Detention Basins

Design Guidance

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California Department of Transportation
HQ Division of Design

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List of Abbreviations

AASHTO	American Association of State Highway Transportation Officials
ASTM	American Society of Testing and Materials
BMP	Best Management Practice
BEES	Basic Engineering Estimating System
Caltrans	California Department of Transportation
CRZ	Clear Recovery Zone, (AASHTO Clear Zone)
CDA	contributing drainage area
CF	cubic foot
cfs	cubic feet per second
CSS	Context Sensitive Solutions
CY	cubic yard
DPP	Design Pollution Prevention
DPPIA	Design Pollution Prevention Infiltration Area
FHWA	Federal Highway Administration
FP	Federal Project
ft	foot/feet
ft/s	foot/feet per second
H	horizontal
HQ	Headquarters
H:V	Horizontal:Vertical
HDM	Highway Design Manual
hr	hour
HEC	Hydraulic Engineering Circular
in	inches
LID	Low Impact Development
max	maximum
min	minimum
NPDES	National Pollutant Discharge Elimination System
nSSP	Non-Standard Special Provision
OHSD	Office of Hydraulics and Stormwater Design
PA/ED	Project Approval/Environmental Document
PDT	Project Development Team
PE	Project Engineer
PECE	Preliminary Engineer's Cost Estimate
PID	Project Initiation Document
PPCE	Project Planning Cost Estimate
PPDG	Project Planning and Design Guide – Stormwater Quality Handbook
PM	Post Mile
PS&E	Plans, Specifications, and Estimates
R	radius
RSP	Rock Slope Protection
RWQCB	Regional Water Quality Control Board
S	slope
SQFT	square feet
SQYD	square yard
SSHM	Small Storm Hydrology Method
SSP	Standard Special Provision
SWDR	Stormwater Data Report
SWRCB	State Water Resources Control Board
TBMP	Treatment Best Management Practice
Typ	typical
V	vertical
WQF	Water Quality Flow
WQV	Water Quality Volume

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Section 1

Introduction

This document provides guidance to Caltrans Designers for incorporating Caltrans-Approved Detention Basins Treatment Best Management Practices (TBMPs) into projects during the planning and design phases of Caltrans highways and facilities. Detention Basins are bermed or excavated areas designed to temporarily detain runoff to allow sediment and particulates to settle out prior to runoff being discharged. Detention Basins treat runoff through sedimentation and infiltration when the basin is unlined. A Detention Basin may also be known as a detention pond. The primary functions of this document are to:

1. Describe a Detention Basin
2. Provide design guidance
3. Review the required elements for implementing the Detention Basin into Plans, Specifications, and Estimates (PS&E) packages
4. Provide a design example

It is assumed that the need for post construction TBMPs has already been determined in accordance with the guidelines and procedures presented in the Project Planning and Design Guide (PPDG; Caltrans 2019b).

The following guidance is provided based on Caltrans pilot studies and professional design experience. Designers may utilize alternatives to the calculation methodologies presented in this guidance. Alternative calculations and design decisions must be documented in the project Stormwater Data Report (SWDR) and the Project File. The SWDR template can be found in the PPDG.

1.1 Design Responsibility

The Project Engineer (PE) is responsible for the design of Detention Basin hydrology, hydraulics, grading, and traffic because they are part of the highway drainage system. The designer must consider the highway grading plans and the impacts stormwater infiltration may have on the roadway especially in consideration of Clear Recovery Zone (CRZ). Coordination with other functional experts is necessary to implement successful and functioning Detention Basins.

Refer to Chapter 800 of the Highway Design Manual (HDM), the Headquarters (HQ) Office of Hydraulics and Stormwater Design (OHSD), and District Hydraulics for project drainage requirements. If a vegetated Detention Basin is proposed, contact the District Landscape Architect for appropriate plant selection based on the physiographic region and the purpose of the BMP. To achieve sustainability requirements, the Project Development Team (PDT) is encouraged to use native and climate appropriate vegetation that does not require irrigation and requires the least amount of maintenance.

1.2 Detention Basins

Detention Basins utilize bermed or excavated areas to detain runoff long enough for the sediment and particulates to settle out under quiescent conditions prior to the runoff being discharged. Detention Basins are typically designed to completely drain after a storm event and are normally dry between rain events. Detention Basins may be configured in many shapes to meet right-of-way restrictions and should conform to the available space and topography. Ease of maintenance and construction should be considered. A Detention Device can also be configured using a vault, and, while much of this document would also apply, the structural aspects of vault design are beyond the scope of this document. Consult OHSD and the Division of Engineering Services Office of Design and Technical Services if a vault style Detention Device is under consideration.

The intent of this guidance is for designing water quality Detention Basins, which may be used in conjunction with other requirements such as flood control and hydromodification. It is preferred that events greater than the Water Quality Event be bypassed around the BMP with an upstream flow splitter to prevent resuspension of captured pollutants and to minimize the size of the BMP. Flows may be passed through the BMP, typically over a spillway or through an overflow riser if bypass is not feasible. Other design criteria may also be necessary.

The objective of a water quality Detention Basin (i.e., TBMP) is to reduce the sediment and particulate loading in runoff from the Water Quality Event. Detention Basins are highly effective at removing trash. They are in the medium effective range for sediments, metals, bacteria, oil and grease, and organics, and have low removal effectiveness for nutrients as noted in TC-22 of the California Stormwater Quality Association (CASQA) manual (CASQA 2003). They are also effective at removing pesticides, pathogens, turbidity, temperature, and mercury as noted in the PPDG.

A schematic of a Detention Basin is shown in Figure 1-1, while an isometric view is shown in Figure 1-2. Consult with Geotechnical Design, Hydraulics, and Traffic Safety if within the CRZ.

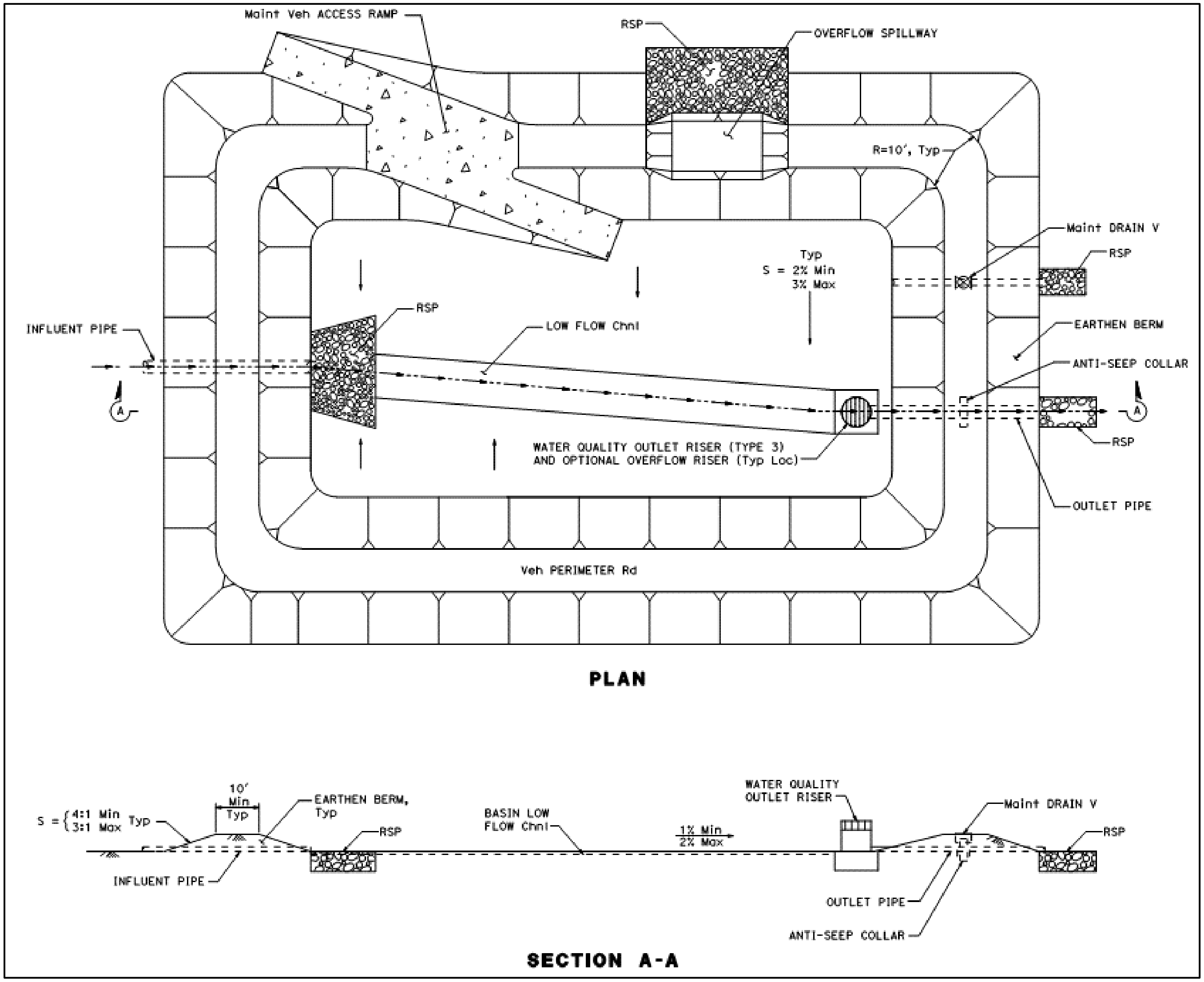

Figure 1-1. Detention Basin Schematic

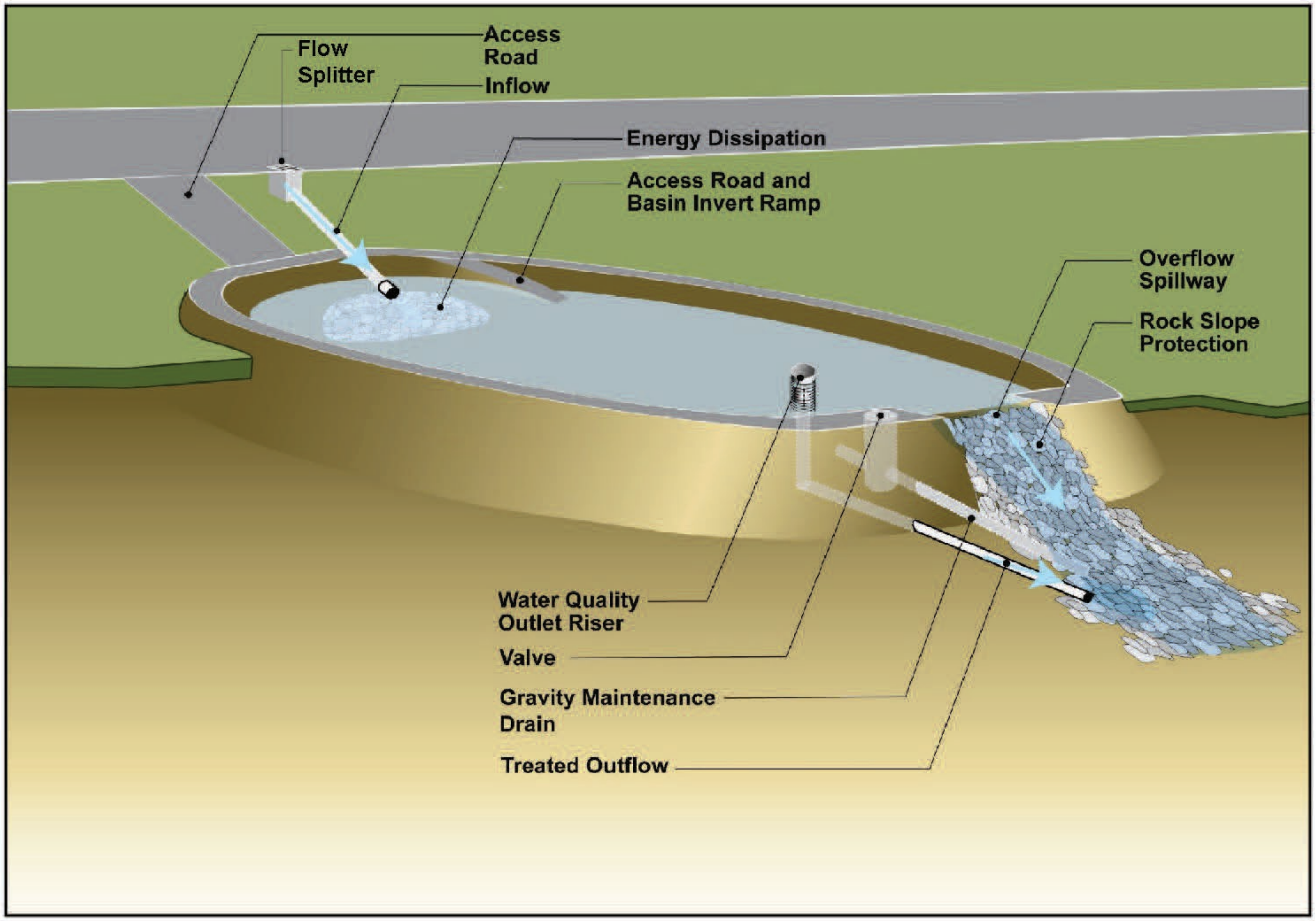

Figure 1-2. Detention Basin Isometric View

Section 2

Basis of Detention Basin Design

Detention Basins may be considered whenever site conditions are favorable, safety criteria are met, and where flow velocities can be mitigated to prevent scour. The site should have sufficient area for pretreatment BMPs (e.g., Biofiltration Strips, Biofiltration Swales, TST) upstream of the basin. Detention Basins can be considered alone or as part of a treatment train.

Checklist T-1, Part 4 in the PPDG, assists in evaluating the initial feasibility of Detention Basins for a project. The checklist identifies design elements that should be considered during design. Once the feasibility of the device has been confirmed using Checklist T-1, Part 4 in the PPDG, use the following subsections to further understand the design elements of a Detention Basins for a given site.

2.1 Design Considerations

The primary design parameter for sizing Detention Basins is the water quality volume (WQV). The WQV, or portion thereof, is equal to the minimum volume of the Detention Basin, which does not include any additional volume due to overflow events and freeboard. Freeboard is defined and described below.

Detention Basins must safely pass events that are larger than the water quality event used for design. The release of larger events is typically accomplished as overflow through an overflow spillway or riser set at an elevation related to the WQV. The overflow event used in the design of the weir must be consistent with the intensity, duration, and frequency of the rainfall event used in the roadway drainage design for that contributing drainage area (CDA) generating runoff to the Detention Basin (and from other sources that cannot be redirected around the Detention Basin) as discussed in the HDM, Chapter 830, Topic 831. Overflow weirs must also be considered for offline placement of TBMPs in the event that clogging or other unusual conditions occur. The maximum water level in the Detention Device should not cause seepage of water under the roadway to within 8 inches of the roadway subgrade.

Associated with the overflow event, a minimum freeboard of 1 ft should be provided between the water surface elevation during the overflow event and the lowest elevation of the confinement to protect the physical integrity of the Detention Basin and downstream facilities.

In addition, Detention Basins should be able to operate by gravity flow while limiting clogging of the water quality outlet and providing a proper overflow spillway or overflow riser for larger runoff volumes. The basins should only require occasional maintenance and cleaning.

2.2 Preliminary Design Criteria

The guidelines described below are intended for standard configuration designs under normal conditions and typical external loading requirements. General siting and design guidelines for Detention Basins are as follows (refer to PPDG, Table B-4 for additional information):

- Detention Basins should be designed with a volume equal to the WQV, or portion thereof, as described in Section 4.1.1.
- Discharge should be accomplished through a water quality outlet riser with a debris rack or other acceptable means of preventing clogging at the entrance of the outflow device. Minimum water quality outlet orifice size is 0.5 in.
- The water quality outlet should be designed to empty the Detention Basin within a maximum 96 hours.
- Size: Flow-path-to-width ratios are usually 2:1 or greater, and basin water depths generally range from 2 to 8 ft.
- Protect groundwater when designing TBMPs. Coordinate with District/Regional National Pollutant Discharge Elimination System (NPDES) Coordinator and Regional Water Quality Control Board (RWQCB) when high infiltration rates and high groundwater are present. The seasonally high groundwater should be at least 5 ft below the invert of the Detention Basin unless justified by adequate groundwater information or RWQCB concurrence (if liner is not used).
- Coordinate with Geotechnical Design to discuss methods to mitigate high infiltration rates.
- Liners are needed on earthen Detention Basins when located over a known contaminated groundwater plume unless approved by the local RWQCB.
- Sufficient hydraulic head should be available to prevent an objectionable backwater condition in the upstream roadway storm drain system.
- Basin shape/configuration should result in as natural an appearance as possible.

Detention Basins must meet certain design criteria to perform as an effective TBMP. The primary factors to be incorporated in the design are found in Table 2-1.

Table 2-1. Standard Detention Basin Siting and Design Criteria		
Parameter	Min. Value	Max. Value
Runoff Volume	For water quality treatment: WQV, or portion thereof	Site Dependent[1]
Side Slope Ratio (H:V)	4:1	3:1
Flow Path-to-Width Ratio	2:1 (recommended)	
Freeboard	1 ft	
Drawdown Time	Up to 96 hours	
Separation between Groundwater and Basin Invert (use a liner if separation is between 1 ft and 5 ft)	5 ft	
Depth of Cover over Liner (if Liner Required)	1 ft	

Notes

1. *A Detention Basin constructed only for water quality purposes should not be sized larger than the WQV as reduced treatment of the more frequent storms will result.*

2.3 Safety Considerations

Detention Basin BMPs should be located using the general roadway drainage considerations for safety and CRZ concept in the AASHTO manual (AASHTO 2011). Traffic safety is an important part of highway drainage facility design. The Detention Basin should provide a traversable section for errant traffic leaving the traveled way within the CRZ (HDM Topics 304, 309, and 861.4). Coordinate with other functional experts such as District Traffic Operations, District Maintenance, District Hydraulics, Geotechnical Design, and Traffic Safety, as applicable.

Consult with District Traffic Operations for all proposed BMP placements to determine if guard railing is required. Detention Basins should have detailing such as fences, that preclude ready access by the public.

2.4 Restrictions/Coordination

Successful implementation and utilization of the Detention Basin as a TBMP will require proper siting by the PDT with coordination of District Hydraulics, District Maintenance, District Traffic Operations, Geotechnical Design, and Traffic Safety, as applicable. Detention Basin design decisions and coordination must be documented in the SWDR and project file.

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Section 3

BMP Layout

3.1 Detention Basin Layout

As stated in Section 2.1, the shape/configuration of a Detention Basin should conform to the site and result in as natural an appearance as possible. Whenever feasible, and especially if the facility will be in view of the traveling public, attempt to configure the Detention Basin in a non-rectilinear shape for aesthetic purposes. Consider the application of Context Sensitive Solutions (CSS) to ensure that community-sensitive issues have been considered in implementing the facility. Consult with the District Landscape Architect.

The layout of the Detention Basin is set by positioning the basin relative to the direction of the incoming flow, and also by adhering to the limitations of the Detention Basin design. If the incoming flow enters the Detention Basin through the berm constituting the shorter berm dimension, then the flow may enter at a skew of up to 45 degrees. If the incoming flow approaches at an angle greater than 45 degrees, then the following is a list of possible solutions that may apply:

- In order for the entry angle to be less than 45 degrees, the inflow pipe should enter through a side wall, with the edge of the pipe being no less than 1 ft away from the corner of the 'inflow' wall (i.e., the wall opposite the water quality outlet).
- The Detention Basin should be realigned to match the direction of the incoming flow.
- The incoming drainage system should be realigned by inserting some type of elbow or bend upstream of the entrance into the Detention Basin.
- To compensate for the entry angle being greater than 45 degrees, an internal baffle wall should be provided to direct the flow, protect against scour, and to ensure a flow path-to-width ratio of 2:1.

Incoming flows should not enter the Detention Basin in such a manner as to cause short circuiting of the basin, nor should incoming flows impinge directly upon an adjacent berm. Figure 3-1 shows a sample Detention Basin layout, illustrating the inlet configuration described above.

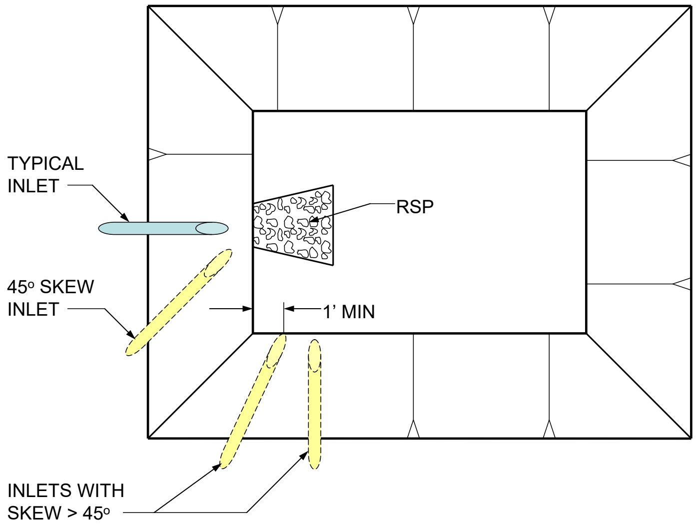

Figure 3-1. Detention Basin Inlet Configuration

The Detention Basin footprint must fit within the proposed site. The inlet and outlet drain pipe locations and elevations must match the hydraulic requirements of both the basin and the upstream and downstream drainage conveyance facilities.

3.2 Water Quality Outlet Requirements

Discharge of a Detention Basin should be accomplished through a water quality outlet with a debris rack or other acceptable means of preventing clogging at the entrance of the water quality outflow orifices. A rock pile or rock-filled gabions can serve as an alternative to the debris screen around the inlet of the water quality device, although the PE should be aware of the potential for extra maintenance involved should the pore spaces in the rock pile clog. Proper hydraulic design of the outlet is critical to achieving good performance of the Detention Basin. The water quality outlet riser should be designed to empty the device within 96 hours. 40 to 48 hours is recommended.

The two most common water quality outlet problems that occur are:

- The capacity of the water quality outlet orifice is too great, resulting in only partial filling of the Detention Basin for the WQV and a shorter than designed drawdown time.
- The water quality outlet clogs because it is not adequately protected against trash and debris.

The following water quality outlet types are recommended for use:

- A single orifice water quality outlet with or without the protection of a riser pipe.
- Riser perforated vertically (orifices allocated evenly on two rows).

Design guidance for single orifice water quality outlets is presented in the following text.

Flow Control Using Orifices at The Bottom of the Device: The outlet control orifice should be sized using the following equation:

$$a = \frac{2A(H-Ho)^{0.5}}{3600CT(2g)^{0.5}} \quad \text{(Eq. 1)}$$

where:

a	=	total area of orifice (SQFT)[1]
A	=	surface area of the device at mid elevation (SQFT)
C	=	orifice coefficient (see discussion on following page)
T	=	drawdown time of full device (recommend 40 hrs)
g	=	gravity (32.2 ft/s^2)
H	=	elevation when the device is full (ft)
Ho	=	final elevation when device is empty (ft)

For a riser perforated vertically (orifices in single or multiple columns), use:

$a_t = [2A \times h_{max}]/[3600 \times C \times T(2g\{h_{max} - h_{centroid\ of\ orifices}\})^{0.5}]$ (Eq. 2)

with terms as shown in Eqn. 1 except:

a_t	=	total area of orifices in the perforated riser, (SQFT);
h_{max}	=	maximum vertical distance from lowest orifice to the maximum water surface (ft);
$h_{centroid\ of\ orifices}$	=	vertical distance from the lowest orifice to the centroid of the orifice configuration (ft).

Care must be taken in the selection of C; 0.60 is most often recommended and used however, based on actual tests, GKY (1989), "Outlet Hydraulics of Extended Detention Facilities for Northern Virginia Planning District Commission", recommends the following:

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[1] In the 'single orifice' design, the total orifice area is placed at one elevation, and may be configured using one or several orifices, at the designer's option. (Eq. 1&2)

C = 0.66 for thin materials; where the thickness is equal to or less than the orifice diameter

C = 0.80 when the material is thicker than the orifice diameter

Allocate the orifices evenly on two rows. Separate the holes by 3x hole diameter vertically, and by 120 degrees horizontally. If more than two orifice rows are used, a special design is required.

See Section 9 of the Supplemental Details Design Guidance (Caltrans 2020b) for information on perforated riser water quality outlet risers which may also be configured to serve as the primary or secondary overflow structures for Detention Basins.

3.3 Space and Site Considerations

Detention Basins require sufficient space and generally should be sited in an unobstructed location that can be easily accessed by maintenance vehicles. Consideration should be made for a perimeter access road, safe access to and from the site by way of local streets or access roads, and a maintenance access ramp to the basin invert. Any exception from these provisions requires the concurrence from the Maintenance Stormwater Coordinator, and if the site conditions do not meet all of the requirements in Section 2.2, a Special Design will be required. Section 6 presents guidelines on how Special Designs may be achieved.

3.4 Vegetation of Invert and Side Slopes

Detention Basins will be more visually appealing to the traveling public and will function more effectively if the invert is vegetated rather than having a non-vegetated bottom and/or non-vegetated side slopes. This will also minimize erosion from the side slopes of the basin. If a vegetated invert is used, consider using a design that effectively dissipates energy and protects the basin inlet from erosion. For types of vegetation that can function effectively in Detention Basins within each of the various ecological sub regions of a District, consult with the District Landscape Architect.

Section 4
Design Elements

Certain supplemental structures and devices may be required in the construction of Detention Basins. These supplemental design elements are discussed in detail in the Supplemental Details Design Guidance. It is the PE's responsibility to determine which of the Detention Basin supplemental design elements are required for a specific site.

4.1 Contributing Drainage Area and WQV

The WQV generated by the BMP CDA is calculated using the Small Storm Hydrology Method (PPDG Section 5.3). The Caltrans Infiltration Tool version IT4 can be used when the BMP site is conductive for infiltration. An explanation of CDA delineation and WQV calculation and example can be found in Section 3 of the DPPIA Design Guidance (Caltrans 2019a).

4.2 Design Storm

Both storm volume and peak flows must be considered in the evaluation of runoff conditions. The Design Storm is the event that generates the peak flows that the drainage facilities are designed to handle (HDM Topic 831). Continue to use the Rational Method from HDM Chapter 810, the runoff coefficients in HDM Topic 819.2, and the total CDA in acres (including the BMP footprint) for drainage design and flood flows. The average rainfall intensity used in the Rational Method is for the Design Storm frequency and for a duration equal to the time of concentration. See the National Oceanic and Atmospheric Administration (NOAA) website for precipitation frequency data at https://hdsc.nws.noaa.gov/hdsc/pfds/. For the purpose of this guidance manual, the term Design Storm used in reference to designing drainage facilities will refer to the peak drainage facility design event as determined in accordance with the HDM. An example calculation of Design Storm flow can be found in Section 3 of the DPPIA Design Guidance.

4.3 Overflow Events

Flows exceeding those associated with the WQV may be diverted around the Detention Basin through an upstream flow splitter (refer to the Flow Splitters Design Guidance (Caltrans 2020c) for more details) or may be allowed to travel through the Detention Basin, with release through an overflow device. Using a flow splitter minimizes scouring of previously deposited materials within the Detention Basin. However, all Detention Basins must be equipped with an overflow device sized to accommodate the Design Storm flows in case clogging of the upstream flow splitter or other unusual condition occur. The overflow structure may be in the form of a Type 1 or Type 2 water quality outlet, an overflow riser, or an overflow spillway. Even when a Type 1 or Type 2 water quality outlet is used, an additional outlet (riser or spillway) is often supplied to prevent overtopping of the walls or berms should blockage of the riser occur, based on a downstream risk assessment.

4.4 Overflow Risers

Overflow risers are vertical pipes that act as sharp-crested weirs designed to pass flows in excess of those associated with the WQV and are similar in structure to water quality outlet risers except that the flow is not regulated. Minimum riser pipe diameter should be 3 ft (for maintenance reasons). Overflow risers are used when overflow spillways are not practical. Details of overflow risers can be found in Section 8 of the Supplemental Details Design Guidance.

4.5 Overflow Spillways

Detention Basins may also be equipped with an overflow spillway designed to safely handle flows associated with the Design Storm flow (see Section 4.2). Overflow spillways are broad-crested weirs intended to control the location where the flows would overtop the basin perimeter in order to avoid structural damage to the embankment, and to direct the flows into the downstream conveyance system or other applicable discharge point. Minimum spillway length is 3 ft and is measured perpendicular to flow. Details of overflow spillways and their design parameters can be found in Section 5 of the Supplemental Details Design Guidance.

4.6 Flow Splitters

Flow splitters are upstream drainage bifurcation structures designed to direct the more frequent flows to Detention Basins and provide a bypass during peak flow conditions. Flow that corresponds to the maximum allowable WQV, or portion thereof, will enter the Detention Basin, while the remainder will bypass the structure through an overflow pipe. Possible conditions requiring the implementation of a flow splitter in conjunction with a Detention Basin are listed below:

- Backwater effect in the Detention Basin
- Large peak storm effects
- Inlet pipe elevation constraints
- Available capacity of overflow discharge pipe connection
- Downstream effects of an overflow spillway

A detailed hydraulic analysis will be required to properly size and design the flow splitter structure, which is covered in the Flow Splitters Design Guidance.

4.7 Litter and Trash Considerations

Caltrans has developed a Statewide Trash Implementation Plan (Plan; Caltrans 2019c) to prevent the discharge of trash to surface waters through stormwater discharges. The Plan identifies statewide Significant Trash Generating Areas (STGAs) requiring consideration of full trash capture BMPs.

Full trash capture should be included in the design of a Detention Basin within a watershed where any of the following exists:

1. A Total Maximum Daily Load (TMDL) restriction for trash
2. Discharges to a 303(d) listed waterway for trash
3. Has been identified as an STGA
4. Required by a Regional Basin Plan

The Detention Basin is a Caltrans approved treatment device that can be certified as a multi benefit full trash capture BMP. The full-capture volume is calculated using the 1-year, 1-hour storm event depth. Refer to the Multi Benefit Treatment BMP Trash Full Capture Requirements Design Guide (Caltrans 2018) for specifics on design details.

Additionally, the PE may include a pretreatment device to capture the gross solids (e.g., paper, plastics, glass) and naturally occurring debris that may be conveyed by stormwater to the Detention Basin. The device should be designed to remove all litter and solids 5 mm and larger. This pretreatment can be provided by the Caltrans approved Gross Solids Removal Devices (GSRDs) TBMP or other devices that meet the requirements for full trash capture.

Use of other devices requires a detailed design by the PE and must be coordinated with the District/Regional Design Stormwater Coordinator, District Hydraulics, Traffic Safety, District Maintenance Stormwater Coordinator, and OHSD, as appropriate. Consult with DEA and OHSD for design approval or to determine if a Special Design or pilot is required. Design decisions and coordination on the trash device must be documented in the SWDR.

4.8 Maintenance Drain Valves

Maintenance drain valves are outlet mechanisms for draining a Detention Basin in the event that the water quality outlet pipe becomes clogged and the basin fails to drain the retained runoff within the specified drain time of up to 96 hours.

The maintenance drain valve shall be accessible from a location outside the Detention Basin to allow maintenance personnel to operate the valve in wet conditions without having to enter into the water storage area. If there is a pipe between the basin and the drain valve, the slope of the pipe should be a minimum of 2 percent to minimize sediment buildup at the valve. The valve-pipe connections should be watertight, and the valve box containing the valve operator should be designed to support traffic loads. Details of maintenance drain valves can be found in Section 4 of the Supplemental Details Design Guidance.

4.9 Anti-Seep Collar

Anti-seep collars prevent water from seeping around the outside of an underground pipe, and thus effectively protect the pipe from failure due to loss of bedding caused by subsurface water flow. Anti-seep collars are generally used in sloped applications such as outlet pipes for Detention Basins or for a pipe between a basin and a drain valve. Connections between the pipe and the collars should be watertight, and the collars should be constructed against undisturbed or compacted embankment material. If a Detention Basin is constructed of concrete, which is rare but not implausible, then anti-seep collars would not be required. Details of anti-seep collars can be found in Section 2 of the Supplemental Details Design Guidance.

4.10 Low Flow Channels

Low flow channels are hard surface channels (e.g., concrete) constructed along the bottom of Detention Basins to convey low flow runoff and/or base flow directly from the inlet to the water quality outlet without erosion. The low flow channel also prevents standing water from accumulating within the device after a storm event. Channel cross sections can be trapezoidal or triangular (i.e., V-ditch). Low flow channels are designed to be mounted and crossed by maintenance equipment and vehicles. Details of low flow channels can be found in Section 7 of the Supplemental Details Design Guidance.

4.11 Maintenance Access Ramps

Vehicle access should be provided around the perimeter of the Detention Basin with a maintenance access ramp to the basin invert. Maintenance vehicles of various types and sizes must be allowed access for routine maintenance visits, including the possible use of a backhoe and truck for trash and debris removal. District Maintenance should be consulted to discuss the access needs for a particular site. Details of maintenance access ramps can be found in Section 10 of the Supplemental Details Design Guidance.

4.12 Geomembrane Liners

Geomembrane liners are impermeable liners placed under the Detention Basin bottom to facilitate maintenance, protect groundwater, and prevent infiltration of runoff in areas where pollutant plumes are present. Liners are generally only required if the groundwater separation distance between the basin invert and seasonally high groundwater is between 1 ft and 5 ft, or if the groundwater is contaminated. To prevent uplift, the seasonally high groundwater should never be higher than the elevation of the basin liner. Details for geomembrane liner placement can be found in Section 6 of the Supplemental Details Design Guidance.

4.13 Baffle Walls

Baffle walls are constructed barriers used to deflect flow to achieve the recommended 2:1 length-to-width ratio in a Detention Basin where the natural basin geometry does not provide the 2:1 ratio between the inlet(s) and the outlet structure. A baffle wall increases the distance of the flow path and the residence time, eliminating the short circuiting of the flow and thereby maintaining detention time. Details for baffle walls can be found in Section 3 of the Supplemental Details Design Guidance.

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Section 5

PS&E Preparation

This section provides guidance for incorporating Detention Basins into the PS&E package, discusses the typical specifications that may be required, and presents information about estimating the construction costs.

While every effort has been made to provide accurate information here, the PE is responsible for incorporating all design aspects of Detention Basins into the PS&E in accordance with the requirements of Section 2 of the Construction Contract Development Guide (Caltrans 2019d).

5.1 PS&E Drawings

The Detention Basin design does not include standard drawings or details, so the PE is responsible for incorporating the design into the PS&E in accordance with the procedures typically followed when developing a PS&E package. For example, the applicable layout, grading, drainage, and detail sheets should be updated to reflect the required design features of the Detention Basin.

The PS&E drawings for most projects having Detention Basins may include:

- Layout(s): Show location(s) of the Detention Basin. This is a recommended option, as its use will aid in recognizing, both within and outside Caltrans, that Infiltration Basins were placed within the project limits.
- Grading or Contour Grading(s): As Detention Basins are primarily earthwork features, they should be shown on Contour Grading sheets or grading plans. Other associated grading surrounding the Detention Basin should be shown on these sheet(s).
- Drainage Details: Inflow and outflow detailing should be shown including the overflow release device (e.g., spillway through the confining berm or through a CMP riser). These details may be shown in the Drainage Detail sheets, at the option of the PE.
- Drainage Plan(s), Profiles, Details, and Quantities:
  - Drainage Plan sheets should show each Detention Basin in plan view, along with other existing (or proposed) drainage conveyance devices that direct the runoff into the device and overflow from the device.
  - Drainage Profile sheets should show the Detention Basin in profile within the drainage conveyance system. These sheets should also call out the specific Detention Basin inlet and outlet flow line (surface) elevations and invert elevation.

   - Drainage Detail sheets should show any other detailing needed for the construction of the Detention Basin not provided elsewhere in the contract plans (e.g., under Construction Details).
   - Drainage Quantity sheets should include all pay and non-pay items associated with the construction of the Detention Basins, except for those items that will be placed on the Summary of Quantities sheets.
- Planting Plans/Erosion Control Plans: These sheets are used to show the requirements for the vegetative portion of the Detention Basin, if needed. and nearby areas including soil amendments, planting, and similar items for the interior of the Detention Basin and nearby areas (prepared by the District Landscape Architect).Planting quantities (e.g., hydroseed) for each Detention Basin should be provided.
- Temporary Water Pollution Control Plans: These sheets are used to show the temporary BMPs used to establish the Detention Basin BMPs and compliance with the Construction General Permit.

5.2 Specifications

Contract specifications for projects that include Detention Basins may include a combination of Standard Specifications, Standard Special Provisions (SSPs), and non-Standard Special Provisions (nSSPs). In some cases, specific nSSPs have been developed by OHSD.

Special provisions for the various items of work directly needed to construct the Detention Basin could be organized under an umbrella ‘Detention Basin’ nSSP with the required items listed as subheadings. Payment would be made for ‘each’ Detention Basin. Optionally, separate listings could be made for each contract item of work, with separate measurements and payments. The PE and the District Office Engineer should consider which method would better serve the project.

5.2.1 Standard Specifications

Listed below are Standard Specifications that would typically be used for a project that constructs a Detention Basin TBMP. Consider the construction of the Detention Basin in the context of the entire project to determine if other Standard Specifications may be required.

13 Water Pollution Control

17 General (Earthwork and Landscape)

19 Earthwork

20 Landscape

21 Erosion Control

64 Plastic Pipe

68 Subsurface Drains

70 Miscellaneous Drainage Facility

71 Existing Drainage Facilities

72 Slope Protection

96 Geosynthetics

5.2.2 Standard Special Provisions

SSPs may be included for projects that construct a Detention Basin TBMP. Consider the construction of Detention Basins in the context of the entire project to determine if SSPs are required. The SSP topics that should be considered by the PE for inclusion in the Contract Special Provisions depend on the types of appurtenant facilities and materials proposed for the project. Consult the current index of SSPs available on the Office of Construction Contract Standards section of the Caltrans website. Each SSP topic should also be examined to determine whether additional/referenced SSP sections are needed to completely specify the proposed work.

5.2.3 Non-Standard Special Provisions

A project that constructs a Detention Basin may require an nSSP to provide details to assure that the design assumptions are constructed properly. The PE and PDT should decide the most appropriate specifications for the site-specific site conditions to meet design requirements and other goals in the HDM (e.g., safety, slope stability). If the PE and PDT deem nSSPs necessary, coordinate with OHSD. OHSD can provide nSSPs to support the design.

OHSD has developed an nSSP to cover the many variables that a Detention Basin may contain and is available upon request.

5.3 Project Cost Estimates

Project Cost Estimates are required at every phase of the project: Project Initiation Document (PID), Project Approval/Environmental Document (PA/ED), and PS&E. The Caltrans Division of Design, Office of Project Support has developed the following website to assist in the development of cost estimates:

http://www.dot.ca.gov/hq/oppd/costest/costest.htm

This website includes links to Chapter 20 Project Development Cost Estimates of the Project Development Procedures Manual and Caltrans Cost Estimating Guidelines. In addition to Chapter 20, this website includes other useful cost estimating information on project cost escalation, contingency and supplemental work, and cost estimating templates for the planning and design phases of the project. These templates may be used to track estimates relating to costs for incorporating TBMPs.

5.3.1 PID and PA/ED Phases

A preliminary cost estimate, Project Planning Cost Estimate (PPCE), is required as an attachment of the SWDR during the PID phase of the project. A refined version of the PPCE is developed in PA/ED phase. For details on what needs to be included in PPCE, refer to Section 6.4.9 and Appendix F of the PPDG.

This estimate will need to be modified as the project progresses. If some design is conducted during the PA/ED phase of the project, it is possible that a more refined estimate could be made using the methods in Section 5.3.2. A cost escalation should be added for projects that are anticipated to advertise more than a year after the date of the estimate.

5.3.2 PS&E Phase

Preliminary Engineer's Cost Estimates (PECE) are initiated at the beginning of PS&E and are updated until the completion of PS&E. PECEs focus on the construction costs of the project and the stormwater BMPs and are input into the Basic Engineering Estimating System (BEES). Verify the quantities for inclusion in the project cost estimate to identify which should be considered Final Pay items, and to determine appropriate unit prices for each. Develop all necessary earthwork quantities for each specific Detention Basin location and determine limits of excavation and backfill.

5.4 Developing Detention Basin Cost Estimates

Develop a quantity-based cost estimate, regardless of availability of specific unit cost or quantity data. As the design process proceeds, the project cost estimate should be updated as new data becomes available. Identify contract items required to construct the Detention Basin.

Table 5-1 includes typical contract items that may be included in the unit cost (CY and SQFT) estimate if they are required for Detention Basins. Table 5-1 is not a complete list and must be modified on a project-specific basis to accommodate all aspects of design.

Table 5-1. Example Detention Basin Estimate

Contract Item	Type	Unit	Quantity	Price	Amount
Clearing and Grubbing		LS			
Roadway Excavation		CY			
Embankment		CY			
Alternative Pipe Culvert		LF			
Drainage Inlet Marker		EA			
Rock Blanket		SQFT			
Permeable Material		CY			
Impermeable Liner		SQYD			
Class D Filter Fabric		SQYD			
Baffle Wall		SQFT			
Lean Concrete Backfill		CY			
Erosion Control (e.g., Dry Seed)		SQFT			
Rock Slope Protection		CY			

When developing costs based on unit quantities, the unit costs should be based upon the most recent Caltrans Contract Cost Data Book, and District 8 Cost Data Base for current similar projects.

https://sv08data.dot.ca.gov/contractcost/

Use the project specifications, SSPs, and nSSPs to develop a list of items for which unit costs should be supplied. Carefully check that all items of work are accounted for either as pay or non-pay items.

Watch for the costs associated with earthwork for each specific Detention Basin location, as that item of work will have the most variable costs for this TBMP. For Detention Basin earthwork, use Section 19-2 Roadway Excavation of the Standard Specifications.

Estimate the total cost of each Detention Basin used on the project for tracking TBMP costs at PS&E. Document all BMP costs in the project SWDR at PS&E.

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Section 6

Special Design

This section provides guidance for situations where the specific project requirements do not meet the design parameters specified in Section 2 of this guidance document. The following recommendations are provided as alternatives to expand the applicability of Detention Basins beyond the standard design criteria. Note that any of the following design approaches may require additional engineering, such as a structural or hydraulic analysis.

6.1 Alternative BMP Sizing

The calculations in this guidance assume instantaneous runoff to the BMP (i.e., 'slug-flow') which does not consider active treatment during the event, leading to conservative sizing designs. A sizing alternative to account for timing of runoff is to perform rainfall-runoff and unsteady-flow storage routing computations for the BMP. When the runoff is distributed over the duration of an event, early-event runoff can be treated and released before the peak runoff arrives. Using these calculations, the BMP does not need to be sized to store the entire runoff volume at once (i.e., 'slug-flow'), leading to smaller designs. By accounting for active treatment occurring during the event, an increase in the treated WQV listed in Tables 4-1 to 4-4 of up to 50 percent can be expected. Details of this methodology and findings are discussed in the Review of Design Guidance for Sizing Media Filters for Stormwater Quality Treatment (Caltrans 2019e).

Additionally, when an infiltrative BMP is installed in a Type A or Type B soil the BMP footprint can be reduced while treating the same WQV. The following figure shows an example of how accounting for active treatment and native soil type using the Caltrans Infiltration Tool IT4 tool impacts BMP size. The example shows that in a Type A soil a BMP can be 60% smaller than if it were installed in Type C or Type D soils.

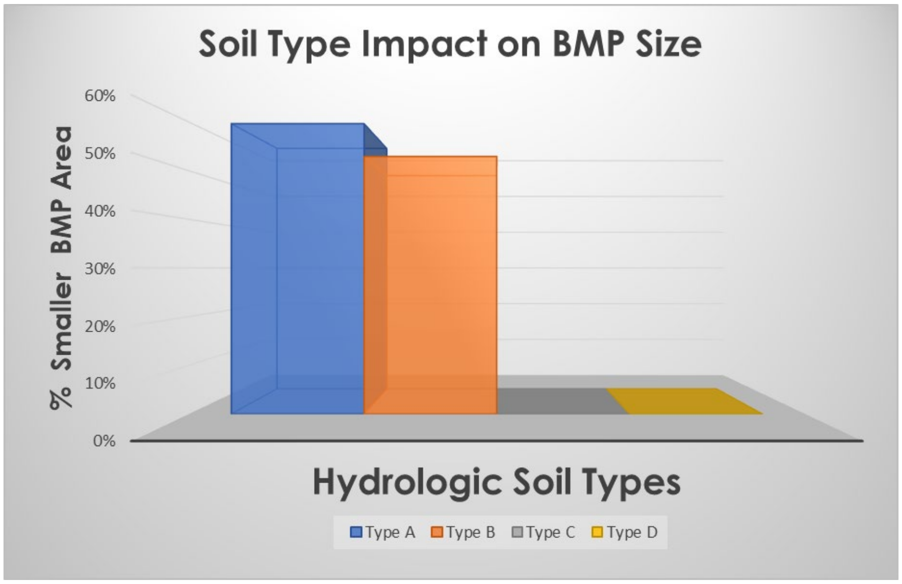

Figure 6-1. BMP Size Reduction Based on Soil Type

Alternative calculations may be used by the PE for a specific project and must be developed by a qualified professional in consultation with the District/Regional Design Stormwater Coordinator and documented in the SWDR. Consult with DEA and OHSD for design approval or to determine if a Special Design or pilot is required.

6.2 Dual Purpose Detention Device

A Detention Device designed for dual purposes of water quality and attenuation of peak flows requires additional hydraulic design considerations and potentially special outflow device configurations not included in this guidance document. For this situation, consult with District Hydraulics and the District/Regional Design Stormwater Coordinator.

6.3 Vault-Type Detention Device

If a vault-type Detention Device is being considered, consult with OHSD and the Division of Engineering Services Office of Design and Technical Services.

Section 7

Detention Basin Design Example

This section presents an example on how to design a Detention Basin using the information and procedure outlined in this guidance document. The sample project location is a new 4-lane freeway with single-lane entrance and exit ramps. There is no median between the eastbound and westbound lanes. A Detention Basin has been selected as the TBMP for all impervious surfaces within the project limits.

Step 1: Define project parameters

Project Limits:	PM 17.6 to PM 18.3
Lane Widths:	12 ft
Highway Shoulder Widths:	8 ft
Total Length of New Ramps:	1.36 miles
Ramp Lane Widths:	12 ft
Ramp Shoulder Widths (inside and outside):	6 ft
Volumetric Runoff Coefficient (100% Impervious):	0.89
Precipitation Depth (from Basin Sizer [CSUS 2013]):	0.75 in
Design Storm Peak Flow:	22.14 cfs
Nappe:	1.33 ft (estimated)
Breadth of Crest of Weir:	15 ft (estimated)

Step 2: Calculate Total Impervious Area and WQV

First, calculate total area of new ramps:

1.36 miles x 5,280 ft/mile x [12 ft + (2 shoulders x 6 ft)] = 172,339 SQFT = <u>3.96 acres</u>

Next, calculate total area of new freeway:

0.7-mile x 5,280 ft/mile x (4 lanes x 12 ft) + 0.7-mile x 5,280 ft/mile x (2 shoulders x 8 ft)

= 236,544 SQFT = <u>5.43 acres</u>

Therefore, Total Impervious Area = 3.96 acres + 5.43 acres = **9.39 acres**

Next, calculate WQV:

WQV = R_v (P/12) A

Where:

WQV = Runoff volume generated by the 85th percentile 24-hr storm event (CF)

R_v = Volumetric Runoff Coefficient, 0.89

P = Precipitation Depth, 0.75 in

A = Contributing Drainage Area, 9.39 ac = 409,028 SQFT

WQV = 0.89 x 0.75 in (1 in /12 ft) x 409,028 SQFT = **22,752 CF**

Step 3: Calculate Detention Basin Dimensions

Given:

Basin Volume = WQV = 22,752 CF (minimum to start)

Drawdown Time = 48 hours

Basin Flow-Path-to-Width Ratio = 2:1

Basin Side Slope Ratio = 4:1 (H:V)

Basin Depth at WQV = 4 ft

The equation for solving for the volume of a trapezoidal basin is:

Volume = $(W \times L \times H_W) + [(W+L) \times Z \times H_W^2)] + [(4/3) \times (Z^2) \times (H_W^3)]$

Where:

W = Width at basin invert

L = Length at basin invert

Z = Basin side slope (H:V)

H_w = Depth of basin at WQV

However:

H_w at WQV = 4 ft (given)

$W = W_{WQV} – (2 \times Z \times H_w)$

$L = L_{WQV} – (2 \times Z \times H_w)$, where $L_{WQV} = 2 \times W_{WQV}$

Therefore, solve for the invert width and lengths that would result in the desired WQV while providing the 2:1 flow-path-to-width ratio at WQV. Using the first column of Table 7-1, locate the row that corresponds to a WQV of 22,752 CF. Reading across the row and selecting the values for L and W that correspond to the given basin depth (H_w) of 4 ft, we find:

W = Width at basin invert = **34 ft**

L = Length at basin invert = **99 ft**

$W_{WQV} = W + 2 \times Z \times H_w$ = **66 ft**

$L_{WQV} = L + 2 \times Z \times H_w$ = **131 ft**

Table 7-1. Detention Basin Invert Dimensions										
Side Slope Ration = 4:1 (H:V), Flow-Path-to-Width Ratio at WQV = 2:1										
WQV (ft3)	Hw = 3		Hw = 3.5		Hw = 4		Hw = 4.5		Hw = 5	
	L	W	L	W	L	W	L	W	L	W
5,000	52	14	46	9	41	5	37	1	NA	NA
5,500	55	16	49	11	44	6	40	2	NA	NA
6,000	57	17	51	12	46	7	42	3	NA	NA
6,500	60	18	54	13	49	9	44	4	NA	NA
7,000	62	19	56	14	51	10	46	5	42	1
7,500	65	21	58	15	53	11	48	6	44	2
8,000	67	22	61	17	55	12	50	7	46	3
8,500	69	23	63	18	57	13	52	8	47	4
9,000	72	24	65	19	59	14	54	9	49	5
9,500	74	25	67	20	61	15	55	10	51	6
10,000	76	26	69	21	62	15	57	11	52	6
10,500	78	27	70	21	64	16	59	12	54	7
11,000	80	28	72	22	66	17	60	12	56	8
11,500	82	29	74	23	68	18	62	13	57	9
12,000	84	30	76	24	69	19	64	14	59	10
12,500	85	31	78	25	71	20	65	15	60	10
13,000	87	32	79	26	72	20	67	16	61	11
13,500	89	33	81	27	74	21	68	16	63	12
14,000	91	34	82	27	76	22	70	17	64	12
14,500	93	35	84	28	77	23	71	18	66	13
15,000	94	35	86	29	78	23	72	18	67	14
15,500	96	36	87	30	80	24	74	19	68	14
16,000	97	37	89	31	81	25	75	20	69	15
16,500	99	38	90	31	83	26	76	20	71	16
17,000	101	39	92	32	84	26	78	21	72	16
17,500	102	39	93	33	85	27	79	22	73	17
18,000	104	40	95	34	87	28	80	22	74	17
18,500	105	41	96	34	88	28	81	23	76	18
19,000	107	42	97	35	89	29	83	24	77	19
19,500	108	42	99	36	91	30	84	24	78	19
20,000	110	43	100	36	92	30	85	25	79	20
20,500	111	44	101	37	93	31	86	25	80	20
21,000	113	45	103	38	94	31	87	26	81	21
21,500	114	45	104	38	96	32	89	27	82	21
22,000	115	46	105	39	97	33	90	27	83	22
22,500	117	47	107	40	98	33	91	28	84	22
23,000	118	47	108	40	99	34	92	28	86	23
23,500	119	48	109	41	100	34	93	29	87	24
24,000	121	49	110	41	102	35	94	29	88	24
24,500	122	49	111	42	103	36	95	30	89	25

Table 7-1. Detention Basin Invert Dimensions

Side Slope Ration = 4:1 (H:V), Flow-Path-to-Width Ratio at WQV = 2:1

WQV (ft3)	Hw = 3		Hw = 3.5		Hw = 4		Hw = 4.5		Hw = 5	
	L	W	L	W	L	W	L	W	L	W
25,000	123	50	113	43	104	36	96	30	90	25
26,000	126	51	115	44	106	37	98	31	92	26
26,500	127	52	116	44	107	38	99	32	93	27
27,000	128	52	117	45	108	38	100	32	94	27
27,500	130	53	119	46	109	39	101	33	95	28
28,000	131	54	120	46	110	39	102	33	96	28
28,500	132	54	121	47	111	40	103	34	96	28
29,000	133	55	122	47	112	40	104	34	97	29

Step 4: Calculate Water Quality Outlet Orifice Size

Use the Supplemental Details Design Guidance to calculate the orifice sizing for the water quality outlet riser.

Step 5: Calculate Length of Overflow Spillway

For a broad-crested weir,

$Q = C_{BCW} \times L \times H^{1.5}$

where:

Q = Discharge = 22.14 cfs (given)

C_{BCW} = Broad-crested weir coefficient (see Table 7-2 for values)

L = Broad-crested weir length, ft

H = Nappe (head above weir crest) = 1.33 ft (given)

Breadth of Crest of Weir = 15 ft (given). The breadth of weir is defined to be the width of the weir in the direction of flow, and the value of C_{BCW} varies with the breadth. Rearrange the equation above to solve directly for the spillway length L as follows:

$L = Q / (C_{BCW} \times H^{1.5}) = 22.14 / (2.64 \times 1.33^{1.5}) =$ **5.5 ft**

Table 7-2. Broad-Crested Weir Coefficients[2]			
Head	Breadth of Crest of Weir (ft)		
(ft)	5.00	10.00	15.00
0.20	2.34	2.49	2.68
0.40	2.50	2.56	2.70
0.60	2.70	2.70	2.70
0.80	2.68	2.69	2.64
1.00	2.68	2.68	2.63
1.20	2.66	2.69	2.64
1.40	2.65	2.67	2.64
1.60	2.65	2.64	2.63
1.80	2.65	2.64	2.63
2.00	2.65	2.64	2.63
2.50	2.67	2.64	2.63
3.00	2.66	2.64	2.63
3.50	2.68	2.64	2.63
4.00	2.70	2.64	2.63
4.50	2.74	2.64	2.63
5.00	2.79	2.64	2.63
5.50	2.88	2.64	2.63

Step 6: Determine Overall Length and Width at Berm Elevation

Freeboard = 1 ft (minimum)

Nappe during overflow event = 1.33 ft

The maximum water elevation can be calculated as the WQV elevation plus the design nappe during an overflow event as follows:

Setting the Detention Basin invert elevation at zero,

WQV elevation = H = 4 ft

Nappe depth = 1.33 ft

Maximum water elevation = 4 ft + 1.33 ft = 5.33 ft

The Freeboard is 1 foot above the maximum water elevation. Therefore, the Detention Basin dimensions at the berm elevation are:

Total Length = L_{WQV} + [2 x Z x (Nappe + Freeboard)]

= 131 ft + [2 x 4 x (1.33 ft + 1 foot)] = 149.64 ft ≈ **150 ft**

[2] Table from Federal Highway Administration (FHWA) Hydraulic Engineering Circular (HEC) No. 22, Table 8-1 (FHWA 2009).

Similarly,

Total Width = W_{WQV} + [2 x Z x (Nappe + Freeboard)]

= 66 ft + [2 x 4 x (1.33 ft + 1 foot)] = 84.64 ft ≈ **85 ft**

Step 7: Determine Other Required Features

- Maintenance access road around basin
- Ramp to basin invert
- Upstream diversion (optional)
- Water quality outlet structure
- Scour protection on inflow and spillway
- Vegetation at invert and side slopes

Section 8

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