Appendix J. Supporting Analysis for LID Scenarios

The analysis of two scenarios representing different levels of LID implementation was conducted to support the development of watershed management plan recommendations, discussed in Sections 6.1 and 7.4.1. One is based on basic adoption of LID practices as specified by the 2007 Order (called "*Basic LID*"), and another based on a higher level of LID implementation (called "*Enhanced LID*"). The degree to which LID practices will be required in the future depends on many factors. There is currently some uncertainty in the Agua Hedionda watershed about future requirements – implementation of pending TMDLs may include a stormwater management component, with recommendation for specific BMPs to optimize reductions for target pollutants. Communities may elect to implement LID to varying degrees. The modeled LID scenarios should not be interpreted as extremes in design, nor should the results be seen as absolute. Many other scenarios with varying degrees of LID implementation could be conceived, and pollutant removal performance is based on central tendencies from monitoring studies, but inherently contains some uncertainty. The scenarios also use generic site assumptions, but in reality each site is unique and presents its own opportunities for adoption of LID practices.

Assumptions

Assumptions for each of the two scenarios were developed for the following representative land uses as shown in Table J-1. The sites were conceptualized as a typical unit of land use draining to a peak flow control structure. For instance, a 10-acre strip shopping center was assumed to be treated by a single peak control structure. Single family residential developments can be quite large, but it was assumed that 20 acres represents a typical drainage area to a peak control structure. The multi-family and industrial sites were assumed to be somewhat larger.

Table J-1. *Basic* and *Enhanced LID* Scenario Land Use Categories

Land Use	Percent Impervious Area	Comments	Assumed Site Area
Medium Density Residential	33%	Single family homes	20 acres
Multi-family Residential	65%	Mix of large buildings, roads/parking areas, and pervious surfaces distributed throughout the site	40 acres
Commercial	85%	Small strip shopping center	10 acres
Industrial/Warehouse	72%	Industrial facility in center of site, surrounding by access roads and parking areas	60 acres

Treatment practices at each site were selected based on several criteria – current stormwater management requirements, physical environment constraints, site-specific feasibility, and cost considerations. The *Basic LID* scenario is based on the combined use of vegetated swales (or bioswales) for water quality treatment of part of the site, and an extended dry detention basin treating all of the site, providing both hydrologic control for the 2001/2007 Order requirements, as well as water quality treatment benefits. The site assumptions and configurations for the *Basic LID* scenario are identical to those used in the Agua Hedionda Watershed Modeling and Geomorphic Analysis Report (Tetra Tech, 2008b) for the same land uses. The *Enhanced LID* scenario begins with the *Basic LID* scenario assumptions, but assumes a higher level of treatment, balancing feasibility and cost considerations. For instance, bioretention is not used due to the uncertainty regarding proper vegetation and potential increased cost if an underdrain system is required. Porous pavement was included but not used extensively, again due to uncertainty about infiltration. Large cisterns for irrigation water were included for the Multi-family and Commercial classes, where the combination of large roof surface area and centralized irrigation systems are assumed to make the practice more cost effective. Some of the scenarios assume more significant impervious area reductions as well. Specific changes implemented in the *Enhanced LID* scenario include:

- Medium Density Residential – A cluster design is used, grouping the housing units closer together on smaller lots, and leaving one-third of the site as undeveloped open space. Impervious area is reduced by decreasing driveway length, sidewalk use, and overall road footprint.
- Multifamily Residential – Impervious area is reduced somewhat by more efficient layout. Porous pavement is used for all sidewalks. The swales treat a greater proportion of the site. Large cisterns capture roof runoff, and reuse the water for irrigation.
- Commercial – Porous pavement is used for large fraction of the parking area. Large cisterns capture roof runoff, and reuse the water for irrigation.
- Industrial – The most challenging site, with layout constraints and little economic incentive for cisterns for irrigation. Porous pavement parking spaces is assumed (a small fraction of the total paved surface), and the swales treat a greater proportion of the site.

More detailed information about site layout assumptions for *Basic LID* and *Enhanced LID* is shown in Table J-2 and Table J-3. In the *Basic LID* scenario, there are two types of drainage areas – one where runoff is captured by a vegetated swale and then conveyed to an extended dry detention basin (EDD) for peak flow control and further water quality treatment, and another where runoff is captured and treated by the EDD only. The EDD is the same physical basin in both drainage areas, but it is assumed that only part of the site can reasonably be laid out to drain to a vegetated swale. The table shows the relative percentages in each drainage area type; for instance, swales treat 50 percent of the site for Medium Density Residential, while for Commercial, swales treat only 30 percent of the site. The Commercial site, at 85 percent impervious area, has limited space for a swale so a smaller percentage was used; on the other hand, single-family residential sites are more amenable to swale placement, which can be located adjacent to roads.

The *Enhanced LID* scenario table shows how adjustments to site design that increase the use of LID practices affects the sites' layouts. For instance, the use of a cluster design reduces road area by compacting the development area, and allows for the addition of undisturbed open space land cover, which has reduced pollutant loading rates. Note that the use of porous pavement is not listed in the BMP Treatment column, but as a land cover change (i.e., traditional pavement converted to porous pavement). Porous pavement does not typically receive runoff from adjacent surfaces, so it is modeled as a surface that provides treatment to itself. Cistern storage is assumed to be used for irrigation and contribute no direct surface runoff loads; however, a fraction of annual runoff is assumed to bypass the cisterns when they fill during large storm events, and the bypassed runoff is conveyed to the EDD.

The site layouts and BMP configurations were then modeled using the Site Evaluation Tool (SET). The SET was also used to estimate the benefits of the stormwater BMP retrofit sites as discussed in Appendix F, and more information about the SET itself, the development of loading rates from the LSPC model, and BMP performance assumptions are discussed there. In addition to calculating annual runoff and pollutant loads, the SET provides scoping-level storm event hydrographs for site outflow, and includes an estimation of BMP influence on the hydrographs. The SET was configured to represent storm event depths for the Agua Hedionda watershed, and the EDD influence on storm events was modified to represent 2007 Order requirements.

Table J-2. *Basic LID* Scenario Site Configuration

Medium Density Residential (33.8% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site	
		Swale → EDD*	EDD Only*
House	11.2%	5.6%	5.6%
Driveway	6.8%	3.4%	3.4%
Sidewalk	4.6%	2.3%	2.3%
Road	11.2%	5.6%	5.6%
Lawn	66.2%	33.1%	33.1%
Undisturbed Open Space	0.0%		
Total:	100.0%	50.0%	50.0%

Multi-family Residential (65% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site	
		Swale → EDD*	EDD Only*
Building	30.0%	7.5%	22.5%
Sidewalk	5.0%	1.3%	3.7%
Pavement (access, parking)	30.0%	7.5%	22.5%
Lawn	35.0%	8.7%	26.3%
Total:	100.0%	25.0%	75.0%

Commercial (85% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site	
		Swale → EDD*	EDD Only*
Building	42.5%	12.7%	29.8%
Pavement	42.5%	12.8%	29.7%
Lawn	15.0%	4.5%	10.5%
Total:	100.0%	30.0%	70.0%

Industrial (72% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site	
		Swale → EDD*	EDD Only*
Building	48.0%	14.4%	33.6%
Pavement	24.0%	7.2%	16.8%
Lawn	28.0%	8.4%	19.6%
Total:	100.0%	30.0%	70.0%

*Notes
"Swale → EDD" signifies a drainage area where a vegetated swale conveys treated runoff to an Extended Dry Detention Basin
"EDD Only" signifies a drainage area where runoff goes directly to an Extended Dry Detention Basin

Table J-3. *Enhanced LID* Scenario Site Configuration

Medium Density Residential (24.8% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site	
		Swale → EDD*	EDD Only*
House	10.2%	5.1%	5.1%
Porous Pavement (patios)	1.0%	0.5%	0.5%
Driveway	4.6%	2.3%	2.3%
Sidewalk	1.5%	0.8%	0.7%
Road	7.5%	3.7%	3.8%
Lawn	42.2%	21.1%	21.1%
Undisturbed Open Space	33.0%		33.0%
Total:	100.0%	33.5%	66.5%

Multi-family Residential (60% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site		
		Swale → EDD*	EDD Only*	Cistern → EDD*
Building	30.0%			30.0%
Porous Pavement (sidewalk)	5.0%	2.5%	2.5%	
Pavement (access, parking)	25.0%	12.5%	12.5%	
Lawn	40.0%	20.0%	20.0%	
Total:	100.0%	35.0%	35.0%	30.0%

Commercial (85% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site		
		Swale → EDD*	EDD Only*	Cistern → EDD*
Building	42.5%			42.5%
Pavement	21.3%	6.4%	14.9%	
Porous Pavement (parking)	21.2%		21.2%	
Lawn	15.0%	4.5%	10.5%	
Total:	100.0%	10.9%	46.6%	42.5%

Industrial (72% Impervious)

Site Component	Total Percent	BMP Treatment Percent of Site	
		Swale → EDD*	EDD Only*
Building	48.0%	28.8%	19.2%
Pavement	18.0%	10.8%	7.2%
Porous Pavement (parking)	6.0%		6.0%
Lawn	28.0%	16.8%	11.2%
Total:	100.0%	56.4%	43.6%

*Notes
"Swale → EDD" signifies a drainage area where a vegetated swale conveys treated runoff to an Extended Dry Detention Basin
"EDD Only" signifies a drainage area where runoff goes directly to an Extended Dry Detention Basin
"Cistern → EDD" signifies a drainage area where overflow from a Cistern is conveyed to an Extended Dry Detention Basin

Results

As seen in Table J-4 and Table J-5, the *Basic LID* scenario is projected to significantly reduce sediment loads by about 60 – 70 percent, and fecal coliform loads by almost 90 percent. However, nutrient load reductions are considerably less, 35 – 45 percent for nitrogen and 25 – 30 percent for phosphorus. The *Enhanced LID* scenario improves sediment removal for some of the land uses, but shows dramatic gains in nutrient removal – about 50 – 65 percent for nitrogen and 30 – 60 percent for phosphorus.

Most of the removal is accomplished by BMP treatment, but the land cover changes implemented in Medium Density Residential (decrease in impervious cover and protection of undeveloped open space) and Multi-family Residential (decrease in impervious cover) also result in load reductions for most of the parameters (Table J-5). For instance, in the Medium Density Residential scenarios, the post-developed load (prior to BMP treatment) for total nitrogen under *Basic LID* is 71 lb/yr, while the *Enhanced LID* scenario is reduced to 54 lb/yr. This demonstrates the importance of load reduction at the source.

Figure J-1 through Figure J-8 show the estimated hydrographs for each land use and scenario combination for the 2-yr, 5-yr, and 10-yr 24-hr storm events. The most dramatic differences between the *Basic* and *Enhanced LID* scenarios are seen in the Multi-family Residential and Commercial land use simulations. Both of the land uses utilized large cisterns, adding significant additional storage volume that mitigates both the duration and peak during the most intense periods of rainfall.

Further discussion of results can be found in Sections 6.1 and 7.4.1.

Table J-4. Predicted Loads for Post-Developed Conditions (before and after treatment) for *Basic* and *Enhanced LID* Scenarios

Medium Density Residential	*Basic LID*		*Enhanced LID*	
	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP
Total Nitrogen (lb/yr)	71	39	54	30
Total Phosphorus (lb/yr)	5.61	3.95	4.35	3.08
Sediment (ton/yr)	27.4	8.3	22.6	7.9
Fecal Coliform (# x 10^9/yr)	1,043	125	758	90

Multi-family Residential	*Basic LID*		*Enhanced LID*	
	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP
Total Nitrogen (lb/yr)	201	131	192	70
Total Phosphorus (lb/yr)	17.9	13.5	16.9	7.2
Sediment (ton/yr)	32.5	13.2	36.1	10.4
Fecal Coliform (# x 10^9/yr)	3,458	415	3,239	225

Commercial	*Basic LID*		*Enhanced LID*	
	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP
Total Nitrogen (lb/yr)	67	42	67	28
Total Phosphorus (lb/yr)	6.9	5.1	6.9	3.2
Sediment (ton/yr)	5.8	2.2	5.8	1.9
Fecal Coliform (# x 10^9/yr)	574	69	574	14

Industrial	*Basic LID*		*Enhanced LID*	
	Pre-BMP	Post-BMP	Pre-BMP	Post-BMP
Total Nitrogen (lb/yr)	345	218	345	179
Total Phosphorus (lb/yr)	33.9	25.2	33.9	23.1
Sediment (ton/yr)	45.5	17.6	45.5	12
Fecal Coliform (# x 10^9/yr)	3,765	452	3,765	450

Table J-5. Percent Reduction of Loads for *Basic* and *Enhanced LID* Scenarios

Medium Density Residential	Percent Reduction of Load	
	Basic LID	***Enhanced LID***
Total Nitrogen	45%	58%
Total Phosphorus	30%	45%
Sediment	70%	71%
Fecal Coliform	88%	91%

Multi-family Residential	Percent Reduction of Load	
	Basic LID	***Enhanced LID***
Total Nitrogen	35%	65%
Total Phosphorus	25%	60%
Sediment	59%	68%
Fecal Coliform	88%	93%

Commercial	Percent Reduction of Load	
	Basic LID	***Enhanced LID***
Total Nitrogen	37%	58%
Total Phosphorus	26%	54%
Sediment	62%	67%
Fecal Coliform	88%	98%

Industrial	Percent Reduction of Load	
	Basic LID	**Enhanced LID**
Total Nitrogen	37%	48%
Total Phosphorus	26%	32%
Sediment	61%	74%
Fecal Coliform	88%	88%

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	9.84	31.78	2.72
5-yr 24-hr storm (cfs)	30.46	60.87	20.51
10-yr 24-hr storm (cfs)	41.48	72.22	30.83

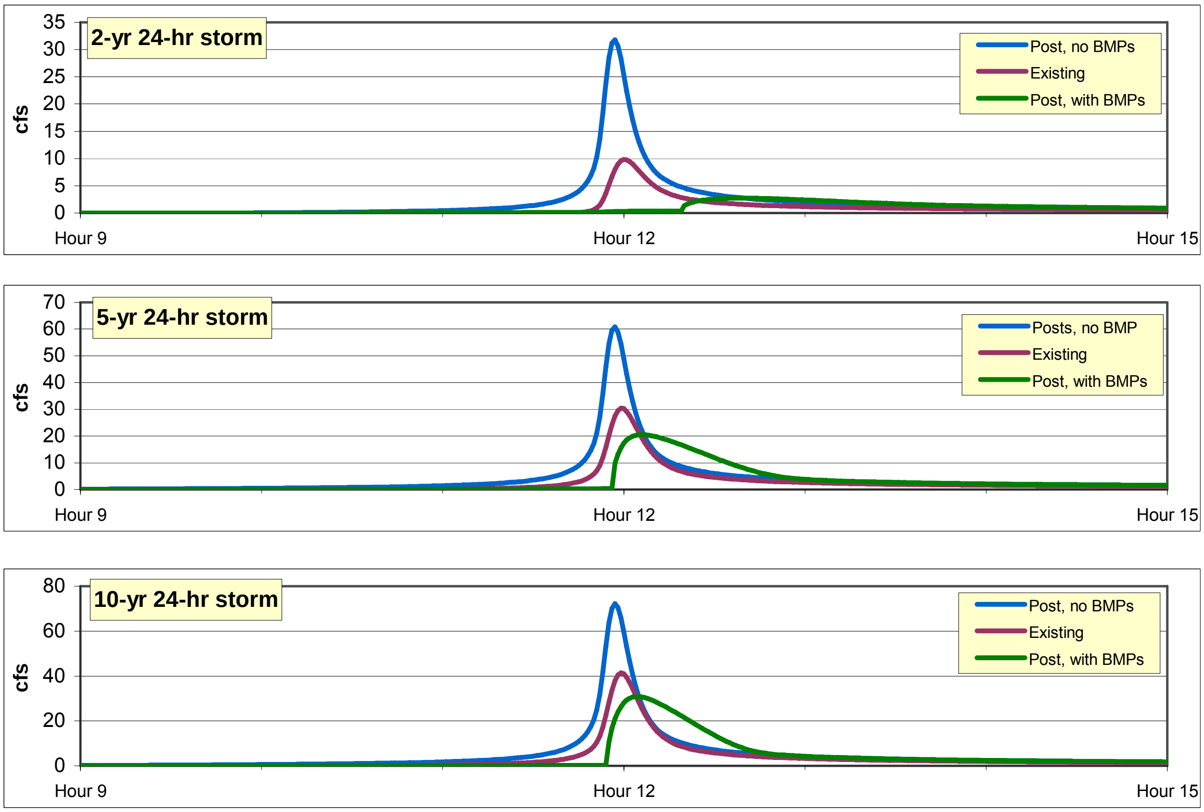

Figure J-1. Storm Event Peak Flow and Hydrographs, Medium Density Residential Land Use, *Basic LID* Scenario

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	9.84	26.64	3.25
5-yr 24-hr storm (cfs)	30.46	50.14	20.92
10-yr 24-hr storm (cfs)	41.48	64.18	31.96

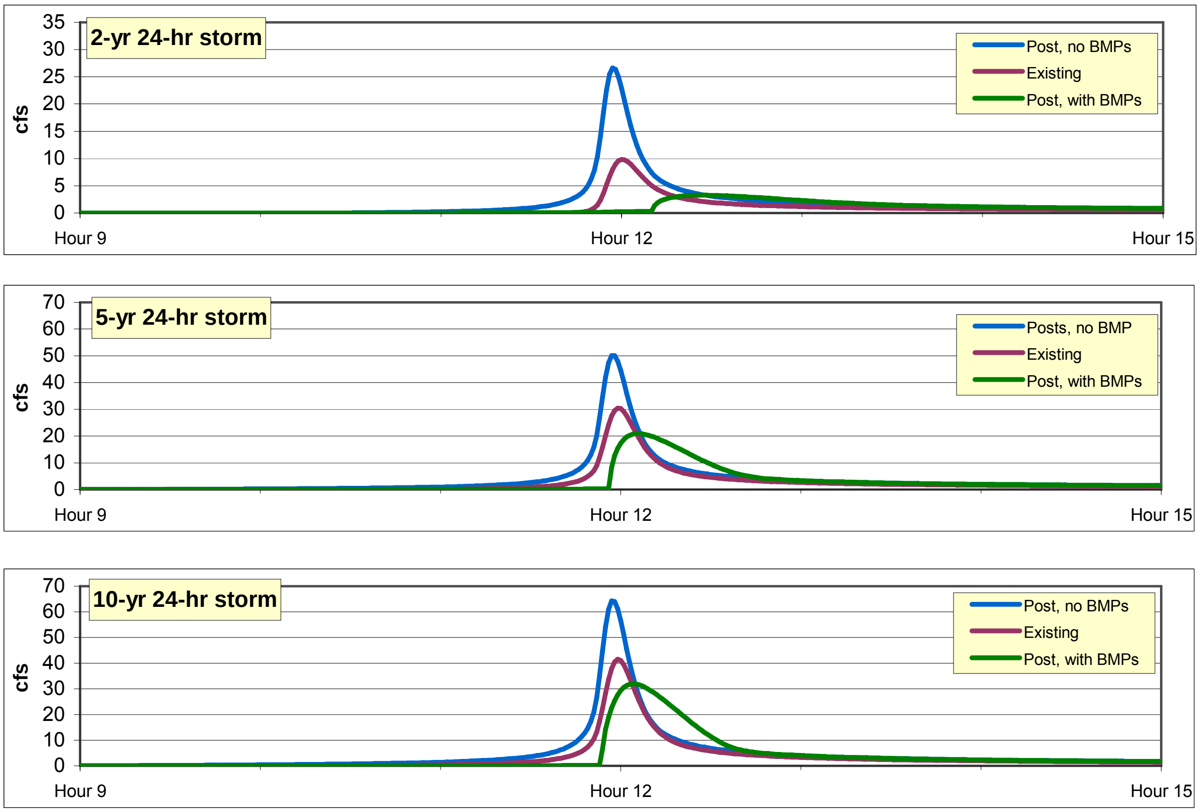

Figure J-2. Storm Event Peak Flow and Hydrographs, Medium Density Residential Land Use, *Enhanced LID* Scenario

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	34.77	112.60	9.78
5-yr 24-hr storm (cfs)	82.02	177.39	53.90
10-yr 24-hr storm (cfs)	105.66	210.48	79.22

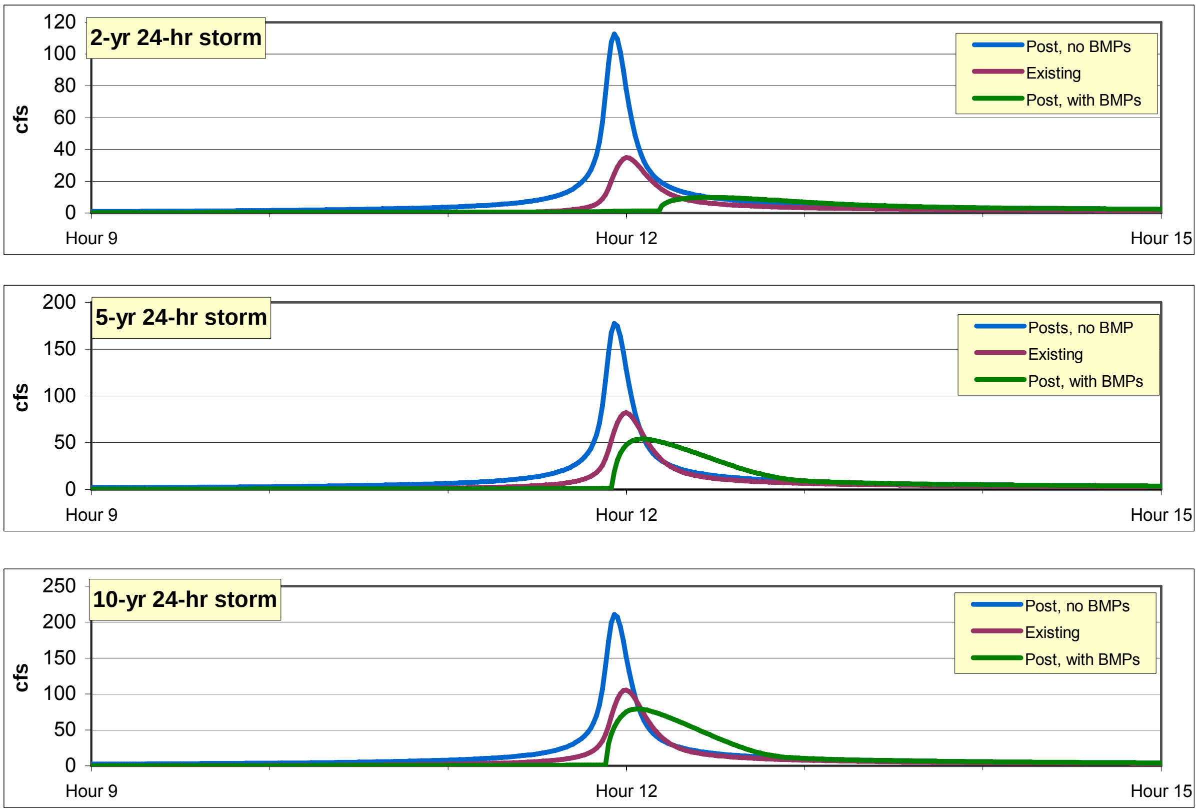

Figure J-3. Storm Event Peak Flow and Hydrographs, Multi-family Residential Land Use, *Basic LID* Scenario

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	34.77	104.52	1.13
5-yr 24-hr storm (cfs)	82.02	167.74	25.96
10-yr 24-hr storm (cfs)	105.66	199.92	53.50

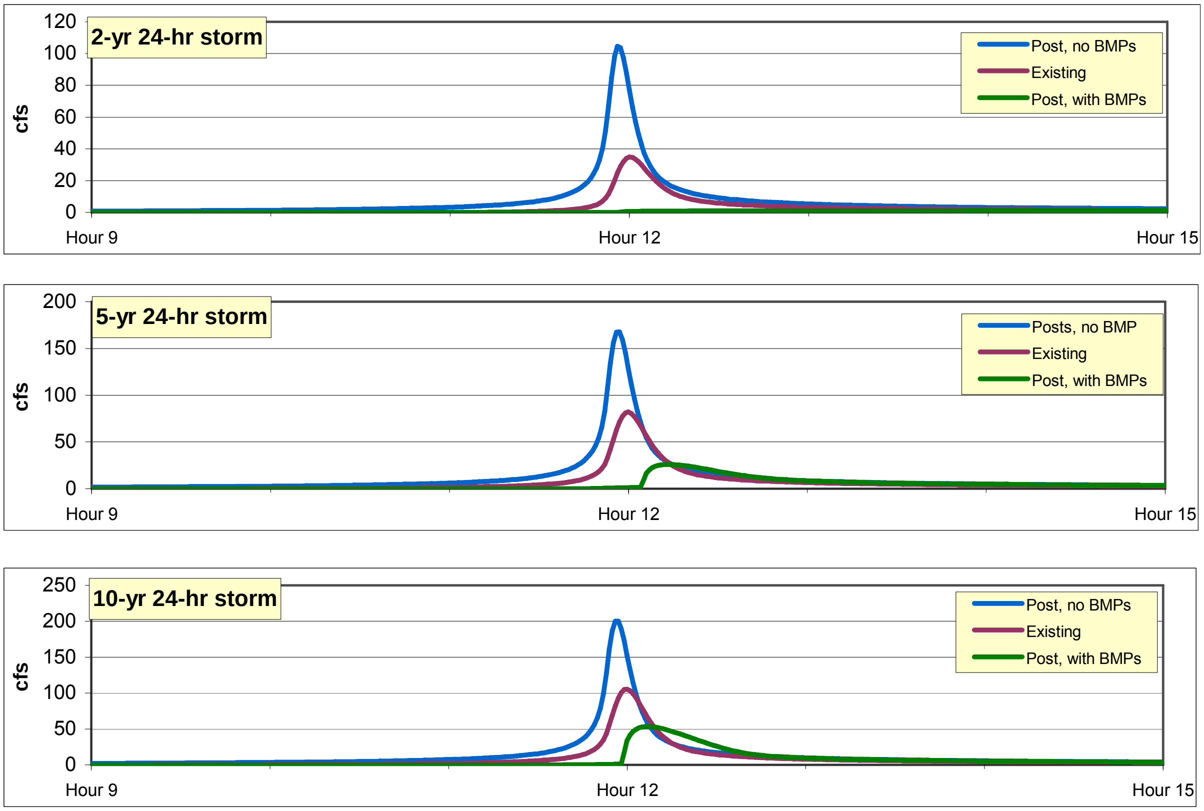

Figure J-4. Storm Event Peak Flow and Hydrographs, Multi-family Residential Land Use, *Enhanced LID* Scenario

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	11.33	40.95	2.33
5-yr 24-hr storm (cfs)	26.80	64.09	16.47
10-yr 24-hr storm (cfs)	34.54	74.55	24.53

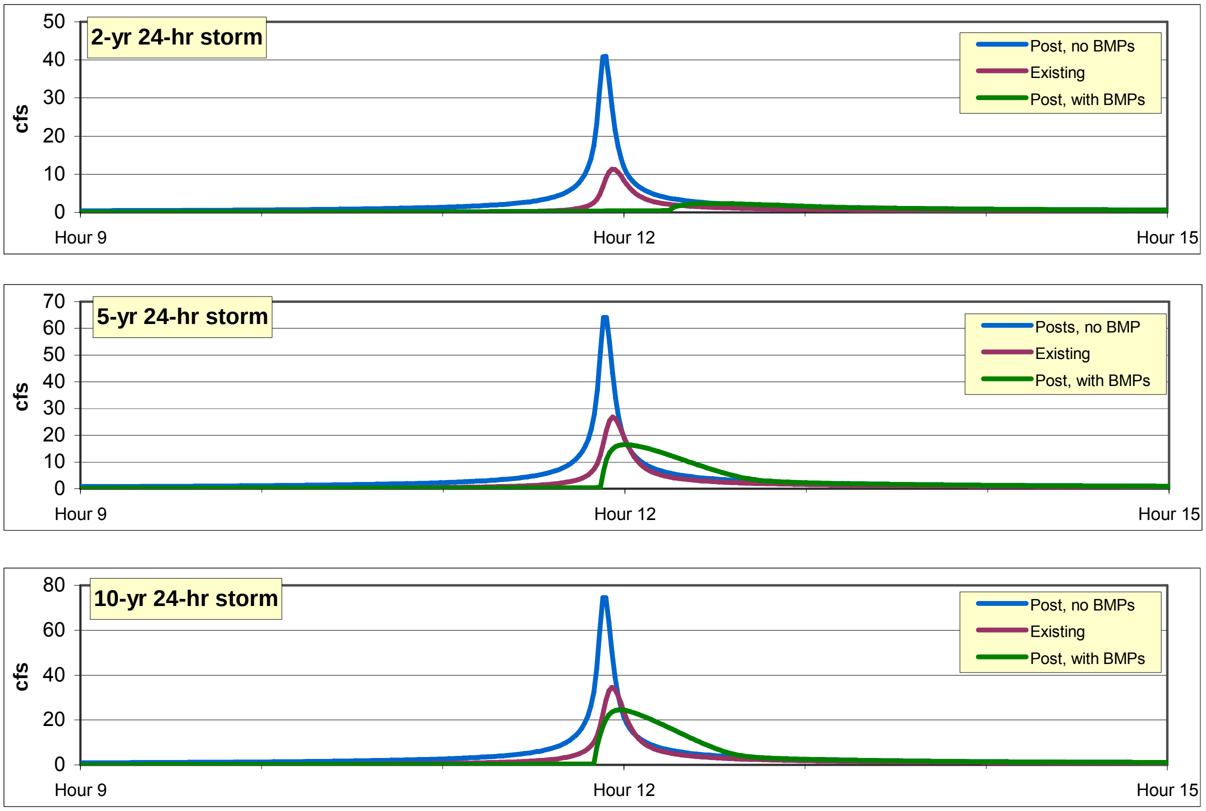

Figure J-5. Storm Event Peak Flow and Hydrographs, Commercial Land Use, *Basic LID* Scenario

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	11.33	40.95	0.26
5-yr 24-hr storm (cfs)	26.80	64.09	1.09
10-yr 24-hr storm (cfs)	34.54	74.55	3.90

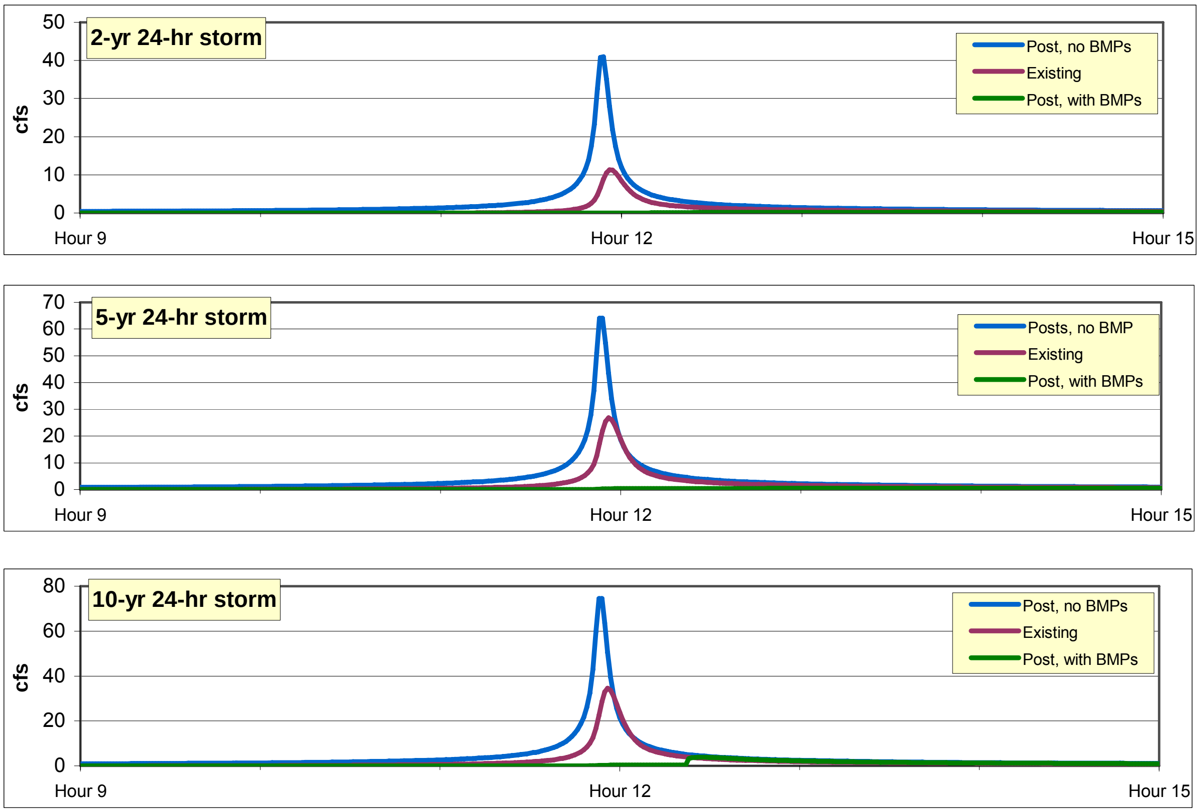

Figure J-6. Storm Event Peak Flow and Hydrographs, Commercial Land Use, *Enhanced LID* Scenario

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	**23.20**	**167.77**	**8.41**
5-yr 24-hr storm (cfs)	**71.89**	**272.81**	**48.00**
10-yr 24-hr storm (cfs)	**97.72**	**307.48**	**71.20**

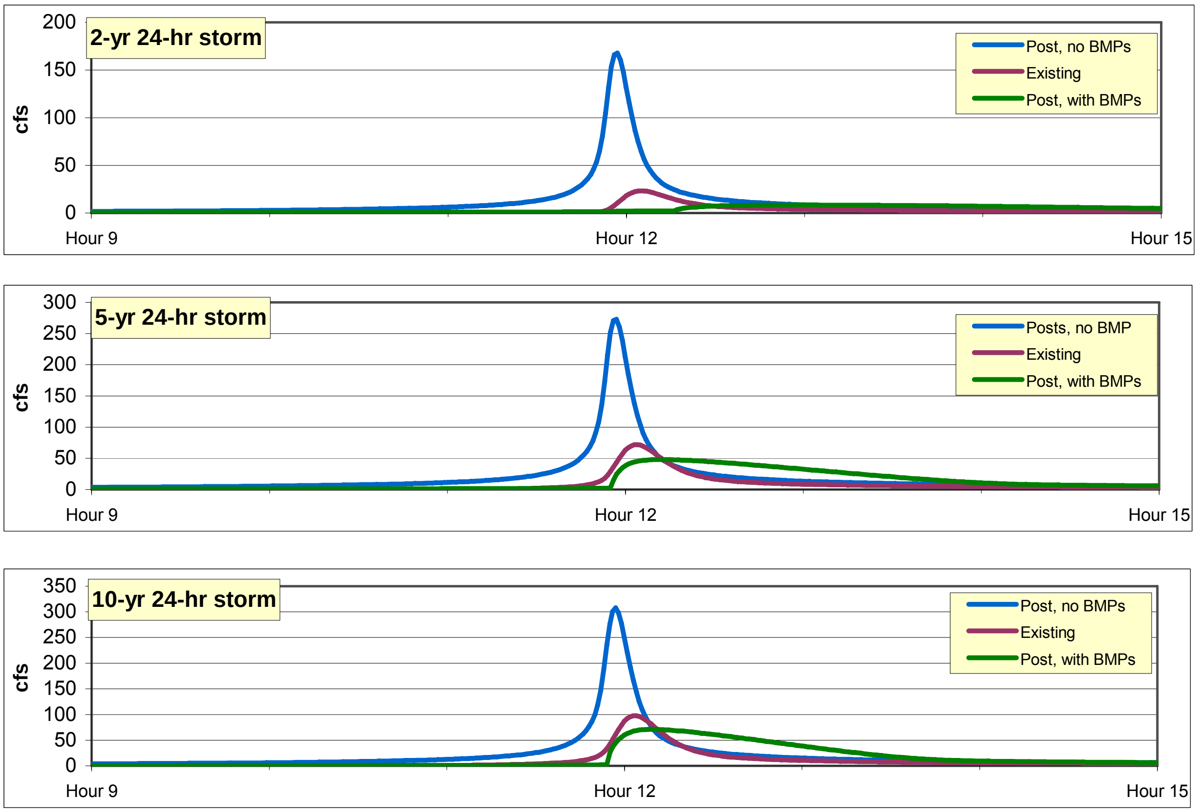

Figure J-7. Storm Event Peak Flow and Hydrographs, Industrial Land Use, *Basic LID* Scenario

	Existing Landuse	Design without BMPs	Design with BMPs
2-yr 24-hr storm (cfs)	23.20	167.77	7.32
5-yr 24-hr storm (cfs)	71.89	272.81	45.57
10-yr 24-hr storm (cfs)	97.72	307.48	68.03

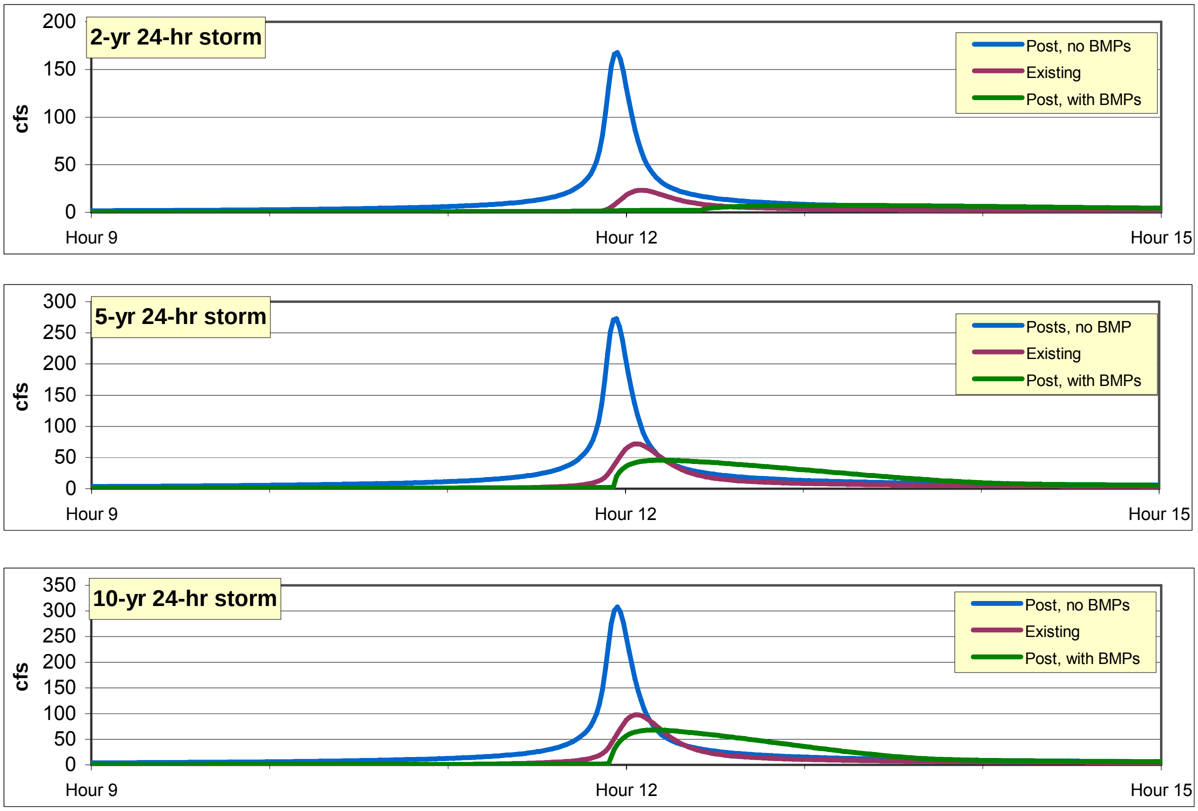

Figure J-8. Storm Event Peak Flow and Hydrographs, Industrial Land Use, *Enhanced LID* Scenario

(This page left intentionally blank.)