CITY OF VENTURA

October 13, 2010

Mr. Arne Anselm
Water Quality Manager
Ventura County Watershed Protection District
800 South Victoria Avenue
Ventura, CA 93009-1600

SUBJECT: DRAFT VENTURA COUNTY TECHNICAL GUIDANCE MANUAL COMMENTS

Dear Mr. Anselm:

Thanks you for the opportunity to review and comment on the Draft Technical Guidance Manual. Enclosed for your information is an illustration of the new permit requirements on a newly entitled development project in Downtown Ventura, prepared by the City's Consultant, Mr. Paul Crabtree. Also forwarded are some comments and suggestions to make the manual more flexible and easier to use. This is being emailed separately as a PDF document for your consideration.

We look forward to working with you as the new Technical Guidance Manual goes through the adoption process. If you have any questions or need additional information, please contact Dave Ward, Planning Manager, at 677-3964.

Sincerely,

Jeffrey Lambert, AICP
Community Development Director

Enclosures

CRABTREE GROUP, INC.
ENGINEERING SMART GROWTH

Jeffrey Lambert, AICP
Community Development Director
City of Ventura
501 Poli Street
Ventura, CA 93001

October 12, 2010

Regarding: Review and case study analysis of 2010 TGM

Dear Jeffrey,

In accordance with your request, I am pleased to present this case study analysis of the 2010 Technical Guidance Manual (TGM) Stakeholder Draft dated September 27, 2010.

The analysis consists of:

a. This cover letter as a summary.
b. A case study of an already permitted redevelopment project - Encanto Del Mar Courtyard Apartments – with three different scenarios. (The case study is not subject to the new MS4 because it has already been permitted, and is used as an example only for analysis purposes.)
c. A set of comments based on a complete reading and test use of the 571 page document.

There are elements of the MS4 itself that are controversial, but since it is already a formal legal requirement, I have avoided any reference to controversial elements; and focused on the outcomes and efficacy of the TGM as a guidance document.

Case Study. The Encanto Del Mar Courtyard Housing (Encanto) case studies are included as Attachments 1A, 1B, 1C and are summarized herewith. As of October 7, 2010 Encanto has been permitted by the City of Ventura and is out for bid. This case is being studied as a way to evaluate an actual urban core redevelopment high-density case in relation to the proposed Technical Guidance Manual (TGM). Encanto is an infill redevelopment project located at 351 Thompson Blvd (near Oak Street) in downtown Ventura. There are 37 affordable rental units being built in four 3-story courtyard buildings over a podium garage that contains all required parking spaces. Further project details are provided in the Attachments.

Scenario 1A evaluated the project itself AND the adjacent parking lot as one project. The parking lot retrofit was a condition of the project planning approval. It was found that the combined project could comply with the new MS4 through modifications of the onsite planter boxes, and conversion of all the adjacent parking lot green space to bioretention cells with underdrains. The compliance was fairly easy due to the use of the adjacent parking lot green spaces.

CRABTREE GROUP, INC.
ENGINEERING SMART GROWTH

Scenario 1B evaluated the project itself without the adjacent parking lot, and assumed that all onsite planter boxes could be converted to LID-compliant planter box designs. This scenario could not comply on site and required 0.06 acre-feet of off-site mitigation.

Scenario 1C evaluated the project itself, without the adjacent parking lot, and assumed that all roofs could be converted to green roofs, and the planter boxes could be made LID-compliant. This scenario complied with the new MS4 with those onsite BMPs.

Case Study Lessons Learned.

1. Urban core higher-density redevelopment projects built over podium parking will likely use lots of planter boxes that by themselves may not satisfy on site BMP requirements, and these projects will either mitigate off-site or will build green roofs to comply. Green roofs, per the TGM, are "optional" (not mandatory) but are counted as pervious landscape area which provides a strong incentive for their use. According to the 2009 EPA report on green roofs http://www.epa.gov/nrmrl/pubs/600r09026/600r09026.pdf there are significant stormwater benefits to green roofs (approximately 50% of the annual rainfall landing on them can be absorbed), but also significant costs - a green roof system can add $6 to $40 per square foot in initial costs and $1 to $2 per square foot in annual maintenance costs. Urban form would also be affected by a green roof incentive in that the form of buildings would tend toward flat roofs as compared to sloped roofs. A Google Earth trip to Stuttgart (famous for its millions of sf of green roofs) shows that most of the green roofs are located on big box buildings that stand in stark contrast to the traditional urban form.
2. The new revision to the MS4 to allow biofiltration as a volume-control BMP, while possibly affecting runoff volumes negatively, provides significant compliance flexibility. (Biofiltration is a hold/treat/release method with several BMP configurations that operate in difficult soils conditions.)
3. The off-site mitigation route is a complex formula and process in the TGM that should be simplified. If the calculations themselves can't be shortened, a nomograph or Xcel spreadsheet application would help to simplify and speed the calculations.

   The actual implementation and administrative for off-site mitigation has (in accordance with the MS4 permit) been left in the hands of Approval Agencies, and an applicant will be left without offsite options unless and until the Approval Agency has this in place. The TGM could/should provide guidance to the Approval Agencies in setting this up so that it can be done quickly and efficiently and uniformly.
4. Redevelopment Project Area Master Plans (RPAMPs) could significantly enhance compact redevelopment in urban cores, address localized contextual issues with the MS4 itself, more efficiently allocate public and private resources; all while healing the watershed. The concern, again, is that the RPAMP process could be so prohibitively onerous and costly, such that RPAMPs are not even attempted by the towns and cities of Ventura County. The TGM

CRABTREE GROUP, INC.
ENGINEERING SMART GROWTH

could/should provide guidance to the Approval Agencies in setting up RPAMPs so that it can be done more quickly and efficiently and uniformly.

Comments to the TGM document. A majority of the TGM comments had to do with how urban context and community form was depicted in the TGM, and in most cases a comment was accompanied by a recommendation. The MS4 and TGM rely heavily on Low Impact Development (LID) techniques. LID developed a superior approach to low-intensity-event rainwater treatment that has created a paradigm shift in the stormwater industry. LID though, like many of us, was a child of sprawl, was reared in sprawl, and struggles with the shift to smarter land use principles. Over the last couple of decades LID developed techniques to lower the impacts of greenfield low-density subdivisions, power centers, and mega-complexes; and the techniques have applicability in more traditional, smarter, urban settings as well. Some indicators of the inertia: Smart Growth is tagged as an "alternative compliance" method, the regulations are much more site-based than context-based or watershed-based, the "tried-and-true" LID standards and graphics are mostly of the sprawl paradigm. The EPA recognizes the problems and is undergoing a rewrite of the NPDES that, we hope, will address these issues and more.

The MS4 does not mandate that a smarter urban framework be avoided in the TGM, but in fact explicitly requires a Smart Growth approach in Part 4 Section E. I. 1 (a); so there is an obligation and opportunity to depict in words and graphics, some of the more Smart Growth and urban renditions of LID as exemplars. A guidance manual does establish a reality, and that reality should aim to embrace the smarter visions expressed in the MS4 and by the people of Ventura County.

The other comments have to do with clarity within the document. Plan reviewers and designers and developers tend to not read an entire 571 page document (plus the 121 page MS4), but tend to rely on quick takes, and then interpret them literally. Some additional clarity of the document would contribute to a deeper understanding and usefulness of the Guidance.

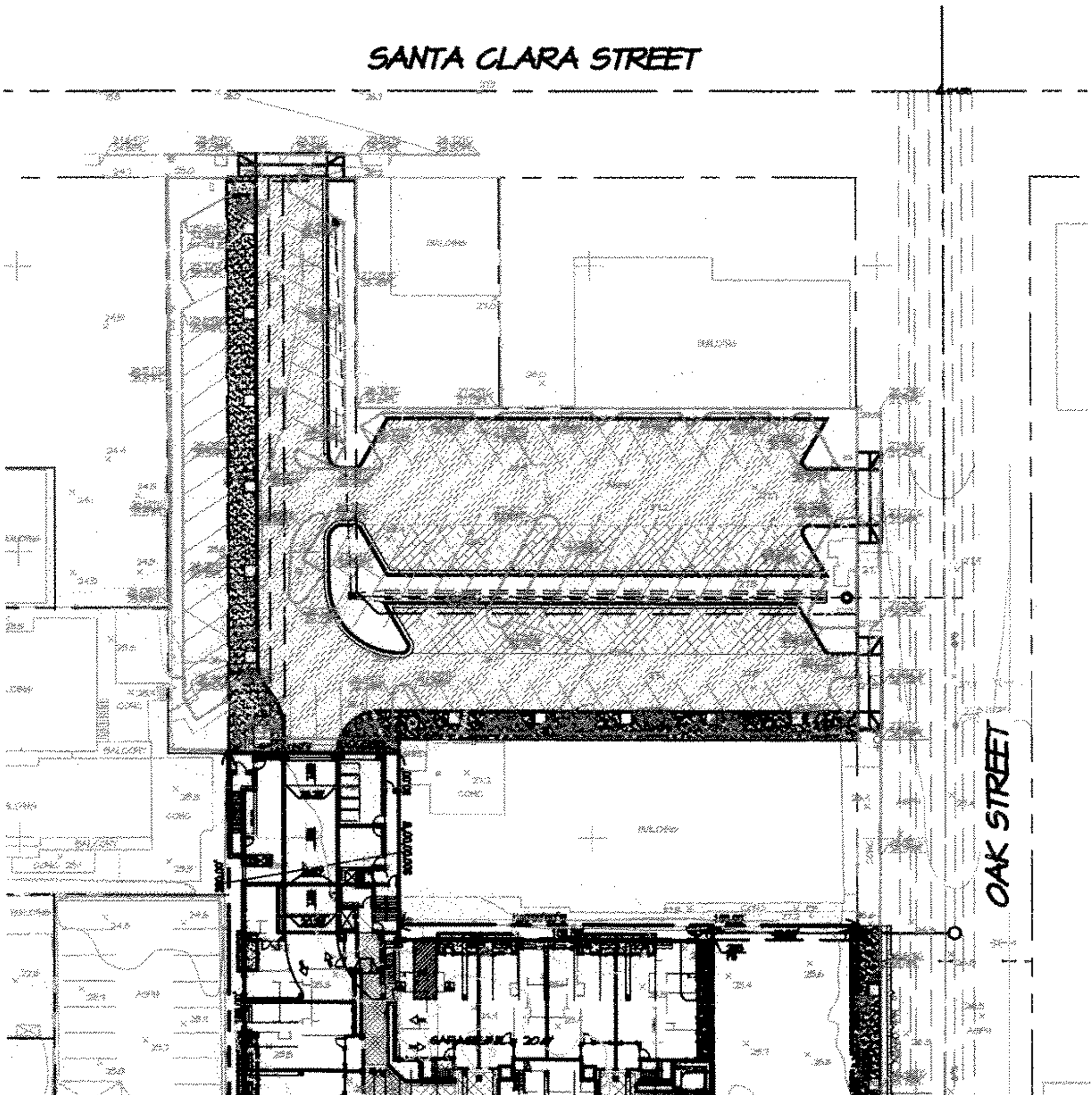
Allow me to apologize in advance for any inadvertent errors. As you know, the timeframe was extremely short and peer reviewers are scarce.

Sincerely,

Paul Crabtree, PE, CNU-A

For and on behalf of Crabtree Group Inc.
Civil Engineers and Town Planners
Ventura, CA   Salida, CO

Attachments



2

LOCATION MAP
SCALE 1" = 50'

Case Study 1A (includes adjacent parking lot and green roofs)

Encanto Del Mar Courtyard Apartments

A Case Study for Compliance with the Ventura County Technical Guidance Manual for Stormwater Control Measures - Manual Update 2010

Introduction. As of October 7, 2010 Encanto Del Mar Courtyard Apartments (Encanto) has been permitted by the City of Ventura and is out for bid. The case is being studied as a way to evaluate an actual case in relation to the proposed Technical Guidance Manual (TGM).

Project Description. Encanto is an infill redevelopment project located at 351 Thompson Blvd (near Oak Street) in downtown Ventura. There are 37 affordable rental units being built in four 3-story courtyard buildings over a podium garage. The unit sizes vary, but average 925 square feet. The site size itself is 0.58 acres – a density of 63 units/acre. However an offsite public parking lot revision/renovation and alley dedication was a required element of the project and involves a land disturbance of 0.72 acres. The offsite street frontage improvements consist of 0.12 acres (5,450 sf). The total land disturbance is 1.43 acres. The Planning designation is: Downtown Specific Plan – Urban Core T6.1. Required building setbacks are zero feet. The required parking for the project (42 spaces) is provided in the podium garage. (See attached Site Plan).

Stormwater Management Control Measures Design Decision Flowchart (Figure 2-1)

Step 1: Determine Project Applicability?

New development and redevelopment projects meeting the applicability criteria contained in Section 4.E.II of Order R4-2010-0108 [presented in Section 1.5 of the 2010 TGM] must include control measures specified in the 2010 TGM.

Yes, this is a Redevelopment Project that is equal to 1 acre or greater of disturbed area that adds more than 10,000 square feet of impervious surface area. It is also a land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site.

Step 1a: Determine RPAMP Eligibility?

If a project is located within the boundary of a Redevelopment Project Area Master Plan (RPAMP), the stormwater management requirements in the RPAMP take precedence over the control measures and performance criteria specified in this 2010 TGM.

No, the project is not located within an RPAMP.

Step 1b: Single Family Hillside Homes or Step 1c: Roadway Project?

No.

Step 2: Assess Site Conditions

The next step is to collect site information that is critical for the selection and implementation of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. The following information should be documented: topography, soil type and geology, groundwater, geotechnical considerations, offsite drainage, existing utilities, and Environmentally Sensitive Areas. In addition, soil and infiltration testing should be conducted.

Site Description. The site previously held a gas station that had a leaking underground storage tank (LUST) that was remediated in 1993. Six observation wells were constructed as part of the remediation program, and the LUST file is now closed. Geotracker now depicts another LUST across Oak Street, the site of a gas station, observation wells have been constructed, and the LUST case is still open.

The site is located within the catchment area of a 303 (d)-listed impaired waterbody – Promenade Beach is listed as Category 5 (in need of TMDLs) for the indicator Bacteria. City storm sewers are located adjacent to the site, and drain to the Figueroa culvert at Promenade Beach. The culvert outlet has an "Archy" that diverts dry weather flows to the Water Reclamation and Treatment Facility – capacity of the Archy is 40 gallons per minute.

According to the Ventura County soils maps, the site has Ventura County Category 5 soils. A detailed geotechnical investigation of the property determined that the upper 30 feet of soils consist of lean clays, historical groundwater at a depth of 9 feet, and the site is subject to Liquefaction Hazards due to groundwater depth, soil type, and proximity to seismic faults. No infiltration tests were conducted. The vacant site is quite flat – the tendency is less than 2% gradient falling from east to west and about 0.5% gradient from north to south. Adjacent to the north is the Salvation Army building, and an apartment building is adjacent to the west. A Gold Coast Transit bus stop fronts the site.

Step 3: Apply Site Design Principles and Techniques

Site Planning

1) Retention BMPs should be considered as early as possible in the site planning process.

No infiltration BMPs were incorporated into the site plan due to the clay soils, previous contamination due to LUST, relatively high groundwater, and liquefaction potential. Other retention BMPs considered in this scenario are green roofs (ET) and rainwater harvesting.

2) Project applicants should anticipate and plan for the space requirements of Retention and Biofiltration BMPs, per Table 4-1:

Table 4-1: Rule of Thumb Space Requirements for BMPs

BMP Type	% of Contributing Drainage Area
Infiltration	3 to 10
Rainwater Harvesting (Cistern)	0 to 10
Evapotranspiration (Green Roof)	1 to 1 ratio of impervious cover treated
Biofiltration	3 to 5
Dry Extended Detention Basin	1 to 3
Wet Detention Basin	1 to 3
Sand Filters	0 to 5
Cartridge Media Filter	0 to 5

Infiltration is not feasible as noted above.
Rainwater Harvesting (Cistern) may be feasible - it appears that a tower could be placed in the remainder parcel, at the west side of the podium entry drive. Or an underground location, under the parking lot may be feasible.
Evapotranspiration (Green Roof) is feasible. 13 roofs at 900 sf each = 11,700 sf = 0.27 acres
Biofiltration (bioretention with underdrain) was included in the parking lot retrofit. There are a number of planter boxes that could be biofilters.
Dry or Wet Extended Detention Basin are not feasible – site is too small.
Sand Filter may be feasible, if needed.
Cartridge Media Filter may be feasible, if needed and space available..

Step 4: Apply Source Control Measures

Source Control Measures are operational practices that reduce potential pollutants at the source.

Applicable Source Control Measures are: Covered and screened Trash Enclosure Area (current design complies).

Step 5: Apply BMPs to Reduce EIA to ≤5%

This section and Figure 2-2 describe the process for reducing EIA to ≤5%.

Step 5a: Calculate Allowable EIA

Project Area: 1.43 Acres   EIA allowable = 1.43 x 5% = 0.07 acres

Step 5b: Calculate Impervious Area to be Retained

The impervious area from which runoff must be retained onsite is the total impervious area minus the $EIA_{allowable}$, which can be calculated as follows: $A_{Retain} = TIA - EIA_{allowable} = (IMP*A_{project}) - EIA_{allowable}$

Total Impervious Area (TIA): 0.72 acres IMP = 0.50
Streets: 0.12 acres.
Building Area: 0.58 – 0.02 (planter boxes) – 0.02 (planters) – 0.27 (green roofs) = 0.27 acres
Public Parking Lot and Alley area: 0.72 – 0.12 pervious pavers – 0.06 bioret w/ – 0.09 remainder parcel ls – 0.4 other landscape = 0.41 acres. Or, 0.33 asphalt + 0.08 concrete = 0.41 acres.

A_{Retain} = 0.72 - 0.07 = 0.65 acres

Step 5c: Calculate the Volume to be Retained (SQDV)

All Retention BMPs used to render impervious surfaces "ineffective" should be properly sized to retain the volume of water that results from the water quality design storm. The design storm volume, referred to in the TGM as the Stormwater Quality Design Volume (SQDV) can be calculated using the following four allowable methodologies: (use the 0.75 inch method)

$V_{Retain} = C*(0.75/12)*A_{retain}$ (Equation 2-3)
Where: V_{Retain} = the stormwater quality design volume (SQDV) that must be retained onsite (ac-ft)
C = runoff coefficient (equals 0.95 for impervious surfaces)
0.75 = the design rainfall depth (in) [based on SQDV sizing method 3]
A_{Retain} = the drainage area from which runoff is retained (acres), calculated using Equation 2-2

V_{Retain} = 0.04 ac-feet

Step 5d: Select and Size Onsite Retention BMPs to Achieve 5% EIA

Infiltration is not feasible due to site soil conditions.
Green roofs (ET) though optional, are being considered for this scenario, and 0.27 acres of pervious surface is credited.
Rainwater Harvesting (RWH) feasibility. The 48-hour low-flow water use of the planter boxes/landscape area during the rainy season is approximately: 3 mm/day x 2 days x .02 acres x 1 inch/25.4 mm x 43560 sf/acre x ft/12 inch = 18 cubic feet (negligible). Assuming that rainwater could be used in residential toilets, the volume that can be used within 48 hours considering all "allowable and reliable demand" is approximately calculated as follows. Under present codes and regulations, rainwater could feasibly be used for toilet flushing without requiring disinfection or fine filtering. With low-flow toilets (2 gallons/flush) and 10 flushes per unit per day: 20 gallons per unit x 37 units x 2 days/ 7.5 gallons/cubic foot = 200 cubic feet = 0.005 ac-feet - probably not enough to warrant the cistern, pumps, and extra set of pipes.

Conclusion: Only the "green roof" retention BMP significantly addresses the V_{Retain}.

Step 5e: Select and Size Biofiltration BMPs to Reduce EIA to ≤5%

Retention BMPs must be used onsite to the maximum extent practicable. Projects that demonstrate technical infeasibility to reduce EIA < 5% by using Retention BMPs are eligible to use Biofiltration BMPs to achieve the EIA performance standard.

Biofiltration BMPs must be sized to treat 1.5 times the volume not retained using Retention BMPs.
The onsite biofiltered volume ($V_{Biofilter}$) can be calculated as follows: $V_{Biofilter} = (V_{Retain} - V_{Achieved}) * 1.5$ (Eqtn. 2-4)
Where:
$V_{Biofilter}$ = the volume that must be captured and treated in a Biofiltration BMP (ac-ft)
V_{Retain} = the stormwater quality design volume (SQDV) that must be retained (ac-ft) (established in Step 5c)
$V_{Achieved}$ = the volume retained onsite using Retention BMPs (ac-ft)

$V_{Biofilter}$ = (0.04 ac-feet – 0) * 1.5 = 0.06 ac-ft

Can this site feasibly treat 0.06 ac-feet though biofiltration? It has 0.06 ac of bioretention with underdrain and 0.02 ac of planter boxes, and 0.4 acre of the remainder parcel could be bioretention with underdrain, if needed.

See Bioretention with Underdrain/Planter Box Sizing Worksheet (attached) that concludes that the planter boxes and the bioretention with underdrains satisfy the requirement for 5% EIA. (Remainder parcel strip at the alley not needed).

Step 7: Apply Treatment Control Measures

Stormwater runoff from EIA and developed pervious surfaces shall be mitigated using Retention BMPs, Biofiltration BMPs, or Treatment Control Measures (Chapter 6) selected per the BMP selection process outlined in Section 3.4 and Figure 2-4.

Identify Receiving Waters and Determine Pollutants of Concern: The receiving water is Promenade Beach of the Pacific Ocean, which is listed as Category 5 (in need of TMDLS) for the indicator Bacteria. The Pollutant Priority Grouping is:

1. Legacy. The site is a former, but closed out, LUST site, so legacy soil contamination in the form of petroleum is a concern. This concern can be addressed through the limitation of infiltration BMPs, and good construction control practices.
2. Moderate Priority. Per Table 3-2, the planned land use could be a source for Sediments , Trash and Debris (Gross Solids and Floatables) Pesticides and Herbicides, Organic Materials/Oxygen Demanding Substances, Oil and Grease/Organics Associated with Petroleum, Bacteria and Viruses, Nitrogen and Phosphorus.
3. High Priority: Planned land uses are expected sources of a pollutant and the receiving water bodies are impaired by that pollutant. Bacteria is a high priority pollutant of concern. Unsterilized compost should be avoided in soil amendments for all landscape areas.

Apply Retention BMPs, Biofiltration BMPs, and/or Treatment Control Measures to Treat Remaining SQDV or SQDF to Address the Pollutants of Concern:

All of the pollutants of concern are filtered out by biofiltration, and especially by the soil media in biofiltration BMPs. The planter boxes and the bioretention basins with underdrains both address these concerns.

The SQDV was treated with these controls, so compliance has been achieved.

Step 8: Continue Project Design Process: Flood Control and Hydromodification Requirements

The project applicant should continue with the design process to address additional requirements including flood control and hydromodification control criteria.

Step 8a: Flood Control Requirements

Applicants shall comply with Ventura County and local approval agency regulations on floodplain and floodway management.

This step has been complied with in the original project design.

Step 8b: Hydromodification (Flow/Volume/Duration) Control Criteria

This project is exempt as it discharges to a city storm sewer that has a controlled outlet to the ocean.

Step 9: Develop Maintenance Plan

The Maintenance Plan would be routine in this case, based on the BMP templates, and the Maintenance Agreement template.

E.5 VEG-1 Bioretention/VEG-2 Planter Box

Sizing Methodology

Bioretention areas can be sized using one of two methods: a simple sizing method or a routing method. The simple sizing procedure is summarized below. Continuous simulation modeling, routing spreadsheets, and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of bioretention may be used to size facilities. Alternative sizing methodologies should be prepared with good engineering practices. For the routing modeling method, refer to the Sand Filter design guidance (FILT-1). A bioretention sizing worksheet and example are provided in this appendix. Planter boxes are sized the same as bioretention areas with underdrains using parameters appropriate for planter boxes.

With either method, the runoff entering the facility must completely drain the ponding area within 48 hours, and runoff must be completely infiltrated within 96 hours. Bioretention is to be sized, with or without underdrains, such that the SQDV will fill the available ponding depth, the void spaces in the planting soil, and the optional aggregate layer.

Step 1: Determine the stormwater quality design volume (SQDV)

Bioretention areas should be sized to capture and treat the water quality design volume (see Section E.1).

Step 2: Determine the Design Percolation Rate

Sizing is based on the design saturated hydraulic conductivity (K_{sat}) of the amended soil layer. A target K_{sat} of 5 inches per hour is recommended for newly installed non-proprietary amended soil media. The media K_{sat} will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the amended soil layer. A factor of safety of 2.0 should be applied such that the resulting recommended design percolation rate is 2.5 inches per hour. This value should be used for sizing unless sufficient rationale is provided to justify a higher design percolation rate.

Step 3: Calculate the bioretention or planter box surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Select a surface ponding depth (d_p) that satisfies geometric criteria and congruent with the constraints of the site. Selecting a deeper ponding depth (18 inches maximum) generally yields a smaller footprint, however requires greater consideration for public safety and energy dissipation.

2) Compute time for selected ponding depth to filter through media:

$$t_{ponding} = \frac{d_p}{K_{design}} 12 \frac{in}{ft} \leq 48 \text{ hours} \quad \text{(Equation E-26)}$$

Where:

$t_{ponding}$ = required drain time of surface ponding (48 hrs)

d_p = selected surface ponding water depth (ft)

K_{design} = design saturated hydraulic conductivity (in/hr) (see Step 2, above)

If $t_{ponding}$ exceeds 48 hours, return to (1) and reduce surface ponding or increase media K_{design}. Otherwise, proceed to next step.

Note: In nearly all cases, $t_{ponding}$ will not approach 48 hours unless a low Kdesign is specified.

3) Compute depth of water that may be considered to be filtered during the design storm event as follows:

$$d_{filtered} = Minimum\left[\frac{K_{design} \times T_{routing}}{12 \, in/ft}, \frac{d_p}{2}\right] \quad \text{(Equation E-27),}$$

Where:

$d_{filtered}$ = depth of water that may be considered to be filtered during the design storm event (ft) for routing calculations; this value should not exceed half of the surface ponding depth (d_p)

K_{design} = design saturated hydraulic conductivity (in/hr) (see Step 2, above)

$T_{routing}$ = storm duration that may be assumed for routing calculations; this should be assumed to be **3 hours** unless rationale for an alternative assumption is provided

d_p = selected surface ponding water depth (ft)

4) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_p + d_{filtered}} \quad \text{(Equation E-28)}$$

Where:

A_{req}	=	required area at bottom of filter area (ft^2); does not account for side slopes and freeboard
$SQDV$	=	stormwater quality design volume (ft^3)
d_p	=	selected surface ponding water depth (ft)
$d_{filtered}$	=	depth of water that can be considered to be filtered during the design storm event (ft) for routing calculations (See previous step)

Step 4: Calculate the bioretention total footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is measured at the filter bottom area (toe of side slopes).

Step 5: Calculate underdrain system capacity

Underdrains are required for planter boxes and bioretention with underdrains. For guidance on sizing, refer to step 5 of the worksheet below. Alternatively, the Ventura County Hydrology Manual can be used for pipe sizing guidance.

Sizing Worksheet

Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ = acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ %
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$= acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA= acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} = acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p(1-imp)$	C =
1-9. Enter design rainfall depth of the storm (in), P_i (see Table D-3)	P_i = in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV= ft^3
Step 2: Determine the design percolation rate	
2-1. Enter the design saturated hydraulic conductivity of the amended filter media (2.5 in/hr recommended rate), K_{design}	K_{design} = in/hr

Step 3: Calculate Bioretention/Planter Box surface area	
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV = ft^3
3-2. Enter design saturated hydraulic conductivity (in/hr), K_{design}	K_{design} = in/hr
3-3. Enter ponding depth (max 1.5 ft for Bioretention, 1 ft for Planter Box) above area, d_p	d_p = ft
3-4. Calculate the drawdown time for the ponded water to filter through media (hours), $t_{ponding} = (d_p/K_{design}) \times 12$	$t_{ponding}$= hrs
3-5. Enter the storm duration for routing calculations (use 3 hours unless there is rationale for an alternative), $T_{routing}$	$T_{routing}$ = hrs
3-6. Calculate depth of water (ft) filtered by using the following two equations: $d_{filtered,1} = (K_{design} \times T_{routing})/12$ $d_{filteret,2} = d_p /2$	$d_{filtered,1}$ = ft $d_{filtered,2}$ = ft
3.7 Enter the resultant depth (ft) (the lesser of the two calculated above), $d_{filtered}$	$d_{filtered}$ = ft
3-8. Calculate the infiltrating surface area as follows (ft^2): $A_{req} = SQDV/(d_p + d_{filtered})$	A_{req} = ft^2
Step 4: Calculate Bioretention Area Total Footprint	
4-1. Calculate total footprint required by including a buffer for side slopes and freeboard (ft^2) [A_{req} is measured at the as the filter bottom area (toe of side slopes)], A_{tot}	A_{tot} = ft^2
Step 5: Calculate Underdrain System Capacity	
To calculate the underdrain system capacity, continue through steps 5-1 to 5-7.	

5-1. Calculated filtered flow rate to be conveyed by the longitudinal drain pipe, $Q_f = K_{design} A_{req}/43{,}200$	$Q_f =$ cfs
5-2. Enter minimum slope for energy gradient, S_e	$S_e =$
5-3. Enter Hazen-Williams coefficient for plastic, C_{HW}	$C_{HW} =$
5-4. Enter pipe diameter (min 6 inches), D	$D =$ in
5-5. Calculate pipe hydraulic radius (ft), $R_h = D/48$	$R_h =$ ft
5-6. Calculate velocity at the outlet of the pipe (ft/s), $V_p = 1.318 C_{HW} R_h^{0.63} S_e^{0.54}$	$V_p =$ ft/s
5-7. Calculate pipe capacity (cfs), $Q_{cap} = 0.25\pi(D/12)^2 V_p$	$Q_{cap} =$ cfs

Case Study 1B (includes site only, no green roofs)

Encanto Del Mar Courtyard Apartments

A Case Study for Compliance with the Ventura County Technical Guidance Manual for Stormwater Control Measures - Manual Update 2010

Introduction. As of October 7, 2010 Encanto Del Mar Courtyard Apartments (Encanto) has been permitted by the City of Ventura and is out for bid. The case is being studied as a way to evaluate an actual case in relation to the proposed Technical Guidance Manual (TGM).

Project Description. Encanto is an infill redevelopment project located at 351 Thompson Blvd (near Oak Street) in downtown Ventura. There are 37 affordable rental units being built in four 3-story courtyard buildings over a podium garage. The unit sizes vary, but average 925 square feet. The site is 0.58 acres – a density of 63 units/acre. The offsite street frontage improvements consist of 0.12 acres (5,450 sf). The total land disturbance is 0.7 acres. The Planning designation is: Downtown Specific Plan – Urban Core T6.1. Required building setbacks are zero feet. The required parking for the project (42 spaces) is provided in the podium garage. (See attached Site Plan).

Stormwater Management Control Measures Design Decision Flowchart (Figure 2-1)

Step 1: Determine Project Applicability?

New development and redevelopment projects meeting the applicability criteria contained in Section 4.E.II of Order R4-2010-0108 [presented in Section 1.5 of the 2010 TGM] must include control measures specified in the 2010 TGM.

Yes, this is a Redevelopment Project that is a land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site.

Step 1a: Determine RPAMP Eligibility?

If a project is located within the boundary of a Redevelopment Project Area Master Plan (RPAMP), the stormwater management requirements in the RPAMP take precedence over the control measures and performance criteria specified in this 2010 TGM.

No, the project is not located within an RPAMP.

Step 1b: Single Family Hillside Homes or Step 1c: Roadway Project?

No.

Step 2: Assess Site Conditions

The next step is to collect site information that is critical for the selection and implementation of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. The following information should be documented: topography, soil type and geology, groundwater, geotechnical considerations, offsite drainage, existing utilities, and Environmentally Sensitive Areas. In addition, soil and infiltration testing should be conducted.

Site Description. The site previously held a gas station that had a leaking underground storage tank (LUST) that was remediated in 1993. Six observation wells were constructed as part of the remediation program, and the LUST file is now closed. Geotracker now depicts another LUST across Oak Street, the site of a gas station, observation wells have been constructed, and the LUST case is still open.

The site is located within the catchment area of a 303(d)-listed impaired waterbody – Promenade Beach is listed as Category 5 (in need of TMDLs) for the indicator Bacteria. City storm sewers are located adjacent to the site, and drain to the Figueroa culvert at Promenade Beach. The culvert outlet has an "Archy" that diverts dry weather flows to the Water Reclamation and Treatment Facility – capacity of the Archy is 40 gallons per minute.

According to the Ventura County soils maps, the site has Ventura County Category 5 soils. A detailed geotechnical investigation of the property determined that the upper 30 feet of soils consist of lean clays, historical groundwater at a depth of 9 feet, and the site is subject to Liquefaction Hazards due to groundwater depth, soil type, and proximity to seismic faults. No infiltration tests were conducted. The vacant site is quite flat – the tendency is less than 2% gradient falling from east to west and about 0.5% gradient from north to south. Adjacent to the north is the Salvation Army building, and an apartment building is adjacent to the west. A Gold Coast Transit bus stop fronts the site.

Step 3: Apply Site Design Principles and Techniques

Site Planning

1) Retention BMPs should be considered as early as possible in the site planning process.

No infiltration BMPs were incorporated into the site plan due to the clay soils, previous contamination due to LUST, relatively high groundwater, and liquefaction potential. Green roofs (which are an optional BMP) were not included in this scenario. Rainwater Harvesting will be considered.

2) Project applicants should anticipate and plan for the space requirements of Retention and Biofiltration BMPs, per Table 4-1:

Table 4-1: Rule of Thumb Space Requirements for BMPs

BMP Type	% of Contributing Drainage Area
Infiltration	3 to 10
Rainwater Harvesting (Cistern)	0 to 10
Evapotranspiration (Green Roof)	1 to 1 ratio of impervious cover treated
Biofiltration	3 to 5
Dry Extended Detention Basin	1 to 3
Wet Detention Basin	1 to 3
Sand Filters	0 to 5
Cartridge Media Filter	0 to 5

Infiltration is not feasible as noted above.
Rainwater Harvesting (Cistern) may be feasible. It appears that storage could may be feasible in an underground location, such as under the podium.
Evapotranspiration (Green Roof) is optional and is not being considered in this scenario.
Biofiltration (planter boxes) could be incorporated.
Dry or Wet Extended Detention Basin are not feasible – site is too small.
Sand Filter may not feasible due to compact site area – may be feasible under the frontage sidewalk.
Cartridge Media Filter may be feasible.

Step 4: Apply Source Control Measures

Source Control Measures are operational practices that reduce potential pollutants at the source.

Applicable Source Control Measures are: Trash Enclosure Area (current design complies).

Step 5: Apply BMPs to Reduce EIA to ≤5%

This section and Figure 2-2 describe the process for reducing EIA to ≤5%.

Step 5a: Calculate Allowable EIA

Project Area: 0.7 Acres EIA allowable = 0.7 x 5% = 0.04 acres

Step 5b: Calculate Impervious Area to be Retained

The impervious area from which runoff must be retained onsite is the total impervious area minus the $EIA_{allowable}$, which can be calculated as follows: $A_{Retain} = TIA - EIA_{allowable} = (IMP*A_{project}) - EIA_{allowable}$

Total Impervious Area (TIA): 0.66 acres IMP = 0.94
Streets: 0.12 acres.
Building Area: 0.58 – 0.02 (planter boxes) – 0.02 (planters) = 0.54 acres

A_{Retain} = 0.66- 0.04 = 0.62 acres

Step 5c: Calculate the Volume to be Retained (SQDV)

All Retention BMPs used to render impervious surfaces "ineffective" should be properly sized to retain the volume of water that results from the water quality design storm. The design storm volume, referred to in the TGM as the Stormwater Quality Design Volume (SQDV) can be calculated using the following four allowable methodologies: (use the 0.75 inch method)

$V_{Retain} = C*(0.75/12)*A_{retain}$ (Equation 2-3)
Where: V_{Retain} = the stormwater quality design volume (SQDV) that must be retained onsite (ac-ft)
C = runoff coefficient (equals 0.95 for impervious surfaces)
0.75 = the design rainfall depth (in) [based on SQDV sizing method 3]
A_{Retain} = the drainage area from which runoff is retained (acres), calculated using Equation 2-2

V_{Retain} = 0.04 ac-feet

Step 5d: Select and Size Onsite Retention BMPs to Achieve 5% EIA

Infiltration is not feasible due to site soil conditions.
Green roofs (ET) are optional, and not being considered for this scenario.
Rainwater Harvesting (RWH) feasibility. The 48-hour low-flow water use of the planter boxes/landscape area during the rainy season is approximately: 3 mm/day x 2 days x .02 acres x 1 inch/25.4 mm x 43560 sf/acre x ft/12 inch = 18 cubic feet (negligible). Assuming that rainwater could be used in residential toilets, the volume that can be used within 48 hours considering all "allowable and reliable demand" is approximately calculated as follows. Under present codes and regulations, rainwater could feasibly be used for toilet flushing without requiring disinfection or fine filtering. With low-flow toilets (2 gallons/flush) and 10 flushes per unit per day: 20 gallons per unit x 37 units x 2 days/ 7.5 gallons/cubic foot = 200 cubic feet = 0.005 ac-feet - probably not enough to warrant the cistern, pumps, and extra set of pipes.

Conclusion: No retention BMPs significantly address the Vretain.

Step 5e: Select and Size Biofiltration BMPs to Reduce EIA to ≤5%

Retention BMPs must be used onsite to the maximum extent practicable. Projects that demonstrate technical infeasibility to reduce EIA < 5% by using Retention BMPs are eligible to use Biofiltration BMPs to achieve the EIA performance standard.

Biofiltration BMPs must be sized to treat 1.5 times the volume not retained using Retention BMPs.
The onsite biofiltered volume ($V_{Biofilter}$) can be calculated as follows: $V_{Biofilter} = (V_{Retain} - V_{Achieved}) * 1.5$ (Eqtn. 2-4)
Where:
$V_{Biofilter}$ = the volume that must be captured and treated in a Biofiltration BMP (ac-ft)
V_{Retain} = the stormwater quality design volume (SQDV) that must be retained (ac-ft) (established in Step 5c)
$V_{Achieved}$ = the volume retained onsite using Retention BMPs (ac-ft)

$V_{Biofilter}$ = (0.04 ac-feet – 0) * 1.5 = 0.06 ac-ft

Can this site feasibly treat 0.06 ac-feet though biofiltration? It has 0.02 ac of planter boxes.

See Bioretention with Underdrain/Planter Box Sizing Worksheet (attached) that concludes that the planter boxes do not satisfy the requirement for 5% EIA. 1925 sf of planter boxes are needed and only 870 sf are provided.

Has the site "maximized its biofiltration capacity" per Table 3-1 and Section 3.2? Yes it has. Per Table 3-1, the site plan should allow at least 1% of the site area for biofiltration, since the zoning allows zero setbacks. .01 x .58 ac = .0058 acres The site already provides for .02 ac of planter boxes.

Step 6: Alternative Compliance

Certain new development and redevelopment project types are eligible for alternative compliance measures if onsite Retention BMPs and Biofiltration BMPs cannot feasibly be used to meet the 5% EIA standard.

This project is an Infill, Redevelopment, Smart Growth (all 7 categories). It is eligible for Alternative Compliance.

Stormwater runoff from impervious surfaces and developed pervious surfaces that is not fully retained onsite (up to the SQDV) shall be mitigated using Treatment Control Measures.
Alternative compliance may be met through two options:

- Offsite mitigation project; or
- Offsite mitigation fee.

Alternative compliance options will be based on the "mitigation volume." The mitigation volume is the difference between the volume of runoff associated with 5% EIA and the volume of runoff associated with the actual EIA achieved onsite less than or equal to 30% (≤30%) EIA. The offsite mitigation requirement for EIA in excess of 30% (>30%) is 1.5 times the amount of stormwater not managed onsite.

1) Determine the volume of runoff that is retained and biofiltered onsite ($V_{Ret/Bio}$), using Equation 2-5 below:
$V_{Ret/Bio} = (V_{Achieved} + (V_{Biofiltered}/1.5))$ (Equation 2-5)
Where:
$V_{Ret/Bio}$ = the total volume of runoff retained and/or biofiltered onsite using Retention and Biofiltration BMPs
$V_{Achieved}$ = the runoff volume retained onsite using Retention
$V_{Biofiltered}$ = the runoff volume biofiltered onsite

$V_{Ret/Bio}$ = 0 + 1300 cubic feet = 1300 cubic feet

2) Determine the Mitigation Volume ($V_{Mitigation}$), using Equation 2-6 below:
$V_{Mitigation} = V_{Retain} - V_{Ret/Bio}$ (Equation 2-6)
Where:
$V_{Mitigation}$ = the volume of runoff that must be mitigated offsite
V_{Retain} = the SQDV that must be retained onsite per the 5% EIA
$V_{Ret/Bio}$ = the total volume of runoff retained and/or biofiltered onsite using Retention and Biofiltration BMPs

$V_{Mitigation}$ = 2885 – 1300 = 1585 cubic feet

For the scenario where the effective impervious area of the project is greater than 30% due to infeasibility, the runoff volume associated with the effective impervious area up to 30% must be mitigated offsite at a one-to-one ratio and the runoff volume associated with the effective impervious area greater than 30% must be mitigated offsite at 1.5 times the volume.

1) Determine the area of the impervious portion of the drainage area from which runoff is retained or biofiltered at 30% EIA ($A_{30\%EIA}$), using Equation 2-7 below:
$A_{30\%EIA} = (IMP * A_{project}) - (30\% * A_{project})$ (Equation 2-7)
Where:
$A_{30\%EIA}$ = the impervious portion of the drainage area from which runoff would have been retained or biofiltered at 30% EIA (acres)
IMP = total imperviousness of project area (%)/100
$A_{project}$ = the total project area (acres)

$A_{30\%EIA}$ = (.94 * .7) – (30% * .7) = .45 acres

2) Determine the total volume that would have been retained or biofiltered onsite at 30% EIA ($V_{30\%EIA}$), using Equation 2-8 below:
$V_{30\%EIA} = C^*(0.75/12)^*A_{30\%EIA}$ (Equation 2-8)
Where:
$V_{30\%EIA}$ = the stormwater quality design volume (SQDV) retained or biofiltered at 30% EIA (note: for the purposes of this calculation, the biofiltered volume does not include the 1.5 multiplier)
C = runoff coefficient [equals 0.95 for impervious surfaces]
0.75 = the design rainfall depth (in) [based on SQDV sizing method 3]
$A_{30\%EIA}$ = the impervious area from which runoff would have been retained or biofiltered at 30% EIA (acres)

$V_{30\%EIA}$ = .03 ac-ft

3) Determine the impervious area from which runoff is actually retained ($A_{ActualEIA}$). This is the total amount of impervious area that drains to properly sized Retention or Biofiltration BMPs.
$A_{ActualEIA} = (IMP^*A_{project}) - (EIA\%^*A_{project})$
Where:
$A_{ActualEIA}$ = the impervious portion of the drainage area from which runoff is retained or biofiltered using the actual EIA achieved on-site (acres)
IMP = total imperviousness of project area (%)/100
$A_{project}$ = the total project area (acres)
EIA% = percent EIA actually achieved on-site

$A_{ActualEIA}$ = (.94*.7) – 870/1925 * .7 = .68 - .32 = .36 acres

4) Determine the volume that is actually retained onsite ($V_{ActualEIA}$), using Equation 2-9 below:
$V_{ActualEIA} = C^*(0.75/12)^*A_{AcutalEIA}$ (Equation 2-10)
Where:
$V_{AcutalEIA}$ = the stormwater quality design volume (SQDV) that is retained and/or biofiltered onsite
C = runoff coefficient [equals 0.95 for impervious surfaces]
0.75 = the design rainfall depth (in) [based on SQDV sizing method 3]
$A_{ActualEIA}$ = the area associated with the Actual EIA achieved onsite, (i.e., the area from which runoff is retained or biofiltered (acres) [See # 3 above]

$V_{ActualEIA}$ = .02 ac-ft

Determine the Mitigation Volume for 30% EIA using Equation 2-10 below:
$V_{Mitigation30\%} = V_{Retain} - V_{30\%EIA}$ (Equation 2-11)
Where:
$V_{Mitigation30\%}$ = the mitigation volume for Project site with 30% EIA
V_{Retain} = the SQDV that must be retained onsite per the 5% EIA
$V_{30\%EIA}$ = the runoff that would have been retained and/or biofiltered at 30% EIA (note: for the purposes of this calculation, the biofiltered volume does not include the 1.5 multiplier.)

$V_{Mitigation30}$ = 2885 cubic feet - .03 ac-ft = 1580 cubic feet = .04 ac-feet

Determine the Mitigation Volume for >30% (EIA $V_{Mitigation>30\%}$), using Equation 2-11 below:
$V_{Mitigation>30\%} = (V_{30\%EIA} - V_{ActualEIA})^*1.5$
Where:
$V_{Mitigation>30\%}$ = the mitigation volume for >30% EIA
$V_{30\%EIA}$ = the stormwater quality design volume (SQDV) retained or biofiltered at 30% EIA (note: for the purposes of this calculation, the biofiltered volume does not include the 1.5 multiplier)
$V_{ActualEIA}$ = the stormwater quality design volume (SQDV) that is actually retained and/or biofiltered onsite

$V_{Mitigation>30\%}$ = (.03 - .02)*1.5 = .02 ac-ft

Determine the Total Mitigation Volume ($V_{MitigationTotal}$), using Equation 2-12 below:

$V_{MitigationTotal} = V_{Mitigation>30\%} + V_{Mitigation30\%}$ (Equation 2-13)

Where:

$V_{MitigationTotal}$ = the total mitigation volume for 30% EIA

$V_{Mitigation>30\%}$ = the mitigation volume for >30% EIA

$V_{Mitigation30\%}$ = the mitigation volume for 30% EIA

$V_{MitigationTotal}$ = .02 + .04 = .06 ac-ft = 2600 cubic feet.

Selecting Offsite Mitigation Projects

Project applicants may identify offsite mitigation projects. Project applicants are responsible for completing offsite mitigation projects that will retain the mitigation volume. Offsite mitigation projects must adhere to the following criteria:

- Offsite mitigation projects must be located within the same hydrologic area (see map in Appendix B)
- Offsite mitigation projects should mitigate similar (or higher) pollutant loading land uses, if possible.
- Offsite mitigation projects must be completed as soon as possible and at the latest, within 4 years of the certificate of occupancy for the original project.

There are 6 street tree grates proposed for the public RW of the project. Proprietary Silva Cells, or Filterra (with Bacterra media amendment) or a similar BMP would treat the runoff from the street in front of the project – helping to filter street runoff that would otherwise discharge directly to the Promenade Beach. Also see below regarding Sand Filters under the public sidewalk in front of the project.

Step 7: Apply Treatment Control Measures

Stormwater runoff from EIA and developed pervious surfaces shall be mitigated using Retention BMPs, Biofiltration BMPs, or Treatment Control Measures (Chapter 6) selected per the BMP selection process outlined in Section 3.4 and Figure 2-4.

Identify Receiving Waters and Determine Pollutants of Concern: The receiving water is Promenade Beach of the Pacific Ocean, which is listed as Category 5 (in need of TMDLS) for the indicator Bacteria. The Pollutant Priority Grouping is:

1. Legacy. The site is a former, but closed out, LUST site, so legacy soil contamination in the form of petroleum is a concern. This concern can be addressed through the limitation of infiltration BMPs, and good construction control practices.
2. Moderate Priority. Per Table 3-2, the planned land use could be a source for Sediments , Trash and Debris (Gross Solids and Floatables) Pesticides and Herbicides, Organic Materials/Oxygen Demanding Substances, Oil and Grease/Organics Associated with Petroleum, Bacteria and Viruses, Nitrogen and Phosphorus.
3. High Priority: Planned land uses are expected sources of a pollutant and the receiving water bodies are impaired by that pollutant. Bacteria is a high priority pollutant of concern. Unsterilized compost should be avoided in soil amendments for all landscape areas.

Apply Retention BMPs, Biofiltration BMPs, and/or Treatment Control Measures to Treat Remaining SQDV or SQDF to Address the Pollutants of Concern:

All of the pollutants of concern are filtered out by biofiltration, and especially by the soil media in biofiltration BMPs. The planter boxes address these concerns.

A portion of the SQDV was not treated with planter boxes. Remaining SQDV: 2885 cubic feet – 1300 cubic feet = 1585 cubic feet untreated. A possible TCM to treat that additional volume would be a Sand Filter located in the sidewalk (under permeable pavers) along the Thompson Street frontage. The pretreatment would be the planter boxes, the discharge would be to the storm drain which is about 7' deep, so should accommodate the underdrains of the sand filter. Per TCM 4 calculations, the required sand filter sf to treat the remainder of the SQDV is 555 square feet. The frontage is 170 feet long and the sidewalks 10 feet wide, so a 4 foot wide strip of permeable pavers over a sand filter would suffice (provided public works approved it).

Step 8: Continue Project Design Process: Flood Control and Hydromodification Requirements
The project applicant should continue with the design process to address additional requirements including flood control and hydromodification control criteria.

Step 8a: Flood Control Requirements
Applicants shall comply with Ventura County and local approval agency regulations on floodplain and floodway management.

This step has been complied with in the original project design.

Step 8b: Hydromodification (Flow/Volume/Duration) Control Criteria

This project is exempt as it discharges to a city storm sewer that has a controlled outlet to the ocean.

Step 9: Develop Maintenance Plan

The Maintenance Plan would be routine in the case, based on the BMP templates, and the Maintenance Agreement template.

E.5 VEG-1 Bioretention/VEG-2 Planter Box

Sizing Methodology

Bioretention areas can be sized using one of two methods: a simple sizing method or a routing method. The simple sizing procedure is summarized below. Continuous simulation modeling, routing spreadsheets, and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of bioretention may be used to size facilities. Alternative sizing methodologies should be prepared with good engineering practices. For the routing modeling method, refer to the Sand Filter design guidance (FILT-1). A bioretention sizing worksheet and example are provided in this appendix. Planter boxes are sized the same as bioretention areas with underdrains using parameters appropriate for planter boxes.

With either method, the runoff entering the facility must completely drain the ponding area within 48 hours, and runoff must be completely infiltrated within 96 hours. Bioretention is to be sized, with or without underdrains, such that the SQDV will fill the available ponding depth, the void spaces in the planting soil, and the optional aggregate layer.

Step 1: Determine the stormwater quality design volume (SQDV)

Bioretention areas should be sized to capture and treat the water quality design volume (see Section E.1).

Step 2: Determine the Design Percolation Rate

Sizing is based on the design saturated hydraulic conductivity (K_{sat}) of the amended soil layer. A target K_{sat} of 5 inches per hour is recommended for newly installed non-proprietary amended soil media. The media K_{sat} will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the amended soil layer. A factor of safety of 2.0 should be applied such that the resulting recommended design percolation rate is 2.5 inches per hour. This value should be used for sizing unless sufficient rationale is provided to justify a higher design percolation rate.

Step 3: Calculate the bioretention or planter box surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Select a surface ponding depth (d_p) that satisfies geometric criteria and congruent with the constraints of the site. Selecting a deeper ponding depth (18 inches maximum) generally yields a smaller footprint, however requires greater consideration for public safety and energy dissipation.

2) Compute time for selected ponding depth to filter through media:

$$t_{ponding} = \frac{d_p}{K_{design}} 12\frac{in}{ft} \leq 48 \text{ hours} \qquad \text{(Equation E-26)}$$

Where:

$t_{ponding}$ = required drain time of surface ponding (48 hrs)

d_p = selected surface ponding water depth (ft)

K_{design} = design saturated hydraulic conductivity (in/hr) (see Step 2, above)

If $t_{ponding}$ exceeds 48 hours, return to (1) and reduce surface ponding or increase media K_{design}. Otherwise, proceed to next step.

Note: In nearly all cases, $t_{ponding}$ will not approach 48 hours unless a low Kdesign is specified.

3) Compute depth of water that may be considered to be filtered during the design storm event as follows:

$$d_{filtered} = Minimum\left[\frac{K_{design} \times T_{routing}}{12 \, in/ft}, \frac{d_p}{2}\right] \qquad \text{(Equation E-27),}$$

Where:

$d_{filtered}$ = depth of water that may be considered to be filtered during the design storm event (ft) for routing calculations; this value should not exceed half of the surface ponding depth (d_p)

K_{design} = design saturated hydraulic conductivity (in/hr) (see Step 2, above)

$T_{routing}$ = storm duration that may be assumed for routing calculations; this should be assumed to be **3 hours** unless rationale for an alternative assumption is provided

d_p = selected surface ponding water depth (ft)

4) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_p + d_{filtered}} \qquad \text{(Equation E-28)}$$

Where:

A_{req}	=	required area at bottom of filter area (ft^2); does not account for side slopes and freeboard
$SQDV$	=	stormwater quality design volume (ft^3)
d_p	=	selected surface ponding water depth (ft)
$d_{filtered}$	=	depth of water that can be considered to be filtered during the design storm event (ft) for routing calculations (See previous step)

Step 4: Calculate the bioretention total footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is measured at the filter bottom area (toe of side slopes).

Step 5: Calculate underdrain system capacity

Underdrains are required for planter boxes and bioretention with underdrains. For guidance on sizing, refer to step 5 of the worksheet below. Alternatively, the Ventura County Hydrology Manual can be used for pipe sizing guidance.

Sizing Worksheet

Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ = acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ %
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$= acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA= acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} = acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p (1-imp)$	C =
1-9. Enter design rainfall depth of the storm (in), P_i (see Table D-3)	P_i = in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV= ft^3
Step 2: Determine the design percolation rate	
2-1. Enter the design saturated hydraulic conductivity of the amended filter media (2.5 in/hr recommended rate), K_{design}	K_{design} = in/hr

Step 3: Calculate Bioretention/Planter Box surface area		
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV =	ft^3
3-2. Enter design saturated hydraulic conductivity (in/hr), K_{design}	K_{design} =	in/hr
3-3. Enter ponding depth (max 1.5 ft for Bioretention, 1 ft for Planter Box) above area, d_p	d_p =	ft
3-4. Calculate the drawdown time for the ponded water to filter through media (hours), $t_{ponding} = (d_p/K_{design}) \times 12$	$t_{ponding}$=	hrs
3-5. Enter the storm duration for routing calculations (use 3 hours unless there is rationale for an alternative), $T_{routing}$	$T_{routing}$ =	hrs
3-6. Calculate depth of water (ft) filtered by using the following two equations: $d_{filtered,1} = (K_{design} \times T_{routing})/12$ $d_{filteret,2} = d_p/2$	$d_{filtered,1}$ = $d_{filtered,2}$ =	ft ft
3.7 Enter the resultant depth (ft) (the lesser of the two calculated above), $d_{filtered}$	$d_{filtered}$ =	ft
3-8. Calculate the infiltrating surface area as follows (ft^2): $A_{req} = SQDV/(d_p + d_{filtered})$	A_{req} =	ft^2
Step 4: Calculate Bioretention Area Total Footprint		
4-1. Calculate total footprint required by including a buffer for side slopes and freeboard (ft^2) [A_{req} is measured at the as the filter bottom area (toe of side slopes)], A_{tot}	A_{tot} =	ft^2
Step 5: Calculate Underdrain System Capacity		
To calculate the underdrain system capacity, continue through steps 5-1 to 5-7.		

5-1. Calculated filtered flow rate to be conveyed by the longitudinal drain pipe, $Q_f = K_{design} A_{req}/43{,}200$	$Q_f =$ cfs
5-2. Enter minimum slope for energy gradient, S_e	$S_e =$
5-3. Enter Hazen-Williams coefficient for plastic, C_{HW}	$C_{HW} =$
5-4. Enter pipe diameter (min 6 inches), D	$D =$ in
5-5. Calculate pipe hydraulic radius (ft), $R_h = D/48$	$R_h =$ ft
5-6. Calculate velocity at the outlet of the pipe (ft/s), $V_p = 1.318 C_{HW} R_h^{0.63} S_e^{0.54}$	$V_p =$ ft/s
5-7. Calculate pipe capacity (cfs), $Q_{cap} = 0.25\pi(D/12)^2 V_p$	$Q_{cap} =$ cfs

Case Study 1C (site only, add green roofs)

Encanto Del Mar Courtyard Apartments

A Case Study for Compliance with the Ventura County Technical Guidance Manual for Stormwater Control Measures - Manual Update 2010

Introduction. As of October 7, 2010 Encanto Del Mar Courtyard Apartments (Encanto) has been permitted by the City of Ventura and is out for bid. The case is being studied as a way to evaluate an actual case in relation to the proposed Technical Guidance Manual (TGM).

Project Description. Encanto is an infill redevelopment project located at 351 Thompson Blvd (near Oak Street) in downtown Ventura. There are 37 affordable rental units being built in four 3-story courtyard buildings over a podium garage. The unit sizes vary, but average 925 square feet. The site is 0.58 acres – a density of 63 units/acre. The offsite street frontage improvements consist of 0.12 acres (5,450 sf). The total land disturbance is 0.70 acres. The Planning designation is: Downtown Specific Plan – Urban Core T6.1. Required building setbacks are zero feet. The required parking for the project (42 spaces) is provided in the podium garage. (See attached Site Plan).

Stormwater Management Control Measures Design Decision Flowchart (Figure 2-1)

Step 1: Determine Project Applicability?

New development and redevelopment projects meeting the applicability criteria contained in Section 4.E.II of Order R4-2010-0108 [presented in Section 1.5 of the 2010 TGM] must include control measures specified in the 2010 TGM.

Yes, this is a Redevelopment Project that is a land-disturbing activity that results in the creation or addition or replacement of 5,000 square feet or more of impervious surface area on an already developed site.

Step 1a: Determine RPAMP Eligibility?

If a project is located within the boundary of a Redevelopment Project Area Master Plan (RPAMP), the stormwater management requirements in the RPAMP take precedence over the control measures and performance criteria specified in this 2010 TGM.

No, the project is not located within an RPAMP.

Step 1b: Single Family Hillside Homes or Step 1c: Roadway Project?

No.

Step 2: Assess Site Conditions

The next step is to collect site information that is critical for the selection and implementation of Retention BMPs, Biofiltration BMPs, and Treatment Control Measures. The following information should be documented: topography, soil type and geology, groundwater, geotechnical considerations, offsite drainage, existing utilities, and Environmentally Sensitive Areas. In addition, soil and infiltration testing should be conducted.

Site Description. The site previously held a gas station that had a leaking underground storage tank (LUST) that was remediated in 1993. Six observation wells were constructed as part of the remediation program, and the LUST file is now closed. Geotracker now depicts another LUST across Oak Street, the site of a gas station, observation wells have been constructed, and the LUST case is still open.

The site is located within the catchment area of a 303(d)-listed impaired waterbody – Promenade Beach is listed as Category 5 (in need of TMDLs) for the indicator Bacteria. City storm sewers are located adjacent to the site, and drain to the Figueroa culvert at Promenade Beach. The culvert outlet has an "Archy" that diverts dry weather flows to the Water Reclamation and Treatment Facility – capacity of the Archy is 40 gallons per minute.

According to the Ventura County soils maps, the site has Ventura County Category 5 soils. A detailed geotechnical investigation of the property determined that the upper 30 feet of soils consist of lean clays, historical groundwater at a depth of 9 feet, and the site is subject to Liquefaction Hazards due to groundwater depth, soil type, and proximity to seismic faults. No infiltration tests were conducted. The vacant site is quite flat – the tendency is less than 2% gradient falling from east to west and about 0.5% gradient from north to south. Adjacent to the north is the Salvation Army building, and an apartment building is adjacent to the west. A Gold Coast Transit bus stop fronts the site.

Step 3: Apply Site Design Principles and Techniques

Site Planning

1) Retention BMPs should be considered as early as possible in the site planning process.

No infiltration BMPs were incorporated into the site plan due to the clay soils, previous contamination due to LUST, relatively high groundwater, and liquefaction potential. Green roofs and rainwater harvesting are considered.

2) Project applicants should anticipate and plan for the space requirements of Retention and Biofiltration BMPs, per Table 4-1:

Table 4-1: Rule of Thumb Space Requirements for BMPs

BMP Type	% of Contributing Drainage Area
Infiltration	3 to 10
Rainwater Harvesting (Cistern)	0 to 10
Evapotranspiration (Green Roof)	1 to 1 ratio of impervious cover treated
Biofiltration	3 to 5
Dry Extended Detention Basin	1 to 3
Wet Detention Basin	1 to 3
Sand Filters	0 to 5
Cartridge Media Filter	0 to 5

Infiltration is not feasible as noted above.
Rainwater Harvesting (Cistern) may be practical, if it could be incorporated into, or under the podium.
Evapotranspiration (Green Roof) though optional, is being considered. 13 roofs at 900 sf each = 11,700 sf = 0.27 acres
Biofiltration. There are a number of planter boxes that could be biofilters. 0.02 acres in area
Dry or Wet Extended Detention Basin are not feasible – no space available.
Sand Filter – no space available on site, possible under sidewalk frontage.
Cartridge Media Filter may be feasible depending on the footprint.

Step 4: Apply Source Control Measures

Source Control Measures are operational practices that reduce potential pollutants at the source.

Applicable Source Control Measures are: Covered and screened Trash Enclosure Area (current design complies).

Step 5: Apply BMPs to Reduce EIA to ≤5%

This section and Figure 2-2 describe the process for reducing EIA to ≤5%.

Step 5a: Calculate Allowable EIA

<u>Project Area</u>: 0.70 Acres   <u>EIA allowable</u> = 0.70 x 5% = 0.04 acres

Step 5b: Calculate Impervious Area to be Retained

The impervious area from which runoff must be retained onsite is the total impervious area minus the $EIA_{allowable}$, which can be calculated as follows: $A_{Retain} = TIA - EIA_{allowable} = (IMP * A_{project}) - EIA_{allowable}$

Total Impervious Area (TIA): 0.39 acres IMP = 0.56
Streets: 0.12 acres.
Building Area: 0.58 – 0.02 (planter boxes) – 0.02 (planters) – 0.27 (green roofs) = 0.27 acres

A_{Retain} = 0.39 – 0.04 = 0.35 acres

Step 5c: Calculate the Volume to be Retained (SQDV)

All Retention BMPs used to render impervious surfaces "ineffective" should be properly sized to retain the volume of water that results from the water quality design storm. The design storm volume, referred to in the TGM as the Stormwater Quality Design Volume (SQDV) can be calculated using the following four allowable methodologies: (use the 0.75 inch method)

$V_{Retain} = C^*(0.75/12)^*A_{retain}$ (Equation 2-3)
Where: V_{Retain} = the stormwater quality design volume (SQDV) that must be retained onsite (ac-ft)
C = runoff coefficient (equals 0.95 for impervious surfaces)
0.75 = the design rainfall depth (in) [based on SQDV sizing method 3]
A_{Retain} = the drainage area from which runoff is retained (acres), calculated using Equation 2-2

V_{Retain} = 0.02 ac-feet

Step 5d: Select and Size Onsite Retention BMPs to Achieve 5% EIA

Infiltration is not feasible due to site soil conditions.
Green roofs (ET) though optional, are being considered for this scenario, and 0.27 acres of pervious surface is credited.
Rainwater Harvesting (RWH) feasibility. The 48-hour low-flow water use of the planter boxes/landscape area during the rainy season is approximately: 3 mm/day x 2 days x .02 acres x 1 inch/25.4 mm x 43560 sf/acre x ft/12 inch = 18 cubic feet (negligible). Assuming that rainwater could be used in residential toilets, the volume that can be used within 48 hours considering all "allowable and reliable demand" is approximately calculated as follows. Under present codes and regulations, rainwater could feasibly be used for toilet flushing without requiring disinfection or fine filtering. With low-flow toilets (2 gallons/flush) and 10 flushes per unit per day: 20 gallons per unit x 37 units x 2 days/ 7.5 gallons/cubic foot = 200 cubic feet = 0.005 ac-feet - probably not enough to warrant the cistern, pumps, and extra set of pipes.

Conclusion: Only the "green roof" retention BMP significantly addresses the VRetain.

Step 5e: Select and Size Biofiltration BMPs to Reduce EIA to ≤5%

Retention BMPs must be used onsite to the maximum extent practicable. Projects that demonstrate technical infeasibility to reduce EIA < 5% by using Retention BMPs are eligible to use Biofiltration BMPs to achieve the EIA performance standard.

Biofiltration BMPs must be sized to treat 1.5 times the volume not retained using Retention BMPs.
The onsite biofiltered volume ($V_{Biofilter}$) can be calculated as follows: $V_{Biofilter} = (V_{Retain} - V_{Achieved}) * 1.5$ (Eqtn. 2-4)
Where:
$V_{Biofilter}$ = the volume that must be captured and treated in a Biofiltration BMP (ac-ft)
V_{Retain} = the stormwater quality design volume (SQDV) that must be retained (ac-ft) (established in Step 5c)
$V_{Achieved}$ = the volume retained onsite using Retention BMPs (ac-ft)

$V_{Biofilter}$ = (0.02 ac-feet – 0) * 1.5 = 0.03 ac-ft

Can this site feasibly treat 0.03 ac-feet through biofiltration? It has 0.02 ac of planter boxes.

See Bioretention with Underdrain/Planter Box Sizing Worksheet (attached) that concludes that the planter boxes satisfy the requirement for 5% EIA. 670 Square feet of planter boxes are required, and 870 square feet are provided.

Step 7: Apply Treatment Control Measures

Stormwater runoff from EIA and developed pervious surfaces shall be mitigated using Retention BMPs, Biofiltration BMPs, or Treatment Control Measures (Chapter 6) selected per the BMP selection process outlined in Section 3.4 and Figure 2-4.

Identify Receiving Waters and Determine Pollutants of Concern: The receiving water is Promenade Beach of the Pacific Ocean, which is listed as Category 5 (in need of TMDLS) for the indicator Bacteria. The Pollutant Priority Grouping is:

1. Legacy. The site is a former, but closed out, LUST site, so legacy soil contamination in the form of petroleum is a concern. This concern can be addressed through the limitation of infiltration BMPs, and good construction control practices.
2. Moderate Priority. Per Table 3-2, the planned land use could be a source for Sediments , Trash and Debris (Gross Solids and Floatables) Pesticides and Herbicides, Organic Materials/Oxygen Demanding Substances, Oil and Grease/Organics Associated with Petroleum, Bacteria and Viruses, Nitrogen and Phosphorus.
3. High Priority: Planned land uses are expected sources of a pollutant and the receiving water bodies are impaired by that pollutant. Bacteria is a high priority pollutant of concern. Unsterilized compost should be avoided in soil amendments for all landscape areas.

Apply Retention BMPs, Biofiltration BMPs, and/or Treatment Control Measures to Treat Remaining SQDV or SQDF to Address the Pollutants of Concern:

All of the pollutants of concern are filtered out by biofiltration, and especially by the soil media in biofiltration BMPs. The planter boxes address these concerns.

The SQDV was treated with these controls, so compliance has been achieved.

Step 8: Continue Project Design Process: Flood Control and Hydromodification Requirements

The project applicant should continue with the design process to address additional requirements including flood control and hydromodification control criteria.

Step 8a: Flood Control Requirements

Applicants shall comply with Ventura County and local approval agency regulations on floodplain and floodway management.

This step has been complied with in the original project design.

Step 8b: Hydromodification (Flow/Volume/Duration) Control Criteria

This project is exempt as it discharges to a city storm sewer that has a controlled outlet to the ocean.

Step 9: Develop Maintenance Plan

The Maintenance Plan would be routine in the case, based on the BMP templates, and the Maintenance Agreement template.

E.5 VEG-1 Bioretention/VEG-2 Planter Box

Sizing Methodology

Bioretention areas can be sized using one of two methods: a simple sizing method or a routing method. The simple sizing procedure is summarized below. Continuous simulation modeling, routing spreadsheets, and/or other forms of routing modeling that incorporate rainfall-runoff relationships and infiltrative (flow) capacities of bioretention may be used to size facilities. Alternative sizing methodologies should be prepared with good engineering practices. For the routing modeling method, refer to the Sand Filter design guidance (FILT-1). A bioretention sizing worksheet and example are provided in this appendix. Planter boxes are sized the same as bioretention areas with underdrains using parameters appropriate for planter boxes.

With either method, the runoff entering the facility must completely drain the ponding area within 48 hours, and runoff must be completely infiltrated within 96 hours. Bioretention is to be sized, with or without underdrains, such that the SQDV will fill the available ponding depth, the void spaces in the planting soil, and the optional aggregate layer.

Step 1: Determine the stormwater quality design volume (SQDV)

Bioretention areas should be sized to capture and treat the water quality design volume (see Section E.1).

Step 2: Determine the Design Percolation Rate

Sizing is based on the design saturated hydraulic conductivity (K_{sat}) of the amended soil layer. A target K_{sat} of 5 inches per hour is recommended for newly installed non-proprietary amended soil media. The media K_{sat} will decline between maintenance cycles as the surface becomes occluded and particulates accumulate in the amended soil layer. A factor of safety of 2.0 should be applied such that the resulting recommended design percolation rate is 2.5 inches per hour. This value should be used for sizing unless sufficient rationale is provided to justify a higher design percolation rate.

Step 3: Calculate the bioretention or planter box surface area

Determine the size of the required infiltrating surface by assuming the SQDV will fill the available ponding depth plus the void spaces in the media, based on the computed porosity of the filter media and optional aggregate layer.

1) Select a surface ponding depth (d_p) that satisfies geometric criteria and congruent with the constraints of the site. Selecting a deeper ponding depth (18 inches maximum) generally yields a smaller footprint, however requires greater consideration for public safety and energy dissipation.

2) Compute time for selected ponding depth to filter through media:

$$t_{ponding} = \frac{d_p}{K_{design}} 12 \frac{in}{ft} \leq 48 \text{ hours} \qquad \text{(Equation E-26)}$$

Where:

$t_{ponding}$ = required drain time of surface ponding (48 hrs)

d_p = selected surface ponding water depth (ft)

K_{design} = design saturated hydraulic conductivity (in/hr) (see Step 2, above)

If $t_{ponding}$ exceeds 48 hours, return to (1) and reduce surface ponding or increase media K_{design}. Otherwise, proceed to next step.

Note: In nearly all cases, $t_{ponding}$ will not approach 48 hours unless a low Kdesign is specified.

3) Compute depth of water that may be considered to be filtered during the design storm event as follows:

$$d_{filtered} = Minimum\left[\frac{K_{design} \times T_{routing}}{12 \, in/ft}, \frac{d_p}{2}\right] \qquad \text{(Equation E-27),}$$

Where:

$d_{filtered}$ = depth of water that may be considered to be filtered during the design storm event (ft) for routing calculations; this value should not exceed half of the surface ponding depth (d_p)

K_{design} = design saturated hydraulic conductivity (in/hr) (see Step 2, above)

$T_{routing}$ = storm duration that may be assumed for routing calculations; this should be assumed to be **3 hours** unless rationale for an alternative assumption is provided

d_p = selected surface ponding water depth (ft)

4) Calculate required infiltrating surface area (filter bottom area):

$$A_{req} = \frac{SQDV}{d_p + d_{filtered}} \qquad \text{(Equation E-28)}$$

Where:

A_{req}	=	required area at bottom of filter area (ft^2); does not account for side slopes and freeboard
$SQDV$	=	stormwater quality design volume (ft^3)
d_p	=	selected surface ponding water depth (ft)
$d_{filtered}$	=	depth of water that can be considered to be filtered during the design storm event (ft) for routing calculations (See previous step)

Step 4: Calculate the bioretention total footprint

Calculate total footprint required by including a buffer for side slopes and freeboard; A_{req} is measured at the filter bottom area (toe of side slopes).

Step 5: Calculate underdrain system capacity

Underdrains are required for planter boxes and bioretention with underdrains. For guidance on sizing, refer to step 5 of the worksheet below. Alternatively, the Ventura County Hydrology Manual can be used for pipe sizing guidance.

Sizing Worksheet

Step 1: Determine water quality design volume	
1-1. Enter Project area (acres), $A_{project}$	$A_{project}$ = acres
1-2. Enter the maximum allowable percent of the Project area that may be effective impervious area (refer to permit), ranges from 5-30%, $\%_{allowable}$	$\%_{allowable}$ %
1-3. Determine the maximum allowed effective impervious area (ac), $EIA_{allowable} = (A_{project})*(\%_{allowable})$	$EIA_{allowable}$= acres
1-4. Enter Project impervious fraction, *Imp* (e.g. 60% = 0.60)	Imp=
1-5. Determine the Project Total Impervious area (acres), $TIA=A_{project}*Imp$	TIA= acres
1-6. Determine the total area from which runoff must be retained (acres), $A_{retain}=TIA-EIA_{allowable}$	A_{retain} = acres
1-7. Determine pervious runoff coefficient using Table E-1, C_p	C_p =
1-8. Calculate runoff coefficient, $C = 0.95*imp + C_p\ (1-imp)$	C =
1-9. Enter design rainfall depth of the storm (in), P_i (see Table D-3)	P_i = in
1-10. Calculate rainfall depth (ft), $P = P_i/12$	P = ft
1-11. Calculate water quality design volume (ft^3), $SQDV=43560 \bullet C*P*A_{retain}$	SQDV= ft^3

Step 2: Determine the design percolation rate	
2-1. Enter the design saturated hydraulic conductivity of the amended filter media (2.5 in/hr recommended rate), K_{design}	K_{design} = in/hr

Step 3: Calculate Bioretention/Planter Box surface area	
3-1. Enter water quality design volume (ft^3), *SQDV*	SQDV = ft^3
3-2. Enter design saturated hydraulic conductivity (in/hr), K_{design}	K_{design} = in/hr
3-3. Enter ponding depth (max 1.5 ft for Bioretention, 1 ft for Planter Box) above area, d_p	d_p = ft
3-4. Calculate the drawdown time for the ponded water to filter through media (hours), $t_{ponding} = (d_p/K_{design}) \times 12$	$t_{ponding}$= hrs
3-5. Enter the storm duration for routing calculations (use 3 hours unless there is rationale for an alternative), $T_{routing}$	$T_{routing}$ = hrs
3-6. Calculate depth of water (ft) filtered by using the following two equations: $d_{filtered,1} = (K_{design} \times T_{routing})/12$ $d_{filteret,2} = d_p /2$	$d_{filtered,1}$ = ft $d_{filtered,2}$ = ft
3.7 Enter the resultant depth (ft) (the lesser of the two calculated above), $d_{filtered}$	$d_{filtered}$ = ft
3-8. Calculate the infiltrating surface area as follows (ft^2): $A_{req} = SQDV/(d_p + d_{filtered})$	A_{req} = ft^2
Step 4: Calculate Bioretention Area Total Footprint	
4-1. Calculate total footprint required by including a buffer for side slopes and freeboard (ft^2) [A_{req} is measured at the as the filter bottom area (toe of side slopes)], A_{tot}	A_{tot} = ft^2
Step 5: Calculate Underdrain System Capacity	
To calculate the underdrain system capacity, continue through steps 5-1 to 5-7.	

5-1. Calculated filtered flow rate to be conveyed by the longitudinal drain pipe, $Q_f = K_{design} A_{req}/43{,}200$	Q_f = cfs
5-2. Enter minimum slope for energy gradient, S_e	S_e =
5-3. Enter Hazen-Williams coefficient for plastic, C_{HW}	C_{HW} =
5-4. Enter pipe diameter (min 6 inches), D	D = in
5-5. Calculate pipe hydraulic radius (ft), $R_h = D/48$	R_h = ft
5-6. Calculate velocity at the outlet of the pipe (ft/s), $V_p = 1.318 C_{HW} R_h^{0.63} S_e^{0.54}$	V_p = ft/s
5-7. Calculate pipe capacity (cfs), $Q_{cap} = 0.25\pi(D/12)^2 V_p$	Q_{cap} = cfs