Chapter 10
LID MONITORING CASE STUDIES

Low Impact Development (LID) is a stormwater management strategy that can be used to reduce runoff and pollutant loadings by managing runoff close to its source. Chapter 8 of this Manual describes LID monitoring philosophy, study design, data acquisition, and reporting methods. Information about how to interpret and evaluate LID monitoring data is included in Chapter 9. The primary focus of these previous two chapters is on site level (or watershed scale) LID studies. This chapter presents and summarizes four case studies of site level LID monitoring projects that provide insight into methods potentially applicable to future monitoring projects. The four sites include:

1) Cross Plains, WI

2) Burnsville, MN

3) Jordan Cove, CT

4) Somerset, MD

All four studies use a Reference/Paired Watershed approach (Clausen and Spooner 1993), also known as the Before-After/Control Impact (BACI) study method. These case studies were chosen as examples because they each differ slightly, while together they cover a number of different stages of LID. Exhibit 10-1 summarizes the major monitoring design components for a quick comparison between each of the four case studies.

Exhibit 10-1. Case Studies Summary

Case Study	Flow Data resolution [mins]	# of rain gages	# of flow locations	Automated Samples?	Grab Samples	Organics / Nutrient Samples?	Metal Samples?	Other Measured parameters?
Cross Plains, WI								
Control (Traditional)	1	1	1	Y	Y	Y	N	Y
Treatment (LID)	1	1	3	Y	Y	Y	N	Y
Burnsville, MN								
Control (Traditional)	5	-	1	N	N	N	N	N
Treatment (LID)	5	1	1	N	N	N	N	N
Jordan Cove, CN								
Control #1 (Traditional)	NR	-	1	Y	Y	Y	Y	Y
Control #2 (Traditional)	NR	-	1	Y	Y	Y	Y	Y
Treatment (LID)	NR	1	1	Y	Y	Y	Y	Y
Somerset, MD								
Control (Traditional)	2	1	1	Y	N	Y	Y	N
Treatment (LID)	2	-	1	Y	N	Y	Y	N

NR – Not reported

10.1 Cross Plains, WI

The Cross Plains LID monitoring study was performed by the U.S. Geological Survey (USGS) in cooperation with Wisconsin Department of Natural Resources. This study compared a residential subdivision using LID techniques to one using a more conventional, fully connected stormwater conveyance system. The objectives of the study were to determine whether using LID techniques in a residential subdivision improved the quality of the stormwater runoff and/or reduced the runoff volume compared to the more traditional approaches.

The Cross Plains study used a paired or reference watershed approach. Two watersheds were monitored: one with a conventional stormwater system built in the early 90s; and the other with LID stormwater concepts. The conventional watershed had the following characteristics: curbs; gutters; a storm sewer discharging to a detention basin; larger street widths (40 ft); and a mix of single dwellings and commercial land. The LID watershed

contained the following characteristics: LID stormwater conveyance; grass swales; small detention followed by a large infiltration basin; an infiltration trench; more open area; single dwellings; and narrow street widths (32 ft). Exhibit 10-2 shows the LID (left) and the traditional (right) watersheds.

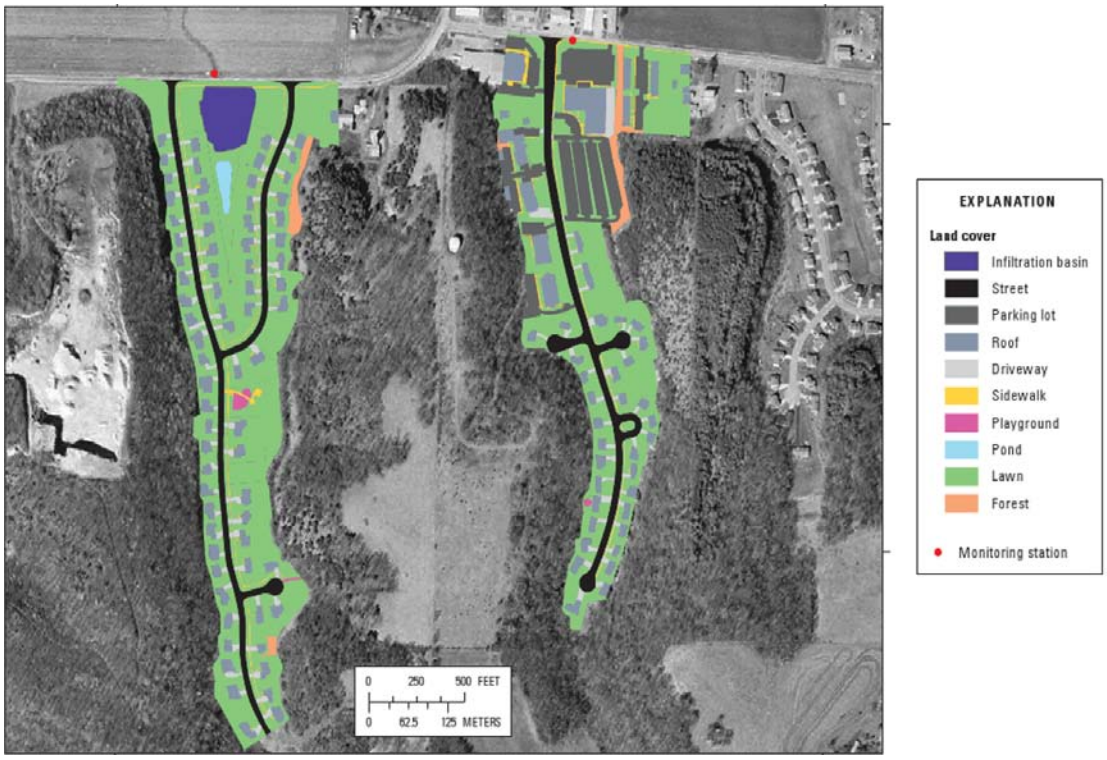

Exhibit 10-2. Aerial View of a LID Site and a Traditional Watershed (Selbig and Bannerman 2008)

This study shows a relatively intensive monitoring plan, as indicated by the two additional flow measurement locations located in the LID watershed. These two additional flow measurement locations were positioned at the end of the grass swale emptying into the small detention basin and at the entrance of the infiltration basin or outlet of the detention basin. Water quality sampling was not performed at these two stations.

Sampling was performed at the outlets of both catchments. For each sampling event, volume weighted sampling started once a specific water depth (0.1 to 0.15 ft) at the weir was reached, and continued to resample once a given volumetric threshold was calculated using one minute monitored flow increments.

Results from the study show that the LID catchment reduced the frequency of discharge, runoff volume and peak flows for most storms. The LID watershed produced measureable discharge in only six events with precipitation depth less than 0.4 inches, while the conventional watershed produced discharge in 180 events with precipitation depth less than 0.4 inches. The conventional catchment produced between 1.3 and 9.2 times more discharge than the LID catchment on an annual basis over the 6 years monitored.

The authors of the study noted that "with large storms and saturated soils, the ability of low-impact design techniques to reduce runoff, and thus constituent loads, can be greatly diminished" (Selbig and Bannerman 2008). In two years of the 6-year study, the LID watershed discharged greater loads of total solids, total suspended solids, and total phosphorus than the conventional catchment, with the majority of discharge loads from the LID basin associated with infrequent large events.

For more information, see the USGS document by Selbig and Bannerman (2008).

10.2 Burnsville, MN

The Burnsville monitoring study is an example of a simple LID monitoring study as it contains only two flow monitoring stations at which no samples were collected. The study purely focused on the volume and peak flow reduction of LID practices.

The rain garden retrofit and monitoring project in Burnsville, MN used a reference watershed approach. Two catchments with similar characteristics were evaluated during two monitoring periods. Exhibit 10-3 shows a plan view of the treated catchment.

Exhibit 10-3. Burnsville Rain Garden Treatment Area (Barr Engineering 2006)

The monitoring focused primarily on the flow out of the bottom of the watershed. The first period of monitoring was a calibration period that lasted nearly two years. This calibration period included no treatment in either catchment and was conducted simply to obtain a paired data set with which to statistically compare the responses of the two watersheds. Exhibit 10-4 shows the results of paired event runoff volumes from the two watersheds during the calibration period, both without control.

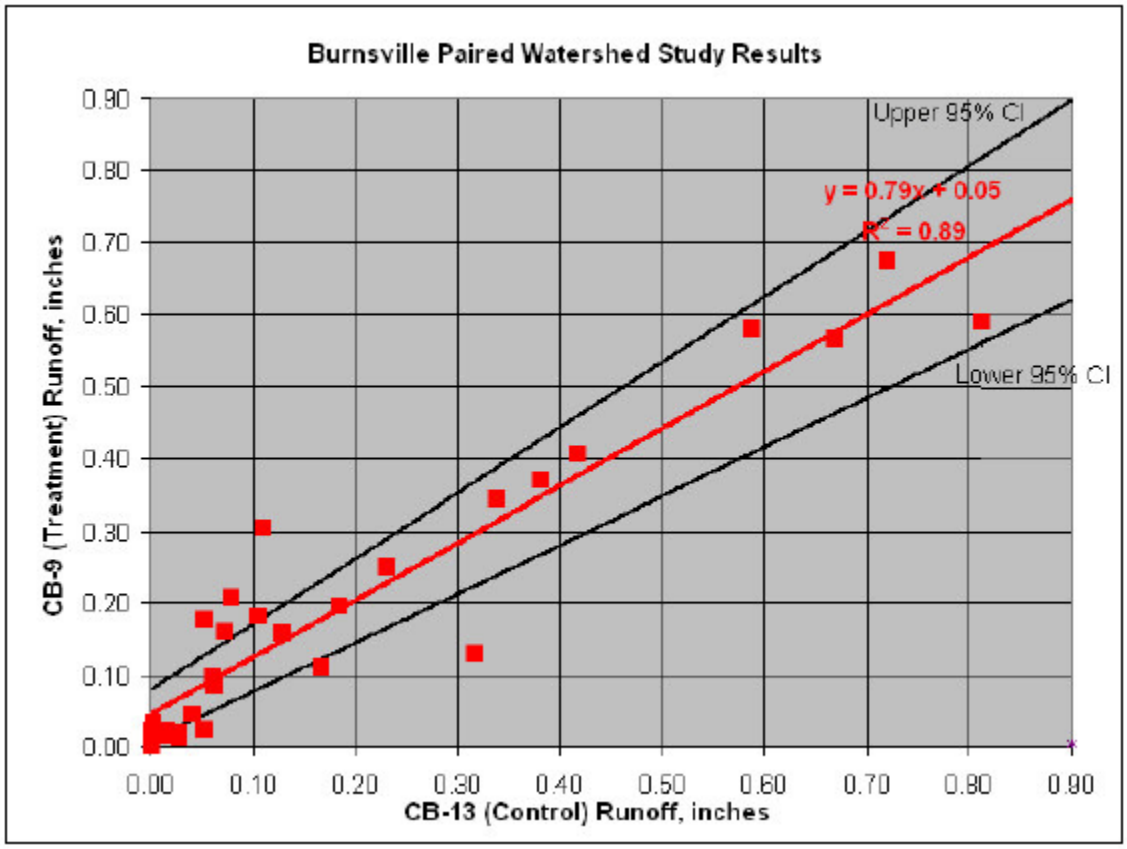

Exhibit 10-4. Scatter Plot of Paired Runoff Volumes from the Control and Treatment Watersheds, before Treatment Was Applied (Barr Engineering 2006)

Results showed consistently lower runoff from the treatment catchment (prior to retrofit), which was factored into eventual conclusions.

A second monitoring period, the treatment period, lasted approximately one and one-half years. During the treatment period, one catchment was being treated and one remained unchanged. The treatment catchment is termed "treatment" because 17 rain gardens were installed after the end of the calibration period. The rain gardens were placed in the front yard adjacent to the streets, and in the backyard.

The results show that the 17 rain gardens had a marked effect on reducing the runoff from the treatment catchment compared to the untreated site for the same storm events. It was reported that the cumulative effect of the 17 rain gardens reduced runoff volumes by as much as 90 percent (Barr Engineering 2006). An example storm response is shown in Exhibit 10-5, and the plot of discharge per area post-retrofit is displayed in Exhibit 10-6.

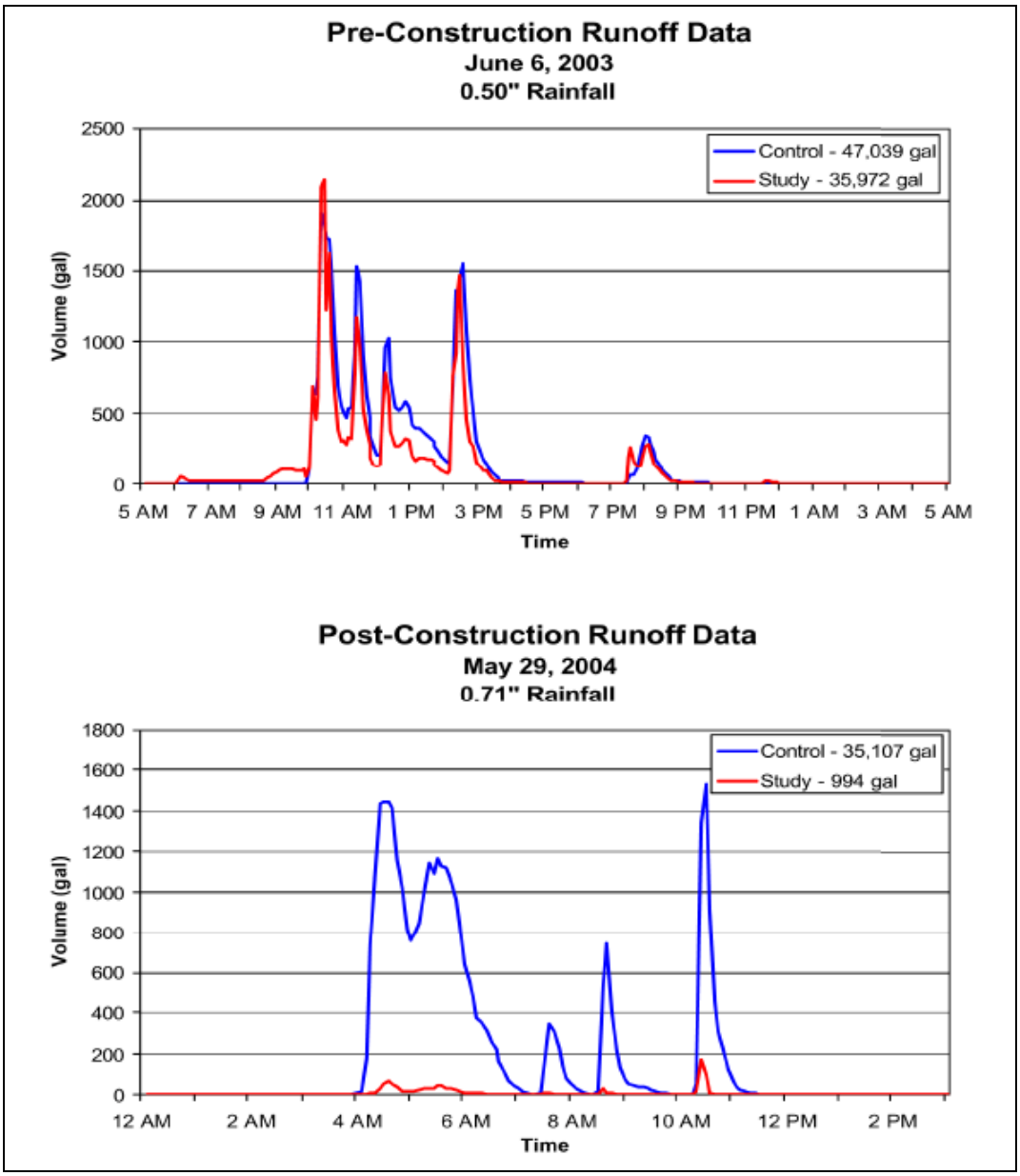

Exhibit 10-5. Pre- and Post-Construction Runoff Data at Control and Test Watersheds
(Barr Engineering 2006)

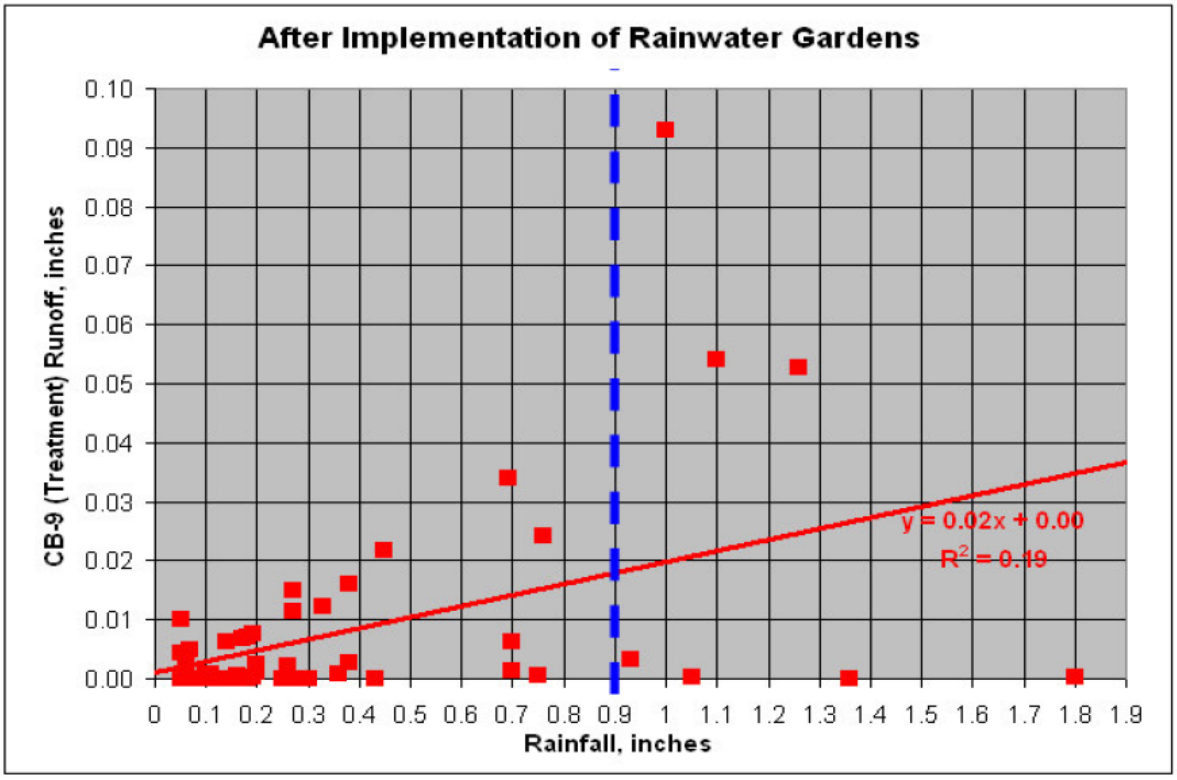

Exhibit 10-6. Scatter Plot of Discharge Volume per Area Versus Rainfall after Retrofit
(Barr Engineering 2006)

Exhibit 10-6 demonstrates consistently effective control of discharge volume, particularly below the design depth of the retrofit rainwater gardens (0.9 inch). As discussed in Chapter 9, a scatter plot method of interpretation enables an assessment of the variability of performance (typically cause by antecedent conditions and storm shape) with storm depth, as well as general conclusions about performance. It is interesting to note that a storm as large as 1.8 inches produced no runoff from the site, while a storm as small as 0.05 inches produced measureable runoff.

10.3 Jordan Cove, CT

Similar to the two case studies above, the Jordan Cove monitoring project also used a reference watershed approach. In this study, funded largely by the EPA and the Connecticut Environmental Protection Department, three catchments were monitored to study the effects of different types of development and compare traditional methods to the LID approach. The three catchments included: (1) a control catchment, which did not change during any time of the monitoring period; (2) a traditional catchment, which used traditional stormwater design (e.g., curbs, gutters, and sewers) and was constructed during the monitoring period; and (3) a LID catchment that used stormwater concepts, such as bioswales, open areas, clustered house layout, bioretention cells and permeable pavements, and was constructed during the monitoring period. Examples of LID practices installed on this site are shown in Exhibits 10-7 and 10-8.

Exhibit 10-7. Jordan Cove Bioswale (UCONN, 2007)

Exhibit 10-8. Jordan Cove Permeable Pavement (UCONN, 2007)

The monitoring schedule was partitioned into three periods: (1) Calibration, during which no changes occurred; (2) Construction, during which one traditional watershed was developed along with the LID catchment; and (3) Post-construction. This phased plan facilitated the

study of the changing effects on water quality and runoff quantity throughout the entire development process.

Monitoring consisted of flow measurements and samples collected at the outlet of each catchment. Samples were collected for each 500 ft^3 of runoff. The water quality parameters monitored were total suspended solids, total phosphorus, total Kjeldahl-N, ammonia-N, nitrate+nitrite-N, fecal coliform, biological oxygen demand, copper, zinc, and lead. In addition to the watershed monitoring at the outlets, various ancillary studies were performed to analyze how the lot properties in the LID catchment influenced water quality and runoff. For example, three studies performed on the LID catchment include: (1) Driveway runoff study; (2) Lawn nutrient study; and (3) Household surveys. Cost estimates for the various items built in the traditional and LID catchment were also documented.

Conclusions made by this study included:

1) Post-development peak flow rates and runoff volumes can be equal to those of predevelopment by using LID concepts for the events monitored.

2) Post-development total suspended solids (TSS) levels were greater than predevelopment levels

3) Nitrogen and phosphorus exports were reduced below the project goal of 65 percent and 40 percent, respectively. However, bacterial export was not reduced to the goal of 85 percent. (Note: Percent removals are not advised as measures of performance by the authors of this guidance Manual.)

10.4 Somerset, MD

During the Somerset monitoring project, Cheng et al. (2003) also used a reference watershed approach to analyze the differences in hydrologic performance between a traditional development and a LID development. Exhibit 10-9 shows an aerial view of the project site and the location of the two monitoring stations. The LID catchment contained grass swales, a disconnected impervious area, and bioretention practices. The conventional watershed contained a typical stormwater system of curbs, gutters, and a storm pipe system. Both watersheds were monitored with a single rain gage, two stream gages, and two automatic water quality samplers.

Exhibit 10-9. Somerset Monitored Watershed (Cheng et al. 2003)

The monitoring stations were programmed to measure flow at two minute increments and collect samples at every 250 ft^3 of the volume for small events and at every 500 ft^3 of volume for large events. This volume-weighted procedure produced an event mean concentration for each storm event. The samples were tested for the following constituents: lead, zinc, copper, total nitrogen, total phosphorus, and TSS. Overall, most annual loads were reduced at the LID site compared to the conventionally developed watershed, while total nitrogen remained the same and total phosphorus loading increased. Additionally, fewer events that produced runoff occurred at the LID site than the conventionally-developed watershed and fewer events with peak flow greater than 0.1 cfs/acre were produced (Exhibit 10-10).

Exhibit 10-11 shows that the effectiveness of the LID watershed is greatly reduced after available temporary storage is filled. While the initial peak in the monitored storm resulted in a significantly lower peak flow than in the conventional watershed, subsequent intra-storm peak intensities actually resulted in greater peak runoff than from the conventional watershed. This is similar to the observation by Selbig and Bannerman (2008) that the effectiveness of LID practices "can be greatly reduced" in saturated conditions. Nonetheless, the study still found a reduction in surface discharge of approximately 40 percent compared to the conventional site over the period of record, reflecting the importance of smaller, more frequent storms in long-term cumulative hydrologic response.

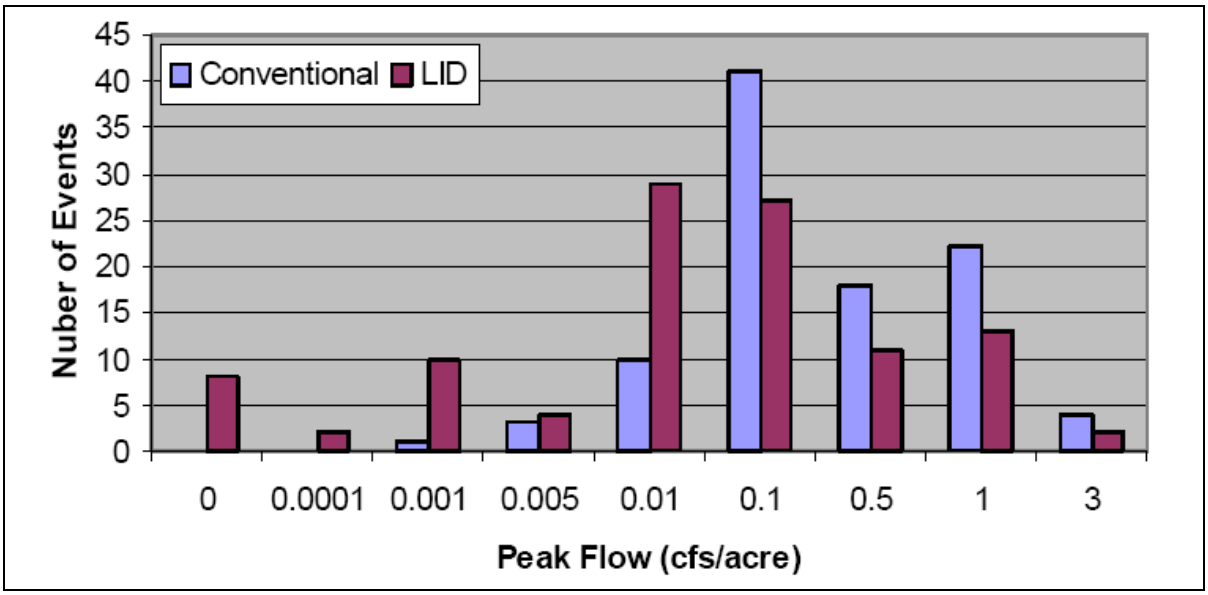

Exhibit 10-10. Frequency of Peak Flow Discharges (Cheng et al. 2003)

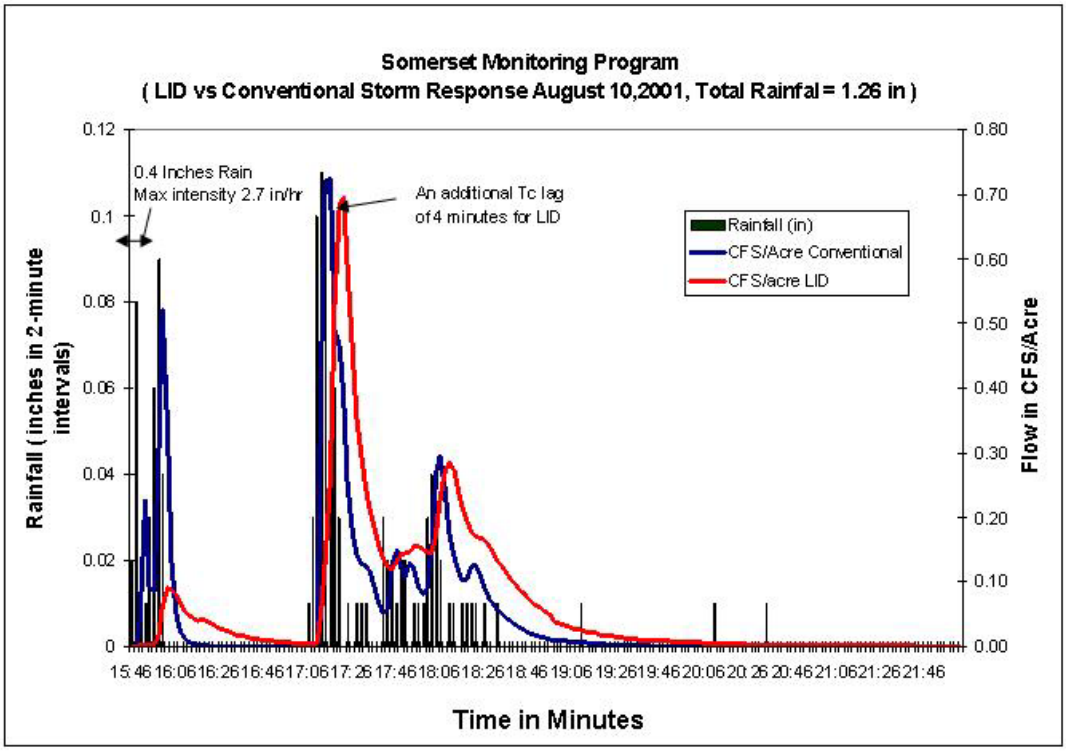

Exhibit 10-11. LID vs. Conventional Storm Responses (Cheng et al. 2003)

10.5 Conclusions

While site level LID studies are still relatively rare compared to practice-level studies, a variety of site level studies do exist and more are expected to be completed in the coming years. To date, most studies have been based on a Reference/Paired Watershed approach, also known as the Before-After/Control Impact (BACI) study method, as is recommended by this Manual. Results of these studies have been interpreted by researchers in ways generally consistent with the recommendations of this Manual. Review of existing studies is a worthwhile undertaking when planning a site level LID monitoring study.

10.6 References

Barr Engineering Company. 2006. *Burnsville Stormwater Retrofit Study*. Prepared for City of Burnsville.

Cheng, M.S., Coffman, L.S., Zhang, Y., and J.Z. Licsko. 2003. *Comparison of Hydrological Responses from Low Impact Development with Conventional Development*. In Proceedings of World Water & Environmental Resources Congress 2003. Environmental and Water Resources Institute (EWRI), American Society of Civil Engineers, Philadelphia, Pennsylvania, June 23-26, 2003.

Clausen, J.C. 2007. *Jordan Cove Watershed Project: Final Report.* Prepared for U.S. Environmental Protection Agency (EPA) and Connecticut Department of Environmental Protection.

Clausen, J.C. and J. Spooner. 1993. *Paired Watershed Study Design*. Prepared for U.S. Environmental Protection Agency (EPA) Office of Water, Washington, D.C. 841-F-93-009.

Selbig, W.R., and R.T. Bannerman. 2008. A *comparison of runoff quantity and quality from two small basins undergoing implementation of conventional- and low-impact-development (LID) strategies, Cross Plains, Wisconsin, Water Years 1999–2005*. U.S. Geological Survey (USGS) Scientific Investigations Report 2008–5008. 57 p.

University of Connecticut (UCONN). 2007. Jordan Cove Urban Watershed Project Website. http://jordancove.uconn.edu/ Accessed, October 27, 2009. Use of photos for informational purposes is permitted with attribution.