RAMP METER DESIGN MANUAL

Prepared by:
Traffic Operations Program

In Cooperation with:
Design and Local Programs
and
Department of California Highway Patrol

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Foreword

Caltrans is committed to using ramp metering as an effective traffic management strategy to maintain an efficient freeway system and protect the investment made in constructing freeways by keeping them operating at or near capacity. Ramp Metering is an integral part of the Traffic Operations Program Strategic Plan which outlines the program's commitment to focus first on implementing operational strategies to reduce congestion and increase safety on California's state highway system.

This manual has been prepared to give Caltrans designers, as well as consulting engineers hired by Caltrans, and cities/counties performing design work on State highways, a comprehensive document covering the design and operation of ramp meters. It is a supplement to, but does not supersede Caltrans' Highway Design and Traffic Manuals, Standard Plans, Standard Specifications, Standard Special Provisions, and other current design policies. This Manual is not a textbook or a substitute for engineering knowledge, experience, or judgement. It is not intended that any standard of conduct or duty toward the public shall be created or imposed by the distribution of this manual. Special situations may call for variations as conditions and experience warrant. However, on state highways significant variations are subject to Headquarters approval.

This manual describes traffic operational policies, design standards and practices for ramp metering installations at new or existing entrance ramps. Projects within freeway segments identified in the <u>Ramp Meter Development Plan</u> should include provisions for ramp metering. It is the responsibility of the designer to allow the appropriate lead time needed to include ramp metering in a project. *However, before beginning any ramp meter design, designers shall contact the District Operations Branch responsible for ramp metering for direction on the application of these guidelines.*

HOW TO USE THIS MANUAL: As these guidelines are a supplement to the Highway Design Manual (HDM), the use of **boldface** type and <u>underlining</u> are used herein to indicate mandatory and advisory design standards respectively. The requirements, pertaining to compliance with these design standards, are detailed in Topic 82 of the HDM.

Boxed text indicates traffic operational policies. Any deviation from the traffic operational policies advised in these guidelines will require a justification that may be provided in the project report. Concurrence with deviations from the traffic operational policies shall be obtained from the Traffic Operations Program Manager or his/her designated representative unless otherwise stated.

Italics are used to indicate procedural requirements; specifically, the involvement of Traffic Operations personnel (from both the District and Headquarters) and the Project Development Coordinator and/or the Geometric Reviewer from Design and Local Programs in the decision making process.

CHAPTER ONE

I. DESIGN OF METERED RAMPS

Geometric ramp design for new facilities should normally be based upon the projected peak-hour traffic volumes 20 years after completion of construction, except as stated in the Highway Design Manual (HDM) Index 103.2.

Geometric ramp design for operational improvement projects (including ramp meters) should be based on current peak-hour traffic volume (this is considered to be data that is less than two years old). If this data is not available it should be obtained before proceeding with design. Peak hour traffic data from the annual Traffic Volumes book is not adequate for this application.

The design advice and typical designs that follow should not be directly applied to ramp meter installation projects, especially retrofit designs, without giving consideration to "customizing" the geometric design features to meet site and traffic conditions (i.e. design highway volume, geometry, speeds, etc.). Every effort should be made by the designer to exceed the recommended minimum standards provided herein, where conditions are not restrictive.

All geometric designs for ramp metering installations shall be discussed with the Project Development Coordinator or Geometric Reviewer from Design and Local Programs. **Design features or elements which deviate from the mandatory standards of the HDM or these guidelines require the approvals described in HDM Index 82.2**

A. Metered Single-Lane Entrance Ramps

Geometrics for a single-lane ramp meter should be provided for volumes up to 900 vehicles per hour (vph) (see Figures 1 and 2). <u>Where truck volumes (3-axle or more) are 5% or greater on ascending entrance ramps to freeways with sustained upgrades exceeding 3% (i.e. at least throughout the merge area), a minimum 150 m length of auxiliary lane should be provided beyond the ramp convergence point.</u>[1]

A multi-lane ramp segment may be provided to increase vehicle storage within the available ramp length (see Section D, Storage Length) and/or to create a preferential lane for HOVs.

B. Metered Multi-Lane Entrance Ramps

When entrance ramp volumes exceed 900 vph, and/or when an HOV lane is determined to be necessary, a two or three lane ramp segment should be provided. Figures 3 through 5 illustrate typical designs for metered two-lane ramps; and Figures 6 and 7 illustrate typical designs for metered three lane ramps. On two-lane loop ramps, normally only the right lane needs to be widened to accommodate design vehicle off-tracking.

Three-lane metered ramps are typically needed to serve peak (i.e. commute) hour traffic along urban and suburban freeway corridors. The adverse effects of bus and truck traffic on the operation of these ramps (i.e. off-tracking, sight restriction, acceleration of characteristics on upgrades, etc.) is minimized when the ramp alignment is tangential or consists of curve radii not less the 90 m.

The recommended widths for metered ramps are:

	Pavement Widths		
Metered	Traveled[2]	Shoulder	
Ramp	Way	Inside	Outside
1-lane	3.6 m	1.2 m	2.4 m
2-lane	7.2 m	1.2 m	2.4 m
3-lane	10.8 m	0.6 m	0.6 m

[1]A guide for determining the additional length of acceleration lane needed for grades is in Table X-5 of "A Policy on Geometric Design of Highways and Streets, 1994" by AASHTO.

On local street entrance ramps, the multi-lane segment should transition to a single lane width between the ramp meter limit line and the 2 m separation point (from the mainline edge of traveled way).

The lane drop transition should be accomplished with a taper of 50:1 unless a lesser taper is warranted by site and/or project specific conditions which control the ramp geometry and/or anticipated maximum speed of ramp traffic. For example, "loop" entrance ramps would normally not allow traffic to attain speeds which would warrant a 50:1 lane drop taper. Also, in retrofit situations, existing physical, environmental or R/W constraints may make it impractical to provide a 50:1 taper, especially if the maximum anticipated approach speed will be less than 80 km/h. Therefore, depending on approach geometrics and speed, the lane drop transition should be accomplished with a taper of between 30 and 50:1. **However, the lane drop taper past the limit line shall not be less than 15 to 1.**

Where truck volumes (3-axle or more) are 5% or greater on ascending entrance ramps to freeways with sustained upgrades exceeding 3% (i.e. at least throughout the merge area), a minimum 300 m length of auxiliary lane should be provided beyond the ramp convergence point.[3]

When ramp volumes exceed 1,500 vph, a 300 m minimum length of auxiliary lane should be provided beyond the ramp convergence point. If an auxiliary lane is included, the ramp lane transition may be extended to the convergence point. However, the proximity of the nearest interchange may warrant weaving analysis before the ramp lane transition is extended beyond the 2 m separation point. A longer auxiliary lane should be considered where mainline/ramp gradients and truck volumes warrant additional length.

[2] See the Highway Design Manual, Index 504.3, for providing additional ramp width for radii 90 m or less.

[3] A guide for determining the additional length of acceleration lane needed for grades is in Table X-5 of "A Policy on Geometric Design of Highways and Streets, 1994" by AASHTO.

C. Metered Freeway-to-Freeway Connectors

Freeway-to-freeway connectors may also be metered when warranted. The need to meter a freeway-to-freeway connector should be determined on an individual basis. Because connector ramps provide a link between two high speed facilities, drivers do not expect to stop, nor do they expect to approach a stopped vehicle.

The installation of ramp meters on connector ramps shall be limited to those facilities which meet or exceed the following geometric design criteria:

- standard lane and shoulder widths
- "tail light" sight distance, measured from 1070 mm eye height to a 600 mm object height, is provided for a design speed of 80 km/h minimum

All lane drop transitions on connectors shall be accomplished with a taper of 50:1 minimum (see Figures 8 and 9).

D. Storage Length

In keeping the Strategic Plan to maximize the effectiveness of operational strategies, an important design consideration for a ramp meter system is providing adequate storage for queues. *The District Operations Branch responsible for ramp metering shall be consulted to determine the desirable ramp meter storage.*

Ramp meters have practical lower and upper output limits of 240 and 900 vph per lane, respectively. Ramp meter signals set for flow rates outside this range tend to have high violation rates and cannot effectively control traffic. Therefore, on a ramp with peak hour volume between 500 and 900, a two-lane ramp meter may be provided to double the vehicles stored within the available storage area. A single-lane ramp meter should be used when rates are below 500 vph and no HOV preferential lane is provided.

To minimize the impact on local street operation, every effort should be made to meet the recommended storage length. Wherever feasible, ramp metering storage should be contained on the ramp by either widening or lengthening it. Improvements to the local street system in the vicinity of the ramp should also be thoroughly investigated where there is insufficient storage length on the ramp and the ramp queue will adversely affect local street operation. The storage length that can be provided on the ramp may be limited by the weaving distance to the next off-ramp and available right of way. These improvements can include widening or restriping the street(s) or intersection(s) to provide additional storage or capacity. Signal timing revisions along the corridor feeding the ramp can also enhance the storage capability. These will require coordination with the local agency consistent with the regional traffic operations strategy. Ultimately system-wide adaptive ramp metering will coordinate with local street and arterial signal systems.

The current peak period 5, 6, or 15 minute arrival rates and anticipated or current ramp meter discharge rates should be used to determine the storage length required for ramp metering (see Arrival-Discharge Chart in the Appendix). It is recommended that a minimum vehicle spacing of 9 m be used for designing storage on metered ramps. Additional spacing should be provided for locations where there are significant percentages of trucks, buses, or recreational vehicles.[4]

It is the responsibility of Caltrans, on Caltrans initiated projects, to mitigate the effect of ramp metering, for initial as well as future operational impacts, on local streets that intersect and feed entrance ramps to the freeway. Developers and/or local agencies, however, should be required to mitigate any impact to existing ramp meter facilities, future ramp meter installations, or local streets, when those impacts are attributable to new development and/or local agency roadway improvement projects.

[4]Tom, G. & Fong, H. Vehicle Spacing for the Design of Metered Ramps, October 1992, FHWA/CA/TO/TOS-92-4

E. Structural Section

In planning for the possibility of future widening, the structural section for the ramp shoulders should be equal to the ramp traveled way structural section . In locations where failure of loop detectors due to asphalt concrete pavement deterioration is a concern, a Portland Cement Concrete (PCC) pad may be considered on new construction and rehabilitation projects. The concrete pad should cover the metering detector loop area upstream and downstream of the limit line.

F. Meter Location

On single-lane ramps, the ramp meter signal standard should be placed on the driver's left (see Chapter Two, Section A and Figure 12).

G. Limit Line Location

The limit line location will be determined by the selected transition taper, but should be a minimum of 23 m upstream of the 7 m point on the entrance ramp as shown in Figures 1 through 9. A single 300 mm solid white line shall be placed across all metered lanes. Staggered limit lines shall not be used.

H. HOV Preferential Lane

Ramp meter installations should operate in conjunction with, and complement other transportation management system elements and transportation modes. As such, ramp meter installations should include preferential treatment of carpools and transit riders. Specific treatment(s) must be tailored to the unique conditions at each ramp location, however the standard or base treatment upon which other strategies are designed is the High Occupancy Vehicle (HOV) preferential lane.

An HOV preferential lane shall be provided at all ramp meter locations.

In general, the vehicle occupancy requirement for ramp meter HOV preferential lanes will be two or more persons per vehicle. At some locations, a higher vehicle occupancy requirement may be necessary. The occupancy should be based on the HOV demand and coordination with other HOV facilities in the vicinity.

A preferential lane should typically be placed on the left, however demand and operational characteristics at the ramp entrance may dictate otherwise. The *District Operations Branch responsible for ramp metering shall determine which side of the ramp they shall be placed, and whether or not the HOV lane will be metered.*

- ❒ It is the policy of Districts 4, 6, 8, and 11 to meter the HOV preferential lane

- ❒ Districts 3, 7, and 12 <u>typically</u> do not meter the HOV preferential lane

Access to the HOV preferential lane may be provided in a variety of ways depending on interchange type and the adequacy of storage provided for queued vehicles (see Figures 17 and 18). Where queued vehicles are expected to block access to the HOV preferential lane, direct or separate access should be considered. Designs should consider pedestrian/ bicycle volumes, especially when the entrance ramp is located near a school or the local highway facility includes a designated bicycle lane or route. *Contact the Traffic Operations Reviewer and the Geometric Reviewer to discuss the application of specific design and/or general issues related to the design of HOV preferential lane access.*

Signing for an HOV preferential lane should be placed to clearly indicate which lane is designated for HOVs. Real-time signing at the ramp entrance, such as an overhead extinguishable message sign, may be necessary at some locations if pavement delineation and normal signing do not provide drivers with adequate lane usage information. To avoid trapping Single Occupancy Vehicles (SOVs) in an HOV preferential lane, pavement delineation at the ramp entrance should lead drivers into the SOV lane.

I. Modifications to Existing HOV Preferential Lanes

Changes in traffic conditions, proposals for interchange modifications, recurrent operational problems affecting the local facility, or the need to further improve mainline operations through more restrictive metering all provide an opportunity to reevaluate the need for an HOV preferential lane. HOV preferential lanes should remain in place or be added to the scope of projects generated in response to any of the above scenarios. Alternate solutions should be investigated before removal is considered. For example: Better control over ramp traffic can be attained by retrofitting ramps to meter HOV traffic which bypasses the ramp meter (District 3, 7, and 12). Underutilization of an existing lane plus the need for additional Right of Way for storage; the availability of an alternate HOV entrance ramp within 2 km; or the availability of a direct HOV access (drop) ramp will typically provide adequate justification for the removal of a preferential lane at specific locations.

The District Division Chief for Operations - in consultation with the HQ Traffic Liaison- is responsible for approving decisions to remove HOV preferential lanes. Written documentation should be provided in the appropriate project document(s).

J. Enforcement Areas and Maintenance Pullouts

Enforcement areas should be provided on all two-lane and three-lane ramps with HOV lanes.

On single- lane ramps, a paved enforcement area is not necessary but the area should be graded to facilitate future ramp widening (see Figure 1). Enforcement areas are used by the California Highway Patrol (CHP) to enforce vehicle occupancy requirements. At locations where the HOV lane is metered, the enforcement area should begin as close to the limit line as practical. Where unmetered, it should begin approximately 50 m downstream of the limit line. On three-lane ramps, the enforcement area should be downstream of the mast arm standard, approximately 21 m from the limit line. The length of the enforcement area and its distance downstream of the limit line may be adjusted to fit conditions at the ramp with CHP approval.

The District Operations Branch responsible for ramp metering shall coordinate enforcement issues with the California Highway Patrol. The CHP Area Commander shall be contacted during the Project Report stage, prior to design, to discuss any variations needed to the enforcement area designs shown in this Manual. Variations shall be discussed with the Traffic Operations Reviewer and the Project Development Coordinator and/or Geometric Reviewer.

A paved pullout area near the controller cabinet (see Standard Plan H8) should be provided for safe and convenient access for Maintenance and Operations personnel . If a pullout cannot be provided, a paved or "all weather" walkway should be provided to the controller cabinet.

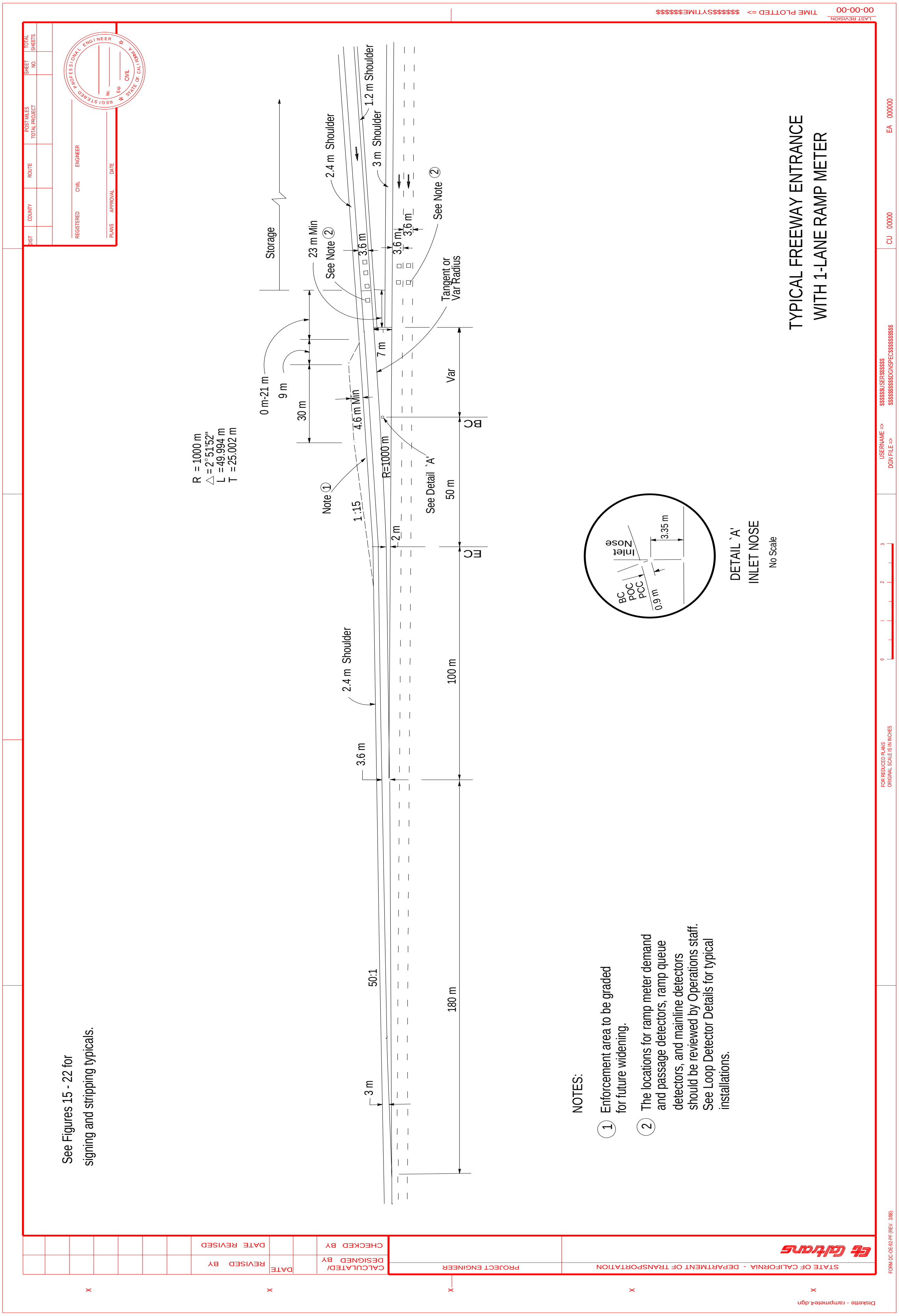
TYPICAL FREEWAY ENTRANCE
WITH 1-LANE RAMP METER
See Figures 15 - 22 for
signing and stripping typicals.
NOTES:
1 Enforcement area to be graded for future widening.
2 The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff. See Loop Detector Details for typical installations.
DETAIL `A'
INLET NOSE
No Scale
Inlet Nose
BC
POC
PCC
0.9 m
3.35 m
R = 1000 m
△ = 2°51'52"
L = 49.994 m
T = 25.002 m
Storage
23 m Min
See Note 2
2.4 m Shoulder
1.2 m Shoulder
3 m Shoulder
3.6 m
Tangent or
Var Radius
0 m-21 m
9 m
30 m
7 m
4.6 m Min
Note 1
1:15
R=1000 m
See Detail `A'
Var
BC
50 m
EC
2 m
2.4 m Shoulder
100 m
3.6 m
50:1
180 m
3 m
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Figure 1

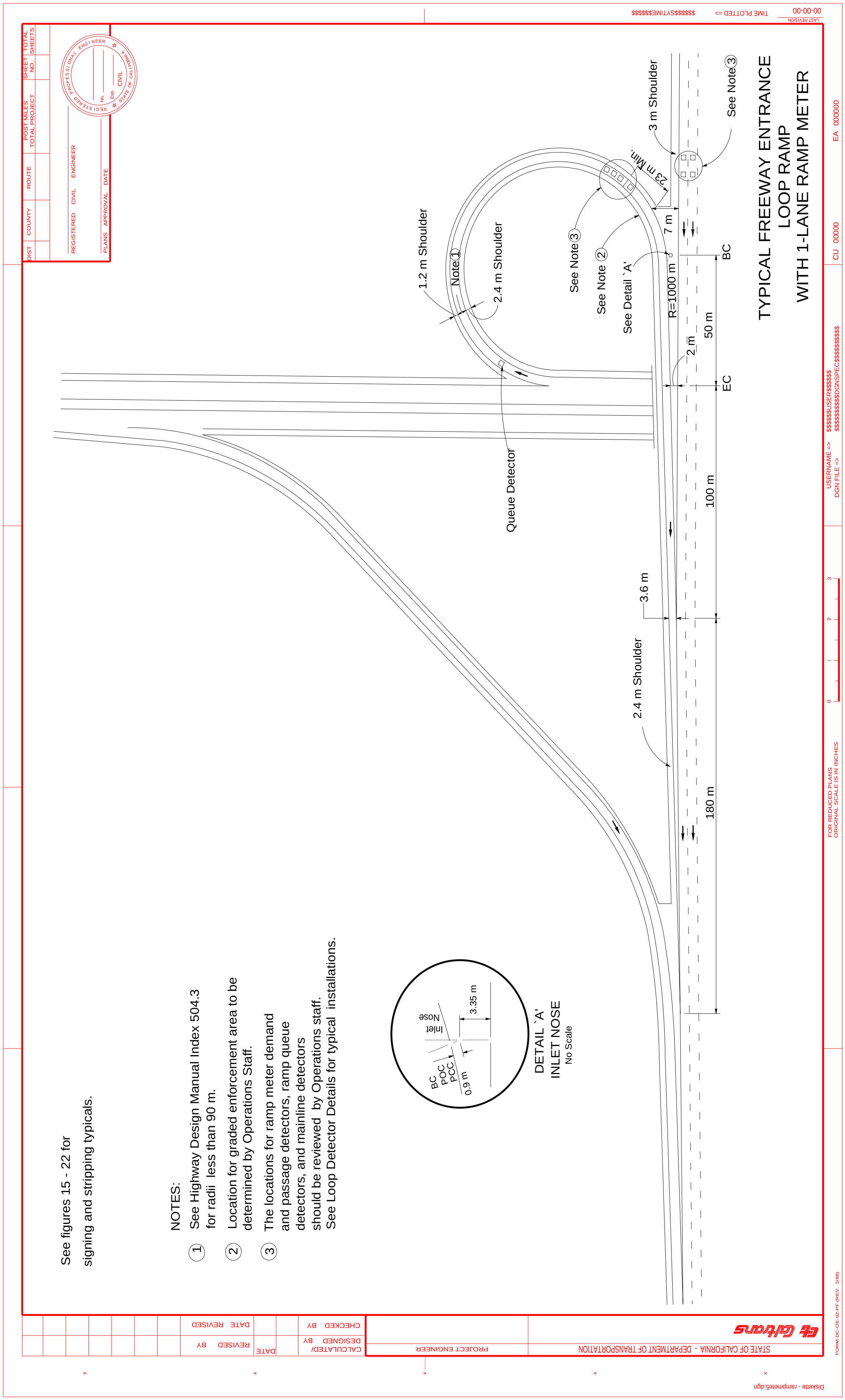
TYPICAL FREEWAY ENTRANCE
LOOP RAMP
WITH 1-LANE RAMP METER
See figures 15 - 22 for
signing and stripping typicals.
NOTES:
1 See Highway Design Manual Index 504.3
for radii less than 90 m.
2 Location for graded enforcement area to be
determined by Operations Staff.
3 The locations for ramp meter demand
and passage detectors, ramp queue
detectors, and mainline detectors
should be reviewed by Operations staff.
See Loop Detector Details for typical installations.
DETAIL 'A'
INLET NOSE
No Scale
Inlet
Nose
3.35 m
BC
POC
PCC
0.9 m
1.2 m Shoulder
Note 1
2.4 m Shoulder
Queue Detector
See Note 3
See Note 2
See Detail 'A'
23 m Min.
3 m Shoulder
See Note 3
7 m
R=1000 m
2 m
BC
EC
50 m
100 m
180 m
3.6 m
2.4 m Shoulder
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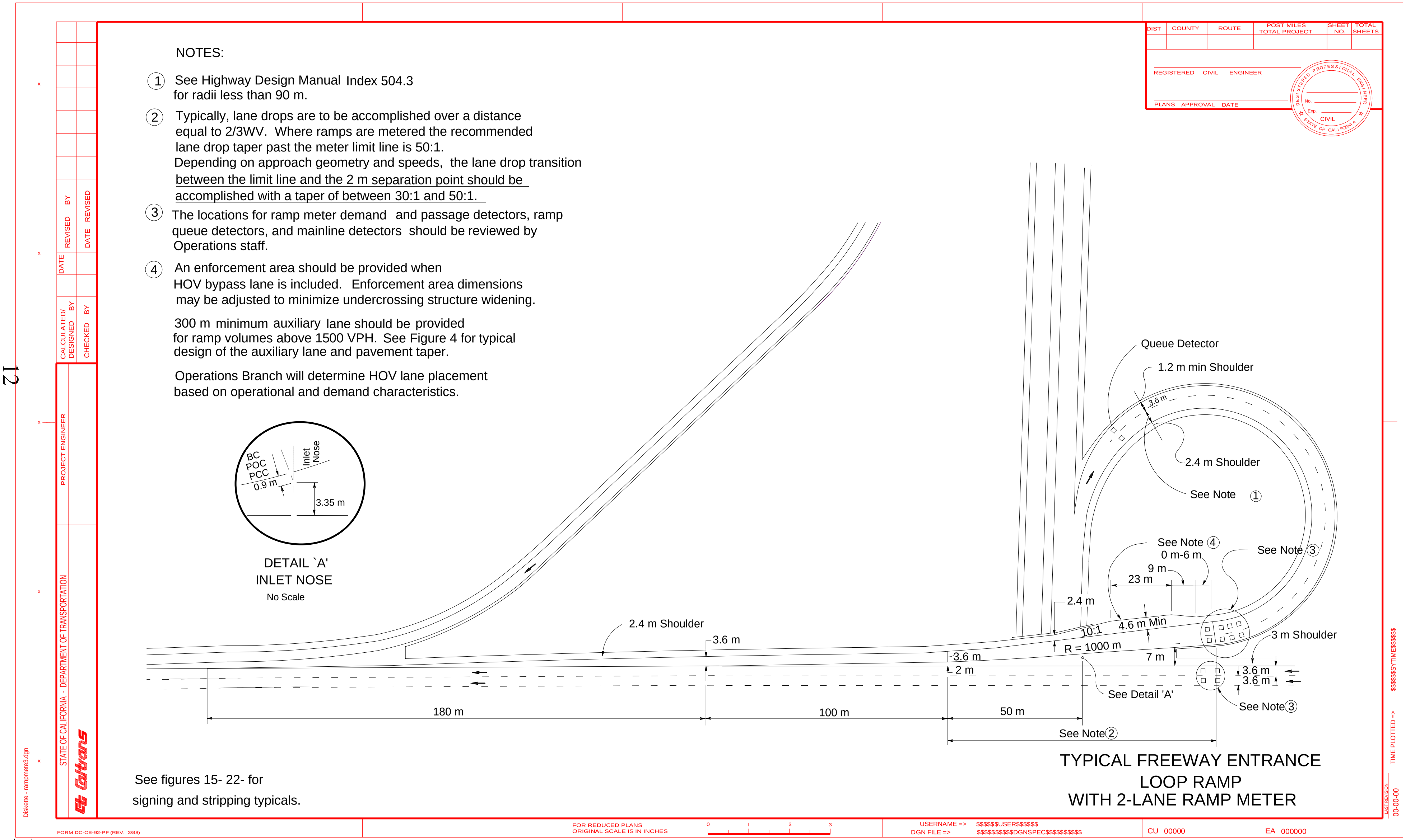
Figure 2



NOTES:
1 See Highway Design Manual Index 504.3 for radii less than 90 m.
2 Typically, lane drops are to be accomplished over a distance equal to 2/3WV. Where ramps are metered the recommended lane drop taper past the meter limit line is 50:1. Depending on approach geometry and speeds, the lane drop transition between the limit line and the 2 m separation point should be accomplished with a taper of between 30:1 and 50:1.
3 The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff.
4 An enforcement area should be provided when HOV bypass lane is included. Enforcement area dimensions may be adjusted to minimize undercrossing structure widening.
300 m minimum auxiliary lane should be provided for ramp volumes above 1500 VPH. See Figure 4 for typical design of the auxiliary lane and pavement taper.
Operations Branch will determine HOV lane placement based on operational and demand characteristics.
BC
POC
PCC
0.9 m
Inlet Nose
3.35 m
DETAIL `A'
INLET NOSE
No Scale
Queue Detector
1.2 m min Shoulder
3.6 m
2.4 m Shoulder
See Note 1
See Note 4
0 m-6 m
9 m
23 m
See Note 3
2.4 m
10:1
4.6 m Min
R = 1000 m
7 m
3 m Shoulder
3.6 m
3.6 m
See Detail 'A'
See Note 3
2.4 m Shoulder
3.6 m
3.6 m
2 m
180 m
100 m
50 m
See Note 2
TYPICAL FREEWAY ENTRANCE
LOOP RAMP
WITH 2-LANE RAMP METER
See figures 15- 22- for signing and stripping typicals.
DIST
COUNTY
ROUTE
POST MILES TOTAL PROJECT
SHEET NO.
TOTAL SHEETS
REGISTERED CIVIL ENGINEER
PLANS APPROVAL DATE
REGISTERED PROFESSIONAL ENGINEER
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Exp.
CIVIL
STATE OF CALIFORNIA
STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
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FOR REDUCED PLANS ORIGINAL SCALE IS IN INCHES
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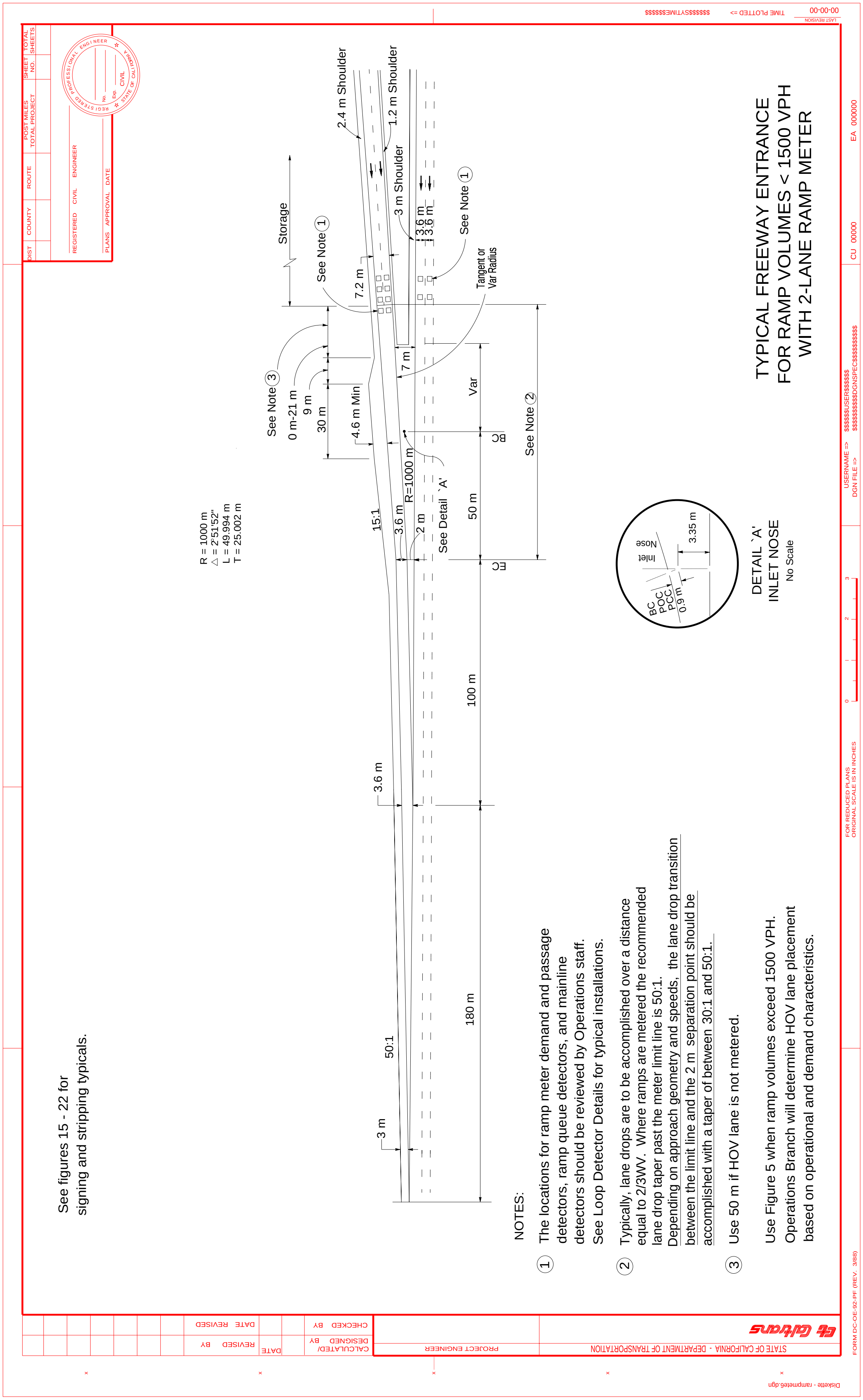
Figure 3


TYPICAL FREEWAY ENTRANCE
FOR RAMP VOLUMES < 1500 VPH
WITH 2-LANE RAMP METER
See figures 15 - 22 for
signing and stripping typicals.
R = 1000 m
△ = 2°51'52"
L = 49.994 m
T = 25.002 m
2.4 m Shoulder
1.2 m Shoulder
3 m Shoulder
3.6 m
3.6 m
Storage
See Note 1
See Note 1
7.2 m
Tangent or
Var Radius
See Note 3
0 m-21 m
9 m
30 m
4.6 m Min
7 m
Var
BC
See Note 2
15:1
3.6 m
R=1000 m
2 m
See Detail `A'
50 m
EC
100 m
3.6 m
180 m
50:1
3 m
DETAIL `A'
INLET NOSE
No Scale
Inlet
Nose
BC
POC
PCC
0.9 m
3.35 m
NOTES:
1 The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff. See Loop Detector Details for typical installations.
2 Typically, lane drops are to be accomplished over a distance equal to 2/3WV. Where ramps are metered the recommended lane drop taper past the meter limit line is 50:1. Depending on approach geometry and speeds, the lane drop transition between the limit line and the 2 m separation point should be accomplished with a taper of between 30:1 and 50:1.
3 Use 50 m if HOV lane is not metered.
Use Figure 5 when ramp volumes exceed 1500 VPH. Operations Branch will determine HOV lane placement based on operational and demand characteristics.
STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
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PROJECT ENGINEER
CALCULATED/ DESIGNED BY
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DATE
REVISED BY
DATE REVISED
DIST
COUNTY
ROUTE
POST MILES TOTAL PROJECT
SHEET NO.
TOTAL SHEETS
REGISTERED CIVIL ENGINEER
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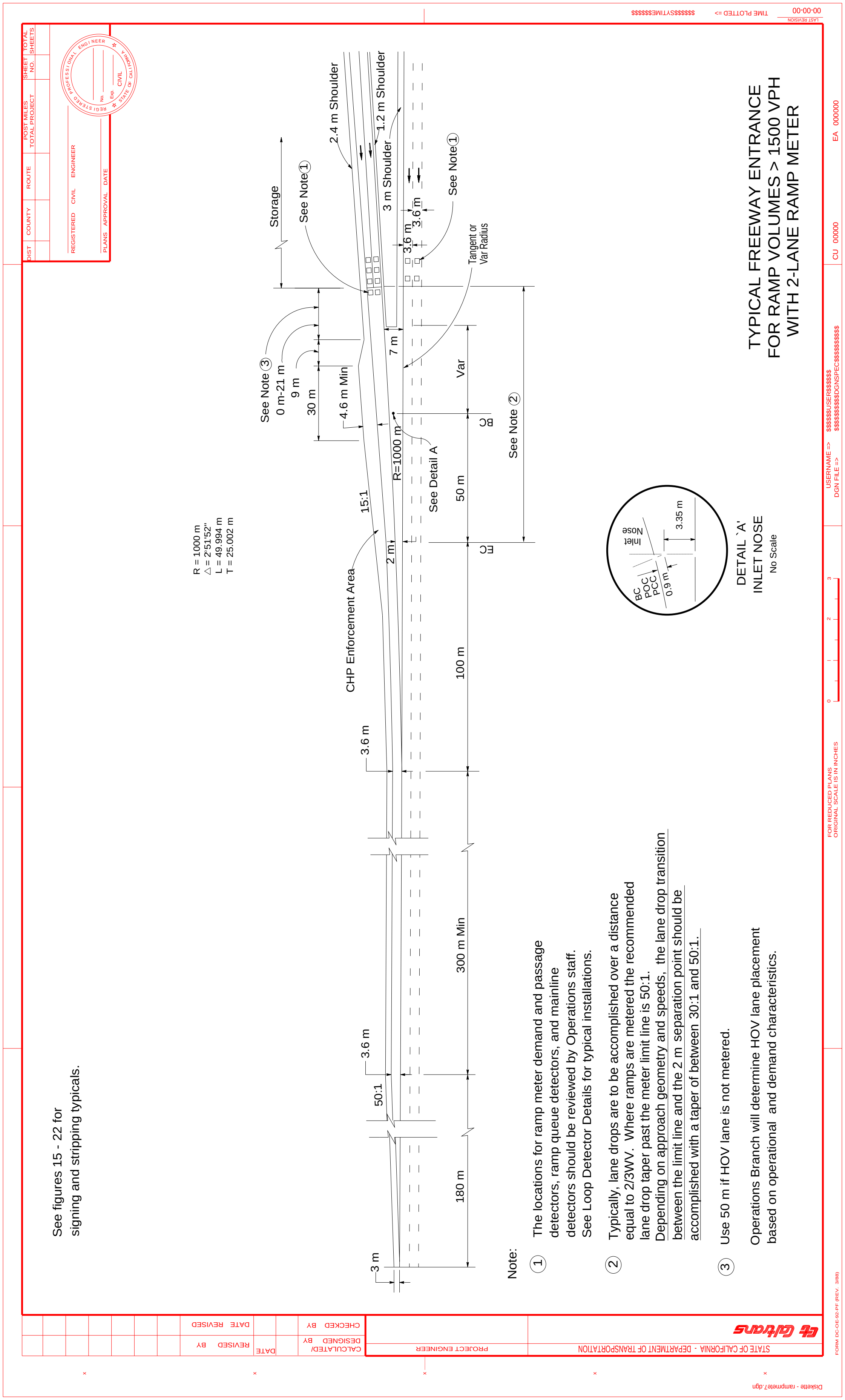
Figure 4


See figures 15 - 22 for
signing and stripping typicals.
R = 1000 m
△ = 2°51'52"
L = 49.994 m
T = 25.002 m
See Note 3
0 m-21 m
9 m
30 m
4.6 m Min
Storage
See Note 1
2.4 m Shoulder
1.2 m Shoulder
3 m Shoulder
3.6 m
3.6 m
See Note 1
Tangent or
Var Radius
CHP Enforcement Area
15:1
3 m
50:1
3.6 m
3.6 m
2 m
R=1000 m
7 m
See Detail A
180 m
300 m Min
100 m
50 m
Var
EC
BC
See Note 2
Note:
1 The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff. See Loop Detector Details for typical installations.
2 Typically, lane drops are to be accomplished over a distance equal to 2/3WV. Where ramps are metered the recommended lane drop taper past the meter limit line is 50:1. Depending on approach geometry and speeds, the lane drop transition between the limit line and the 2 m separation point should be accomplished with a taper of between 30:1 and 50:1.
3 Use 50 m if HOV lane is not metered.
Operations Branch will determine HOV lane placement based on operational and demand characteristics.
BC
POC
PCC
0.9 m
Inlet
Nose
3.35 m
DETAIL `A'
INLET NOSE
No Scale
TYPICAL FREEWAY ENTRANCE
FOR RAMP VOLUMES > 1500 VPH
WITH 2-LANE RAMP METER
DIST
COUNTY
ROUTE
POST MILES
TOTAL PROJECT
SHEET NO.
TOTAL SHEETS
REGISTERED CIVIL ENGINEER
PLANS APPROVAL DATE
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CALCULATED/
DESIGNED BY
CHECKED BY
DATE
REVISED BY
DATE REVISED
FOR REDUCED PLANS
ORIGINAL SCALE IS IN INCHES
USERNAME => $$$$$$USER$$$$$$
DGN FILE => $$$$$$$$$$DGNSPEC$$$$$$$$$$$
CU 00000
EA 000000
TIME PLOTTED => $$$$$$SYTIME$$$$$$
LAST REVISION
00-00-00
FORM DC-OE-92-PF (REV. 3/88)
Diskette - rampmete7.dgn

Figure 5

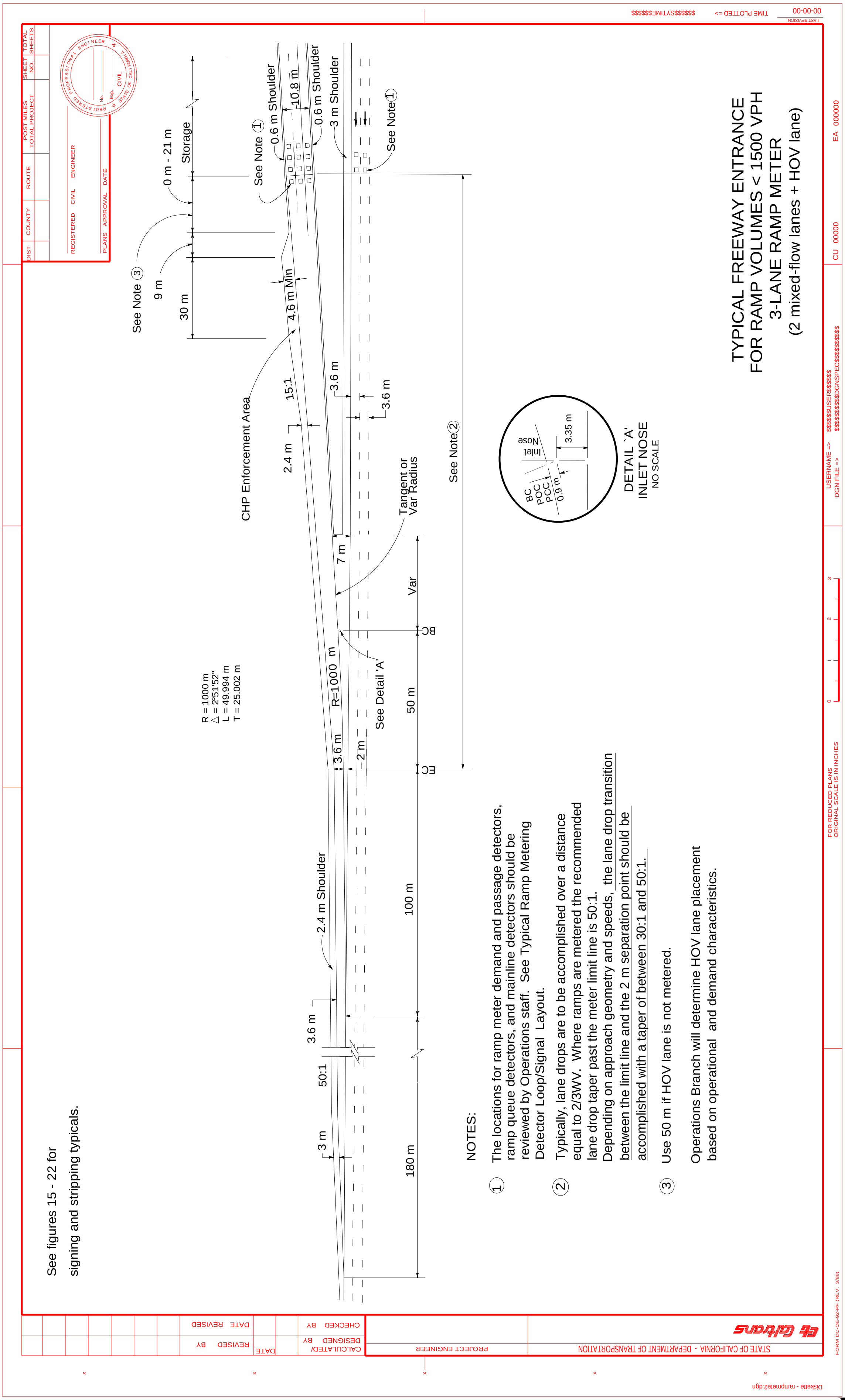
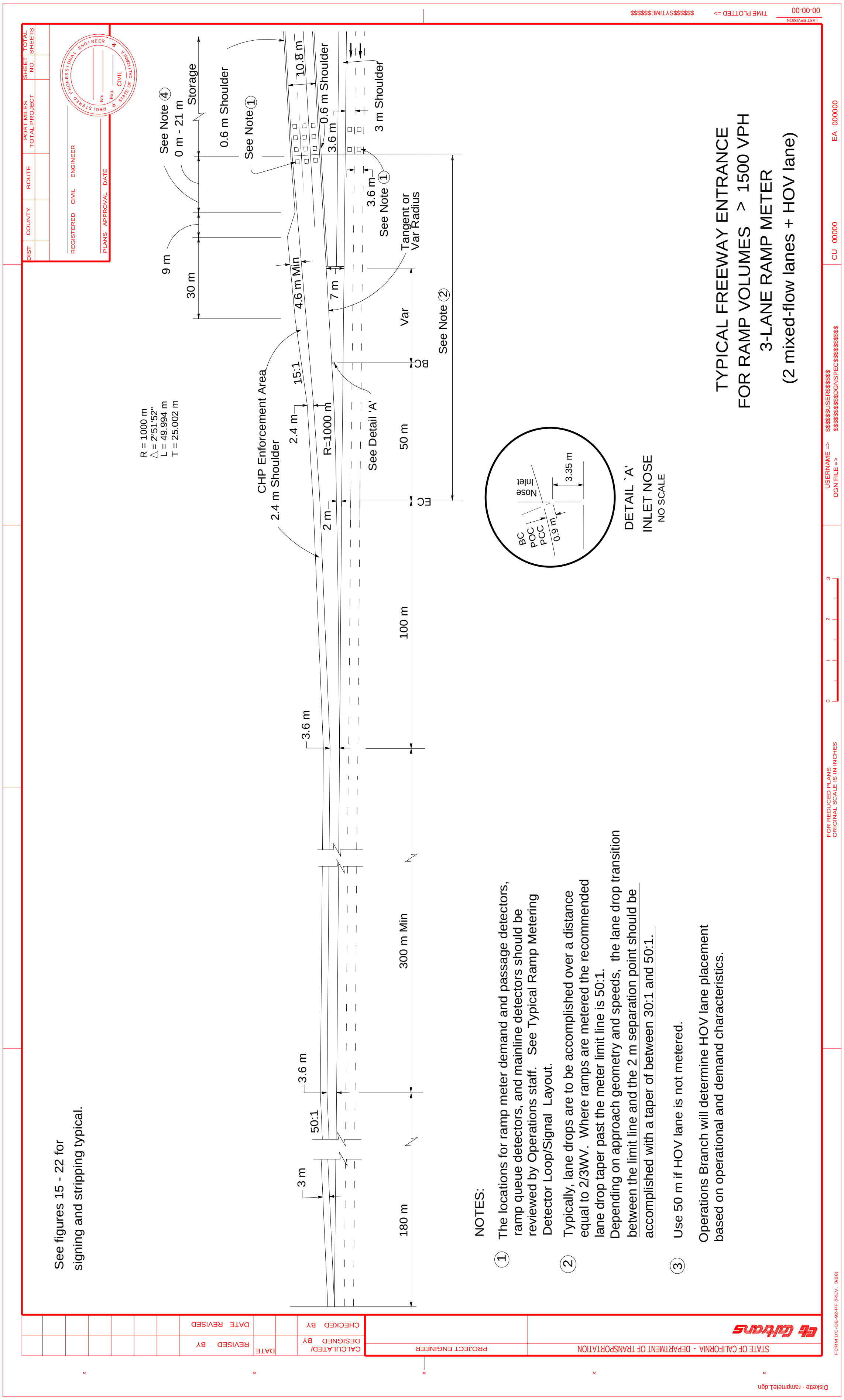

TYPICAL FREEWAY ENTRANCE
FOR RAMP VOLUMES < 1500 VPH
3-LANE RAMP METER
(2 mixed-flow lanes + HOV lane)
See figures 15 - 22 for
signing and stripping typicals.
NOTES:
1 The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff. See Typical Ramp Metering Detector Loop/Signal Layout.
2 Typically, lane drops are to be accomplished over a distance equal to 2/3WV. Where ramps are metered the recommended lane drop taper past the meter limit line is 50:1. Depending on approach geometry and speeds, the lane drop transition between the limit line and the 2 m separation point should be accomplished with a taper of between 30:1 and 50:1.
3 Use 50 m if HOV lane is not metered.
Operations Branch will determine HOV lane placement based on operational and demand characteristics.
DETAIL 'A'
INLET NOSE
NO SCALE
Inlet Nose
BC
POC
PCC
0.9 m
3.35 m
R = 1000 m
△ = 2°51'52"
L = 49.994 m
T = 25.002 m
See Note 3
9 m
30 m
0 m - 21 m Storage
See Note 1
0.6 m Shoulder
10.8 m
0.6 m Shoulder
3 m Shoulder
See Note 1
4.6 m Min
CHP Enforcement Area
15:1
2.4 m
3.6 m
3.6 m
See Note 2
Tangent or Var Radius
7 m
Var
BC
See Detail 'A'
R=1000 m
50 m
3.6 m
2 m
EC
2.4 m Shoulder
100 m
3.6 m
50:1
3 m
180 m
STATE OF CALIFORNIA · DEPARTMENT OF TRANSPORTATION
Caltrans
PROJECT ENGINEER
CALCULATED/DESIGNED BY
CHECKED BY
REVISED BY
DATE REVISED
DATE
DIST
COUNTY
ROUTE
POST MILES TOTAL PROJECT
SHEET NO.
TOTAL SHEETS
REGISTERED CIVIL ENGINEER
PLANS APPROVAL DATE
REGISTERED PROFESSIONAL ENGINEER
CIVIL
STATE OF CALIFORNIA
CU 00000
EA 000000
USERNAME => $$$$$$USER$$$$$$
DGN FILE => $$$$$$$$$$DGNSPEC$$$$$$$$$$
TIME PLOTTED => $$$$$$$$TIME$$$$$$
00-00-00
LAST REVISION
FOR REDUCED PLANS ORIGINAL SCALE IS IN INCHES
0
1
2
3
FORM DC-OE-92-PF (REV. 3/98)
Diskette - rampmete2.dgn

Figure 6



TYPICAL FREEWAY ENTRANCE
FOR RAMP VOLUMES > 1500 VPH
3-LANE RAMP METER
(2 mixed-flow lanes + HOV lane)
See figures 15 - 22 for
signing and stripping typical.
R = 1000 m
Δ = 2°51'52"
L = 49.994 m
T = 25.002 m
See Note 4
0 m - 21 m
Storage
0.6 m Shoulder
See Note 1
10.8 m
0.6 m Shoulder
3.6 m
3 m Shoulder
3.6 m
See Note 1
Tangent or
Var Radius
9 m
30 m
4.6 m Min
7 m
Var
See Note 2
CHP Enforcement Area
2.4 m Shoulder
15:1
2.4 m
R=1000 m
See Detail 'A'
BC
EC
50 m
2 m
100 m
3.6 m
300 m Min
3.6 m
50:1
3 m
180 m
Nose
Inlet
3.35 m
BC
POC
PCC
0.9 m
DETAIL `A'
INLET NOSE
NO SCALE
NOTES:
1 The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff. See Typical Ramp Metering Detector Loop/Signal Layout.
2 Typically, lane drops are to be accomplished over a distance equal to 2/3WV. Where ramps are metered the recommended lane drop taper past the meter limit line is 50:1. Depending on approach geometry and speeds, the lane drop transition between the limit line and the 2 m separation point should be accomplished with a taper of between 30:1 and 50:1.
3 Use 50 m if HOV lane is not metered.
Operations Branch will determine HOV lane placement based on operational and demand characteristics.
DIST
COUNTY
ROUTE
POST MILES TOTAL PROJECT
SHEET NO.
TOTAL SHEETS
REGISTERED CIVIL ENGINEER
PLANS APPROVAL DATE
REGISTERED PROFESSIONAL ENGINEER
CIVIL
STATE OF CALIFORNIA
CU 00000
EA 000000
USERNAME => $$$$$$USER$$$$$$
DGN FILE => $$$$$$$$$$DGNSPEC$$$$$$$$$$
TIME PLOTTED => $$$$$$$SYTIME$$$$$$$
LAST REVISION 00-00-00
FOR REDUCED PLANS ORIGINAL SCALE IS IN INCHES
STATE OF CALIFORNIA · DEPARTMENT OF TRANSPORTATION
PROJECT ENGINEER
CALCULATED/ DESIGNED BY
CHECKED BY
REVISED BY
DATE REVISED
DATE
Diskette - rampmete1.dgn

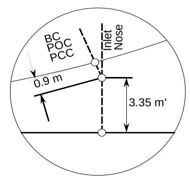
Figure 7

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

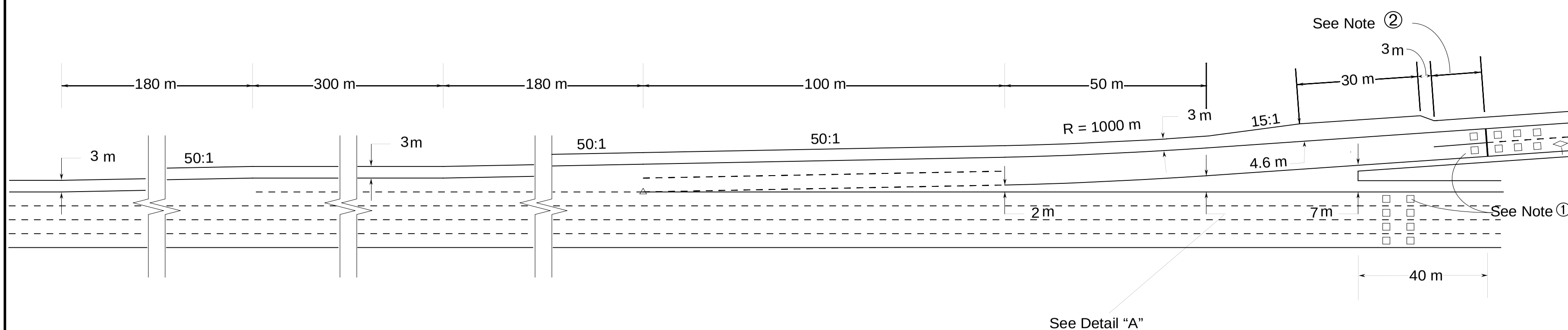
REGISTERED CIVIL ENGINEER

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER
No.
Exp.
CIVIL
STATE OF CALIFORNIA



DETAIL "A"
INLET NOSE
No Scale



NOTES:

① The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff. See Typical Ramp Metering Detector Loop/Signal Layout.

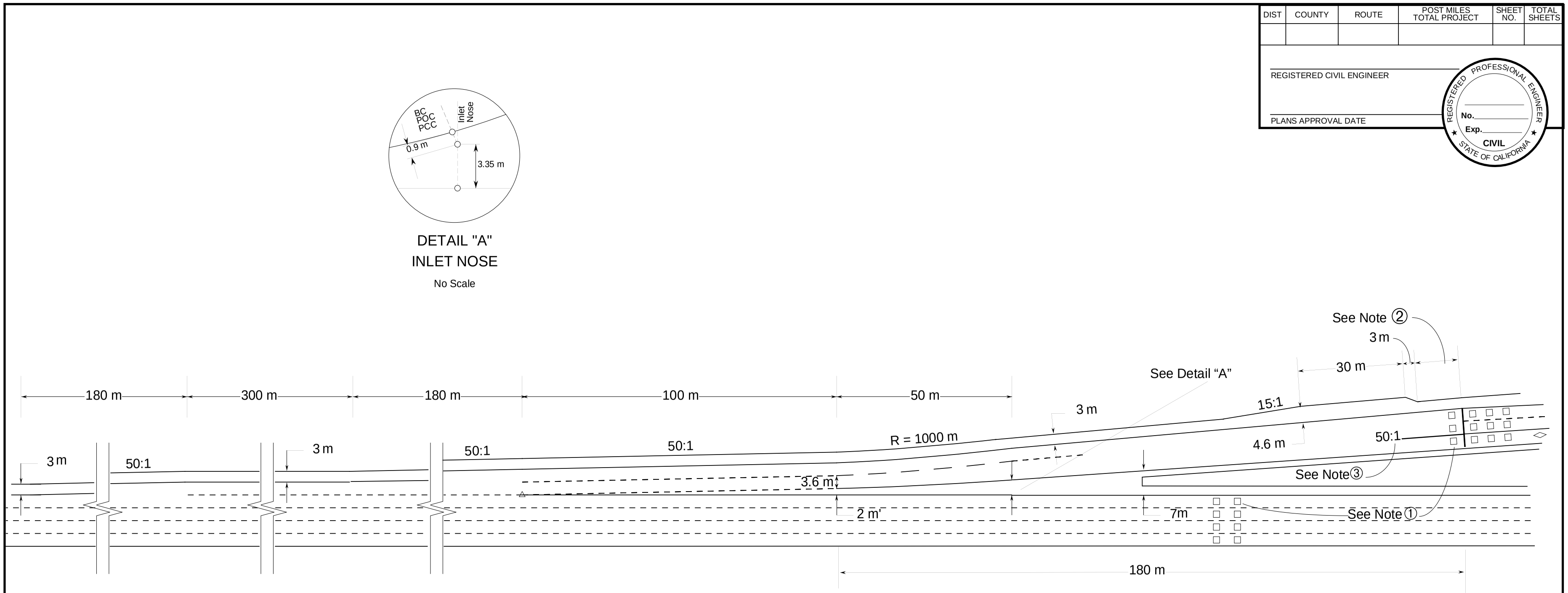
② Use 0 m– 21 m if HOV lane is metered. Use 50 m if HOV lane is not metered.

Operations staff will determine HOV lane placement based on operational and demand characteristics.

Typically, lane drops are to be accomplished over a distance equal to 2/3 WV, but the lane drop transition should be accomplished with at least a 50:1 taper.

TYPICAL FREEWAY CONNECTOR
2-LANE METER
(1 mixed-flow lane + 1 HOV lane)

Figure 8



NOTES:

① The locations for ramp meter demand and passage detectors, ramp queue detectors, and mainline detectors should be reviewed by Operations staff. See Typical Ramp Metering Detector Loop/Signal Layout.

② Use 0 m– 21 m if HOV lane is metered. Use 50 m if HOV lane is not metered.

③ Typically, lane drops are to be accomplished over a distance equal to 2/3 WV, but the lane drop transition should be accomplished with at least a 50:1 taper.

Operations staff will determine HOV lane placement based on operational and demand characteristics.

TYPICAL FREEWAY CONNECTOR
3-LANE METER
(2 mixed-flow lanes + HOV lane)

Figure 9

CHAPTER TWO

II. RAMP METER HARDWARE

The minimum ramp metering equipment that should be installed at each entrance ramp is described below. Some locations may require additional equipment. *The District Operations Branch responsible for ramp metering shall be consulted to determine if any additional equipment is required and should review all signal, controller, loop detector, and advance warning devices.*

A. Signal Heads and Standards

1. One- and Two-Lane Ramps: Install upper three- section (300 mm red, yellow and green lenses) and lower two- or three-section heads (200 mm lenses) on a Type 1 standard. A two section lower head should be used for "one car per green" output and a three section lower head for "two cars per green" output. A one-section head with a 200 mm red lens (signal status indicator) should be installed on the backside of Type 1 standards for enforcement (see Figure 10). For a one-lane ramp, install standard on the left side of ramp. At 2-lane ramps, a Type 1 standard and signal heads should be installed on each side of the ramp. No signal standard is needed for non-metered HOV lanes. Standards should be approximately 1 m from the edge of shoulder and 300 mm downstream of the limit line. On ramps with minimal shoulders and flat slopes, standards should be placed in locations that reduce knock-downs.

Some locations may need a special wall-mount design or a mast arm for situations where the wall restricts the room for a normal Type 1 standard. Lighting standards, such as Type 15, may be used to illuminate the limit line during pre-dawn or evening conditions.

2. Three-Lane Ramps: Install three, three-section heads (two—three section heads, if HOV lane is not metered) on mast arm standard located on the right side of the ramp approximately 21 m downstream of the limit line. Type 26 or Type 27 with wind velocity of 129 km/hr is recommended. Programmed visibility (PV) heads should be used to limit visibility from mainline traffic. However, freeway connectors with limited sight distance or high speed approach traffic may require the use of standard heads for better visibility. Guardrail or barrier should be considered where mast arm installation is less than 9 meters from traveled way.

Also install upper (300 mm red, yellow and green lenses) and lower (200 mm lenses) heads on Type 1 standards on each side of the ramp. The signal status indicator should be included (see Figure 10). As an option, R90 signs (STOP HERE ON RED) attached to wood posts may be installed at the limit line in place of the Type 1 standards.

B. Detector Loops

Consult current Standard Plans ES-5A and 5B for detector types and installation, sawcut, slot and winding details. Loop configuration should be Type A or Type E and centered in the lane. Type Q loops may be used for demand and passage loops on entrance ramps.

1. Mainline Detector Loops: Two loops per lane should be installed on the mainline. Spacing shall be 6.1 m from leading edge to leading edge (see Figure 11). *Contact the District Operations Branch responsible for ramp metering to determine location of mainline loops.* In general, the mainline loops should be located upstream of the entrance ramp nose, opposite the limit line. Location of the detectors should be adjusted to avoid transverse pavement joints or structures.

2. Ramp Detector Loops: Ramp loops (demand and passage) should be installed for each entrance lane near the limit line as shown in Figures 12 and 13. An oversized loop may be considered where the lane width is greater than 3.6 m, such as for loop on ramps.

The number and spacing of ramp loops should be determined by the District Operations Branch responsible for ramp metering.

- District 11 typically uses 4 demand loops
- Districts 3, 4, 6, 8 typically use 3 demand loops
- Districts 7, 12 typically use 2 demand loops

Consult with the district for the location of an additional count loop downstream. An oversized loop may be needed to increase accuracy of counts. Concrete pads may be used to help prevent loop failure, see Chapter One, Section E.

3. <u>Exit Ramp Detector Loops</u>: One loop per exit ramp lane should be installed for count information and loop calibration (see Figure 11). *District Operations Branch responsible for ramp metering should be consulted to determine the location of the loops.*

4. <u>Queue Detectors Loops:</u> One loop per entrance ramp lane should be installed for queue detection near the connection of the surface street.

C. Controller Assembly

One Controller Cabinet should generally be installed for each entrance ramp. In some cases three lanes can be accommodated by one controller. *Exact number and location of controller cabinets will be determined by District Operations Branch responsible for ramp metering*. In general, the cabinet should be located to minimize the possibility of being hit by an errant vehicle and to allow safe and convenient access by Maintenance and Operations personnel. If possible, it should be located where the signal faces can be observed. Refer to the Traffic Manual Chapter 9 and Standard Plans for location and installation details. If the Cabinet is not located in an easily accessible location, a paved access area should be provided. (see Chapter 1, Section J).

Cabinets should include a Model 170 or Model 2070 controller, an input file with sensor units, an output file with load switches, a power distribution assembly, and a modem. Controller units furnished by others must pass testing conducted by Caltrans' laboratory or an independent laboratory that will conduct the testing of the controller equipment in accordance with Caltrans' testing procedures.

Electrical Service shall be provided for each controller/cabinet assembly.

D. Communications

Install one telephone demarcation cabinet per telephone service point. *District Operations Branch responsible for ramp metering, in coordination with the telephone company, will determine the telephone requirements and the exact location.* If more than one entrance ramp is to be metered, a telephone bridge should be installed in the telephone demarcation cabinet or in the controller cabinet which is nearest to the telephone demarcation cabinet.

At locations where telephone service is not available or too costly, new communication technologies such as fiber-optic, microwave, or radiowaves may be proposed.

E. Advance Warning

In general, an advance warning device should be installed at ramps where sight distance to the ramp meter signal or queue is impaired.

It is recommended that advance warning be placed at all locations to indicate that metering is operational. It should be installed near the ramp entrance facing each direction of traffic entering the ramp. It should also be visible to surface street traffic before entering the ramp.

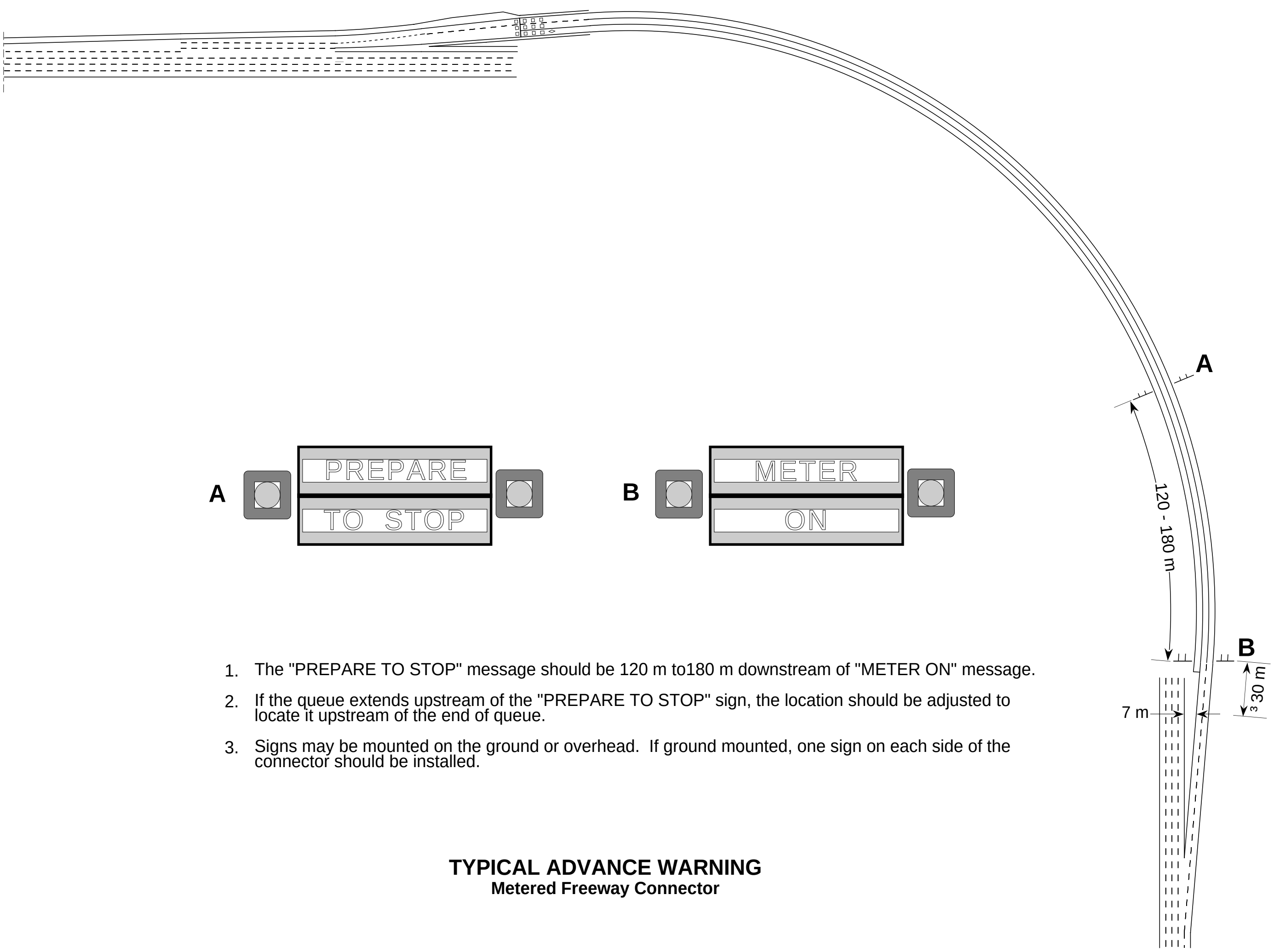
A flashing beacon with "Signal Ahead" (W41) mounted beneath it may be used or an internally illuminated "METER ON" sign (see Figure 14). The flashing beacon or "METER ON" sign should be activated during metering operation. Additional flashing beacons should be provided on long ramps where signals cannot be seen on the approach. *The type of warning device should be determined by District Operations Branch responsible for ramp metering.*

> On freeway-to-freeway connectors, high visibility extinguishable message signs (EMS) should be installed for advance warning (see Figure 14).

On connectors, a sequence of two signs should be used. The "METER ON" sign should be installed at least 30 m downstream from the 7 m point of the exit gore area. The "PREPARE TO STOP" sign should be installed 120 m to 180 m downstream of the "METER ON" sign and at least 300 m upstream of the limit line (see below). If the queue extends upstream of the "PREPARE TO STOP" sign, its location should be adjusted or an additional sign installed upstream of the end of queue.

On local street ramps with high approach speeds, the same installation as connectors should be used if possible. However, the length of local street ramps may require the sign spacing to be reduced. The minimum distance between the "PREPARE TO STOP" sign and the limit line should be the maximum queue length sustained for at least 15 minutes plus the stopping sight distance for the approach speed. The minimum distance between the "METER ON" sign and the "PREPARE TO STOP" sign should be 90 m. *Consult the District Operations Branch responsible for ramp metering for exact placement.*

The EMSs may be installed overhead or ground-mounted. If ground-mounted on a multi-lane connector ramp, a sign on each side of the connector should be installed for each message. Additional EMSs may be placed in advance on the mainline to indicate that the connector meter is on. Power for the EMSs should be sourced out of the designated load switches in the controller cabinet.

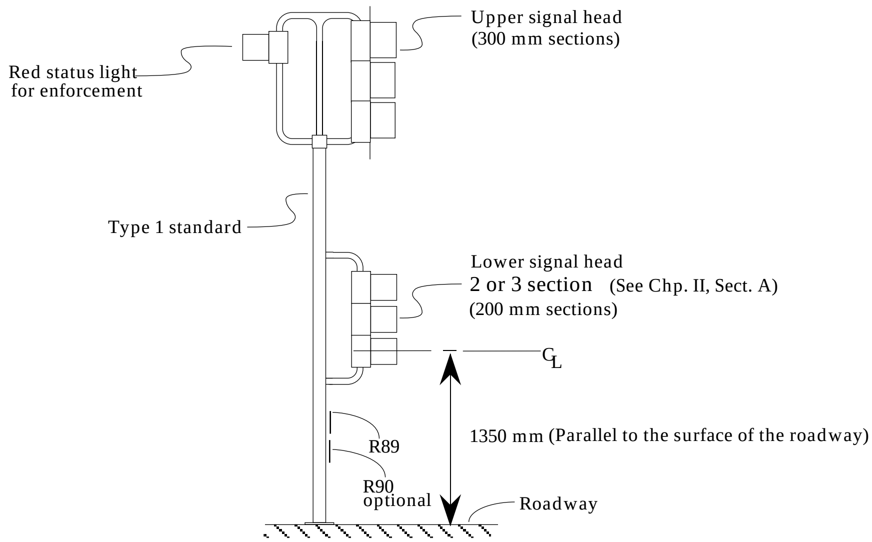


1. The "PREPARE TO STOP" message should be 120 m to180 m downstream of "METER ON" message.
2. If the queue extends upstream of the "PREPARE TO STOP" sign, the location should be adjusted to locate it upstream of the end of queue.
3. Signs may be mounted on the ground or overhead. If ground mounted, one sign on each side of the connector should be installed.

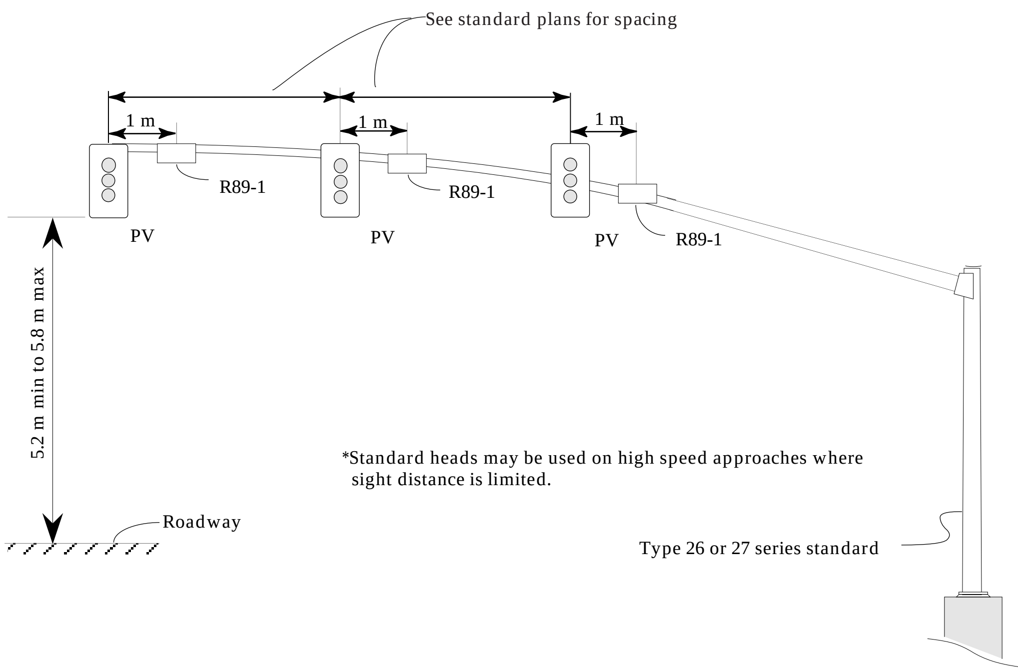
TYPICAL ADVANCE WARNING
Metered Freeway Connector

TYPICAL SIGNAL STANDARD INSTALLATOINS

See Standard Plans



TYPICAL SIGNAL STANDARD
For 1-, 2- and 3-Lanes
not to scale



SIGNALS MOUNTED ON MAST ARM
not to scale

Use on 3-lane ramp where HOV lane is metered
Use two signal heads if HOV lane is not metered

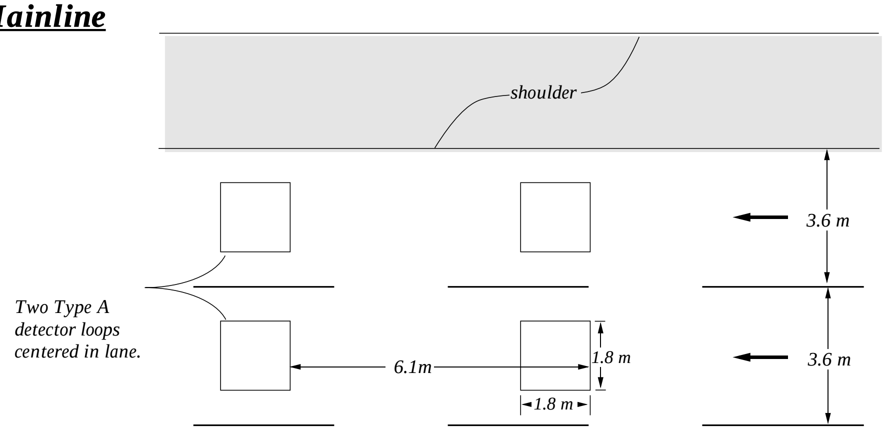
Figure 10

Typical Ramp Metering Detector Loop/Signal Layout

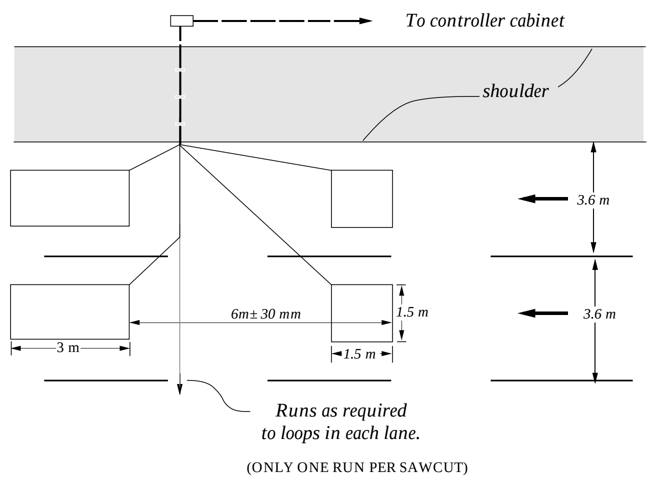
(not to scale)

See Standard Plans for loop installation procedures, and sawcut, slot, and winding details.

Mainline



Mainlane Loops used by District 11



Queue/Exit /Count Loop

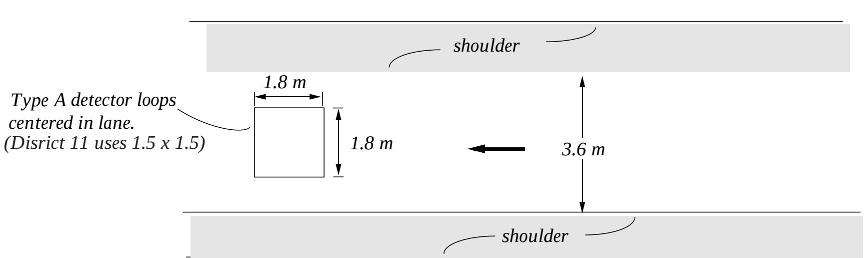


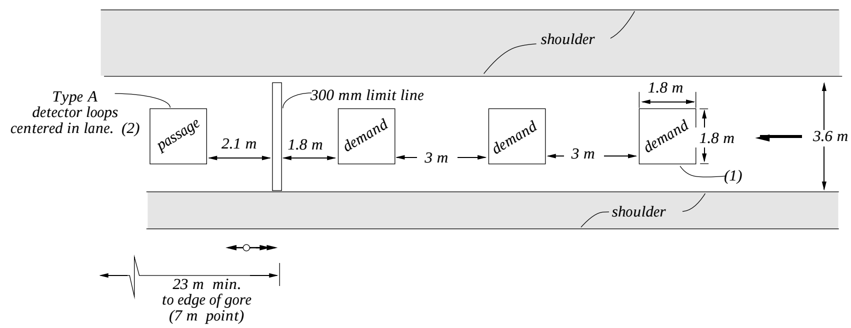
Figure 11

Typical Ramp Metering Detector Loop/Signal Layout

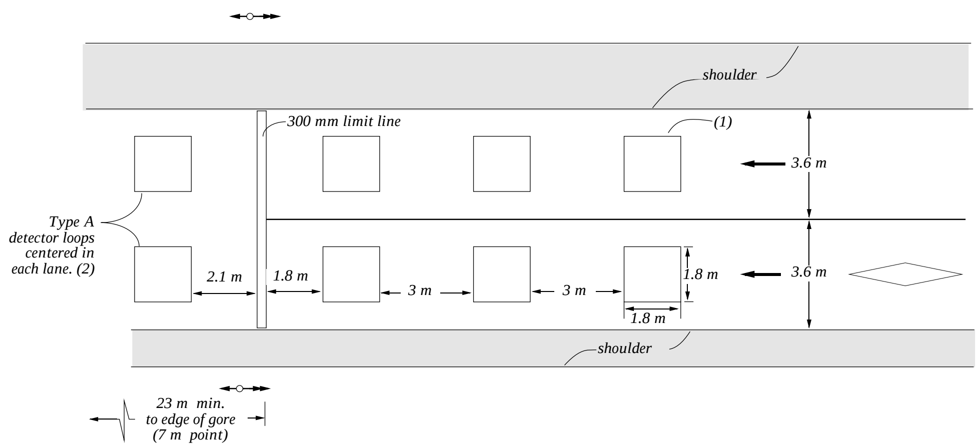
(not to scale)

See Standard Plans for loop installation procedures, and sawcut, slot, and winding details.

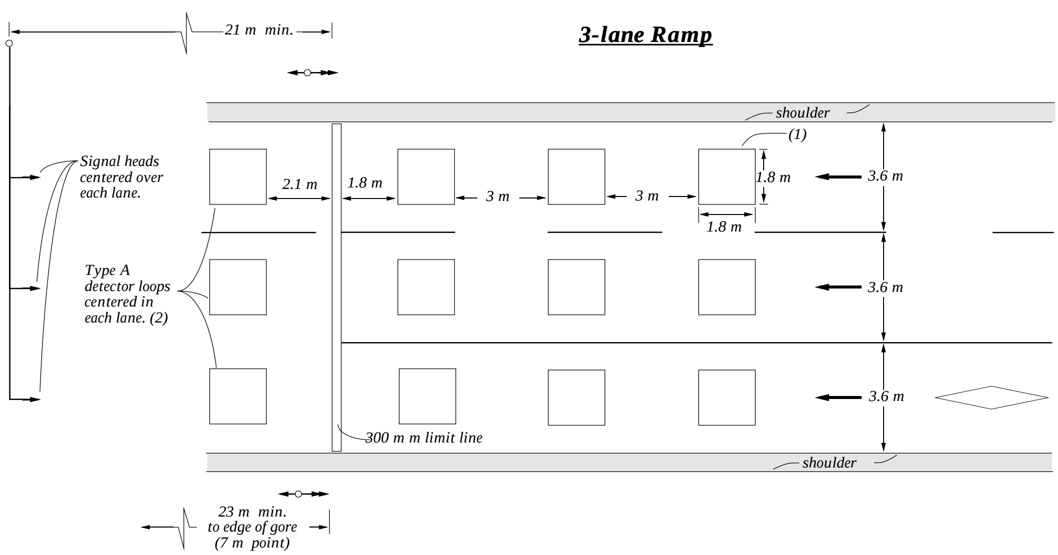
1-lane Ramp



2-lane Ramp



3-lane Ramp



Notes:

(1) See section on Ramp Detector Loops for number of demand loops to be used

(2) Type Q detector loops may be used.

Figure 12

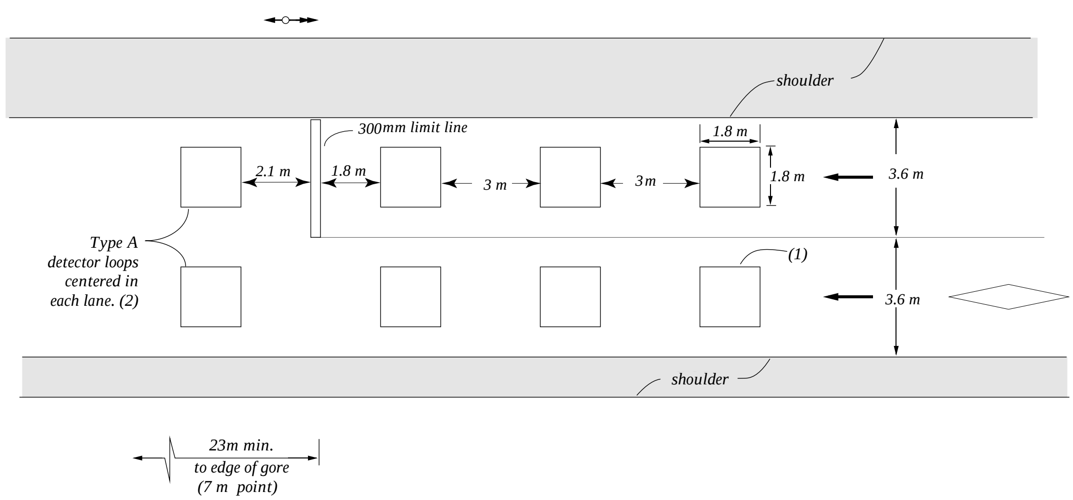
Typical Ramp Metering Detector Loop/Signal Layout

2- and 3-lane
(not to scale)

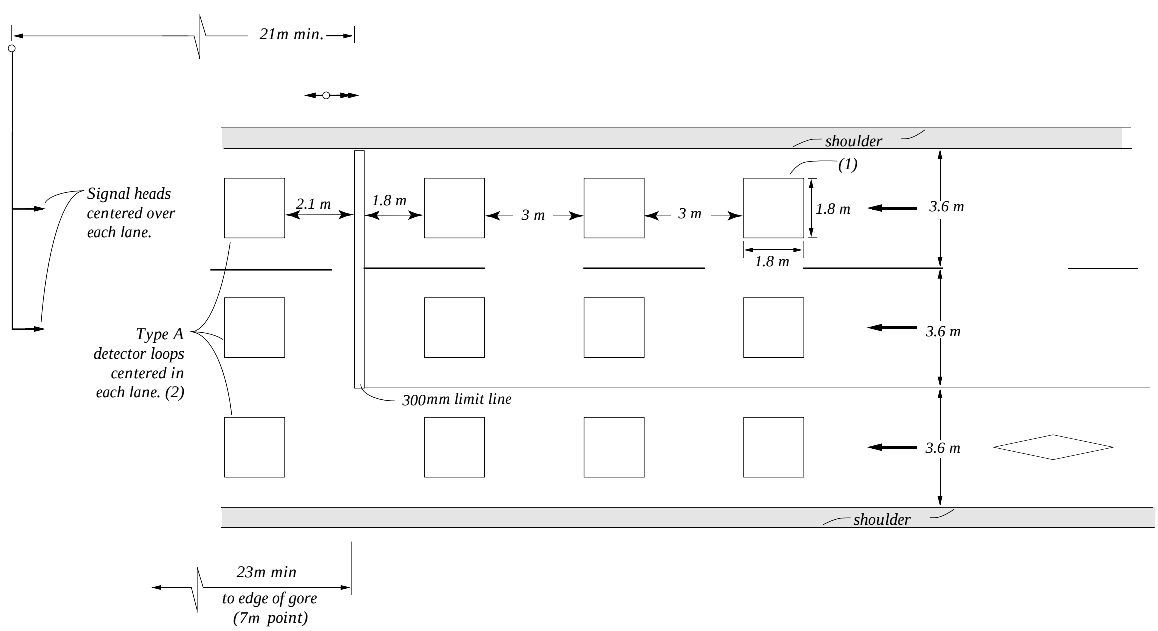
See Standard Plans for loop installation procedures, and sawcut, slot, and winding details.

Non-metered HOV Lanes

2-lane Ramp



3-lane Ramp

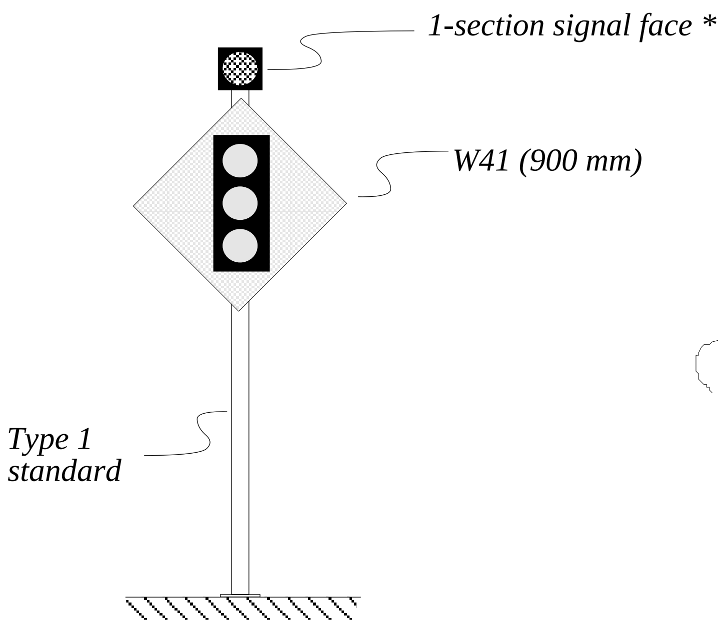


Notes: (1) *See section on Ramp Detector Loops for number of demand loops to be used*
(2) *Type Q detector loops may be used.*

Figure 13

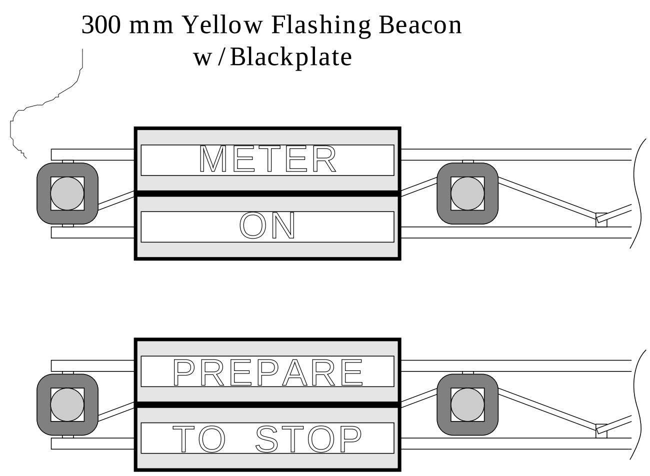
Advance Warning Installations

not to scale



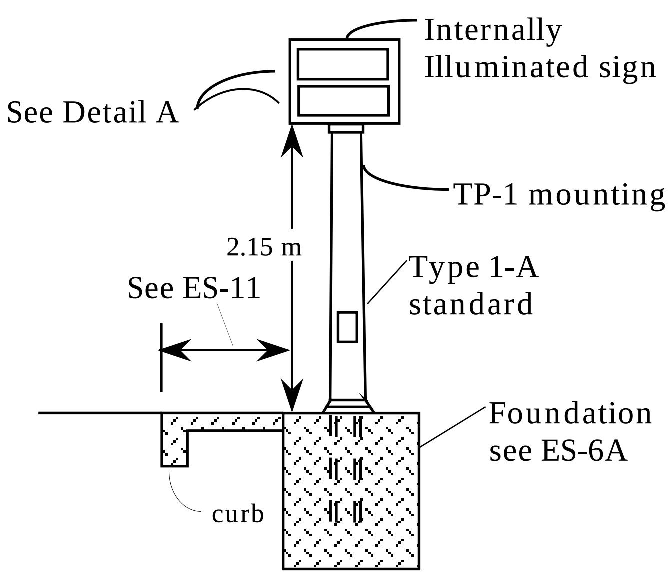
Flashing Beacon

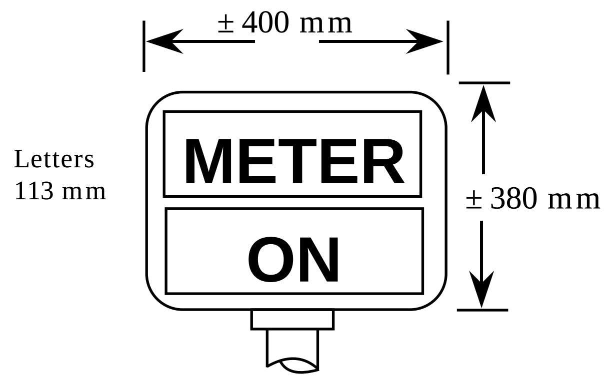
*   Where early morning or late afternoon sun will be behind the beacon, a backplate should be used.



Extinguishable Message Signs
(SEE ES-27A and B)

Typical "METER ON" Sign





Detail A

Figure 14

CHAPTER THREE

III. SIGNING AND PAVEMENT MARKINGS

A. Advance Warning

See Chapter Two, Section E for advance warning signing.

B. Signing and Striping Typicals

All signs and markings shall conform to Chapters 4 and 6 of the Traffic Manual and the Standard Plans. Exceptions should be reviewed by the Headquarters Traffic Operations Liaison.

Figures 15 to 22 show typical signing and striping used on metered ramps. Figure 23 gives more detail on recommended signing.

See Chapter One, Section G for limit line placement.

C. Vehicles Per Green

Where a Type 1 standard is used, place a sign under the lower signal head, indicating the number of vehicles allowed for each green. Where a mast arm is used, place a sign indicating the number of vehicles allowed for each green to the right of each signal head.

R89 “ONE CAR PER GREEN”

R89-1 “ONE CAR PER GREEN EACH LANE”

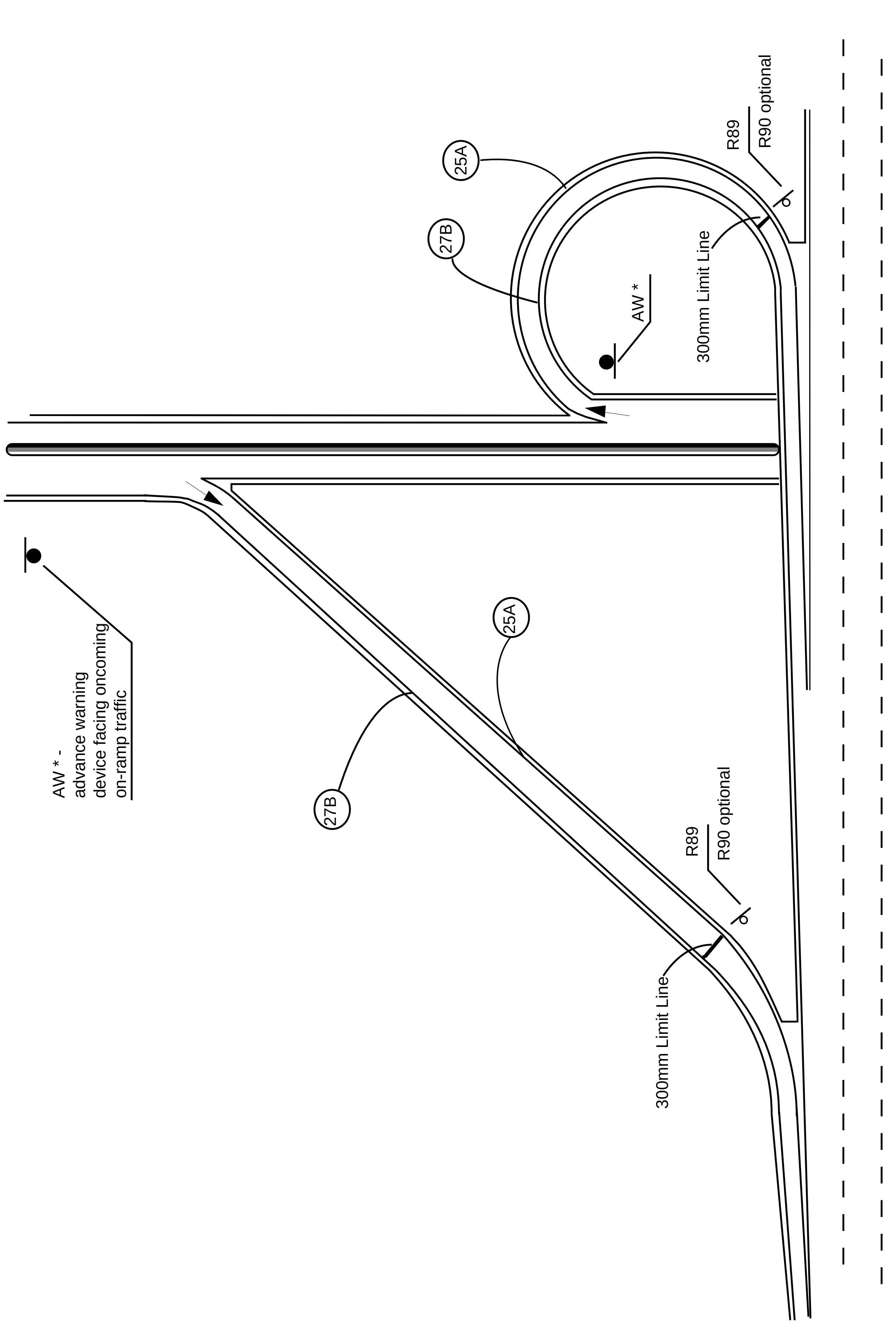
R89-2 “ONE CAR PER GREEN THIS LANE”

An alternate message indicates "2" cars per green.

D. HOV Signing and Pavement Markings

The standard signing for an HOV preferential lane should be placed to clearly indicate which lane is designated for HOVs. The standard HOV lane pavement marking shall be an elongated diamond (see Figure 24). Markings should be placed adjacent to R91 HOV signs. The pavement legend "CAR POOL LANE" may be painted between the diamond symbols on new projects to supplement, but not substitute for, the standard HOV lane markings. These legend markings, after their initial application, should not be maintained. An additional set of signs and pavement markings should be placed on long ramps (see Figures 17 and 18).

An R91 with the times indicated or a "WHEN METERED" indication allows SOVs in the lane during non-metering hours. An R91 without the times prohibits SOVs from using the HOV lane at all times (see Figure 23).



SIGNING &STRIPING TYPICAL
(not to scale)
1-Lane Diagonal On-ramp
1-Lane Loop On-ramp

* See Figure 14 for options

Figure 15

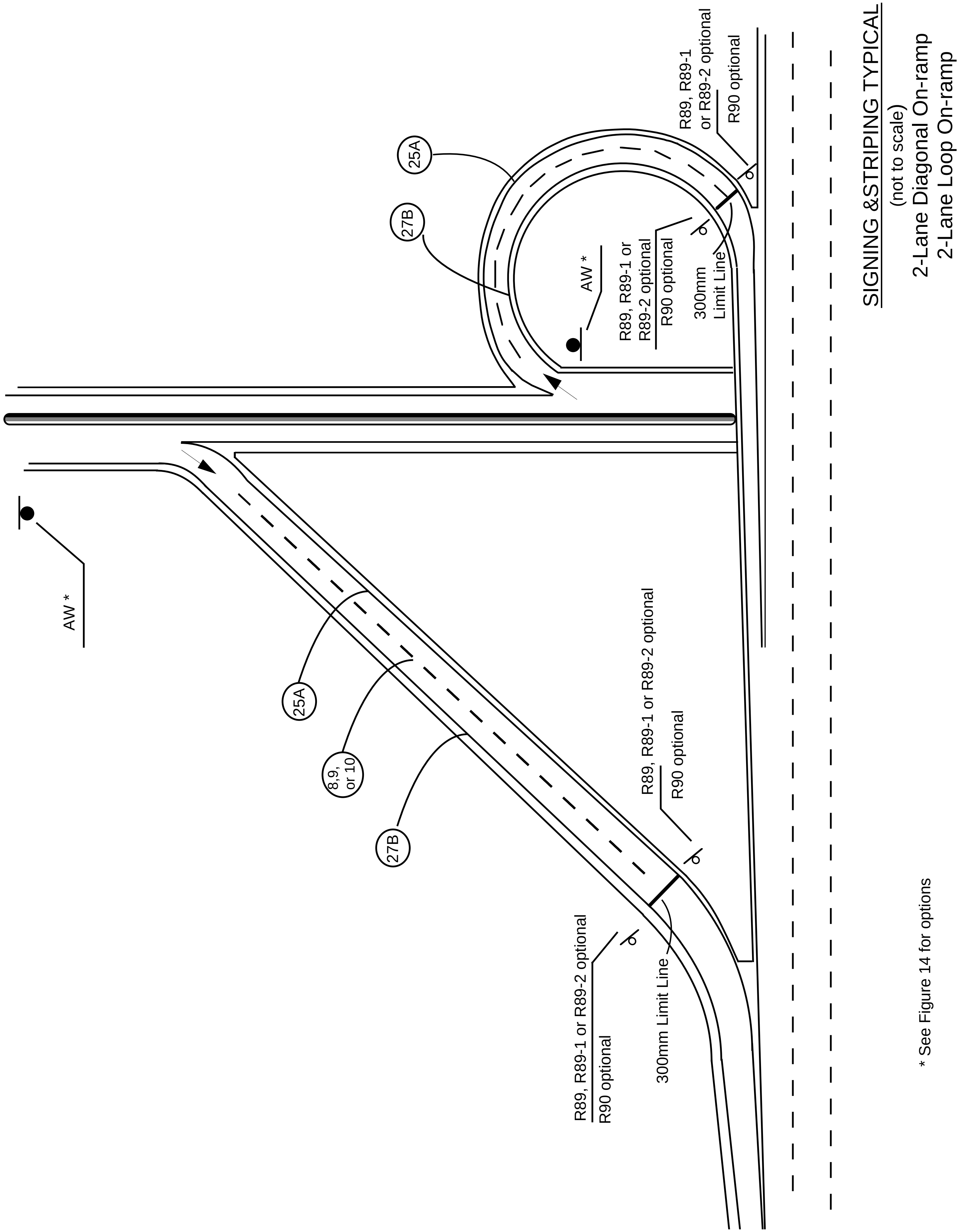
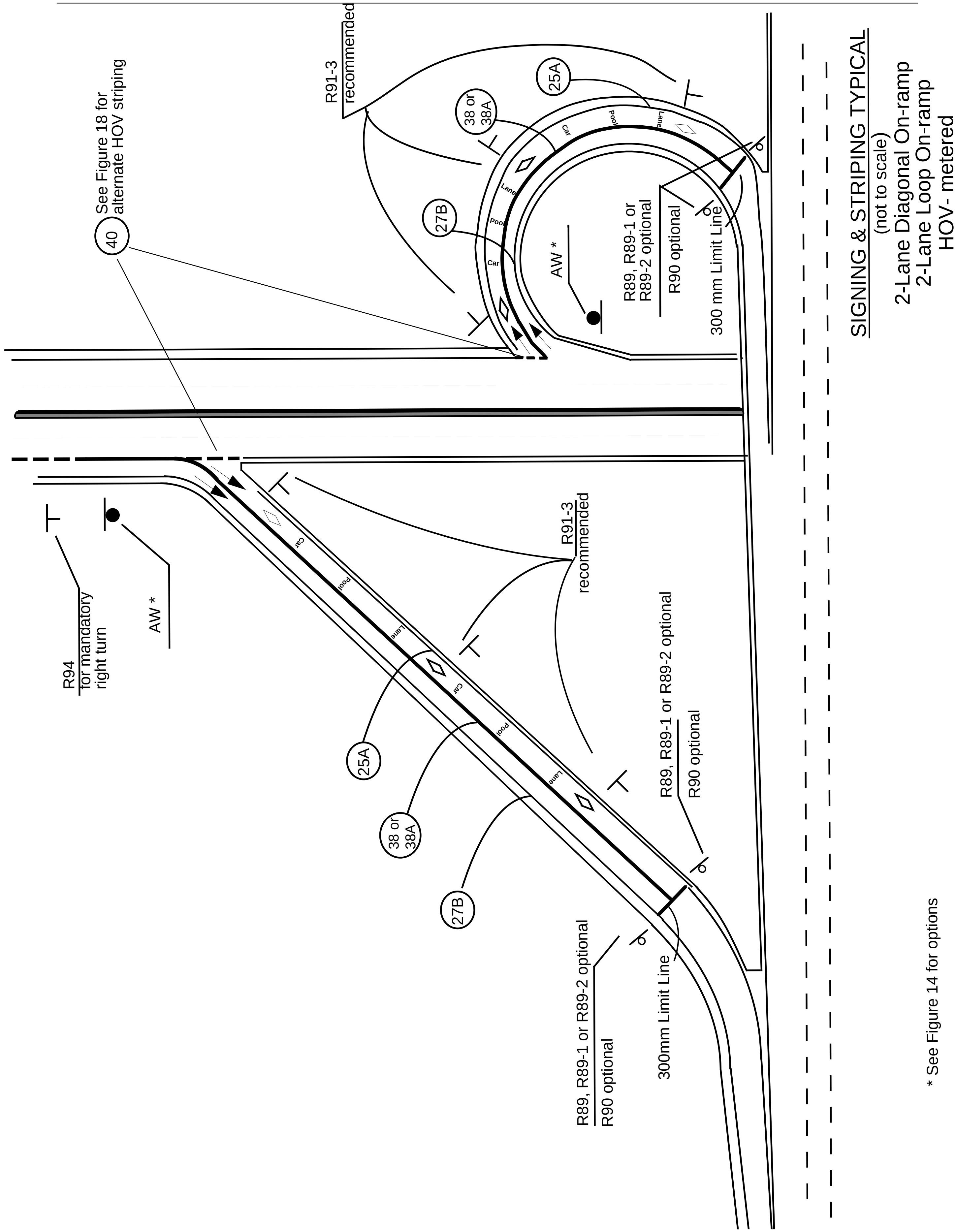

SIGNING &STRIPING TYPICAL
(not to scale)
2-Lane Diagonal On-ramp
2-Lane Loop On-ramp
25A
27B
AW *
R89, R89-1
or R89-2 optional
R90 optional
R89, R89-1 or
R89-2 optional
R90 optional
300mm
Limit Line
AW *
25A
8,9,
or 10
27B
R89, R89-1 or R89-2 optional
R90 optional
R89, R89-1 or R89-2 optional
R90 optional
300mm Limit Line
* See Figure 14 for options

Figure 16



SIGNING & STRIPING TYPICAL
(not to scale)
2-Lane Diagonal On-ramp
2-Lane Loop On-ramp
HOV- metered
40 See Figure 18 for alternate HOV striping
R91-3 recommended
25A
38 or 38A
27B
AW *
R89, R89-1 or R89-2 optional
R90 optional
300 mm Limit Line
R91-3 recommended
R94 for mandatory right turn
AW *
R89, R89-1 or R89-2 optional
R90 optional
25A
38 or 38A
27B
R89, R89-1 or R89-2 optional
R90 optional
300mm Limit Line
Car Pool Lane
* See Figure 14 for options

Figure 17

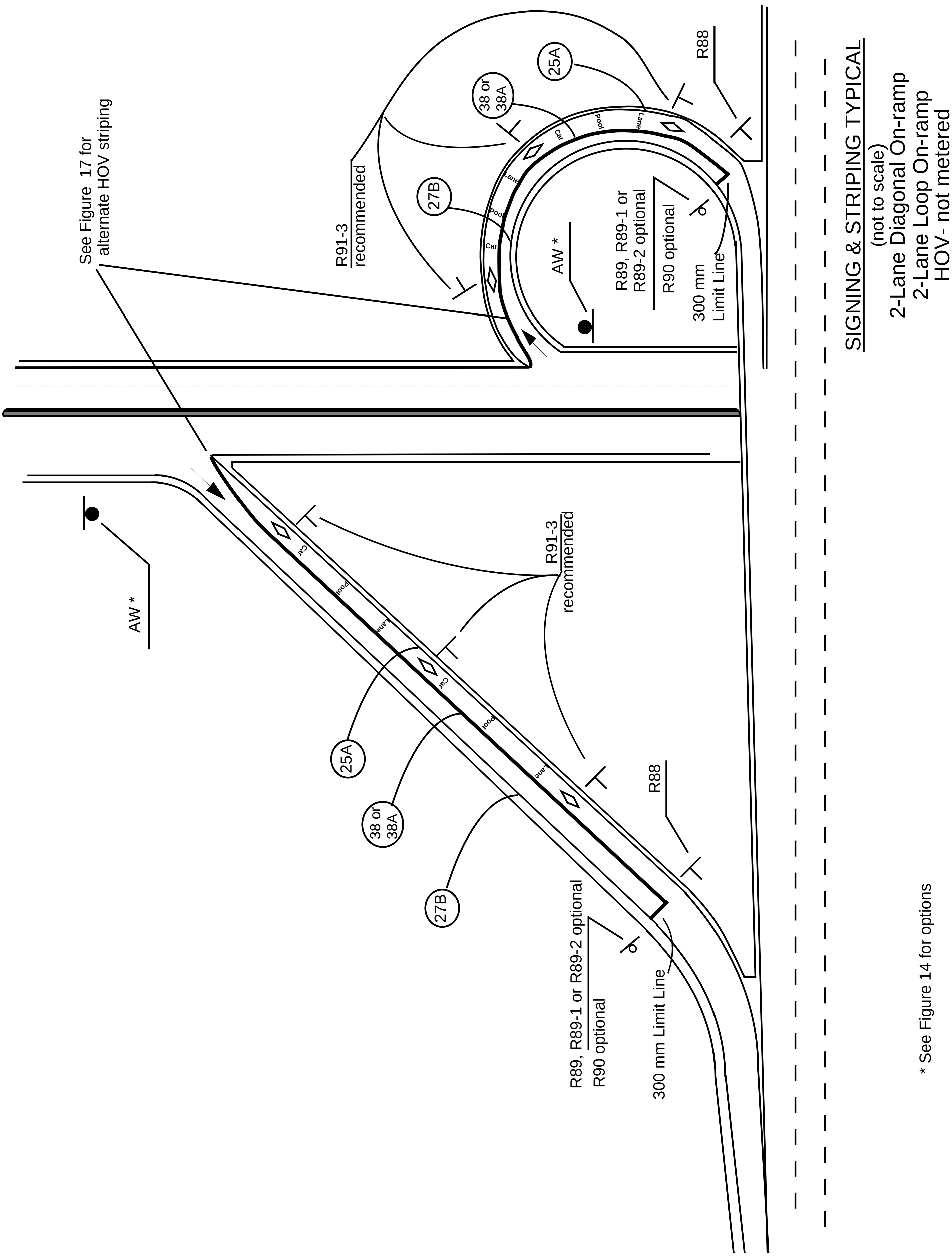
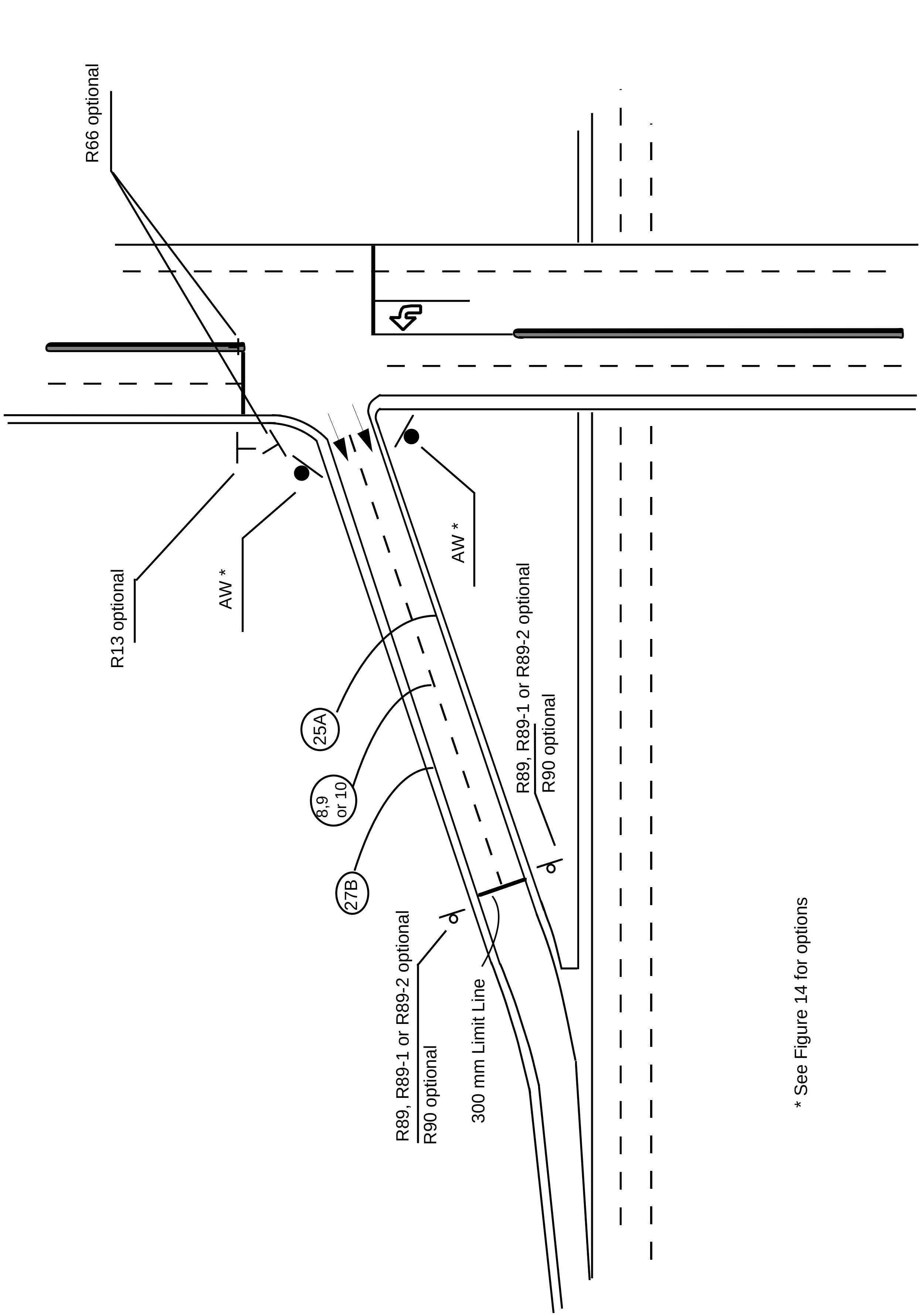

SIGNING & STRIPING TYPICAL
(not to scale)
2-Lane Diagonal On-ramp
2-Lane Loop On-ramp
HOV- not metered
See Figure 17 for alternate HOV striping
R91-3 recommended
27B
38 or 38A
25A
R88
AW *
R89, R89-1 or R89-2 optional
R90 optional
300 mm Limit Line
Car
Pool
Lane
R89, R89-1 or R89-2 optional
R90 optional
300 mm Limit Line
* See Figure 14 for options

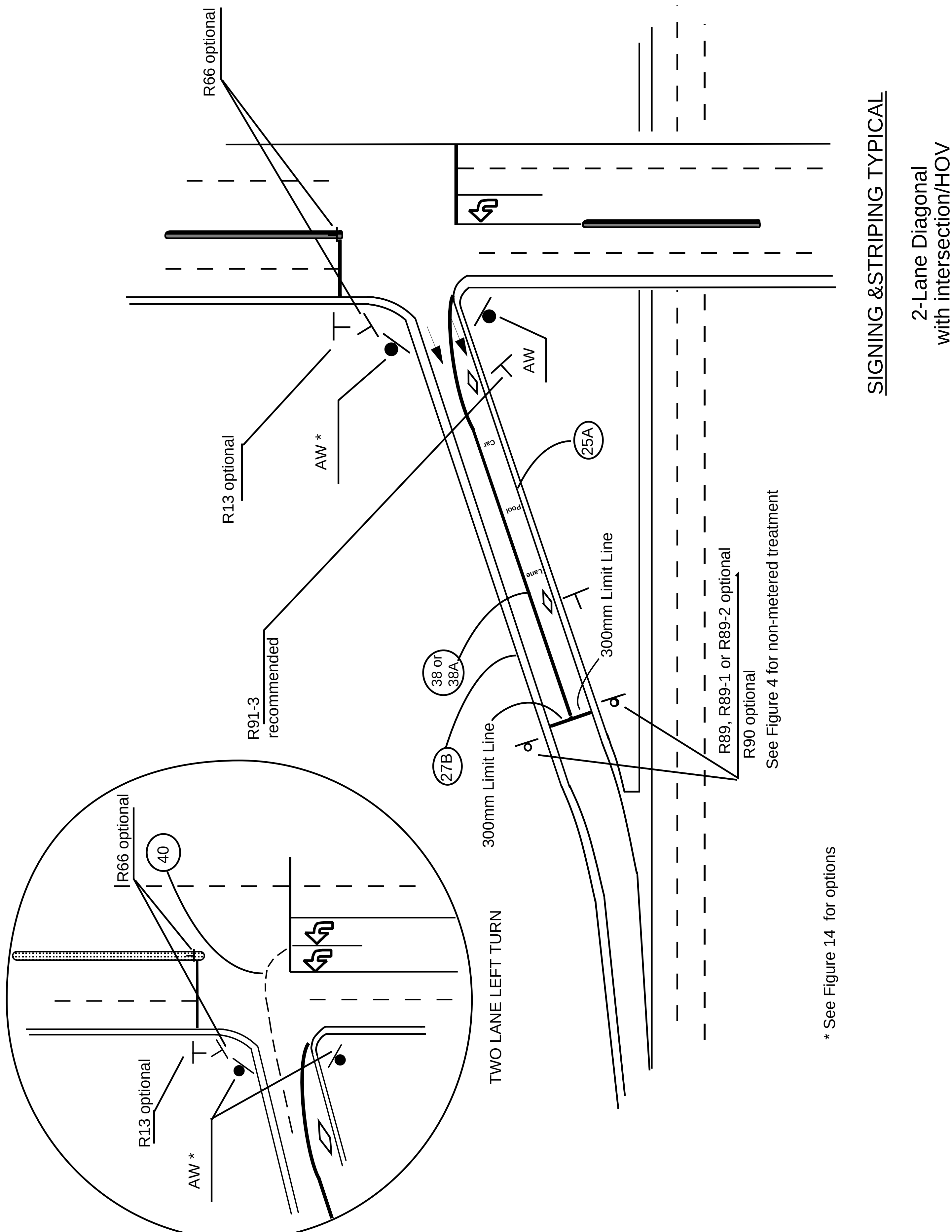
Figure 18



SIGNING &STRIPING TYPICAL

2-Lane Diagonal
with intersection

Figure 19

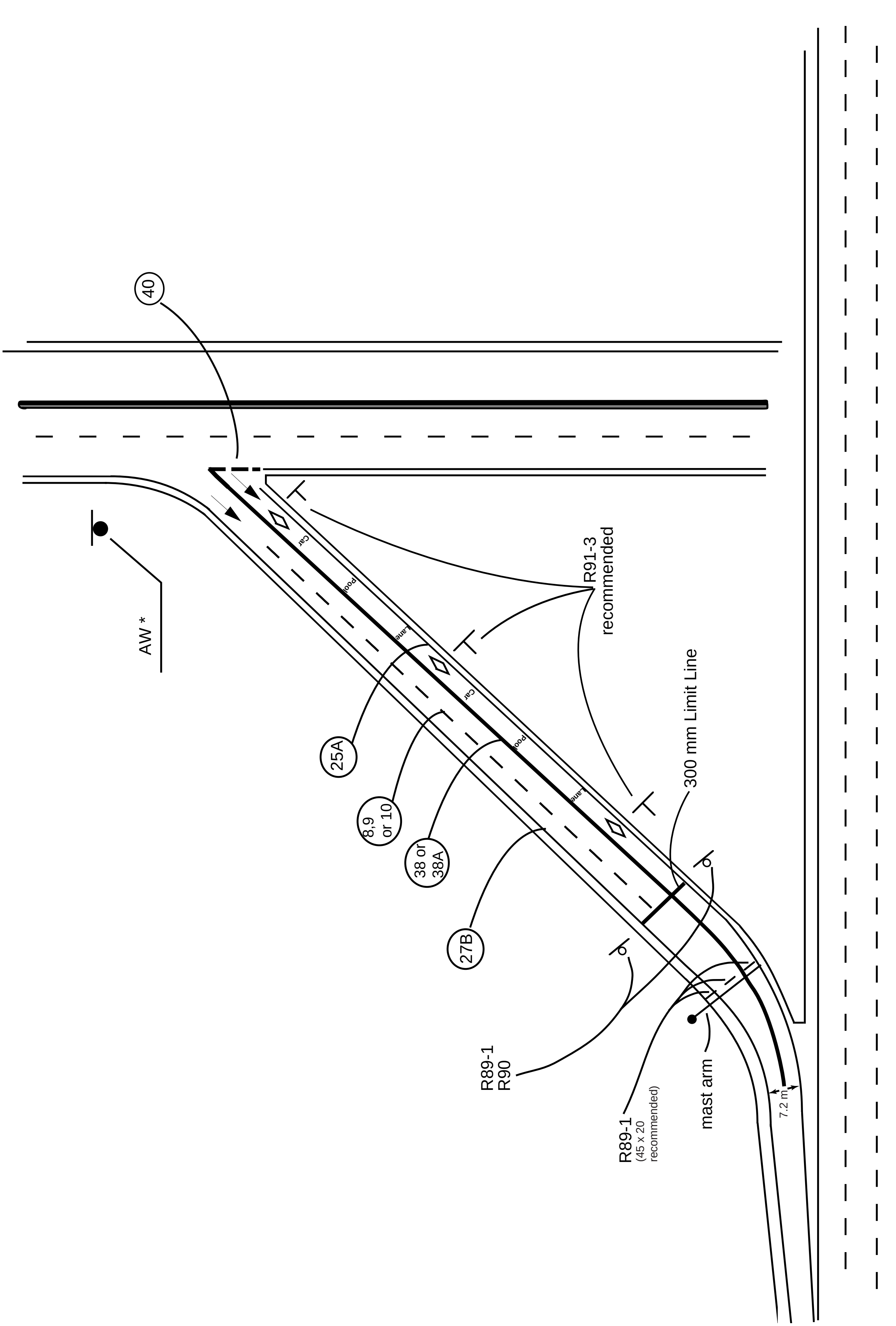


R66 optional
R13 optional
AW *
R91-3
recommended
AW
25A
Car
Pool
Lane
300mm Limit Line
38 or
38A
27B
300mm Limit Line
R89, R89-1 or R89-2 optional
R90 optional
See Figure 4 for non-metered treatment
* See Figure 14 for options
SIGNING &STRIPING TYPICAL
2-Lane Diagonal
with intersection/HOV
TWO LANE LEFT TURN
40
R66 optional
R13 optional
AW *

Figure 20

SIGNING & STRIPING TYPICAL

3-Lane Diagonal On-ramp
with HOV - metered



* See Figure 14 for options

Figure 21

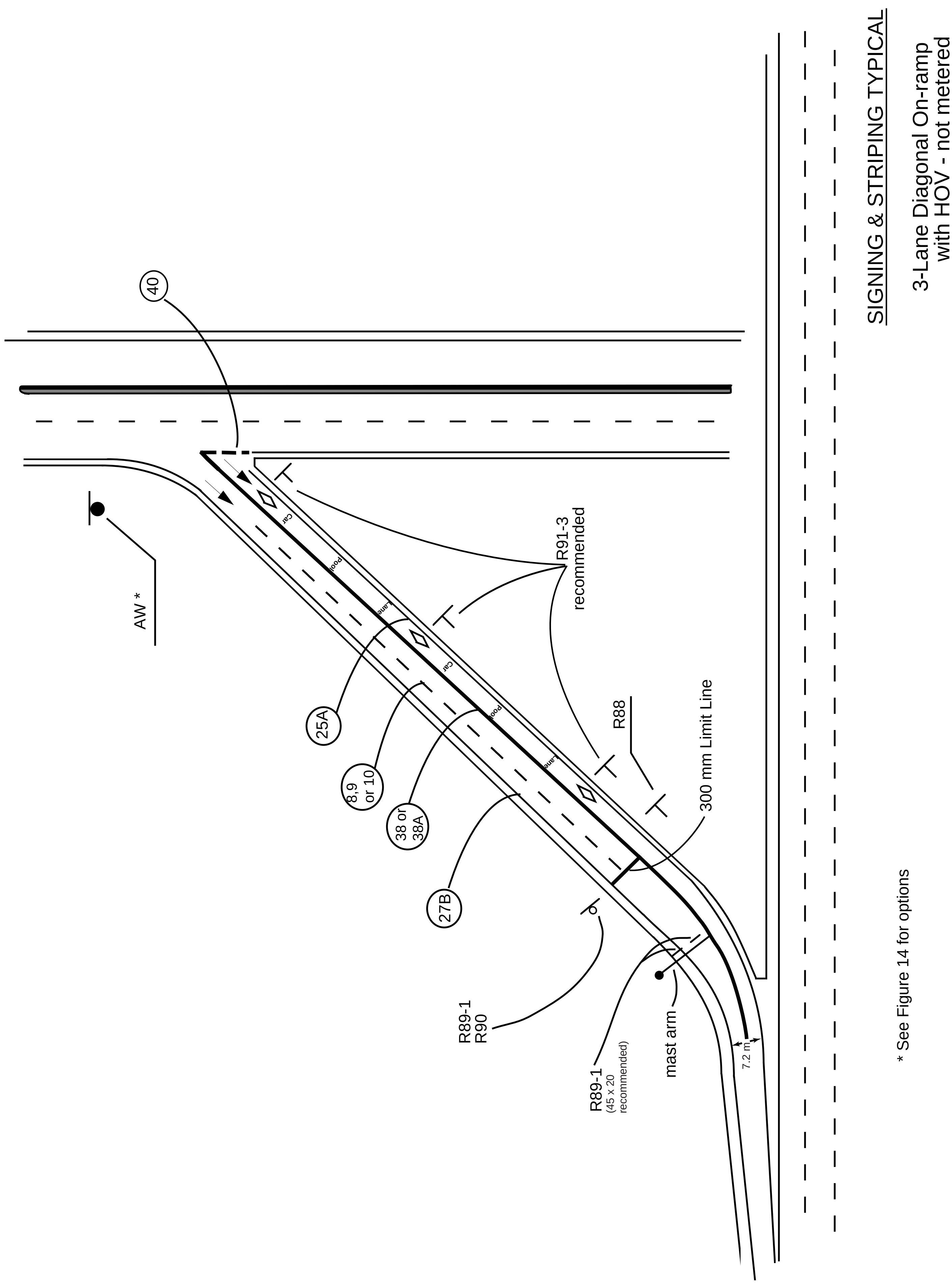
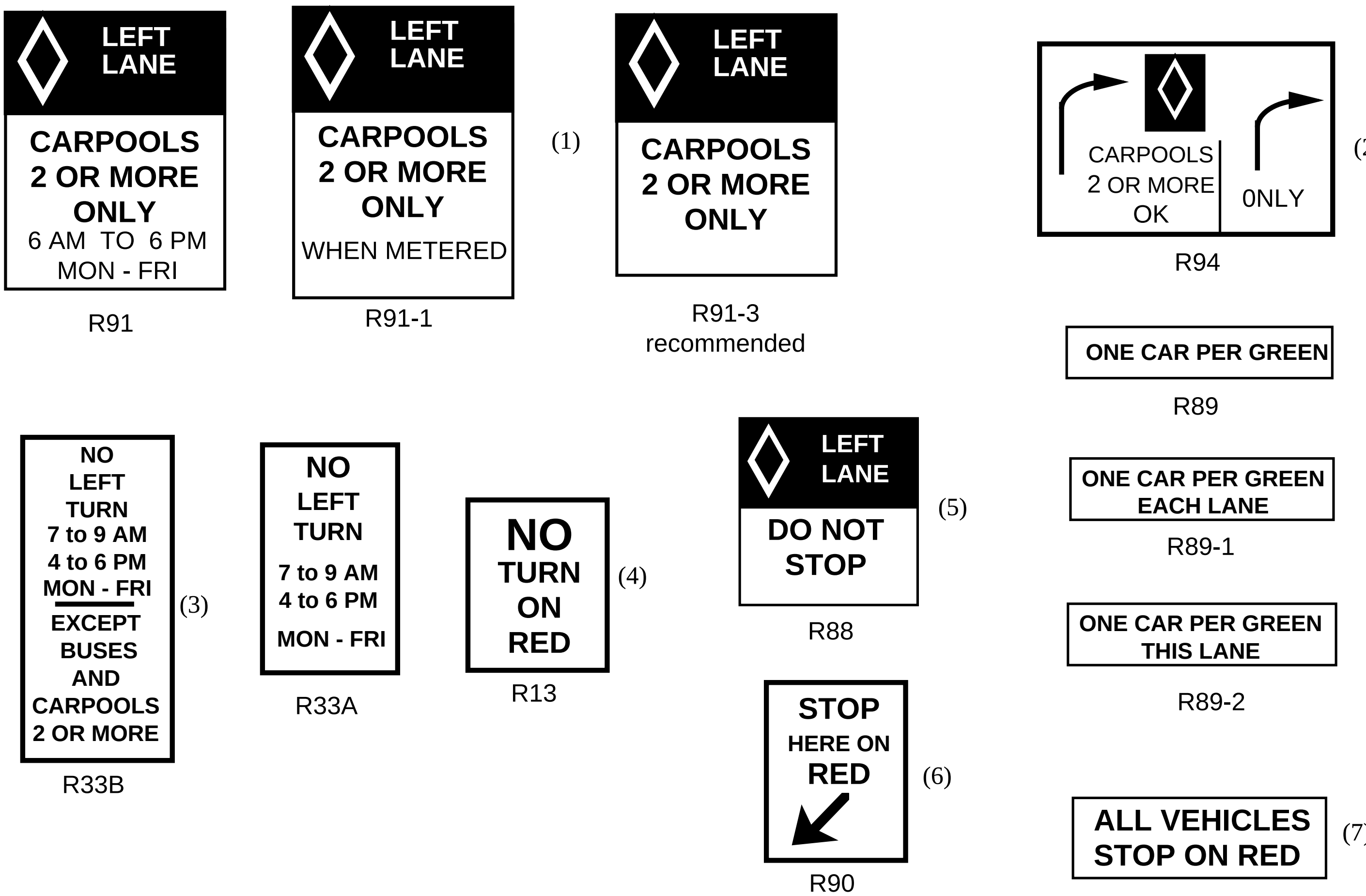

SIGNING & STRIPING TYPICAL
3-Lane Diagonal On-ramp
with HOV - not metered
40
AW *
R91-3
recommended
Car
Pool
Lane
25A
8,9
or 10
38 or
38A
27B
R88
300 mm Limit Line
R89-1
R90
R89-1
(45 x 20
recommended)
mast arm
7.2 m
* See Figure 14 for options

Figure 22

TYPICAL RAMP METER AND HOV SIGNING

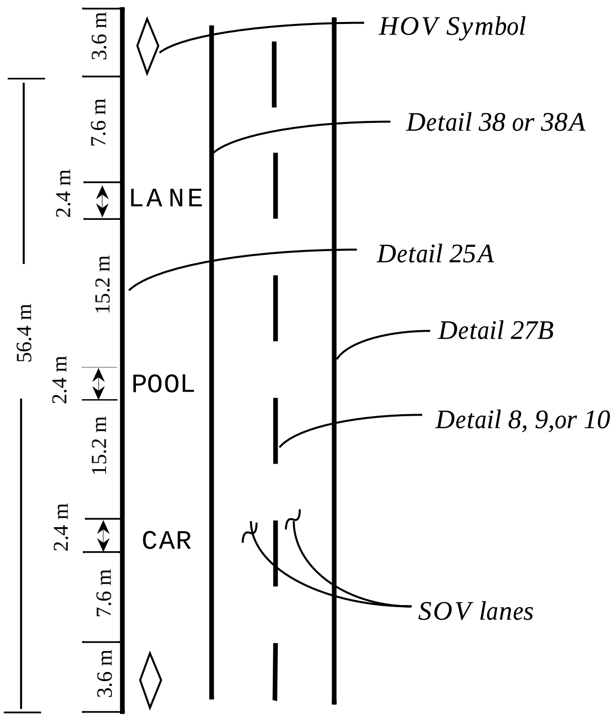


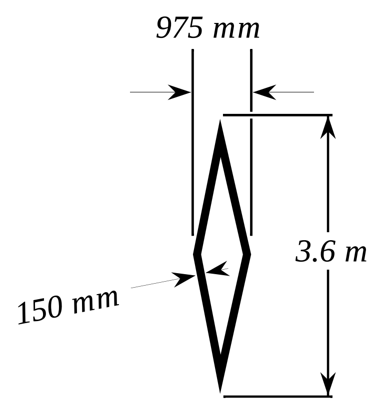
NOTES:

1. An R91 with the times indicated or a "WHEN METERED" indication allows SOVs in the lane during non metering periods. An R91 without the times prohibits SOVs from using the HOV lane at all times.
2. Advance HOV signs, R94, may be installed on local streets when striped for mandatory right turn.
3. "No Left Turn" signs, R33A or B, should be installed on local streets (with concurrence of local agency) whenever left turns are restricted during peak hours.
4. " No Turn on Red" signs, R13, may be used to restrict right turns onto ramp. Hours / days of restriction may be added.
5. “Do Not Stop” signs, R88, should be used to indicate that the HOV lane is not required to stop. Signs should be placed on the same side as the HOV lane, upstream of the meter.
6. "Stop Here on Red ", R90, should be placed on the Type 1 standards near the limit line at a three-lane ramp meter, and is optional at other locations.
7. “All Vehicles Stop on Red” should be placed when converting a non-metered HOV bypass lane to a metered operation. Also may be used on new installations where potential for confusion exists.

Figure 23

Typical HOV Pavement Markings





HOV Lane Symbol
(not to scale)

See Chapter 6 of the Traffic Manual for Striping Details

Figure 24

Contacts

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Carol Pearce	Traffic Operations, Sacramento - District 3	916 327-3854	8-467-3854
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Afsaneh Razavi	Traffic Management - District 7	213 897-0267	8-647-0267
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Mort Fahrtash	Traffic Systems Development - District 12	714 724-2453	8-655-2453

Glossary

Demand Loops

Inductive loops placed upstream of the limit line to detect approaching vehicles

HDM

Highway Design Manual

HOV

High occupancy vehicle. For ramp meter bypass lanes, this is usually a vehicle with 2 or more persons. Also called preferential lanes.

Inductive Loop Detector

A device used to detect the presence and passage of vehicles in a lane by sensing changes in an electromagnetic field surrounding the loop detector due to vehicles passing through it. For ramp meters, loop detectors are used for presence and passage at the meter, for presence near the entrance to the ramp (queue), and for presence and passage on the mainline.

Passage Loops

Inductive loops placed downstream of the limit line to detect passing vehicles

Ramp Metering

A method of controlling traffic entering a freeway so that demand for a bottleneck section, or any other section, will not exceed capacity. The primary objective of ramp control is to reduce overall travel time to the total traffic stream — freeway and surface street vehicles.

SOV

Single occupant vehicle

Type 170 Controller

A microprocessor-based device used to control ramp meter signals based on information from the loop detectors.

Type 2070 Controller

A VME based controller utilizing a 16 bit microprocesser that can be used to control ramp meter signals based on information from the loop detectors. It has the capability of providing more functionality than the older 170 controller.

VPH

Vehicles per hour

APPENDIX

Deputy Directive 35 - Ramp Metering
Ramp Metering Policy Procedures
Sample Exception to Ramp Metering Fact Sheet
Arrival Discharge Chart

California Department of Transportation

DEPUTY DIRECTIVE

Number: DD-35

Refer to
Director's Policy: 08-FreewaySystem Management

Effective Date: 1-3-95

Supersedes: P&P 91-01

Title: Ramp Metering

POLICY

Caltrans is committed to using ramp metering as an effective traffic management strategy to maintain an efficient freeway system and protect the investment made in constructing freeways to keeping them operating at or near capacity flow rates.

DEFINITION/ BACKGROUND

Ramp metering is the common method of ramp entry control. It has been an effective tool in reducing congestion on California freeways since the late 1960's. Caltrans has installed over 1300 ramp meters throughout the state and proposes their installation on all urban freeway entrance ramps where metering will improve or maintain effective operations along free-way corridors.

RESPONSIBILITES

The Traffic Operations Program Manager is responsible for the develop-ment, review and dissemination of policies, guidelines, and procedures for ramp metering (see Ramp Metering Policy Procedures).

The State and Local Project Development Program Manager is responsi-ble for the development and review of geometric design standards for ramp metering and supports the inclusion of ramp metering in projects within freeway segments identified in the Ramp Meter Development Plan.

District Directors are responsible for developing local agency support for ramp metering; implementing ramp metering policies and procedures; and providing justification for deviation from established policy and procedures.

APPLICABILITY

Any employees involved with ramp metering activities.

ORIGINAL SIGNED BY

LEE F. DETER
Deputy Director
Maintenance and Operations

Distribution:B

RAMP METERING POLICY PROCEDURES

State of California
Business, Housing and Transportation Agency
Department of Transportation
Traffic Operations
August 1997

RAMP METERING POLICY PROCEDURES

I. PURPOSE

The purpose of these procedures is to provide guidelines for implementing the Department's ramp metering policy (DD-35).

II. BACKGROUND

Metering has proven to be an effective traffic operations tool to maximize the efficiency of a corridor. The primary objective of metering is to reduce congestion and the overall travel time of the total traffic stream - on both freeway and surface streets. Ramp metering reduces congestion by:

- Maintaining more consistent freeway throughput.
- Utilizing the capacity of the freeway corridor more efficiently.
- Providing incentives for increased use of carpools, vanpools, and public transit by including preferential lanes which offer time savings to High Occupancy Vehicles (HOV) at ramp meters.

Secondary benefits include the reduction of congestion-related accidents and air pollution. Ramp meters operate most effectively when upstream mainline traffic is controlled. This control can be accomplished by installing additional ramp meters, metering freeway to freeway connectors or mainline control. These procedures focus on the implementation of ramp metering systems through a coordinated effort involving Caltrans planners, designers, operations personnel, local agency staff, the California Highway Patrol (CHP), and the public.

III. PROCEDURES

A. It is the District's responsibility to maintain an acceptable level of service on the freeway system, to make the most effective use of each transportation corridor, and to protect the public's investment in the system.

Each District that currently operates, or expects to operate, ramp meters within the next ten years shall prepare a Ramp Meter Development Plan (RMDP) identifying the freeway segments, including freeway to freeway connectors, that are expected to be metered within this period. The RMDP should also identify free way segments where upstream mainline control is necessary to maintain effective overall freeway operations. The RMDP shall be updated biennially and be included in local Congestion Management Plans.

B. Projects which propose the modification of an existing interchange or the construction of a new interchange within the freeway segments identified in the RMDP, regardless of funding source, should include provisions for ramp meters. This applies to all projects that have an approved Project Study Report dated July 1991 or later (the date of the original Policy and Procedure). These provisions, as defined in the Ramp Meter Design Guidelines, should include right of way, geometrics to accommodate vehicle storage and HOV bypass lanes, ramp meter equipment, and CHP enforcement areas. Projects which propose additional capacity within freeway segments identified in the RMDP shall include provisions for ramp meters and shall implement the ramp meters at all entrance ramps within the project limits. In freeway segments identified in the RMDP where mainline control is necessary to maintain effective overall freeway operation, additional freeway capacity should not be constructed without an analysis of the operational impacts to downstream segments. Districts are responsible for performing appropriate environmental studies for ramp metering projects.

C. The District will work in partnership with metropolitan planning organizations, regional transportation planning agencies, and congestion management agencies to program ramp metering projects and develop implementation plans. Coordination and consultation should be documented and concurrence may be obtained in any form the District considers appropriate.

D. The <u>Ramp Meter Design Guidelines</u> prepared by the Division of Traffic Operations , in cooperation with the Division of State and Local Project Development, and the CHP shall be used when designing ramp metering facilities. This document is a compilation of design information and operational practices used statewide.

E. HOV preferential lanes shall be considered wherever ramp meters are installed. The need for HOV bypass lanes should be included in the Project Study Report, Project Information Report, Project Report, and Environmental Document. If an HOV preferential lane is not included in a proposal to ramp meter, the reasons should be addressed in the appropriate document.

The District is responsible for consulting with the CHP on project features which affect enforcement activities such as HOV lane violations, enforcement pads, etc. Coordination and consultation should be documented.

F. When selecting the appropriate metering method for the HOV preferential lane, the following criteria should be used:

Control: An analysis of HOV traffic volumes shall be made to determine the impact on mainline traffic flows. Where adverse impacts exist , consideration should include metering the HOV preferential lane and/or more restrictive metering of the SOV lane(s). Consideration should be given to metering the HOV preferential lane if platoons from local signalized intersections adversely affect the operation of the freeway. Storage capacity and effects to local arterials should also be addressed.

Merge Conditions: Prior to entering the freeway, all vehicles on the on-ramp should be provided with adequate space to safely merge with each other. The safest merge condition is when the speeds of the merging vehicles are identical. When the speed differentials between HOVs and SOVs are excessive, consideration should be given to metering the HOV lane. All ramps should be designed in accordance with the Ramp Meter Design Guidelines which detail adequate merging distances.

Enforcement: The ability to safely enforce occupancy violations of HOV lanes is essential. The CHP should be consulted for their recommendation of enforcement operations at each HOV preferential lane location.

Corridor Operations: In corridors where ramp meters are already operational, the existing metering method may be used as a criteria for additional installations in the same corridor. Should alternate metering methods be proposed along a corridor, local agencies should be consulted.

The criteria listed above can be applied to new and existing ramp meter installations. If it is being applied to an existing ramp meter, the following criteria should also be used:

Accident History: The accident history of the ramp needs to be investigated. If either the ramp or any portion of the freeway within 500 feet of the ramp gore has been flagged as a high accident concentration location (Table C), each acci dent report should be reviewed in detail to determine whether or not the HOV operation during the metered period was a contributing factor. If evidence suggests that it could have been a contributing factor to the accident, consideration should be given to metering the HOV preferential lane.

G. Districts shall provide justification for deviation from the policy and these procedures and concurrence shall be obtained from the Headquarters Traffic Operations District Liaison. Deviations from design standards require the approval of the Project Development Coordinator in the Office of Project Planning and Design.

H. The Division of Traffic Operations provides District personnel with technical assistance and support on the design and operation of ramp meter systems and assists in the preparation of the District's RMDP.

CONTENTS OF EXCEPTIONS TO RAMP METERING POLICY FACT SHEET:

PROJECT DESCRIPTION

Briefly describe the project. Note the type of project and/or major elements of work to be done.

RAMP METERING POLICY NON-COMPLIANCE FEATURES

Describe the proposed or existing ramp metering policy non-compliance feature(s). (Note: Deviations from advisory or mandatory design standards shall be addressed as required by the *Project Development Procedures Manual,* the *Highway Design Manual* and applicable District Directives.) Design exceptions to standards to be attached to Ramp Meter Policy Fact Sheet.

REASON FOR THE EXCEPTION

Be thorough but brief. Supportive factors may include right-of-way or space constraints, environmental concerns, inordinate costs, etc. Show an estimate of the added cost above the proposed project cost that would be required to conform to the ramp metering policy for which exception is being documented. The estimate does not have to be highly developed but must be realistic.

FUTURE CONSTRUCTION

Describe any planned future projects in the immediate vicinity of the requested ramp meter exception, but do not make any commitments (e.g., ramp metering as part of future projects) unless there is a certainty that they can be followed through.

PROPOSED EXCEPTION REVIEWS AND CONCURRENCE

Note reviews by HQ Traffic Operations, the District Liaison and District Office of Traffic Systems. Give dates of reviews and discuss any comments that were made and their disposition.

REMARKS

Note clarifying remarks. Discuss impacts on project delivery schedule and project costs, if any. Discuss impacts of ramp metering policy non-compliance features.

ATTACHMENTS

Provide a locations map and/or vicinity map for the project, indicating the location of the requested exception(s) to the ramp metering policy. Also provide cross-sections and/or special details as necessary to illustrate the policy non-compliance condition. Letters, resolutions, traffic studies, etc., which help to clarify the reasons for the exception request, may be attached.

SIGNATURE SHEET

The Fact Sheet signature page shall conform to the attached.

Dist-Co-Rte-KP
Source Unit -EA
Project Cost

FACT SHEET

EXCEPTION TO
RAMP METERING POLICY

Prepared by:

(Name), Registered C.E.	Date	Telephone

Approval recommended by:

(Name), Project Manager	Date	Telephone

Concurrence by:

(Name), District Liaison HQ Traffic Operations	Date	Telephone

Approved by:

(Name), District Division Chief, Operations	Date

Instructions for Using Arrival Discharge Chart

The chart is designed for arrival and discharge rates in vehicles per hour, in 1/10 hour time intervals. The area of each grid under the curve represents 100 vehicles/hour x 0.1 hours = 10 vehicles.

Use of the chart is explained below.

1. Plot the arrival rates for each 1/10 hour time period in bar graph style. The chart can accommodate a maximum study period of 1.6 hours.

2. On the same chart, plot the discharge rate in the same manner.

3. Beginning with time zero, move to the point where the arrival rate exceeds the discharge rate. This is the starting point where delay begins. Ignore the portion prior to the starting point where the arrival rate fails to exceed the discharge rate. This portion experiences no delay.

4. For each time interval of the chart to the right of the starting point where queue begins, calculate the area under the arrival rate curve. Record on Line A the number on the right side of the graph that corresponds to the arrival rate.

5. Do the same for the area under the discharge rate curve and record on Line B.

6. Calculate delta for each time interval. This is the cumulative difference of the area on Lines A and B, taken from time zero to the time interval in question.

7. Delta continues to increase as long as the arrival rate exceeds the discharge rate. At the point where the discharge rate exceeds the arrival rate, delta begins to decrease representing dissipation of the queue, and there is no further delay.

8. Determine the maximum delta and the sum of the deltas. Enter the data on the left side of the chart to determine maximum queue (vehicles), total delay (vehicle-hour), total vehicles delayed, and average delay.

The number of cars in the queue at the end of any 1/10 hour time period is equal to the total number of arrivals minus the total number discharged up to the end of that time period. This is calculated by taking the difference between the areas under the arrival and discharge curves, and multiplying by 10. The maximum queue occurs at the end of the 1/10 hour time period which marks the greatest difference between arrival and discharge areas.

Any delta x 10 represents the number of vehicles stored in the queue for that time period. The delay in each 1/10 hour time period equals the number of vehicles in the queue (delta x 40) multiplied by the length of time (1/10 hour). For example, if delta for one of the columns is 3.2, the delay for that 1/10 hour is 3.2 x 10 x 1/10 = 3.2 vehicle-hours. The total delay is summation of the individual 1/10 hour time increments, so the total delay = Σdelta.

The total number of vehicles delayed is the same as the total number of arriving vehicles. Every vehicle which arrives during the time when there is a queue is delayed to some extent. Total vehicles delayed = ΣLine A x 10.

ROUTE 10 INTERCHANGE BROWN ROAD RAMP NB - EB

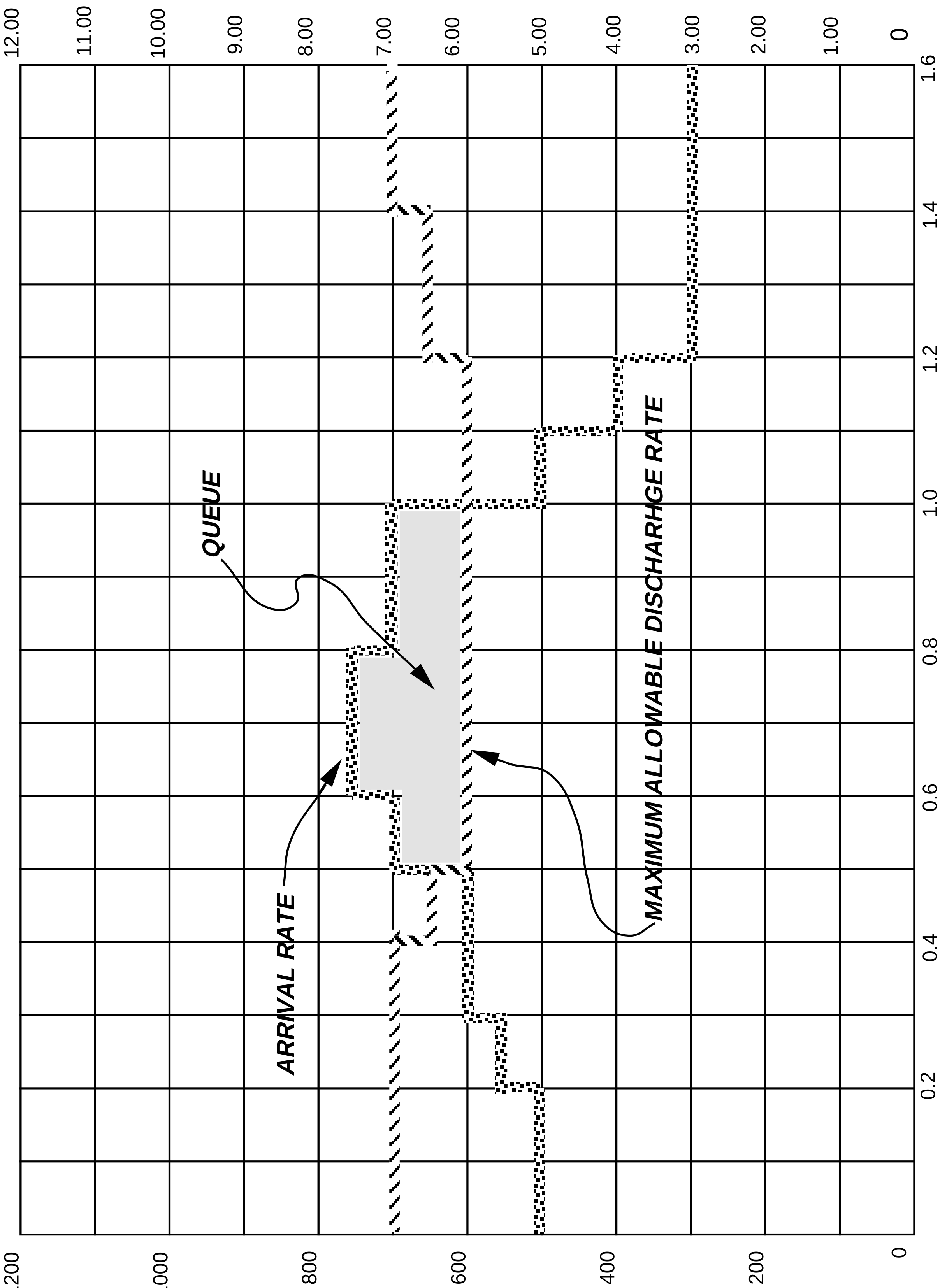
BEGINNING TIME 0630 RAMP COUNT DATE 5/10/92

MAX QUEUE = MAX Δ X 10= 60 (60.4) VEHICLES

TOTAL DELAY = ΣΔ = 26.76 VEHICLE HOURS

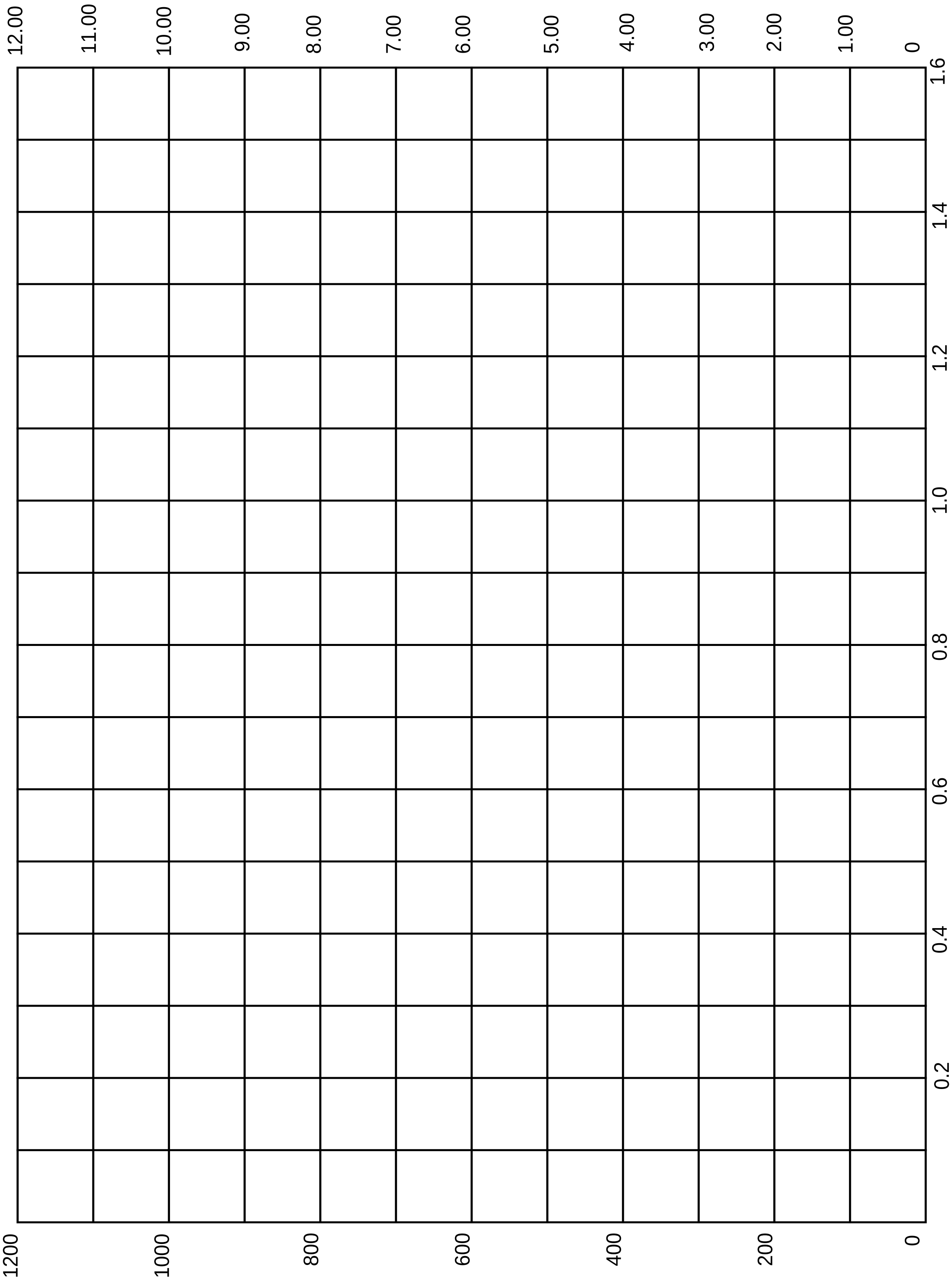
TOTAL VEHICLES DELAYED = ΣA X 10 = 480 VEHICLES

AVERAGE DELAY TOTAL DELAY/TOTAL VEH. = 0.05 HOURS



	0–0.1	0.1–0.2	0.2–0.3	0.3–0.4	0.4–0.5	0.5–0.6	0.6–0.7	0.7–0.8	0.8–0.9	0.9–1.0	1.0–1.1	1.1–1.2	1.2–1.3	1.3–1.4	1.4–1.5	1.5–1.6
A. Arriv	—	—	—	—	—	7.00	7.52	7.52	7.00	7.00	5.00	4.00	3.00			
B. Disch						6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00			
Δ=ΣA−ΣB						1.00	2.52	4.04	5.04	6.04	5.04	3.04	0.04			

ROUTE_______INTERCHANGE___________________________RAMP ______________
BEGINNING TIME______________________RAMP COUNT DATE____________
MAX QUEUE = MAX Δ X 10=____________________________VEHICLES
TOTAL DELAY = ΣΔ =_________________________________VEHICLE HOURS
TOTAL VEHICLES DELAYED = ΣA X 10 = _________________VEHICLES
AVERAGE DELAY   TOTAL DELAY/TOTAL VEH. =_________HOURS



A. Arriv	B. Disch	Δ=ΣA−ΣB