Debris-Control Structures

Hydraulic Engineering Circular No. 9 March 1971 *

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Archival
Superceded by HEC-9
3rd edition - October 2005

CONTENTS

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Archival
Superceded by HEC-9
3rd edition - October 2005

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DEBRIS-CONTROL STRUCTURES

Prepared by
G. Reihsen, Highway Engineer, Region 7
and
L. J. Harrison, Highway Engineer
Hydraulics Branch, Bridge Division

PREFACE

The original edition of this Circular was prepared in 1964 in cooperation with the Region 7 and Washington offices of the Federal Highway Administration (formerly Bureau of Public Roads) and the California Division of Highways. This revision incorporates comments received from users and an additional remark on safety.

The Circular is based principally on California practice and experience since the publication of the chapter on debris-control in California Culvert Practice [1/]. The authors are indebted to Messrs. Kenneth Fenwick and Walter Whitnack of the California Division of Highways for their cooperation in furnishing standard plans and photographs and in arranging for field inspections. Particular credit is due to the hydraulics and maintenance engineers of California Highway Districts I, II, IV, VII, and VIII for relating their experiences with these structures. Permission to use plans prepared by the highway departments of California, Washington, and Hawaii is acknowledged. Special recognition is given to Mr. J. Kieley of Region 7, Federal Highway Administration, for his review and helpful suggestions in the preparation of the manuscript.

Archival
Superseded by HEC 9
3rd edition - October 2005

INTRODUCTION

General

Water-borne debris problems and structures used for controlling debris are discussed in this Circular. An accumulation of debris at inlets of highway drainage structures is a frequent cause of unsatisfactory performance or malfunction. This accumulation may result in failure of the drainage structure or overtopping of the roadway by

1/ State of California Division of Highways, California Culvert Practice, Sacramento, California, 2nd Edition, pp. 13-31, 1955.

flood waters and possible damage to the roadway and other property. Consideration of the need for debris-control structures should be an essential part of all hydraulic structure designs. The emphasis in this publication is on culverts because their relatively limited waterway area is subject to clogging by retention of debris at the inlet.

Debris can be controlled by three methods: (a) intercepting the debris at or above the inlet; (b) deflecting the debris for detention near the inlet; or (c) passing the debris through the structure. In some locations, it may be desirable to provide a relief opening either in the culvert itself or by installing a separate, smaller pipe with the inlet higher than the principal culvert inlet. The choice of method depends upon the size, quantity and type of debris, the potential hazard to life and property, the costs involved and maintenance proposed. The debris-control structure selected to meet the needs of the site must be compatible with the need for a forgiving roadside for errant vehicles. Some examples shown herein do not fully meet this criterion but were selected to illustrate the control device only.

Often the waterway opening is arbitrarily increased in an attempt to pass debris through the culvert. The additional cost of such an approach is usually greater than that for a device installed to control debris. On the other hand, when debris from the drainage basin can be passed through the structure without clogging, maintenance costs will be less than when debris is intercepted and subsequently requires removal.

A debris-control structure may have several of the following advantages:

(a) Prevents traffic delays due to an accumulation of drift on the roadway or washouts caused by clogged culverts.

(b) Allows for planned maintenance rather than emergency maintenance during floods when other situations arise which also require immediate attention.

(c) Avoids providing a "safety factor" in sizing a culvert to accommodate debris.

(d) Provides a safeguard against damaging buoyant forces when an accumulation of drift at the culvert entrances causes part-full flow.

(e) Gives maintenance forces a method for correcting drift problems at existing culverts.

Archival
Superceded by HEC-9
3rd edition - October 2005

In this publication a system of classifying the type of debris expected from any drainage basin is followed by a list of types of debris-control structures. The basis for choosing the type of control structure is given and details of design are discussed.

Classification of Debris

Flood flow reaching a culvert nearly always carries debris which may be either floating material, material heavier than water, or a combination of both. Debris concerns the highway engineer because it can be deposited at the culvert entrance or in the culvert, thus impairing its operation. A thorough study of the extent and type of the debris originating in the drainage basin is essential for proper design of a culvert.

As an aid in selecting an appropriate debris-control structure, the debris from the drainage basin should be classified. A convenient classification system is that of the California Division of Highways which follows:

1. Very Light Floating Debris or No Debris.
2. Light Floating Debris - Small limbs or sticks, orchard prunings, tules and refuse.
3. Medium Floating Debris - Limbs or large sticks.
4. Heavy Floating Debris - Logs or trees.
5. Flowing Debris - Heterogeneous fluid mass of clay, silt, sand, gravel, rock, refuse or sticks.
6. Fine Detritus - Fairly uniform bedload of silt, sand, gravel more or less devoid of floating debris, tending to deposit upon diminution of velocity.
7. Coarse Detritus - Coarse gravel or rock fragments.
8. Boulders - Large boulders and large rock fragments carried as a bedload of flood stage.

Types of Debris-Control Structures

Debris-control structures can have many shapes and can be constructed of a variety of materials. These structures will be divided into the following general types:

Archival
Superceded by HEC-9
3rd edition - October 2005

1. Debris Deflectors - (figs. 1-13) - Structures placed at the culvert inlet to deflect the major portion of the debris away from the culvert entrance. They are normally "V"-shaped in plan with the apex upstream.

2. Debris Racks - (figs. 14-27) - Structures placed across the stream channel to collect the debris before it reaches the culvert entrance. Debris racks are usually vertical and at right angles to the streamflow, but they may be skewed with the flow or inclined with the vertical.

3. Debris Risers - (figs. 28-34) - A closed-type structure placed directly over the culvert inlet to cause deposition of flowing debris and fine detritus before it reaches the culvert inlet. Risers are usually built of metal pipe. Risers are also used as relief devices in the event the entrance becomes plugged with debris (figs. 33, 34, 43, 45, and 51).

4. Debris Cribs - (figs. 35-39) - Open crib-type structures placed vertically over the culvert inlet in log-cabin fashion to prevent inflow of coarse bedload and light floating debris.

5. Debris Fins - (figs. 40-45) - Walls built in the stream channel upstream of the culvert. Their purpose is to aline debris, such as logs, with the axis of the culvert so that the debris will pass through the culvert barrel without clogging the inlet. They are sometimes used on bridge piers to deflect drift.

6. Debris Dams and Basins - (figs. 46-51) - Structures placed across well-defined channels to form basins which impede the streamflow and provide storage space for deposits of detritus and debris.

7. Floating Drift Boom - Logs or timbers which float on the water surface to collect floating drift. Drift booms require guides or stays to hold them in place laterally. They are limited in use and will not be discussed further.

8. Combination Devices - (figs. 28, 29, 43, 45, 48, and 51) - A combination of two or more of the preceding debris-control structures at one site to handle more than one type of debris and to provide additional insurance against a clogged culvert inlet.

Archival
Superseded by HEC-9
3rd edition - October 2005

DESIGN OF DEBRIS-CONTROL STRUCTURES

Preliminary Field Studies

Proper design of a debris-control structure must be preceded by a field study of the debris problem. Among the factors to be considered are possible future changes in the type of debris that might result from new industry or changes in land use within the drainage basin. As an example, logging in a previously virgin area could change the nature of the debris problem from one of "medium floating debris" to "heavy floating debris." Fire also could change the type and quantity of debris reaching culverts making it necessary to take remedial action for debris control.

Culverts located at the end of urban drainage channels are often clogged by refuse dumped into the channel or by trash washed off the city streets. Under such conditions, a rack can usually be installed at low cost to prevent clogging. However, urban locations require careful design since malfunction of the debris-control structure will often cause flooding and damage to adjacent property.

An estimate of the quantity as well as the type of debris is needed by the designer so that an adequate debris storage area can be provided immediately upstream from the control structure. Information on the types and quantities of debris resulting from past floods are an invaluable guide in selecting the type of debris-control structure. Such information could be secured from maintenance personnel, from inhabitants of the immediate area or by personal observation. Access to the debris storage area is needed for periodic removal of debris.

Determining the allowable headwater and the height of embankment above the invert of the culvert at the inlet is also necessary in selecting the type of control structure best suited to the particular problem. Damage that would result from a plugged culvert should be estimated to evaluate the need for a debris-control structure.

To summarize, the field survey data should include:

(1) Classification of the expected debris as to type.

(2) Quantity of expected debris.

(3) Future changes in debris type or quantity due to potential changes in land use.

(4) Information from which the designer can estimate streamflow velocities in the vicinity of the culvert.

Archival
Superceded by HEC-9
3rd edition - October 2005

(5) Topographic map or cross sections of the area available for storage of debris at the site, accessibility of the storage area for debris removal and the probable frequency of clean-out.

(6) Possible damage that would result from debris clogging the drainage structure.

Selecting Type of Structure

The safety of highway traffic should be an overriding consideration in the selection of the type of debris-control device. The culvert end and the debris-control structure should be located beyond the usual recovery area for errant vehicles or the debris-control structure should be designed to enhance the drivers chance of recovery 2/. At existing sites where modifications cannot be made to meet this objective, an appropriate vehicle restraining device or an impact attenuating device should be provided on the roadside.

In order for a debris-control structure to perform its intended function, the type of debris must be anticipated and the appropriate device selected to prevent the culvert entrance from clogging. Table 1, based on experience with different types of structures, provides a guide for selecting control structures for various debris classifications. Suitable devices for each debris classification are shown by "X". When the expected debris is not all of one classification, the table also provides guidance for selecting a combination of control devices.

Archival
Superceded by HEC-9
3rd edition - October 2005

2/ Highway Research Board, Traffic-Safe and Hydraulically Efficient Drainage Practice, NCHRP Synthesis of Highway Practice No. 3, Washington, D. C., 38p., 1969.

TABLE 1 - Guide for selecting type of structures suitable for various debris classifications

Debris Classification \ Type of Structure	Deflector	Rack	Riser	Crib	Fin	Dam and Basin	Boom
Light Floating Debris		X		X			X
Medium Floating Debris	X	X					X
Heavy Floating Debris	X				X		
Flowing Debris			X			X	
Fine Detritus			X			X	
Coarse Detritus			X	X		X	
Boulders	X						

Archival
Superceded by HEC-9
3rd edition - October 2005

Debris Deflectors

The function of a debris deflector (figs. 1-13) is to divert medium and heavy floating debris and large rocks from the culvert inlet for accumulation in a storage area where it can be removed after the flood subsides. The storage area provided must be adequate to retain the anticipated type and quantity of debris expected to be accumulated during any one storm or between cleanouts. The deflector should be built at the culvert entrance and aligned with the stream rather than the culvert so that accumulated debris will not tend to block the channel.

Single deflectors can be built over batteries of pipe culverts (fig. 6) or individual deflectors can be built over each pipe of a battery (fig. 11). Their structural stability and orientation with the flow make deflectors particularly suitable for large culverts, high velocity flow, and with debris such as heavy logs, stumps, or large boulders.

Plates I and II show general dimensional details of debris deflectors. The angle at the apex of the deflector should be between 15° and 25°, and the total area of the two sides of the deflector should be at least 10 times the cross-sectional area of the culvert. Spacing between vertical members should not be greater than the minimum culvert dimension nor less than 1/2 the minimum dimension. A spacing of 2/3 the minimum dimension is commonly used. The base width and height of the deflector should be at least 1.1 times the respective dimensions of the culvert. Where headwater from the design flood is expected to be above the top elevation of the deflector and floating debris is anticipated, horizontal members should be placed across the top. The spacing of horizontal members on the top should be no greater than 1/2 the smallest dimension of the culvert opening. The upstream member is vertical on most existing installations. However, a sloping member at the apex (sloping downstream from bottom of member) would reduce the impact of heavy floating debris and boulders, and probably prevent debris from gathering at that point. Deflectors with a sloping member at the apex are highly recommended by maintenance personnel.

Debris deflectors are usually built of heavy rail or steel sections (figs. 1-11), although timber (figs. 12, 13) and steel pipe are sometimes used for light debris. For economy salvaged railroad rails may be used if available. Figure 10 and Plate II show a deflector that uses a cable as its lower longitudinal member. This modification has proved superior in locations where heavy boulders damage rigid members. Wire and post debris deflectors (fig. 9) have been used for light floating debris.

Archival - Superceded by HEC-9 3rd edition - October 2005

Debris Racks

A debris rack (figs. 14-27) is essentially a barrier across the stream channel which stops debris that is too large to pass through the culvert. Debris racks vary greatly in size and in the material used in their construction. Height of racks should allow some free-board above the expected depth of flow in the upstream channel for the design flood. Racks 10 to 20 feet high have been constructed. The rack may be vertical or inclined and may be placed over the culvert inlet (figs. 14, 15, 19, 22, 23, 24, 26, 27, and 29) or upstream from the culvert (figs. 16, 18, 21, and 25). Figure 20 shows a rack protecting the inlet of a down drain. Racks should not be placed in the plane of the culvert entrance, since they induce plugging when thus positioned. Access to the rack is necessary for maintenance.

The rack should be placed well upstream from the culvert entrance in those locations where a well-defined channel exists. However, they should not be placed so far upstream that debris enters the channel between the rack and the culvert inlet. If a large debris storage area exists at the rack location, the frequency of maintenance is reduced and added safety is provided against overtopping the installation during a single storm. Some racks have not required maintenance for several years.

Plates III through VI, inclusive, show the general dimensional details of debris racks. The total straining area of a rack should be at least ten times the cross-sectional area of the culvert being protected. Vertical bars are generally spaced from 1/2 to 2/3 the minimum culvert dimension. This spacing permits the lighter debris to pass through the rack and the culvert. In urban areas, (fig. 19) bar spacing of racks should be a maximum of 6 inches and tied to the culvert headwall by top bars to prevent entrance of children. Under these conditions it is preferable to hold the lowest edge of rack about six inches above the flow line of the ditch, permitting some debris to pass under the rack during low flows. The close spacing of the bars creates a debris trap and increases the maintenance required.

Generally, racks do not have top or horizontal members extending from the rack to the culvert headwall although there are exceptions (fig. 15). The overall dimensions of the rack should be a function of the amount of debris expected per storm, the frequency of storms, and the schedule of expected cleanouts. When a rack is installed at the upstream end of the wingwalls, it should be at least as high as the culvert parapet.

Since vertical racks receive the full impact of floating debris and boulders, their structural design should incorporate brace members set in concrete. Inclined racks and rubber tires (fig. 17) have been used to help reduce the impact of heavy debris striking at high velocity.

Chain-link fence has been used for removal of light debris where stream velocities are low. The fence barrier has a particular advantage in tidal areas where the functioning of flap or check gates is hampered by light debris gathering on gate seats and thereby blocking complete closure of the gates.

Debris Risers

Debris risers (figs. 28-34) generally consist of a vertical culvert pipe and are usually suitable for culvert installations of less than 54-inch diameter. This type of debris-control structure is used where considerable height of embankment is available and where debris consists of flowing masses of clay, silt, sand, sticks, or medium floating debris without boulders. Risers are seldom structurally stable under high-velocity flow conditions because of their vulnerability to damage by impact.

Archival - Superceded by HEC-9 3rd edition - October 2005

Risers placed above the streambed at the bottom of steep, narrow draws cause ponding with a reduction in velocity and deposition of sediment. The resulting flat-bottom basin gives maintenance personnel a place to work when either culvert cleanout or debris removal is necessary. This basin also produces deposition of heavier debris upstream at the entrance to the basin where the debris cannot clog the drainage structure. To avoid vibration of the riser pipe and unstable flow conditions, the riser diameter should be about 1 foot larger than the culvert diameter.

Plates VII through X, inclusive, show the general dimensional details of debris risers. The riser should be covered by a grate or cage to prevent clogging of the culvert. The grate bars can be reinforcing steel or other such material with vertical spacing not greater than 1/2 the diameter of the culvert. Slots or holes are placed in the sides of the riser to carry low flow (fig. 32). It is preferable to have these holes punched before galvanizing to avoid deterioration by rust. The holes are considered to have no hydraulic capacity under peak flow conditions because of the likelihood of their becoming plugged by light floating debris and silt. It is good practice to build riser pipes at least 36 inches in diameter to provide an area large enough for maintenance access. It is also desirable to connect the grate bars to a coupling band, rather than directly to the riser pipe, so the grate can be removed should cleaning be required. If the embankment is of sufficient height, provisions should be made to extend the riser vertically if necessary. This can be accomplished by means of standard coupling bands in the case of corrugated metal pipe risers.

Archival
Superceded by HEC-9
3rd edition - October 2005

Installations have been built with the riser pipe at an angle between vertical and the stream grade (fig. 28). This reduces the impact of debris at the elbow and assists in moving debris through the culvert. A corrugated metal pipe reducing elbow can be used to connect risers to the culvert inlet, although damage to the metal elbow from falling rocks may occur. Occasionally, concrete is placed inside the elbow to prevent the metal from wearing through by this abrasive action. A solution for extremely severe conditions is to connect riser and culvert by a concrete junction box having the inside shaped as an elbow. A corrugated metal pipe riser usually costs less than a debris crib because of the labor involved in construction of the latter. Risers may be used as relief structures, either independent of the main culvert or in conjunction with it (figs. 33, 34, 43, 45, and 51).

Debris Cribs

A debris crib (figs. 35-39), often called a "bear trap," is particularly adapted to small-size culverts where a sharp change in stream grade or constriction of the channel causes deposition of detritus at the culvert inlet. The crib is usually placed directly over the culvert inlet and is generally built up in log-cabin fashion although other designs are sometimes used.

Plate XI shows the general dimensional details of a debris crib. Spacing between bars should be about 6 inches. A crib may be open (figs. 36-38) or covered (figs. 35, 39) with horizontal top members spaced equal to the crib members. Debris can almost envelop a crib without completely blocking the flow and plugging the culvert. When an open crib is used as a riser and an accumulation of detritus is expected to build up, provision can be made for increasing the heights as needed (figs. 36, 37). Cribs and risers are somewhat similar, but cribs are more appropriate than risers where the culvert has little cover and the detritus is coarse. Cribs have been built as high as 50 feet above a pipe invert with little change in the efficiency of the facility. Due to the debris type and site conditions associated with debris risers and cribs, field inspections of all types of existing debris-control structures have shown these two types to be most consistently successful in producing an efficient, maintenance-free installation.

Debris Fins

The debris fin is a thin wall of concrete, steel, or timber installed parallel with the flow (figs. 40-45). They have been used successfully with large culverts where the debris consists mostly of floating material that would pass through the culvert if oriented parallel with the culvert barrel. Material that is not aligned by the fin to pass through the culvert is retained at the front of the fin for later removal by maintenance personnel. If the fin is sloped upward toward the culvert, debris that does not pass through the culvert will be floated upward and prevented from blocking the culvert inlet. At bridge piers, long debris will generally ride up on the fin and fall off in an aligned position. Fins have also been successful in reducing ice clogging by displacing ice sheets upward along the sloping top surface.

Fins on culverts are usually concrete and located on the centerline of a single culvert (figs. 43-45) or as extensions of the interior walls of multiple box culverts (figs. 41, 42). The upstream end of the fin should be rounded and sloped upward toward the culvert, as shown in figures 40 and 41, to reduce impact, turbulence, and the probability of gathering debris, rather than vertical as shown in figures 42-45.

A debris fin is usually constructed to the height of the culvert; hence, its effectiveness is limited after the inlet becomes submerged. Based on experience, a fin length of 1½ to 2 times the culvert height

Archival
Superseded by HEC 9
3rd edition October 2005

is recommended. The leading edge would thus have a slope of from $1\frac{1}{2}$:1 to 2:1. Wall thickness should be the minimum needed to satisfy structural requirements in order to minimize disturbance to flow. Fins are generally not used on culverts with a minimum dimension of less than 4 feet.

Since depth of scour at bridge piers is proportional to the width of pier projected normal to the direction of flow, buildup of debris on piers often contributes to bridge failure by scour. Debris fins have been successfully used to align debris with the waterway opening and to avoid the accumulation of debris on bridge piers. When used for this purpose, however, fins should be carefully aligned with flow in order to avoid increasing the projected pier width and a corresponding greater depth of scour.

When used at bridge piers, debris fins are usually constructed of steel or treated timber piling and bracing. Pile penetration should be sufficient to withstand predicted scour depths.

Debris Dams and Basins

On streams carrying heavy sediment and debris loads it is often economically impracticable to provide a culvert large enough to carry surges of debris. If the height of embankment and storage area at the highway are not sufficient for a riser or crib, a debris dam and settling basin placed some distance upstream from the culvert might be feasible. These are sometimes used to trap heavy boulders or coarse gravel that would clog culverts, especially on low fills. In some locations debris dams have been built to provide the added benefit of ground water recharge resulting from ponded water.

Debris dams (figs. 46-51) can be built of precast concrete beams placed in crisscross or log-cabin fashion with rock dumped between the members (fig. 50). Other dams have been built of rock held in place by wire (figs. 47, 49).

The extent of preliminary investigation required for the design of a dam should be commensurate with the size and cost of the structure and the hazard created by failure of the culvert to carry the flow. Information is needed concerning watertightness of the reservoir, suitability of the foundations for supporting the dam, and the availability of construction materials.

Earth or rock fill dams are usually desirable. A spillway should be constructed as a channel outside the limits of the dam. A number of debris dams were built in Southern California and were found to have lower construction costs than the annual cost of removing the debris that otherwise would have been deposited adjacent to and within drainage structures.

Archival
Superceded by HEC-9
3rd edition - October 2005

Combined Debris Controls

Each drainage basin presents its own debris problem. Often more than one problem exists and two or more types of debris-control structures must be used. At some locations it may be preferable to remove the larger debris at a location upstream from the culvert and to remove the smaller material nearer the culvert inlet. At other locations it may be advisable to install two types of devices so that one will function if the other fails. For example, figure 33 shows a debris riser installed over the entrance of a culvert to provide the water access to the culvert in the event the culvert entrance becomes plugged. Figure 34 shows the same installation after a flood.

Figures 43 and 45 show a culvert protected by both a debris fin and a debris riser. Figure 51 shows an installation consisting of a debris dam and settling basin with a debris deflector at the inlet and a debris riser.

MAINTENANCE

The standard or frequency of maintenance must be considered in the design of a debris-control structure. Structures located on a primary highway may have a higher frequency of maintenance than those on a secondary highway. If a low standard of maintenance is to be provided, it may be desirable to use a different type debris-control structure requiring less attention or choose a larger culvert. This consideration may also determine the choice when two or more alternatives are available.

Provisions must be made for maintenance access to the debris-control structure site. A means of access is often difficult to provide, particularly where a high embankment exists. However, such installations usually require less maintenance because of the added debris storage available. If haul roads to debris-control installations are not practical, it may be necessary to provide an area where mechanical equipment such as a crane could be located for removing debris without disrupting highway traffic. Some debris barriers must be cleaned after each major storm.

Maintenance problems may require modifications in control device design. For example, positive debris control could become essential for an extremely long culvert necessitating reduction in the size of openings in the debris-control structure to remove all debris that might clog the culvert.

Archival
Superceded by HEC-9
3rd edition - October 2005

Figure 1. Steel rail debris deflector for large rock.

Figure 2. Steel rail debris deflector.

Archived
Superceded by HEC-9
3rd edition - October 2005

Figure 3. Steel rail debris deflector for fine detritus.

Figure 4. Steel rail debris deflector in area of heavy flowing debris.

Figure 5. Steel rail debris deflector.

Figure 6. Steel rail debris deflector for battery of culverts (See Fig. 7).

Figure 7. Installation shown in Figure 6 during flood; function well under heavy debris flow.

Figure 8. Steel rail debris deflector. Note storage area for debris resulting from culvert projection.

Figure 9. Wire and post debris deflector for light floating debris.

Figure 10. Steel rail and cable debris deflector. Cable's flexibility more desirable than rail's rigidity in boulder areas.

Archival
Superceded by HEC-9
3rd edition, October 2005

Figure 11. Steel debris deflectors installed at entrances to a battery of culverts.

Figure 12. Timber pile debris deflector for boulders and heavy floating debris.

Figure 13. Timber pile debris deflector protected culvert during heavy floods. Nearby culverts without deflectors were plugged.

Archival
Superceded by HEC-9
3rd edition - October 2005

Figure 14. Rail debris rack over sloping inlet. Heavy debris and boulders ride over rack and leave flow to culvert unimpeded.

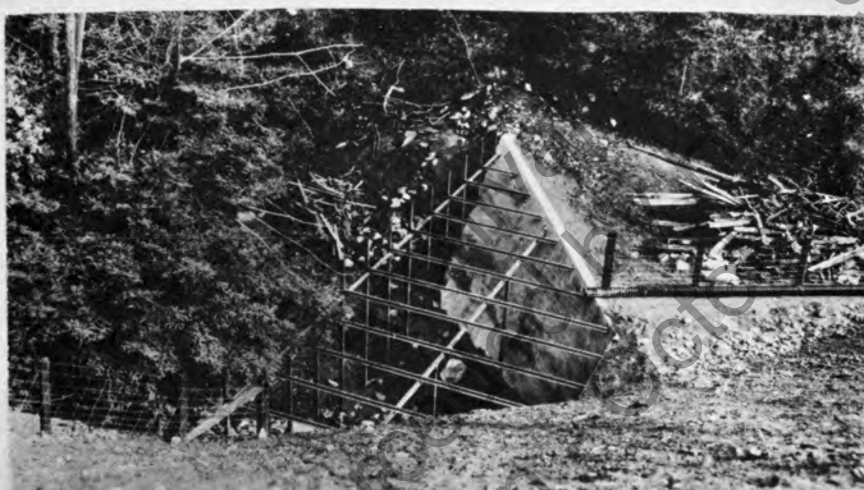

Figure 15. Rail debris rack with top members in area of logging operations.

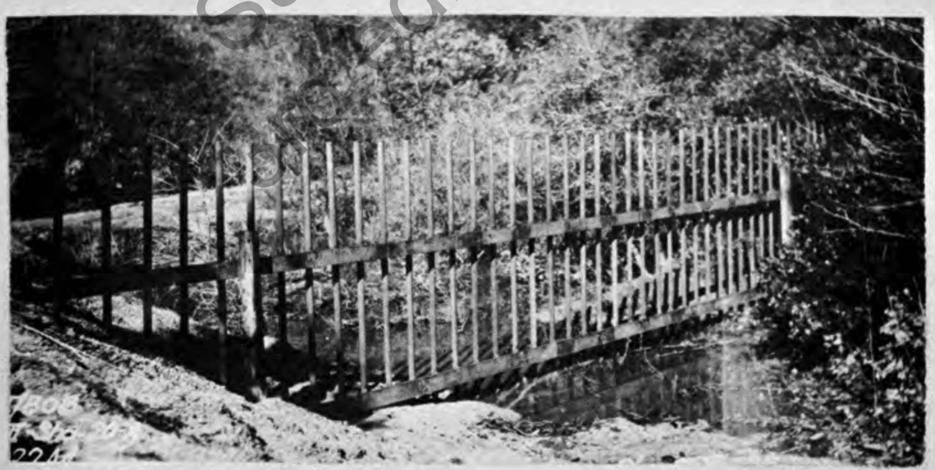

Figure 16. Post and rail debris rack, in place for 35 years, for light to medium floating debris installed 100' upstream of culvert.

Figure 17. Steel debris rack downstream of culvert on beach. Rubber tires reduce impact of logs.

Figure 18. Rail debris rack. Note large straining area provided.

Figure 19. Hinged steel debris rack in urban area. Due to nature of debris and possible entry by children, bar spacing is close.

Figure 20. Debris control hinged installation of reinforcing steel at inlet to roadside downdrain.

Figure 21. Steel debris rack.

Figure 22. Debris rack used in State of Washington. (See Plate III for design dimensions.)

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Figure 23. Rail debris rack in arid region. (See Fig. 24.)

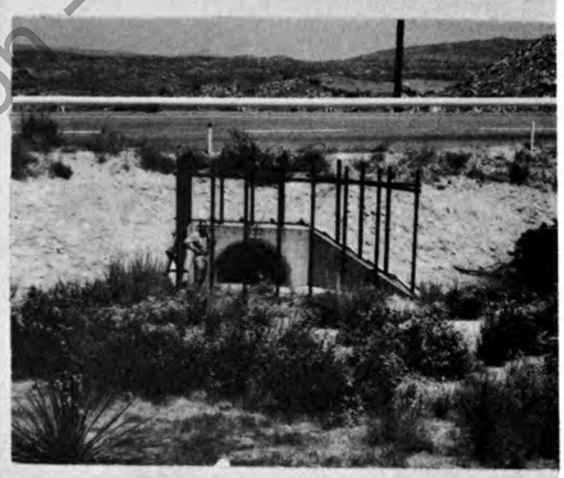

Figure 24. Installation shown in Fig. 23 after several years of fine silt deposition at entrance.

Figure 25. Steel debris rack probably saved the culvert from plugging.

Figure 26. Pipe grill debris rack. Vertical fence at downstream end to prevent debris from spreading over ponding area.

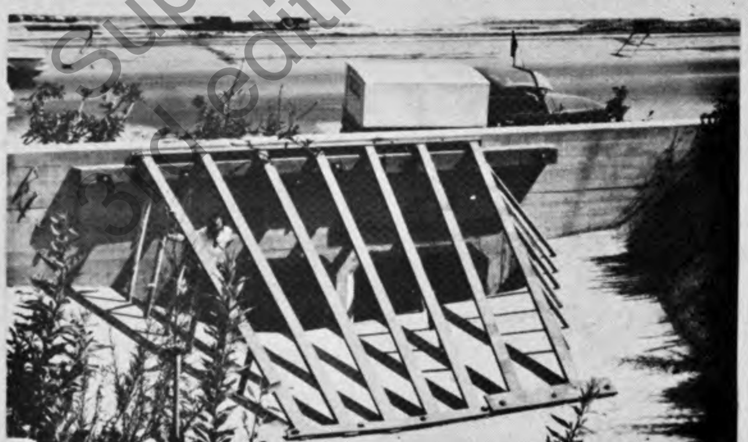

Figure 27. Steel grill debris rack with provision for cleanout afforded by concrete paved area in foreground.

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Figure 28. Metal pipe debris riser, with posts to deflect boulders, installed by maintenance forces on 45° angle to vertical.

Figure 29. Post debris rack placed over entrance to metal pipe debris riser after latter had caused deposition.

Figure 30. Metal pipe debris riser required little maintenance. Basin had built up 10'.

Figure 31. Metal pipe debris riser, in place for 25 years, operated well without vertical extension.

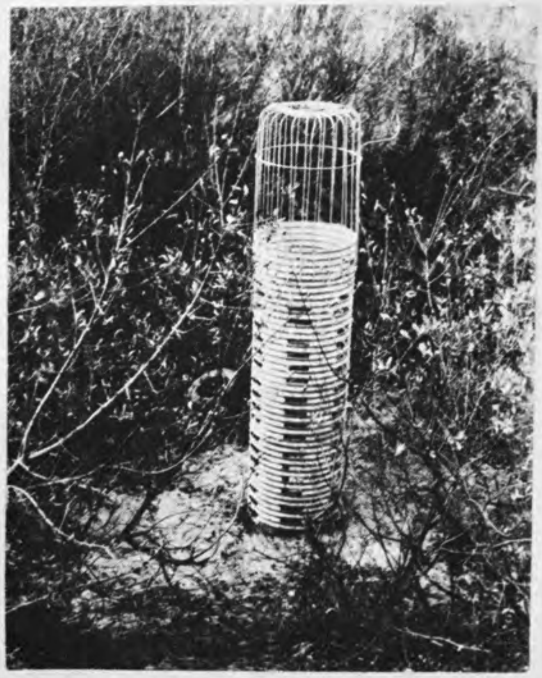

Figure 32. Metal pipe debris riser shows slots for low flows.

Figure 33. Metal pipe debris riser placed during initial construction of culvert provides relief in case the latter becomes plugged. (See Fig. 34.)

Figure 34. Installation shown in Fig. 33 after flood. Riser carried heavy flow during flood. Fence partially surrounding riser of no value for debris control. (Note man at center of photograph.)

Figure 35. Timber debris crib in ideal location, i.e., high roadway embankment and large settling basin.

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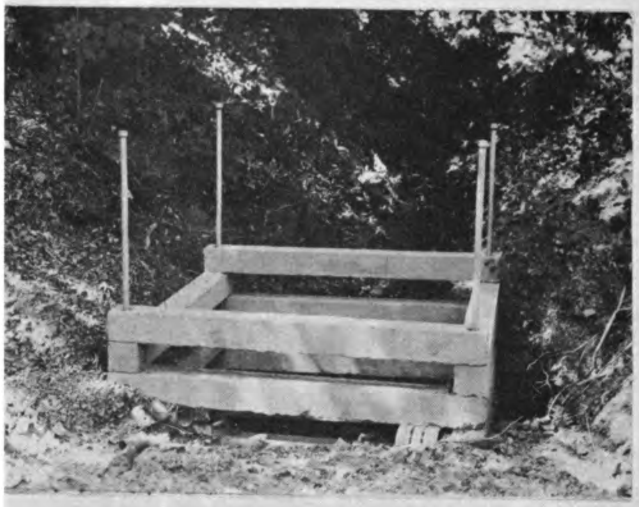


Figure 36. Debris crib of precast concrete sections and metal dowels. Height increased by extending dowels and adding more sections.

Figure 37. Debris crib of precast concrete sections and metal dowels.

Figure 38. Timber debris crib of inexpensive local materials.

Figure 39. Redwood debris crib with spacing to prevent passage of fine material. Basin had built up 30'.

Figure 40. Concrete debris fins with sloping leading edges as extensions of culvert walls.

Figure 41. Concrete debris fin with sloping leading edge as extension of center wall.

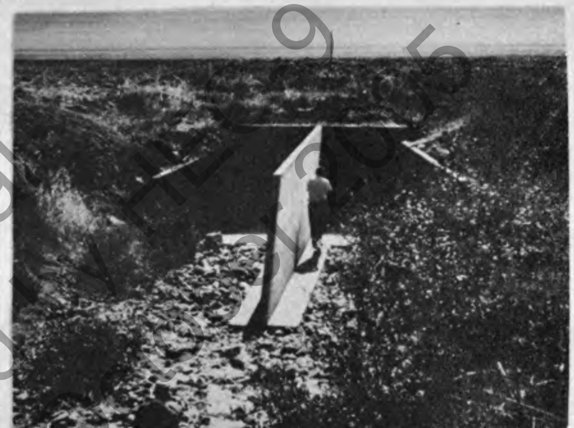


Figure 42. Concrete debris fin with rounded vertical leading edge as extension of culvert center wall.

Figure 43. Concrete debris fin and metal pipe debris riser in conjunction with single corrugated metal pipe culvert.

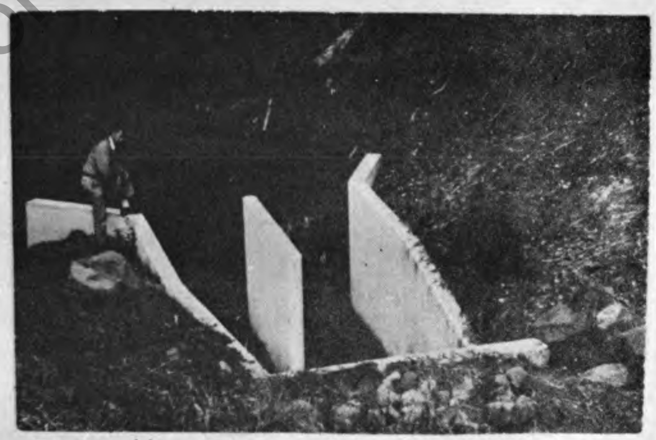


Figure 44. Concrete debris fin for single culvert. Preferable if more area existed between wingwalls and fin.

Figure 45. Debris fin and metal pipe debris riser in conjunction with single barrel culvert.

Figure 46. Metal bin type debris dam.

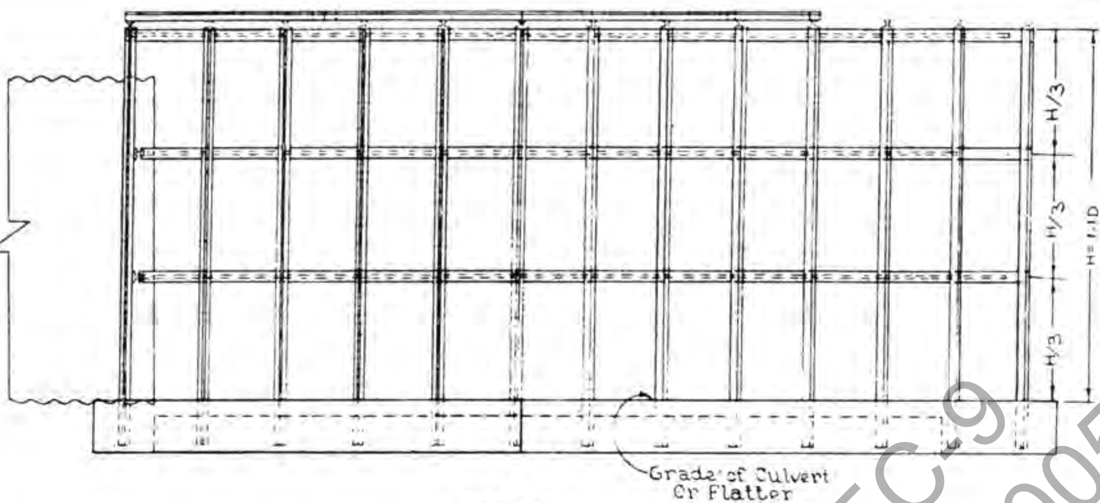
Figure 47. Debris dam of rock and wire.

Figure 48. Debris dam and basin in foreground and steel grill debris rack at culvert entrance in background. (See Fig. 49).

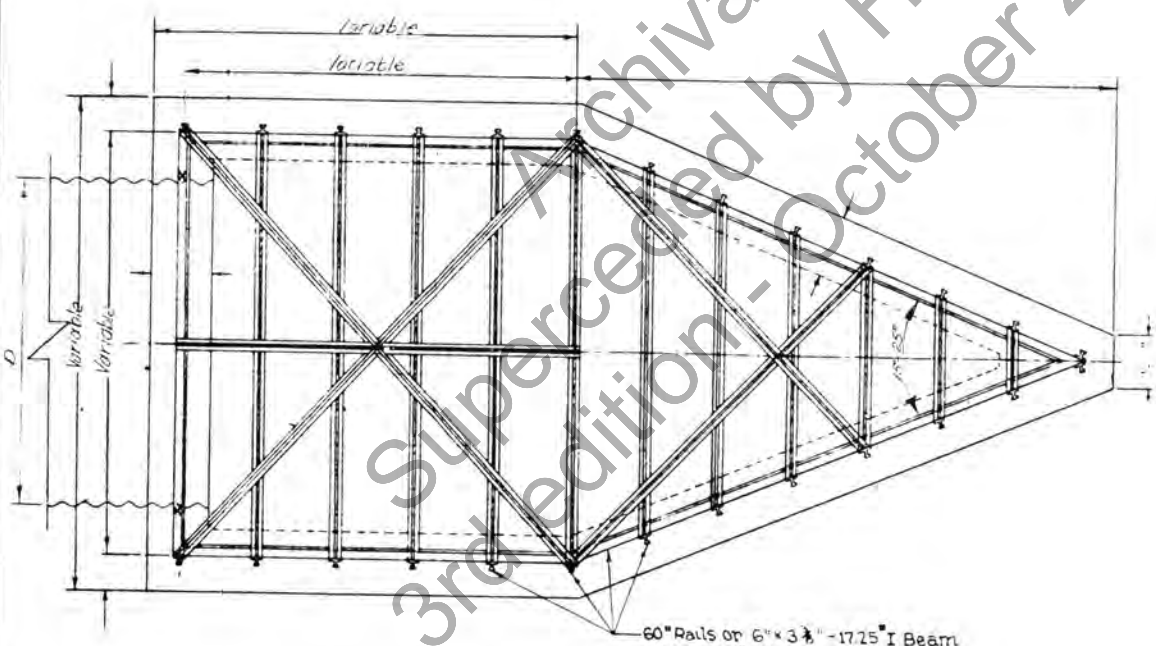
Figure 49. Debris dam of rock and wire shown in Fig. 48.

Figure 50. Debris dam of precast concrete sections fabricated to enable placement in interlocking fashion.

Figure 51. Debris dam and basin along with steel debris rack over culvert entrance in foreground. Metal pipe riser visible over the spillway. Roadway in background.



SIDE ELEVATION



PLAN

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DEBRIS DEFLECTOR
CALIFORNIA DIVISION OF HIGHWAYS
DIVISION II

PLATE I

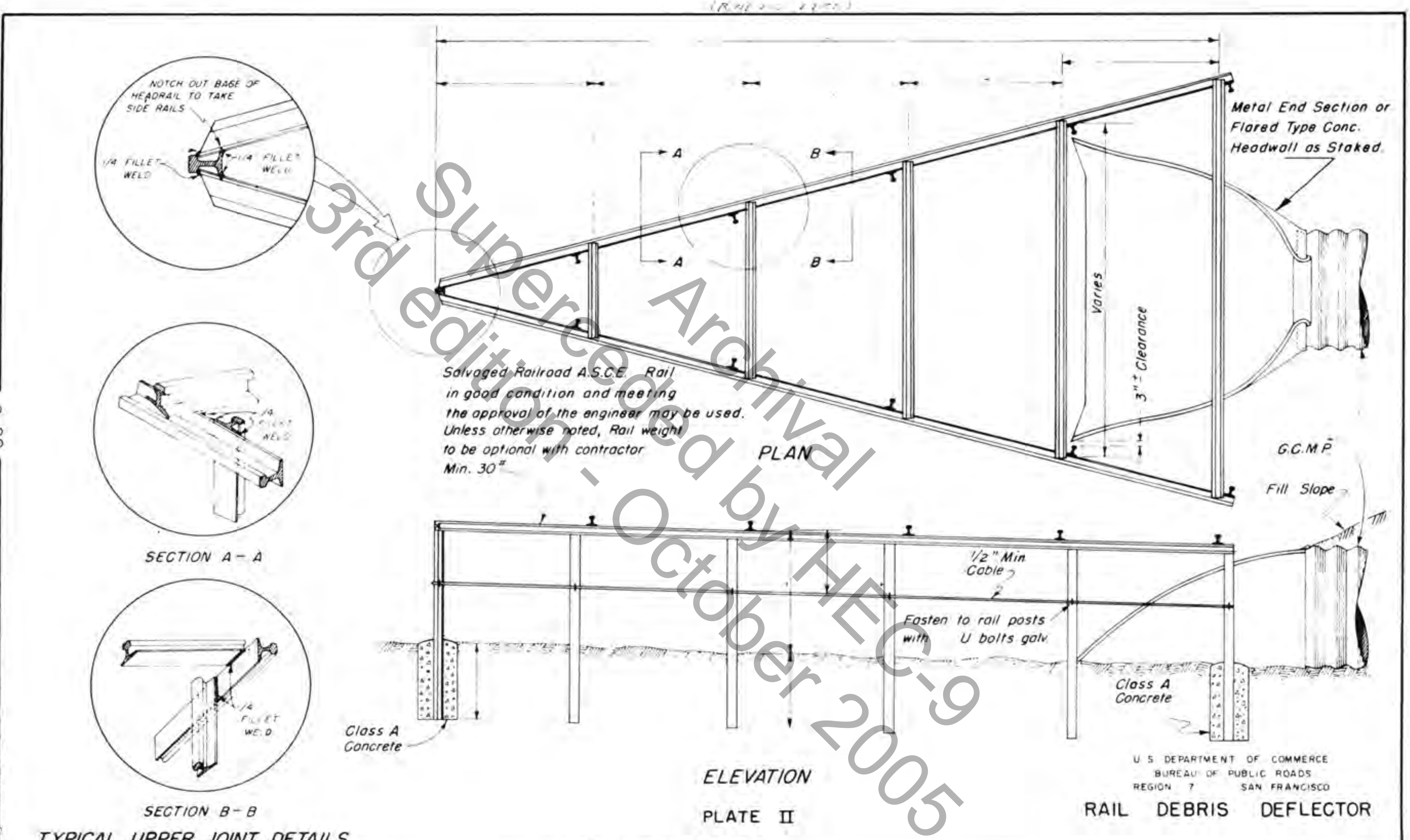

PLATE II

Note: Scales Variable

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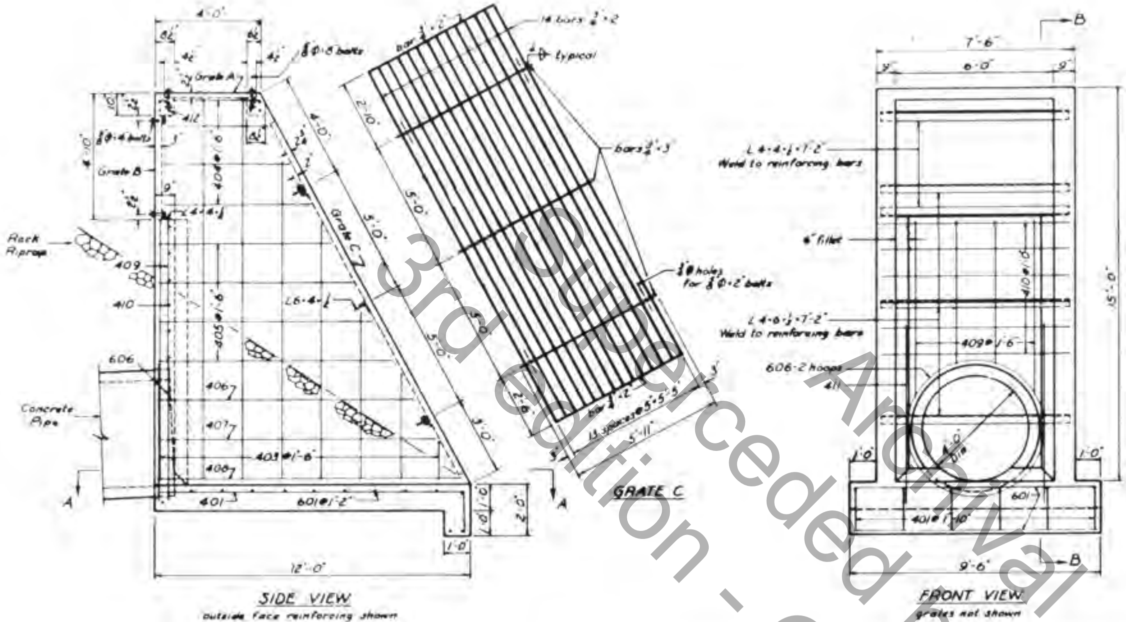
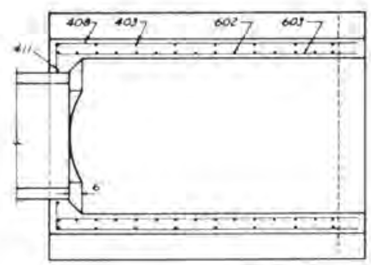
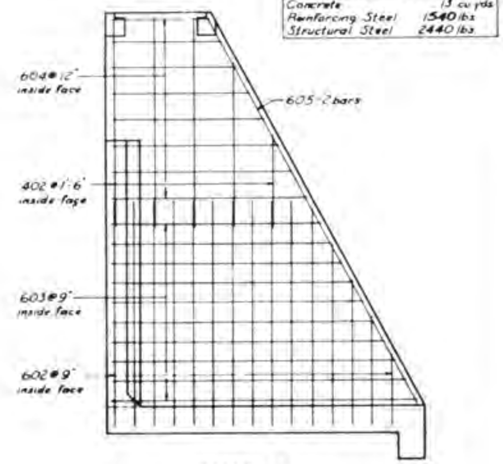
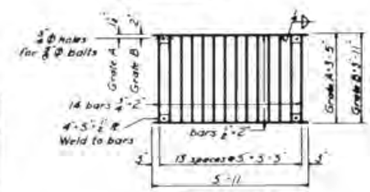
GENERAL NOTES
Concrete shall be Class A (f_c = 3600)
Reinforcing steel shall be deformed bars of intermediate grade conforming to ASTM Specification A15
Structural steel shall be A 36

QUANTITIES	
Concrete	13 cu yds
Reinforcing Steel	1540 lbs
Structural Steel	2440 lbs





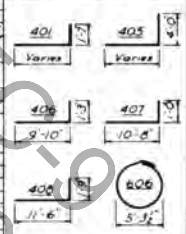




REINFORCING STEEL SCHEDULE

Mark	Location	No	Type	Size	Length	
601	Base	13	str	#6	9'-8"	
401	"	6	bent	4	Varies	2@12'-4", 4@13'-1"
602	Wall, inside face, vert	30	str	6	Varies	20@8'-9", 2 ea @ 8'-0", 6'-9", 5'-6", 4'-0", 2'-6"
603	" " " horiz	20	str	6	Varies	2 ea @ 11'-6", 11'-1", 10'-8", 10'-3", 9'-10", 9'-5", 9'-0", 8'-7", 8'-2", 7'-9"
604	" " " horiz	16	str	6	Varies	2 ea @ 3'-10", 4'-4", 4'-10", 5'-4", 5'-10", 6'-4", 6'-10", 7'-4"
402	" " " vert	10	str	4	Varies	6@5'-0", 2@6'-0", 2@3'-6"
605	Wall, front slope	4	str	6	16'-8"	
403	Wall, outside face, vert	16	str	4	Varies	6@14'-8", 2 ea @ 13'-2", 10'-2", 7'-9", 4'-6", 2'-0"
404	" " " horiz	8	str	4	Varies	2 ea @ 6'-0", 5'-2", 4'-5", 3'-8"
405	" " " horiz	8	bent	4	Varies	2 ea @ 10'-9", 11'-6", 12'-3", 13'-0"
406	" " " horiz	2	bent	4	11'-1"	
407	" " " horiz	2	bent	4	11'-8"	
408	" " " horiz	2	bent	4	13'-3"	
606	Backwall, around pipe	2	bent	6	17'-7"	
409	" inside face, vert	4	str	4	Varies	2@5'-6", 2@6'-9"
410	" " " horiz	6	str	4	7'-2"	
411	" outside face, vert	2	str	4	7'-0"	
412	Strut	8	str	4	7'-2"	

Bending Diagram



All dimensions are out to out

SPECIAL INLET – DEBRIS RACK

WASHINGTON STATE HIGHWAY COMMISSION
DEPARTMENT OF HIGHWAYS
OLYMPIA, WASHINGTON

0 1 2 3
FEET

PLATE III

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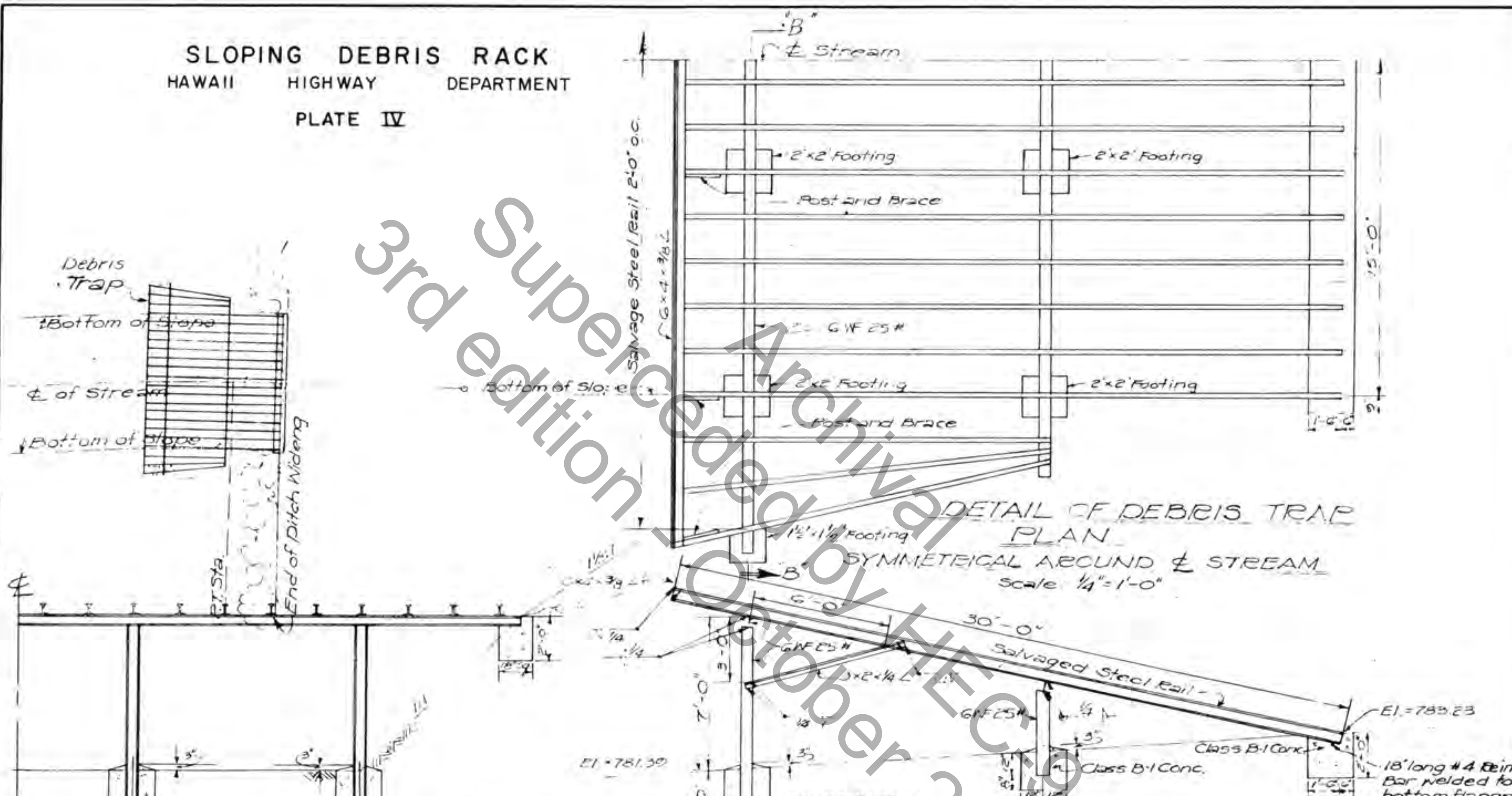
SLOPING DEBRIS RACK

HAWAII HIGHWAY DEPARTMENT

PLATE IV



NOTE:
1. All Connections to be welded.
2. Structural Steel Parts shall be painted in accordance with Standard Specifications and shall have a finished coat of aluminum paint.
3. Foot excavations shall be neat cut

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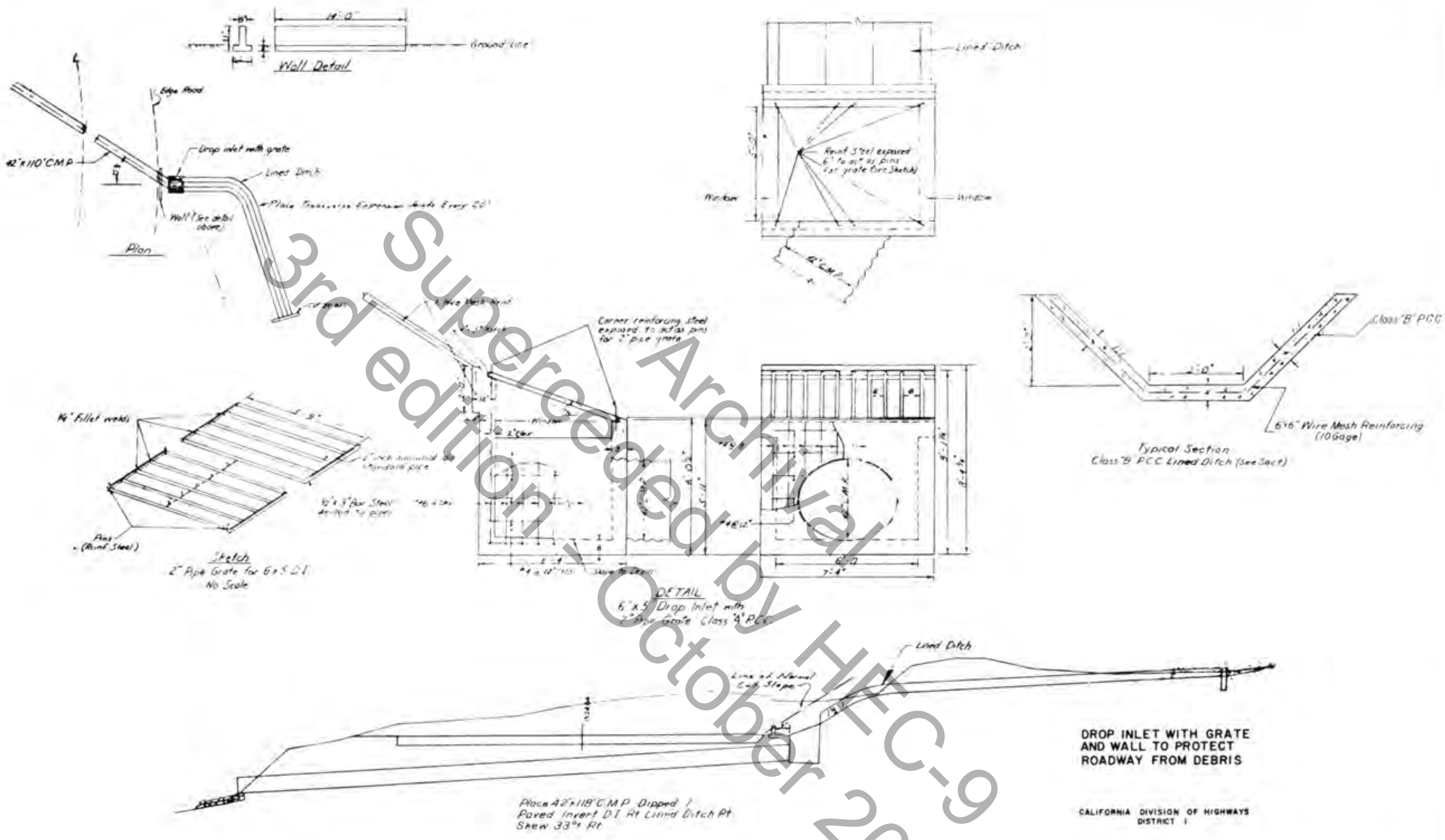

DROP INLET WITH GRATE AND WALL TO PROTECT ROADWAY FROM DEBRIS

CALIFORNIA DIVISION OF HIGHWAYS
DISTRICT I

PLATE V

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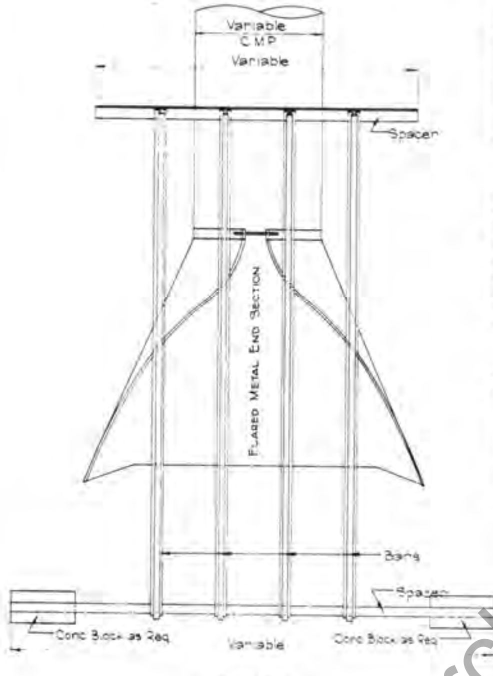


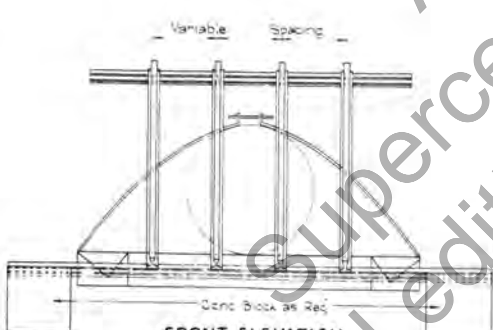
PLAN

BAR SPACING FOR VARIOUS CULVERTS		
C.M.P.	BARS REQUIRED	BAR SPACING
18"	3	1'-0"
24"	4	1'-2"
30"	4	1'-2"
36"	4	1'-8"
42"	5	1'-8"
48"	5	1'-9"

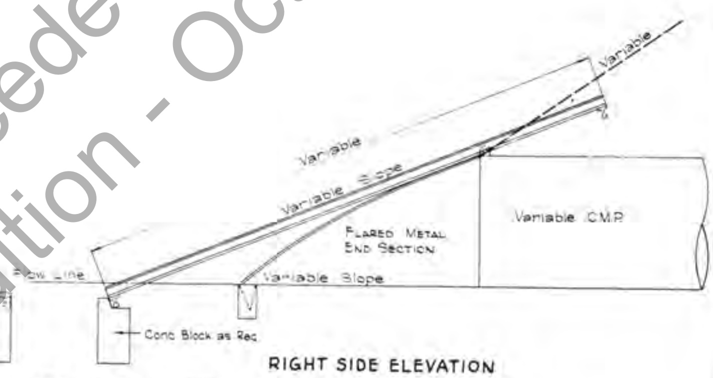
REQUIRED LENGTH OF BARS			
C.M.P.	SLOPE OF BAR	BAR LENGTH	MATERIAL
18"	3:1	8'-3"	Std. 3" Pipe or 25 to 40 Lb. Rail
24"	3:1	11'-0"	" " " " "
30"	3:1	12'-0"	" " " " "
36"	3:1	13'-6"	40# to 60# Rail or Steel I's
42"	3:1	15'-0"	" " " " " "
48"	3:1	16'-6"	" " " " " "

LENGTH OF SPACERS			
C.M.P.	TOP SPACER	BOTTOM SPACER	MATERIAL
18"	6'-0"	8'-0"	4"x4"x3/8" ∠s 40 to 60 Lb. Rail or 3" Pipe
24"	7'-0"	10'-0"	
30"	7'-6"	11'-0"	
36"	8'-0"	12'-0"	
42"	9'-0"	13'-9"	
48"	10'-0"	15'-0"	

NOTE
- Special Treatment Required For Pipes Larger Than 48"
- Minimum Bar Spacing 0'-10"
- Maximum Bar Spacing 2'-0"
- Gradients Steeper Than 15% May Require Special Treatment
- Sizes Shown Are Minimums To Be Used
- Heavier Sections Permitted In All Cases



FRONT ELEVATION



RIGHT SIDE ELEVATION

STANDARD DEBRIS RACK FOR 18" TO 48" C.M.P.'s

FOR USE WITH METAL END SECTION

CALIFORNIA DIVISION OF HIGHWAYS

PLATE VI

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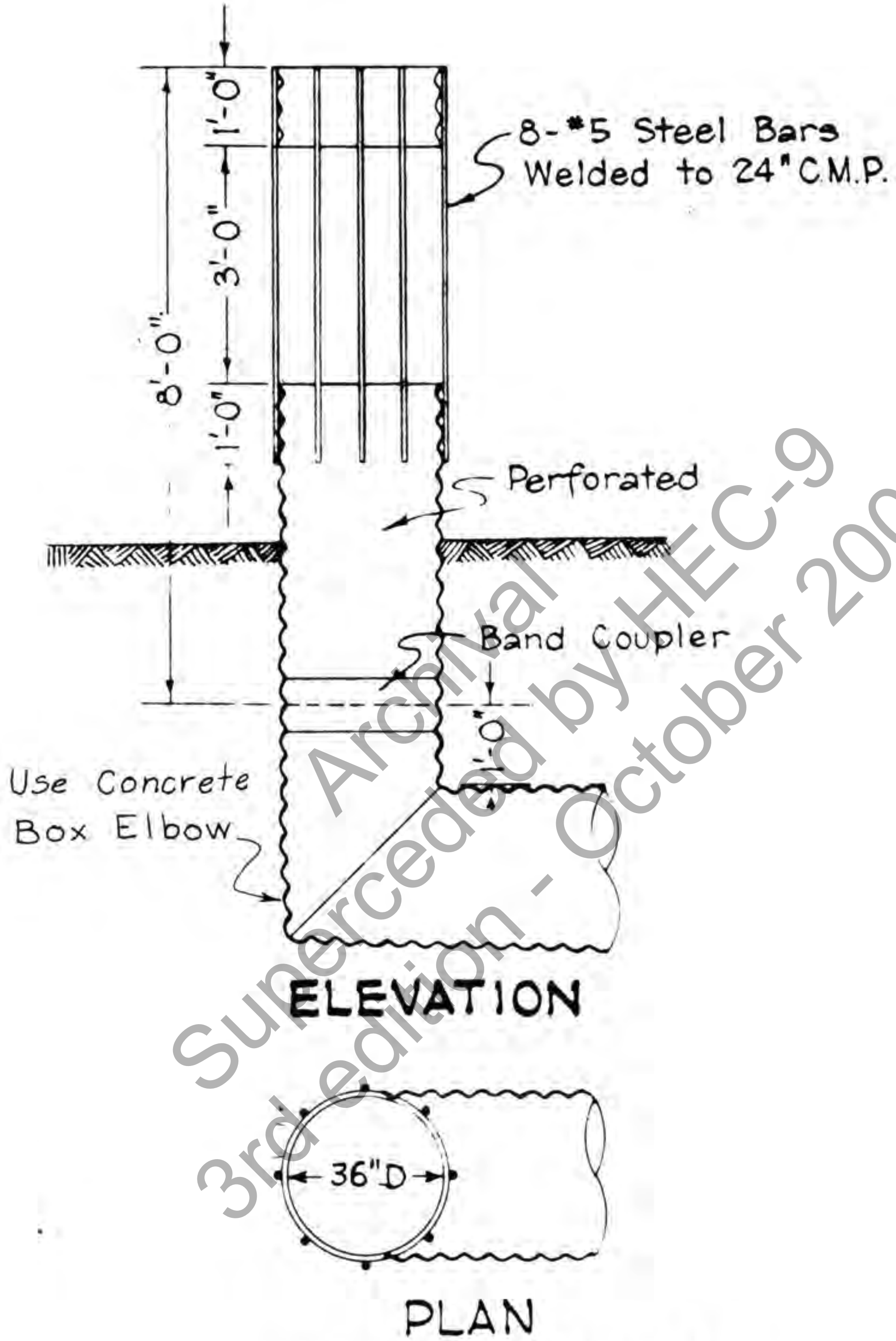

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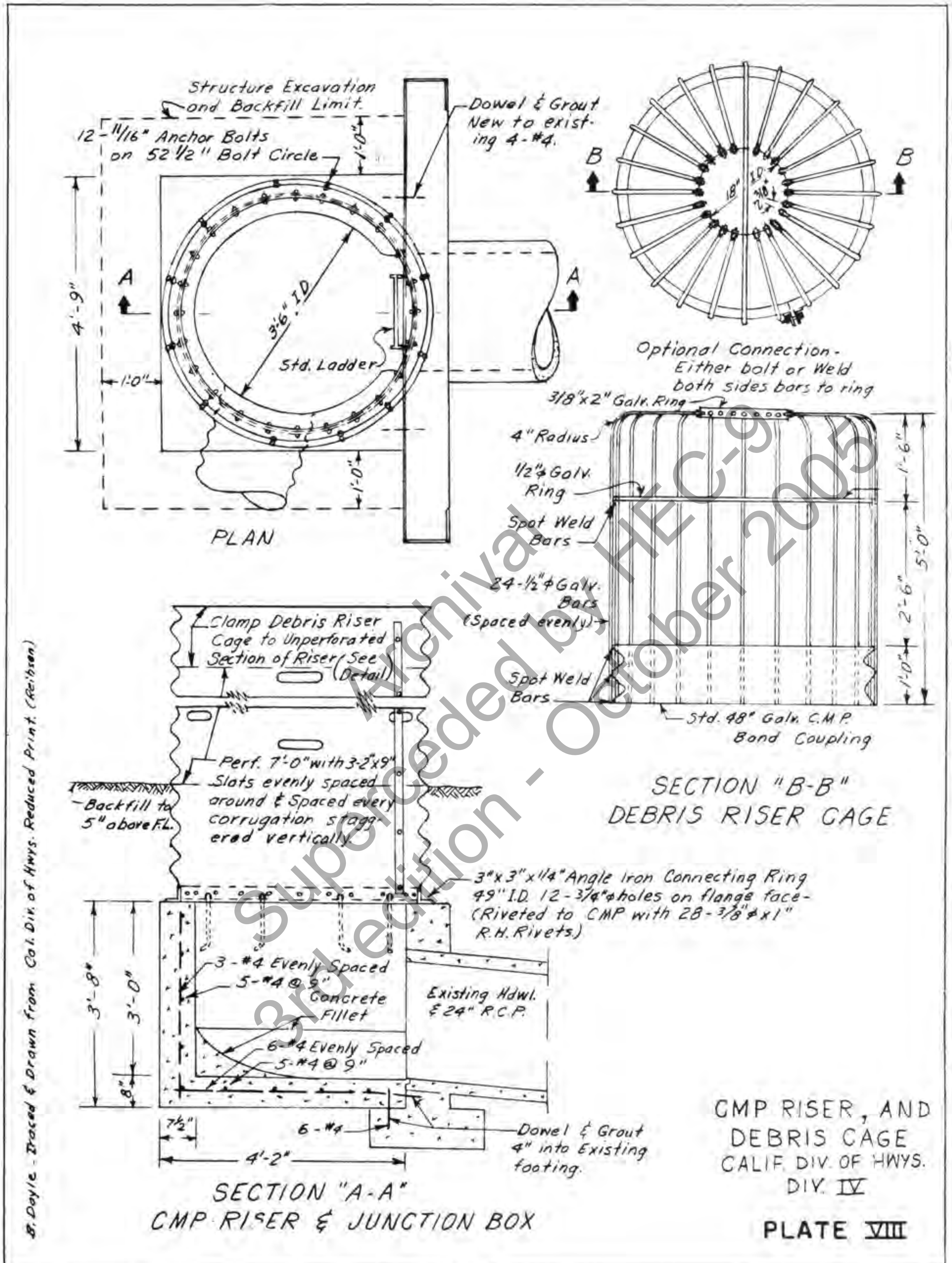
DEBRIS RISER

California Division of Highways

District II

PLATE VII



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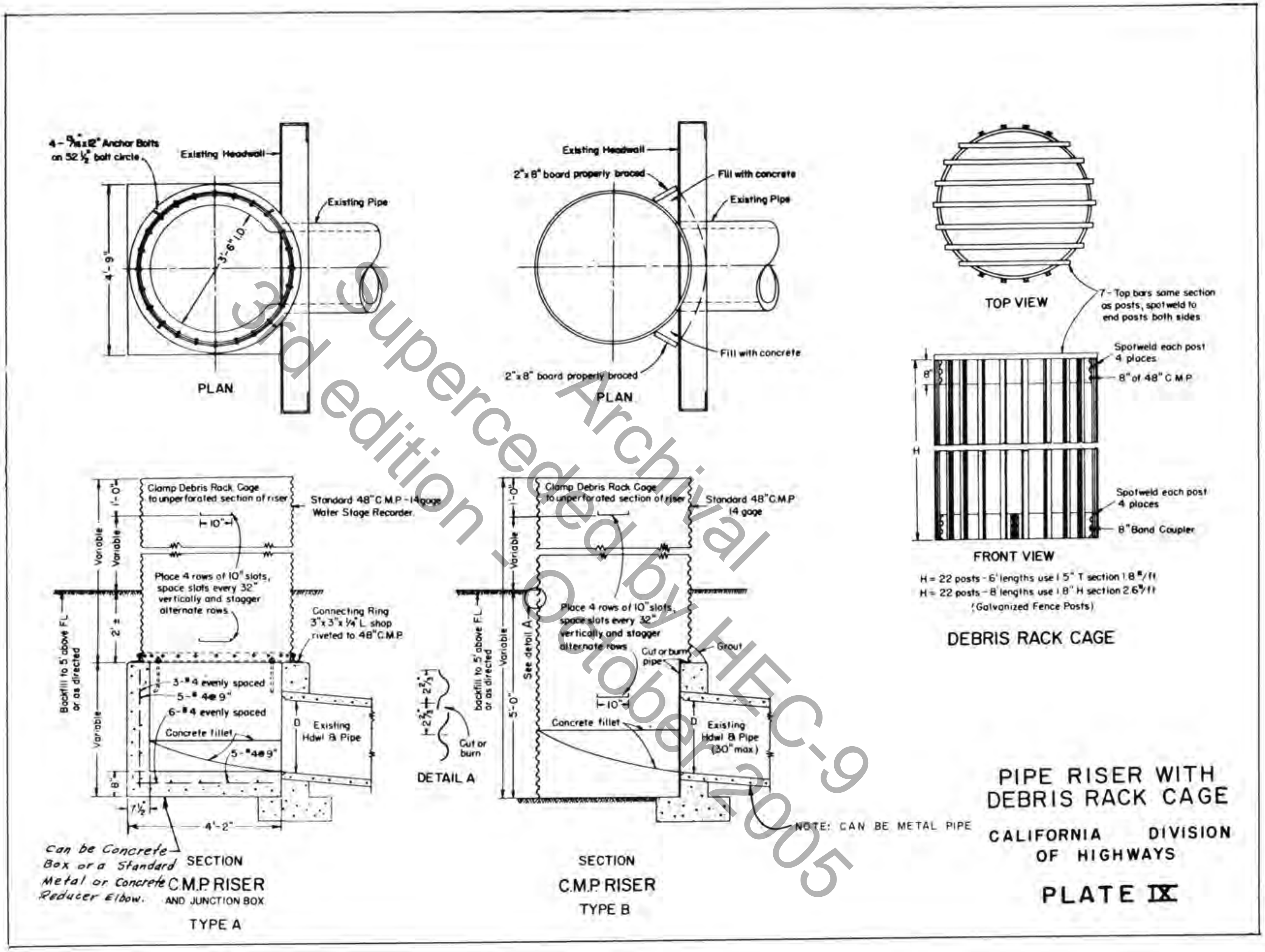

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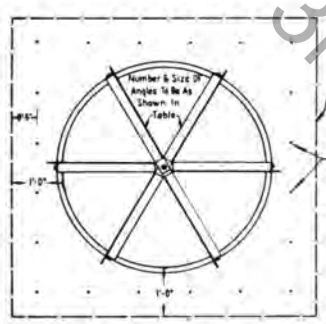
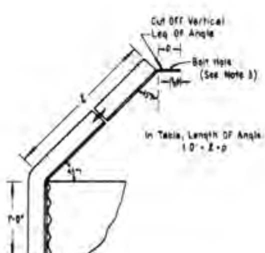
NOTES:

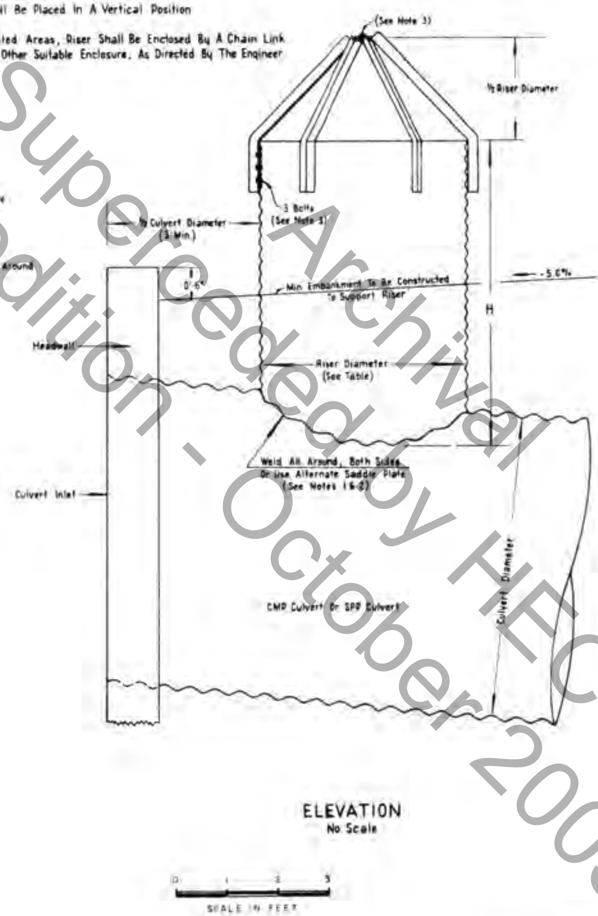
1. Riser To Be Fastened To Culvert By Welding Or Shop-Made Corrugated Metal Saddle Plate.
2. Saddle Plate Shall Be Same Gage Metal As Top Culvert Plates.
3. Cage Angles Shall Be Either Welded Or Bolted To Riser, And Top Joint Of Cage Angles Shall Be Either Welded Or Bolted. Bolt Diameter Shall Be Twice Angle Thickness.
4. All Angles, Nuts And Bolts Shall Be Galvanized.
5. All Welds On Galvanized Metal Shall Be Treated With Zinc Dust In Accordance With Section 66-1.02 G. Of The Standard Specifications.
6. Riser Shall Be Placed In A Vertical Position.
7. In Populated Areas, Riser Shall Be Enclosed By A Chain Link Fence Or Other Suitable Enclosure, As Directed By The Engineer.



TOP VIEW
No Scale



CAGE ANGLE DETAIL
No Scale



ELEVATION
No Scale

CULVERT DIAM.	RISER			RISER CAGE				
	C.M.P.		H*	STEEL				
	DIAM.	GAGE		ANGLE SIZE	NO. OF PIECES	LENGTH, FT.		
INCHES	INCHES		FEET			E FT-IN	P IN	L
36	24	14	4	2" x 2" x 1/4"	4	1'-5"	2"	2'-7"
42	24	14	4	2" x 2" x 1/4"		1'-5"	2"	2'-7"
48	30	14	4	2½" x 2½" x 1/4"		1'-10"	3"	3'-1"
54	36	12	4			2'-1"	3"	3'-4"
60	42	12	6			2'-6"	3"	3'-9"
66	42	12	6			2'-6"	3"	3'-9"
72	48	12	6			2'-10"	3"	4'-1"
78	48	12	6			2'-10"	3"	4'-1"
84	54	12	6	3" x 3" x 1/4"		3'-3"	3"	4'-6"
90	60	10	8			3'-6"	3"	4'-9"
96	60	10	8			3'-6"	3"	4'-9"
102	66	10	8			3'-11"	3"	5'-2"
108	72	10	8	3½" x 3½" x 5/16"		4'-3"	4"	5'-7"
114	72	10	8			4'-3"	4"	5'-7"
120	78	8	8			4'-8"	4"	6'-0"
126	84	8	10			5'-0"	4"	6'-4"
132	84	8	10			5'-0"	4"	6'-4"
138	90	8	10		6	5'-4"	7"	6'-11"
144	96	8	10			5'-8"	7"	7'-3"
150	96	8	10			5'-8"	7"	7'-3"
156	102†	12	12	4" x 4" x 3/8"	8	6'-0"	11"	7'-11"
162	108†	12	12			6'-5"	11"	8'-4"
168	108†	12	12			6'-5"	11"	8'-4"
174	114†	10	12			6'-9"	11"	8'-8"
180	120†	10	12			7'-1"	11"	9'-0"

* H May Be Varied. See Culvert Detail Sheets For Variable H

† Structural Plate Pipe.

STANDARD RELIEF RISER

CALIFORNIA DIVISION OF HIGHWAYS

PLATE X

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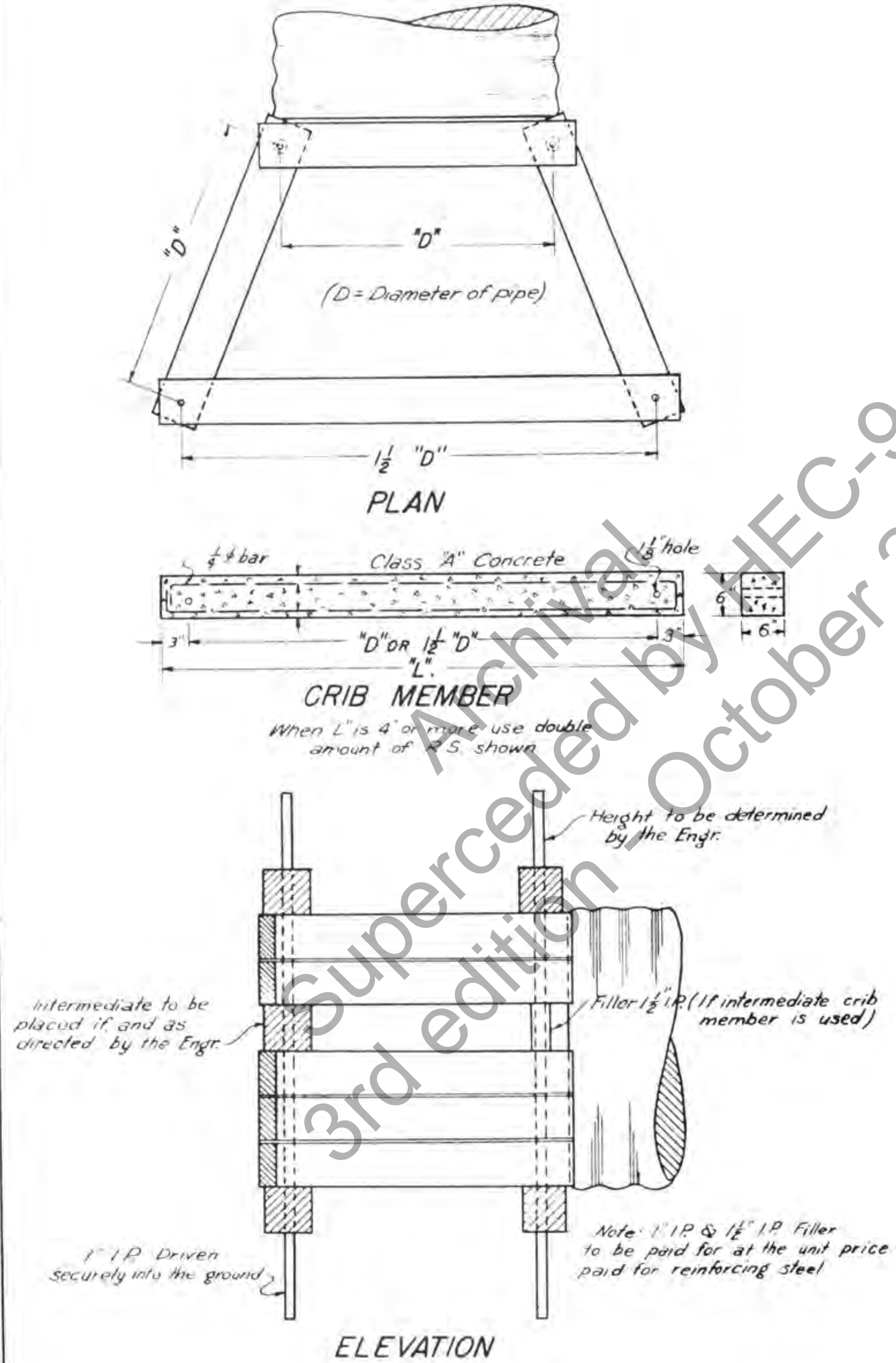

DEBRIS CRIB

CALIFORNIA DIVISION OF HIGHWAYS

DISTRICT 8

PLATE XI

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