

SCVURPPP C.3 Workshop
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Stormwater Treatment Measure Sizing and Design Considerations

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Santa Clara Valley Urban Runoff Pollution Prevention Program

Presentation Overview

- Sizing/Design of Self-Treating and Self-Retaining Areas
- Sizing/Design of Treatment Measures
 - Determining the Water Quality Design Flow and Volume
 - Bioretention and Flow-Through Planters
 - Pervious Pavement and Infiltration Trenches
 - Rainwater Harvesting Cisterns
 - High-Rate Media Filters

Site Design Measures to Reduce Runoff Requiring Treatment

- Self-Treating Areas
- Interceptor Tree Credits
- Self-Retaining Areas



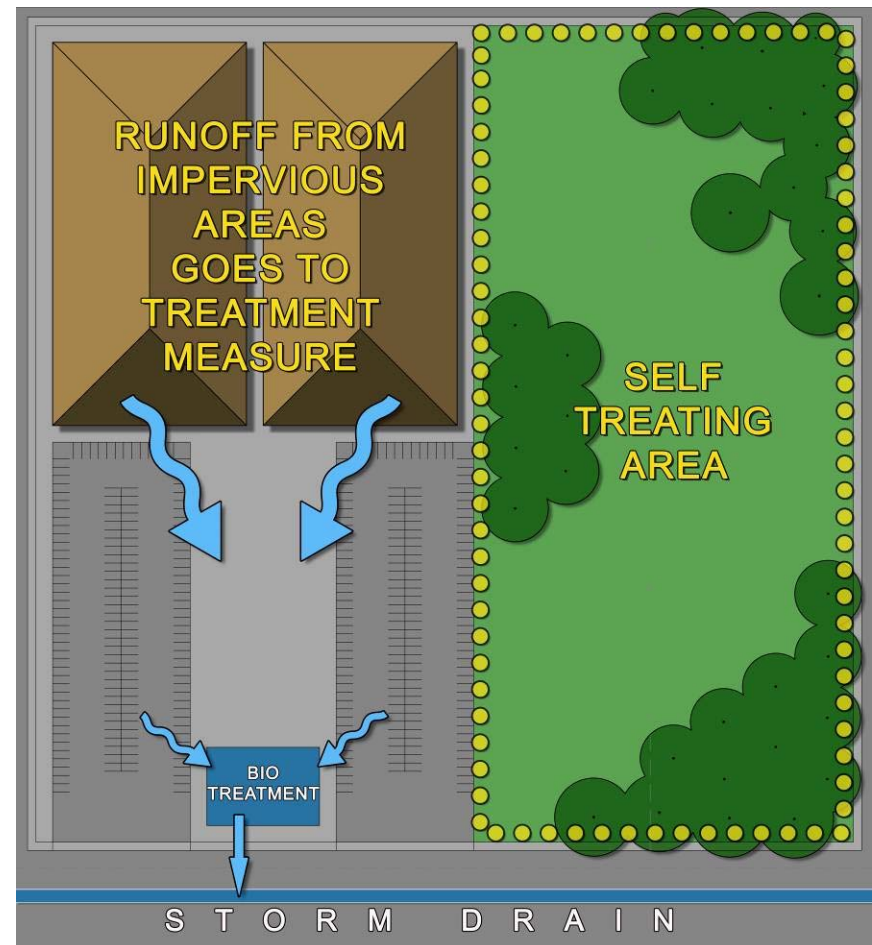
Self-Treating Area

- Pervious area that treats rain falling on itself only, via ponding, infiltration and ET
 - Landscaping
 - Green roof
 - Pervious pavement
 - Artificial turf
- Landscaped areas must retain approx. 1” of rain
- Pervious pavement and artificial turf must be designed to store and infiltrate the C.3.d amount of runoff in order to qualify as self-treating areas



Self-Treating Areas Reduce the Area Requiring Treatment

- Runoff from **pervious** portions of the project (after infiltrating 1") can flow directly to the storm drain (if no mixing with runoff from impervious areas)
- Runoff from **impervious** areas flows to smaller treatment measure



“Interceptor” Tree Credits

- Self-treating area credit allowed based on the interception of rainwater by the tree canopy
- Intended for small areas that can't be treated

Type of Tree Planted or Preserved	Square footage deducted from area requiring stormwater treatment
Evergreen: new planting	200 sq. ft. per tree
Deciduous: new planting	100 sq. ft. per tree
Preserve existing trees (either evergreen or deciduous)	Square footage beneath canopy

Self-Retaining Area

- Pervious area that retains first 1" of rainfall on itself and runoff from adjacent impervious area, up to a 2:1 ratio (impervious:pervious)
 - Roof runoff dispersion to depressed landscaped area
 - Partial green roofs
 - Pervious pavement (with adequate storage)
- No special soils required
- Area must be able to retain up to 3" of ponding

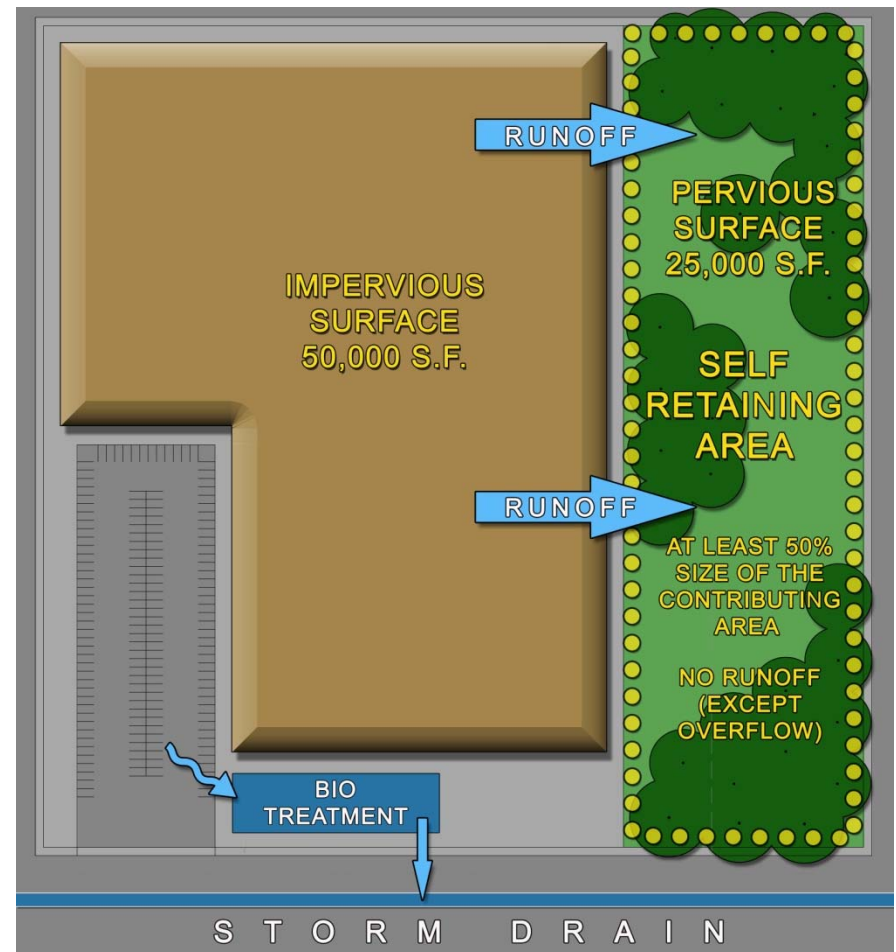


Design of Self-Retaining Areas

- Landscaped areas
 - Plan sheet should indicate a relatively flat, concave, landscaped surface with ponding depth as follows:
 - **Depth = 1 inch + [(Imperv Area ÷ Perv Area) X 1 inch]**
 - Elevation of any area drains should be set at top of ponding depth
- Partial green roofs and pervious pavement
 - Calculate depth of water quality volume using equation above
 - Determine depth of media/aggregate require to store the water quality volume

Self-Retaining Areas Reduce the Area that Requires Treatment

- Runoff from **impervious** portions of the project can flow directly to a **pervious** area that is at least 50% of the size of the contributing area
- Runoff from other impervious areas flows to smaller treatment measure



C.3.d Sizing Criteria for Treatment Measures

- Volume-based sizing criteria:
 - URQM Method - use formula and volume capture coefficients in “Urban Runoff Quality Management”, WEF/ASCE MOP No. 23 (1998), pages 175-178
 - CASQA BMP Handbook Method - Determine volume equal to 80% of the annual runoff, using methodology in Appendix D of the CASQA BMP Handbook (2003) using local rainfall data
 - **Sizing curves specific to Santa Clara Valley provided in Appendix B of C.3 Handbook**

C.3.d Sizing Criteria

- Flow-based sizing criteria:
 - Factored Flood Flow - 10% of the 50-year peak flow rate, determined using Intensity-Duration-Frequency curves from local flood control agency – **NOT USED**
 - Percentile Rainfall Intensity - Flow of runoff produced by a rain event equal to two times the 85th percentile hourly rainfall intensity
 - Data for Santa Clara Valley rain gages in Sizing Worksheets (Appendix B of C.3 Handbook)
 - Uniform Intensity - Flow of runoff resulting from a rain event equal to 0.2 inches per hour intensity

C.3.d Sizing Criteria

- 85th Percentile Rainfall Intensity Data:

Reference Rain Gages	85 th Percentile Hourly Rainfall Intensity (in/hr)	Design Rainfall Intensity (in/hr)*
San Jose Airport	0.087	0.17
Palo Alto	0.096	0.19
Morgan Hill	0.12	0.24

*Design rainfall intensity = 2 X 85th percentile hourly rainfall intensity

- Need to translate rain gage values to site value using ratio of mean annual precipitation (MAP)

C.3.d Sizing Criteria

- Flow-based sizing criteria:
 - Simplified Sizing Approach – Variation of Uniform Intensity Method (0.2 in/hr)
 - Surface area of biotreatment measure is sized to be 4% of the contributing impervious area
 - Based on a runoff inflow of 0.2 in/hr (assume equal to the rainfall intensity), with an infiltration rate through the biotreatment soil of 5 in/hr
($0.2 \text{ in/hr} \div 5 \text{ in/hr} = 0.04$)
 - Conservative approach because does not account for surface ponding – good for planning purposes

C.3.d Sizing Criteria

- Combination Flow & Volume Design Basis:
 - Treatment systems can be sized to treat “at least 80% of total runoff over the life of the project”
 - Option 1: Use a continuous simulation hydrologic model (typically not done for treatment measures)
 - Option 2: Show how treatment measure sizing meets both flow and volume-based criteria
 - Used for bioretention and flow-through planters
 - Appropriate where drainage area is mostly impervious
 - **See guidance in Appendix B of C.3 Handbook**

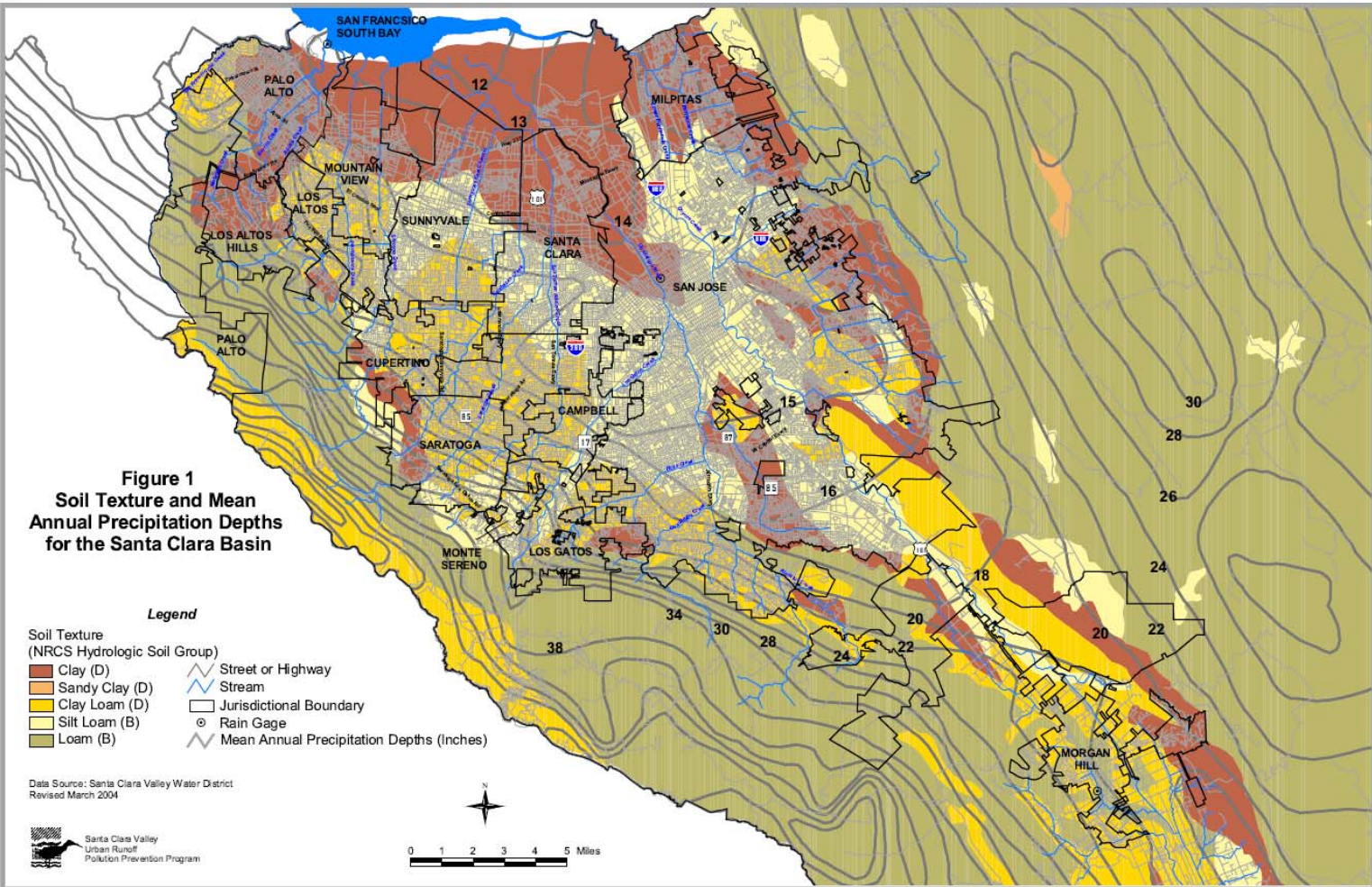
Flow- or Volume-Based Sizing for Treatment Measures?

Table 5-1 Flow and Volume Based Treatment Measure Sizing Criteria		
Type of Treatment Measure	LID?	Hydraulic Sizing Criteria
Bioretention area	Yes	Flow- or volume-based or combination
Flow-through planter box	Yes	Flow- or volume-based or combination
Tree well filter	Yes	Flow-based
Infiltration trench	Yes	Volume-based
Subsurface infiltration system	Yes	Volume-based
Rainwater harvesting and use	Yes	Volume-based
Media filter	No	Flow-based

Sizing Guidance

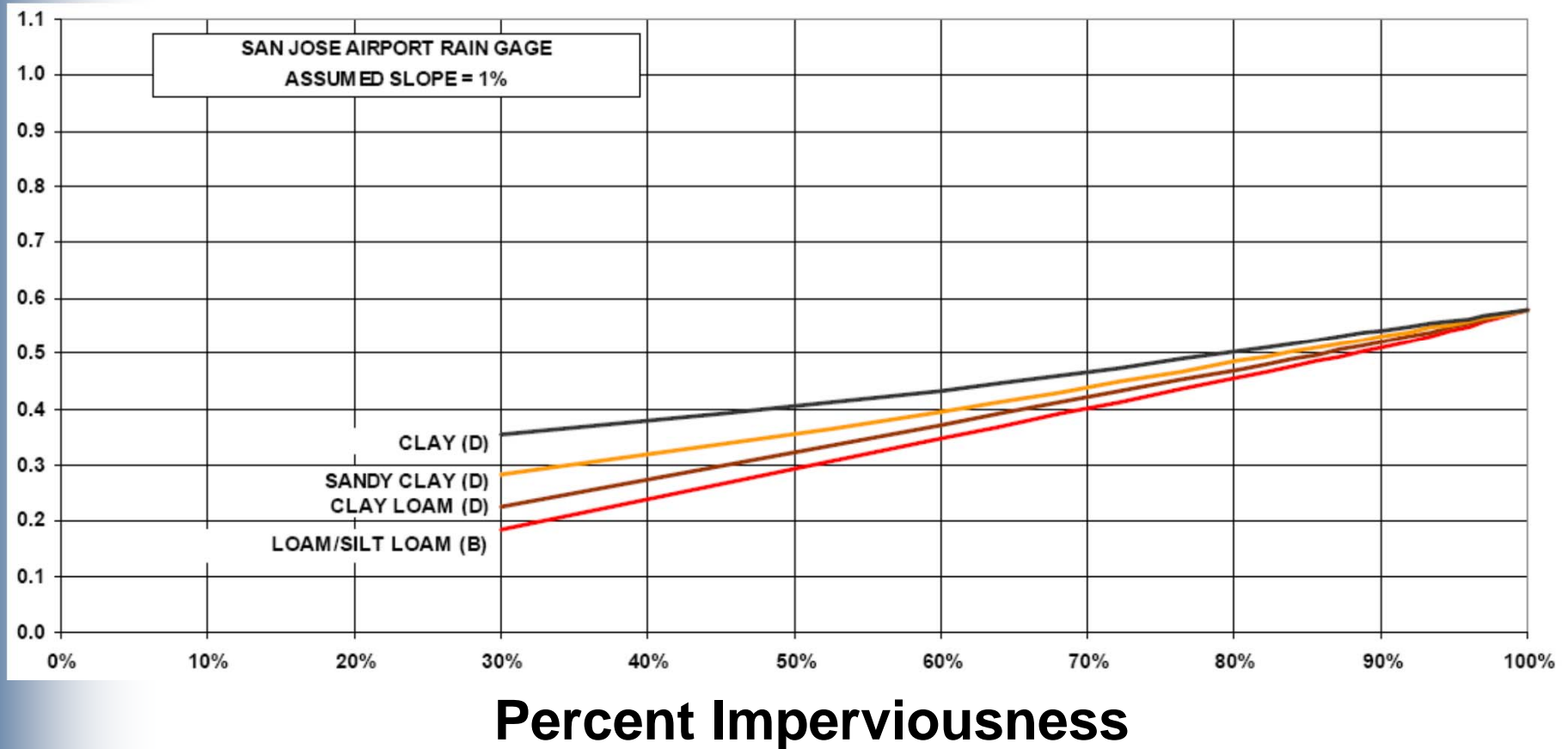
- Appendix B of SCVURPPP C.3 Handbook
 - Worksheets for determining water quality design flow, volume, and combination flow/volume
 - Figure B-1: Soil Texture and Mean Annual Precipitation (MAP) Depths
 - Figures B-2 – B-7: Unit Basin Storage Volume for 80% Capture (3 gages, 1% and 15% slopes)
 - Sizing examples

Figure B-1: Soil Texture and Mean Annual Precipitation (MAP) Depth



Unit Basin Storage Volume for 80% Capture (inches)

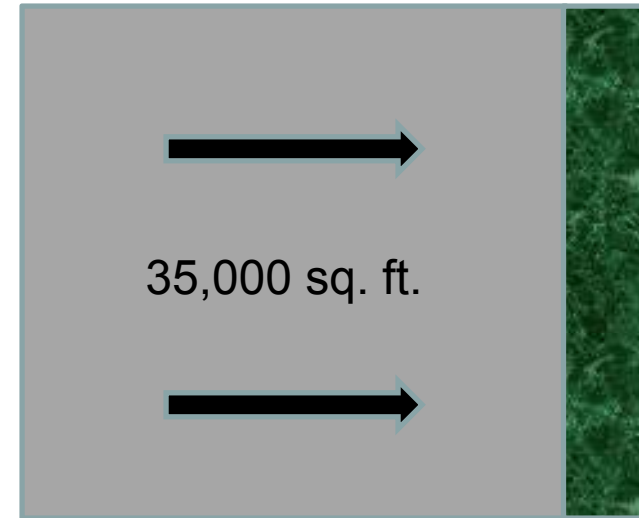
San Jose Rain Gage, 1% Slope



Sizing Example

- Parking lot in Santa Clara

- Area = 35,000 sq. ft.
(0.80 acres)
- 100% impervious
- Slope = 1%
- Mean annual precipitation
(MAP) = 15 inches



- Use the sizing worksheets to determine Q_{WQ} and V_{WQ}

- **Answer: $V_{WQ} = 1,819$ cu. ft.; $Q_{WQ} = 0.103$ cfs**

Sizing Bioretention Facilities

- Simplified Sizing (Flow-Based) Approach
 - Surface area is 4% of contributing impervious area
 - Does not consider storage in surface ponding area
- Volume Based Approach
 - Store V_{wQ} in just surface ponding area
 - Store V_{wQ} in ponding area, soil media & drain rock
- Combination Flow and Volume Approach
 - Compute both Q_{wQ} and V_{wQ}
 - “Route” through facility, allowing ponding

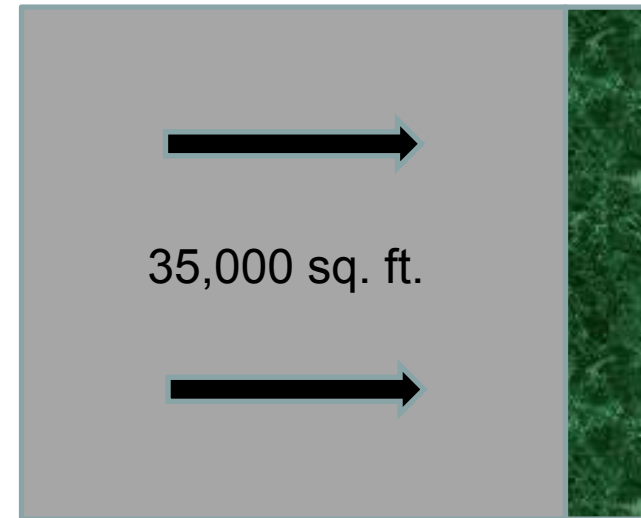
Simplified Sizing Example

- Parking lot in Santa Clara

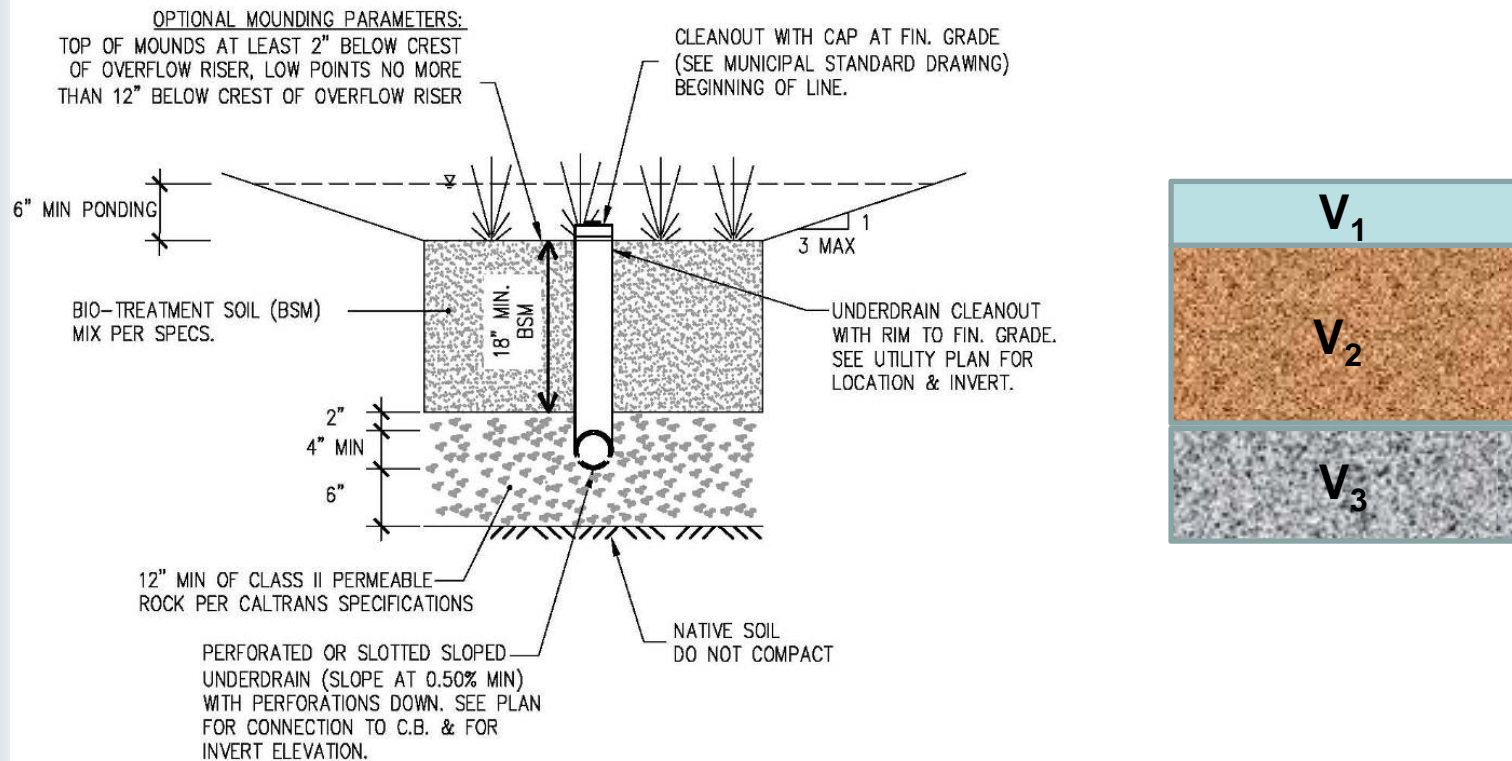
- Area = 35,000 sq. ft.
(0.80 acres)
- 100% impervious
- Slope and MAP – not needed
- Uniform intensity = 0.2 in/hr

- Surface area of bioretention:

- **Area X 0.04 = 1,400 sq. ft.**
- Note: if drainage area contains pervious area, multiply pervious area by 0.1 and add to impervious area to get “equivalent impervious area”




Sizing Bioretention Facilities: Volume-Based Approach



Sizing Bioretention Facilities: Volume-Based Approach

Method 1: Store entire volume in surface ponding area

V_1



Depth (ft)	Porosity	Volume per sq. ft. (cubic feet)
0.5	1.0	0.5

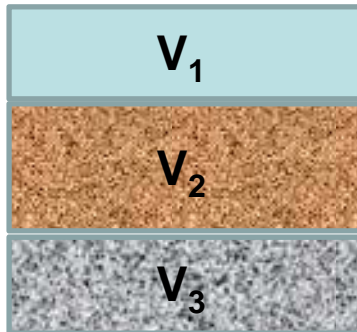
$$\text{Surface Area} = V_{wQ} \text{ (cu.ft.)} \div 0.5 \text{ cu.ft./sq.ft.}$$

Sizing Example:

- **1,819 cu.ft. \div 0.5 cu.ft./sq.ft. = 3,638 sq.ft.**

Sizing Bioretention Facilities: Volume-Based Approach

Method 2: Store volume in ponding area and media



Depth (ft)	Porosity	Volume per sq. ft. (cubic feet)
0.5	1.0	0.5
1.5	0.30	0.45
0.5*	0.40	0.20
Total		1.15

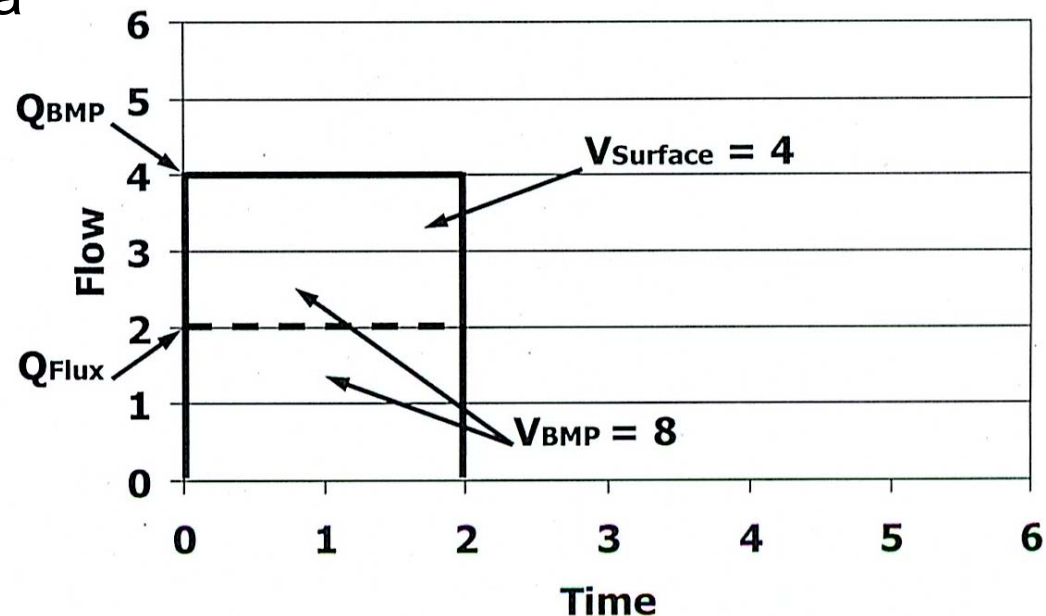
*Depth below underdrain at 6" above bottom

Surface Area = V_{WQ} (cu.ft.) \div 1.15 cu.ft./sq.ft.

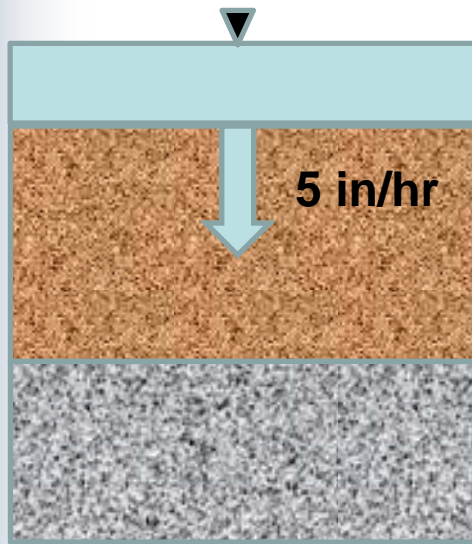
- **1,819 cu.ft. \div 1.15 cu.ft./sq.ft. = 1,582 sq.ft.**

Sizing Bioretention Facilities: Flow & Volume Approach

- “Hydrograph Approach”
 - Runoff is “routed” through the treatment measure
 - Assume rectangular hydrograph that meets both flow and volume criteria

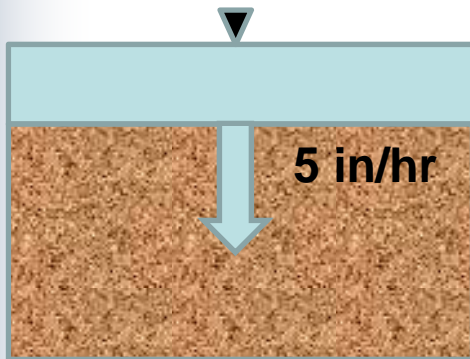


Sizing Bioretention Facilities: Flow & Volume Approach



- Determine V_{wQ}
- Assume constant rainfall intensity of 0.2 in/hr continues throughout the storm (rectangular hydrograph)
- Calculate the duration of the storm by dividing the Unit Basin Storage by the rainfall intensity
- Calculate the volume of runoff that filters through the biotreatment soil at 5 in/hr over the storm duration
- Calculate the volume that remains on the surface and ponding depth

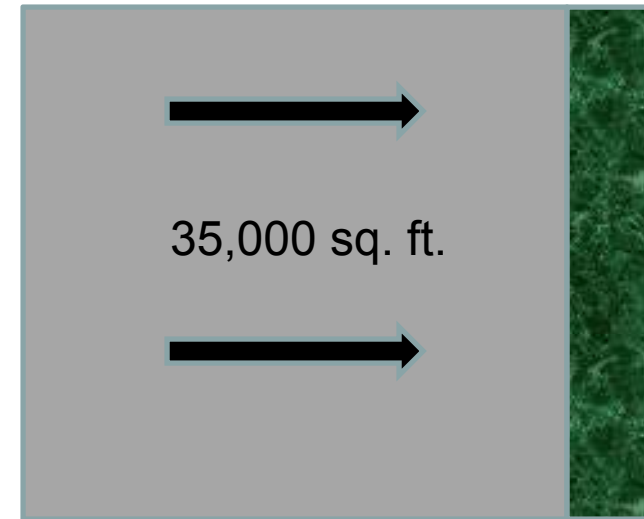
Sizing Bioretention Facilities: Flow & Volume Approach



- To start the calculation, you have to assume a surface area " A_S " -- use 3% of the contributing impervious area as a first guess
- Determine volume of treated water " V_T " during storm:
$$V_T = A_S \times 5 \text{ in/hr} \times \text{duration (hrs)} \times 1 \text{ in}/12 \text{ ft}$$
- Determine volume remaining on the surface " V_S ":
$$V_S = V_{WQ} - V_T$$
- Determine depth " D " of ponding on the surface:
$$D = V_S \div A_S$$
- Repeat until depth is approximately 6 inches

Sizing Example #1, continued

- Parking lot in Santa Clara
 - Area = 35,000 sq. ft. (0.8 acres)
 - 100% impervious
 - $V_{wQ} = 1,819$ cu. ft.
 - UBS Volume = 0.63 in.
- Use the combination flow and volume sizing worksheet to determine the bioretention surface area
- **Answer: 1,000 sq. ft. (with depth = 0.5 ft.)**



Sizing Bioretention Facilities: Comparison of Methods

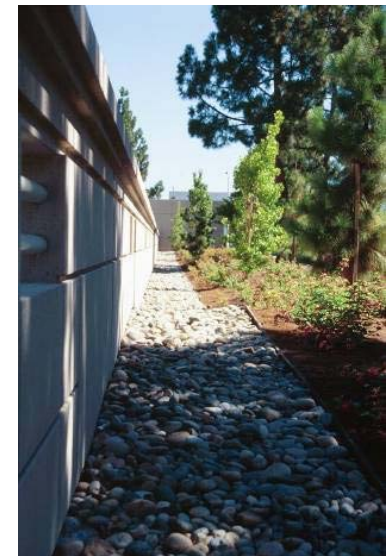
Example: 35,000 sq. ft. parking lot in Santa Clara
MAP= 15 inches, 100% impervious
 $V_{BMP} = 1,819$ cu. ft. (80% of annual runoff)

Sizing Method	Surface Area (sq. ft.)
Simplified Method (flow-based)	1,400
Volume ponded on surface	3,638
Volume stored in unit ($V_1+V_2+V_3$)	1,580
Combination flow & volume	1,000



Sizing Pervious Pavement and Infiltration Trenches

- General Principles
 - Store the V_{wQ} in void space of stone base/subbase and infiltrate into subgrade
 - Surface allows water to infiltrate at a high rate
 - Any underdrains must be placed above the void space needed to store and infiltrate the V_{wQ}



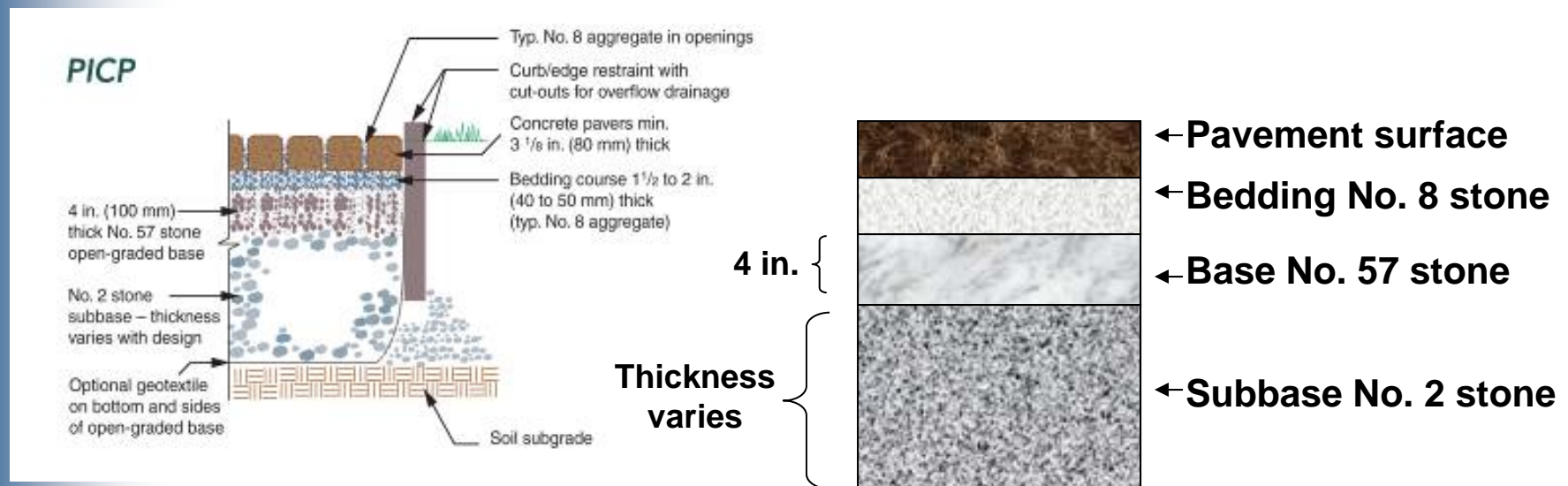
Sizing Pervious Pavement and Infiltration Trenches

■ Pervious Pavement

- May be self-treating area or self-retaining area (accept runoff from other areas)
- Can only be considered a “pervious area” if stone base/subbase sized to store the V_{wQ}
- Can work where native soils have low infiltration rates (stored water depths are relatively small)
- Surface area is usually predetermined
- Base and subbase thickness usually determined by expected traffic load and saturated soil strength
- Slope should be $\leq 3\%$ (or use check dams/trenches)

Pervious Pavement

Typical Section



- Base and subbase layers available for water storage
- Both typically have 40% void space

Pervious Pavement

- Approach to Sizing Pervious Pavement
 - Self-Treating
 - Check the depth of the V_{WQ} in base/subbase:
UBS volume (in.) \div 0.40 = Depth (in.)

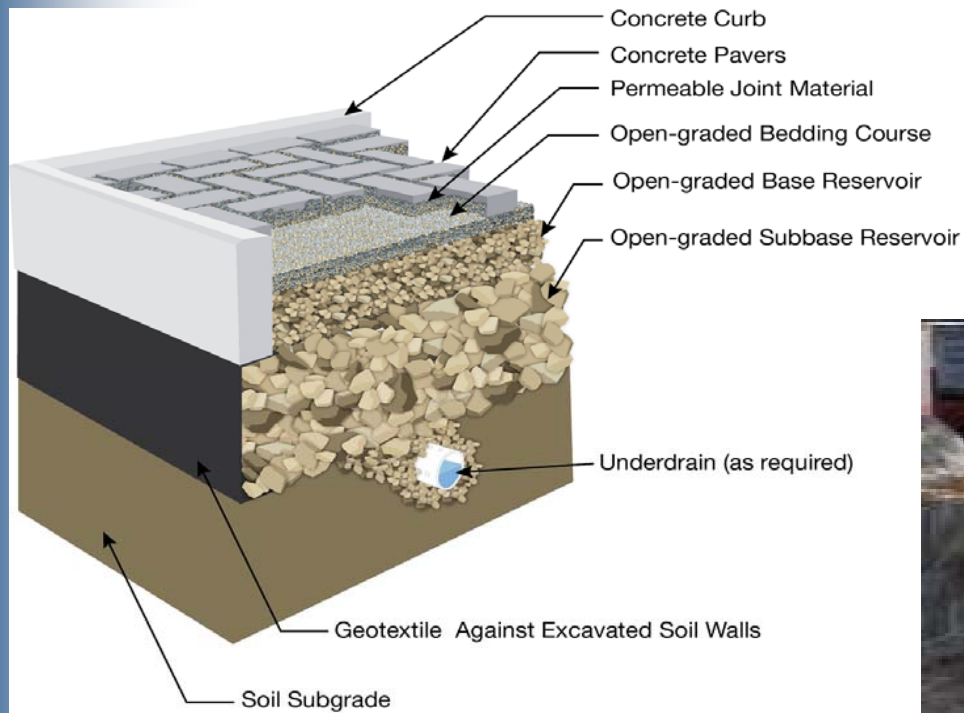
Example: UBS volume = 1.0 in., depth = 2.5 in.
(Minimum depth for vehicular traffic is 10 in.)
 - Check the time required for stored water to drain:
UBS Vol. (in.) \div Infiltration rate (in/hr) = Drain time (hrs)
(recommend < 48 hrs)

Pervious Pavement

- Approach to Sizing Pervious Pavement
 - Self-Retaining (receives runoff from adjacent areas)
 - Add the V_{wQ} for adjacent areas to the V_{wQ} for the pervious pavement area itself, divide the total V_{wQ} by pervious pavement area (or use equation on Slide 8)
 - Do not exceed 2:1 ratio of contributing area to pervious area
 - Check depth of total V_{wQ} in base/subbase:
$$V_{wQ} \text{ (in.)} \div 0.40 = \text{Depth (in.)}$$

Example: $V_{wQ} = 3.0 \text{ in.}$, depth = 7.5 in.
 - Check the time required for stored water to drain:
$$V_{wQ} \text{ (in.)} \div \text{Infiltration rate (in/hr)} = \text{Drain time (hrs)}$$

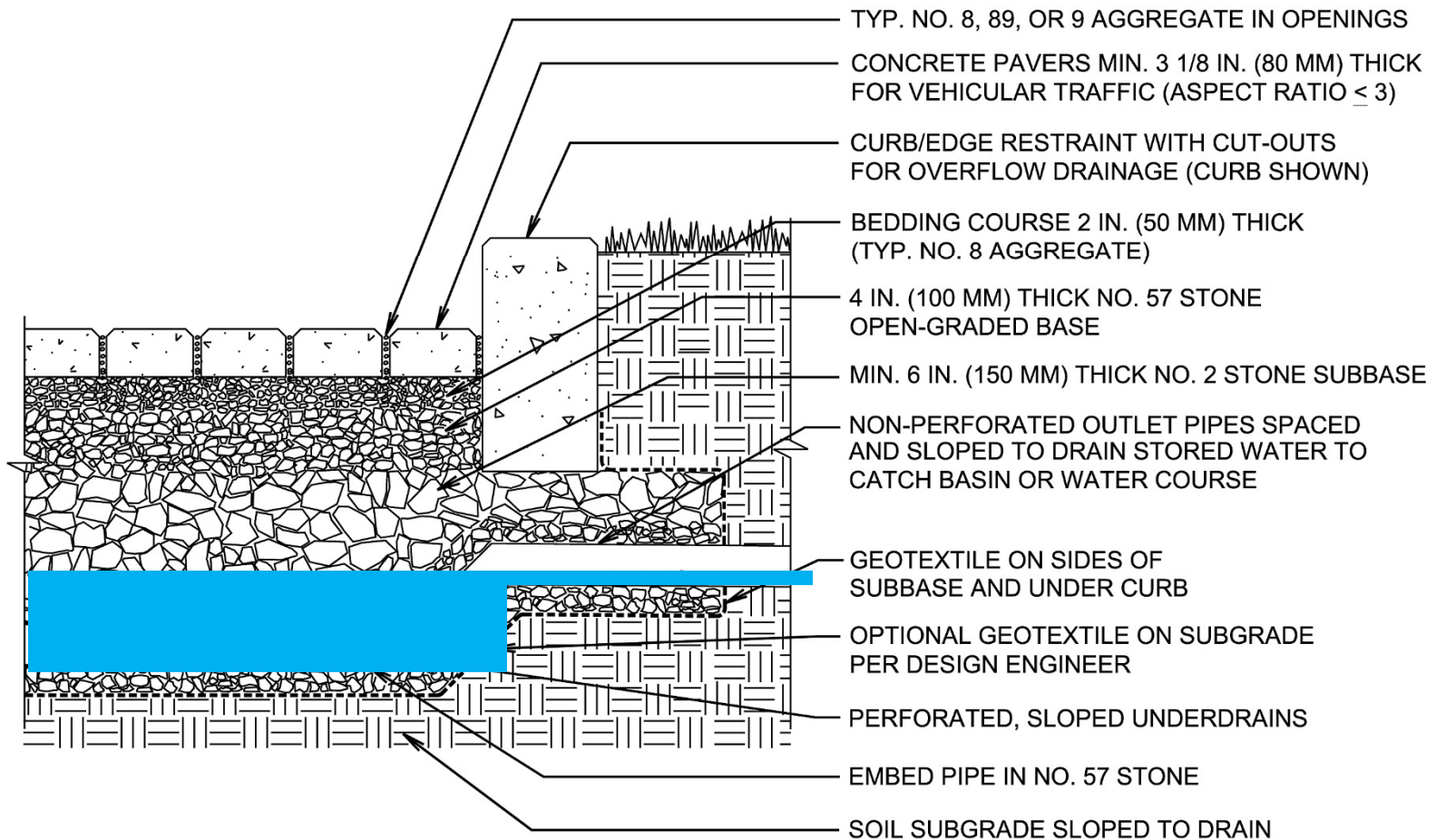
Underdrains: New Approach



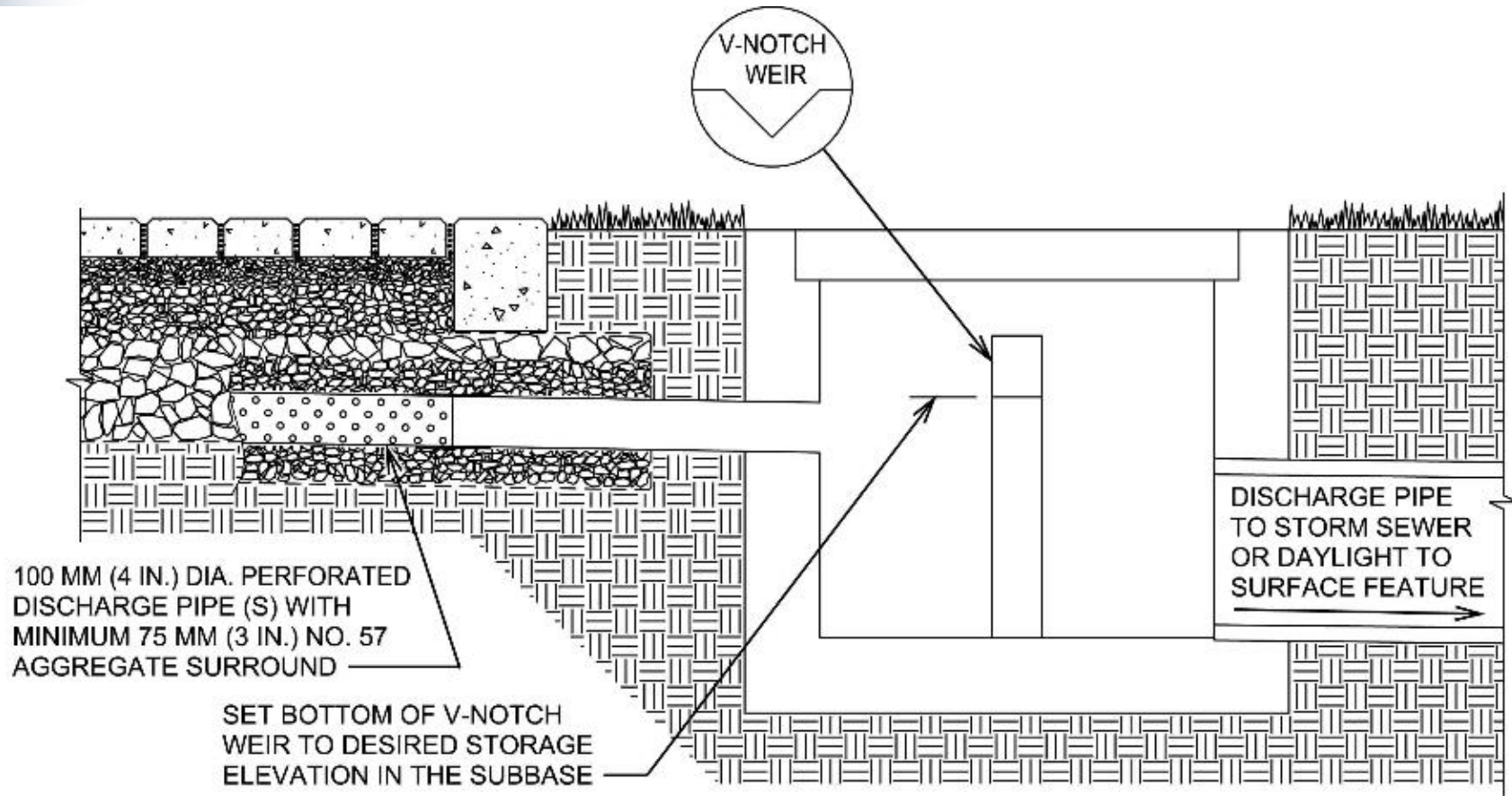
- Underdrain placed in trench at bottom of section with raised outlet to allow water storage in aggregate reservoir



Underdrain: Upturned Elbow



Underdrain: Connection to Catch Basin/Utility Structure



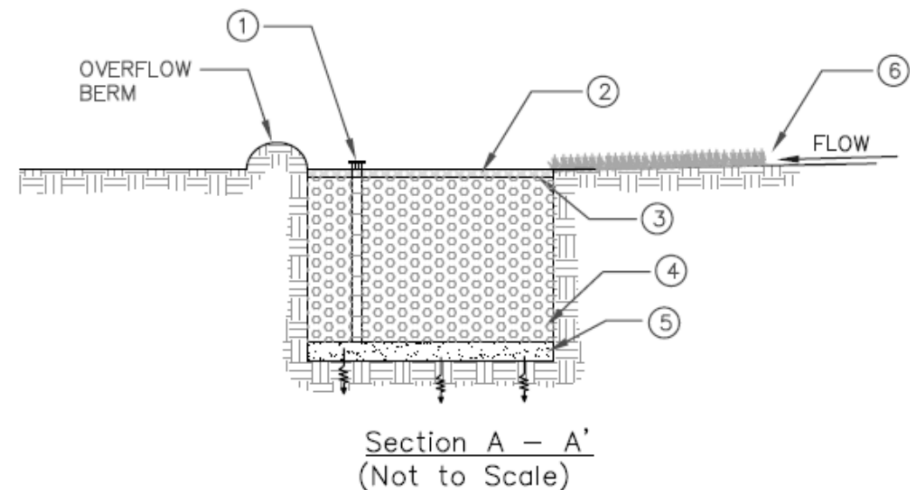
Infiltration Trench Sizing

- Differences from Pervious Pavement
 - More runoff must infiltrate in a smaller footprint
 - Infiltration rate of site soils must be at least 0.5 in/hr (i.e., not suitable for “C” or “D” soils)
 - Trench depths are typically between 3 and 8 feet
 - Infiltration trench is an “infiltration device”
 - Minimum 10-foot separation from seasonal high groundwater level
 - Must meet other MRP and SCVWD requirements
 - Cannot be “deeper than wide” (Class V injection well)

Infiltration Trench Sizing

■ Design Parameters

- Trench depth is calculated based on the soil infiltration rate, aggregate void space, and the trench storage time
- The stone aggregate used in the trench is typically 1.5 to 2.5 inches in diameter, which provides a void space of approximately 35 %
- Trenches should drain within 72 hours
- Place underdrain above void space needed for storage of V_{wQ}



Infiltration Trench Sizing

- Approach to Sizing Infiltration Trenches

- Trench unit storage volume: $S = n \times d$
n = gravel porosity (0.35); d = gravel depth (ft)
- Subsoil unit infiltration capacity: $S_i = k \times t \div 12$
k = subsoil permeability (in/hr); t = time (max 72 hrs)
- Check for trench drainage by infiltration:

If $S \leq S_i$: Increase depth of media until $S = S_i$
to match trench capacity to infiltration capacity
(may decrease surface area needed)

If $S > S_i$: Decrease depth of media until $S = S_i$
(surface area may increase)

Infiltration Trench Sizing

- Approach to Sizing Infiltration Trenches
 - Determine required trench area:
 - $A_T = V_{WQ} \div S$
 A_T = Trench area required to store treatment volume (sq.ft.)
 V_{WQ} = Water quality design volume (cu. ft.)
 S = Trench unit storage volume (cu.ft./sq.ft.)
 - Determine required trench width:
 - $W = A_T \div L$
 W = Width of trench (ft.)
 A_T = Required trench area (sq. ft.)
 L = Length of trench (ft.) (normally length of treatment area)

Sizing Rainwater Harvesting Cisterns

■ Rainwater Harvesting and Use

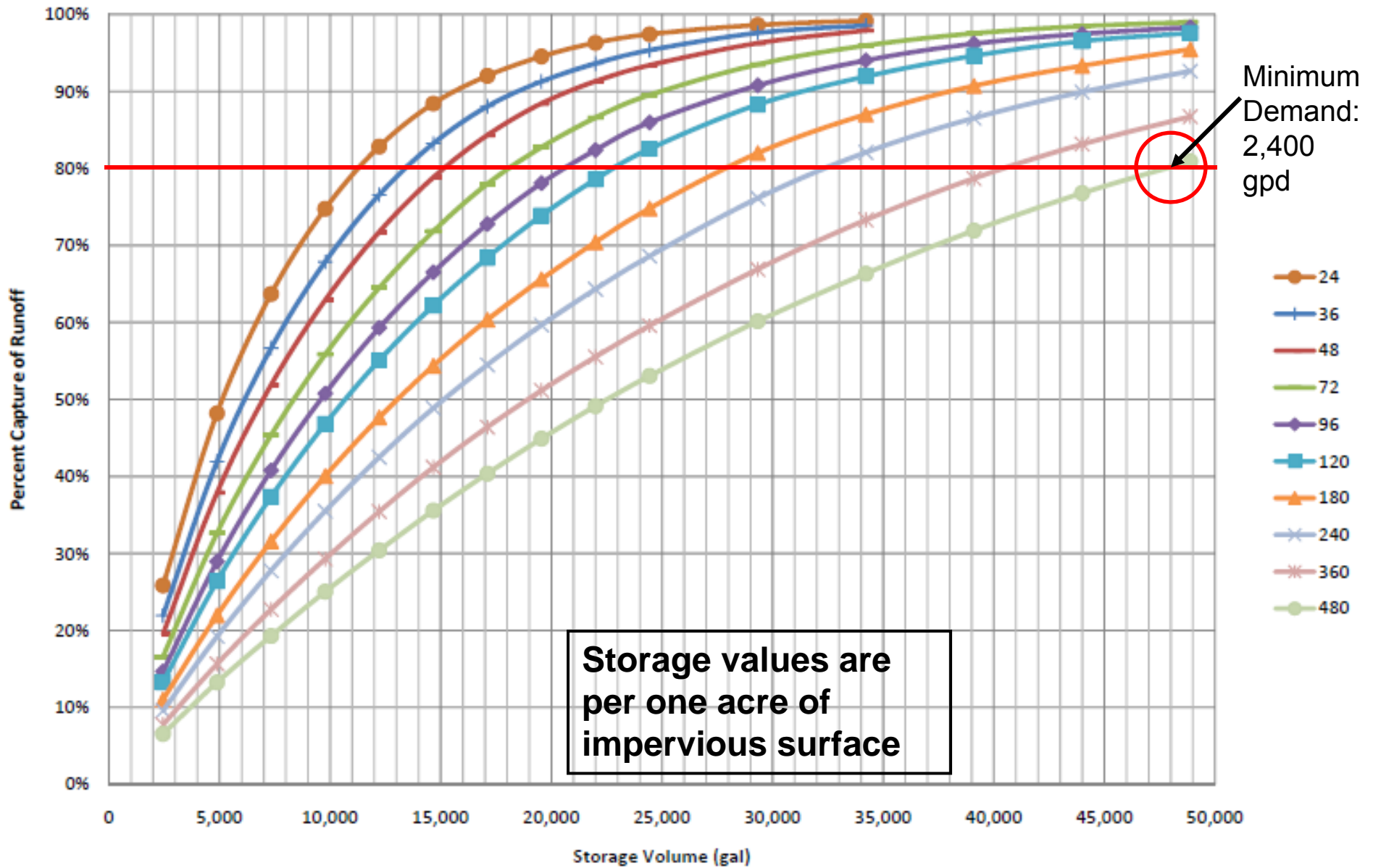
• Types of Demands

- Irrigation
- Toilet flushing
- Other non-potable



- Volume based sizing criteria in C.3.d is 80% capture of the annual runoff
- Need to size with continuous simulation modeling (see curves in Appendix I of C.3 Handbook)
- Key parameters are drawdown time and associated demand requirement

Figure F-11 Percent Capture Achieved by BMP Storage Volume for Various Drawdown Times - San Jose



Estimate Actual Demand

Daily Use Rates for Toilets and Urinals¹

Land Use Type	User Unit	User Unit Factor ²	Daily Use/Unit (gal/day/unit)
Residential	Resident	2.9 residents per dwelling unit	8.6
Office or Retail	Employee (non-visitor)	200 SF per employee	6.9
Schools	Employee (not including students)	50 SF per employee	33.9

¹References: CCCWP Stormwater C.3 Guidebook, 6th edition, 2012; BASMAA LID Feasibility Report, 2011; California Plumbing Code, 2010.

²Use project-specific data if available

Estimate Minimum Demand Required for 80% Capture

Toilet Flushing Demand Required Per Impervious Acre

Rain Gauge ³	Required Demand (gal/day/IA) ⁴	Residential		Office/Retail ⁵	
		No. of residents per IA ⁷	Dwelling Units per IA ⁸	Employees per IA ⁹	Interior Floor Area (sq.ft./IA) ¹⁰
Morgan Hill	6,500	760	260	940	188,000
Palo Alto	2,900	340	116	420	84,000
San Jose	2,400	280	96	350	70,000

See SCVURPPP C.3 Handbook, Appendix I, Attachment 1 for more information.

References: BASMAA LID Feasibility Report, 2011; California Plumbing Code, 2010.

Example: 2-Story Office Building



Check Rainwater Harvesting Feasibility

- Assume rainwater capture area = area of building roof (10,000 SF or 0.23 acres)
- Assume it is a commercial building with interior floor area of 20,000 SF
- Calculate interior floor area per acre of capture area:
 $20,000 \text{ SF} \div 0.23 \text{ acres} = 87,000 \text{ SF/ac}$
- Use App. I, Attachment 1, Table 2 to determine minimum floor area needed to meet toilet flushing demand for 80% capture of annual runoff:
Answer = 70,000 SF per acre of impervious surface
- $87,000 \text{ SF} > 70,000 \text{ SF} \Rightarrow$ Building will have minimum toilet flushing demand to meet C.3

Determine Building Toilet Flushing Demand

- Building interior floor area = 20,000 SF
- Estimate no. of employees:
 - $20,000 \text{ SF} \div 200 \text{ SF/employee} = 100 \text{ employees}$
 - $100 \text{ employees} \times 6.9 \text{ gpd/employee} = 690 \text{ gpd}$
- Convert to equivalent demand per impervious acre (to allow use of sizing curves):
 - $10,000 \text{ SF roof area} \div 43,560 \text{ SF/ac} = 0.23 \text{ ac.}$
 - $690 \text{ gpd} \div 0.23 = 3,000 \text{ gpd per impervious acre}$

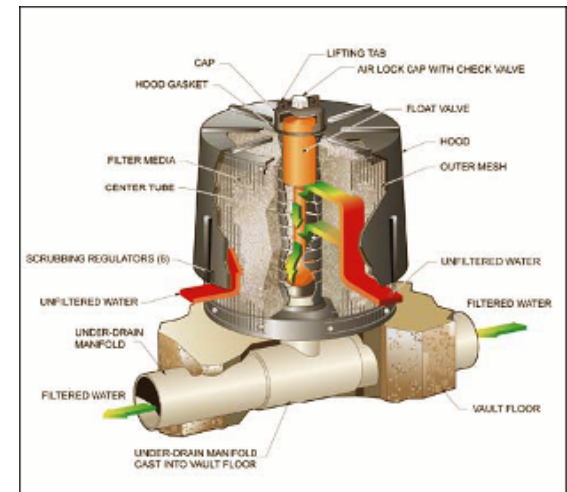
Determine Required Cistern Size

- From sizing curves, find right combination of drawdown time, tank size and required demand:
 - 480-hr (20-day) drawdown \Rightarrow 48,000 gallon tank \Rightarrow 2,400 gpd
 - 360-hr (15-day) drawdown \Rightarrow 40,000 gallon tank \Rightarrow 2,667 gpd
 - 240-hr (10-day) drawdown \Rightarrow 32,000 gallon tank \Rightarrow 3,200 gpd
 - 288-hr (12-day) drawdown \Rightarrow 36,000 gallon tank \Rightarrow 3,000 gpd \checkmark
- Adjust tank size back to actual impervious area:
 - 36,000-gallon tank per 1 acre impervious area
 - $36,000 \times 0.23 \text{ acres} = \underline{8,300\text{-gallon cistern}}$
- Option: Use smaller cistern and provide treatment (e.g., bioretention) for overflow

Sizing High-Rate Media Filters

Media Filters (cartridge type)

- Flow-based Treatment Measure
- Determine Q_{wQ}
- Select a product that is certified by Washington State TAPE program*
- Determine the TAPE-approved design flow rate per cartridge
- Divide Q_{wQ} by the cartridge flow rate to calculate the required number of cartridges (round up)



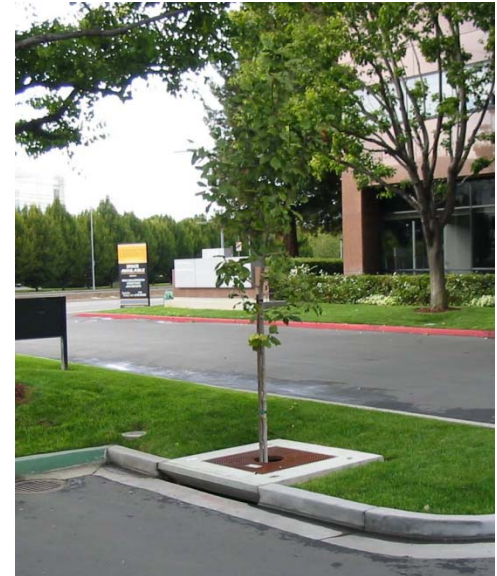
*General Use Level Designation (GULD) for Basic Treatment

See: <http://www.ecy.wa.gov/programs/wq/stormwater/newtech/technologies.html>

Sizing High-Rate Media Filters

Proprietary Tree Box Filters

- Flow-based Treatment Measure
- Determine Q_{wq}
- Select a product that is certified by Washington State TAPE program
- Determine the TAPE-approved infiltration rate for the media
- Calculate the required surface area by dividing Q_{wq} by the infiltration rate (ft/sec)
- A tree box filter that uses biotreatment soil media can be sized like a flow-through planter



Questions?



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