ATTACHMENT D

BMP Sizing Design Calculations
(Water Quality & Hydromodification)

Refer to "Hydromodification Study" for TC-BMP/IMP Design Details

POST PROJECT LAND USE AREA BREAKDOWN (TREATED) - TABLE 3-2 (LID/BMP SUMMARY SIZING CALCULATIONS)

Sub-Basin No.	Basin 1 (ac.)	Basin 2 (ac.)	Basin 3 (ac.)	Basin 4 (ac.)	Basin 5 (ac.)	Basin 6 (ac.)	Basin 7 (ac.)	Basin 8 (ac.)	Basin 9 (ac.)	Basin 10 (ac.)	Basin 15 (ac.)	Total Land Use Area (ac.)
A,Urban Flat (0-5%)	0.00	2.80	0.00	0.00	1.37	0.00	1.71	0.00	0.00	0.26	0.62	6.76
A,Urban Very Steep (>20%)	0.00	0.66	0.00	0.00	0.51	0.00	0.05	0.00	1.44	0.98	0.00	3.63
B,Urban Flat (0-5%)	5.98	3.43	0.25	1.04	8.52	1.45	0.79	0.17	0.00	0.16	0.00	21.78
B,Urban Moderate (5-10%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B,Urban Very Steep (>20%)	1.84	1.56	0.05	0.43	1.39	0.28	0.39	0.00	0.00	0.00	0.00	5.94
C,Urban Flat (0-5%)	9.89	2.63	0.50	2.05	0.00	0.00	0.00	0.39	0.00	0.00	0.00	15.46
C,Urban Moderate (5-10%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C,Urban Very Steep (>20%)	1.96	1.97	0.08	0.04	0.00	0.00	0.00	0.11	0.00	0.00	0.00	4.16
D,Urban Flat (0-5%)	0.00	1.57	0.00	1.22	3.97	0.00	0.07	0.00	0.00	0.02	0.03	6.89
D,Urban Very Steep (>20%)	0.00	0.00	0.00	0.79	0.29	0.00	0.06	0.00	0.00	0.00	0.00	1.14
Roads Flat (0-5%)	4.48	3.16	0.46	3.39	7.64	1.07	0.39	0.27	0.00	0.50	2.59	23.93
Roads Moderate (5-10%)	1.70	2.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	3.96
Dwy Flat (0-5%)	2.07	2.07	0.23	1.33	2.51	0.27	0.00	0.00	0.00	0.00	0.00	8.48
Sidewalk Flat (0-5%)	0.70	0.62	0.03	0.91	1.37	0.20	0.07	0.00	0.00	0.07	0.07	4.02
Sidewalk Moderate (5-10%)	0.46	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82
Parking Lots Flat (0-5%)	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.35
Roof Area	8.74	6.66	0.85	2.84	8.55	0.85	0.02	0.49	0.00	0.00	0.00	29.00
B-Shrubs (>20%)	0.00	0.00	0.00	0.00	3.91	0.00	0.00	0.00	0.00	0.00	0.00	3.91
B-Forest (>20%)	0.00	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.80
Total Basin Area (ac.)	37.82	29.48	2.45	14.04	40.82	4.12	4.16	1.42	1.44	1.99	3.31	141.06
Drains to LID/BMP Type	Detention Pond (BMP 1)	Detention Pond (BMP 2)	Bioretention (BMP 3)	Detention Pond (BMP 4)	Detention Pond (BMP 5)	Bioretention (BMP 6)	Bioretention (BMP 7)	Bioretention (BMP 8)	Bioswale 2 Self-treated	Bioswale 1 Self-treated	Bioswale 3	N/A
Minimum LID/BMP Area (sqft.)*	45,963	36,674	7,760	28,547	67,713	10,048	4,480	3,877	N/A	N/A	N/A	205,062
Proposed LID/BMP Area (sqft.)	49,100	82,700	6,500	37,500	71,600	10,500	7,900	4,850	N/A	N/A	N/A	270,650

* Minimum Area/Volume Based on the County of San Diego SUSMP "Standard Urban Stormwater Management Plan" and Hydromodification Workgroup, BMP Sizing calculator (Version 3.0). Set to Low Flow Threshold of 0.1Q2. (See section 4 for summary calculations of the "Hydromodification Study" for details).

CONTINUE...

POST PROJECT LAND USE AREA BREAKDOWN (TREATED) - TABLE 3-2 (LID/BMP SUMMARY SIZING CALCULATIONS)

Sub-Basin No.	Basin 1 (ac.)	Basin 2 (ac.)	Basin 3 (ac.)	Basin 4 (ac.)	Basin 5 (ac.)	Basin 6 (ac.)	Basin 7 (ac.)	Basin 8 (ac.)	Basin 9 (ac.)	Basin 10 (ac.)	Basin 15 (ac.)	Total Volume (Cu. Ft.)
Minimum Volume 1 (cu. Ft.)	199,908	156,436	6,469	119,642	301,782	8,373	3,734	3,231	N/A	N/A	N/A	799,575
Minimum Volume 2 (cu. Ft.)	N/A	N/A	4,183	N/A	N/A	N/A	114	2,095	N/A	N/A	N/A	6,392
Minimum Volume Total *	199,908	156,436	10,652	119,642	301,782	8,373	3,848	5,326	N/A	N/A	N/A	805,967
Proposed Volume 1 (cu. Ft.)	206,150	354,400	8,550	155,200	304,300	12,475	10,200	6,190	N/A	N/A	N/A	1,057,465
Proposed Volume 2 (cu. Ft.)	N/A	N/A	3,035	N/A	N/A	3,700	3,420	2,100	N/A	N/A	N/A	12,255
Proposed Volume Total	206,150	354,400	11,585	155,200	304,300	16,175	13,620	8,290	N/A	N/A	N/A	1,069,720

* Minimum Area/Volume Based on the County of San Diego SUSMP "Standard Urban Stormwater Management Plan" and Hydromodification Workgroup, BMP Sizing calculator (Version 3.0). Set to Low Flow Threshold of 0.1Q2. (See section 4 for summary calculations of the "Hydromodification Study" for details).

POST-PROJECT LAND USE AREA BREAKDOWN (SELF-TREATED) - TABLE 3-3

Sub-Basin No.	Basin 11 (ac.)	Basin 12 (ac.)	Basin 13 (ac.)	Basin 14 (ac.)	Basin 16 (ac.)	Basin 17 (ac.)	Total Land Use Area (ac.)
A-Forest (0-5%)	0.00	0.00	0.00	0.00	0.13	0.00	0.13
A-Forest (5-10%)	0.00	0.00	0.00	0.00	0.01	0.00	0.01
A-Forest (10-20%)	0.00	0.00	0.00	0.00	0.05	0.00	0.05
A-Forest (>20%)	0.00	0.00	0.00	0.00	2.41	0.00	2.41
A-Shrubs (0-5%)	0.00	0.00	0.00	0.00	0.15	0.00	0.15
A-Shrubs (5-10%)	0.00	0.00	0.00	0.00	0.14	0.00	0.14
A-Shrubs (10-20%)	0.00	0.00	0.00	0.00	1.45	0.00	1.45
A-Shrubs (>20%)	0.00	0.00	0.00	0.00	33.98	0.00	33.98
A-Grass (0-5%)	0.00	0.00	0.00	0.00	0.11	0.61	0.72
B-Forest (0-5%)	0.00	0.08	0.00	0.00	0	0.00	0.08
B-Forest (5-10%)	0.00	0.00	0.01	0.00	0	0.00	0.01
B-Forest (10-20%)	0.00	0.00	0.01	0.00	0	0.00	0.01
B-Forest (>20%)	0.00	0.00	1.40	0.00	0.11	0.00	1.51
B-Grass (0-5%)	0.00	0.00	0.00	0.00	0	0.00	0
B-Grass (5-10%)	0.00	0.00	0.00	0.00	0	0.35	0.35
B-Grass (10-20%)	0.00	0.00	0.00	0.00	0	0.34	0.34
B-Grass (>20%)	0.00	0.00	0.00	0.00	0	0.35	0.35
B-Shrubs (0-5%)	0.04	0.31	0.01	0.00	14.1	0.00	14.46
B-Shrubs (5-10%)	0.23	1.41	0.00	0.00	8.85	0.00	10.49
B-Shrubs (10-20%)	1.81	0.77	0.07	0.00	27.2	0.43	30.28
B-Shrubs (>20%)	0.77	4.16	1.53	0.00	92.68	0.00	99.14
C/D-Forest (0-5%)	0.00	0.00	0.00	0.00	17.49	0.00	17.49
C/D-Forest (5-10%)	0.00	0.00	0.00	0.00	9.02	0.00	9.02

CONTINUE... POST-PROJECT LAND USE AREA BREAKDOWN (SELF-TREATED) - TABLE 3-3

Sub-Basin No.	Basin 11 (ac.)	Basin 12 (ac.)	Basin 13 (ac.)	Basin 14 (ac.)	Basin 16 (ac.)	Basin 17 (ac.)	Total Land Use Area (ac.)
C/D-Forest (10-20%)	0.00	0.00	0.01	0.00	26.56	0.00	26.57
C/D-Forest (>20%)	0.00	0.60	0.30	0.00	46.4	0.00	47.31
C/D-Shrubs (0-5%)	0.03	3.23	0.00	0.00	47.64	0.00	50.90
C/D-Shrubs (5-10%)	0.09	10.44	0.00	0.00	128.81	0.00	139.34
C/D-Shrubs (10-20%)	2.10	34.49	0.00	0.00	481.29	0.00	517.87
C/D-Shrubs (>20%)	7.68	325.79	1.32	0.00	2623.92	0.00	2958.70
C/D-Grass (0-5%)	0.00	0.00	0.00	0.00	0.84	0.00	0.84
C/D-Grass (5-10%)	0.00	0.00	0.00	0.00	0.04	0.00	0.04
B,Urban (0-5%)	0.00	0.15	0.00	0.14	0	0.00	0.29
B,Urban (5-10%)	0.00	0.06	0.00	0.08	0	0.00	0.13
B,Urban (10-20%)	0.01	0.03	0.05	0.05	0	0.00	0.14
B,Urban (>20%)	0.65	1.04	1.26	0.19	0	0.00	3.14
C,Urban (0-5%)	0.00	0.36	0.01	0.00	0	0.00	0.37
C,Urban (5-10%)	0.00	0.06	0.00	0.02	0	0.00	0.08
C,Urban (10-20%)	0.00	0.11	0.00	0.00	0	0.00	0.11
C,Urban (>20%)	0.78	3.00	0.17	0.00	0	0.00	3.95
D,Urban (0-5%)	0.00	0.00	0.00	0.00	0.04	0.00	0.04
D,Urban (5-10%)	0.00	0.00	0.00	0.00	0.01	0.00	0.01
D,Urban (10-20%)	0.00	0.00	0.00	0.00	0.05	0.00	0.05
D,Urban (>20%)	0.00	0.00	0.00	0.00	1.03	0.00	1.03
Sidewalks Flat (0-5%)	0.00	0.00	0.00	0.03	0	0.00	0.03
Total Basin Area (ac.)	14.18	386.09	6.15	0.52	3564.51	2.08	3973.54
Drains Thruough	Bioswale 1	Bioswale 1	Bioswale 1	Bioswale 1	Gomez Creek	Bioswale 2	

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 1
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	37.82
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21868	Drains to Pond	BMP 1	Soil Type B Landscape (0-5%)	5.98	Pervious (Pre)		Type B (moderate infiltration)	Flat - slope (less ...
21869	Drains to Pond	BMP 1	Soil Type B Landscape (>10%)	1.84	Pervious (Pre)		Type B (moderate infiltration)	Steep (greater 10%)
21870	Drains to Pond	BMP 1	Soil Type C Landscape (0-5%)	9.89	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...
21871	Drains to Pond	BMP 1	Soil Type C Landscape (>10%)	1.96	Pervious (Pre)		Type C (slow infiltration)	Steep (greater 10%)
21872	Drains to Pond	BMP 1	Roads, Sidewalks, Dwy (0-5%)	7.25	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...
21873	Drains to Pond	BMP 1	Roads, Sidewalks, Dwy (5-10%)	2.16	Pervious (Pre)		Type C (slow infiltration)	Moderate (5 - 10%)
21874	Drains to Pond	BMP 1	Roofs	8.74	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...

Pond Facility Summary

Scenario	Description	Bottom Area (sqft)	Top Area (sqft)	Depth (ft)	Volume (cft)	Low Orifice (in)	Low Invert (ft)	High Orifice (in)	High Invert (ft)	Weir Length (ft)	Weir Invert (ft)	Facility Soil	Drawdown (hrs)
Design A	BMP 1 - Detention Basin	34000	45963	5	199908.6	4.5	0.00	18.00	2.25	5.00	4.5	B	28.00

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 2
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	29.48
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21877	Drains to Pond	BMP 2	Soil Type A Landscape (0-5%)	2.8	Pervious (Pre)		Type A (low runoff - sandy soi...	Flat - slope (less ...
21878	Drains to Pond	BMP 2	Soil Type A Landscape (>10%)	0.66	Pervious (Pre)		Type A (low runoff - sandy soi...	Steep (greater 10%)
21879	Drains to Pond	BMP 2	Soil Type B Landscape (0-5%)	3.43	Pervious (Pre)		Type B (moderate infiltration)	Flat - slope (less ...
21880	Drains to Pond	BMP 2	Soil Type B Landscape (>10%)	1.56	Pervious (Pre)		Type B (moderate infiltration)	Steep (greater 10%)
21881	Drains to Pond	BMP 2	Soil type C Landscape (0-5%)	2.63	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...
21882	Drains to Pond	BMP 2	Soil Type C Landscape (>10%)	1.97	Pervious (Pre)		Type C (slow infiltration)	Steep (greater 10%)
21883	Drains to Pond	BMP 2	Soil Type D Landscape (0-5%)	1.57	Pervious (Pre)		Type D (high runoff - clay soi...	Flat - slope (less ...
21884	Drains to Pond	BMP 2	Roads, Sidewalks, Dwy (0-5%)	5.85	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...
21885	Drains to Pond	BMP 2	Roads, Sidewalks, Dwy (5-10%)	2.36	Pervious (Pre)		Type C (slow infiltration)	Moderate (5 - 10%)
21886	Drains to Pond	BMP 2	Roof	6.66	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...

Pond Facility Summary

Scenario	Description	Bottom Area (sqft)	Top Area (sqft)	Depth (ft)	Volume (cft)	Low Orifice (in)	Low Invert (ft)	High Orifice (in)	High Invert (ft)	Weir Length (ft)	Weir Invert (ft)	Facility Soil	Drawdown (hrs)
Design A	BMP 2 - Detention Basin	26000	36574	5	156436.7	3.00	0.00	8.00	0.8	5.00	4.5	A	11.00

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 3
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	2.45
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21889	Drains to LID	BMP 3	Soil Type B Landscape (0-5%)	0.25	Pervious (Pre)	Landscaping	Type B (moderate infiltration)	Flat - slope (less ...
21890	Drains to LID	BMP 3	Soil type B Landscape (>10%)	0.05	Pervious (Pre)	Landscaping	Type B (moderate infiltration)	Moderate (5 - 10%)
21891	Drains to LID	BMP 3	Soil Type C Landscape (0-5%)	0.5	Pervious (Pre)	Landscaping	Type C (slow infiltration)	Flat - slope (less ...
21892	Drains to LID	BMP 3	Soil Type C Landscape (>10%)	0.08	Pervious (Pre)	Landscaping	Type C (slow infiltration)	Moderate (5 - 10%)
21893	Drains to LID	BMP 3	Roads, Sidewalks, Dwy (0-5%)	0.72	Pervious (Pre)	Concrete or asphalt	Type C (slow infiltration)	Moderate (5 - 10%)
21896	Drains to LID	BMP 3	Roof	0.85	Pervious (Pre)	Roofs	Type C (slow infiltration)	Moderate (5 - 10%)

LID Facility Summary

BMP ID	Type	Description	Plan Area (sqft)	Volume 1(cft)	Volume 2(cft)	Orifice Flow (cfs)	Orifice Size (inch)
BMP 3	Bioretention	BMP 3 - Bioretention	7760	6469	4183	0.060	1.00

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 4
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	14.04
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21898	Drains to Pond	BMP 4	Soil Type B Landscape (0-5%)	1.04	Pervious (Pre)		Type B (moderate infiltration)	Flat - slope (less ...
21899	Drains to Pond	BMP 4	Soil Type B Landscape (>10%)	0.43	Pervious (Pre)		Type B (moderate infiltration)	Steep (greater 10%)
21900	Drains to Pond	BMP 4	Soil Type C Landscape (0-5%)	2.05	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...
21901	Drains to Pond	BMP 4	Soil Type C Landscape (>10%)	0.04	Pervious (Pre)		Type C (slow infiltration)	Steep (greater 10%)
21902	Drains to Pond	BMP 4	Soil Type D Landscape (0-5%)	1.22	Pervious (Pre)		Type D (high runoff - clay soi...	Flat - slope (less ...
21903	Drains to Pond	BMP 4	Soil Type D Landscape (>10%)	0.79	Pervious (Pre)		Type D (high runoff - clay soi...	Steep (greater 10%)
21904	Drains to Pond	BMP 4	Roads, Sidewalks, Dwy (0-5%)	5.63	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...
21905	Drains to Pond	BMP 4	Roof	2.84	Pervious (Pre)		Type C (slow infiltration)	Flat - slope (less ...

Pond Facility Summary

Scenario	Description	Bottom Area (sqft)	Top Area (sqft)	Depth (ft)	Volume (cft)	Low Orifice (in)	Low Invert (ft)	High Orifice (in)	High Invert (ft)	Weir Length (ft)	Weir Invert (ft)	Facility Soil	Drawdown (hrs)
Design A	BMP 4 - Detention Basin	19309	28547	5	119642.7	2.5	0.00	12.00	2.00	5.00	4.5	B	35.00

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 5
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	40.83
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21963	Drains to Pond	BMP 5	Soil Type A Landscape (0-5%)	1.37	Pervious (Pre)		Type A (low runoff - sandy soi...	Flat - slope (less ...
21964	Drains to Pond	BMP 5	Soil Type A Landscape (>10%)	0.51	Pervious (Pre)		Type A (low runoff - sandy soi...	Steep (greater 10%)
21965	Drains to Pond	BMP 5	Soil Type B Landscape (0-5%)	8.52	Pervious (Pre)		Type B (moderate infiltration)	Flat - slope (less ...
21966	Drains to Pond	BMP 5	Soil Type B Landscape (>10%)	1.39	Pervious (Pre)		Type B (moderate infiltration)	Steep (greater 10%)
21967	Drains to Pond	BMP 5	Soil Type D Landscape (0-5%)	3.97	Pervious (Pre)		Type D (high runoff - clay soi...	Flat - slope (less ...
21968	Drains to Pond	BMP 5	Soil Type D Landscape (>10%)	0.29	Pervious (Pre)		Type D (high runoff - clay soi...	Steep (greater 10%)
21969	Drains to Pond	BMP 5	Roads, Sidewalks, Dwy (0-5%)	11.52	Pervious (Pre)		Type B (moderate infiltration)	Flat - slope (less ...
21970	Drains to Pond	BMP 5	Roofs	8.55	Pervious (Pre)		Type B (moderate infiltration)	Flat - slope (less ...
21971	Drains to Pond	BMP 5	Soil Type B Shrubs (>10%)	3.91	Pervious (Pre)		Type B (moderate infiltration)	Steep (greater 10%)
21972	Drains to Pond	BMP 5	Soil Type B Forest (>10%)	0.8	Pervious (Pre)		Type B (moderate infiltration)	Steep (greater 10%)

Pond Facility Summary

Scenario	Description	Bottom Area (sqft)	Top Area (sqft)	Depth (ft)	Volume (cft)	Low Orifice (in)	Low Invert (ft)	High Orifice (in)	High Invert (ft)	Weir Length (ft)	Weir Invert (ft)	Facility Soil	Drawdown (hrs)
Design A	BMP 5 - Detention Basin	53000	67713	5	301782.5	4.00	0.00	13.00	2.00	5.00	4.5	B	38.00

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 6
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	4.12
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21975	Drains to LID	BMP 6	Soil Type B Landscape (0-5%)	1.45	Pervious (Pre)	Landscaping	Type B (moderate infiltration)	Flat - slope (less ...
21976	Drains to LID	BMP 6	Soil Type B Landscape (>10%)	0.28	Pervious (Pre)	Landscaping	Type B (moderate infiltration)	Flat - slope (less ...
21977	Drains to LID	BMP 6	Roads, Sidewalks, Dwy (0-5%)	1.54	Pervious (Pre)	Concrete or asphalt	Type B (moderate infiltration)	Flat - slope (less ...
21978	Drains to LID	BMP 6	Roofs	0.85	Pervious (Pre)	Roofs	Type B (moderate infiltration)	Flat - slope (less ...

LID Facility Summary

BMP ID	Type	Description	Plan Area (sqft)	Volume 1(cft)	Volume 2(cft)	Orifice Flow (cfs)	Orifice Size (inch)
BMP 6	Bioretention	BMP 6 - Bioretention	10048	8373	0.00	0.085	2.00

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 7
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	4.16
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21981	Drains to LID	BMP 7	Soil Type A Landscape (0-5%)	1.71	Pervious (Pre)	Landscaping	Type A (low runoff - sandy soi...	Flat - slope (less ...
21982	Drains to LID	BMP 7	Soil Type A Landscape (>10%)	0.05	Pervious (Pre)	Landscaping	Type A (low runoff - sandy soi...	Flat - slope (less ...
21983	Drains to LID	BMP 7	Soil Type B Landscape (0-5%)	0.79	Pervious (Pre)	Landscaping	Type B (moderate infiltration)	Flat - slope (less ...
21984	Drains to LID	BMP 7	Soil Type B Landscape (>10%)	0.39	Pervious (Pre)	Landscaping	Type B (moderate infiltration)	Flat - slope (less ...
21985	Drains to LID	BMP 7	Soil Type D Landscape (0-5%)	0.07	Pervious (Pre)	Landscaping	Type D (high runoff - clay soi...	Flat - slope (less ...
21986	Drains to LID	BMP 7	Soil Type D Landscape (>10%)	0.06	Pervious (Pre)	Landscaping	Type D (high runoff - clay soi...	Flat - slope (less ...
21987	Drains to LID	BMP 7	Roads, Sidewalks, Dwy (0-5%)	0.46	Pervious (Pre)	Concrete or asphalt	Type B (moderate infiltration)	Flat - slope (less ...
21988	Drains to LID	BMP 7	Roads, Sidewalks, Dwy (5-10%)	0.27	Pervious (Pre)	Concrete or asphalt	Type B (moderate infiltration)	Moderate (5 - 10%)
21989	Drains to LID	BMP 7	Roofs	0.02	Pervious (Pre)	Roofs	Type B (moderate infiltration)	Flat - slope (less ...
21990	Drains to LID	BMP 7	Parking Lots (0-5%)	0.35	Pervious (Pre)	Concrete or asphalt	Type B (moderate infiltration)	Flat - slope (less ...

LID Facility Summary

BMP ID	Type	Description	Plan Area (sqft)	Volume 1(cft)	Volume 2(cft)	Orifice Flow (cfs)	Orifice Size (inch)
BMP 7	Bioretention	BMP 7 - Bioretention	4480	3734	114	0.075	1.00

Project Summary

Project Name	Project - 5508rpl4
Project Applicant	Shapouri & associates
Jurisdiction	County of San Diego
Parcel (APN)	110-090-01
Hydrologic Unit	San Luis Rey

Compliance Basin Summary

Basin Name:	DMA/BASIN 8
Receiving Water:	1
Rainfall Basin	Lake Wohlford
Mean Annual Precipitation (inches)	19.5
Project Basin Area (acres):	1.42
Watershed Area (acres):	0.00
SCCWRP Lateral Channel Susceptiblity (H, M, L):	
SCCWRP Vertifical Channel Susceptiblity (H, M, L):	
Overall Channel Susceptibility (H, M, L):	HIGH
Lower Flow Threshold (% of 2-Year Flow):	0.1

Drainage Management Area Summary

ID	Type	BMP ID	Description	Area (ac)	Pre-Project Cover	Post Surface Type	Drainage Soil	Slope
21993	Drains to LID	BMP 8	Soil Type B Landscape (0-5%)	0.17	Pervious (Pre)	Landscaping	Type B (moderate infiltration)	Flat - slope (less ...
21994	Drains to LID	BMP 8	Soil Type C Landscape (0-5%)	0.39	Pervious (Pre)	Landscaping	Type C (slow infiltration)	Flat - slope (less ...
21995	Drains to LID	BMP 8	Soil Type C Landscape (>10%)	0.11	Pervious (Pre)	Landscaping	Type C (slow infiltration)	Flat - slope (less ...
21996	Drains to LID	BMP 8	Roads (0-5%)	0.27	Pervious (Pre)	Concrete or asphalt	Type C (slow infiltration)	Flat - slope (less ...
21997	Drains to LID	BMP 8	Roofs	0.49	Pervious (Pre)	Roofs	Type C (slow infiltration)	Flat - slope (less ...

LID Facility Summary

BMP ID	Type	Description	Plan Area (sqft)	Volume 1(cft)	Volume 2(cft)	Orifice Flow (cfs)	Orifice Size (inch)
BMP 8	Bioretention	BMP 8 - Bioretention	3877	3231	2095	0.034	0.9

Design Considerations

- Tributary Area
- Area Required
- Hydraulic Head

Description

Dry extended detention ponds (a.k.a. dry ponds, extended detention basins, detention ponds, extended detention ponds) are basins whose outlets have been designed to detain the stormwater runoff from a water quality design storm for some minimum time (e.g., 48 hours) to allow particles and associated pollutants to settle. Unlike wet ponds, these facilities do not have a large permanent pool. They can also be used to provide flood control by including additional flood detention storage.

California Experience

Caltrans constructed and monitored 5 extended detention basins in southern California with design drain times of 72 hours. Four of the basins were earthen, less costly and had substantially better load reduction because of infiltration that occurred, than the concrete basin. The Caltrans study reaffirmed the flexibility and performance of this conventional technology. The small headloss and few siting constraints suggest that these devices are one of the most applicable technologies for stormwater treatment.

Advantages

- Due to the simplicity of design, extended detention basins are relatively easy and inexpensive to construct and operate.
- Extended detention basins can provide substantial capture of sediment and the toxics fraction associated with particulates.
- Widespread application with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency

Targeted Constituents

☑	Sediment	▲
☑	Nutrients	●
☑	Trash	■
☑	Metals	▲
☑	Bacteria	▲
☑	Oil and Grease	▲
☑	Organics	▲

Legend *(Removal Effectiveness)*

● Low ■ High

▲ Medium

relationships resulting from the increase of impervious cover in a watershed.

Limitations

- Limitation of the diameter of the orifice may not allow use of extended detention in watersheds of less than 5 acres (would require an orifice with a diameter of less than 0.5 inches that would be prone to clogging).
- Dry extended detention ponds have only moderate pollutant removal when compared to some other structural stormwater practices, and they are relatively ineffective at removing soluble pollutants.
- Although wet ponds can increase property values, dry ponds can actually detract from the value of a home due to the adverse aesthetics of dry, bare areas and inlet and outlet structures.

Design and Sizing Guidelines

- Capture volume determined by local requirements or sized to treat 85% of the annual runoff volume.
- Outlet designed to discharge the capture volume over a period of hours.
- Length to width ratio of at least 1.5:1 where feasible.
- Basin depths optimally range from 2 to 5 feet.
- Include energy dissipation in the inlet design to reduce resuspension of accumulated sediment.
- A maintenance ramp and perimeter access should be included in the design to facilitate access to the basin for maintenance activities and for vector surveillance and control.
- Use a draw down time of 48 hours in most areas of California. Draw down times in excess of 48 hours may result in vector breeding, and should be used only after coordination with local vector control authorities. Draw down times of less than 48 hours should be limited to BMP drainage areas with coarse soils that readily settle and to watersheds where warming may be determined to downstream fisheries.

Construction/Inspection Considerations

- Inspect facility after first large to storm to determine whether the desired residence time has been achieved.
- When constructed with small tributary area, orifice sizing is critical and inspection should verify that flow through additional openings such as bolt holes does not occur.

Performance

One objective of stormwater management practices can be to reduce the flood hazard associated with large storm events by reducing the peak flow associated with these storms. Dry extended detention basins can easily be designed for flood control, and this is actually the primary purpose of most detention ponds.

Dry extended detention basins provide moderate pollutant removal, provided that the recommended design features are incorporated. Although they can be effective at removing some pollutants through settling, they are less effective at removing soluble pollutants because of the absence of a permanent pool. Several studies are available on the effectiveness of dry extended detention ponds including one recently concluded by Caltrans (2002).

The load reduction is greater than the concentration reduction because of the substantial infiltration that occurs. Although the infiltration of stormwater is clearly beneficial to surface receiving waters, there is the potential for groundwater contamination. Previous research on the effects of incidental infiltration on groundwater quality indicated that the risk of contamination is minimal.

There were substantial differences in the amount of infiltration that were observed in the earthen basins during the Caltrans study. On average, approximately 40 percent of the runoff entering the unlined basins infiltrated and was not discharged. The percentage ranged from a high of about 60 percent to a low of only about 8 percent for the different facilities. Climatic conditions and local water table elevation are likely the principal causes of this difference. The least infiltration occurred at a site located on the coast where humidity is higher and the basin invert is within a few meters of sea level. Conversely, the most infiltration occurred at a facility located well inland in Los Angeles County where the climate is much warmer and the humidity is less, resulting in lower soil moisture content in the basin floor at the beginning of storms.

Vegetated detention basins appear to have greater pollutant removal than concrete basins. In the Caltrans study, the concrete basin exported sediment and associated pollutants during a number of storms. Export was not as common in the earthen basins, where the vegetation appeared to help stabilize the retained sediment.

Siting Criteria

Dry extended detention ponds are among the most widely applicable stormwater management practices and are especially useful in retrofit situations where their low hydraulic head requirements allow them to be sited within the constraints of the existing storm drain system. In addition, many communities have detention basins designed for flood control. It is possible to modify these facilities to incorporate features that provide water quality treatment and/or channel protection. Although dry extended detention ponds can be applied rather broadly, designers need to ensure that they are feasible at the site in question. This section provides basic guidelines for siting dry extended detention ponds.

In general, dry extended detention ponds should be used on sites with a minimum area of 5 acres. With this size catchment area, the orifice size can be on the order of 0.5 inches. On smaller sites, it can be challenging to provide channel or water quality control because the orifice diameter at the outlet needed to control relatively small storms becomes very small and thus prone to clogging. In addition, it is generally more cost-effective to control larger drainage areas due to the economies of scale.

Extended detention basins can be used with almost all soils and geology, with minor design adjustments for regions of rapidly percolating soils such as sand. In these areas, extended detention ponds may need an impermeable liner to prevent ground water contamination.

The base of the extended detention facility should not intersect the water table. A permanently wet bottom may become a mosquito breeding ground. Research in Southwest Florida (Santana et al., 1994) demonstrated that intermittently flooded systems, such as dry extended detention ponds, produce more mosquitoes than other pond systems, particularly when the facilities remained wet for more than 3 days following heavy rainfall.

A study in Prince George's County, Maryland, found that stormwater management practices can increase stream temperatures (Galli, 1990). Overall, dry extended detention ponds increased temperature by about 5°F. In cold water streams, dry ponds should be designed to detain stormwater for a relatively short time (i.e., 24 hours) to minimize the amount of warming that occurs in the basin.

Additional Design Guidelines

In order to enhance the effectiveness of extended detention basins, the dimensions of the basin must be sized appropriately. Merely providing the required storage volume will not ensure maximum constituent removal. By effectively configuring the basin, the designer will create a long flow path, promote the establishment of low velocities, and avoid having stagnant areas of the basin. To promote settling and to attain an appealing environment, the design of the basin should consider the length to width ratio, cross-sectional areas, basin slopes and pond configuration, and aesthetics (Young et al., 1996).

Energy dissipation structures should be included for the basin inlet to prevent resuspension of accumulated sediment. The use of stilling basins for this purpose should be avoided because the standing water provides a breeding area for mosquitoes.

Extended detention facilities should be sized to completely capture the water quality volume. A micropool is often recommended for inclusion in the design and one is shown in the schematic diagram. These small permanent pools greatly increase the potential for mosquito breeding and complicate maintenance activities; consequently, they are not recommended for use in California.

A large aspect ratio may improve the performance of detention basins; consequently, the outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 1.5:1 (L:W) where feasible. Basin depths optimally range from 2 to 5 feet.

The facility's drawdown time should be regulated by an orifice or weir. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes. The outlet design implemented by Caltrans in the facilities constructed in San Diego County used an outlet riser with orifices

Figure 1
Example of Extended Detention Outlet Structure

sized to discharge the water quality volume, and the riser overflow height was set to the design storm elevation. A stainless steel screen was placed around the outlet riser to ensure that the orifices would not become clogged with debris. Sites either used a separate riser or broad crested weir for overflow of runoff for the 25 and greater year storms. A picture of a typical outlet is presented in Figure 1.

The outflow structure should be sized to allow for complete drawdown of the water quality volume in 72 hours. No more than 50% of the water quality volume should drain from the facility within the first 24 hours. The outflow structure can be fitted with a valve so that discharge from the basin can be halted in case of an accidental spill in the watershed.

Summary of Design Recommendations

(1) Facility Sizing - The required water quality volume is determined by local regulations or the basin should be sized to capture and treat 85% of the annual runoff volume. See Section 5.5.1 of the handbook for a discussion of volume-based design.

Basin Configuration – A high aspect ratio may improve the performance of detention basins; consequently, the outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 1.5:1 (L:W). The flowpath length is defined as the distance from the inlet to the outlet as measured at the surface. The width is defined as the mean width of the basin. Basin depths optimally range from 2 to 5 feet. The basin may include a sediment forebay to provide the opportunity for larger particles to settle out.

A micropool should not be incorporated in the design because of vector concerns. For online facilities, the principal and emergency spillways must be sized to provide 1.0 foot of freeboard during the 25-year event and to safely pass the flow from 100-year storm.

(2) Pond Side Slopes - Side slopes of the pond should be 3:1 (H:V) or flatter for grass stabilized slopes. Slopes steeper than 3:1 (H:V) must be stabilized with an appropriate slope stabilization practice.

(3) Basin Lining – Basins must be constructed to prevent possible contamination of groundwater below the facility.

(4) Basin Inlet – Energy dissipation is required at the basin inlet to reduce resuspension of accumulated sediment and to reduce the tendency for short-circuiting.

(5) Outflow Structure - The facility's drawdown time should be regulated by a gate valve or orifice plate. In general, the outflow structure should have a trash rack or other acceptable means of preventing clogging at the entrance to the outflow pipes.

The outflow structure should be sized to allow for complete drawdown of the water quality volume in 72 hours. No more than 50% of the water quality volume should drain from the facility within the first 24 hours. The outflow structure should be fitted with a valve so that discharge from the basin can be halted in case of an accidental spill in the watershed. This same valve also can be used to regulate the rate of discharge from the basin.

The discharge through a control orifice is calculated from:

$$Q = CA(2gH\text{-}H_o)^{0.5}$$

where:
- Q = discharge (ft^3/s)
- C = orifice coefficient
- A = area of the orifice (ft^2)
- g = gravitational constant (32.2)
- H = water surface elevation (ft)
- H_o = orifice elevation (ft)

Recommended values for C are 0.66 for thin materials and 0.80 when the material is thicker than the orifice diameter. This equation can be implemented in spreadsheet form with the pond stage/volume relationship to calculate drain time. To do this, use the initial height of the water above the orifice for the water quality volume. Calculate the discharge and assume that it remains constant for approximately 10 minutes. Based on that discharge, estimate the total discharge during that interval and the new elevation based on the stage volume relationship. Continue to iterate until H is approximately equal to H_o. When using multiple orifices the discharge from each is summed.

(6) Splitter Box - When the pond is designed as an offline facility, a splitter structure is used to isolate the water quality volume. The splitter box, or other flow diverting approach, should be designed to convey the 25-year storm event while providing at least 1.0 foot of freeboard along pond side slopes.

(7) Erosion Protection at the Outfall - For online facilities, special consideration should be given to the facility's outfall location. Flared pipe end sections that discharge at or near the stream invert are preferred. The channel immediately below the pond outfall should be modified to conform to natural dimensions, and lined with large stone riprap placed over filter cloth. Energy dissipation may be required to reduce flow velocities from the primary spillway to non-erosive velocities.

(8) Safety Considerations - Safety is provided either by fencing of the facility or by managing the contours of the pond to eliminate dropoffs and other hazards. Earthen side slopes should not exceed 3:1 (H:V) and should terminate on a flat safety bench area. Landscaping can be used to impede access to the facility. The primary spillway opening must not permit access by small children. Outfall pipes above 48 inches in diameter should be fenced.

Maintenance

Routine maintenance activity is often thought to consist mostly of sediment and trash and debris removal; however, these activities often constitute only a small fraction of the maintenance hours. During a recent study by Caltrans, 72 hours of maintenance was performed annually, but only a little over 7 hours was spent on sediment and trash removal. The largest recurring activity was vegetation management, routine mowing. The largest absolute number of hours was associated with vector control because of mosquito breeding that occurred in the stilling basins (example of standing water to be avoided) installed as energy dissipaters. In most cases, basic housekeeping practices such as removal of debris accumulations and vegetation management to ensure that the basin dewaters completely in 48-72 hours is sufficient to prevent creating mosquito and other vector habitats.

Consequently, maintenance costs should be estimated based primarily on the mowing frequency and the time required. Mowing should be done at least annually to avoid establishment of woody vegetation, but may need to be performed much more frequently if aesthetics are an important consideration.

Typical activities and frequencies include:

- Schedule semiannual inspection for the beginning and end of the wet season for standing water, slope stability, sediment accumulation, trash and debris, and presence of burrows.
- Remove accumulated trash and debris in the basin and around the riser pipe during the semiannual inspections. The frequency of this activity may be altered to meet specific site conditions.
- Trim vegetation at the beginning and end of the wet season and inspect monthly to prevent establishment of woody vegetation and for aesthetic and vector reasons.
- Remove accumulated sediment and regrade about every 10 years or when the accumulated sediment volume exceeds 10 percent of the basin volume. Inspect the basin each year for accumulated sediment volume.

Cost

Construction Cost

The construction costs associated with extended detention basins vary considerably. One recent study evaluated the cost of all pond systems (Brown and Schueler, 1997). Adjusting for inflation, the cost of dry extended detention ponds can be estimated with the equation:

$$C = 12.4V^{0.760}$$

where: C = Construction, design, and permitting cost, and
V = Volume (ft^3).

Using this equation, typical construction costs are:

$ 41,600 for a 1 acre-foot pond

$ 239,000 for a 10 acre-foot pond

$ 1,380,000 for a 100 acre-foot pond

Interestingly, these costs are generally slightly higher than the predicted cost of wet ponds (according to Brown and Schueler, 1997) on a cost per total volume basis, which highlights the difficulty of developing reasonably accurate construction estimates. In addition, a typical facility constructed by Caltrans cost about $160,000 with a capture volume of only 0.3 ac-ft.

An economic concern associated with dry ponds is that they might detract slightly from the value of adjacent properties. One study found that dry ponds can actually detract from the perceived value of homes adjacent to a dry pond by between 3 and 10 percent (Emmerling-Dinovo, 1995).

Maintenance Cost

For ponds, the annual cost of routine maintenance is typically estimated at about 3 to 5 percent of the construction cost (EPA website). Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Table 1 presents the maintenance costs estimated by Caltrans based on their experience with five basins located in southern California. Again, it should be emphasized that the vast majority of hours are related to vegetation management (mowing).

Table 1 Estimated Average Annual Maintenance Effort

Activity	Labor Hours	Equipment & Material ($)	Cost
Inspections	4	7	183
Maintenance	49	126	2282
Vector Control	0	0	0
Administration	3	0	132
Materials	-	535	535
Total	**56**	**$668**	**$3,132**

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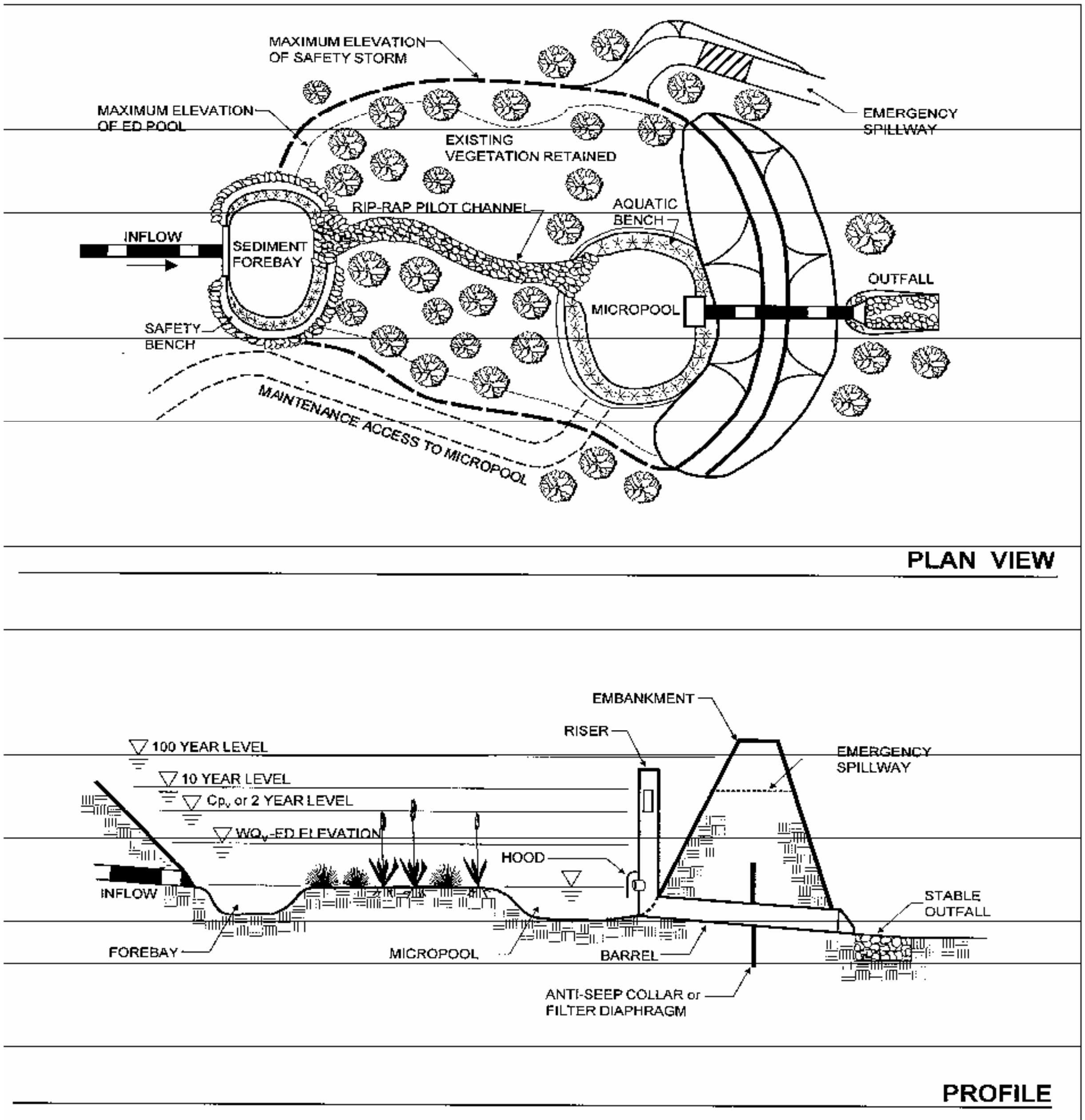

Schematic of an Extended Detention Basin (MDE, 2000)

Design Considerations

- Tributary Area
- Area Required
- Slope
- Water Availability

Description

Vegetated swales are open, shallow channels with vegetation covering the side slopes and bottom that collect and slowly convey runoff flow to downstream discharge points. They are designed to treat runoff through filtering by the vegetation in the channel, filtering through a subsoil matrix, and/or infiltration into the underlying soils. Swales can be natural or manmade. They trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. Vegetated swales can serve as part of a stormwater drainage system and can replace curbs, gutters and storm sewer systems.

California Experience

Caltrans constructed and monitored six vegetated swales in southern California. These swales were generally effective in reducing the volume and mass of pollutants in runoff. Even in the areas where the annual rainfall was only about 10 inches/yr, the vegetation did not require additional irrigation. One factor that strongly affected performance was the presence of large numbers of gophers at most of the sites. The gophers created earthen mounds, destroyed vegetation, and generally reduced the effectiveness of the controls for TSS reduction.

Advantages

- If properly designed, vegetated, and operated, swales can serve as an aesthetic, potentially inexpensive urban development or roadway drainage conveyance measure with significant collateral water quality benefits.

Targeted Constituents

☑	Sediment	▲
☑	Nutrients	●
☑	Trash	●
☑	Metals	▲
☑	Bacteria	●
☑	Oil and Grease	▲
☑	Organics	▲

Legend *(Removal Effectiveness)*

● Low ■ High

▲ Medium

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- Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible.

Limitations

- Can be difficult to avoid channelization.
- May not be appropriate for industrial sites or locations where spills may occur
- Grassed swales cannot treat a very large drainage area. Large areas may be divided and treated using multiple swales.
- A thick vegetative cover is needed for these practices to function properly.
- They are impractical in areas with steep topography.
- They are not effective and may even erode when flow velocities are high, if the grass cover is not properly maintained.
- In some places, their use is restricted by law: many local municipalities require curb and gutter systems in residential areas.
- Swales are mores susceptible to failure if not properly maintained than other treatment BMPs.

Design and Sizing Guidelines

- Flow rate based design determined by local requirements or sized so that 85% of the annual runoff volume is discharged at less than the design rainfall intensity.
- Swale should be designed so that the water level does not exceed 2/3rds the height of the grass or 4 inches, which ever is less, at the design treatment rate.
- Longitudinal slopes should not exceed 2.5%
- Trapezoidal channels are normally recommended but other configurations, such as parabolic, can also provide substantial water quality improvement and may be easier to mow than designs with sharp breaks in slope.
- Swales constructed in cut are preferred, or in fill areas that are far enough from an adjacent slope to minimize the potential for gopher damage. Do not use side slopes constructed of fill, which are prone to structural damage by gophers and other burrowing animals.
- A diverse selection of low growing, plants that thrive under the specific site, climatic, and watering conditions should be specified. Vegetation whose growing season corresponds to the wet season are preferred. Drought tolerant vegetation should be considered especially for swales that are not part of a regularly irrigated landscaped area.
- The width of the swale should be determined using Manning's Equation using a value of 0.25 for Manning's n.

Construction/Inspection Considerations

- Include directions in the specifications for use of appropriate fertilizer and soil amendments based on soil properties determined through testing and compared to the needs of the vegetation requirements.
- Install swales at the time of the year when there is a reasonable chance of successful establishment without irrigation; however, it is recognized that rainfall in a given year may not be sufficient and temporary irrigation may be used.
- If sod tiles must be used, they should be placed so that there are no gaps between the tiles; stagger the ends of the tiles to prevent the formation of channels along the swale or strip.
- Use a roller on the sod to ensure that no air pockets form between the sod and the soil.
- Where seeds are used, erosion controls will be necessary to protect seeds for at least 75 days after the first rainfall of the season.

Performance

The literature suggests that vegetated swales represent a practical and potentially effective technique for controlling urban runoff quality. While limited quantitative performance data exists for vegetated swales, it is known that check dams, slight slopes, permeable soils, dense grass cover, increased contact time, and small storm events all contribute to successful pollutant removal by the swale system. Factors decreasing the effectiveness of swales include compacted soils, short runoff contact time, large storm events, frozen ground, short grass heights, steep slopes, and high runoff velocities and discharge rates.

Conventional vegetated swale designs have achieved mixed results in removing particulate pollutants. A study performed by the Nationwide Urban Runoff Program (NURP) monitored three grass swales in the Washington, D.C., area and found no significant improvement in urban runoff quality for the pollutants analyzed. However, the weak performance of these swales was attributed to the high flow velocities in the swales, soil compaction, steep slopes, and short grass height.

Another project in Durham, NC, monitored the performance of a carefully designed artificial swale that received runoff from a commercial parking lot. The project tracked 11 storms and concluded that particulate concentrations of heavy metals (Cu, Pb, Zn, and Cd) were reduced by approximately 50 percent. However, the swale proved largely ineffective for removing soluble nutrients.

The effectiveness of vegetated swales can be enhanced by adding check dams at approximately 17 meter (50 foot) increments along their length (See Figure 1). These dams maximize the retention time within the swale, decrease flow velocities, and promote particulate settling. Finally, the incorporation of vegetated filter strips parallel to the top of the channel banks can help to treat sheet flows entering the swale.

Only 9 studies have been conducted on all grassed channels designed for water quality (Table 1). The data suggest relatively high removal rates for some pollutants, but negative removals for some bacteria, and fair performance for phosphorus.

Table 1 Grassed swale pollutant removal efficiency data							
	Removal Efficiencies (% Removal)						
Study	TSS	TP	TN	NO_3	Metals	Bacteria	Type
Caltrans 2002	77	8	67	66	83-90	-33	dry swales
Goldberg 1993	67.8	4.5	-	31.4	42–62	-100	grassed channel
Seattle Metro and Washington Department of Ecology 1992	60	45	-	-25	2–16	-25	grassed channel
Seattle Metro and Washington Department of Ecology, 1992	83	29	-	-25	46–73	-25	grassed channel
Wang et al., 1981	80	-	-	-	70–80	-	dry swale
Dorman et al., 1989	98	18	-	45	37–81	-	dry swale
Harper, 1988	87	83	84	80	88–90	-	dry swale
Kercher et al., 1983	99	99	99	99	99	-	dry swale
Harper, 1988.	81	17	40	52	37–69	-	wet swale
Koon, 1995	67	39	-	9	-35 to 6	-	wet swale

While it is difficult to distinguish between different designs based on the small amount of available data, grassed channels generally have poorer removal rates than wet and dry swales, although some swales appear to export soluble phosphorus (Harper, 1988; Koon, 1995). It is not clear why swales export bacteria. One explanation is that bacteria thrive in the warm swale soils.

Siting Criteria

The suitability of a swale at a site will depend on land use, size of the area serviced, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of the swale system (Schueler et al., 1992). In general, swales can be used to serve areas of less than 10 acres, with slopes no greater than 5 %. Use of natural topographic lows is encouraged and natural drainage courses should be regarded as significant local resources to be kept in use (Young et al., 1996).

Selection Criteria (NCTCOG, 1993)

- Comparable performance to wet basins
- Limited to treating a few acres
- Availability of water during dry periods to maintain vegetation
- Sufficient available land area

Research in the Austin area indicates that vegetated controls are effective at removing pollutants even when dormant. Therefore, irrigation is not required to maintain growth during dry periods, but may be necessary only to prevent the vegetation from dying.

The topography of the site should permit the design of a channel with appropriate slope and cross-sectional area. Site topography may also dictate a need for additional structural controls. Recommendations for longitudinal slopes range between 2 and 6 percent. Flatter slopes can be used, if sufficient to provide adequate conveyance. Steep slopes increase flow velocity, decrease detention time, and may require energy dissipating and grade check. Steep slopes also can be managed using a series of check dams to terrace the swale and reduce the slope to within acceptable limits. The use of check dams with swales also promotes infiltration.

Additional Design Guidelines

Most of the design guidelines adopted for swale design specify a minimum hydraulic residence time of 9 minutes. This criterion is based on the results of a single study conducted in Seattle, Washington (Seattle Metro and Washington Department of Ecology, 1992), and is not well supported. Analysis of the data collected in that study indicates that pollutant removal at a residence time of 5 minutes was not significantly different, although there is more variability in that data. Therefore, additional research in the design criteria for swales is needed. Substantial pollutant removal has also been observed for vegetated controls designed solely for conveyance (Barrett et al, 1998); consequently, some flexibility in the design is warranted.

Many design guidelines recommend that grass be frequently mowed to maintain dense coverage near the ground surface. Recent research (Colwell et al., 2000) has shown mowing frequency or grass height has little or no effect on pollutant removal.

Summary of Design Recommendations

1) The swale should have a length that provides a minimum hydraulic residence time of at least 10 minutes. The maximum bottom width should not exceed 10 feet unless a dividing berm is provided. The depth of flow should not exceed 2/3rds the height of the grass at the peak of the water quality design storm intensity. The channel slope should not exceed 2.5%.

2) A design grass height of 6 inches is recommended.

3) Regardless of the recommended detention time, the swale should be not less than 100 feet in length.

4) The width of the swale should be determined using Manning's Equation, at the peak of the design storm, using a Manning's n of 0.25.

5) The swale can be sized as both a treatment facility for the design storm and as a conveyance system to pass the peak hydraulic flows of the 100-year storm if it is located "on-line." The side slopes should be no steeper than 3:1 (H:V).

6) Roadside ditches should be regarded as significant potential swale/buffer strip sites and should be utilized for this purpose whenever possible. If flow is to be introduced through curb cuts, place pavement slightly above the elevation of the vegetated areas. Curb cuts should be at least 12 inches wide to prevent clogging.

7) Swales must be vegetated in order to provide adequate treatment of runoff. It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing, water-resistant grasses. If possible, divert runoff (other than necessary irrigation) during the period of vegetation

establishment. Where runoff diversion is not possible, cover graded and seeded areas with suitable erosion control materials.

Maintenance

The useful life of a vegetated swale system is directly proportional to its maintenance frequency. If properly designed and regularly maintained, vegetated swales can last indefinitely. The maintenance objectives for vegetated swale systems include keeping up the hydraulic and removal efficiency of the channel and maintaining a dense, healthy grass cover.

Maintenance activities should include periodic mowing (with grass never cut shorter than the design flow depth), weed control, watering during drought conditions, reseeding of bare areas, and clearing of debris and blockages. Cuttings should be removed from the channel and disposed in a local composting facility. Accumulated sediment should also be removed manually to avoid concentrated flows in the swale. The application of fertilizers and pesticides should be minimal.

Another aspect of a good maintenance plan is repairing damaged areas within a channel. For example, if the channel develops ruts or holes, it should be repaired utilizing a suitable soil that is properly tamped and seeded. The grass cover should be thick; if it is not, reseed as necessary. Any standing water removed during the maintenance operation must be disposed to a sanitary sewer at an approved discharge location. Residuals (e.g., silt, grass cuttings) must be disposed in accordance with local or State requirements. Maintenance of grassed swales mostly involves maintenance of the grass or wetland plant cover. Typical maintenance activities are summarized below:

- Inspect swales at least twice annually for erosion, damage to vegetation, and sediment and debris accumulation preferably at the end of the wet season to schedule summer maintenance and before major fall runoff to be sure the swale is ready for winter. However, additional inspection after periods of heavy runoff is desirable. The swale should be checked for debris and litter, and areas of sediment accumulation.

- Grass height and mowing frequency may not have a large impact on pollutant removal. Consequently, mowing may only be necessary once or twice a year for safety or aesthetics or to suppress weeds and woody vegetation.

- Trash tends to accumulate in swale areas, particularly along highways. The need for litter removal is determined through periodic inspection, but litter should always be removed prior to mowing.

- Sediment accumulating near culverts and in channels should be removed when it builds up to 75 mm (3 in.) at any spot, or covers vegetation.

- Regularly inspect swales for pools of standing water. Swales can become a nuisance due to mosquito breeding in standing water if obstructions develop (e.g. debris accumulation, invasive vegetation) and/or if proper drainage slopes are not implemented and maintained.

Cost

Construction Cost

Little data is available to estimate the difference in cost between various swale designs. One study (SWRPC, 1991) estimated the construction cost of grassed channels at approximately \$0.25 per ft^2. This price does not include design costs or contingencies. Brown and Schueler (1997) estimate these costs at approximately 32 percent of construction costs for most stormwater management practices. For swales, however, these costs would probably be significantly higher since the construction costs are so low compared with other practices. A more realistic estimate would be a total cost of approximately \$0.50 per ft^2, which compares favorably with other stormwater management practices.

Table 2 Swale Cost Estimate (SEWRPC, 1991)

			Unit Cost			Total Cost		
Component	Unit	Extent	Low	Moderate	High	Low	Moderate	High
Mobilization / Demobilization-Light	Swale	1	$107	$274	$441	$107	$274	$441
Site Preparation								
Clearing[b]	Acre	0.5	$2,200	$3,800	$5,400	$1,100	$1,900	$2,700
Grubbing[c]	Acre	0.25	$3,800	$5,200	$6,600	$950	$1,300	$1,650
General Excavation[d]	Yd^3	372	$2.10	$3.70	$5.30	$781	$1,376	$1,972
Level and Till[e]	Yd^2	1,210	$0.20	$0.35	$0.50	$242	$424	$605
Sites Development								
Salvaged Topsoil Seed, and Mulch[f]	Yd^2	1,210	$0.40	$1.00	$1.60	$484	$1,210	$1,936
Sod[g]	Yd^2	1,210	$1.20	$2.40	$3.60	$1,452	$2,904	$4,356
Subtotal	--	–	--	–	--	$5,116	$9,388	$13,660
Contingencies	Swale	1	25%	25%	25%	$1,279	$2,347	$3,415
Total	--	–	--	–	--	$6,395	$11,735	$17,075

Source: (SEWRPC, 1991)

Note: Mobilization/demobilization refers to the organization and planning involved in establishing a vegetative swale.

[a] Swale has a bottom width of 1.0 foot, a top width of 10 feet with 1:3 side slopes, and a 1,000-foot length.

[b] Area cleared = (top width + 10 feet) x swale length.

[c] Area grubbed = (top width x swale length).

[d] Volume excavated = (0.67 x top width x swale depth) x swale length (parabolic cross-section).

[e] Area tilled = (top width + $\frac{8(\text{swale depth}^2)}{3(\text{top width})}$) x swale length (parabolic cross-section).

[f] Area seeded = area cleared x 0.5.

[g] Area sodded = area cleared x 0.5.

Table 3 Estimated Maintenance Costs (SEWRPC, 1991)

Component	Unit Cost	Swale Size (Depth and Top Width)		Comment
		1.5 Foot Depth, One-Foot Bottom Width, 10-Foot Top Width	3-Foot Depth, 3-Foot Bottom Width, 21-Foot Top Width	
Lawn Mowing	\$0.85 / 1,000 ft^2/ mowing	\$0.14 / linear foot	\$0.21 / linear foot	Lawn maintenance area=(top width + 10 feet) x length. Mow eight times per year
General Lawn Care	\$9.00 / 1,000 ft^2/ year	\$0.18 / linear foot	\$0.28 / linear foot	Lawn maintenance area = (top width + 10 feet) x length
Swale Debris and Litter Removal	\$0.10 / linear foot / year	\$0.10 / linear foot	\$0.10 / linear foot	–
Grass Reseeding with Mulch and Fertilizer	\$0.30 / yd^2	\$0.01 / linear foot	\$0.01 / linear foot	Area revegetated equals 1% of lawn maintenance area per year
Program Administration and Swale Inspection	\$0.15 / linear foot / year, plus \$25 / inspection	\$0.15 / linear foot	\$0.15 / linear foot	Inspect four times per year
Total	--	**\$0.58 / linear foot**	**\$ 0.75 / linear foot**	--

Maintenance Cost

Caltrans (2002) estimated the expected annual maintenance cost for a swale with a tributary area of approximately 2 ha at approximately $2,700. Since almost all maintenance consists of mowing, the cost is fundamentally a function of the mowing frequency. Unit costs developed by SEWRPC are shown in Table 3. In many cases vegetated channels would be used to convey runoff and would require periodic mowing as well, so there may be little additional cost for the water quality component. Since essentially all the activities are related to vegetation management, no special training is required for maintenance personnel.

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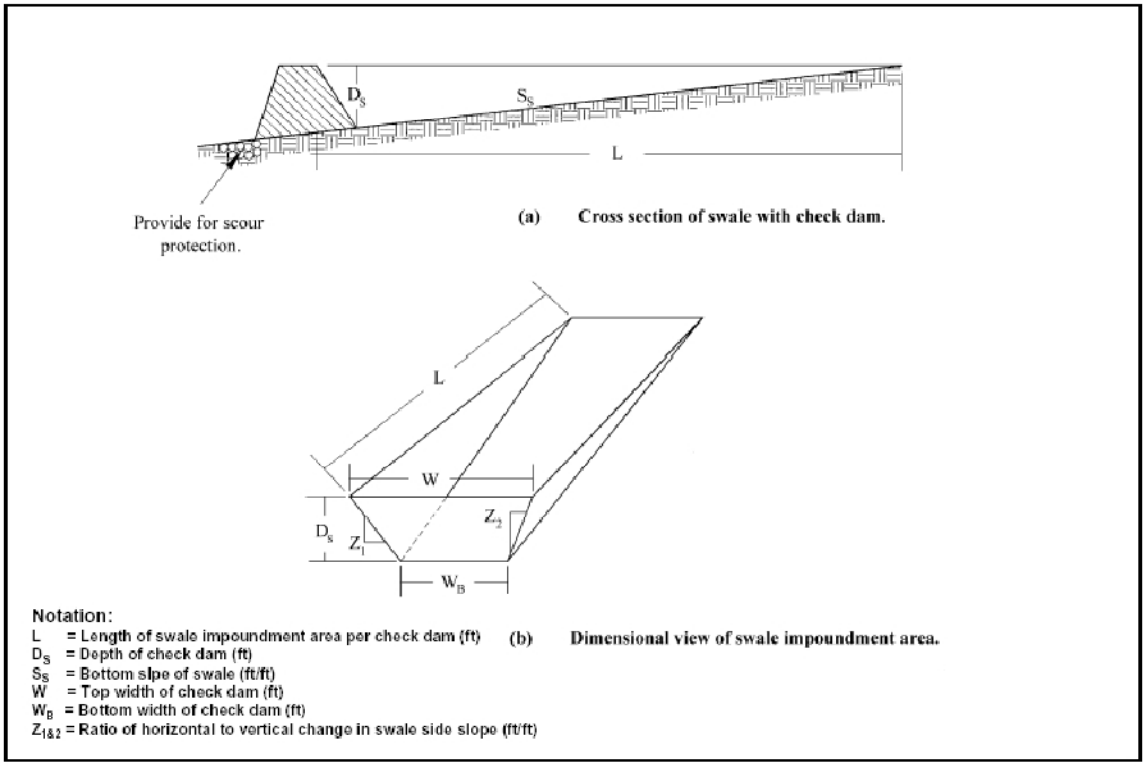

D_S
S_S
L
Provide for scour protection.
(a) Cross section of swale with check dam.
L
W
D_S
Z₁
Z₂
W_B
(b) Dimensional view of swale impoundment area.
Notation:
L = Length of swale impoundment area per check dam (ft)
D_S = Depth of check dam (ft)
S_S = Bottom slpe of swale (ft/ft)
W = Top width of check dam (ft)
W_B = Bottom width of check dam (ft)
$Z_{1\&2}$ = Ratio of horizontal to vertical change in swale side slope (ft/ft)

Design Considerations

- Soil for Infiltration
- Tributary Area
- Slope
- Aesthetics
- Environmental Side-effects

Description

The bioretention best management practice (BMP) functions as a soil and plant-based filtration device that removes pollutants through a variety of physical, biological, and chemical treatment processes. These facilities normally consist of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. The runoff's velocity is reduced by passing over or through buffer strip and subsequently distributed evenly along a ponding area. Exfiltration of the stored water in the bioretention area planting soil into the underlying soils occurs over a period of days.

Targeted Constituents

☑	Sediment	■
☑	Nutrients	▲
☑	Trash	■
☑	Metals	■
☑	Bacteria	■
☑	Oil and Grease	■
☑	Organics	■

Legend *(Removal Effectiveness)*

● Low ■ High

▲ Medium

California Experience

None documented. Bioretention has been used as a stormwater BMP since 1992. In addition to Prince George's County, MD and Alexandria, VA, bioretention has been used successfully at urban and suburban areas in Montgomery County, MD; Baltimore County, MD; Chesterfield County, VA; Prince William County, VA; Smith Mountain Lake State Park, VA; and Cary, NC.

Advantages

- Bioretention provides stormwater treatment that enhances the quality of downstream water bodies by temporarily storing runoff in the BMP and releasing it over a period of four days to the receiving water (EPA, 1999).

- The vegetation provides shade and wind breaks, absorbs noise, and improves an area's landscape.

Limitations

- The bioretention BMP is not recommended for areas with slopes greater than 20% or where mature tree removal would be required since clogging may result, particularly if the BMP receives runoff with high sediment loads (EPA, 1999).

- Bioretention is not a suitable BMP at locations where the water table is within 6 feet of the ground surface and where the surrounding soil stratum is unstable.
- By design, bioretention BMPs have the potential to create very attractive habitats for mosquitoes and other vectors because of highly organic, often heavily vegetated areas mixed with shallow water.
- In cold climates the soil may freeze, preventing runoff from infiltrating into the planting soil.

Design and Sizing Guidelines

- The bioretention area should be sized to capture the design storm runoff.
- In areas where the native soil permeability is less than 0.5 in/hr an underdrain should be provided.
- Recommended minimum dimensions are 15 feet by 40 feet, although the preferred width is 25 feet. Excavated depth should be 4 feet.
- Area should drain completely within 72 hours.
- Approximately 1 tree or shrub per 50 ft^2 of bioretention area should be included.
- Cover area with about 3 inches of mulch.

Construction/Inspection Considerations

Bioretention area should not be established until contributing watershed is stabilized.

Performance

Bioretention removes stormwater pollutants through physical and biological processes, including adsorption, filtration, plant uptake, microbial activity, decomposition, sedimentation and volatilization (EPA, 1999). Adsorption is the process whereby particulate pollutants attach to soil (e.g., clay) or vegetation surfaces. Adequate contact time between the surface and pollutant must be provided for in the design of the system for this removal process to occur. Thus, the infiltration rate of the soils must not exceed those specified in the design criteria or pollutant removal may decrease. Pollutants removed by adsorption include metals, phosphorus, and hydrocarbons. Filtration occurs as runoff passes through the bioretention area media, such as the sand bed, ground cover, and planting soil.

Common particulates removed from stormwater include particulate organic matter, phosphorus, and suspended solids. Biological processes that occur in wetlands result in pollutant uptake by plants and microorganisms in the soil. Plant growth is sustained by the uptake of nutrients from the soils, with woody plants locking up these nutrients through the seasons. Microbial activity within the soil also contributes to the removal of nitrogen and organic matter. Nitrogen is removed by nitrifying and denitrifying bacteria, while aerobic bacteria are responsible for the decomposition of the organic matter. Microbial processes require oxygen and can result in depleted oxygen levels if the bioretention area is not adequately aerated. Sedimentation occurs in the swale or ponding area as the velocity slows and solids fall out of suspension.

The removal effectiveness of bioretention has been studied during field and laboratory studies conducted by the University of Maryland (Davis et al, 1998). During these experiments, synthetic stormwater runoff was pumped through several laboratory and field bioretention areas to simulate typical storm events in Prince George's County, MD. Removal rates for heavy metals and nutrients are shown in Table 1.

Table 1 Laboratory and Estimated Bioretention Davis et al. (1998); PGDER (1993)

Pollutant	Removal Rate
Total Phosphorus	70-83%
Metals (Cu, Zn, Pb)	93-98%
TKN	68-80%
Total Suspended Solids	90%
Organics	90%
Bacteria	90%

Results for both the laboratory and field experiments were similar for each of the pollutants analyzed. Doubling or halving the influent pollutant levels had little effect on the effluent pollutants concentrations (Davis et al, 1998).

The microbial activity and plant uptake occurring in the bioretention area will likely result in higher removal rates than those determined for infiltration BMPs.

Siting Criteria

Bioretention BMPs are generally used to treat stormwater from impervious surfaces at commercial, residential, and industrial areas (EPA, 1999). Implementation of bioretention for stormwater management is ideal for median strips, parking lot islands, and swales. Moreover, the runoff in these areas can be designed to either divert directly into the bioretention area or convey into the bioretention area by a curb and gutter collection system.

The best location for bioretention areas is upland from inlets that receive sheet flow from graded areas and at areas that will be excavated (EPA, 1999). In order to maximize treatment effectiveness, the site must be graded in such a way that minimizes erosive conditions as sheet flow is conveyed to the treatment area. Locations where a bioretention area can be readily incorporated into the site plan without further environmental damage are preferred. Furthermore, to effectively minimize sediment loading in the treatment area, bioretention only should be used in stabilized drainage areas.

Additional Design Guidelines

The layout of the bioretention area is determined after site constraints such as location of utilities, underlying soils, existing vegetation, and drainage are considered (EPA, 1999). Sites with loamy sand soils are especially appropriate for bioretention because the excavated soil can be backfilled and used as the planting soil, thus eliminating the cost of importing planting soil.

The use of bioretention may not be feasible given an unstable surrounding soil stratum, soils with clay content greater than 25 percent, a site with slopes greater than 20 percent, and/or a site with mature trees that would be removed during construction of the BMP.

Bioretention can be designed to be off-line or on-line of the existing drainage system (EPA, 1999). The drainage area for a bioretention area should be between 0.1 and 0.4 hectares (0.25 and 1.0 acres). Larger drainage areas may require multiple bioretention areas. Furthermore, the maximum drainage area for a bioretention area is determined by the expected rainfall intensity and runoff rate. Stabilized areas may erode when velocities are greater than 5 feet per second (1.5 meter per second). The designer should determine the potential for erosive conditions at the site.

The size of the bioretention area, which is a function of the drainage area and the runoff generated from the area is sized to capture the water quality volume.

The recommended minimum dimensions of the bioretention area are 15 feet (4.6 meters) wide by 40 feet (12.2 meters) long, where the minimum width allows enough space for a dense, randomly-distributed area of trees and shrubs to become established. Thus replicating a natural forest and creating a microclimate, thereby enabling the bioretention area to tolerate the effects of heat stress, acid rain, runoff pollutants, and insect and disease infestations which landscaped areas in urban settings typically are unable to tolerate. The preferred width is 25 feet (7.6 meters), with a length of twice the width. Essentially, any facilities wider than 20 feet (6.1 meters) should be twice as long as they are wide, which promotes the distribution of flow and decreases the chances of concentrated flow.

In order to provide adequate storage and prevent water from standing for excessive periods of time the ponding depth of the bioretention area should not exceed 6 inches (15 centimeters). Water should not be left to stand for more than 72 hours. A restriction on the type of plants that can be used may be necessary due to some plants' water intolerance. Furthermore, if water is left standing for longer than 72 hours mosquitoes and other insects may start to breed.

The appropriate planting soil should be backfilled into the excavated bioretention area. Planting soils should be sandy loam, loamy sand, or loam texture with a clay content ranging from 10 to 25 percent.

Generally the soil should have infiltration rates greater than 0.5 inches (1.25 centimeters) per hour, which is typical of sandy loams, loamy sands, or loams. The pH of the soil should range between 5.5 and 6.5, where pollutants such as organic nitrogen and phosphorus can be adsorbed by the soil and microbial activity can flourish. Additional requirements for the planting soil include a 1.5 to 3 percent organic content and a maximum 500 ppm concentration of soluble salts.

Soil tests should be performed for every 500 cubic yards (382 cubic meters) of planting soil, with the exception of pH and organic content tests, which are required only once per bioretention area (EPA, 1999). Planting soil should be 4 inches (10.1 centimeters) deeper than the bottom of the largest root ball and 4 feet (1.2 meters) altogether. This depth will provide adequate soil for the plants' root systems to become established, prevent plant damage due to severe wind, and provide adequate moisture capacity. Most sites will require excavation in order to obtain the recommended depth.

Planting soil depths of greater than 4 feet (1.2 meters) may require additional construction practices such as shoring measures (EPA, 1999). Planting soil should be placed in 18 inches or greater lifts and lightly compacted until the desired depth is reached. Since high canopy trees may be destroyed during maintenance the bioretention area should be vegetated to resemble a terrestrial forest community ecosystem that is dominated by understory trees. Three species each of both trees and shrubs are recommended to be planted at a rate of 2500 trees and shrubs per hectare (1000 per acre). For instance, a 15 foot (4.6 meter) by 40 foot (12.2 meter) bioretention area (600 square feet or 55.75 square meters) would require 14 trees and shrubs. The shrub-to-tree ratio should be 2:1 to 3:1.

Trees and shrubs should be planted when conditions are favorable. Vegetation should be watered at the end of each day for fourteen days following its planting. Plant species tolerant of pollutant loads and varying wet and dry conditions should be used in the bioretention area.

The designer should assess aesthetics, site layout, and maintenance requirements when selecting plant species. Adjacent non-native invasive species should be identified and the designer should take measures, such as providing a soil breach to eliminate the threat of these species invading the bioretention area. Regional landscaping manuals should be consulted to ensure that the planting of the bioretention area meets the landscaping requirements established by the local authorities. The designers should evaluate the best placement of vegetation within the bioretention area. Plants should be placed at irregular intervals to replicate a natural forest. Trees should be placed on the perimeter of the area to provide shade and shelter from the wind. Trees and shrubs can be sheltered from damaging flows if they are placed away from the path of the incoming runoff. In cold climates, species that are more tolerant to cold winds, such as evergreens, should be placed in windier areas of the site.

Following placement of the trees and shrubs, the ground cover and/or mulch should be established. Ground cover such as grasses or legumes can be planted at the beginning of the growing season. Mulch should be placed immediately after trees and shrubs are planted. Two to 3 inches (5 to 7.6 cm) of commercially-available fine shredded hardwood mulch or shredded hardwood chips should be applied to the bioretention area to protect from erosion.

Maintenance

The primary maintenance requirement for bioretention areas is that of inspection and repair or replacement of the treatment area's components. Generally, this involves nothing more than the routine periodic maintenance that is required of any landscaped area. Plants that are appropriate for the site, climatic, and watering conditions should be selected for use in the bioretention cell. Appropriately selected plants will aide in reducing fertilizer, pesticide, water, and overall maintenance requirements. Bioretention system components should blend over time through plant and root growth, organic decomposition, and the development of a natural soil horizon. These biologic and physical processes over time will lengthen the facility's life span and reduce the need for extensive maintenance.

Routine maintenance should include a biannual health evaluation of the trees and shrubs and subsequent removal of any dead or diseased vegetation (EPA, 1999). Diseased vegetation should be treated as needed using preventative and low-toxic measures to the extent possible. BMPs have the potential to create very attractive habitats for mosquitoes and other vectors because of highly organic, often heavily vegetated areas mixed with shallow water. Routine inspections for areas of standing water within the BMP and corrective measures to restore proper infiltration rates are necessary to prevent creating mosquito and other vector habitat. In addition, bioretention BMPs are susceptible to invasion by aggressive plant species such as cattails, which increase the chances of water standing and subsequent vector production if not routinely maintained.

In order to maintain the treatment area's appearance it may be necessary to prune and weed. Furthermore, mulch replacement is suggested when erosion is evident or when the site begins to look unattractive. Specifically, the entire area may require mulch replacement every two to three years, although spot mulching may be sufficient when there are random void areas. Mulch replacement should be done prior to the start of the wet season.

New Jersey's Department of Environmental Protection states in their bioretention systems standards that accumulated sediment and debris removal (especially at the inflow point) will normally be the primary maintenance function. Other potential tasks include replacement of dead vegetation, soil pH regulation, erosion repair at inflow points, mulch replenishment, unclogging the underdrain, and repairing overflow structures. There is also the possibility that the cation exchange capacity of the soils in the cell will be significantly reduced over time. Depending on pollutant loads, soils may need to be replaced within 5-10 years of construction (LID, 2000).

Cost

Construction Cost

Construction cost estimates for a bioretention area are slightly greater than those for the required landscaping for a new development (EPA, 1999). A general rule of thumb (Coffman, 1999) is that residential bioretention areas average about $3 to $4 per square foot, depending on soil conditions and the density and types of plants used. Commercial, industrial and institutional site costs can range between $10 to $40 per square foot, based on the need for control structures, curbing, storm drains and underdrains.

Retrofitting a site typically costs more, averaging $6,500 per bioretention area. The higher costs are attributed to the demolition of existing concrete, asphalt, and existing structures and the replacement of fill material with planting soil. The costs of retrofitting a commercial site in Maryland, Kettering Development, with 15 bioretention areas were estimated at $111,600.

In any bioretention area design, the cost of plants varies substantially and can account for a significant portion of the expenditures. While these cost estimates are slightly greater than those of typical landscaping treatment (due to the increased number of plantings, additional soil excavation, backfill material, use of underdrains etc.), those landscaping expenses that would be required regardless of the bioretention installation should be subtracted when determining the net cost.

Perhaps of most importance, however, the cost savings compared to the use of traditional structural stormwater conveyance systems makes bioretention areas quite attractive financially. For example, the use of bioretention can decrease the cost required for constructing stormwater conveyance systems at a site. A medical office building in Maryland was able to reduce the amount of storm drain pipe that was needed from 800 to 230 feet - a cost savings of $24,000 (PGDER, 1993). And a new residential development spent a total of approximately $100,000 using bioretention cells on each lot instead of nearly $400,000 for the traditional stormwater ponds that were originally planned (Rappahanock,). Also, in residential areas, stormwater management controls become a part of each property owner's landscape, reducing the public burden to maintain large centralized facilities.

Maintenance Cost

The operation and maintenance costs for a bioretention facility will be comparable to those of typical landscaping required for a site. Costs beyond the normal landscaping fees will include the cost for testing the soils and may include costs for a sand bed and planting soil.

References and Sources of Additional Information

Coffman, L.S., R. Goo and R. Frederick, 1999: Low impact development: an innovative alternative approach to stormwater management. Proceedings of the 26th Annual Water Resources Planning and Management Conference ASCE, June 6-9, Tempe, Arizona.

Davis, A.P., Shokouhian, M., Sharma, H. and Minami, C., "Laboratory Study of Biological Retention (Bioretention) for Urban Stormwater Management," *Water Environ. Res.*, 73(1), 5-14 (2001).

Davis, A.P., Shokouhian, M., Sharma, H., Minami, C., and Winogradoff, D. "Water Quality Improvement through Bioretention: Lead, Copper, and Zinc," *Water Environ. Res.*, accepted for publication, August 2002.

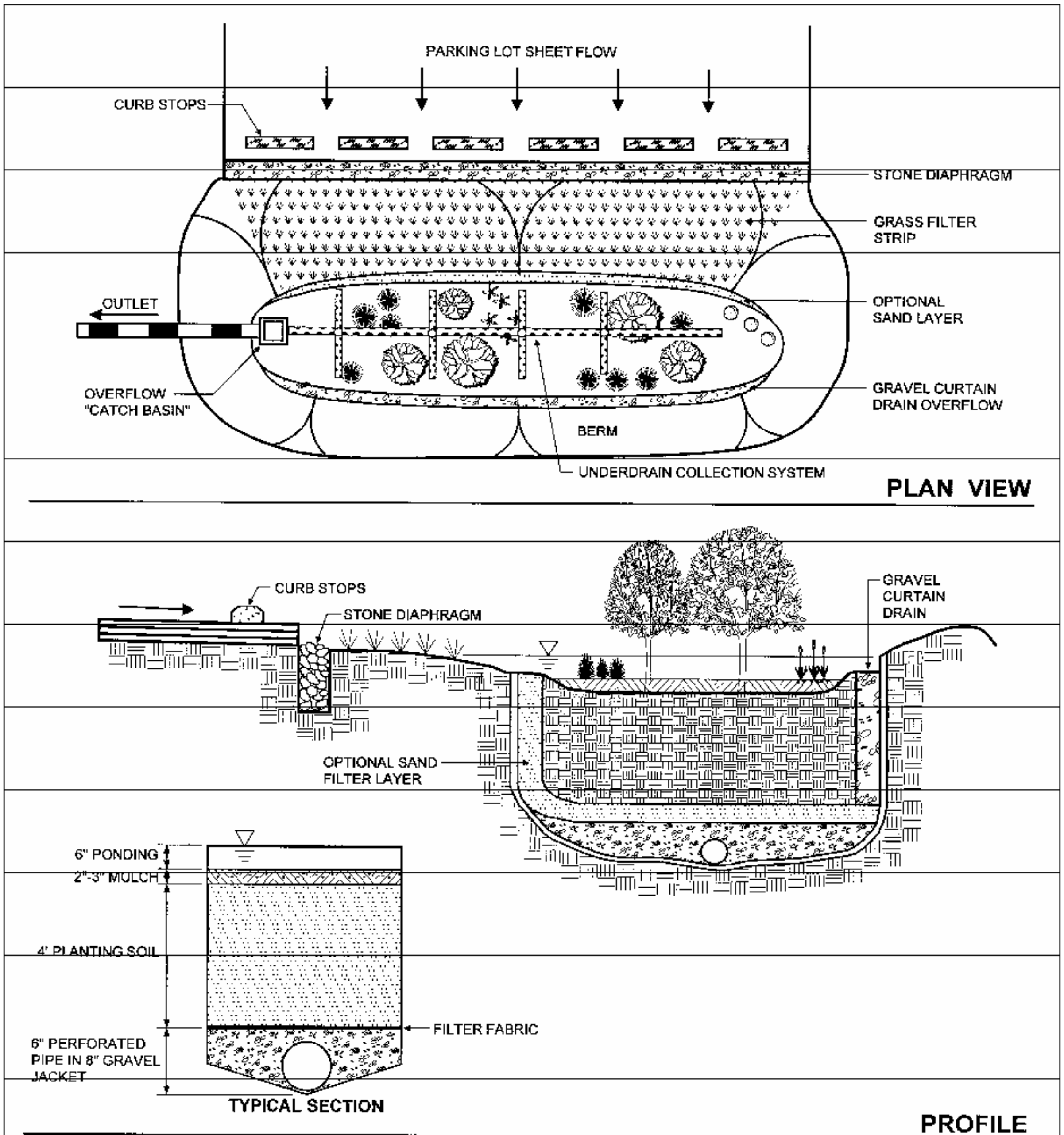
Kim, H., Seagren, E.A., and Davis, A.P., "Engineered Bioretention for Removal of Nitrate from Stormwater Runoff," *WEFTEC 2000 Conference Proceedings on CDROM Research Symposium, Nitrogen Removal*, Session 19, Anaheim CA, October 2000.

Hsieh, C.-h. and Davis, A.P. "Engineering Bioretention for Treatment of Urban Stormwater Runoff," *Watersheds 2002, Proceedings on CDROM Research Symposium*, Session 15, Ft. Lauderdale, FL, Feb. 2002.

Prince George's County Department of Environmental Resources (PGDER), 1993. Design Manual for Use of *Bioretention in Stormwater Management*. Division of Environmental Management, Watershed Protection Branch. Landover, MD.

U.S. EPA Office of Water, 1999. Stormwater Technology Fact Sheet: Bioretention. EPA 832-F-99-012.

Weinstein, N. Davis, A.P. and Veeramachaneni, R. "Low Impact Development (LID) Stormwater Management Approach for the Control of Diffuse Pollution from Urban Roadways," *5th International Conference Diffuse/Nonpoint Pollution and Watershed Management Proceedings*, C.S. Melching and Emre Alp, Eds. 2001 International Water Association



Schematic of a Bioretention Facility (MDE, 2000)

ATTACHMENT E

Geotechnical Certification Sheet

The design of stormwater treatment and other control measures proposed in this plan requiring specific soil infiltration characteristics and/or geological conditions has been reviewed and approved by a registered Civil Engineer, Geotechnical Engineer, or Geologist in the State of California.

______________________________ ____________

Name Date

GEOCON
INCORPORATED
GEOTECHNICAL ■ ENVIRONMENTAL ■ MATERIALS

Project No. 07511-32-02
November 27, 2012

Capstone Partners, LLC
1545 Faraday Avenue
Carlsbad, California 92008

Attention: Mr. Mark Hayden

Subject: SUPPLEMENTAL GEOTECHNICAL RECOMMENDATIONS
WARNER RANCH
SAN DIEGO COUNTY, CALIFORNIA

References:
1. *Geologic Reconnaissance, Warner Ranch, San Diego County, California,* prepared by Geocon Incorporated, dated March 3, 2011.
2. *County of San Diego Preliminary Grading Plan, Warner Ranch, Tract No. 5508 rp14*, Sheets 1 through 10, prepared by Shapouri & Associates, dated November 30, 2012.

Dear Mr. Hayden:

We have prepared this correspondence to document our recent discussions with Mr. Mike Shapouri of Shapouri and Associates regarding the proposed water quality basins at the subject site. Based on the soil and geologic conditions, groundwater elevations, and close proximity to structures, we recommend the water quality basins incorporate an impermeable liner in the design which will prevent water infiltration into the underlying soils. The strength and thickness of the membrane, and construction method should be adequate to assure that the liner will not be compromised throughout the life of the system. In addition, civil engineering provisions should be implemented to assure that the capacity of the system is never exceeded resulting in over topping of the liner or basin.

Should you have any questions regarding this correspondence, or if we may be of further service, please contact the undersigned at your convenience.

Very truly yours,

GEOCON INCORPORATED

Trevor E. Myers
RCE 63773

REGISTERED PROFESSIONAL ENGINEER
TREVOR E. MYERS
No. RCE63773
CIVIL
STATE OF CALIFORNIA

David B. Evans
CEG 1860

PROFESSIONAL GEOLOGIST
DAVID B. EVANS
No. 1860
CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

(e-mail) Addressee
(e-mail) Shapouri & Associates
Attention: Mr. Mike Shapouri

6960 Flanders Drive ■ San Diego, California 92121-2974 ■ Telephone 858.558.6900 ■ Fax 858.558.6159

ATTACHMENT F

Maintenance Plan

Maintenance Plan Funding

The proposed hydromodification facilities at Warner Ranch will fall under second maintenance mechanisms, as defined within the County of San Diego"Standard Urban Storm Water Mitigation Plan Requirements for Development Aplications", dated January, 2011.

Second Category

The on-site BMPs constructed during the ultimate build-out will fall under the second category maintenance mechanisms, requiring that a Stormwater Facilities Maintenance Agreement, with Easement and Covenants be entered into between the owner and the County of San Diego, obliging the owner/HOA to maintain the project category two BMPs into perpetuity. Prior to recordation of the agreement, the owner/ developer will provide the County with security to back up the maintenance agreement, which shall remain in place for an interim period of 5 years. The amount of the security shall equal the estimated cost of 2 years of maintenance activities.

The BMPs (vegetated swale) servicing the public right-of-way (SR76) will ultimately be maintained by caltrans or the owner/HOA. Agreements for maintenance will be secured prior to issuance of building permit.

PRIVATE TREATMENT CONTROL BMP
OPERATION AND MAINTENANCE VERIFICATION FORM

BIOFILTER

1. Transcribe the following information from your notification letter and make corrections as necessary:

Permit No.:

BMP Location:

Responsible Party: WHP Warner Ranch L.P.

Phone Number: (760) 804-6900 ☐ *Check here for Phone Number Change*

Responsible Party Address: 1545 Faraday, Carlsbad, CA 92008

Number Street Name & Suffix City/Zip

☐ *Check here for Address Change*

2. Using the Table below, please describe the inspections and maintenance activities that have been conducted during the last year, and date(s) maintenance was performed. Under "Results of Inspection," indicate whether maintenance was required based on each inspection, and if so, what type of maintenance. If maintenance was required, provide the date maintenance was conducted and description of the maintenance. Refer to the back of this sheet for information describing typical maintenance indicators and maintenance activities. If no maintenance was required based on the inspection results, state "no maintenance required."

Date of Inspection	Results of Inspection	Date Maintenance Completed and Description of Maintenance Conducted

3. Attach copies of available supporting documents (photographs, copies of maintenance contracts, and/or maintenance records).

4. Sign the bottom of the form and return to:

County of San Diego Watershed Protection Program
Treatment Control BMP Tracking
5201 Ruffin Road, Suite P, MS 0326
San Diego, CA 92123

Signature of Responsible Party **Print Name** **Date**

PRIVATE TREATMENT CONTROL BMP
OPERATION AND MAINTENANCE VERIFICATION FORM
BIOFILTER

Biofilters Include:

☐ **Vegetated Filter Strip** ☑ **Vegetated Swale** ☑ **Bioretention Facility**

Routine maintenance is needed to ensure that flow is unobstructed, that erosion is prevented, and that soils are held together by plant roots and are biologically active. Typical maintenance consists of the following:

Bioretention BMPs Inspection and Maintenance Checklist	
Typical Maintenance Indicators	**Typical Maintenance Actions**
Accumulation of sediment, litter, or debris	Remove and properly dispose of accumulated materials, without damage to the vegetation.
Poor vegetation establishment	Examine the vegetation to ensure that it is healthy and dense enough to provide filtering and to protect soils from erosion. Replenish mulch as necessary, remove fallen leaves and debris, prune large shrubs or trees, and mow turf areas.
Overgrown vegetation	Mow or trim as appropriate, but not less than the design height of the vegetation (typically 4-6 inches for grass). Confirm that irrigation is adequate and not excessive and that sprays do not directly enter overflow grates. Replace dead plants and remove noxious and invasive vegetation.
Erosion due to concentrated irrigation flow	Repair/re-seed eroded areas and adjust the irrigation system.
Erosion due to concentrated stormwater runoff flow	Repair/re-seed eroded areas and make appropriate corrective measures such as adding erosion control blankets, adding stone at flow entry points, or re-grading where necessary.
Standing water (BMP not draining)	Abate any potential vectors by filling holes in the ground in and around the biofilter facility and by insuring that there are no areas where water stands longer than 48 hours following a storm. If mosquito larvae are present and persistent, contact the San Diego County Vector Control Program at (858) 694-2888. Mosquito larvicides should be applied only when absolutely necessary and then only by a licensed individual or contractor.
Obstructed inlet or outlet structure	Clear obstructions.
Damage to structural components such as weirs, inlet, or outlet structures	Repair or replace as applicable.

ATTACHMENT G

Treatment Control BMP Certification

COUNTY OF SAN DIEGO
DEPARTMENT OF PUBLIC WORKS
POST-CONSTRUCTION TRACKING AND
INVENTORY REPORT

General Project Information

Permit Number: TM 5508 SWMP Category (Major/Minor): Major
Location / Address: Pala Road/State Route 76
Engineer of Work: M. H. Shapouri State Registration Number: C52794
Company Name: Shapouri & Associates
Address: P.O. Box 676221 Rancho Santa Fe, CA 92062
Email Address: Mike@shapouri.com
Phone Number: 858-756-8340

Priority Development Project – Step 1: ____________

Percent Impervious Before Construction: % 0.5
Percent Impervious After Construction: % 13.8

Project Disturbed Area: approx. 145.76 Acres

Hydromodification Management – Step 3:
Yes ☑ or No ☐

Primary or Secondary Pollutants of Concerns – Step 4 *(check all that apply)*
☑ Sediment
☑ Nutrients
☑ Organic Compounds
☑ Bacteria and Viruses
☑ Trash and Debris
☑ Oxygen Demanding Substances
☑ Oil and Grease
☑ Pesticides

Project Specific Site Design, LID and Source Control BMPs

All selected Site Layout Strategies, LID, and Source Control BMPs must be shown on the Plan.

Site Layout Strategies – Step 5 *(check all that apply)*
☑ Limitation of Development Envelope
☑ Minimization of imperviousness
☑ Setbacks from creeks, wetlands, and riparian habitats
☑ Preservation of Natural Drainages
☑ Using drainage as a design element

Disperse Runoff from Impervious Surfaces to Pervious – Step 5 *(check all that apply)*
☑ Street and Road Design
☑ Driveway, Sidewalk, Bikepath Design
☑ Landscape Design
☑ Parking Lot Design
☑ Building Design
☑ Direct Runoff to Treatment BMP(s)

Source BMPs – Step 6 *(check all that apply)*

- ☑ Stormdrain Signage and Stenciling
- ☐ Trash Storage Areas
- ☑ Private Road Drainage System
- ☐ Dock Areas
- ☐ Vehicle Wash Areas
- ☐ Equipment Wash Areas
- ☐ Fueling Areas
- ☐ Outdoor Storage Areas
- ☑ Efficient Landscape Irrigation Design
- ☑ Residential Driveways & Guest Parking
- ☐ Maintenance Bays
- ☐ Outdoor Processing Areas
- ☑ Parking Areas

Post-construction Treatment Control BMP Information

Responsible Party for Maintenance – Step 8:
Name ____ Phone Number (___) _____________
Street Number __________ Street Name ____
City _____________________ State ___________________________ Zip_______________
Email Address: ____

Project Maintenance Category (1, 2, 3 or 4): ___

Project Specific Treatment Control BMPs

BMP Identifier*	BMP Type	BMP Pollutant of Concern Efficiency (H,M,L) – Table 11	Final Construction Date *(to be completed by County inspector)*	Final Construction Inspector Name *(to be completed by County inspector)*

* For location of BMP's, see approved Record Plan dated _______________, plan sheet ____.

Record Plan Certification

I certify that the above items for this project are in substantial conformance with the approved plans. Yes ☐ or No ☐

Please sign your name and seal. [SEAL]

Print Name: ___________________________________

Sign Name: ___________________________________