turns

State Makes Exhaustive Study of Truck-Trailer Paths on Short Radius Turns

By J. C. YOUNG, Traffic Engineer, Division of Highways

The prevalence of large truck and trailer and tractor-truck semitrailer combinations on California highways makes the room required for these vehicles on short radius turns at intersections and connecting ramps an important consideration in geometric design.

In order to determine lane widths and shapes for minimum design, several large truck combinations were driven in short radius turns on an airport, and the resulting tracks were measured and plotted. This report presents the results of the trials and provides recommended curve data and lane widths which will accommodate the largest legal vehicles in California. These maximum legal vehicles are 60 feet in over-all length. The maximum legal length of the trailer portion of a tractor-semitrailer combination is 35 feet.

Track widths are given in tabular form for various radii and central angles. The track width of a legal semitrailer turning 180 degrees on a 50-foot outside radius is 20.2 feet. The sharpest turn recommended is a 50-foot radius for the outside lane edge. Allowing a two-foot tolerance, the radius of the outside wheel track becomes 48 feet for which the net track width is 21.0 feet. The lane width including a tolerance of 2.0 feet on both sides is 25 feet.

CHANNELIZED INTERSECTIONS and grade separations frequently require turning lanes to provide for very low hourly traffic volumes; in other words, for "occasional" vehicles. It is essential to provide for these occasional turning movements, but it is impracticable to provide long radius curves which more important turning movements would justify.

California design for cases of this kind frequently provide curbs on both sides of the turning lanes, or, in the case of channelized intersections, islands whose boundaries comprise segments of imaginary turning lanes. In order to maintain traffic flow in these turns, they must be passable by the largest legal vehicle, although this class comprises a small percentage of total traffic.

Apparatus used for making trace on pavement (Front overhang of bus)

For the purpose of presenting this material in the form of a magazine article it was necessary to reduce the drawings of test truck paths to an odd scale. A few drawings, not essential to the sense of the text, are omitted entirely. Readers who are interested in scaling dimensions may write to the State Highway Engineer, attention of J. C. Young, Traffic Engineer, and drawings on a scale of 1″ = 20′ will be furnished. Available drawings which are not shown in this article include minimum turns for the 2-axle truck, 3-axle truck (left turn), 2-axle bus, truck and trailer type 3-3, train type 2-S2-2; and 180°, 50-foot radius turns of the 2-axle bus, 3-S2, 3-3, and 2-S2-2.

It has been California practice to lay out a geometric line, i.e. compounded circular curves, as the inside lane edge, and to allow a lane width from this edge which is dependent on radius alone. However, the width needed changes not only with the radius of the curve but also with the central angle. Furthermore, increasing the inside edge radius does not necessarily make the lane passable.

Available information on lane widths required by semitrailers is based on experiments made about ten years ago on a semitrailer having an over-all wheel base of 35 feet and a distance from kingpin to rear axle of 21 feet. Measurements made of random vehicles in California show that in 1949, 98 percent of all California 3-S2 combinations exceed 35 feet in over-all

Apparatus used for making trace on pavement (Rear wheel of trailer)

wheel base and 88 percent of them exceed 21 feet in distance from kingpin to forward rear axle.

It was therefore decided to conduct physical experiments with the view of determining simple geometrically shaped paths which would accommodate large vehicles. It would, of course, be possible to lay out a circular inside edge, adding sufficient width for any vehicle to negotiate the turning lane around the circular curve. In this case, it would still be necessary to determine the widths experimentally. However, circular inside edges call for considerable extra pavement which would be unusable by any vehicles; even passenger cars.[1]

VEHICLE TYPES

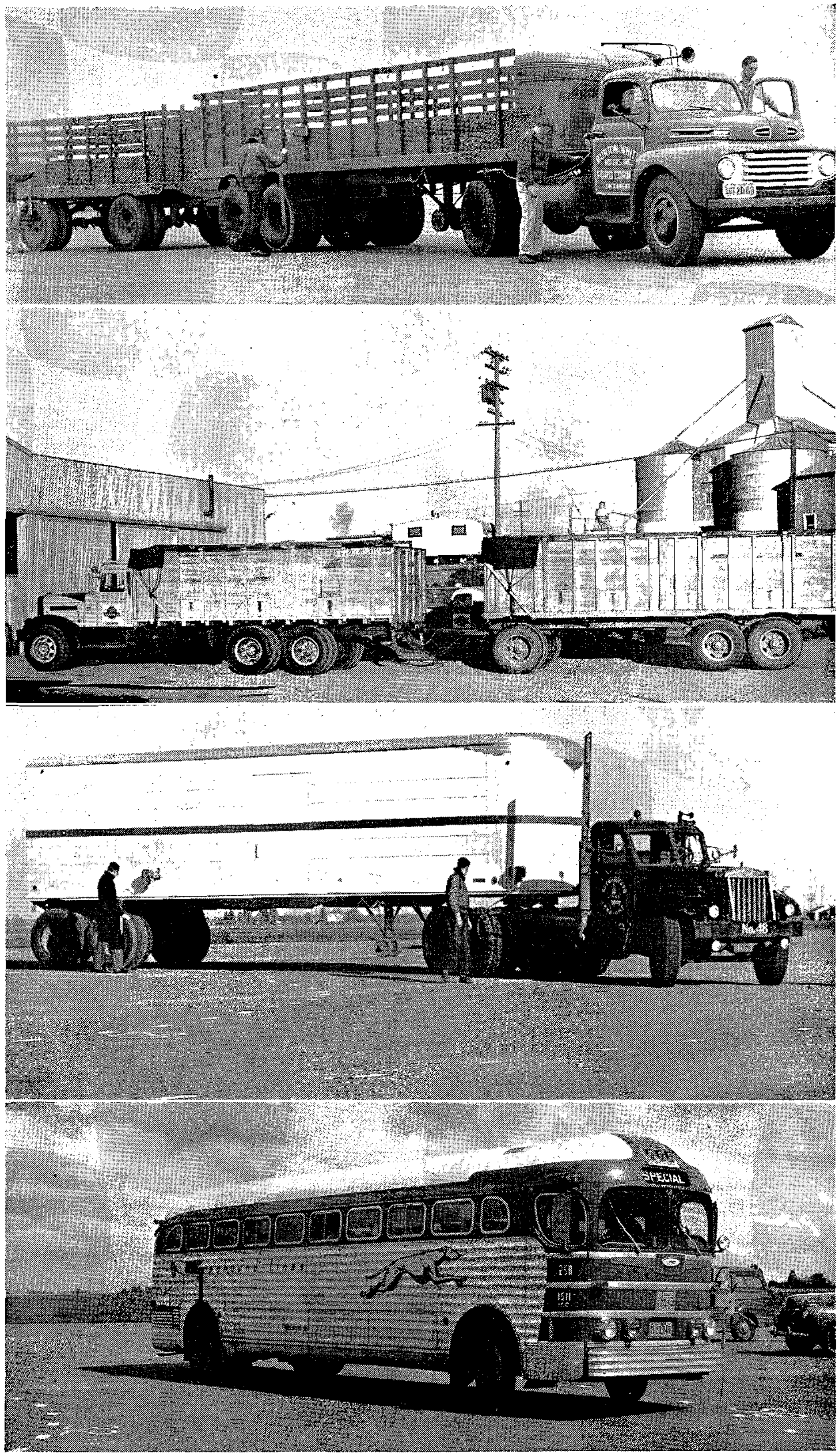
With the cooperation of the trucking industry and truck and trailer dealers, critical vehicles of types which approach or equal the legal size limits in California were taken to an abandoned airstrip and driven around various kinds of turns.

The vehicles used are diagrammed in Plate 1 and are briefly described as follows:

a. 2-axle truck, 17.5 ft. wheel base, 25.4 ft. over-all length
b. 3-axle truck, 21.0 ft. wheel base, 29.6 ft. over-all length
c. Tractor-truck and semitrailer type 3-S2, having:
   20.0 ft. wheel base, tractor
   29.0 ft. kingpin to rearmost semitrailer axle
   46.0 ft. over-all wheel base
   50.8 ft. over-all length
   35.0 ft. over-all length of semitrailer van (maximum legal size)
d. Tractor-truck, semitrailer and full trailer, type 2-S2-2, 60.0 ft. over-all length (maximum legal length)
e. Truck and trailer type 3-3, 60.0 ft. over-all length (maximum legal length)
f. 2-axle bus, 22.0 ft. wheel base, 34.7 ft. over-all length
g. Tractor-truck and articulated semitrailer type 3-AS2, having:
   19.8 ft. wheel base, tractor
   31.3 ft. kingpin to rearmost axle
   48.1 ft. over-all wheel base
   53.0 ft. over-all length
   35.5 ft. over-all length of semitrailer van

Four of the vehicles used in the tests are shown in accompanying photographs.

The relative importance of the various types in actual road use, and a



UPPER—Tractor-truck, semi-trailer and trailer, Type 2-S2-2. BELOW—Truck and trailer, Type 3-3. NEXT—Tractor-truck and semitrailer, Type 3-S2. BOTTOM—Two-axle bus

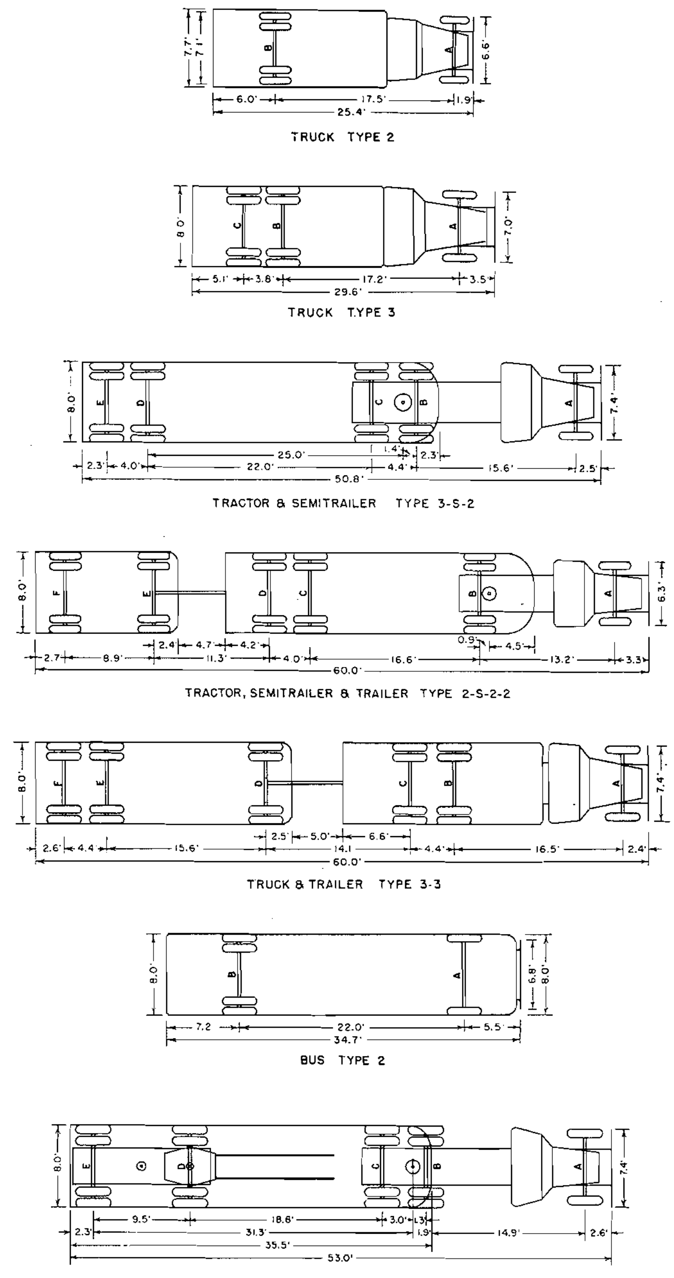
[1] A discussion of the merits of compound curves for inside lane edges on sharp turns is found in "A Policy on Intersections at Grade," American Association of State Highway Officials (Washington, 1940) (pp. 13-16).

comparison of the test vehicles with those on the road, is afforded by the annual Loadometer Survey conducted by the California State-wide Highway Planning Survey. This survey consists of a random sample of all commercial vehicles at 20 points throughout the state highway system.

Semitrailers Critical Vehicles

Of all vehicles having more than four tires (that is, of all trucks and combinations exceeding the pickup and panel delivery type), 30 percent are semitrailers. Of these 30 percent, one-half are of the 3-S2 type. It will be developed later in this report that the 3-S2 is the critical vehicle on turns, insofar as lane width is concerned, and the prevalence of this type on the road signifies its importance in design. The vehicle used for the tests (see photograph) is typical of the 3-S2's found on the road. During the 1949 survey, it was found that in over-all wheel base, 48 percent of the type were within two feet of the wheel base of the test vehicle (14 percent were from two to four feet longer); and in distance from kingpin swivel to forward rear axle of the semitrailer, 57 percent were within one foot of the test vehicle (10 percent were from one to three feet longer, and 33 percent were shorter by more than one foot).

Two points are made here: First, that the vehicle used for the tests is not so exceptionally large that it can ever be ignored in design; and second, that the vehicle used for tests, for purposes of lane width determination, is large enough (i.e., long enough from swivel to axle) so that the data derived from the tests may be depended upon to accommodate practically all legal vehicles in California. In fact, the van body on the test vehicle was 35.0 feet, exactly the legal limit for any single unit, and it would be extremely unlikely that a van of this length could have a significantly longer wheel base than the test vehicle.



Dimensions of Test Vehicles **Plate I**

DESCRIPTION OF TESTS

Tests made included:

1. Runs of each vehicle type to determine the sharpest curve which could be used for the outside lane edge that will accommodate all vehicles.

2. Runs of each vehicle type on predetermined paths, to determine lane widths for various curve shapes. These runs were made in the following separate ways:

a. Inside rear wheel following predetermined compound curves of various radius combinations.

b. Inside rear wheel following circular path.

c. Outside front wheel following circular path.

In all the tests an apparatus was mounted on the vehicles to produce marks on the pavement, as shown in accompanying photographs. The apparatus was very simple and consisted essentially of reservoirs to hold the marking fluid (whitewash), together with outlet tubes which were positioned to flow from critical points on the vehicles, namely:

1. The outer front end of the vehicle, which usually overhangs the outer front wheel path on short radius curves;
2. The outer front wheel at the hub;
3. The inner rear wheel of the tractor, or leading vehicle of combinations;
4. The inner rear wheel of the trailer.

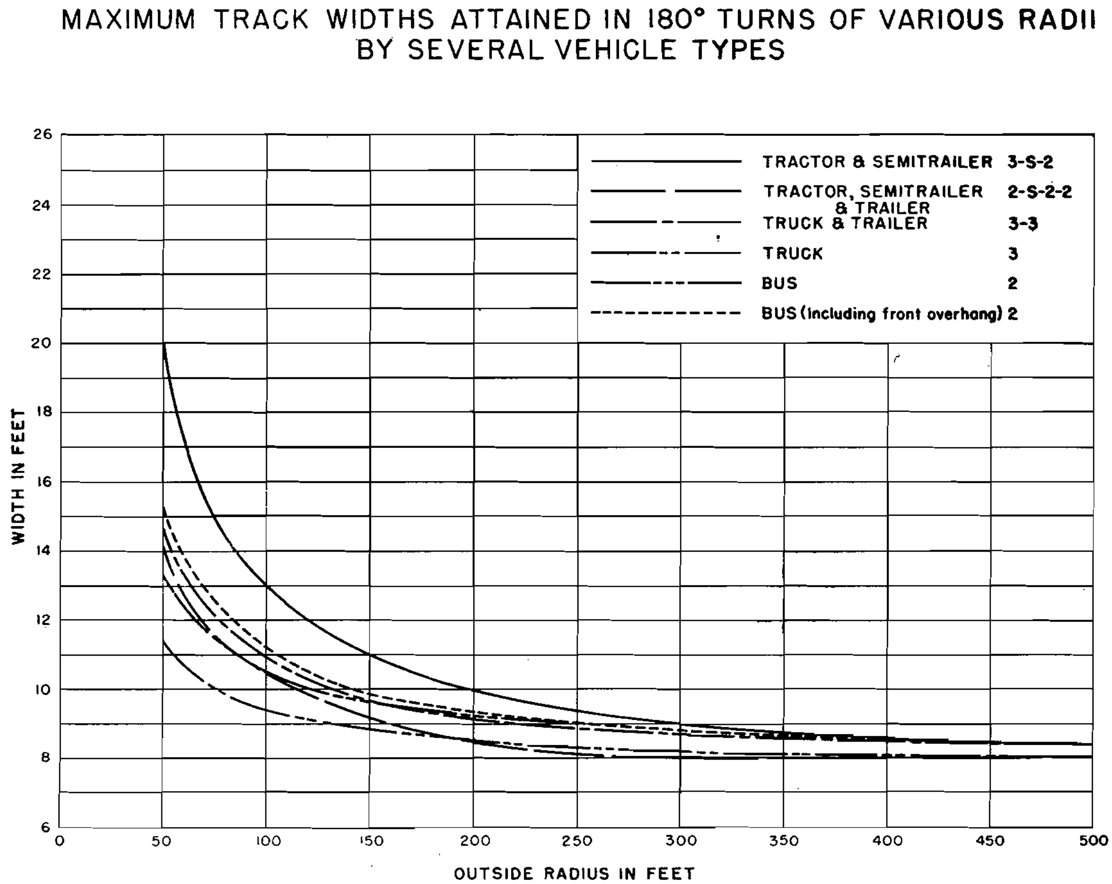


Plate 2

The tests consisted merely of driving the several vehicles at slow speeds (3 to 6 m.p.h.) around various types of curves, leaving whitewash traces at the outside and inside edges of the paths occupied. The traces were then recorded in terms of polar coordinates, and were later plotted up in the office on large scale drawings (5 feet to the inch, or 1:60).

RESULTS OF THE TESTS

Sharpest Curves by Various Vehicles

In this phase of the tests, each test vehicle was successively driven in right-hand and left-hand turns on a blank pavement, leaving marks as they fell; in other words, it was not attempted to follow a presurveyed mark. In each case, the steering wheel was "cramped" over as far as it would go. *Typical paths are shown in Plates 9 to 12.*

The critical radii are listed in *Table 1*. The minimum radius for the three-axle truck is the largest of any of the vehicle types; 45.0 feet for left turns and 43.0 feet for right turns. The same truck towing a full trailer describes the same outer wheel path. All other types and combinations having a shorter wheel base in the tractor unit are able to turn within these outside curves.

Required Outside Radius

It is seen in *Table 1* that several vehicles require an outside radius of at least 43 to 45 feet when being driven under ideal conditions and at very low rates of speed (the bus, in making a right turn, requires a 42.8-foot radius for the front tire, but the front end overhang is 2.3 feet).

It was concluded that for minimum practical turns which would be built to accommodate all vehicles, 50 feet is the least radius of front wheel track which would be worth investigating for lane widths. It may also be noted in *Table 1* that the types requiring the greater lane widths were those whose outside radius was less than the minimum for other types. In other words, turns must be built with an outside radius sufficient to accommodate a bus, but must be wide enough to accommodate a semitrailer. The semitrailer lane width shown in *Table 1* is not significant, because turns of such short outside radius (33.6 feet) are not practical or possible of negotiating by other large vehicles.

Transition From Tangent to Curve

Before proceeding to discuss the test runs on fixed paths, attention is invited to some other facts revealed by the minimum radius drawings. First, transition (variable radius) curves comprise a portion of the wheel paths of both front outside and rear inside wheels. For long combinations making turns of moderate central angles, the inside track is wholly transitional. For this reason, minimum possible turns are difficult to describe other than graphically. The actual paths drawn to scale are almost the only way of testing design.

Second, the transition at the beginning of the outside wheel curve attains a *sharper* curvature than the minimum radius *(see Plate 9)*, and the offset from the circular curve (produced) is minor at slow speeds. It is apropos here to call attention to a common fallacy; namely, that when entering a circular curve from a tangent, the front wheels must be abruptly changed from a straight-ahead position to a specified angle. On the contrary, the only way a vehicle can enter a circular curve with the front wheel is to turn the steering gear gradually.

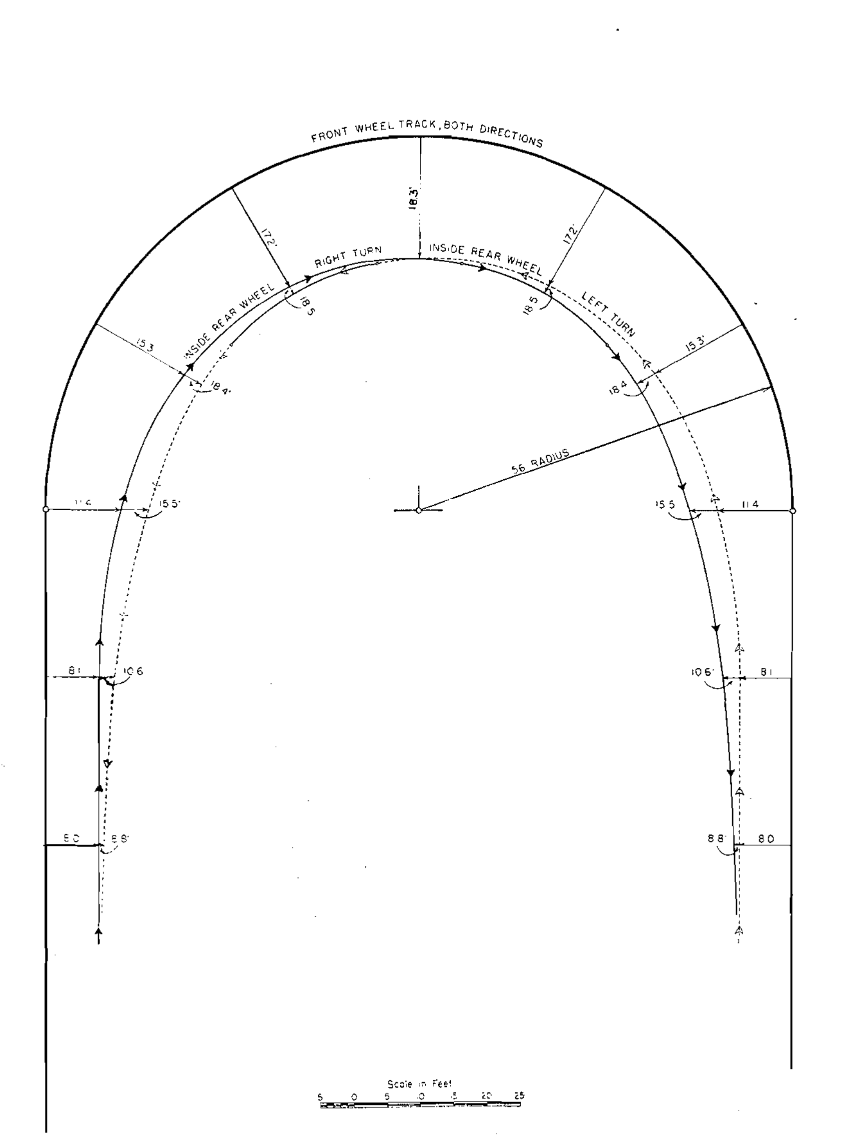
Circular Curve Not Abrupt

Suppose that the vehicle is traveling on a straight line, is brought to a halt, and the front wheels are turned to an angle while the vehicle is in a standing position. Upon resuming the motion of the vehicle, the front wheels will take off in the direction in which they are pointed, and their traces will form a definite angle, rather than a point of tangency. This means that far from being impossible, as has been held in many quarters for 30 years or more, a circular course *is* negotiable from a tangent, and at slow speeds is the natural way for a vehicle to change direction.

Third, the tractor-truck semitrailer invariably makes a wider track than the truck and trailer, although the latter is longer. *Comparison of Plates 11 and 12, which show the effect of the tongue and swiveled axle on the full trailer, reveals the reason for the difference in width.*[2]

COMPOUND CURVES

In an attempt to find out what lane widths would be required for symmetrical compound inside edge curves which have been in use in California, five such curves, having various central angles, were surveyed and painted on the pavement. These curves are described as follows:



Left-hand and Right-hand Turns on 56-Foot Outside Radius; Vehicle Type 3-S2 Plate 3

	3-center compound curves			
Central angle degrees	R_1 feet	R_2 feet	R_3 feet	Offset for R_2 feet
60	120	32	120	5
90	120	32	120	5
120	120	32	120	5
135	120	32	120	5
180	120	32	120	5

It was found that it was very difficult for the drivers to follow these tracks with their rear wheels, requiring continuous jockeying and resulting in an irregular wobble path for the front wheels. Furthermore, the general path of the front wheel followed no describable geometrical form because the natural path of the truck calls for a longer transition at the end of the curve than it does at the beginning.

It was then attempted to drive the trucks around a circular path for the inside lane edge. In other words, it was attempted to make the rear wheel follow a circle. This resulted in the front end making a sort of pear shaped line, which would be very impractical for purposes of tabulating or design, since it would bulge out into the adjacent lanes at take-off and merging points.

[2] The statement made in this paragraph applies to the conventional semitrailer with fixed axles. There is a patented type of trailer which has no front axle and in that respect is a "semi" trailer, but has articulated rear axles, and for a given body length occupies considerably less lane width.

A discussion of this trailer is included in the appendix of this article.

CURVE DATA FOR INSIDE AND OUTSIDE EDGES OF LANES WHICH WILL ACCOMMODATE LARGE SEMITRAILER COMBINATIONS

Table 7

RADIUS OF OUTSIDE EDGE	RANGE OF CENTRAL ANGLES	THREE-CENTER COMPOUND CURVES FOR INSIDE LANE EDGE				
R_o	Δ	R_1	R_2	R_3	e	s
FEET	DEGREES	FEET	FEET	FEET	FEET	FEET
50 (2)	60° to 90° (1)	180	45	250	59	15
	91° to 180°	120	30	200	48	4.5
	OVER 180°	80	25	200	50	0
60	60° to 90° (1)	120	55	300	69	13.5
	91° to 210°	120	40	300	58.5	1.5
	OVER 210°	80	38	300	60	0
67	60° to 90° (1)	120	60	300	74	10
	91° to 180°	120	49	300	66	2.5
	OVER 180°	100	46	300	67	0
75	40° to 59°	200	90	300	104	17
	60° to 210°	120	57	300	74	1.5
	OVER 210°	120	55	300	75	0
100	0° to 30°	220	(3)			
	31° to 60°	200	90	400	104	5.5
	OVER 60°	120	83	400	100	0
150	0° to 25°	300	(3)			
	OVER 25°	300	135	400	150	0
200 (4)	0° to 20°	400	(3)			
	OVER 20°	400	186	400	200	0

(1) Radii of less than 75 feet for angles of less than 60°, or less than 100 feet for angles less than 40°, are not recommended because of short lengths.

(2) 50 feet radius will allow for practically no initial speed of large vehicles; this set of figures for use in critical locations only.

(3) Single circular curve.

(4) For any radius between 200 and 500 feet use concentric curves, inside radius 14 feet less than outside radius, with circular transition curves of twice the central radius.

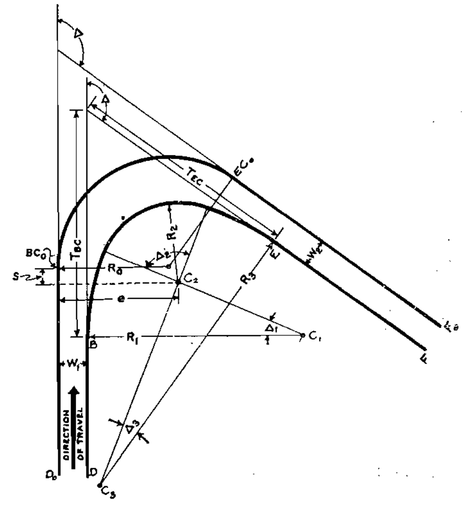


Plate 4

FORMULAS FOR LAYOUT COMPUTATIONS

$$\cos \Delta_1 = \frac{R_1 - (e - W_1)}{R_1 - R_2}$$

$$\cos \Delta_3 = \frac{R_3 - (R_o - W_2) - S \sin \Delta - (e - R_o) \cos \Delta}{R_3 - R_2}$$

$$T_{BC} = (R_1 - R_2) \sin \Delta_1 + \frac{R_o - W_2 + S \sin \Delta + (e - R_o) \cos \Delta}{\sin \Delta} - \frac{(e - W_1)}{\tan \Delta}$$

$$T_{EC} = (R_3 - R_2) \sin \Delta_3 + \frac{(e - W_1)}{\sin \Delta} - \frac{R_o - W_2 + S \sin \Delta + (e - R_o) \cos \Delta}{\tan \Delta}$$

The next step was the construction of nonsymmetrical 3-center curves, which were laid out as follows:

				3-center compound curves	
				Offset for R_2	
Central angle, degrees	R_1 feet	R_2 feet	R_3 feet	From approach tangent feet	From leaving tangent feet
90	120	40	120	4	14
120	120	40	120	4	14
180	120	40	120	4	14

Somewhat the same difficulty was found in running these curves that occured with the previous set. However, the outside track followed a generally circular path.

CIRCULAR CURVES

In contrast to the process of predetermining a geometric path for rear wheels and the difficulty of attempting to develop the outside curve which corresponded, it was found practical to keep the front wheels on a circular path and simply to record the spiral path of the rear wheel which naturally followed. A circular path for the front wheels is also a natural path and for turns at slow speeds the transitions at beginning and end of the curve are short and of small offset. For the same reason that it was found difficult to drive anything but a circle or definite geometric path with the front wheel during the tests, it may be concluded that channelization or ramp design should similarly be based upon geometrical paths for the outside front wheel, using this path as the independent line, and determining the inside edge as a dependent function thereof.

Circular curves of the following angles and radii were painted on the ground and run with the front wheel of each vehicle type on the curve:

Radius, ft.	Central angle
50	180°
53	90°, 120°, 180°
56	90°, 120°, 180°
75	180°
100	180°
200	160°
300	136°
500	100°

The maximum track width attained by each vehicle type in making a 180-degree turn on each radius is shown on *Plate 2*. These widths varied from slightly greater than the eight-foot vehicle width at radii greater than 300 feet to more than 20 feet for the semitrailer at 50-foot radius. The semitrailer combination produced a wider track than any other type at all radii. It was from 0.5 foot wider, on a 250-foot radius, to five feet wider on a 50-foot radius, than any other type.

Since the semitrailer track is adequate, at outside radii of 50 feet or greater, for all other types, the remainder of this report is devoted to the detailed results obtained from runs of that vehicle type. Design which provides for this type is the minimum permissible, and tracks made by other vehicles are only of academic interest.

Plate 3 shows the tracks made by the 3-S2 in turning 180 degrees both left and right on a 56-foot outside radius. The left and right paths are congruent if folded left hand to right hand. This fact was tested for other radii as well, and it was found true that left and right turns are always congruent provided the outside radius remains the same.[3]

Plates 5, 6, 7 and 8 show the tracks made by the 3-S2 semitrailer combination for various radii and angles. These drawings were constructed from field notes of the marks actually produced by the vehicle in following the stated circular curves with the outside front wheel, through 180 degrees of azimuth. The off-going spiral of the rear wheel is a constant shape for every angle and radius, the length of which varries according to the total track width attained. When the angle between the tractor and the semitrailer has reached the value necessary to produce a certain track width, and the front wheel is then driven along a straight line, the process by which the angle was attained has no effect on the future course of the rear wheel.

Tables 2 to 6 show track widths for each radius with various central angles. They were prepared by scaling from large scale original drawings of the plates.[4] Track widths for radii and central angles not shown in the tables may be interpolated, bearing in mind that the test methods and the nature of the work do not justify accuracy closer than one-half foot, plus or minus. The widths are shown to a tenth of a foot for convenience and to smooth out irregularities which would result if one-half foot deviations were connected on a large scale layout.

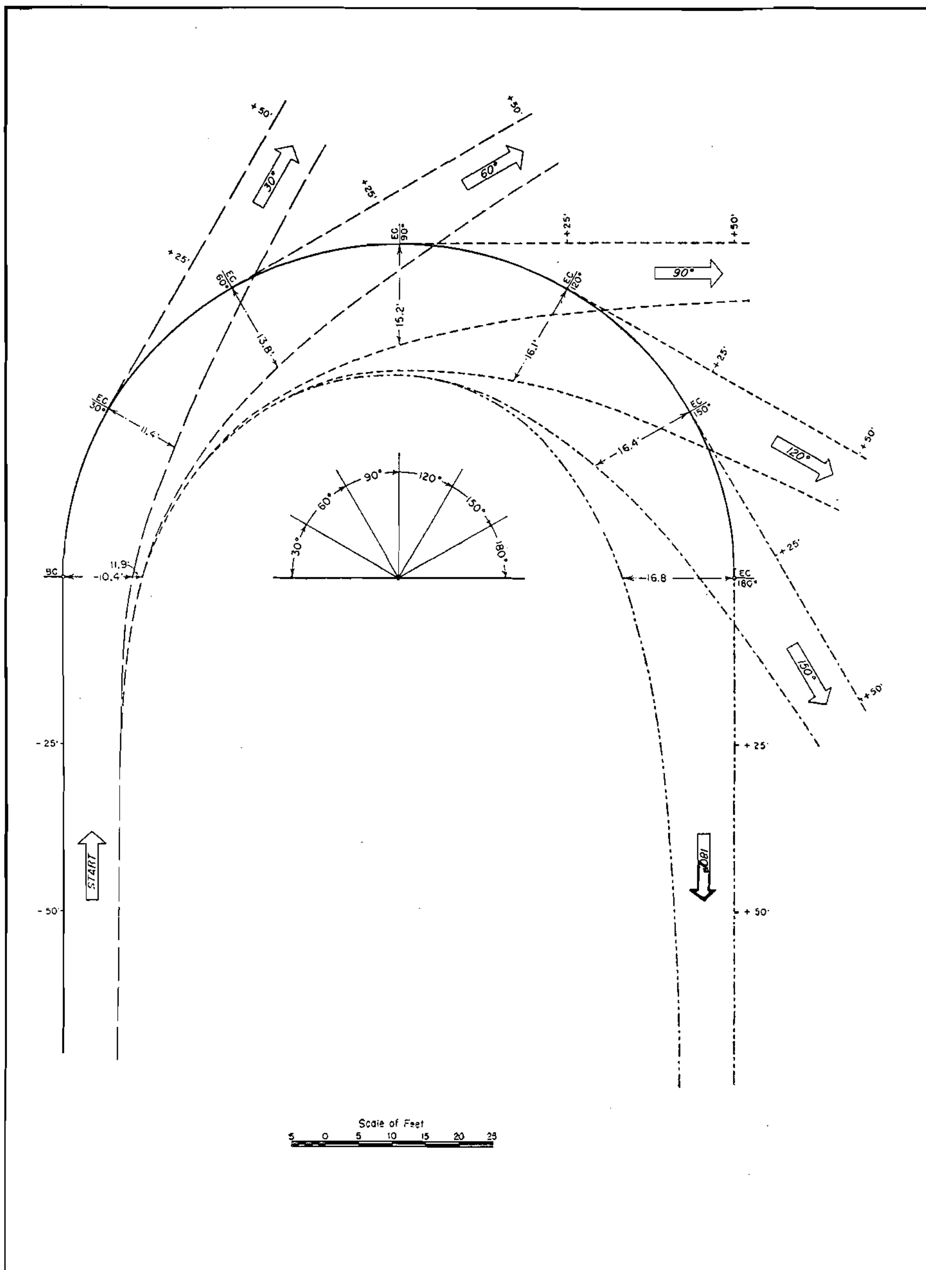
APPLICATION TO DESIGN

As has been explained above, the outside wheel track has to be tied in to the inside wheel track in order to be sure that the resulting lane will have adequate width. The curves made by the two wheels will not necessarily be concentric.

For practical application in most cases, it will be feasible to lay a circular curve which represents the outside of the lane. The problem then becomes to lay a geometric curve of some shape which will provide adequate width within this outside circular curve, and at the same time will not create a large area of unusable pavement.

For the convenience of designers, inside lane edges which correspond to certain outside edge radii, namely 50, 60, 67, 75, 100, 150, and 200 feet, have been determined by a process of trial and error, and are listed in *Plate 4*. The curve data in this table will closely approximate the lanes required for the radii specified, and may be used if these radii will fit topographic or other physical controls.[5]

The data given in *Plate 4* may also be used to test intersections which include islands or other obstructions, by laying



Semitrailer Wheel Tracks, 50-ft. Outside Radius   Plate 5

[3] The absolute minimum turn that can be made to the right has a smaller radius than the minimum turn which can be made to the left. However, if a right turn is made at a radius equal to the minimum left turn radius, the track widths of both will be equal.

[4] Table 3-A is interpolated from the other tables for the convenience of designers who desire to use a 67-foot radius for outside lane edge.

[5] A three-center compound curve for an inside pavement edge may be regarded as a circular curve at a widened distance from the outside edge, or centerline, with circular transitions at each end from the non-widened approaches to the widened center curve. This concept is not new. It is found, as an example, in the California Division of Highways "Manual of Instructions for Surveys and Plans" (1931) (p. 108).

imaginary lanes equal to those in the table.

Should the outside radii given in *Plate 4* not prove adaptable to the particular problem at hand, as will often be the case when designing complex interchanges or any other junctions involving structures, recourse may be had to the track width tables *(Tables 2 to 6 inclusive)*.

In using either table it is important to keep in mind:

(1) *The outside* (i.e., the side farthest from the center of the curve) *must be tied in with the inside edge*. Merely laying out the inside lane edge without a tied-in outside edge is not sufficient to insure a passable lane.

TABLE 1

MINIMUM RADIUS TURNS

Vehicle type	Direction of turn	Radius, feet: Outside front wheel track	Radius, feet: Inner rear wheel track	Track width, feet
Truck—2 axle	Right	33.2	22.0	11.2
	Left	39.8	29.6	10.2
Truck—3 axle	Right	43.0	30.7	12.3
	Left	*45.0	33.0	12.0
Bus—2 axle	Right	42.8	28.9	13.9
	Left	41.8	28.0	13.8
Semitrailer 3-S2	Right	33.6	0.0	**33.6
	Left	43.4	20.6	22.8
Full trailer 3-3	Right	43.0	26.6	16.4
	Left	*45.0	29.0	16.0
Train 2-S2-2	Right	31.1	†	†
	Left	34.0	15.4	18.6

* Controlling Radius
** Maximum track width
† Undetermined; continuous spiral

TABLE 2

TRACTOR TRUCK-SEMITRAILER TRACK WIDTHS, 50-FOOT OUTSIDE RADIUS

Width in feet at various stations [1]

Tangent deflection Δ	Interior angle	BC −50	BC −25	BC	Central angle ahead of BC 15°	30°	45°	60°	75°	90°	105°	120°	135° or more	Back of EC 30°	Back of EC 15°	EC	EC +25	EC +50
30°	150°	8.0	8.5	10.4	11.8											11.4	9.1	8.5
45°	135°	8.0	8.6	11.8	13.5										14.0	12.9	9.7	8.5
60°	120°	8.0	8.6	11.9	14.1	15.3									15.3	13.8	10.0	8.5
75°	105°	8.0	8.6	11.9	14.5	16.0								16.8	16.4	14.7	10.4	8.6
90°	90°	8.0	8.6	11.9	14.5	16.3	17.2							17.8	17.2	15.2	10.6	8.8
105°	75°	8.0	8.6	11.9	14.5	16.3	17.6	18.3						18.6	17.8	15.8	10.8	8.8
120°	60°	8.0	8.6	11.9	14.5	16.3	17.6	18.5	18.8					19.0	18.2	16.1	11.0	8.8
135°	45°	8.0	8.6	11.9	14.5	16.3	17.6	18.5	19.2	19.5				19.5	18.7	16.4	11.0	8.9
150°	30°	8.0	8.6	11.9	14.5	16.3	17.6	18.5	19.2	19.6	19.7			19.6	18.7	16.4	11.1	8.9
165°	15°	8.0	8.6	11.9	14.5	16.3	17.6	18.5	19.2	19.6	20.0	20.1		19.9	19.0	16.6	11.1	9.0
180°		8.0	8.6	11.9	14.5	16.3	17.6	18.5	19.2	19.6	20.0	20.2	20.2	20.1	19.0	16.8	11.1	9.0

[1] Net tire marks, measured along radial lines of outside circular curve.

TABLE 3

TRACTOR TRUCK-SEMITRAILER TRACK WIDTHS, 56-FOOT OUTSIDE RADIUS

Width in feet at various stations [1]

Tangent deflection Δ	Interior angle	BC −50	BC −25	BC	Central angle ahead of BC 15°	30°	45°	60°	75°	90°	105°	120°	135° or more	Back of EC 30°	Back of EC 15°	EC	EC +25	EC +50
30°	150°	8.0	8.1	10.3	11.8											11.1	9.0	8.4
45°	135°	8.0	8.1	11.3	13.4										14.0	12.7	9.6	8.4
60°	120°	8.0	8.1	11.4	13.6	14.7									15.0	13.5	10.0	8.5
75°	105°	8.0	8.1	11.4	13.7	15.3								16.0	15.8	14.2	10.1	8.6
90°	90°	8.0	8.1	11.4	13.7	15.3	16.3							16.8	16.4	14.5	10.2	8.6
105°	75°	8.0	8.1	11.4	13.7	15.3	16.5	17.2						17.5	16.9	15.0	10.4	8.7
120°	60°	8.0	8.1	11.4	13.7	15.3	16.5	17.2	17.7					17.9	17.1	15.0	10.5	8.7
135°	45°	8.0	8.1	11.4	13.7	15.3	16.5	17.2	17.8	18.3				18.2	17.5	15.4	10.6	8.8
150°	30°	8.0	8.1	11.4	13.7	15.3	16.5	17.2	17.8	18.3	18.4			18.4	17.5	15.5	10.6	8.8
165°	15°	8.0	8.1	11.4	13.7	15.3	16.5	17.2	17.8	18.3	18.5	18.5		18.4	17.6	15.5	10.6	8.8
180°		8.0	8.1	11.4	13.7	15.3	16.5	17.2	17.8	18.3	18.5	18.5	18.5	18.4	17.6	15.5	10.6	8.8

[1] Net tire marks, measured along radial lines of outside circular curve.

TABLE 3-A

TRACTOR TRUCK-SEMITRAILER TRACK WIDTHS, 65-FOOT OUTSIDE RADIUS

Tangent deflection Δ	Interior angle	Width in feet at various stations [1] BC —50	BC —25	BC	Central angle ahead of BC 15°	30°	45°	60°	75°	90°	105°	120°	135°	150° or more	Back of EC 15°	EC	EC +25	EC +50
30°	150°	8.0	8.2	10.1	11.6	------	------	------	------	------	------	------	------	------	------	11.0	9.0	8.2
45°	135°	8.0	8.2	10.6	12.4	------	------	------	------	------	------	------	------	------	13.0	11.9	9.4	8.3
60°	120°	8.0	8.2	10.6	12.7	14.0	------	------	------	------	------	------	------	------	14.0	12.6	9.6	8.3
75°	105°	8.0	8.2	10.6	12.7	14.2	15.0	------	------	------	------	------	------	------	14.7	12.9	9.7	8.4
90°	90°	8.0	8.2	10.6	12.7	14.2	15.1	15.5	------	------	------	------	------	------	15.1	13.1	9.8	8.4
105°	75°	8.0	8.2	10.6	12.7	14.2	15.1	15.6	15.8	------	------	------	------	------	15.4	13.4	9.9	8.5
120°	60°	8.0	8.2	10.6	12.7	14.2	15.1	15.6	16.0	16.3	------	------	------	------	15.5	13.5	10.0	8.5
135°	45°	8.0	8.2	10.6	12.7	14.2	15.1	15.6	16.0	16.4	16.4	------	------	------	15.6	13.6	10.1	8.6
150°	30°	8.0	8.2	10.6	12.7	14.2	15.1	15.6	16.0	16.4	16.4	16.4	------	------	15.6	13.6	10.1	8.6
165°	15°	8.0	8.2	10.6	12.7	14.2	15.1	15.6	16.0	16.4	16.4	16.4	16.4	------	15.6	13.6	10.1	8.6
180°	------	8.0	8.2	10.6	12.7	14.2	15.1	15.6	16.0	16.4	16.4	16.4	16.4	16.4	15.6	13.6	10.1	8.6

[1] Net tire marks, measured along radial lines of outside circular curve.

TABLE 4

TRACTOR TRUCK-SEMITRAILER TRACK WIDTHS, 75-FOOT OUTSIDE RADIUS

Tangent deflection Δ	Interior angle	Width in feet at various stations [1] BC —50	BC —25	BC	Central angle ahead of BC 15°	30°	45°	60°	75°	90°	105°	120°	135°	150° or more	Back of EC 15°	EC	EC +25	EC +50
30°	150°	8.0	8.2	9.8	11.0	------	------	------	------	------	------	------	------	------	------	10.5	8.8	8.2
45°	135°	8.0	8.2	10.0	11.8	------	------	------	------	------	------	------	------	------	12.3	11.1	9.0	8.2
60°	120°	8.0	8.2	10.0	12.0	13.3	------	------	------	------	------	------	------	------	13.2	11.6	9.3	8.2
75°	105°	8.0	8.2	10.0	12.0	13.4	14.1	------	------	------	------	------	------	------	13.8	11.8	9.3	8.2
90°	90°	8.0	8.2	10.0	12.0	13.4	14.1	14.5	------	------	------	------	------	------	14.1	12.0	9.4	8.3
105°	75°	8.0	8.2	10.0	12.0	13.4	14.1	14.5	14.7	------	------	------	------	------	14.2	12.1	9.4	8.3
120°	60°	8.0	8.2	10.0	12.0	13.4	14.1	14.5	14.7	14.9	------	------	------	------	14.3	12.1	9.4	8.3
135°	45°	8.0	8.2	10.0	12.0	13.4	14.1	14.5	14.7	14.9	14.9	------	------	------	14.3	12.1	9.4	8.3
150°	30°	8.0	8.2	10.0	12.0	13.4	14.1	14.5	14.7	14.9	14.9	14.9	------	------	14.3	12.1	9.4	8.3
165°	15°	8.0	8.2	10.0	12.0	13.4	14.1	14.5	14.7	14.9	14.9	14.9	14.9	------	14.3	12.1	9.4	8.3
180°	------	8.0	8.2	10.0	12.0	13.4	14.1	14.5	14.7	14.9	14.9	14.9	14.9	14.9	14.3	12.1	9.4	8.3

[1] Net tire marks, measured along radial lines of outside circular curve.

(2) While it is possible for truck-trailer combinations to turn within a 50-foot radius, it is very difficult, and in tests it was found necessary for the truck to make these turns at speeds of approximately five m.p.h. It is recommended that the minimum outside radius be at least 60 feet, which will allow for a reasonable approach speed.

HOW TO USE THE TABLES

(1) Plate 4 (3-Center Curves)

Normally the given data will include the pavement edges of the approach and leaving tangents, and the angle at which they intersect, or Δ. The designer may then lay lines parallel to these pavement edges, which will represent the opposite lane edges. In *Plate 4,* D-B is the pavement edge of the approach tangent, and E-F is the pavement edge of the leaving tangent. Lines D_o-BC_o and EC_o-F_o are laid at lane widths W_1 and W_2 from the pavement edges. W_1 and W_2 will normally be 12 feet, but may be 10 to 14 feet.

TABLE 5

TRACTOR TRUCK-SEMITRAILER TRACK WIDTHS, 100-FOOT OUTSIDE RADIUS

Tangent deflection Δ	Interior angle	Width in feet at various stations [1]																
		BC —50	BC —25	BC	Central angle ahead of BC										Back of EC	EC	EC +25	EC +50
					15°	30°	45°	60°	75°	90°	105°	120°	135°	150° or more	15°			
30°	150°	8.0	8.0	9.4	10.7	------	------	------	------	------	------	------	------	------	------	10.1	8.8	8.2
45°	135°	8.0	8.0	9.4	11.3	------	------	------	------	------	------	------	------	------	11.7	10.6	8.9	8.3
60°	120°	8.0	8.0	9.4	11.3	12.2	------	------	------	------	------	------	------	------	12.3	10.8	9.0	8.4
75°	105°	8.0	8.0	9.4	11.3	12.2	12.8	------	------	------	------	------	------	------	12.6	10.9	9.0	8.4
90°	90°	8.0	8.0	9.4	11.3	12.2	12.8	13.0	------	------	------	------	------	------	12.7	10.9	9.0	8.4
105°	75°	8.0	8.0	9.4	11.3	12.2	12.8	13.0	13.0	------	------	------	------	------	12.7	10.9	9.0	8.4
120°	60°	8.0	8.0	9.4	11.3	12.2	12.8	13.0	13.0	13.0	------	------	------	------	12.7	10.9	9.0	8.4
135°	45°	8.0	8.0	9.4	11.3	12.2	12.8	13.0	13.0	13.0	13.0	------	------	------	12.7	10.9	9.0	8.4
150°	30°	8.0	8.0	9.4	11.3	12.2	12.8	13.0	13.0	13.0	13.0	13.0	------	------	12.7	10.9	9.0	8.4
165°	15°	8.0	8.0	9.4	11.3	12.2	12.8	13.0	13.0	13.0	13.0	13.0	13.0	------	12.7	10.9	9.0	8.4
180°	------------	8.0	8.0	9.4	11.3	12.2	12.8	13.0	13.0	13.0	13.0	13.0	13.0	13.0	12.7	10.9	9.0	8.4

[1] Net tire marks, measured along radial lines of outside circular curve.

TABLE 6

TRACTOR TRUCK-SEMITRAILER TRACK WIDTHS, 200-FOOT OUTSIDE RADIUS

Tangent deflection Δ	Interior angle	Width in feet at various stations [1]																
		BC —50	BC —25	BC	Central angle ahead of BC										Back of EC	EC	EC +25	EC +50
					15°	30°	45°	60°	75°	90°	105°	120°	135°	150° or more	15°			
30°	150°	8.0	8.0	8.4	9.6	------	------	------	------	------	------	------	------	------	------	9.0	8.3	8.2
45°	135°	8.0	8.0	8.4	9.6	------	------	------	------	------	------	------	------	------	9.9	9.1	8.4	8.2
60°	120°	8.0	8.0	8.4	9.6	9.9	------	------	------	------	------	------	------	------	9.9	9.1	8.4	8.2
75°	105°	8.0	8.0	8.4	9.6	9.9	9.9	------	------	------	------	------	------	------	9.9	9.1	8.4	8.2
90°	90°	8.0	8.0	8.4	9.6	9.9	9.9	9.9	------	------	------	------	------	------	9.9	9.1	8.4	8.2
105°	75°	8.0	8.0	8.4	9.6	9.9	9.9	9.9	9.9	------	------	------	------	------	9.9	9.1	8.4	8.2
120°	60°	8.0	8.0	8.4	9.6	9.9	9.9	9.9	9.9	9.9	------	------	------	------	9.9	9.1	8.4	8.2
135°	45°	8.0	8.0	8.4	9.6	9.9	9.9	9.9	9.9	9.9	9.9	------	------	------	9.9	9.1	8.4	8.2
150°	30°	8.0	8.0	8.4	9.6	9.9	9.9	9.9	9.9	9.9	9.9	9.9	------	------	9.9	9.1	8.4	8.2
165°	15°	8.0	8.0	8.4	9.6	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	------	9.9	9.1	8.4	8.2
180°	------------	8.0	8.0	8.4	9.6	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.1	8.4	8.2

[1] Net tire marks, measured along radial lines of outside circular curve.

A circular curve BC_o-EC_o may be selected which will fit physical controls of the particular plan being designed. The center of the middle curve, C_2, is established at distances e and s from BC_o, and the middle curve is described. Curves C_1 and C_3 are laid tangent to the middle curve and to whatever lines are desired; normally pavement- or lane-edges parallel to the approach and leaving tangents.

Holding the distances e and s constant through a wide range of deltas, as this table does, will cause *the offset from the leaving tangent to vary as the* Δ *changes.* Trouble which has been experienced with symmetrical compound curves has been largely due to trying to fix the location of the middle curve at a constant distance from both tangents regardless of Δ.

In solving the equations for Δ_3 and the semitangents, care must be taken to keep the algebraic signs of the various terms correct. For example, sometimes $(e - R_o)$ will be positive and sometimes negative. Furthermore, with Δ of between 90 degrees and 270 degrees, cos Δ will be negative.

(2) Tables 2 to 6 (Track Widths)

For testing previous designs where the radius of the outside edge has already been determined, or for new design where none of the radii given in *Table 7 (Plate 4)* will fit physical controls, and in designing ramps on structures, the following procedure may be used:

Step 1. Draw lines which represent the path of the outside wheels of the truck in the through road and connecting road. ("Outside" means the side farthest from the center of the curve which is being laid out.)

Step 2. Fit a circular curve tangent to the lines produced in Step 1. The radius of this curve may be chosen to fit physical controls, but must be at least 48 feet, which would allow for a 50-foot radius lane edge.

Step 3. Beginning 50 feet before the BC and ending 50 feet beyond the EC, lay off points at distances from the circular curve and approach tangents which are given in *Tables 2 to 6.* For radii and central angles not given in the tables, these distances may be interpolated.

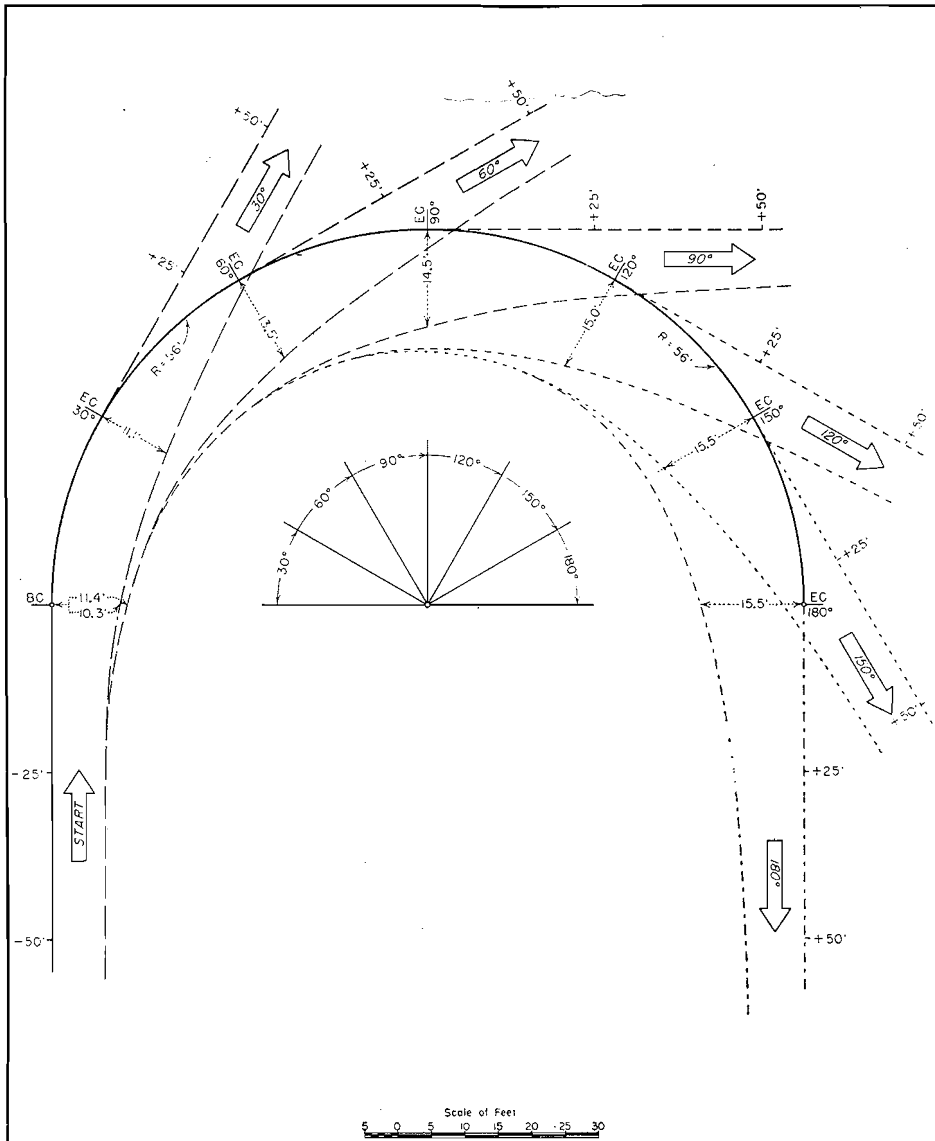
Step 4. (a) Lay a compound curve to fit the plotted points, *being sure to allow leeway*, since the widths given in the tables are neat tire tracks and do not allow for drivers' judgment.

(b) Lay a circular curve around the outside track which has been described in Step 2, allowing similar leeway.

The curves laid in Step 4 may be used for pavement edge, curb lines or island limits, as the case may be.

It is recommended that nothing less than a 60-foot outside radius be used if it is anticipated that the vehicles will be moving at even a nominal rate of speed when they enter the curve.

Templates may be prepared for use as overlays to test certain designs for clearances. *Plate 13* illustrates a possible layout of such templates. It has a scale of 1″ = 50′; however, the transparencies can be made to any desired scale. The radii of *Plate 13* were chosen to allow a two-foot clearance between the front wheel and curbs of 50, 60, 67, and 75 feet in radius. The templates can be produced by photographing *Plate 13* (or a tracing of it) and then transferring the image to sensitized acetate film.



Semitrailer Wheel Tracks. 56-ft. Outside Radius **Plate 6**

CONCLUSIONS

1. In making short-radius turns, a tractor-truck-semitrailer combination having legal dimensions describes a track whose width exceeds the track of any other legal vehicle in California.

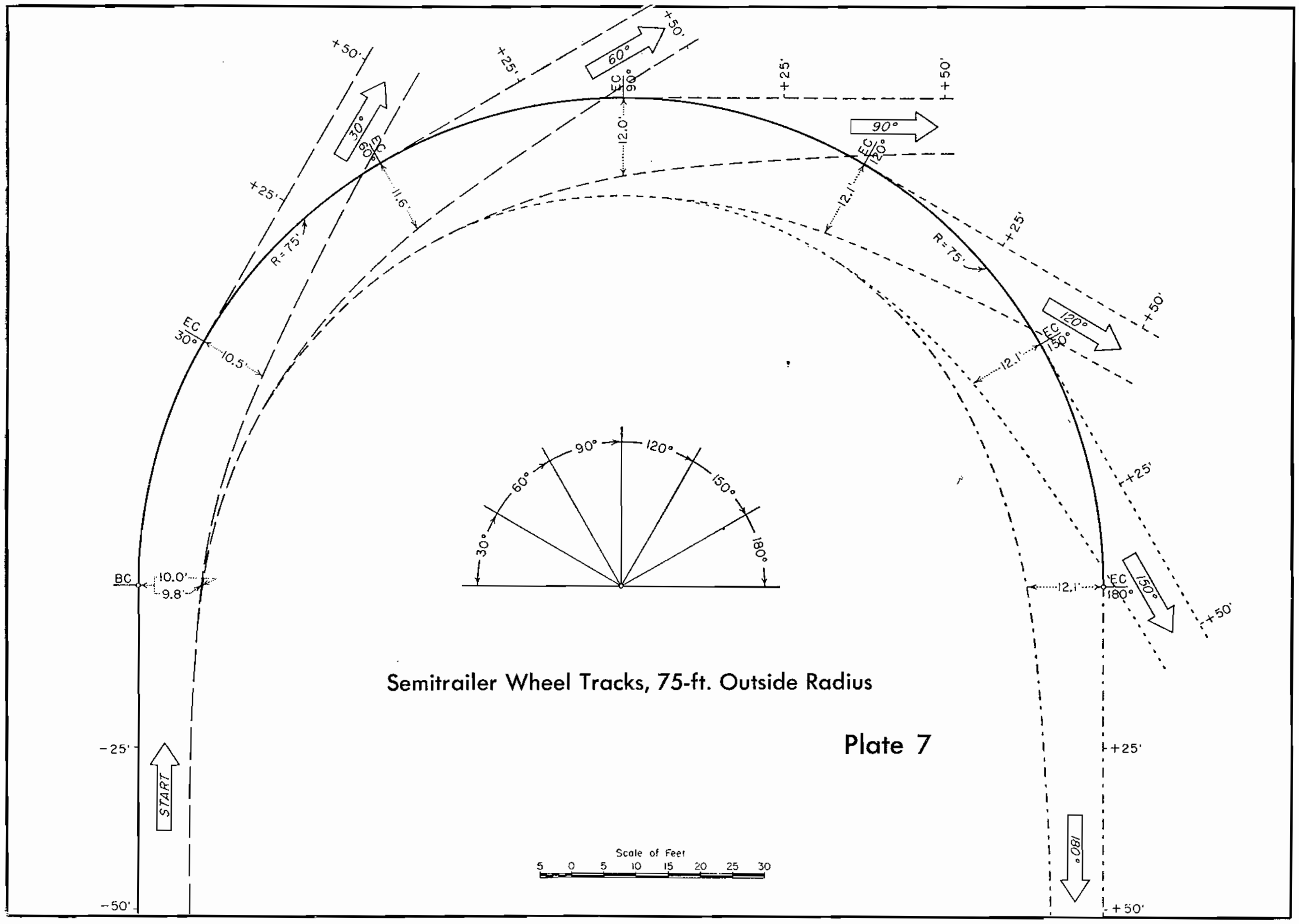
2. The outside track of a vehicle or combination making a short-radius turn at slow speed is a circular curve throughout nearly all of its length and for practical purposes may be considered to be a circular curve connecting the approach and leaving tangents.

3. The sharpest circular curve which can be described by the outside (front) wheel of one legal vehicle is 45 feet. The practical minimum outside radius for turning lanes is 50 feet.

4. All vehicles and combinations, particularly the 3-S2 combination, when making a circular track with the front wheel, produce a spiral track at the rear wheel.

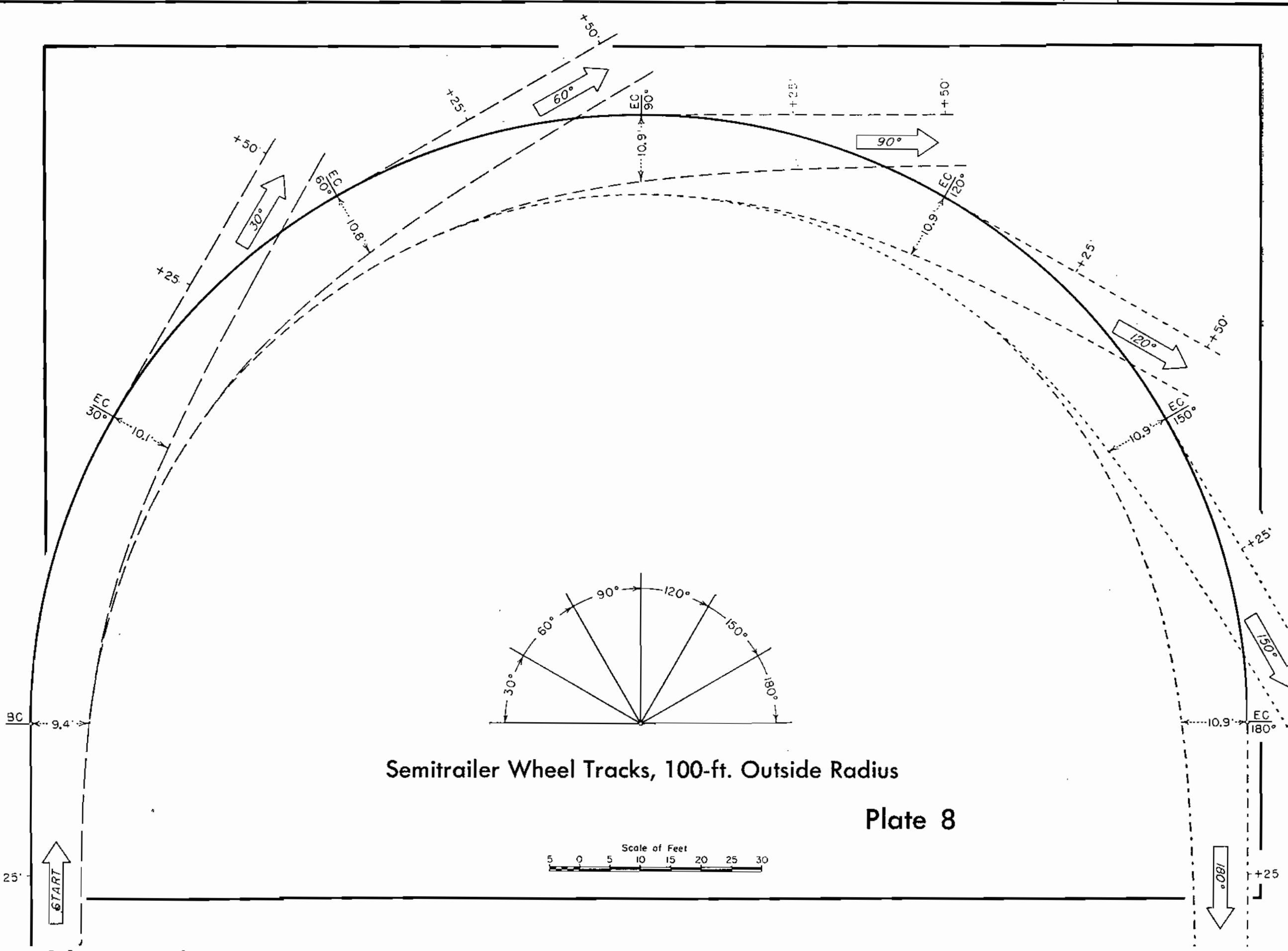
5. The spiral tracks of the rear wheel for left and right turns of equal outside radii are congruent.

6. Track widths for various radii and various central angles are given in Tables 2 to 6. Compound curves which will fit these tracks with recommended leeways are given in *Table 7, Plate 4.* The widths vary from a maximum of 20.2 feet for 50-foot radius curves with 180 degrees of central angle, down to 9.9 feet for 200-foot radius curves with central angles of 45 degrees or more. Standard curve widening for curves of radius greater than 200 feet will amply provide for large vehicles and combinations.



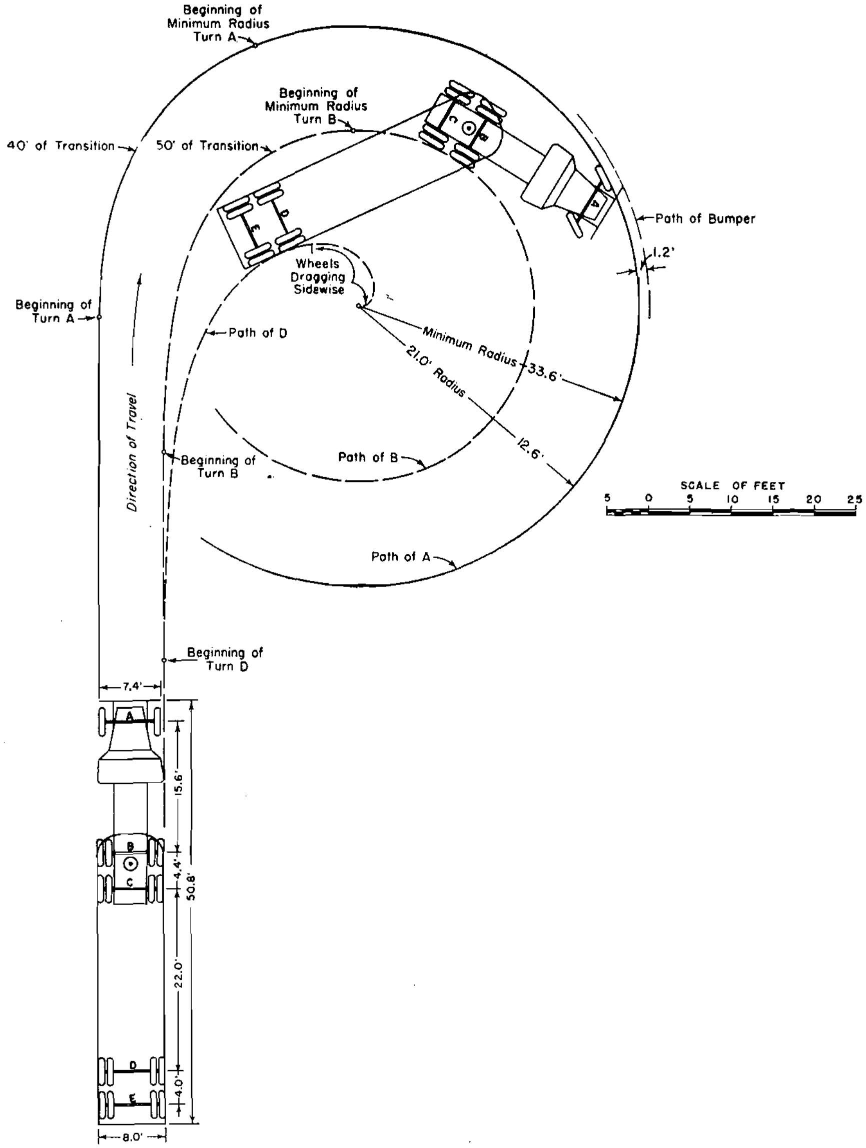
Semitrailer Wheel Tracks, 75-ft. Outside Radius

Plate 7



Semitrailer Wheel Tracks, 100-ft. Outside Radius

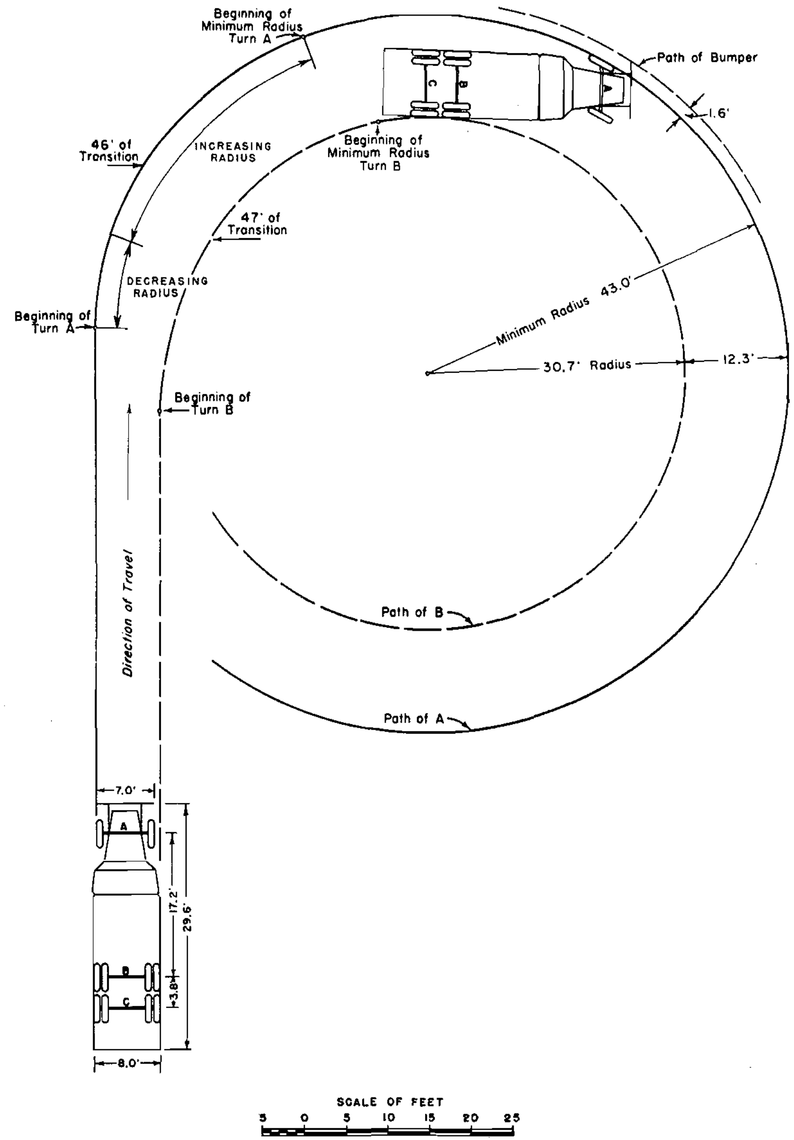
Plate 8



Minimum Radius Right Turn,

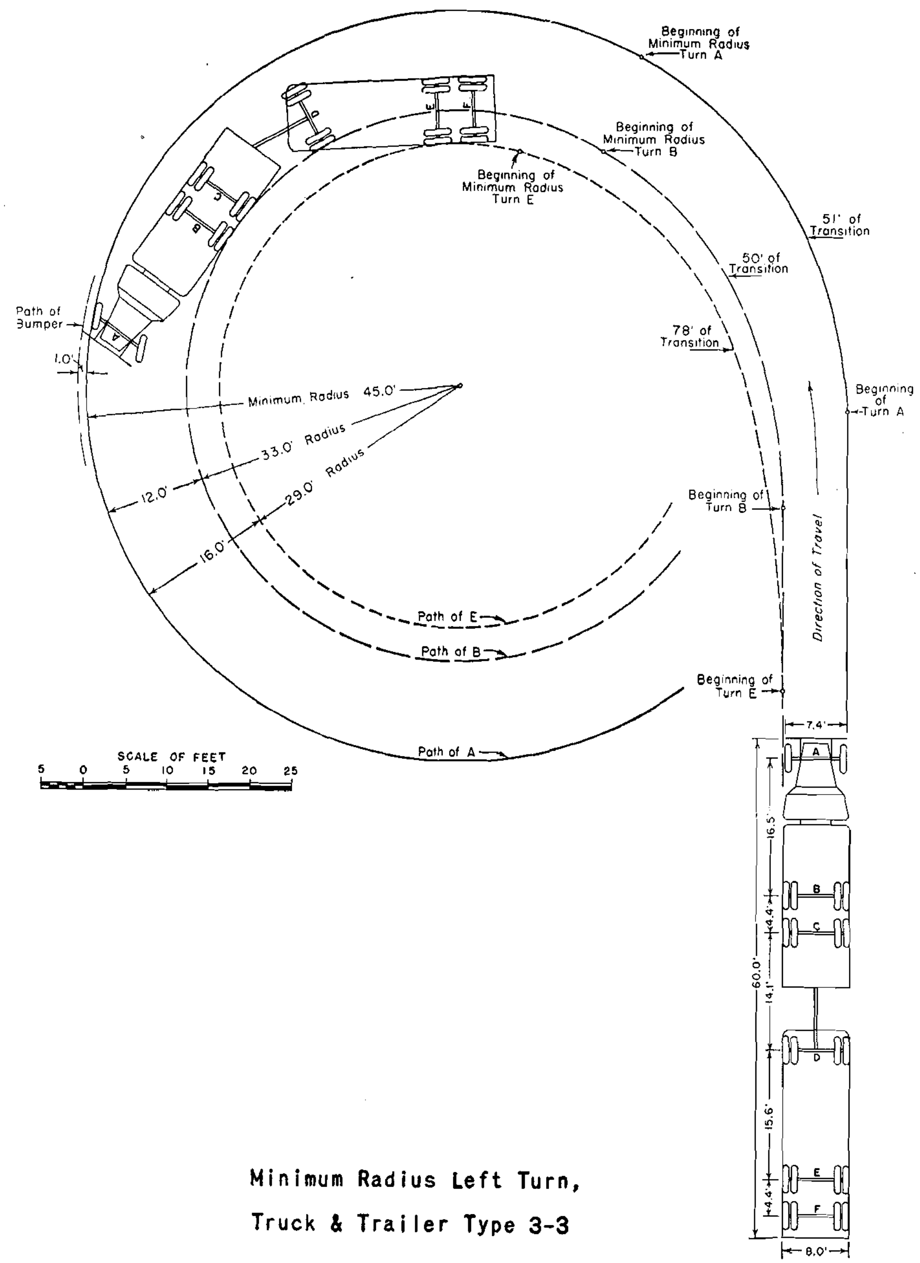
Tractor-truck & Semitrailer Type 3-S2

Plate 10



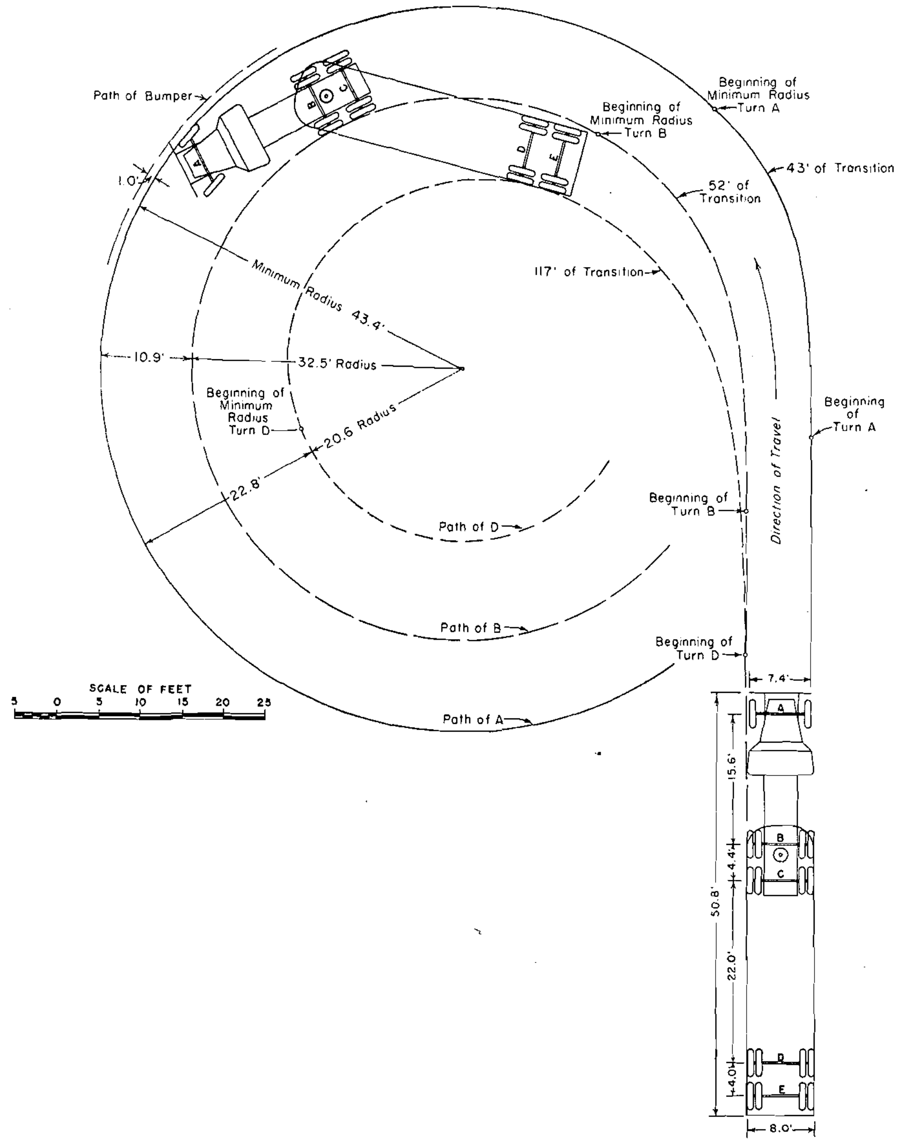
Minimum Radius Right Turn, 3-axle Truck

Plate 9



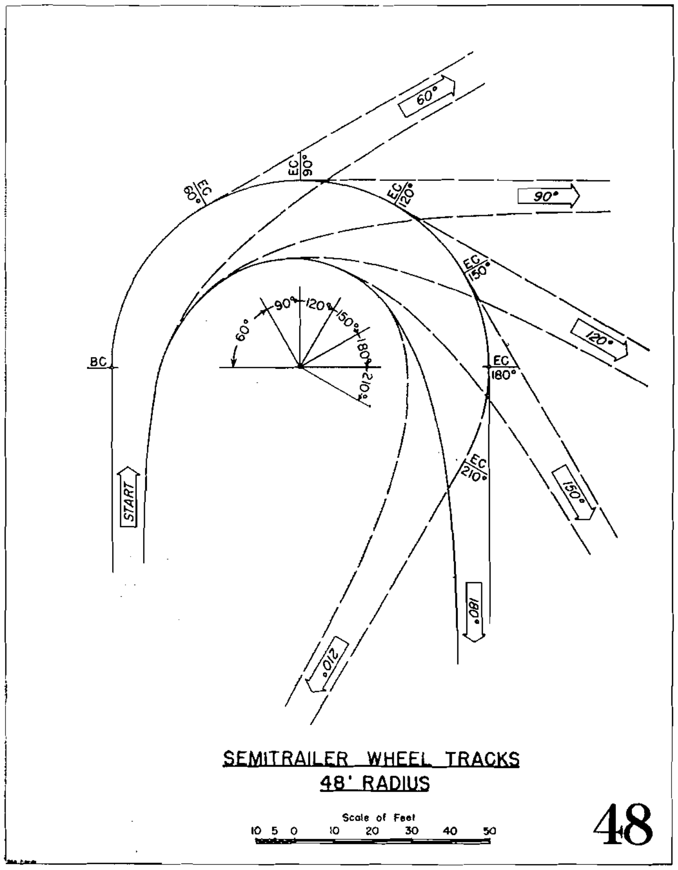
Minimum Radius Left Turn,
Truck & Trailer Type 3-3

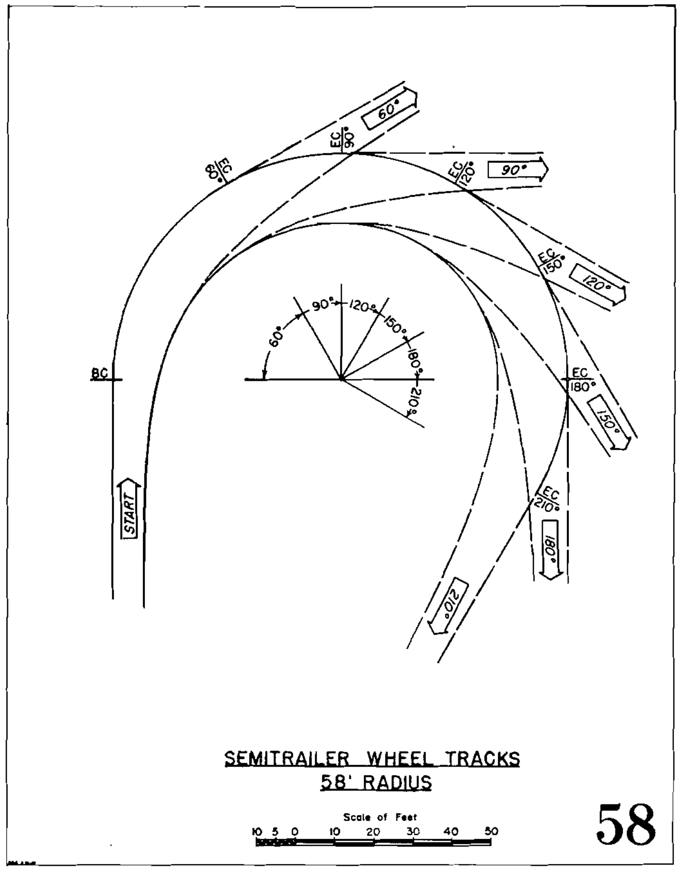
Plate 12



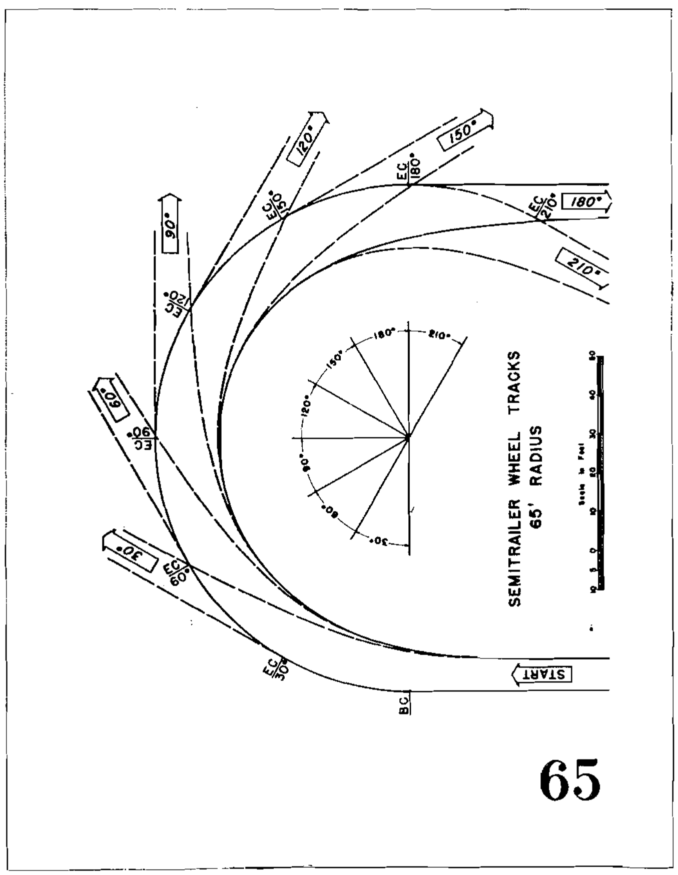
Minimum Radius Left Turn,
Tractor-truck & Semitrailer Type 3-S2

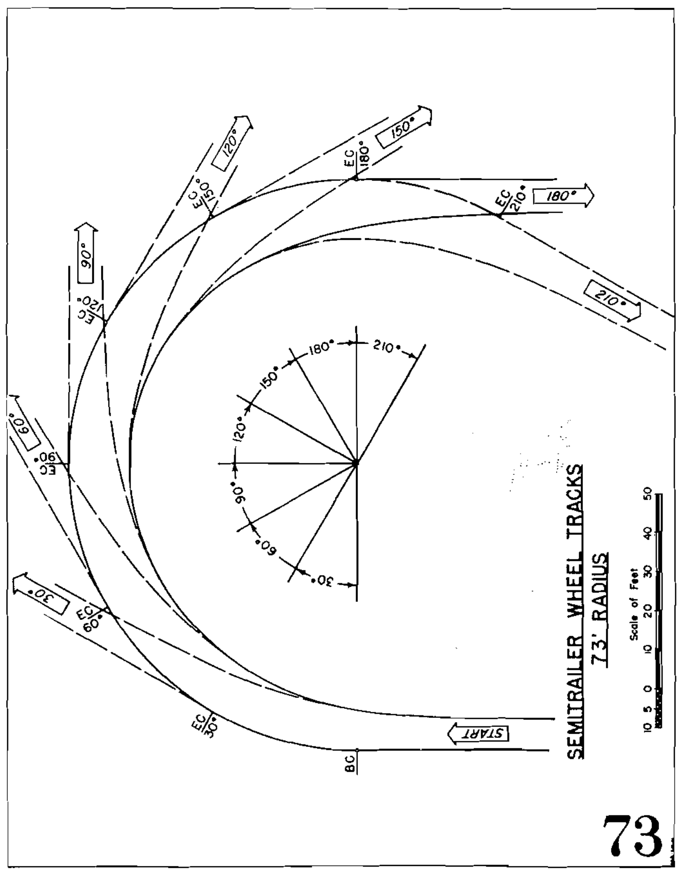
Plate 11





50 SCALE





Templates of Semitrailer Wheel Tracks

Plate 13

APPENDIX

TRACK WIDTHS OF EXTRALEGAL AND UNCONVENTIONAL VEHICLES

The California Vehicle Code limits the over-all length of any single unit to 35 feet, and the length of any coupled combination to 60 feet. There are many reasons besides maximum lane widths for these limitations, but at any rate, one effect of the 35-foot limit is to control the lane width used by semitrailers. The amount of off-tracking is a function of the distance from the swivel connection to the rear axle, and as long as the body length is limited, this distance is limited.

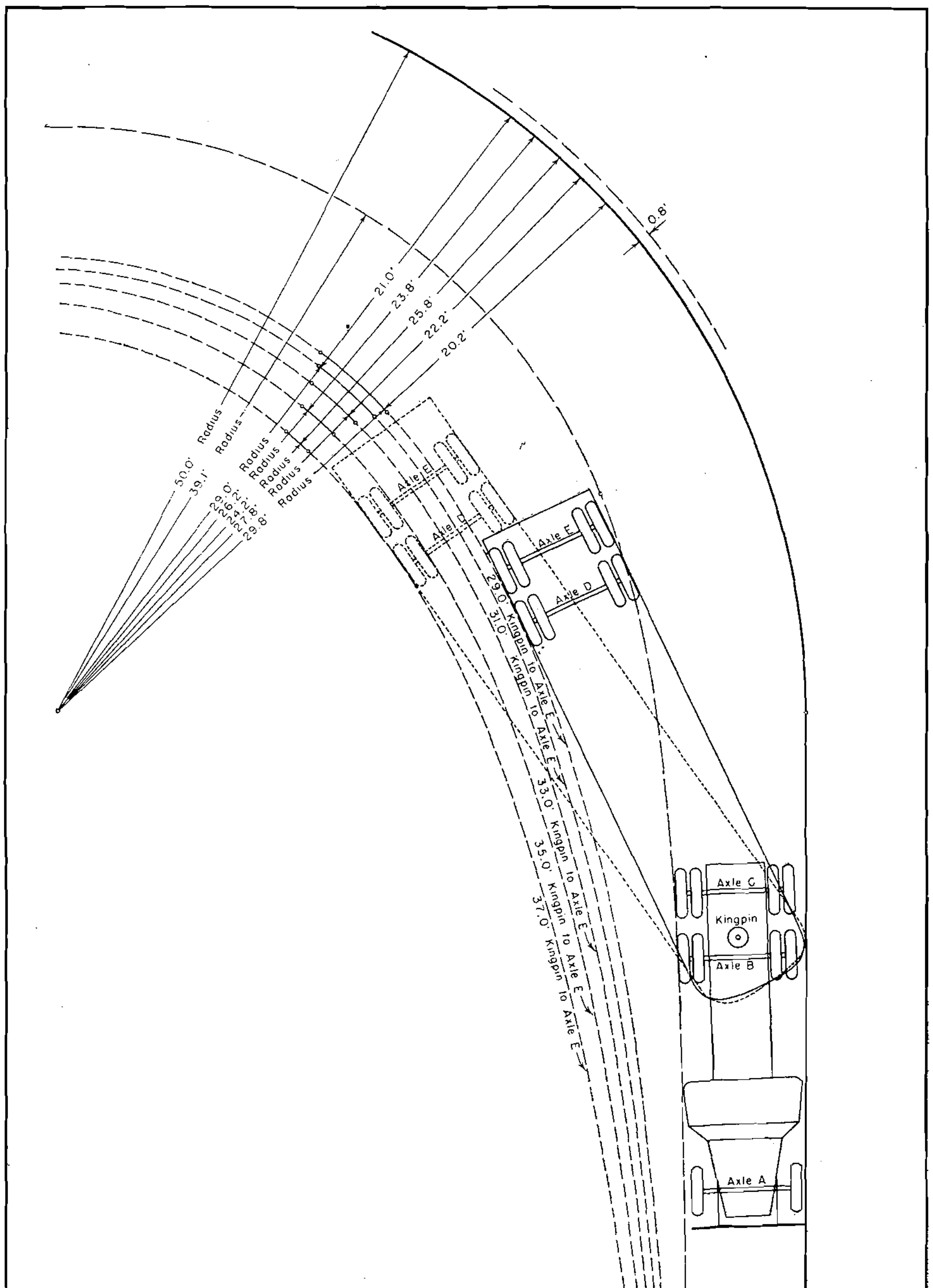
In order to determine what effect the limit on body length *or* wheel base has upon lane width, a semitrailer with conventional 3-axle tractor and 2-axle rear assembly, but with an adjustable length, was tested on the same runs that were made with the van body semitrailer.

It was found that this combination produced a track practically identical to that of the van 3-S2, when the distance from kingpin to rear axle was the same (this distance was 25 feet to the forward rear axle and 29 feet to the rearmost axle).

As the reach pole was lengthened, the track width increased as shown on *Plate 14*. For radii greater than 50 feet, the proportional increase in width was not as great. The approximate relation between additional trailer length and additional track width is shown in *Table 8*, as extracted from *Plate 15*.

TABLE 8

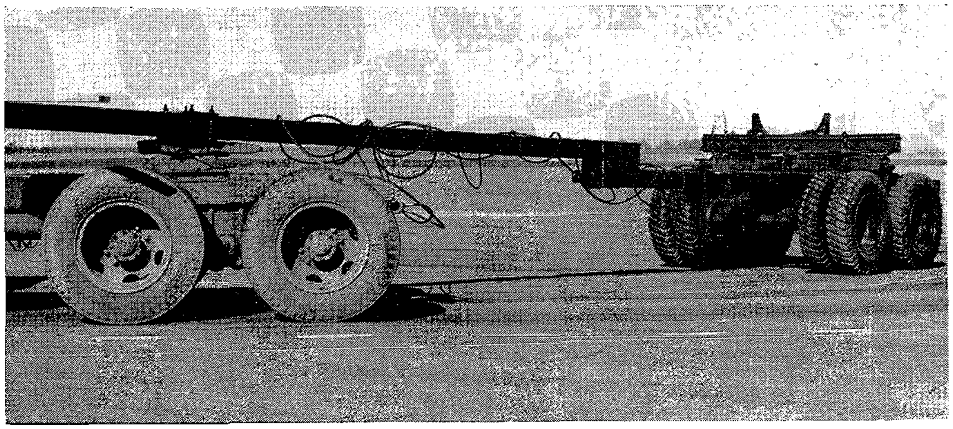
Radius of front wheel track (ft.)	Additional trailer length (ft.)	Additional track width in 180° turns (ft.)
50	2	0.8
	4	2.0
	6	3.6
	8	5.6
75	2	0.8
	4	1.8
	6	2.8
	8	3.8
100	2	0.6
	4	1.2
	6	1.9
	8	2.6
200	2	0.4
	4	0.7
	6	1.1
	8	1.4



Effect of Lengthening Semitrailer — Plate 14

A patented semitrailer named "Monotrailer" was tested on the 53-foot radius turn. As shown in the photograph on the next page, the four rear wheels of this semitrailer are connected to a platform which in itself comprises a sort of full trailer. The van rests on the turntable in the middle of the assembly. The whole assembly assumes an angle with respect to the main van which makes its axis tend to follow the curve of the tractor instead of tending to follow a chord as do the rear axles of a conventional semitrailer.

The comparative tracks of a Monotrailer with a 31-foot reach distance (kingpin to rearmost axle), a semitrailer with a 29-foot reach distance, and a 60-foot truck-trailer are portrayed in *Plate 16*. The track of a conventional semitrailer of the same length is about 4 feet wider.



Extensible semitrailer used in making tests on extra length vehicles

MAXIMUM TRACK WIDTHS ATTAINED IN 180° TURNS OF VARIOUS RADII BY SEMITRAILERS OF SEVERAL LENGTHS

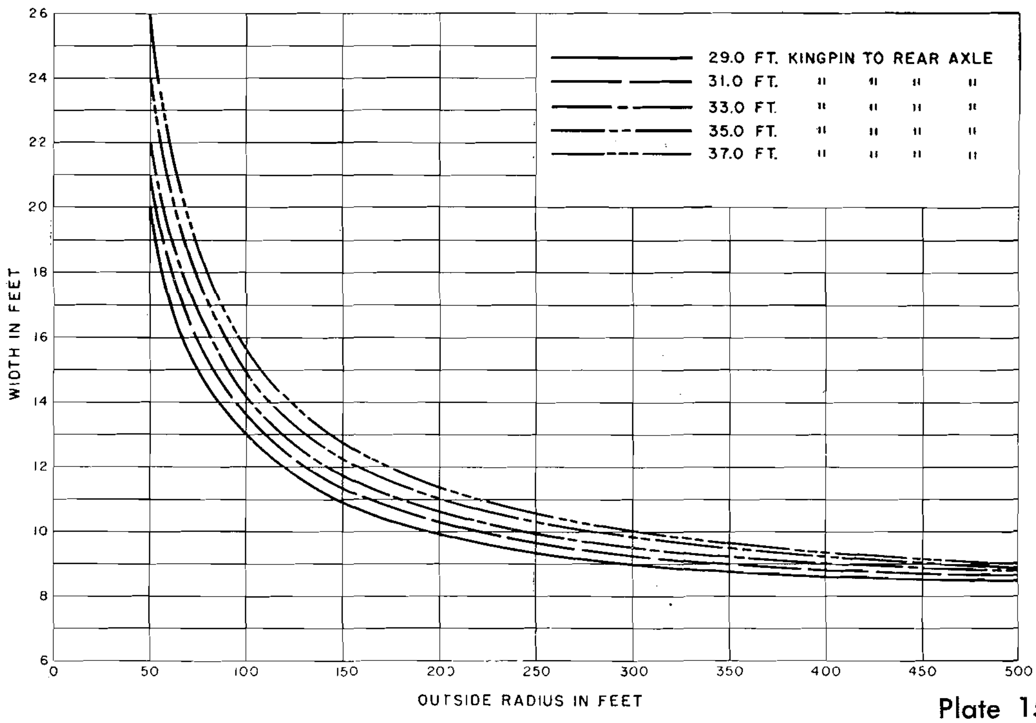
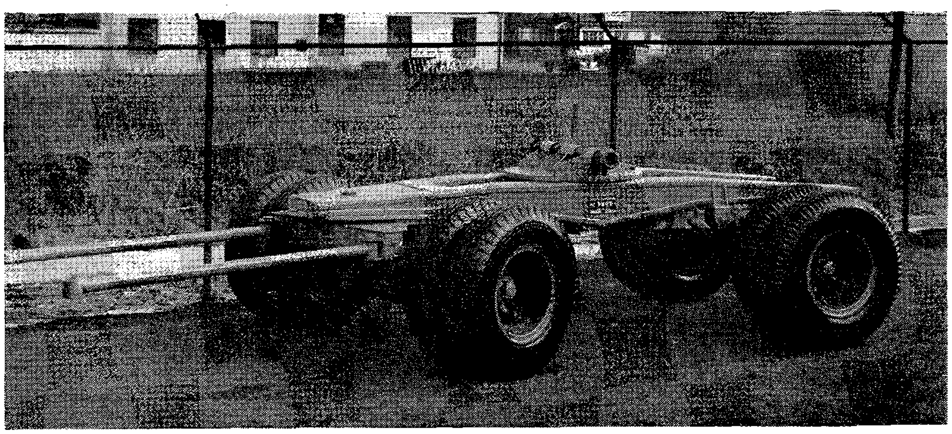


Plate 15



Rear axle assembly of Monotrailer. The tongues form a pantograph, when attached to the main van, which holds the front wheels parallel to the van; while the whole assembly swivels about the turntable on which the van rests

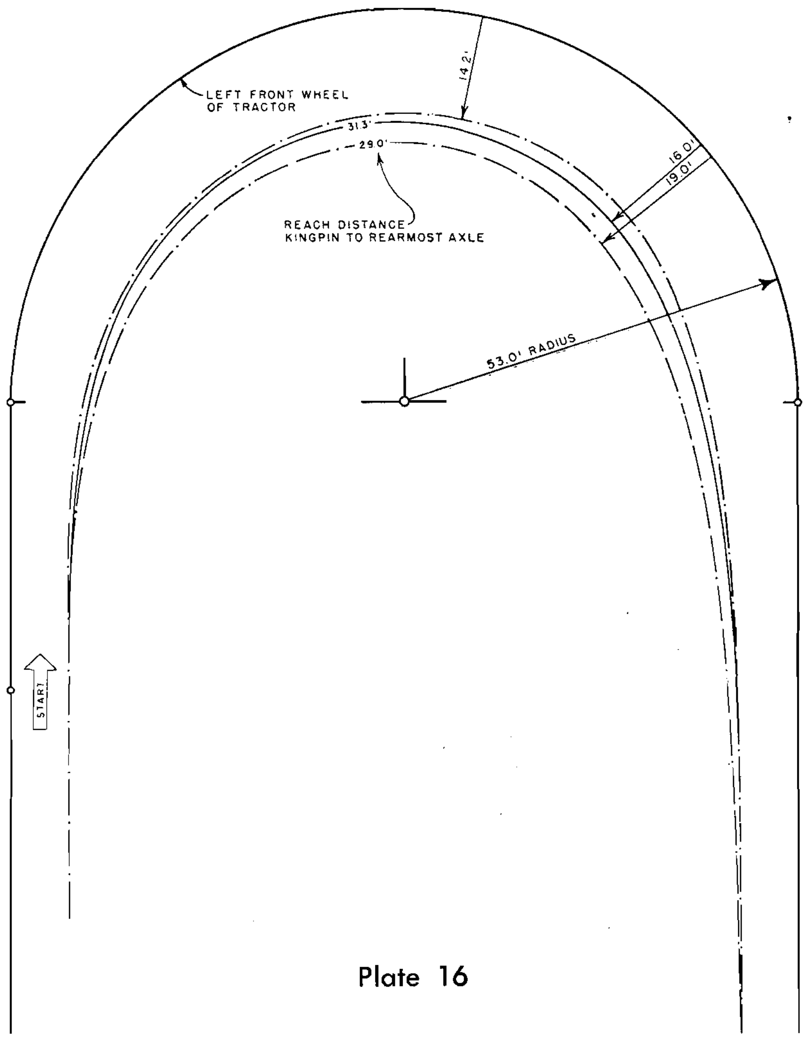


Plate 16

LEGEND

RT. REAR WHEEL OF FULL TRAILER (3-3) 20 FT WHEELBASE.
RT. REAR WHEEL OF ARTICULATED SEMITRAILER 3-AS2, 35 FT. BODY.
RT. REAR WHEEL OF CONVENTIONAL SEMITRAILER 3-S2, 35 FT. BODY.

Comparison of Articulated and Conventional Semitrailers

Acknowledgments

The work was done under the supervision of the Traffic Engineer of the California Division of Highways, who wishes to acknowledge the cooperation and assistance of:

The Western Highway Institute, a cooperative organization of truck and trailer manufacturers and operating lines.

The Fruehauf Trailer Company, for the accompanying photographs, and the trailers and semitrailers used in most of the tests.

The Sacramento Freight Lines, which supplied the tractor-truck and driver used in many of the tests.

Pacific Intermountain Express, which supplied the tractor-truck and driver used in other tests.

Riske Trucking Company, which supplied the 3-axle truck and 3-axle trailer.

Burton-White Motors, Inc., which supplied the tractor-truck and driver used for the 2-S2-2 tests.

The Aerobody, Incorporated, which supplied the Monotrailer.

The Pacific Greyhound Company, which supplied the bus and driver.

In Memoriam

EDWARD A. WOLFE

The many friends and associates of Mr. Edward A. Wolfe learned with sorrow of his death on Saturday afternoon, February 4, 1950. Mr. Wolfe had served long and faithfully with the Division of Highways, having been Maintenance Superintendent of the Escondido territory in District XI since the formation of the district in 1933.

Mr. Wolfe was born in Iowa in 1884, was graduated from DeWitt High School, and studied engineering at Iowa State College for three years. His experience in engineering for railroads and highways was long and varied. He was employed for 13 years as an engineer in Arizona and New Mexico with the Santa Fe; he was employed in Peru, South America, by the Cerro Pasco Mining Company; in Mexico by the Jalapa Railroad and Power Company; later returned to Arizona, pouring the first concrete bridge foundation for the Santa Fe; then was employed by the Northwestern Pacific south of Eureka, and spent two years in Oregon building and operating a logging railroad.

Mr. Wolfe was a veteran of World War I, having served in France with the famous 23d Engineers. Following his wartime service he returned to Arizona as a construction engineer, and went from there to Los Angeles and to San Diego, where he was employed as a contractor's superintendent.

Then, in 1929, came the beginning of Mr. Wolfe's long and valuable service with the Division of Highways. His early employment with the State was in Districts VIII, VII, V, and IV. Following this he transferred to District XI, where he worked until his death. His experience and ability were always a source of satisfaction and pride to the district and to all who worked with and under him. He retained a fine sense of humor under even the most trying circumstances. All of his many friends and associates extend their sincere sympathy to Mrs. Wolfe and their children, for their loss is our loss, too.

Preston L. Fite Retires After Long Service

HARD ON THE HEELS of the retirement of its chief, T. H. Dennis, maintenance engineer, the Maintenance Department of the Division of Highways lost another of its veterans when Preston L. Fite, Senior Engineer, Sacramento Headquarters, retired on March 31st after 32 years of state service.

Fite had been senior highway engineer since 1931. His duties as assistant to the state maintenance engineer have taken him all over the state.

He came West from his birthplace, Philadelphia, Pennsylvania, in 1906. He and his parents settled in Berkeley soon after the San Francisco earthquake and fire. His family moved to Sacramento in 1911. He attended schools in Sacramento as well as in Philadelphia and Berkeley.

He was employed by the highway department as a helper in the State Testing Laboratory at the age of 18. The laboratory then was located on the State Fairgrounds

Joined Survey Crew

Fite next became a member of a state highway survey crew doing highway location work between Grass Valley, Nevada County, and Auburn, Placer County, and later to Nevada City, Nevada County, in 1916.

In 1917, he enlisted in the Navy and later returned to the Highway Department to work out of Lodi, Stockton, San Joaquin County, on location surveys between those points and Sacramento.

He was transferred to Clarksville in 1919. He was timekeeper and later assistant resident engineer on construction work between White Rock and Shingle Springs.

Fite left California in 1921 to accept a position as resident engineer on a construction project of the North Carolina Highway Department. He went to Mexico in 1925 as District Engineer for the National Commission of Roads of Mexico.

Returned in 1926

He returned to California in 1926 and in the spring of 1927 was employed by the Division of Highways, District 10, with headquarters in Sacramento.

He was active in the organization of the State Employees Association, became the first president of the High Sierra Chapter, is a member of the Elks Lodge, the American Legion, the Masonic Lodge and the Commonwealth Club of San Francisco.

Highway Department officials and employees honored Fite at a retirement party on March 30th.

E. G. Poss Retires After 32 Years' Service With the California Division of Highways

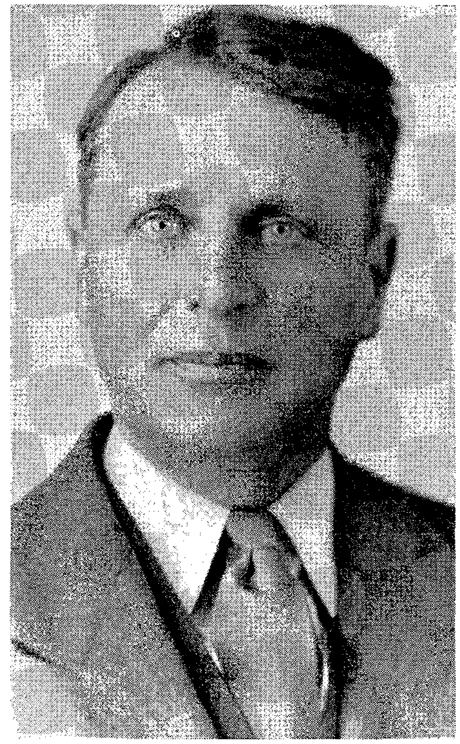
AFTER THIRTY-TWO YEARS of State service, E. G. "Ed" Poss, Assistant District Engineer, District IV of the Division of Highways, retired on January 1, 1950. Immediately thereafter, he left on a month's trip to Mexico where he enjoyed the interesting scenes in the vicinity of Mexico City, as well as the sport of deep sea fishing at Acapulco.

Mr. Poss commenced his engineering career following the Spanish-American War, in which he had seen service. From 1899 to 1918, he was engaged in railroad engineering in Michigan, Tennessee, Florida, and in Mexico, and was also employed by the Northwestern Pacific Railroad as valuation engineer in San Francisco. After this assignment, he chose a career with the Division of Highways, District IV, reporting as Assistant Resident Engineer in March, 1918.

During Ed's career in District IV, he served successively as Assistant Resident Engineer, Resident Engineer, District Right of Way Agent, Construction Engineer, Office Engineer, and, finally, as Assistant District Engineer.

Entirely through correspondence courses and diligent self-education, in the early days of his career he had acquired a thorough knowledge of railway and highway engineering principles, and his knowledge, experience, and good judgment were of great value to his fellow employees as well as to other engineers who contacted the district in matters of mutual concern.

Ed Poss enjoyed a large number of friends among his co-workers as well as in agencies outside of the department. He was held in high regard for his unfailingly genial disposition, his sympathetic understanding of the problems of others, and his sincere desire to help whoever turned to him for assistance.



E. G. Poss

On the evening of March 1, 1950, approximately 120 of Ed's fellow employees gathered at the Tivoli Restaurant in San Francisco to tender him their best wishes upon the occasion of his retirement. He was presented with a number of gifts, most of which were intended to increase his skill as a fisherman, as well as to induce him to pursue this hobby with greater diligence now that sufficient time is available.

Ed's fellow employees are going to miss him around the office but they will be visiting him at his home in the East Oakland hills whenever they wish to reminisce over the "good old days" or to plan some new hunting or fishing venture.

Death Summons Dr. L. I. Hewes, Road Builder

Dr. Laurence Ilsey Hewes, Chief of the Western Regional Office of the Bureau of Public Roads, Department of Commerce, died suddenly in San Francisco on March 2d. He was 74 years old.

Born in Dover, New Hampshire, Dr. Hewes attended Dartmouth College and Yale University, where he earned the degree of Doctor of Philosophy. For 10 years he was an instructor and later professor of mathematics and engineering at Rhode Island College, Yale University and Whitman College.

In 1911 he was employed by the Bureau of Public Roads, at a time when the science of roadbuilding was in its infancy and the needs for modern highways were first being felt. From the beginning, Dr. Hewes has played an important part in highway development, not only in the discharge of his official duties on assignments of great responsibility, but as an original thinker in the uncharted fields through which highway development has advanced.

Authority on Highways

Soon after employment with Public Roads he became Chief of Economics and Maintenance, and was shortly recognized as an authority on highway financing. He was the first to apply systematic procedures in measuring the economic need for highways. With the initiation of federal aid for highways in 1916, Dr. Hewes took an important part in planning the organization's administration and working relations with the states.

Since 1920 he has been in charge of federal aid and national forest road construction in 11 western states, Alaska, and Hawaii. In that capacity he exercised great influence in a large region, and became recognized as an authority on all phases of highway development from the details of design and construction to the broad general policies of planning and economics.

He was chairman of the United States delegation to the International Road Congress held in Munich, Germany, in 1934. In 1946, on leave from Public Roads, he served as engineering consultant to the Government of Saudi Arabia.

Wartime Service

Although he reached retirement age in 1946, his services to the Bureau during the war and postwar periods were so needed that he was requested to carry on, and gladly did so: The progress of his country and its highways were always his primary interest.

Dr. Hewes was a prolific writer, despite his arduous official duties. One of his earliest works, "Highway Bonds," written in collaboration with Professor J. W. Glover in 1915, is still a standard work on the subject. His best-known publication is the two-volume "American Highway Practice," an outstanding textbook for students and engineers alike, published in 1942.

In addition to his numerous bulletins, papers, and speeches in the fields of highway engineering, administration, finance, and economics, he has, in pursuit of his hobbies, written articles on mathematics and biology which have been published in scientific magazines.

Dr. Hewes brought to the highway field an inquiring mind, and a broad education resulting from his studies both within and outside of the field of civil engineering. Always he has been among the leaders in anticipating future needs and in planning to meet them. His own stature has added much to the prestige of Public Roads and of the highway engineering profession generally.

In Memoriam

HARVEY M. TOY

Harvey M. Toy, former Chairman of the California Highway Commission, died in San Francisco on March 1st. His sudden death shocked a host of friends throughout the State.

Financier, owner of a string of hotels and prominent in politics in the 1920's, Mr. Toy was a leader in highway development movements in California for many years. He managed the successful campaign of Friend W. Richardson for Governor in 1922 and was appointed Chairman of the Highway Commission when Richardson assumed office in 1923.

Mr. Toy was a grandson of a 49er. His father, George D. Toy, who died in 1921, amassed a fortune in San Francisco and East Bay real estate and his son increased the family holdings through the purchase of properties in various parts of the State. For years his Manx Hotel on Powell Street in San Francisco was a rendezvous for political leaders and good roads boosters.

Mr. Toy was president of the San Francisco Hotel Association and head of the California Hotelmen's Association. He twice served as president of the California Mission Trails Association. A widow, Juliette E. Toy, a daughter, Mrs. Elizabeth Lassen of Sacramento, and a sister, Mrs. Francis Lucas, survive him.

Texas Reorganizes Highway Department

Complete reorganization of the administrative and executive leadership of the Texas Highway Department modeled after the California Division of Highways, was announced in January by D. C. Greer, State Highway Engineer of Texas.

As in the California Division of Highways, there will be a deputy state highway engineer. Also named are assistant state highway engineers and engineers in charge of planning, construction and maintenance, materials and tests, and road design. In the reorganization, Greer made promotions from the ranks of veteran engineers of his department, as did State Highway Engineer George T. McCoy in revamping the California department.

Pigeon Pass Renamed

Pigeon Pass Road in San Bernardino County, the modernization of which was the subject of an article in the January-February issue of *California Highways and Public Works*, has been officially named Barton Road by the Board of Supervisors of San Bernardino County. The highway was named in honor of Dr. Ben Barton, a pioneer settler, physician, agriculturist, and educator of San Bernardino. His home still stands where he built it on Nevada Street in San Bernardino just north of Barton Road.

Erosion Control

Methods Used on California State Highways Discussed

By H. DANA BOWERS, Supervising Landscape Architect

California, a wrinkled ribbon of land more than 800 miles long lying between the high Sierras and the Pacific Ocean, stretches from the humid forested zone characteristic of the Pacific Northwest to arid northern Mexico, and ranges in elevation from below sea level to more than 14,000 feet. Climatic variations are extreme, as might be expected, and erosion control problems vary correspondingly. Many different types of control have, therefore, been found to be necessary.

The purpose of this series of articles is to discuss the variable factors associated with erosion which affect California roadsides, review the development of erosion control methods by the State Division of Highways, and describe erosion control processes now being employed with reasonable success to stabilize slopes on California state highways. This is the third installment.

It is felt that at least a few of the methods which have proved effective in California may be modified to suit conditions in other regions. Consequently, descriptions have been made as complete and are illustrated as fully as possible in order to permit duplication of these methods by nontechnical personnel.

The erosion problem on agricultural lands is another matter entirely. Since this phase of the subject is adequately treated in publications of the Soil Conservation Service we will consider here only erosion as it directly affects roadsides.

WIND EROSION

When roadway excavations are made through incompletely stabilized sand dunes or the roadway lies in the path of active dunes, wind erosion with the resulting drifting sand becomes a serious problem.

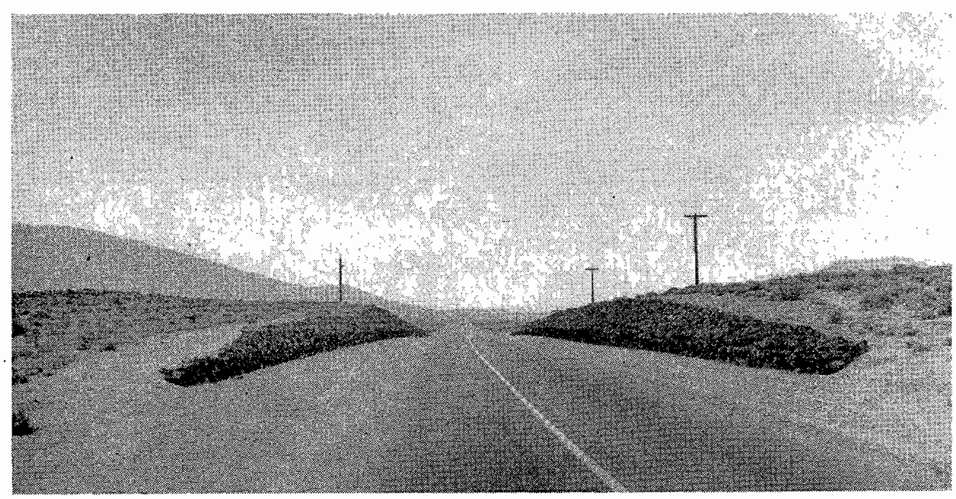
Mechanical methods of control; for example, spraying the sand banks with liquid asphalt, have the advantage of stopping soil movement immediately, but maintenance cost is usually high and increases yearly until finally the original treatment must be repeated. This type of control cannot be considered permanent.

In arid or infertile areas where plant growth is naturally sparse and rock or gravel is plentiful, some form of the mechanical method of control illustrated below may be utilized. The cost of hand placing rock in this manner is high, but this expense may be justified under extreme conditions. A blanket of coarse gravel is also reasonably effective when conditions are not favorable for vegetative growth.

Vegetative Stabilization

Vegetative stabilization of areas subject to wind erosion is both practical and inexpensive. A topsoil blanket, supplemented by seeding, is often sufficient to stop soil loss. If no topsoil is available, seeding, followed by application of a straw mulch worked into the

UPPER—Wind erosion affects both the sandy cut slope and the traveled way. (Near Carmel, Monterey County.) LOWER—Rock placed by hand on sandy cut slope face, controls wind erosion in desert areas. (Near Little Lake, Inyo County)

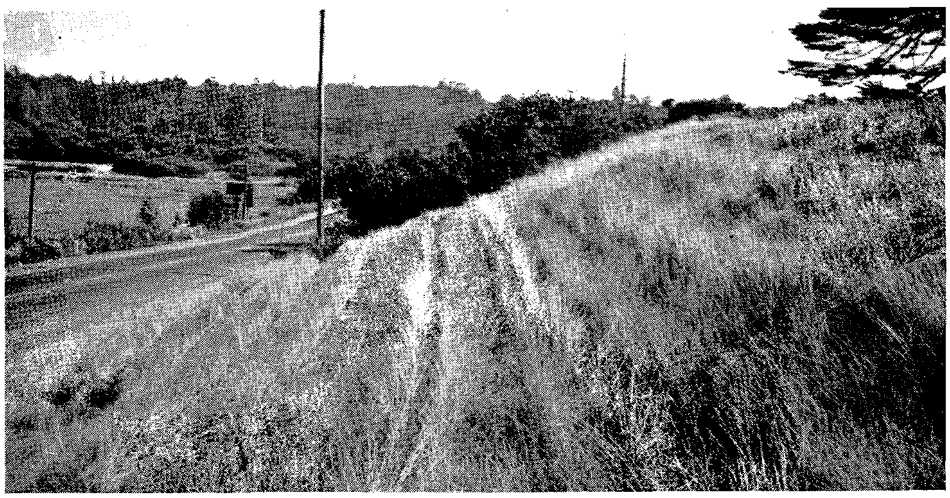


soil with a sheepsfoot roller is usually effective. In extreme cases where the soil is very loose and the wind velocity high, seeding followed by application of a layer of cut brush will give control.

With any of these methods, the function of the humus, mulch or brush is largely to suppress movement of the soil until plants have become established, after which the vegetation alone gives adequate protection.

Moving sand dunes which threaten to overwhelm a highway may be stopped in their tracks by making use of the beach grass which John McLaren found so effective when he reclaimed dune country and transformed wasteland into Golden Gate Park in San Francisco.

A sandy slope, completely stabilized with cut brush and European Beach Grass (Near Pescadero, San Mateo County)



European Beach Grass interplanted with Italian Ryegrass controls wind erosion on a sandy slope. (North of Eureka, Mendocino County)

Barley and weeds growing on a recently stabilized slope. (Near Monterey, Monterey County)

European Beach Grass

European beach grass (*Ammophila arenarial*), a perennial grass with long creeping rootstalks, is one of the world's best sand-binders. It is propagated readily by division, and once established forms clumps which discourage further movement of sand.

Planting is usually done in the late fall when continued rainfall in sufficient quantities to establish plant growth may be expected. A mulch of cut brush or straw may be spread over the area to be stabilized in order to stop movement of sand until vegetation becomes established. Divisions of beach grass are then planted through the mulch into moist sand to a depth of about eight inches. If sufficient moisture continues to be available, growth is reasonably rapid, and by the end of the first season the stand of beach grass is usually sufficiently dense to afford effective control.

If sand movement is not too vigorous, the mulch treatment is often not necessary. Divisions of beach grass may be planted in the sand, and if this planting is supplemented by seeding with Italian ryegrass or a cereal grain, satisfactory control may be obtained.

SEEDING AND GROUND COVER PLANTING

Records left by early-day explorers and missionaries indicate that in their time wildflowers covered the State of California from one end to the other. Few of the annuals and perennials now

A well-vegetated cut slope. Native shrubs are rapidly becoming established. (Near Watsonville, Santa Cruz County)

referred to as native because they have made themselves so thoroughly at home here, had as yet been introduced. Rapidly, however, seeds of new plants were brought in—some as impurities in crop seed, some in the wool or hair of imported animals, some in ship ballast, and some deliberately for forage or agricultural purposes. Finding the climate and soil to their liking, hundreds of these introduced plants became naturalized, and the more aggressive among them literally crowded out the true natives.

The point has now been reached where introduced plants make up the greater part of our herbaceous vegetation. Among these naturalized plants are a number which have been declared noxious weeds because of their growth habits, spiny or prickly nature, difficulty of control, or poisonous effect on livestock, and these must be eradicated on highway rights of way in agricultural areas. Consultation with the local county agricultural commissioner in regard to weed control and seed quarantine regulations is advisable before sowing seed of untested plants in order to avoid introduction of still another pest which would add to our weed control list.

Trial plantings of many varieties of grasses and forage plants have been made for soil stabilization purposes, but for the most part results have been unsatisfactory.

Perennials Unsatisfactory

Perennials are often difficult to establish and, even though a good stand may be obtained, too few plants usually survive the summer drought to provide effective protection the following year. With the exception of Italian ryegrass, also called annual ryegrass *(Lolium multiflorum)*, which grows as a short-lived perennial and naturalizes well along the north seacoast, and alfalfa, which persists in a few locations where conditions are to its liking, the perennials so far tested offer no advantages which would prove them superior to annuals for our purpose.

A roadside planting of Mesembryanthemum edule effectively controls weeds and reduces the fire hazard. (South of Santa Maria)

Willows planted in moist areas assist in stabilization. (Near Watsonville, Santa Cruz County)

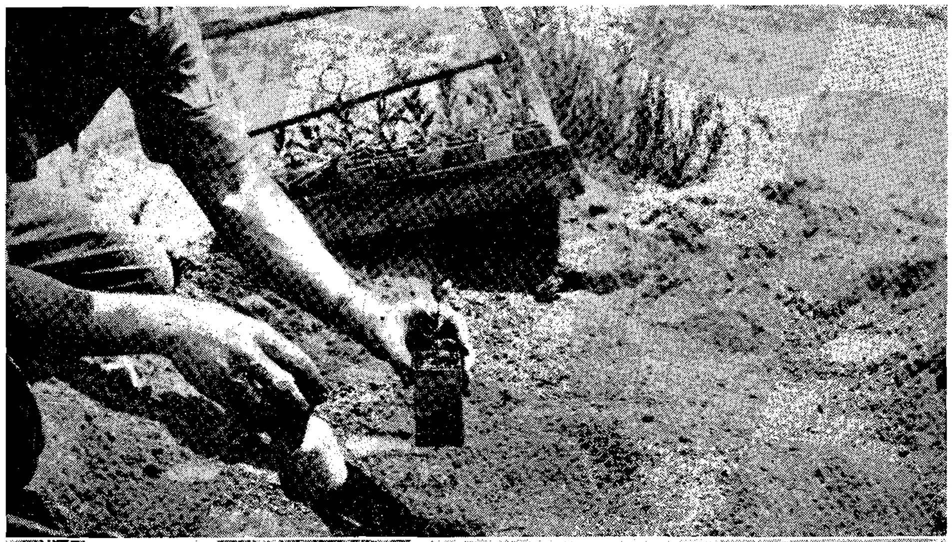
Bermuda grass is extremely effective for soil stabilization in milder sections of the State, but it reseeds so freely and is so difficult to eradicate when once established that it has become a serious agricultural problem in Southern California and the Central Valleys. Public reaction to its use in general highway planting would be immediate and unfavorable. Consequently, Bermuda seed is planted only in localities where the grass is already so thoroughly established that further planting cannot be considered the introduction of a weed pest.

Annuals Not Effective

Annuals are usually effective during the first year but, except for a very few varieties in favored locations, do not seem to reseed themselves well. Native annuals eventually take over anyway, and since they will offer adequate protection when once established, the naturalization of introduced annuals is not considered too important.

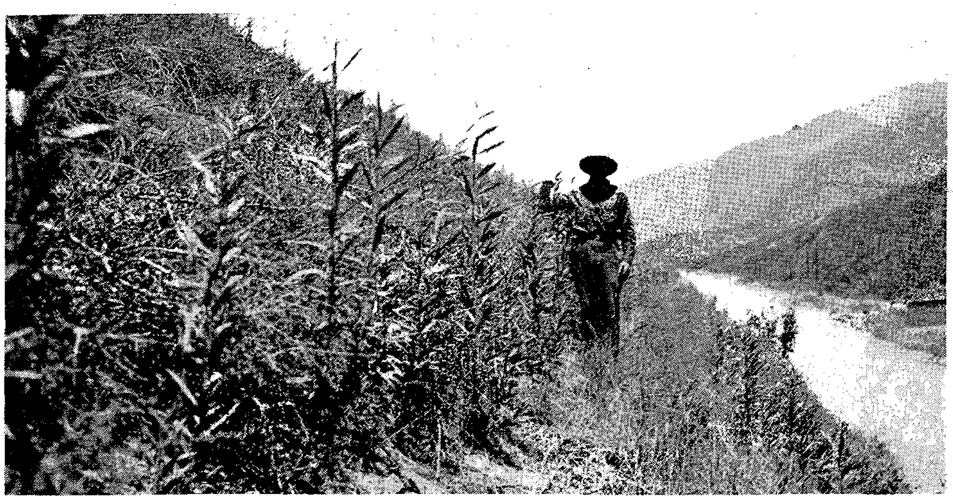
If it were possible to economically obtain seed of the native annuals through commercial channels, a more rapid establishment of a permanent cover could possibly be obtained by sowing this seed during the first year. Neither the quantity of seed available nor the cost makes this procedure practicable, however, since annuals of the type most valuable for stabilization purposes are not useful otherwise, and seed is not harvested commercially.

The conclusion has been reached that almost any annual plant, seed of which is cheap, easy to obtain, and germinates quickly with the first fall rains, will act as a nurse crop and afford adequate and immediate protection. During first year, and to a greater extent the second year, natives appear, germinating from seeds present in the topsoil or from windblown seeds which have been caught and held by the stalks and stubble of the nurse crop. A sparse growth of the introduced annual will probably volunteer the second year, and the protection given by the combination of growing plants, root mats and straw remaining from the previous season's growth, is usually complete.



UPPER—Planting small Eucalyptus rostrata in plant band. LOWER—Growth obtained 28 months after planting. (Between Colton and Ontario, Riverside County)

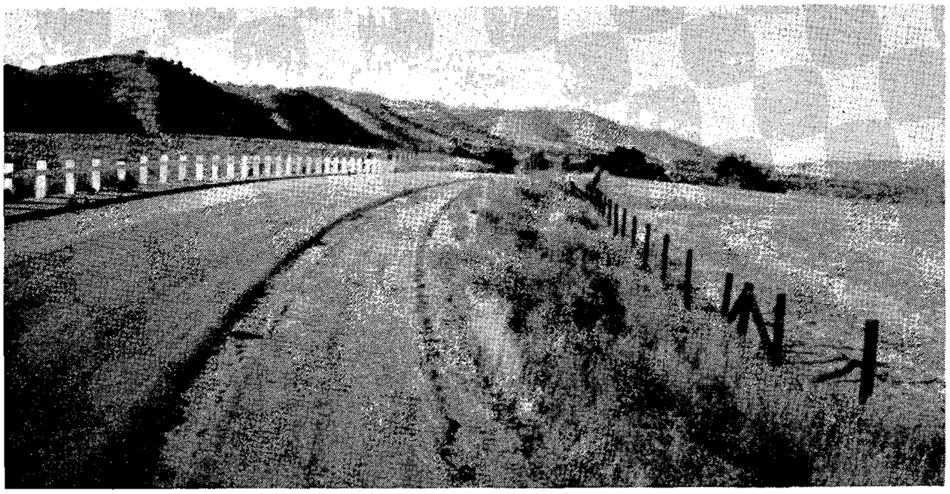
Growth made by Baccharis viminea four months after planting as cuttings. (City Creek Road, San Bernardino County)



Barley Widely Used

Since barley is harvested in many sections of the State, is about the cheapest seed on the local market, is easily obtainable, and has the virtue of germinating quickly after a light rain even when not covered by earth, it has been most frequently used for stabilization planting. Rye grain, oats, and vetch have also been used successfully.

Grain seed is usually sown broadcast on the rough and uncompacted surfaces of the freshly made or topsoiled slopes,



Dry vegetation means that fire hazard is high. (Near Bradley, Monterey County)

and harrowing or dragging the soil to cover the seed under these conditions has not proved necessary. In the event rain falls before seeding can be done, it is necessary that the slope be cultivated to loosen the surface. Barley and other large-size cereal grains are sown at the rate of one pound per 200 square feet, a considerably heavier rate than that used by a farmer when seeding for grain production.

Quantities of wildflower seed have been sown on highway roadsides for purely ornamental purposes, but this practice has been largely abandoned except on recently completed freeways where sprinkling systems are installed. The successful establishment of a good stand of wildflowers from seed is so dependent upon rainfall conditions in unirrigated areas and the cost of the seed is so relatively high that it is difficult to consistently show results justifying the expenditures.

Poppies Not Lasting

When a roadside project is completed at the proper time of year, California poppy seed is often sown on the new slopes. Given an even start with the weeds and grasses, the poppies will generally grow in sufficient quantity to give a colorful appearance the first season, but slowly disappear thereafter except in rare instances.

Seeds and shrubs and trees have been sown on treated slopes with some success. Spanish broom *(Spartium junceum)*, California wild buckwheat *(Eriogonum fasciculatum)*, silvergreen wattle *(Acacia decurrens dealbata)*, *Encelia californica*, and plume albizzia *(Albizzia lophantha)* seem to germinate well, since seed is easily gathered from established stands, some use has been made of these plants.

The selection of evergreen ground cover plants for unirrigated areas is extremely restricted. Ice plant or Hottentot fig *(Mesembryanthemum edule)* is most frequently used along the coast and is very nearly the ideal ground cover plant, since it spreads by runners which root at every node, makes a dense mat which discourages weeds, is not a fire hazard, is propagated cheaply and easily by cuttings which root in from 5 to 10 days, bears attractive flowers, is drought resistant, and is not seriously affected by pests or diseases. It does not spread by seed, and is very effective in controlling erosion.

Ice Plant Use Restricted

Established stands of ice plant growing in soils of low fertility tend to die out or become unthrifty after several years. When this condition is not due to lack of soil moisture following a dry season, these patches may be rejuvenated with an application of fertilizer followed by replanting with fresh cuttings.

Since the succulent leaves of ice plant are composed largely of water, the plant cannot be grown successfully in areas where the temperature falls much below the freezing point. This restricts its use in the State to the milder sections where the temperature never falls below about 25 degrees F., and to that point only for short periods.

Other smaller-leaved members of the mesembryanthemum family are slightly more resistant to frost, but do not spread so rapidly as *mesembryanthemum edule.*

Kikuyu grass *(Pennisetum clandestinum)* has been used as a lawn, and experimental plantings have been made throughout the State. In areas which are subirrigated or which can be given water during the summer, kikuyu grass does quite well. However, it freezes completely back in colder sections and is regarded by suspicion by county agricultural commissioners, who distrust its lusty growth when once established in irrigated districts, and consider that it might become an agricultural pest if widely planted.

Fire-hazard-control strip formed by the "spray and burn" method. Note the quantity of unburned stems left on the slope after a quick burn. (Near Castroville)

Successful Plants

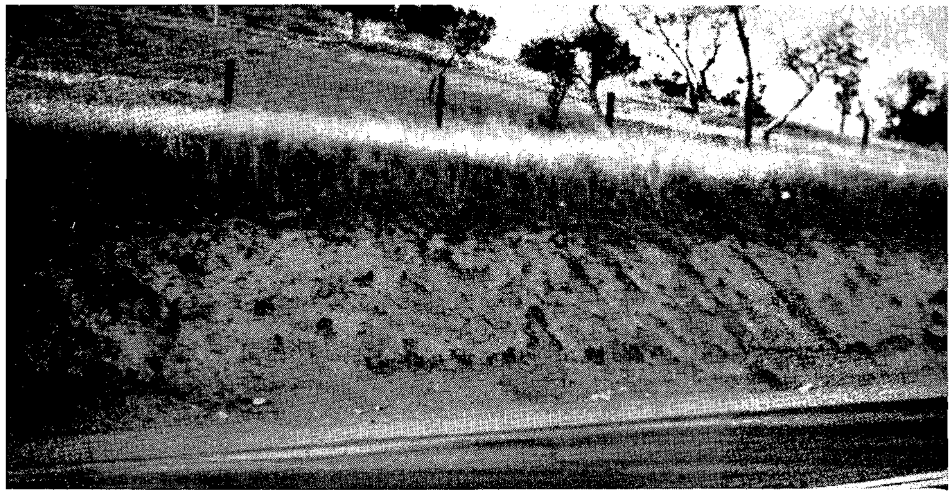
Ground cover establishment on freeway slopes and other areas equipped with sprinkling systems is comparatively simple. The following is a list of plants which do not require routine mowing or cutting back and which have been used successfully for this purpose.

SOUTHERN CALIFORNIA

Lantana sellowiana	Trailing Lantana
Lonicera japonica halliana	Halls Japanese Honeysuckle
Hedera helix	English Ivy
Vinca major	Bigleaf Periwinkle
Vinca minor	Common Periwinkle
Ipomoea leari	Dawnflower Morningglory
Fragaria chilonensis	Chiloe Strawberry
Mesembryanthemum—many species	Ice Plant, Figmarigold

NORTHERN CALIFORNIA AND CENTRAL VALLEY

Lonicera japonica halliana	Halls Japanese Honeysuckle
Rosa wichuraiana	Wichura Rose
Rubus ulmifolius inermis	Evergreen Thornless Blackberry
Hedera helix	English Ivy
Vinca major	Bigleaf Periwinkle
Vinca minor	Common Periwinkle
Hypericum calycinum	Aaronsbeard St. Johnswort
Gazania aurantiaca	Gazania



Fire-hazard-control strip formed by the soil sterilization method. Note beginning of soil loss on slope which had previously been stable. (Near Paso Robles, San Luis Obispo County)

TREE AND SHRUB PLANTING

Since most of the trees and shrubs planted on highway roadsides are evergreens, they are raised in and planted from containers. Practically no balling is practiced, since the cost of handling and planting balled stock is considerably greater than with stock in containers.

One-year-old plants in one-gallon cans are planted preferably at the start of the rainy season, mulched, and watered during the first summer, then left to themselves except in the very arid regions where they must be watered until well established.

The cheapest and so far the most effective method found for establishing plants in the field consists of planting very young plants in plant bands. Plants from seed started in July are pricked out into 2 inch x 2 inch x 4 inch wooden plant bands set in a nursery flat. By October or November, roots have grown to the bottom of the band, and the plants, 2 inches to 4 inches high, are ready to be set out. In the field, a hole is dug just large enough to take the plant band and the bottom of the hole is flattened and firmed with a wooden block so that air pockets will be eliminated and roots at the bottom of the band will contact the soil evenly. The plant, band and all, is set carefully into the hole, and moist soil firmed gently around it to the level of the soil inside the band. A small quantity of water is then used to settle the earth and moisten the root area, a mulch of straw or manure is applied, and the plant normally receives no further attention. A survival rate of 80 percent is not uncommon.

Distinct Advantages

This method has several distinct advantages. The cost of raising the plants, transportation and planting is considerably less than for larger plants; therefore, many more plants can be planted. Maintenance cost is reduced or eliminated, since the small plants grow like seedlings and require no staking or trimming. Any plants which die can be replaced the following planting season for less money than it would take to water them during the summer. Since root development has not been restricted while in the plant band, normal root growth takes place in the soil outside the band almost immediately after planting. The planting operation involves no disturbance of the root system; therefore, the plant is not set back and growth continues without a pause.

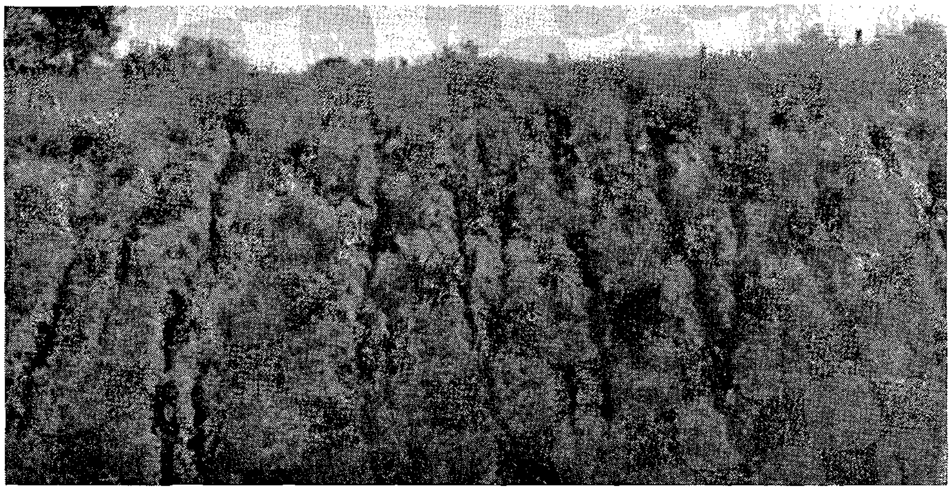
Several precautions must be observed when handling planting stock in bands. The young plants should be planted as soon as the roots appear at the bottom of the band. If planted sooner the roots are dependent entirely upon the moisture contained in the soil within the band itself, and since lateral penetration of moisture through the wooden-band walls seems to be very slow, soil surrounding the roots within the band dries out rather quickly and the plant suffers. If planting is too long postponed after the roots appear at the bottom of the band, the plant is likely to become stunted or suffer a setback when roots are broken during removal of the band from the flat, and the natural tendency of the roots to grow downward may be discouraged. Earth must be moist and firmed evenly in the bottom of the planting hole in order that the roots may penetrate immediately and draw moisture from the outside soil. If moisture conditions in the soil surrounding the plant band are favorable, the plant requires no further watering.

Nursery operations must be closely coordinated with field planting operations in order to insure that plants are planted when the roots are in the proper stage of development. If plants are growing vigorously, this period lasts no longer than two or three weeks.

Plant Bands

Plants which have been handled successfully in plant bands include:

Eucalyptus—many species	Eucalyptus
Eriogonum	California Buckwheat
arborescens	Island Eriogonum
fasciculatum	Flattop Eriogonum
Acacia longifolia	Sydney Acacia
dealbata	Silvergreen-Wattle Acacia
pycnantha	Goldenwattle Acacia
Photinia arbutifolia	Toyon, Christmasberry



Gullies formed in a topsoiled slope by successive rains will increase in depth unless treated with straw. (North of Santa Barbara)

Rhus laurina	Laurel Sumac
Hedera helix (as established cuttings)	English Ivy
Lonicera japonica halliana	Halls Japanese Honeysuckle
Spartium junceum	Spanish Broom, Weaversbroom
Baccharis pilularis	Chaparral Broom, Kidneywort Baccharis
Lavatera assurgentiflora	California Treemallow

and many others.

Cuttings of any of the many species of willow are planted in wet or seepage areas, where the roots tend to restrict movement of saturated soil, and the moisture transpired by the leaves helps to dispose of surplus water.

Baccharis viminea cuttings are frequently planted on fill slopes in the mountains of Southern California where storms of high intensity make elaborate erosion control measures necessary. These cuttings 18 inches to 24 inches long and from ⅜ inch to 1 inch in diameter, are made in the late fall and early spring of the year and are planted right-end-up in moist soil as deeply as possible, preferably with only 3 inches or 4 inches of the cutting left exposed. If the soil is hard, a slender bar must be used to form the planting hole in advance of placing the cutting; but if the soil is saturated, the cutting may be thrust into the wet bank to the proper depth without damaging buds or bark. Roots are formed within a few weeks, and the plant makes a remarkable growth, sometimes sending up shoots 6 feet to 8 feet high the year following planting.

FIRE HAZARDS AND EROSION CONTROL

Since the long dry summer season in California is unfavorable for the growth of perennials, most of the herbaceous vegetation found along our roadsides is annual in habit. Annual grasses predominate, and since these grasses die down in early summer when the soil moisture is exhausted, a mat of dry vegetation is formed which is extremely inflammable. A carelessly thrown cigarette or match, glowing bits of carbon from a faulty muffler, or even sunlight shining thorugh a discarded bottle or bit of broken glass may start a fire which can do considerable damage.

The consequences of a roadside fire are often serious. Not only are trees and brush damaged or destroyed on the highway right of way, but adjoining crops, pasture or forested land may be burned. Smoke blowing across the traveled way may cause serious traffic accidents. Accelerated loss of soil due to the destruction of the protective vegetation may be expected during the following rainy season.

State Responsibility

The principle has been well established that the State is not responsible for damage caused to adjacent property by accidental fires started on highway right of way, but a certain moral obligation to the public is recognized. In line with this obligation, and often at the request of federal and state agencies, the State undertakes certain fire-hazard-control work, which is essentially the establishment of a control strip of growth-free soil as near to the maintained roadside shoulder as physical conditions permit. This strip, from three to six feet or more in width, may be established either by mechanical methods (disk or grader), or by spraying and burning before surrounding grass will burn (diesel oil), or by soil sterilization (sodium chlorate or chlorate-borate).

It is apparent that if a strip of soil on cut banks or fill slopes is denuded of vegetation, it will be acted upon by the erosive forces of wind and water. Some soil loss is probable. A decision must be made, therefore, as to which is more important: The potential damage which could be caused by a roadside fire which may never start or which might not be controlled by a strip firebreak, or the more certain but less spectacular loss of soil with its attendant maintenance problems. It is a difficult decision to make, since only probabilities are involved, and no one can be certain where or when fires will start or predict the intensity of the rains.

Spray and Burn Method

From an erosion control standpoint, and accepting the fire-hazard-control strip as a more or less necessary evil, the "spray and burn" method of denuding the strip seems preferable to soil sterilization. If this method is used, vegetation grows in the strip during the winter season and offers some protection to the slope during the rains. Early in summer before the annuals have died, the strip is sprayed with diesel or an inflammable weed oil high in aromatics, then above-ground growth is burned. The root mat remains below the surface of the soil, and assists in stabilizing the slope until fall rains start the cycle anew.

Soil sterilization on cut and fill slopes, on the other hand, results in year-round suppression of plant growth with resultant lack of protection to the slope at any season. This method has the advantage of remaining effective for several years after application, which means a lower yearly cost for treatment, but slopes so treated show a progressively greater soil loss than slopes which are sprayed and burned. Soil sterilization certainly has a place in suppression of plant growth immediately around guide posts and guard rails and in flat areas not subject to erosion, but should be used very judiciously on slopes which may erode.

Mechanical Methods

Mechanical methods of establishing the control strip seldom complicate the erosion control problem, since equipment can operate efficiently only on relatively flat areas, and slopes are usually not disturbed.

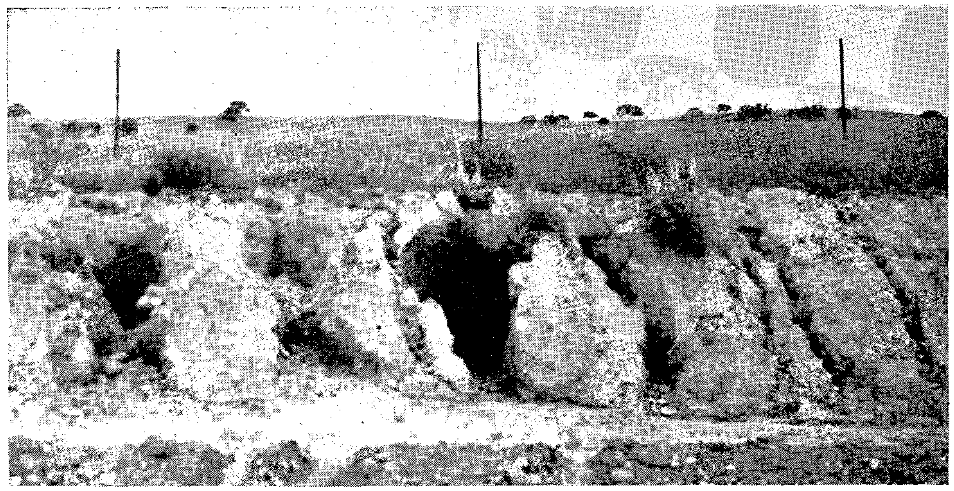
Erosion control treatment of newly formed slopes which involves the use of a straw mulch admittedly increases the fire hazard, but the probability of soil loss is so much greater than the possibility of fire damage that the risk is considered justified. Many miles of new highways bordered by straw-covered slopes have been used by the public for the last several years with remarkably little loss due to fire. It is only after the new slopes have become reasonably well stabilized that establishment of a control strip is considered.

Science may one day discover a fireproofing chemical which will be so cheap and so easily applied that it will be practical for roadside use. Unsightly burned strips would then never mar the scenery, and the slight but inevitable differences of opinion between the erosion-minded and the fire-hazard-conscious agencies would be a thing of the past.

MAINTENANCE OF EROSION CONTROL WORK

There is a certain tendency among highway maintenance crews to consider that slope stabilization treatment applied during construction will adequately protect the slopes without further attention. Unfortunately, this is not the case. No form of vegetative erosion control has yet been found which is so effective that some degree of follow-up treatment does not prove to be necessary before the slope can be considered completely stabilized.

The function which a straw covering performs is to restrict or prevent movement of soil particles. As long as no soil particles are moved, rills or gullies cannot form on a well smoothed slope. Lacking rills or gullies, runoff water is not concentrated in a single channel, but moves slowly and evenly to the bottom of the slope.



Damage caused by runoff water from adjacent property. (Near Goleta, Santa Barbara County)

Once the surface protection of straw is broken, however, soil particles move and small rills form. These rills intersect and form small gullies, which, in turn, act as tributaries to larger gullies, and so on. As the depth of the gullies increases, the area from which they gather runoff water also increases, and the volume of water which appears in the largest gully of a developed system during a light rain is often surprisingly great.

Frequent Inspection

It is obvious, then, that any break in the straw covering must be repaired before soil movement begins in order to take advantage of the protection which the straw blanket is capable of giving.

Frequent inspections, especially during the critical first year, must be given the treated slopes. A sharp lookout must be kept for developing gullies, and additional straw spread in the critical areas before the gullies develop to the point where they become serious. Far better control may be obtained by using a flake of straw at the right time—while the gully is still small—than by using several tons of straw after the damage has been done. Supplementary seeding of weak areas must be carried out if it is apparent that the original seeding is not giving the protection desired. Cuttings of willow or *Baccharis viminea* should be planted in moist or unstable locations in order to dissipate excessive moisture or to assist in stabilizing potential slide areas. If the straw covering has been disturbed by fire or animals or by some other means, it must be replaced in order that the surface protection may continue to be effective.

Constant Vigilance

It goes without saying that constant vigilance is necessary in order to prevent streams of runoff water from above from running over the slope face. Clogged culverts or broken or inadequate berms or intercepting ditches may allow a concentrated stream of water to pour down over the slope, forming large gullies very rapidly. Surface protection is of no value, in this event, and gullies of this type often endanger the roadway itself.

Disposal of sloughed material which must be removed from gutters and shoulders presents a very real problem. If this material is dumped over stabilized slopes in order to get it out of sight or out of the way in the simplest possible manner, the stabilization treatment is then rendered worthless, since gullies forming in the dumped material cut through the buried stabilized surface in a comparatively short time. The effect of this erosion carries on to the very bottom of the slope, and sometimes beyond, since deposited eroded material helps to concentrate runoff water in a definite channel. Furthermore, dumping on a slope which has been planted to shrubs and trees effectively contributes to the failure of the planting, and the consequent loss of the

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Alvarado Canyon

San Diego Completes FAS Limited Freeway

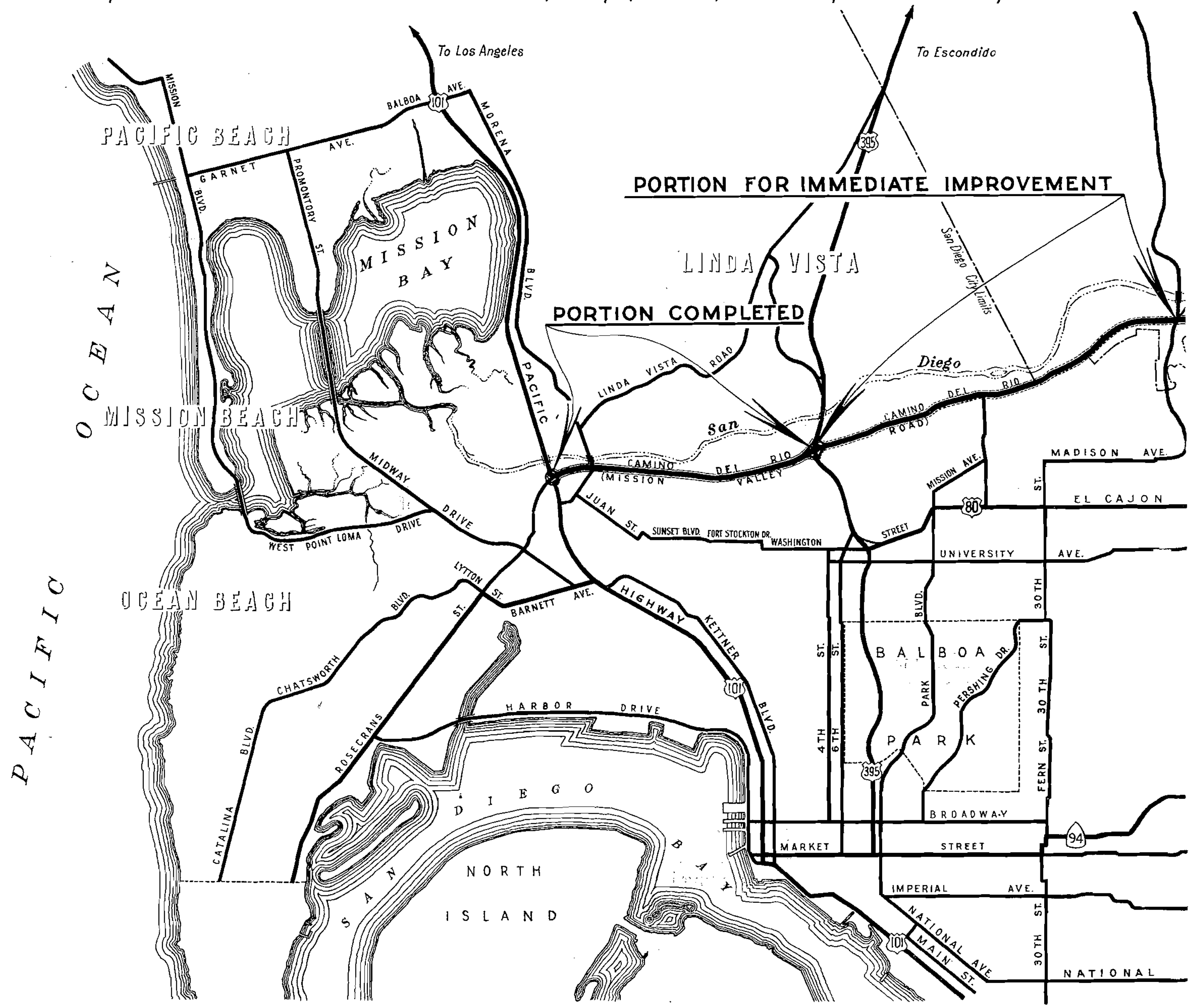
By JOSEPH H. MACK, County Road Commissioner

On January 21, 1950, the easterly 5.09 miles of Federal Aid Secondary Route 732 was officially dedicated and opened to traffic in San Diego County.

This section of FAS Route 732 is locally known as the Alvarado Canyon Road and connects the City of La Mesa at U. S. Highway 80 with the Mission Valley Road at the junction of Fairmount Avenue Extension and FAS Route 731. The Mission Valley Road Section of FAS Route 732 is 3.75 miles long and will soon be under contract, which will complete the improvement of the total length of the route between U. S. Highway 80 and U. S. 395.

This Federal Aid Secondary Route serves the El Cajon-La Mesa area of San Diego County as a limited access highway which by-passes the heavily con-

The map below indicates the over-all importance of the Mission Valley-Alvarado Canyon limited access express way in the San Diego area traffic pattern. This route will enable traffic from El Centro, El Cajon, La Mesa, and similar points to flow freely to connections



gested El Cajon Avenue portion of U. S. 80 through the cities of La Mesa and San Diego. It is also a link in the Master Freeway Plan of Metropolitan San Diego.

16 Years of Effort

The dedication and ribbon cutting ceremony by the City of La Mesa was a fitting climax to the 16 years of effort by the county to make the Alvarado Canyon Road a reality, the first petition to the board of supervisors being dated August 12, 1934.

The five responsible governmental agencies through the following representatives expressed their views about the project at the dedication ceremony: E. F. Strickler, Senior Highway Engineer of the U. S. Bureau of Public Roads; Charles T. Leigh, member of the State Highway Commission; E. E. Wallace, District Engineer, Division of Highways; James A. Robbins, Chairman; David W. Bird and Frank A. Gibson, members of the County Board of Supervisors; Enoch E. Anderson, Mayor of the City of La Mesa and Fred A. Rhodes, City Manager of the City of San Diego.

All of the above agencies and their many officials and employees, cooperated with the county in preparing the plans, obtaining rights of way and in clearing the legal requirements for the construction of this road. This was a clear demonstration that cooperation in the Federal Aid Secondary program can be successfully achieved by all levels of government working on a single project.

State Assistance

The Alvarado Canyon Road was the first limited access freeway project to

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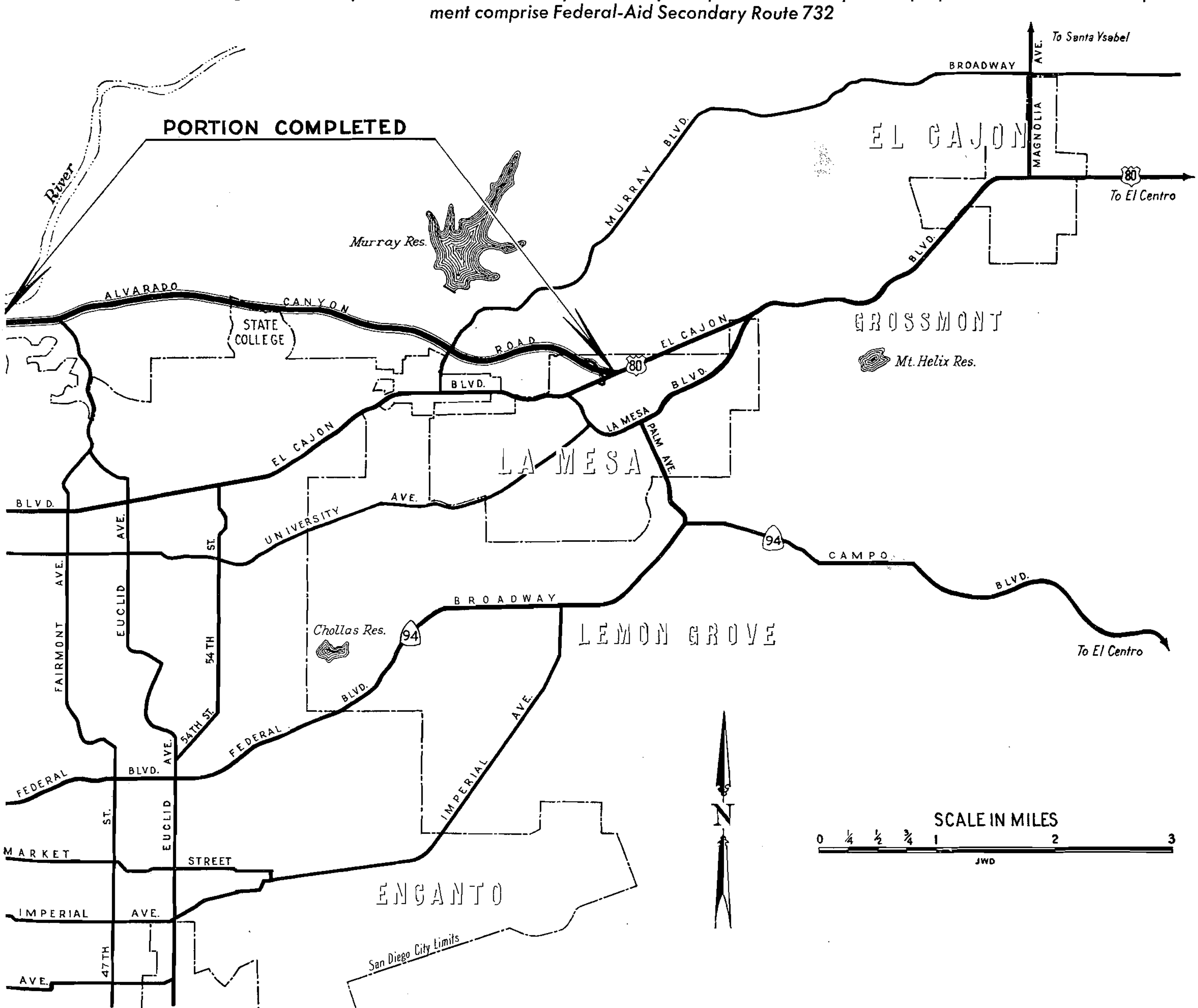
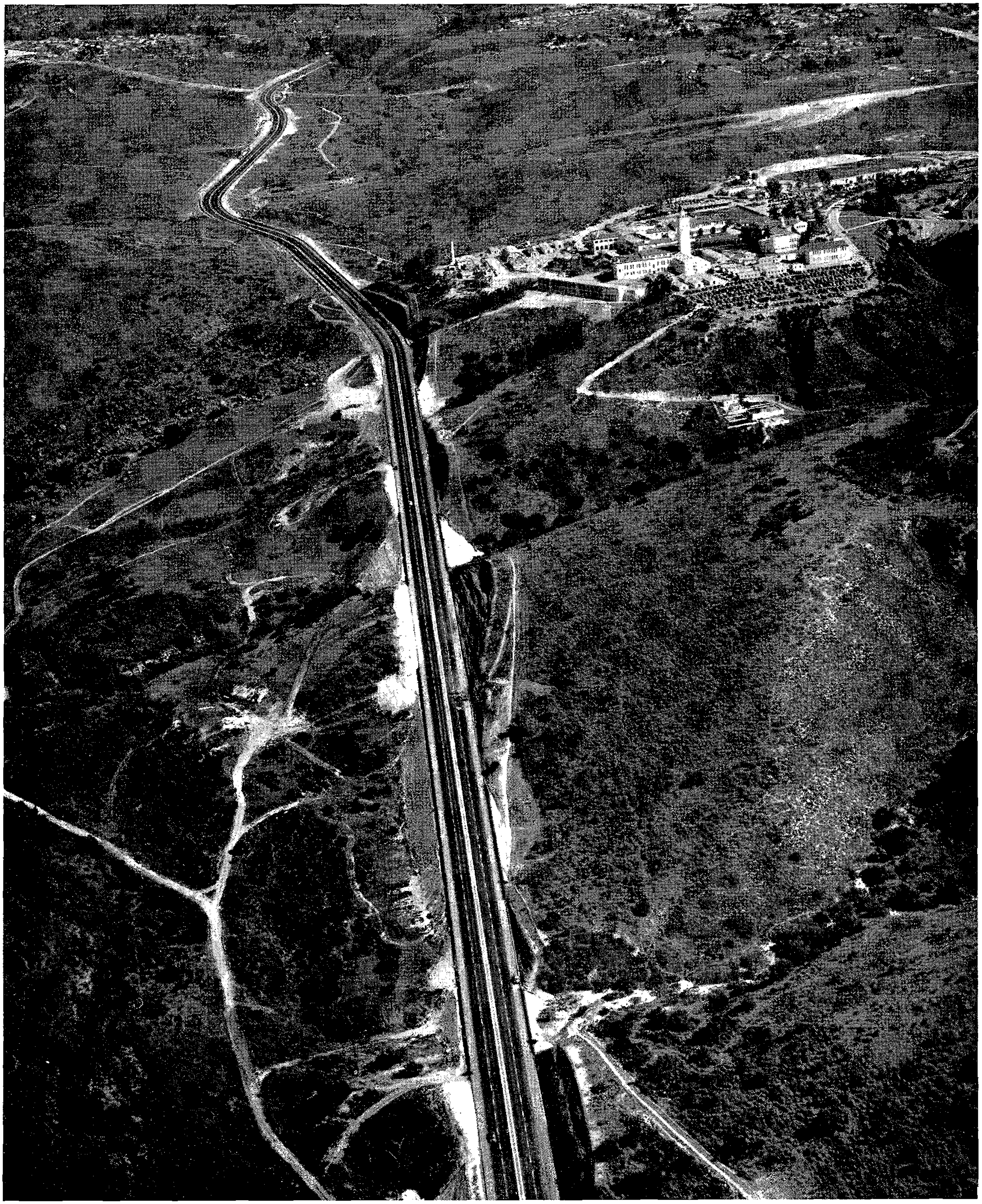
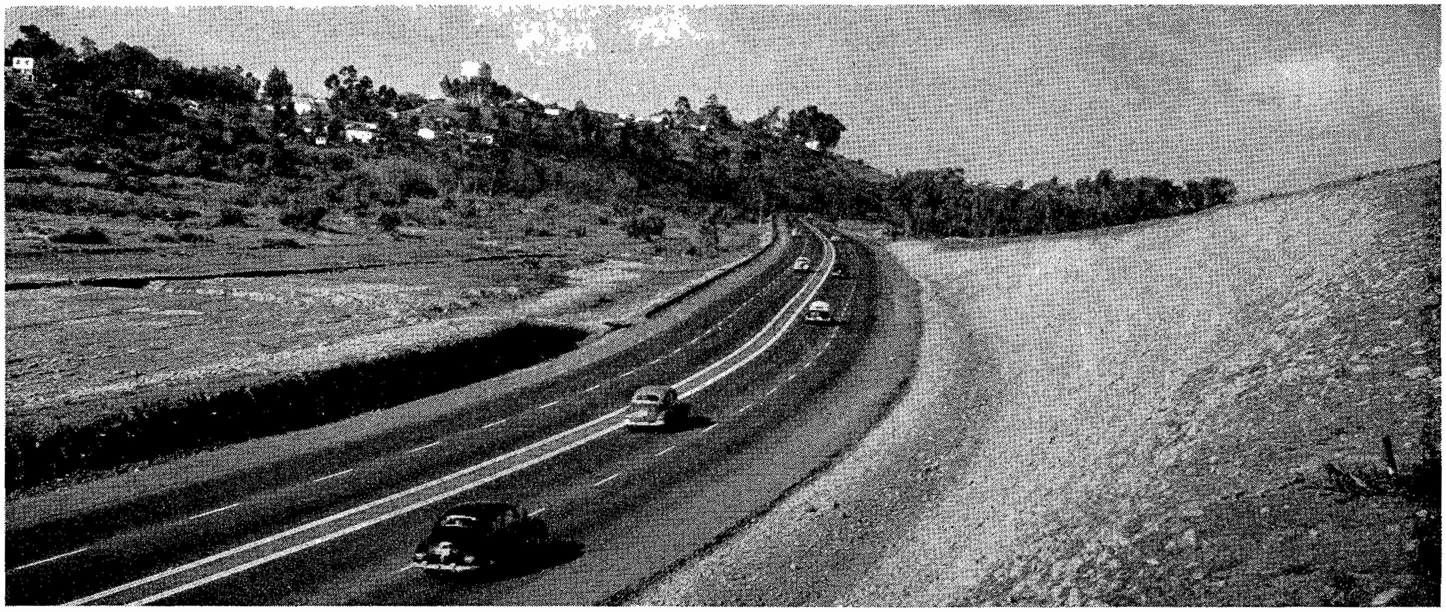
with Fairmount Extension, the Cabrillo Freeway (U. S. 395), and the Pacific Highway (U. S. 101), thus avoiding time-consuming traffic congestion on existing routes. The portion in Alvarado Canyon recently completed and the portion proposed for immediate improvement comprise Federal-Aid Secondary Route 732





Aerial view of Alvarado Canyon Road looking easterly toward La Mesa. San Diego State College on right



UPPER—One of sections requiring heavy excavation. Looking westerly from La Mesa. LOWER—Looking northwesterly along project. Junction with El Cajon Avenue, U. S. 80, in foreground

Alvarado Canyon

Continued from page 43 . . .

be undertaken by the County of San Diego. Invaluable and unselfish engineering assistance by the District XI Office of the State Division of Highways in the design and preparation of plans and specifications, enabled the county, which was extremely short of engineering personnel, to finish the plans in June of 1947.

Delays due to the requirements of the Public Utilities Commission that a grade separation structure be constructed over the tracks of the San Diego & Arizona Eastern Railway Company at the easterly end of the project prevented the advertising for bids until August, 1948.

The contract for the construction of the road was awarded to the Daley Corporation of San Diego on September 27, 1948, with the work getting under way on October 26th.

The road is designed for a speed of 60 miles per hour with a minimum radius curvature of 1,500 feet and a maximum grade of 5.8 percent. Traffic was estimated at 6,000 vehicles per day. Actual traffic count since the highway has been opened is about 7,000 vehicles per day.

All items of work were constructed to the specifications of the State Division of Highways.

Project Cost $826,860

Due to the lack of funds it was decided to place a two-inch road-mixed surface on a one-inch cushion course over 7 or 13 inches of processed selected material. When traffic increases in a few years it will be necessary to pave the road with a high type rigid pavement and curbed median strip.

The roadbed section is 66 feet wide, composed of four traffic lanes divided by a four-foot median strip with eight-foot shoulders, plus three-foot berms or ditches.

The total cost of project was approximately $826,860, exclusive of engineering.

Right of way was provided by San Diego County and the City of La Mesa. Preliminary engineering was provided by San Diego County with the cooperation of the Division of Highways; construction engineering was under the direction of Frank D. Pearce, Resident Engineer for the highway construction and W. V. Cryderman, Resident Engineer for the bridge construction, both from the Division of Highways; the county furnished an assistant resident engineer and survey parties.

The construction costs and construction engineering costs were financed from federal aid secondary funds provided by the Federal Aid Highway Act of 1944, and state matching funds provided by the County Highway Aid Act of 1945 and the Construction and Employment Act of 1946, Chapter 20. The City of La Mesa also provided some funds from its one-quarter-cent gas tax allotment from the State.

HARRY R. SHEPPARD
21ST DISTRICT, CALIFORNIA

HOME ADDRESS:
YUCAIPA, CALIF.

VICE CHAIRMAN
ARMED SERVICES APPROPRIATIONS

Congress of the United States
House of Representatives
Washington, D. C.

January 25, 1950

Hon. Ed. Hyatt
State Engineer
Sacramento, California

Dear Ed:

As members of California's Delegation in the House of Representatives, familiar with your long and distinguished work for California's water resources, we have received with deep regret the news of your retirement. We will miss you. Every part of the State has witnessed some part of your service: the Central Valley Project, the State-wide water plan, the Colorado River projects, the flood control program, and many others. In all these water resources California is richer because of your quarter-century of effective service as State Engineer and in related responsibilities. The California Delegation extends to you its best wishes for your future happiness and success.

Cordially,

BLUEPRINT AND DIAZO REPRODUCTION MATERIALS

By G. G. McGINNESS, Assistant Stores Engineer

Blueprinting is probably the most widely used process for reproduction of drawings, plans and maps. The word "blueprint" is used broadly by many to include other reproduction processes and may mean prints of engineering drawings, a well-defined plan, a program or scheme, or even war strategy. Since Sir John Herschel developed the process in 1842, blueprints have provided the medium for conveying the engineer's or architect's vision of a completed machine or structure to the many craftsmen who do their part in the fabrication and erection.

Actually blueprinting is a distinct process whereby contact photo-reproductions are made by the use of a complex iron salt in contrast to the silver halides used in ordinary photography. The basis of the blueprint process is the changing of a soluble chemical to an insoluble chemical by exposure to light.

Blueprint Paper

Blueprint paper is a white opaque paper free from sulphites, coated with a solution of citrate of iron and ammonia, and ferricyanide of potassium, which, when fresh, is a yellowish-green color. On exposure to light, a chemical reaction takes place rendering the exposed portion of the print insoluble, and when fixed by washing in water, produces a strong blue color. Portions protected from the light by black lines of the tracing wash out, leaving the white paper. Thus the tracing is reproduced on a print with white lines on a blue background. The blue is often intensified by dipping the print in a solution of potassium bichromate.

With age or exposure to light or air, undeveloped blueprint paper turns to a grey-blue color and spoils altogether in a relatively short time.

Most blueprints are made on paper, but those that are to be subjected to very rough handling or are for permanent record may be made on sized cloth.

Blueprints after development are quite stable and if fading does occur, almost 100 percent recovery may be secured by placing the blueprint in the dark for several days.

Blueline prints on either paper or cloth are processed in the same manner as blueprints except that the material is exposed to light through a copy of the tracing with clear lines on a dark brown or opaque background.

Diazo Type Prints

While blueprints just described are better known, and the term "blueprint" is very commonly used, other prints, known as whiteprints, have been in use for the past 20 years and are being used today to a greater extent than many of us realize. These whiteprints are described as being of the diazo type. They have become popular because they are positive or right reading prints, having black or colored lines on white backgrounds, while the blueprints are negative reading prints, having white lines on blue backgrounds. A whiteprint is, therefore, usually easier to read and corrections may be noted thereon with pencil or ink, whereas on a blueprint any corrections or notations must be made with a white or light colored pencil or ink.

All that is drawn or printed on the original is reproduced on the diazo paper in black or color on a white background. As most printed matter such as letters, newspapers, etc., is printed with black ink on a white background, whiteprints combine well with common forms of printing.

Whiteprints Popular

Another reason for the popularity of whiteprints is that they are faster and easier to make. It is estimated by a survey among coated paper manufacturers and reproduction shops that 50 percent of the prints now produced in the United States are of the diazo type.

Diazo type prints fall into two chemical groups. One group is classified as semi-moist and includes such brand names as "BW" (Black and White), "Directo," and "Blacline." They are developed by simple machines which apply a thin film of developing solution to the face of the exposed print. These diazo type prints are known as *one component papers*. The light sensitive diazo dye is a part of the sensitizing solution applied to the paper and the "color giving" or azo coupling compound is contained in the developing salts. By keeping the diazo dye apart from the azo coupling compound the keeping quality or shelf-life of the sensitized paper is enhanced. When these two chemicals merge in the proper medium, they form a dye which produces black or colored dye lines.

Ammonia Developed Papers

The second diazo type group includes ammonia developed papers. The process is associated with such brand names as "Ozalid," "Vapo," "Helios," and "Dri-Print." ("Ozalid" is the word "Diazo" spelled backwards with "L" inserted for phonetic completeness.) These papers are known as *two component papers*.

Here, both chemicals, the diazo dye and the azo coupling component, are coated on the paper and remain practically uncoupled until the paper is placed in the developer medium; in this case, ammonia vapor fumes contained in a sealed chamber. Exposure of ammonia developed papers is accomplished in the same manner as semimoist papers, as mentioned heretofore.

All of these reproduction processes are based upon light passing through transparent papers or cloths and exposing the portions not covered by ink or pencil lines on the tracings. Where the light penetrates, it renders insensitive the diazo dye and where it does not, the diazo dye couples with the azo color compound.

New Development

Recently, a new development has been introduced to the semimoist diazo field. This product is known as "reflex film." It enables one to copy *opaque* subjects, such as magazine pages, and other materials which may be printed

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El Centro Blvd. *Sutter County Works on New Direct Route to Sacramento*

By CARL F. LIND, County Engineer and Road Commissioner

For at least 10 years the officials of Sutter County have talked and planned of a new direct route between Yuba City, the adjacent Sutter County area and the City of Sacramento. This dream is finally coming to a realization with the construction of the newly located El Centro Boulevard, which is on federal aid secondary county Route 926 between Yuba City and Sacramento.

The project was divided into two contracts, one for the 617-foot bridge at Cross Canal and one for the roadway construction from Striplin Road, about 4 miles south of East Nicolaus, to the Sacramento County line, a distance of 7.9 miles.

Cross Canal Bridge

Bids were opened for the bridge on November 17, 1948. Lord & Bishop of Sacramento were low bidders with a bid of $122,140. This bridge is a reinforced concrete slab structure 617 feet in length and 30 feet over-all width with a 26-foot clear roadway width. There are 28 spans supported on precast reinforced concrete pile bents. The end bents were open end type and the bridge was constructed with timber railing; beam type metal plate guard railing was installed on the approaches.

Bids for the roadway portion of the new route were opened February 9, 1949, at which time P. J. Moore & Son and Harms Bros. of Sacramento were low with a bid of $234,033.05.

Due to the lack of funds to complete the entire project to standard construction, it was decided to build the roadway by stage construction. One hundred feet of right of way throughout the project was acquired. A turn pike section was designed using the entire width of right of way with the ditch section providing material for embankment to raise the road bed out of the heavy adobe subbase soil. This section also provided sufficient width for a tractor lane on either side of the pavement.

Cross Canal Bridge on El Centro Boulevard

Through Agricultural Lands

The route traverses agricultural land, the most of which is devoted to rice crops with consequent flooding of adjacent fields and saturation of the subbase. The final road bed was built to provide a traveled way 22 feet in width with four-foot shoulders. Twenty-eight thousand cubic yards of borrow to build bridge approaches were obtained from the channel of the drainage canal. The remaining material was obtained from the ditch sections.

The timing of the grading was very critical, since it was necessary to do the grading work between the period of the winter rains when the country was practically impassable and during spring when the irrigation canals were filled and the adjacent rice fields flooded. It was, therefore, necessary to immediately excavate the ditches of the turn pike section over practically the entire job in order to control drainage and permit grading work to proceed on the roadway itself.

Drainage System

Sand borrow to a depth of nine inches was obtained from local deposits to provide a blanket over the adobe of the graded road bed. A six-inch gravel base was placed over this sand borrow. The gravel was obtained from a county pit on the Bear River, an average haul distance of 15 miles.

For the purpose of drainage, concrete pipe was chosen throughout the entire project. Concrete pipe varied in size from 12-inch for driveway side drains up to double 60-inch pipes.

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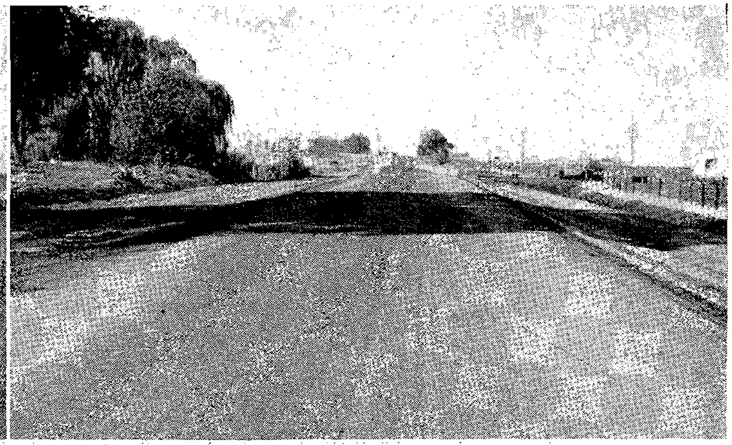
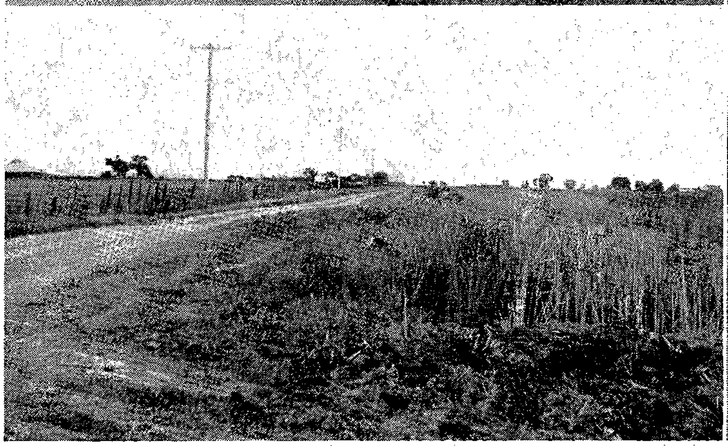
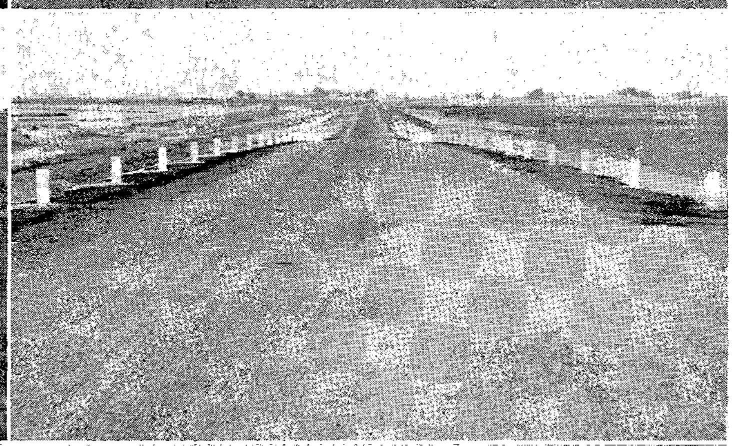
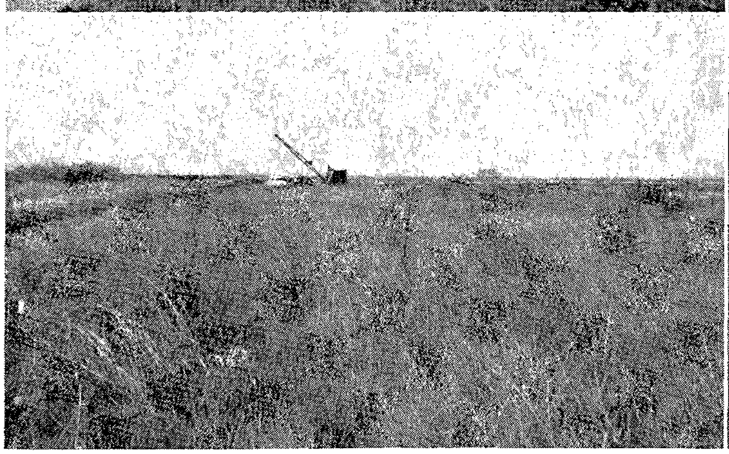
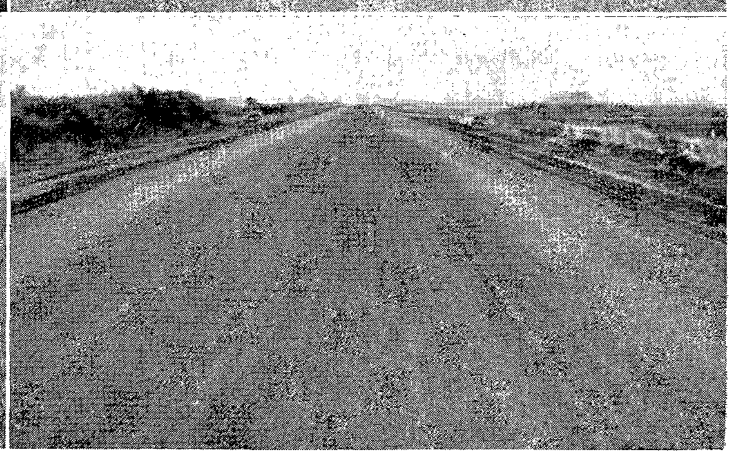
The photos on the opposite page, all looking north, show before-construction views of El Centro Boulevard in left-hand column and after-construction views of same sections in right-hand column

New Route

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they are so arranged and their curvature so flat that it gives the appearance to the traveling public of one long tangent.

The rapid development on the adjacent and formerly agricultural land also required a change from barb wire fences to the more positive protection of chain link fence. Hence, a four-foot chain link fence will be installed throughout the suburban areas requiring 21,850 feet of fence on the expressway and 2,200 feet on the Charter Way extension, or a total of 24,050 lineal feet. This fencing is constructed with state-furnished metal fence posts set 10 feet apart, the posts being braced at 150-foot intervals with the braces and posts set in concrete. This makes a very economical installation and appears to be entirely satisfactory, the cost being approximately 60 cents per lineal foot.

Paving Completed

All of the concrete paving on this project was completed during the 1949 period. However, as winter developed, the work was slowed down and during January and February, 1950, was practically at a standstill. However, with the coming of spring, work is again in full swing and it is anticipated that the project will be completed and opened to traffic prior to June 1, 1950.

During March of 1950 a contract was awarded to R. Goold and Son for the illumination of the major intersections on the project. These illuminations, which consist of 64 individual lights, will be placed at the intersections of the expressway with Mariposa Road, Farmington Road, Main Street, Washington Street, Fremont Street, Waterloo Road, Cherokee Lane and at the north end of the project near Calaveras River and at the intersection of D Street with Route 50. It is expected this work will be completed by the time the project is opened to the general public.

Major Items of Work

The major items of the work which includes the two major contracts are as follows:

Roadway excavation	377,780 c. y.
Imported borrow	100,380 c. y.
Imported base	156,600 c. y.
Imported subgrade material	17,350 c. y.

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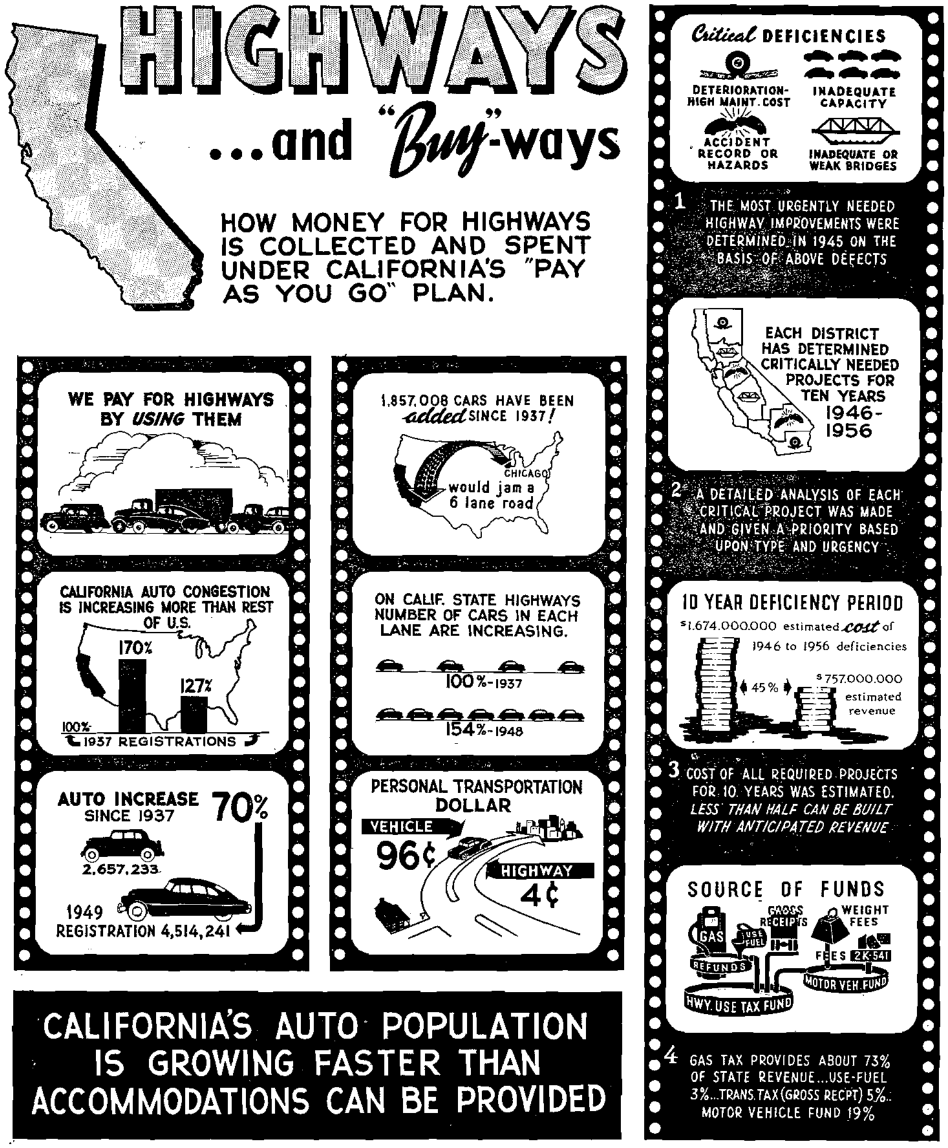


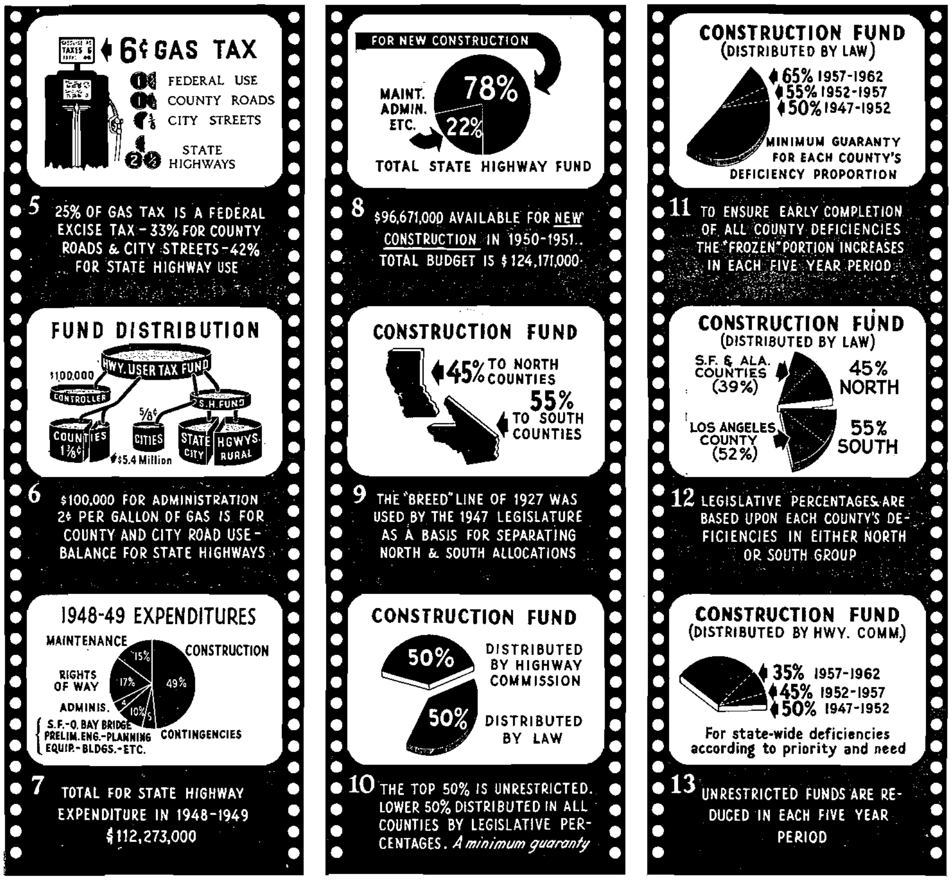
By J. W. VICKREY, Assistant State Highway Engineer

EACH CALIFORNIA motorist today must share the State's streets and highways with over 4½ million other motor vehicle drivers.

There are nearly 60 percent more passenger cars and other motor vehicles on California's highways today than there were a dozen years ago. Over 1,700,000 more cars, trucks, busses, trailers and motorcycles have since been added to the all-time high of 2,650,000 motor vehicles in 1937. California's auto population is continuing to grow at a faster rate than the rest of the United States.

Little do we realize that the increase in the number of motor cars is more rapid than the increase in driving space upon which to operate these motor cars. Today, we have an average of 54 percent more cars on each of the driving lanes than we had 11 years ago. More driving room is the motorists' cry.

Incidentally, it may be noted that for this privilege of highway movement, the average motorist spends but 4 cents for the roads and highways upon which the vehicle must be driven while 96 cents of his transportation dollar is spent on the motor vehicle, its maintenance and the cost of its operation.



Today's most critical highway deficiency is the lack of enough lanes for the rapidly increasing number of motorists in California. By January 1, 1950, the California Highway Commission had declared 1,440 miles of major routes as freeways, of which 675 miles are constructed on a multi-lane standard.

The problem of determining and meeting highway needs was carefully studied in 1945. Critical deficiencies were observed and tabulated to obtain a state-wide picture.

The estimated cost of all proposed projects was based upon expressed trends in construction prices together with a conservative projection as to future costs.

The Collier-Burns Act of 1947 provided an increase in highway revenue which, however, was estimated to cover but 45 percent of the 10-year deficiency program.

Under the Collier-Burns Act, gasoline taxes provide about 73 percent of the streets and highway fund. Although the Collier-Burns Act increased gasoline taxes by 1½ cents per gallon, California is still lower than 28 other states and over one-half cent per gallon less than the average of the Nation.

It should be noted by the motorist that of the 6-cent gas tax that he pays at the service pump, only 4½ cents of that tax is directly available for California's road use. A federal tax of 1½ cents is included. Federal funds amounting to about 20 percent of the funds collected return to California for its road use.

Proposed expenditures for 1950-51 total $124,171,000. Of this amount, approximately 78 percent, or $96,671,000, will be used for new major and minor construction projects including a small percentage for contingencies, for rights of way, preliminary and construction engineering, planning and for the operation of the San Francisco-Oakland Bay Bridge.

Harrison R. Baker Gets Third Term

Governor Earl Warren, on February 11th, reappointed State Highway Commissioner Harrison R. Baker for a third term. The new appointment, subject to confirmation by the State Senate, will expire January 15, 1954.

Originally named to the post on September 14, 1943, Mr. Baker won a three-year term when the newly appointed highway commissioners drew lots for staggered tenures of office. He was reappointed in January 1946 for a four-year term.

NEW NAME ON LIST

LIVERMORE ELEMENTARY SCHOOL DISTRICT
LIVERMORE, CALIFORNIA

MR. KENNETH C. ADAMS, *Editor*
California Highways and Public Works
Sacramento, California

DEAR MR. ADAMS: I have before me a loaned copy of the November-December, 1949, issue of *California Highways and Public Works* and am amazed at the abundance of educational material contained therein.

We shall consider it a favor if you will put our school system on your mailing list.

Respectfully yours,

JOE MICHELL
Superintendent of Schools
President Livermore C. of C.

HIGH PRAISE

THE STATE OF WISCONSIN
Highway Commission
MADISON 2, WISCONSIN

MR. KENNETH C. ADAMS, *Editor*
California Highways and Public Works
Sacramento, California

DEAR SIR: I have found a great deal of interest and value in *California Highways and Public Works* and hope that it may continue to come to me. It is the most valuable magazine of its type that I have had the privilege of seeing.

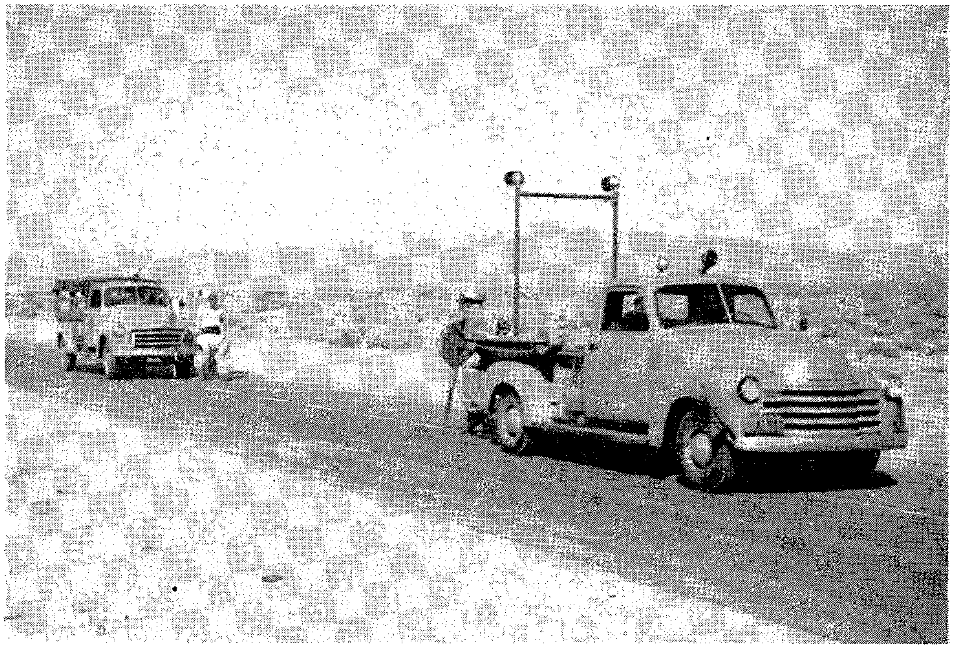
Very truly yours,

STATE HIGHWAY COMMISSION OF WISCONSIN
WAYNE N. VOLK
Traffic Engineer

Traffic Striping

Continued from page 4 . . .

The men placing the spots were required to walk for long distances along the center of the highway between lanes of moving traffic and while watching the rope closely, were unable to clearly observe approaching vehicles. This phase of the work had become so critical that left-handed persons were banned from striping crews because in spotting with the left hand they walked within the traffic lane where vehicles approached them from the rear. Because of their inability to observe these vehicles, several severe injuries have been incurred by left-handed crew men.



Complete spotting equipment upon completion of a run

New Striping Ideas

Much consideration and experiment have gone into efforts to eliminate some of the hazards and to reduce the cost of spotting for new stripes. The traffic striping crew of Highway District VIII under the direction of Foreman W. V. Barrett has developed a few ideas which we feel may be of interest in this respect. Our aim has been to eliminate as far as possible the practice of men working on foot along the center of the highway. By using equipment for this work the crews are assured of greater safety and the work is expedited.

On the front bumper of a light express truck we have mounted a standard paint spray gun with the nozzle adjusted to about three inches above the pavement surface. The spray gun is actuated by means of a solenoid magnet coupled to the control trigger and operated by the operator of the truck by means of a switch button on the steering post. The complete actuating device was taken from a standard automobile starter of the dash button type; however, the starter button was moved to the steering post and fitted with a short lever to permit easy and rapid manipulation.

How It Is Done

To lay out a new stripe a surveyor's transit is set up on an established point on the proposed line about one-half mile ahead. It is sighted back toward the established starting point. Another light express truck equipped with signal lights is parked at the rear of the transit man. The spotting truck is driven in a slightly zigzag course, back and forth across the line of the proposed stripe, not varying more than a foot to either side. The operator is guided by the transit man who indicates by light signals when the nozzle of the spray gun passes across his line of sight. The operator of the spot truck sprays a spot of paint on the pavement at that point and by repeating this operation a line of spots is produced at about 50-foot intervals from the starting point to the transit. The transit man then moves his equipment ahead while the spotting truck remains parked on the last spot to serve as a back sight for the next transit setting. This procedure is repeated until the required distance is covered. By using a hair line sight on the striping machine this line of spots can readily be followed to produce a very satisfactory finished traffic stripe.

Time Is Saved

A great deal of time is saved in spotting by this method—it being possible to spot at the rate of about sixty miles per day as compared to about eight miles per day by the "pig tracking" method. In addition the safety factor is greatly increased because all crew men involved are either within or adjacent to vehicles equipped with flashing red lights which present a very evident warning to approaching motorists. We have not yet had sufficient use of these devices to give any accurate cost data, but it is evident that the saving will be considerable.

This process is still under development and refinements are expected to be made from time to time. Two new ideas we are considering are: First, an easily set, readily adjustable transit mount to expedite the setting of the instrument, and second, the actuating of the spotting spray gun directly by the transit man, by radio control. The latter would eliminate errors due to perception and reflex time of the operator of the spotting truck and also relieve him of the strain of constantly watching the distant light signals. We feel that when these ideas are worked out we will have made appreciable progress in traffic striping procedure.

FOR YOUR PROTECTION

Traffic laws are not unfair restrictions intended to limit the freedom of the motorist. They are intended for everybody's protection, walking or driving. Be safe by obeying them.

Main Street Overhead in foreground. Separation of U. S. 90 and U. S. 50 routes in background

New Route Around Stockton

Continued from page 50 . . .

Structural excavation	24,000	c. y.
Ditch and channel	5,300	c. y.
Overhaul	17,500,000	sta. yds.
Build shoofly trestle	$17,350	
Remove and reconstruct railroad	$22,725	
Class "A" P. C. C. structure	7,938	c. y.
Structural steel	1,499,500	lbs.
Reinforcing steel	1,227,000	lbs.
Timber piling	6,475	l. f.
Concrete piling	8,825	l. f.
Steel railing	2,926	l. f.
Property fence	10.50	miles
CMP "8" to "48"	12,292	l. f.
Welded steel pipe	3,850	l. f.
Mix and Compact CTS	179,400	sq. yd.
Portland cement	6,350	bbls.
Untreated rock base	32,300	tons
Mineral aggregate	15,950	tons
Paving asphalt	764	tons

Cost $3,100,000

The cost of the work including grading, structures, paving and lighting is approximately $2,650,000. The cost of right of way and the reconstruction of utilities amounts to approximately $450,000 for a grand total of approximately $3,100,000 for 5.2 miles of four-lane expressway and two miles of two-lane highway.

A. N. Lund was Resident Engineer at the start of the original contract and after his promotion to Assistant District Construction Engineer, Frank Fleharty took over his duties. The structures were under the general direction of Wayne Deady of the Bridge Department. Work was under the general supervision of M. C. Fosgate, District Construction Engineer.

El Centro Blvd.

Continued from page 48 . . .

Drainage structures included a double 6-foot by 6-foot reinforced concrete box culvert.

In order to allow for future additional base and to keep costs within available funds, it was decided to surface the central 22-foot portion of the 6-inch gravel base with a Class "B" double seal coat.

It is interesting to point out that, although the project is a county project, financing was accomplished with funds provided by the Federal Aid Highway Act of 1944, the County Highway Aid Act of 1945 and Chapter 20 funds. No county funds were necessary thus making the project a tribute to the judicious use of federal aid secondary and state funds.

To Be Extended

Preliminary engineering work was under the supervision of the author. Construction engineering on the roadway portion was handled entirely by engineers of the county road department. Construction engineering of the bridge was undertaken by the State Bridge Department. With the cooperation of District III's Construction Department, Materials Section, and Federal Aid Secondary Department, it is felt that a fine job was achieved.

Sacramento County has extended the road with a similar design section for the next one and one-half miles south of the county line, and sometime in the near future it is hoped that the improvement of this new route will be extended through to Sacramento thus providing a quick and easy route between Sacramento and Yuba City and Marysville.

The newly constructed road lies entirely in Sutter County Supervisorial District Five, of which Eber F. Beilby is the supervisor. Elwyn E. Watkins was resident engineer on the road and E. L. King was resident engineer on the bridge.

HILLS AND CURVES

Never attempt to overtake and pass another car near the crest of a hill or on a curve, where your range of vision is restricted. Keep to your own lane until you have ample sight distance for safe passing.

In Memoriam

WILLIAM TAFT HAIGHT

William Taft Haight, 57, Senior Bridge Engineer with the California Division of Highways, died February 26, 1950, in Glendale, California, after an illness of several months.

Mr. Haight was a graduate of the College of the City of New York and he spent the next five years with the Public Service Commission on the New York Subway and Elevated Railroad System, the New York State Highway Commission and the Baltimore and Ohio Railroad.

He served in the U. S. Army as a commissioned officer during World War I. For four years following the war he was with the New Jersey State Highway Commission, followed by nine years in private engineering and contracting practice in Los Angeles, California, and one year as Construction Engineer, U. S. Forest Service.

From 1933 to 1936 he was on the construction of the San Francisco-Oakland Bay Bridge, followed by four years on bridge construction in Southern California with the Division of Highways.

In 1940 he was called from the reserve into active service with the U. S. Army, and within a period of two years rose from the rank of Captain to that of Colonel and Chief Engineer of the 4th Air Force Area. As such he was in responsible charge of all engineering work connected with the airports of the 4th Air Force area. He was discharged for disability in 1946 and returned to the Bridge Department of the California Division of Highways where he was in direct charge of construction of many millions of dollars worth of bridges in Southern California up to the time of his death.

Col. Haight was awarded the Legion of Merit for "Exceptionally meritorious conduct in the performance of outstanding services from January 1941 to January 1946."

Cooperation

Continued from page 11 . . .

locate themselves and, of primary importance, good highway facilities which will be of the finest when the East Shore Freeway is opened to traffic so as to place San Leandro within 15 minutes of the center of Oakland and within 35 minutes of San Francisco. Here again the developers have extended full cooperation in setting aside the needed portions of their lands until such time as these portions are required for the freeway construction.

All who will enjoy this new East Shore Freeway are deeply indebted to the coordinated efforts of State, county, and city organizations, as well as to the cooperation of the many subdividers along the route, including C. P. Pond, C. W. Leekins, J. E. Kenney, Valley & Lincoln and David D. Bohannon.

AID TO OTHER COUNTRIES

INTERNATIONAL ROAD FEDERATION
WASHINGTON 5, D. C.

MR. KENNETH C. ADAMS, *Editor*
California Highways and Public Works
Sacramento, California

DEAR MR. ADAMS: We have been receiving your magazine "*California Highways and Public Works*" for some time now and have found it very valuable in our work of promoting better highways in other countries of the world.

Cordially yours,

FRANCIS E. TWISS
Director of Planning and Economics

FROM A TAXPAYER

PASADENA, CALIFORNIA

MR. K. C. ADAMS, *Editor*

DEAR MR. ADAMS: I wish to tell you how much, as a taxpayer and property owner, I appreciate your journal both editorially and the high grade and the excellence of its mechanical get-up, and I want to thank you for the share you have in it.

Yours very truly,

CORNELIUS JANSEN

In Memoriam

JOHN A. MOFFITT

It was with deep sorrow that the many friends of John A. Moffitt at the San Francisco-Oakland Bay Bridge and other units of the Division of Highways learned of his sudden death on January 2, 1950.

Mr. Moffitt was born on October 23, 1893, at San Lucas, California. Not long after his graduation from high school in 1912 he entered the United States Postal Service where he remained until May 1917 when he enlisted in the United States Army. He served throughout World War I, taking part in several major battles, and was discharged on June 1, 1919.

He immediately reentered the Postal Service and continued in this work until April 1, 1931, when he was employed by District V of the Division of Highways as a laborer. He later became a highway leadingman and, while working in this capacity, was transferred to the San Francisco-Oakland Bay Bridge on July 1, 1939. He was advanced in 1944 to the position of highway maintenance foreman on the Bay Bridge. In this position, which he still held at the time of his death, he had charge of all roadway maintenance work on the bridge and the continuous 24-hour operation of the emergency fleet of tow, fire, and patrol service trucks.

Mr. Moffitt is survived by his widow, Ethel B. Moffitt, five sons, John A., Jr., William F., David R., James Vargas, and Frederick C., and a daughter, Mrs. Don Kaus, to whom sincere sympathy is extended.

With a profound sense of loss, his associates on the Bay Bridge join his many other friends in saying farewell to "Jack" Moffitt, who was for all of us a symbol of genuine service and an ideal to be imitated in his unselfish devotion to his responsibility.

Freeways

Progress Toward the Ultimate In Highway Transportation

By FRED J. GRUMM, Deputy State Highway Engineer

The following paper was presented by Mr. Grumm to the Highway Division, American Society of Civil Engineers, at the annual meeting of the society in New York.

THE WAR'S END served to emphasize and highlight the accumulating inadequacies in the highway systems of the country. The release from fuel restrictions had the sudden effect of a physical blow in the outpouring of traffic on the highways. All the shortcomings, that had increased so inevitably in the nineteen thirties, were suddenly quite alarmingly apparent. They exceeded the most pessimistic predictions.

The statements in this paper apply particularly to California. Our experience, however, is probably typical and is paralleled by other states and communities. The same phenomena which are presented in our State can be found in a larger picture in the country as a whole or may be reproduced in a smaller community on a reduced scale. Our experience and progress in California should, therefore, be useful.

Whereas motor vehicle registration and highway use increased to over 500 percent from 1920 at 100, expenditures on the state highway system barely reached the 250 percent mark and never exceeded the amount available in 1930. This condition was exaggerated and aggravated by the war.

Highway Deficiencies

For the four years of the war, when maintenance operations were the only permissible activity on the established highways, we devoted the time of our reduced engineering forces to a detailed study of the deficiencies on the state highway system and to the completion of plans for correcting these deficiencies. By the end of the war, we found that these deficiencies had in many instances become critical and we so termed them in our report to the Legislature at its 1945 Session. Of these

Fred J. Grumm

deficiencies the large majority—about 75 percent—were of the type: "inadequate capacity."

Although traffic volume had been steadily increasing, two-lane roads as a whole were still functioning fairly well in the early part of the 'thirties except perhaps for some of the major and more important highways. These were cared for by simply increasing the number of lanes. The troubles of traffic congestion were not too widespread, but by 1935 were attracting the attention of the engineers. The dismal effect of "ribbon city" development became more pronounced and ironically on the very sections of highway we had improved to greater capacity. Conflict of vehicle movements, congestion, increased accidents always accompanied this development of abutting property; and as an attendant corollary there was inevitably the disappointing loss of capacity.

Only Temporary Relief

We were providing only temporary relief when we constructed additional lanes. We were wasting our money and efforts. The motor vehicle user, who contributed the funds for improving and maintaining the highways was getting little return for his money. The abutting property owner, who contributed nothing from property taxes toward the highway improvement, profited by the increased values created and helped destroy the efficiency of the road by his improvements.

The need for highways with maximum capacity and minimum hazard probably came on us gradually, but our awareness of the need came more suddenly. Diligent searchings and explorations for an adequate solution led to tentative consideration of the "freeway principle": The principle of control of access to the roadway. It became a law in California in 1939. Here a freeway is "a highway in respect to which owners of abutting land have no right of easement or access to or from their lands or in respect to which such owners have only a limited or restricted right of easement or access."

Freeway Definition

The American Association of State Highway Officials has adopted the following definition of a freeway: "An expressway with full control of access," and an expressway is: "A divided arterial highway for through traffic with full or partial control of access and generally with grade separations at intersections." Control of access in its adopted definitions is: "The condition where the right of owners or occupants of abutting land or other persons to access, light, air, or view in connection with a highway is fully or partially controlled by public authority."

To the ultimate solution, the important features of the "expressway," such as divided roadway, separated cross-traffic, no left turns, direct interchange facility, ample right of way, no pedestrians, simple and adequate signs, are a definite requirement, but the important fundamental quality that creates the high, lasting character is the "freeway principle."

After the passage of the freeway law in 1939, the discreet application of the principle to our highway improvement produced only a few examples of freeways before our efforts were halted by the war. Opportunity for observation under normal operation was limited as to time and the benefits produced, therefore, were not announced until proof by further experience could be provided. We now have amplified that experience; we have more and substantial proof of the qualities and characteristics of the freeway.

Freeway Benefits

The freeway eliminates the conflicting traffic movements that are induced by development of abutting property; it reduces congestion, accidents, and hazard; it produces greater freedom of vehicle movement and relieves the nervous strain of driving; it produces a highway facility with maximum traffic capacity and this inherent benefit is retained so long as the "freeway principle" is maintained.

Extended studies by the Committee on Highway Capacity of the Highway Research Board have developed evidence of the high capacity of a freeway. A four-lane freeway is equal in capacity to four city streets, 40 feet wide, with parking prohibited, or eight such streets with parking allowed and with the usual amount of left turning and pedestrian interference. Continuous uninterrupted traffic flow, as is possible on a freeway, is the basic reason for high capacity. The "freeway principle" is flexible and adaptable. As part of our present improvement we need but acquire adequate right of way, position our pavements to provide for expansion and thus provide for future needs, at the same time preserving the integrity and beneficial quality of our freeway.

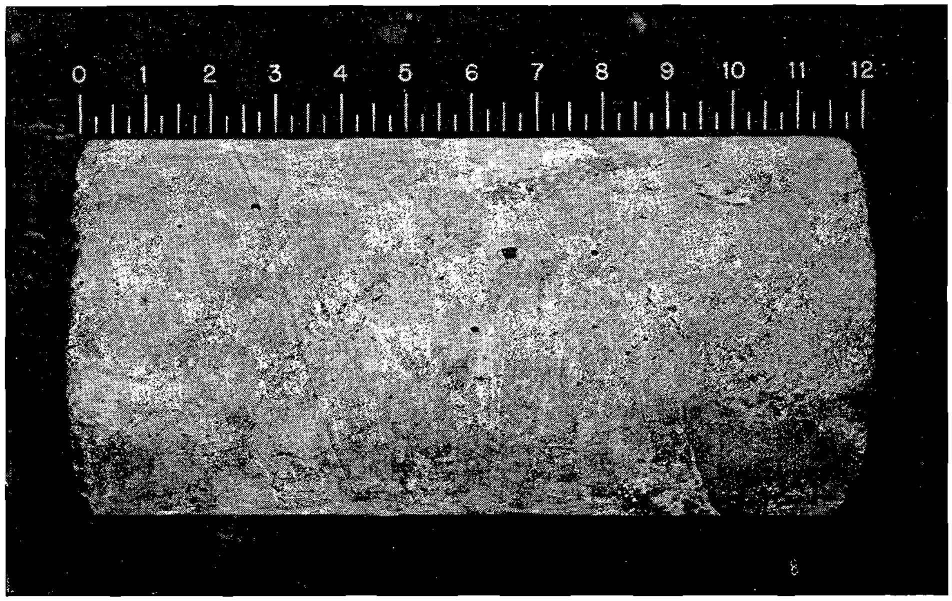
Reduction of Accidents

The freeway is a much safer facility than the ordinary highway. The principal causes of accidents—side friction, conflicting vehicle movement—have been eliminated by the control of access. Comparing accident ratios of Wilshire Boulevard in Los Angeles, a major traffic arterial, with the Arroyo Seco Freeway, we find: Wilshire Boulevard, a 70-80 foot wide street, six traffic lanes, no parking, controlled intersections, carrying approximately 40,000 vehicles daily, has an accident ratio of 2.53 per million vehicle miles; the Arroyo Seco Freeway is a six-lane divided freeway with no parking, no grade intersections, controlled access, carrying approximately 40,000 to 50,000 vehicles daily, has an accident ratio of 0.48 per million vehicle miles—one-fifth of that on Wilshire Boulevard.

Safer Highway Facility

The design features of the freeway all contribute to make it the safer, more comfortable highway facility. The divided roadways reduce the "ap-

Eighteen-Year-Old Concrete Cylinder Unearthed



This photograph shows 18-year-old concrete test cylinder which was unearthed

In connection with the widening of the Carnadero Creek structure on U. S. 101, near Gilroy, excavation in the creek channel unearthed a concrete test cylinder which had been cast 18 years ago during the construction of the original bridge. After it was originally cast the cylinder was apparently buried in the creek bed to complete its curing and then was subsequently either lost or forgotten. The cylinder was in good condition, although the cardboard casting mold had long since disintegrated. In an effort to discover what, if any, effect the aging had worked on the specimen, it was sent to the Division of Highways Laboratory for examination and testing.

During the original construction in 1931, some 14 test specimens were submitted in connection with the work and the average of the breaks for this six-sack concrete was 3,680 p.s.i. Some pavement concrete was also poured and four specimens were tested of the six-sack pavement concrete and they averaged 3,526 p.s.i. The single specimen discovered in 1949 was photographed and subjected to various tests in the laboratory. It was in good condition and developed a very high unit strength.

After 48 hours, soaking in water at 70 degrees to conform to standard conditions, the compressive strength was found to be 6,495 p.s.i. The dynamic modulus of elasticity was found to be 6,702,000 p.s.i. The secant modulus of elasticity at 1,000 p.s.i. was found to be 5,517,000 p.s.i. The weight per cubic foot was 150.4 pounds.

The fracture was of the double cone type and mortar strength was such that considerable fracturing of the coarse aggregates was observed.

Although the test results were possibly of small value in connection with the evaluation of the concrete in the original job, the finding of this cylinder provided an opportunity to make some interesting studies as to the effect of age upon concrete.

proaching" type of accident; the wider lanes and shoulders supplement the elimination of side friction to reduce the "overtaking" type; and separation of grades with the elimination of left turns reduces the "crossing" or "intersecting" type of accident. In the freeway we have developed a highway that possesses the good and desirable qualities of maximum capacity, safety and comfort, and one that is free of the undesirable faults of the ordinary road or street.

Indirectly, the freeway produces other benefits that make it a desirable addition to any community or area. The freeway fosters the economic growth of a community. It enhances the value of adjoining and nearby properties to more than offset the loss of tax revenue from the lands included within the highway right of way and thus removed from the tax rolls. The case study of the Bronx River Parkway made by John Nolen and Henry V. Hubbard and published in their book "Parkways and Land Values" is probably known to you. They present proof that the parkway participated in creating gains in land values in the area affected by the parkway and that these gains were greater in the narrow strip adjacent to it. They indicate that gains of as much as 700 percent may be ascribed to the parkway.

Freeway Boosts Land Values

We recently completed a study of sales of property abutting the freeway in San Joaquin Valley along State Highway Route 4—U. S. 99. All recorded sales of land, abutting the freeway and the frontage or service road, made after the completion of the freeway, were examined. We found that in no case was the payment for land less than the appraised value for which the right of way was acquired. Most of the sales ran from two to six times the appraised value at the time right of way was acquired. Our appraisals were based on fair market value and right of way was acquired at the appraised value. Similar increased values have been observed on other of our freeways.

The reporting of critical deficiencies on the state highway system to the Legislature in 1945 led to the appointment of a legislative Committee on Highways, Streets and Bridges. Its studies extended over a two-year period and embraced county roads and city streets as well as the state highway system. The continuing increase of traffic had also exacted its toll from county roads and city streets. The road and street taxes collected by the local governments were no longer sufficient to meet the demand of increased traffic.

State's Burden Increased

Over the later years a gradual shifting of the burden from local government to the State has taken place. This shift was partly in the transfer of roads and streets to the state highway system and principally in the State's assumption of the greater part, if not all, of the cost of county road and city street administration. These costs are a subsidy to the counties and cities from the State to the extent that very few if any property taxes are levied by the counties and cities for road and street purposes.

The legislative committee's studies resulted in the introduction of bills at the 1947 Legislative Session providing for additional funds derived from motor vehicle and motor vehicle fuel taxes for state highways, county roads and city streets. Over the organized and bitter opposition of the oil companies, the Collier-Burns Highway Law was finally enacted and approved. Increased funds were provided for all three road systems.

Typical Budget

The increased amount produced for state highways exceeds previous amounts by about four times; for construction, about six times. It can be illustrated by using a typical year allotment. The amount available for construction alone in the 1950-1951 Fiscal Year is approximately $90,000,000. Construction in the law is defined to include engineering, rights of way, and construction. The respective percentages of these three are 7, 20, and 70. At the present rate of income, which includes federal aid, about 15 to 20 years will be required to correct the reported state highway deficiencies. These were estimated in 1947 to cost $1,600,000,000, plus.

We are now operating in the third year under the Collier-Burns Highway Act. A budget for the fourth year has been adopted and submitted to the Governor. The deficiencies receiving first attention are, of course, on the major arterials and in the larger metropolitan areas. We are increasing the capacity of these arteries. They are being improved as freeways.

Right of Way for Future

We are securing adequate widths of right of way—basic minimum width 170 feet—to accommodate a six-lane divided highway with all the necessary appurtenances: Acceleration and deceleration lanes, channelized intersection, grade separation and interchange structures, etc.

On some of our rural freeways we are resorting to stage construction. We are omitting temporarily, until traffic needs are sufficient, the ultimate refinements such as separation and interchange structures; but the design is developed and the right of way secured now so that these additional features, which are refinements now but will become necessities, can be readily fitted into place.

We make frequent use of a design providing frontage or service roads where we convert an existing highway into a freeway and where abutting property has been developed.

Status of Freeways

The status of freeways in California as of the end of 1949 was as follows:

	Miles
Total declared freeways at end of war, 9/1/45	588.8
Total declared freeways, 12/31/49	1,440.3
Freeways under construction, 12/31/49	98.2
Freeways completed to 6/30/45	328.7
Freeways completed 7/1/45 to 12/31/49	346.5
Total completed freeways, 12/31/49	675.2

Considerable progress is apparent on such main routes and interstate highways as U.S. 40, U.S. 99, U.S. 101, and U.S. 60, 70, 99 east of Los Angeles. The urban freeways in the Los Angeles and San Francisco Bay Metropolitan Areas are being completed for usable and serviceable distances. Some sections of these latter are of eight-lane divided type.

The "freeway principle" is the most valuable feature of present highway improvement. It will be the principle component of the ultimate highway facility.

The freeway must be recorded as one of the most important developments in highway transportation.

We are making progress. We are providing in our freeway construction a facility that presents the most complete service to traffic yet achieved; a facility that will endure and continue its beneficial service.

Are we not entitled to say that we are making progress toward the ultimate in highway transportation?

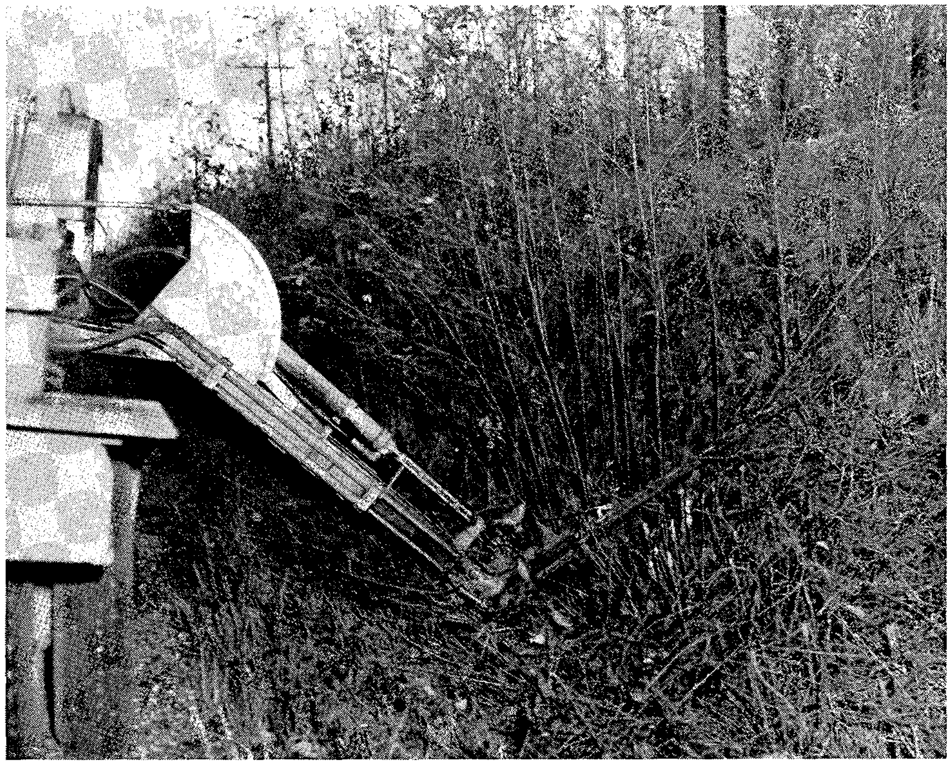
Vegetation Control

Heavy Duty Brush Cutter Is Successful on Highways

By R. A. MILLER, District Maintenance Engineer

BECAUSE OF moderate temperatures and heavy precipitation in various sections of District I, the control of roadside vegetation is a constant problem. It has been observed in a certain section of Del Norte County where an existing highway was abandoned in favor of a new location that within a period of a few years the old highway was impassable due to the vegetation taking over.

The type of vegetation giving the greatest trouble is the alder tree, which thrives in the coastal temperatures and moisture. It is quite common for this tree to increase over an inch a year in diameter and consequently must be controlled continuously.



Brush cutter being demonstrated in Washington, D. C.

Brushing Necessary

Due to the shortage of manpower during the war years, the control of roadside growth was somewhat neglected in favor of keeping the traveled way in traversable condition.

It became apparent in the early part of 1948 that considerable brushing was necessary in order to restore the roadway to its former width and sight distance.

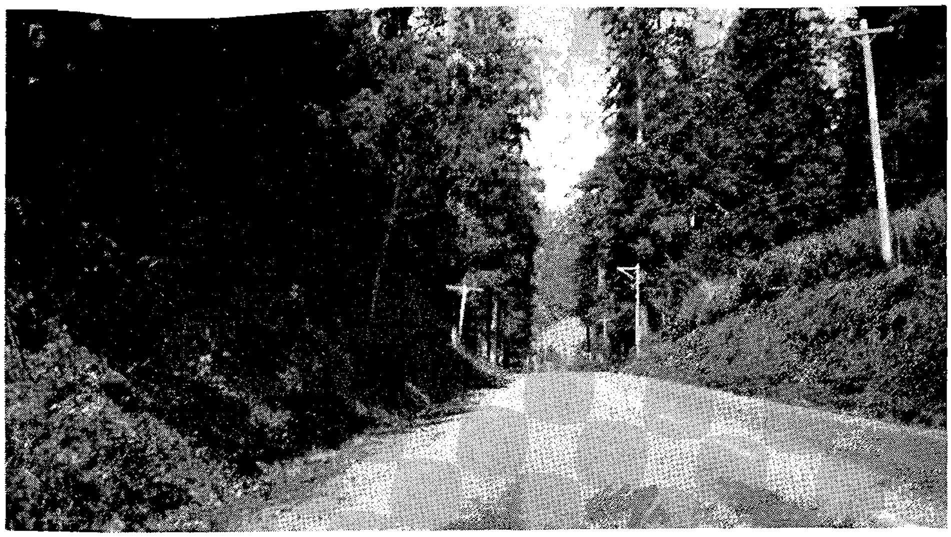
In the early summer of 1948, District I put into operation a heavy-duty brush cutter. This heavy-duty power mower is mounted on a special truck assembly. The machine has an International motor mounted on a revolving and extending carriage on the forward end of the vehicle. A heavy-duty sickle bar is mounted on the end of an extendible boom attached to the carriage.

Here the cutter is making a first pass at the brush

Sickle Bar Control

The sickle bar is controlled by six hydraulic levers and the truck is driven by a separate engine through a conventional gearshift.

The machine will cut a six-foot swath through brush up to approximately three inches in diameter from one-half to one mile per hour, depending upon the diameter and amount of vegetation to be cut.



These high slopes were cleared of bulging growth with mower

The flexibility of the machine is such that the operator is able to cut on any cut or fill slope as well as overhead. Extension of the carriage and boom will permit cutting brush as far as 17 feet from the machine.

Big Money Saving

In many sections on the Redwood Highway, as many as three passes were required because of the heavy brush encountered. The cost of cutting per roadside mile in these areas has been about $82, with a cost of from $25 to $35 per roadside mile for brush removal. Compare these prices with the $400 per roadside mile required when cutting is done by hand.

The subsequent control of vegetation with the brush cutter in the fall of 1949 at those locations previously cut out with the brush cutter in the fall of 1948 shows a decided decrease, being approximately $10 per mile.

Several advantages accrue in the proper control of vegetation other than added width and increased sight distance. It has been noted in several locations that upon completion of clearing operations, the sun and increased circulation of air tends to keep the pavement drier and, consequently, less hazardous because of slippery pavement.

The foreground shows result of mowing brush on slope. Brush in background is typical before-mowing scene

Soil Erosion

Continued from page 41 . . .

investment which has been made in stabilization.

Use of Wet Material

Wet material which is end-dumped from a truck will frequently stand at an angle steeper than 1½:1. This steeper slope can be considered an unstable one, since the 1½:1 angle is that formed naturally by loose soil. When saturated by further rainfall, the dumped material usually slumps, effectively forming channels of concentration which intensify the control problem. When it is necessary to dump wet material over a slope, every effort should be made, first, to flatten and smooth the slope of the dumped material to 1½:1 or flatter, and, second to stabilize the surface with straw, seed, and cuttings as insurance against future trouble.

It is usually possible to find a disposal area in which waste material can be safely dumped within a reasonable hauling distance on most mountain roads. The upper sides of small fills can sometimes be filled in, making a parking or stopping area for the motorist. Other low spots or gentle slopes can be covered with the waste; and if the slope is gentle enough, no further treatment need be given, except, possibly, seeding for the sake of appearance.

Since any form of slope stabilization treatment represents an investment, often a sizeable one, sound economic practice justifies the expenditure of a proportionate amount to protect the investment. The follow-up treatment described here may be carried out so cheaply and so effectively, *if done at the right time*, that its justification should never be questioned.

. . . to be continued

ACKNOWLEDGMENTS

Grateful acknowledgment is hereby made to the many persons who, by their suggestions and encouragement, have contributed to the preparation of this booklet.

Special acknowledgment is due Mr. Chas. C. Morris, Division Engineer of the Public Roads Administration, for suggesting that a publication describing our erosion control methods would be of interest to others faced with similar problems; and later for his review and suggested improvements in the manuscript. Also to Mr. Wilbur H. Simonson, Chief, Roadside

. . . Continued on page 60

In Memoriam

CARL S. T. MARCKHOFF

Veteran of 24 years service with the Division of Highways, Carl S. T. Marckhoff of Sacramento, State Highway Maintenance Superintendent, died on January 17th after a short illness. He had retired on November 18, 1949.

Born in Elgin, Illinois, on November 15, 1889, Mr. Marckhoff had been a resident of California for 30 years. He entered state service in 1921 as Assistant Resident Engineer in District III. He transferred to the Los Angeles office of the Division of Highways as Junior Civil Engineer in June 1924. He left his position for private employment at the end of 1924 but returned to the Division in the summer of 1929 as Resident Engineer in District III. From March 21, 1930, to November 1940, he was Maintenance Superintendent in Districts I, II, IV, V, and X, when he was transferred to the traveling bridge crew. He was brought to the Central Office in Sacramento in June 1944, remaining until his retirement.

Mr. Marckhoff was a member of the Columbus Chapter of the Order of the Eastern Star, the Blue Lodge of the Masons in Elgin, the American Legion and the 23d Engineer Corps Association. He served in France during World War I.

He is survived by his wife, Edith K. Marckhoff; son, William Carl Marckhoff of Pasadena; brothers, Alfred F. Marckhoff of Batavia, Ill., and Lorenz Marckhoff of Omaha, and sisters, Mrs. William Gerrish of San Francisco and Mrs. Ray Hoehn of Hayward. He was the brother of the late Mrs. Dorothea Niederholzer.

ACKNOWLEDGMENTS

Continued from page 59 . . .

Section, Public Roads Administration; Mr. C. J. Kraebel, Division of Forest Influences, U. S. Forest Service; Mr. J. S. Horton, San Dimas Experimental Forest, U. S. Forest Service; Professor Joseph Kittredge, Professor of Forestry, Forest Influences, University of California; and Mr. C. H. Gleason, Forester, U. S. Forest Service, for their valuable suggestions and constructive criticism; and to Mr. L. S. Manning, Associate Landscape Architect, California Division of Highways, for his compilation of this manuscript.

H. DANA BOWERS

PITY THE DISTRICT ENGINEER

The average California motorist has no more difficulty making $5 do the work of 10 than has the Budget Department of the Division of Highways in stretching the gas tax income to meet the need. Both know it can't be done.

J. W. Vickrey, Assistant State Highway Engineer and Chief of the Planning Department of the Division of Highways, at head of table; with Harry L. Kile, Budget Engineer, on his right; and J. C. Womack, Assistant Planning Engineer, on his left; give sympathetic attention to the presentation of plans and programs by each of the 11 highway district engineers. An urgent need for over $200,000,000 worth of work has been presented.

"But," says Vickrey, "what can I do? We estimate that there will be but $96,000,000 available for highway construction for the next fiscal year. Not even a genius could make that do $200,000,000 worth of work."

C. H. Whitmore, District Engineer of District III, with headquarters at Marysville, the dejected looking fellow, and John P. Murphy, his assistant, know just what Vickrey means.

Feeding two continuous blueprint machines in Headquarters Reproduction Department. Machine in foreground running paper tracing at seven feet per minute

Reproduction Materials

Continued from page 47 . . .

on one or both sides. Reflex film functions in the same manner as any photographic reflex paper, the theory being that dark areas absorb light, and light areas reflect light. With reflex film a diazo light sensitive substance is used as sensitizer rather than a photographic emulsion, thereby eliminating the necessity of dark room, washing, and fixing tanks. This new product adds considerably to the versatility of the semimoist diazo type copying field.

Prints on any of these reproduction materials may be made by exposing to sunlight or artificial light. The earliest method followed was exposing the coated stock in a sun frame (like a picture frame) with the tracing between the glass and the print. Developing and fixing was done in small open trays. Although this method is still practical for remote locations where few reproductions are required, most processing is now done by machines equipped with arc lights or high pressure mercury quartz tubes as a light source. These machines handle rolls of paper from 18 inches to 54 inches wide at speeds from 6 lineal inches to 32 lineal feet per minute, and many models expose, develop, wash, fix and dry in one continuous operation with the prints emerging from the machine ready for use.

Reproduction Machines

The California Division of Highways has reproduction machines in 10 of its 11 districts as well as three machines in its Headquarters Reproduction Department. These machines range from those printing a few feet per minute to the most modern, high speed, continuous models. Almost 400,000 square yards (about 80 acres) of reproduction papers, cloth and film are used each year to convey the highway and bridge engineers' designs to the contractors' forces on the job.

For many years, reproduction materials were obtained from distributors through the State Purchasing Division as needed, at prices in excess of those paid by commercial reproduction establishments despite the fact that the California Division of Highways used a greater quantity than most commercial concerns. Research among the present specifications used by commercial and governmental agencies failed to produce a satisfactory guide for the acquisition of these reproduction prod ucts. In order to produce specifications that were rational and consistent with present manufacturing practices an analysis of the results desired was undertaken and the following factors deduced.

Sensitive to Light

Blueprint and diazo reproduction materials are sensitive to light and moisture, so they must be well protected with light and moisture-proof wrappers until ready for use. Even when so protected, they should be stored in a cool dry place to prevent premature aging. If coatings are not carefully compounded, the materials may age rapidly even under ideal storage conditions and not produce satisfactory prints. This aging may become apparent in less than a month, whereas a good coating will not show any appreciable deterioration in four months or more.

A good reproduction material should give excellent prints when exposed to light for various lengths of time within reasonable limits. For example, a paper rated to print at 15 feet per minute should give acceptable prints from about 12½ to 17½ feet per minute. This range of speeds, within which acceptable prints are produced, is defined as the "latitude" of the material.

Water Resistant

The lines on prints should be water resistant as very often the prints are to be tinted with water color and working drawings are occasionally exposed to wet weather on the job. "Bleeding" of the lines under these conditions would be aggravating.

On the job in the field, prints are exposed to direct sunlight from time to time, so they must be lightfast, as fading would make them difficult to read.

As there were no specifications and tests to control these characteristics, the Stores Department of the Division of Highways tested and analyzed a great variety of reproduction materials in order to evaluate their qualities and determine standards consistent with the above needs.

Before any comparative tests could be made, it was found that a standard test tracing was necessary. It was decided to use a cloth tracing 11 inches by 8½ inches with an opaque portion 4 inches by 6 inches and various weights of lines from .005 inch to .040

Operator feeding small paper tracings into continuous ammonia process printer in Headquarters Reproduction Department. Printing on cut sheets at 10 feet per minute

inch. This standard test tracing is described in detail in the specifications for diazo reproduction materials which are quoted in this article.

The principal apparatus developed to test the quality of the test prints is the "reflectometer." This apparatus measures the light reflected from a surface with the aid of a photoelectric cell. A ground milk glass is used as a standard and represents 100 percent reflectance, while a piece of black velvet represents zero reflectance.

Acceptable Print

Figure 1 shows typical curves of an acceptable print. The upper curve shows the contrast index at various printing speeds. Contrast Index as defined in the preceding specifications is the difference in reflectance, in percentage, between the exposed and unexposed portions of a test print. This figure also illustrates the latitude, previously defined, and in this case appears to be 7½ feet per minute. However, as shown by the lower curve, the discoloration of the paper due to uncleared coating, known as "Fog," reduces the latitude to a little over six feet per minute.

On the basis of the Division of Highways specifications, the Stores Department asked the Purchasing Division to call for competitive bids for one year's supply of diazo materials for the whole Division of Highways, to be delivered as requested. Contracts were entered into with two distributors, on the basis of their low bids and conformance of their materials with the above specifications. As a result a savings of over $4,400 on reproduction materials alone is expected for the year.

After observing the workability of the specifications and tests for several months, a few desirable changes are to be incorporated to broaden competition and obtain better materials.

The specifications are being revised to permit three percent of fog on prints on opaque paper. The provision that paper stock shall be 50 percent rag or better is being eliminated to permit the use of good sulphite paper. Experience has shown that rag content is not a definite criterion of a good paper.

Intermediate Prints

Prints are often made on transparent paper from which opaque prints can be made after revision or modification. Such prints on transparent paper are called intermediates. A new important provision is to be included requiring that prints from intermediates must be acceptable when intermixed with cloth tracings of good quality, using a continuous printing device without changing speed of printing and without using any transparentizing treatment. An opacity test is to be added to evaluate this characteristic.

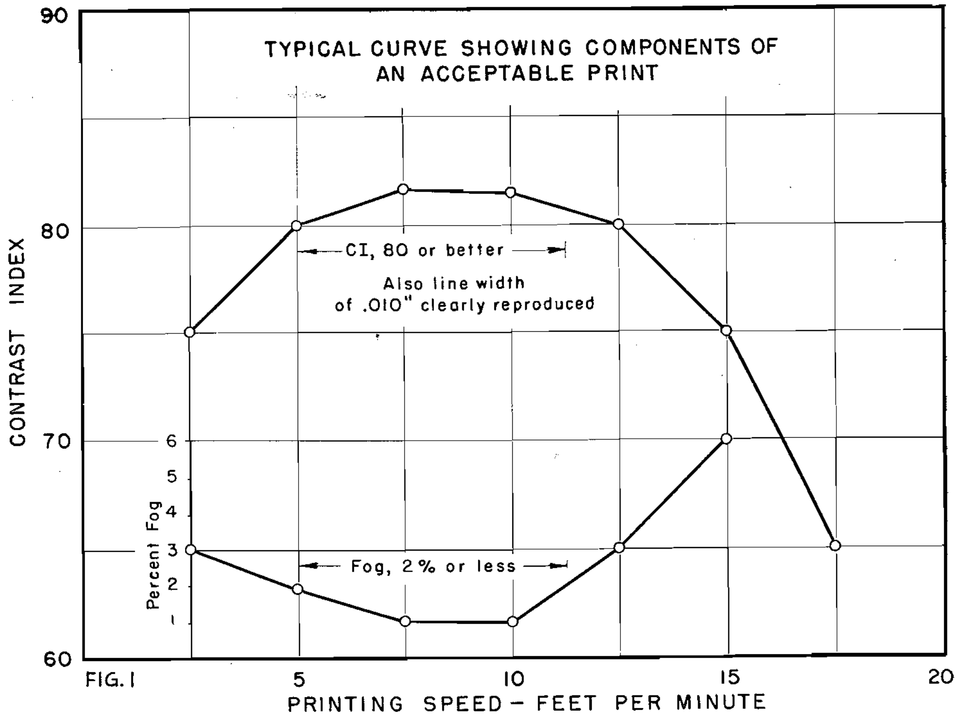


FIG. 1

The Stores Department has also written specifications for blueprint and blueline materials similar to those for diazo products and is conducting research on negative papers to obtain data from which specifications may be prepared.

Saving of Money

The above detailed study exemplifies the engineering approach, study and results as applied to manufactured products used in highway construction. Considerable research and study has been given to materials such as asphalts, cements and aggregates entering directly into construction work, but only since the advent of the Stores Department has the same type of engineering effort been applied to manufactured products, which are necessary accessories to highway construction. It is the present objective of the Stores Department to render this engineering service to all commodities purchased from manufacturers with a consequent savings of highway funds and a decided improvement in quality of products purchased. Fundamentally, Stores Department engineers are continually seeking to acquire the maximum quality for each dollar expended. Each dollar saved means an additional dollar for highway construction and improvement.

Specifications for Reproduction Paper

After exhaustive tests and analyses, the following specifications for diazo reproduction materials were prepared by the Stores Department in conjunction with the Materials and Research Laboratory to obtain the best possible results consistent with cost and our needs. In this work, the engineers of the Stores Department received the close cooperation of Mr. Glen Morgan, Assistant Physical Testing Engineer of the Materials and Research Department, who performed much careful and painstaking work. The Headquarters Reproduction Department also cooperated by making its equipment available for producing test prints.

SCOPE

This specification covers reproduction papers suitable for use in commercial, continuous process printing machines using the dry ammonia vapor developing system. The paper is to be used in the "Ozalid Print Master Machine," Model B, Model F, or Streamliner. All test prints are to be made on a Model B machine at full light intensity.

DEFINITION OF TERMS

Fog—The discoloration of the paper stock due to uncleared coating shall be known as fog.

Contrast Index—The difference in percent reflectance between the exposed and unexposed portion of a test print which has been fully developed.

Latitude—The exposure range at which acceptable prints are obtainable, expressed in feet per minute.

Shelf Life—Maximum age of paper, from date of shipment by California distributor, which will produce an acceptable print.

Lightfastness—Resistance to fading, discoloration or fogging due to sunlight.

Water Resistance—Resistance to "bleeding" or "running" of any portion of the print due to the solubility of the fixed dye.

Standard Test Tracing—The standard test tracing shall be made on a good quality of cloth and shall be eight and one-half by eleven inches. A portion four by six inches shall be opaque. (This is best done by attaching a sheet of black opaque paper to the tracing with a strip of scotch tape.) A series of lines shall run across the tracing, one each of the following width, .040", .020", .010" and .005", correctly labeled. Directly underneath these lines, the following line of printing shall be made with a Leroy lettering pen, size of pen, 00; size of template, 100 (or equal), "Department of Public Works Division of Highways, Sacramento 16, California." A standard waterproof India ink shall be used.

Acceptable Print—A print from the standard test tracing that clearly reproduces a line width of .010" having not more than two percent of fog and a Contrast Index of not less than 80, is an acceptable print.

SPECIFICATIONS

Fog—The cleared portion of the test print shall have not more than two percent fog.

Speed—The printing speed shall not be less than 5 nor more than 15 feet per minute.

Contrast Index—The contrast index shall not be less than 80.

Latitude—The latitude of printing shall not be less than 5 feet per minute.

Shelf Life—The shelf life shall not be less than four months.

Lightfastness—Reduction of contrast index due to sunlight, not more than 10, increase in fog not more than 5 percent.

Water Resistance—When tested as herein described, reflectance of the test specimen shall not be reduced by more than 10%.

Intermediate Paper—Sensitized paper to be used for making temporary or intermediate translucent tracings shall comply with all of the above specifications except those for Water Resistance and Latitude. In addition, the intermediate tracing made from this type of paper must produce an acceptable print.

Paper Stock—The paper stock shall be 50 percent rag or better and of a uniform quality free of any defects that in any way affects the serviceability of the paper, or the uniformity of the sensitized coating. Reproduction paper shall be suitable for use in commercial, continuous process printing machines using the dry ammonia vapor.

Packaging—Each roll shall be one continuous piece and wrapped in a moisture and light proof covering. Sheets shall be similarly protected.

Packing—Unless otherwise specified the commodity shall be delivered in standard commercial containers so constructed as to insure acceptance by common or other carriers for safe transportation, at the lowest rate, to the point of delivery.

Marking—Each roll shall be labeled with the name of the material, the type, class, brand, weight, width, lot number and yardage contained therein.

Each roll or package shall be plainly marked with the date of shipment. This date shall be used to compute the shelf life.

General—Failure to comply with any of these specifications will be cause to reject a bid.

Material will be tested at various times after delivery and any defective paper found in a shipment must be replaced without cost by the vendor.

TEST METHODS

Sampling—Not less than 50 sheets 8½ x 11 inches of each weight and type shall be submitted with the bid as representative of the material to be delivered. Sample sheets shall be properly packaged and labeled.

All tests are to be made by the Division of Highways, Materials and Research Department, Sacramento, California.

Reflectance—All reflectance measurements are to be made with a suitable photoelectric measuring device, provided with a filter to correct the spectral response of the photocell to that of the standard observer curve.

A ground milk glass panel is used as a standard and represents 100 percent reflectance and a piece of black velvet as zero reflectance.

All reflectance measurements are to be made upon a single sheet backed up with the standard ground milk glass panel. Readings are made 24 hours after exposure.

All tests are to be made in triplicate and the average value reported.

Contrast Index and Latitude—A series of prints are made with the standard test tracing using a range of exposures that will produce both under and over exposed prints. Exposure steps of approximately two feet per minute shall be used. It is desirable to plot the contrast index against the exposure in feet per minute. From this curve, the Latitude of the paper is established in accordance with the definition of an acceptable print.

Fog—The reflectance of the back of the cleared portion of a fully exposed and developed test print is to be considered as the maximum reflectance of the paper.

The difference between this figure and readings taken on the cleared portion of the test prints shall be known as fog and reported as percent.

Shelf Life—The shelf life of the paper is to be determined as outlined:

Unexposed sheets are to be conditioned at 70° F. ± 2°, 50 percent relative humidity ± 5 percent for 24 hours. The paper is then placed in a moisture, lightproof container and placed in an oven maintained at 120° F. ± 1° for 72 hours.

After cooling to room temperatures test prints are made at optimum exposure and the contrast index shall not have been reduced by more than 10 nor the fog increased by more than 5 percent.

Water Resistance—A series of lines, .050" wide and .100" apart are drawn with a standard waterproof India ink on an 8½ x 11 inch tracing cloth of good quality. An area of 4 x 6 inches is covered with this gridwork of lines. Prints are made at optimum exposure, and the reflectance of this gridwork is measured. The test prints are dipped five times, two seconds each dip, into distilled water, in such a manner that the lines are horizontal. Drain for five seconds after each dip. After drying, the reflectance is again measured and the difference is reported in percent.

Lightfastness—Test prints shall be exposed to a G. E. S-4 bulb operating at a primary voltage of 115 volts A. C. ± 2 volts. The bulb is used without a reflector, the prints being placed on the inside of a slowly revolving cylinder 18" in diameter. This test is to be made at 70° F. ± 2; 50 percent relative humidity ± 5 percent.

Exposure shall be for 10 hours. The contrast index shall not be reduced by more than 10 nor the fog increased by more than 5 percent.

Uniformity of Coating—Three sheets are developed to produce maximum color and examined for defects in coating and shall be reported as satisfactory or unsatisfactory.

EARL WARREN
Governor of California

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CHARLES H. PURCELL
Director of Public Works

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FRANK B. DURKEE
Deputy Director

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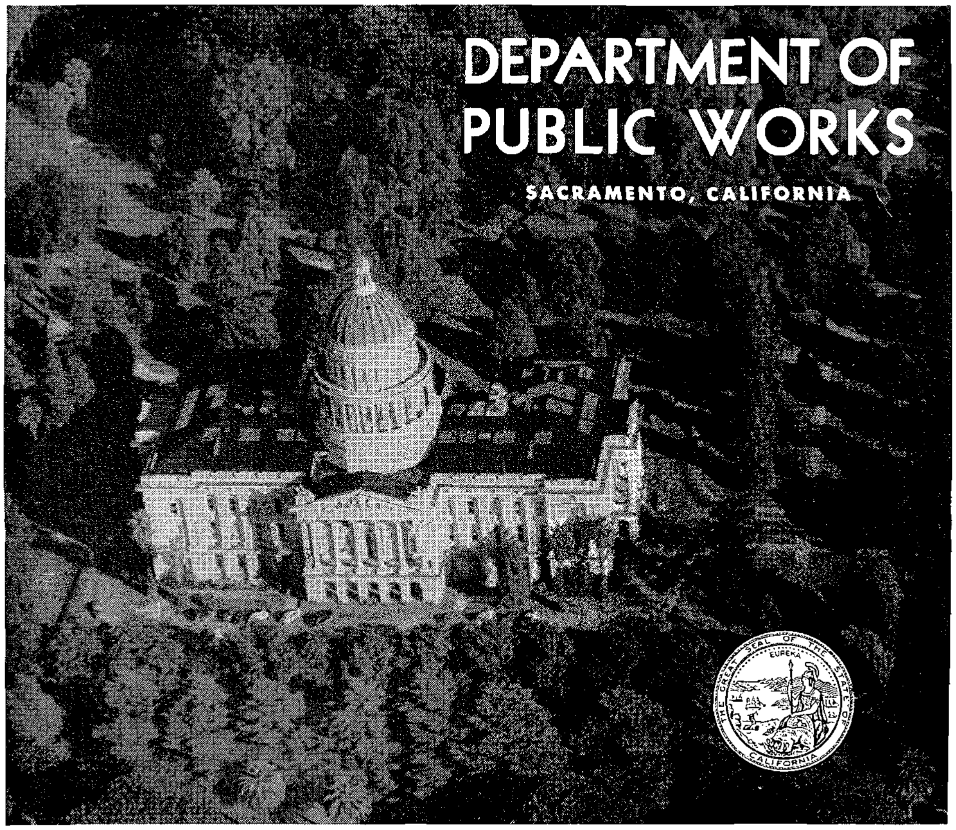

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printed in CALIFORNIA STATE PRINTING OFFICE 22400 3-50 26M

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