UNIVERSITIES COUNCIL ON WATER RESOURCES
JOURNAL OF CONTEMPORARY WATER RESEARCH & EDUCATION
ISSUE 146, PAGES 39-49, DECEMBER 2010

Best Management Practices for Stormwater Management in the Desert Southwest

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Abstract: Despite several decades of experience with stormwater Best Management Practices (BMPs) in the United States, the application of such approaches in the Desert Southwest region has not received adequate attention. One reason for this shortcoming could be the general perception of the insignificance of BMPs in a region with little annual precipitation. However, the Desert Southwest still experiences relatively high rainfall intensity and runoff from rainfall. Sparse vegetation, steep topography, complex soils, unique geology, and rapid land development all contribute increase runoff response. Since the Desert Southwest hosts a large and rapidly growing population, stormwater BMPs are important for protecting the quality and quantity of scarce receiving surface and ground waters. The hydrometereological characteristics of intense short-term precipitation, large inter-storm duration, and smaller annual volumes of rainfall and the region's watershed characteristics are unique; the design of regional stormwater BMPs should consider these characteristics. Also, there is a need for more specific design guidance for implementing general approaches for adapting stormwater BMPs from humid regions to arid settings.
Keywords: *Best management practices, non-point source pollution, stormwater management*

Non-point source pollution is the most prevalent source of water pollution in the United States (U.S. EPA 2005). In order to control non-point source pollution, there is an increasing volume of activities nationwide to support stormwater quality management. Irrespective of the geographic or hydroclimatic location, stormwater quality management has the same purpose or goal: to use a suite of Best Management Practices (BMPs) to reduce the sediment, nutrient, and chemical pollutant loads in stormwater before they reach natural watercourses downstream. However, the means of achieving this goal can be different depending on the region.

Despite over two decades of experience with BMPs much of the previous research and applications have been conducted in and reported from humid regions (more than 500 mm) versus arid (0-250 mm annual rainfall) and semi-arid (250-500 mm annual rainfall) regions. Although there is increasing awareness among practitioners about the fundamental difference between arid and humid regions for BMP design (Caraco 2000; Sayre et al. 2006), such awareness is limited to only a few research papers and studies. For example, the BMP database (International Stormwater BMP Database 2008) has 341 BMP database entries from over 21 states. Out of these, no entries belong to the Desert Southwest (defined here as the Sonoran Desert of Arizona and Southern California; the Mojave Desert of Southern Nevada, Southern California, and parts of Arizona and Utah; and the Chihuahuan Desert of Southern New Mexico and portions of Arizona and Texas). The database, however, includes cases from three semi-arid regions belonging to California, Colorado, and Texas. One reason for such a lack of representation could be a perception that stormwater BMPs are of little significance in desert regions. For example, in Las Vegas, NV, where the average annual rainfall is only approximately 100 mm, a general perception could be that the expense and burden of BMPs are unjustified in an area with such scant rainfall. The limited available studies for the region (Caraco 2000; Sayre et al. 2006) lump both arid and semi-arid regions together and do not distinguish the Desert Southwest from other regions. Thus the implications of such studies, and their associated suggested BMP modifications, mostly represent semi-arid regions. This paper contends that the precipitation characteristics of the Desert Southwest are different than those of the semi-arid regions; thus, the studies of the western or southwestern U.S. in general may not adequately characterize the unique characteristics of the arid Desert Southwest. Similarly, we further argue that water availability, management, and sustainability issues in the Desert Southwest are unique from the rest of the country and thus stormwater BMPs must also be different. The final argument supports a need of greater representation of the issues of stormwater BMPs from the Desert Southwest. A discussion on the suitability of various types of stormwater BMPs (U.S. EPA 2006a, 2006b) is made elsewhere (Acharya et al. 2009) and is not repeated here.

This paper is organized as follows. First, we present some key factors that influence stormwater BMP design. Through analysis of precipitation data, we present an argument as to why the Desert Southwest needs to be considered separately from the semi-arid regions. Second, we justify the need for BMPs in the Desert Southwest despite low annual precipitation and we discuss some specific reasons why cities in the Desert Southwest need special consideration for BMPs. Finally, we reiterate broad principles for BMP design in arid regions together with the overall needs for stormwater management in the Desert Southwest.

Factors Influencing Stormwater BMP Design

The objective of stormwater BMPs is to prevent or reduce the movement of sediment, nutrients, pollutants, or debris from land to surface or ground waters. The natural drivers of such movement are highly dependent on the interaction among entities such as soil, vegetation, land use, storm and runoff characteristics, and processes such as runoff formation, infiltration, erosion, and sediment transport. The natural factors that guide these processes are dependent on topography, geology, soil-geomorphology, and the hydrometeorology of the region.

Hydrometeorological Factors

The hydrometeorology of the arid west is distinct from humid regions. These characteristics are summarized as follows:

1. Although the average and annual total precipitation in the Desert Southwest is much lower than in other regions, the extreme value of rainfall depth and intensity can be significant;

Table 1. Precipitation characteristics of major western U.S. cities.

	Daily precipitation(mm) >=				
	0.25	**2.54**	**12.7**	**25.4**	
	No. of days				
Albuquerque	63.9	27.3	3.9	0.5	240.5
Austin	87.8	51.2	21.2	9.3	854.7
Denver	91	39.5	7.1	2.4	401.6
Boise	89.7	40.9	3.3	0.1	309.6
Las Vegas	28.6	12.1	2.3	0.3	114.0
Los Angeles	35.5	22.6	9	3.6	334.0
Phoenix	37.7	19.3	4.9	1	210.6
Reno	53.6	21.8	2.7	0.4	190.0
Seattle	150	92.1	21.2	4.5	941.6

Source: National Climatic Data Center (2004).

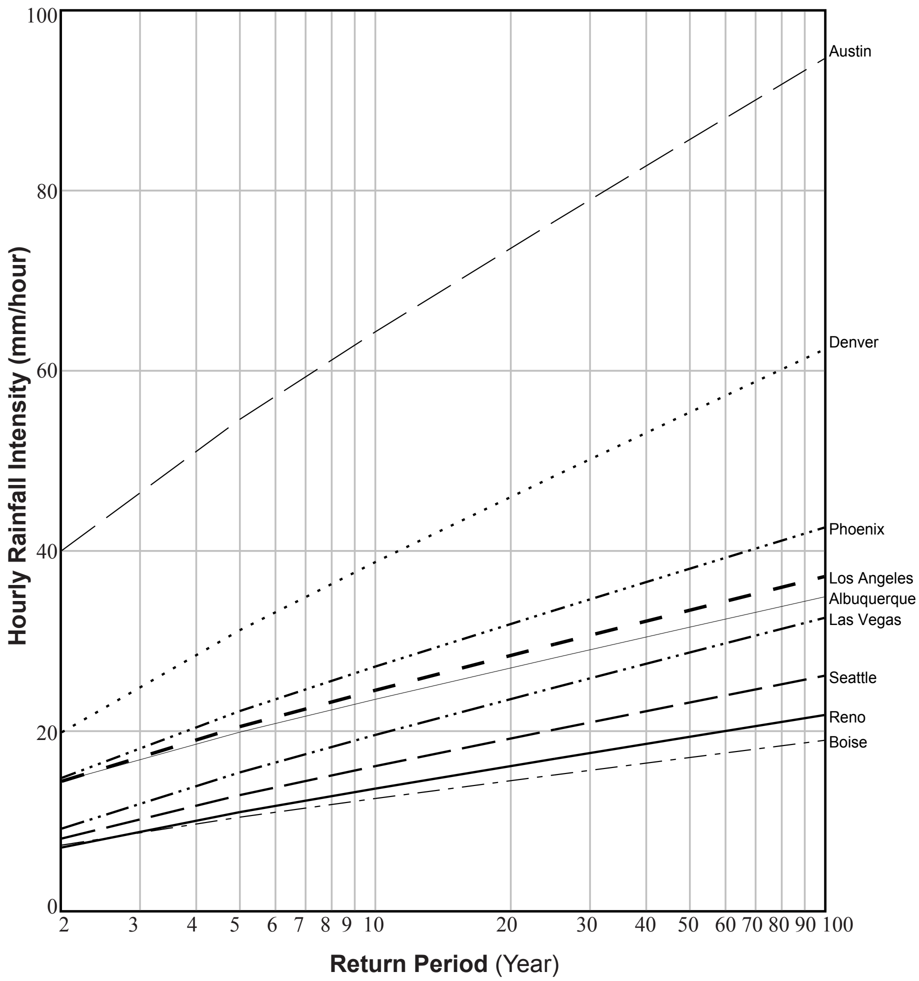

Figure 1. Frequency of hourly rainfall intensity in major western U.S. cities.

2. The number of days of rainfall in a year is low and thus there is a greater inter-storm duration period;
3. Urbanization and land development in arid regions have a significant impact through water use, return flow, and flooding; and
4. The potential evapotranspiration rate is very high.

General Hydrometeorological Characteristics. Table 1 contains the precipitation characteristics of major western cities of the U.S. As can be seen, Las Vegas has the lowest annual precipitation (11.25 cm) and Seattle has the highest (92.5 cm). In terms of the number of days with rainfall greater than or equal to 0.25 cm, cities such as Las Vegas and Phoenix represent the lower end of the spectrum. Cities such as Seattle, Austin, and Denver have very high to moderate annual rainfall and represent the higher range of the spectrum. Clearly, in terms of volume of rainfall and storm frequencies, cities in the region reflect substantial variability. With this in mind, some may argue that BMPs should be recommended in Austin, Denver, or Seattle, but that they might not be applicable to Desert Southwest cities such as Las Vegas and Phoenix. Further, certain design characteristics such as vegetation can play a major role in BMP design in Austin, but their use will be severely constrained in a dryer region such as Las Vegas.

Hourly Intensity-Frequency Curves of Major Western Cities. Based on 1949-2008 hourly rainfall data from National Climatic Data Center, frequency analyses (extreme value distribution, type I) of hourly rainfall intensity were carried out for major western cities and the results are displayed in Figure 1. As can be seen, Austin

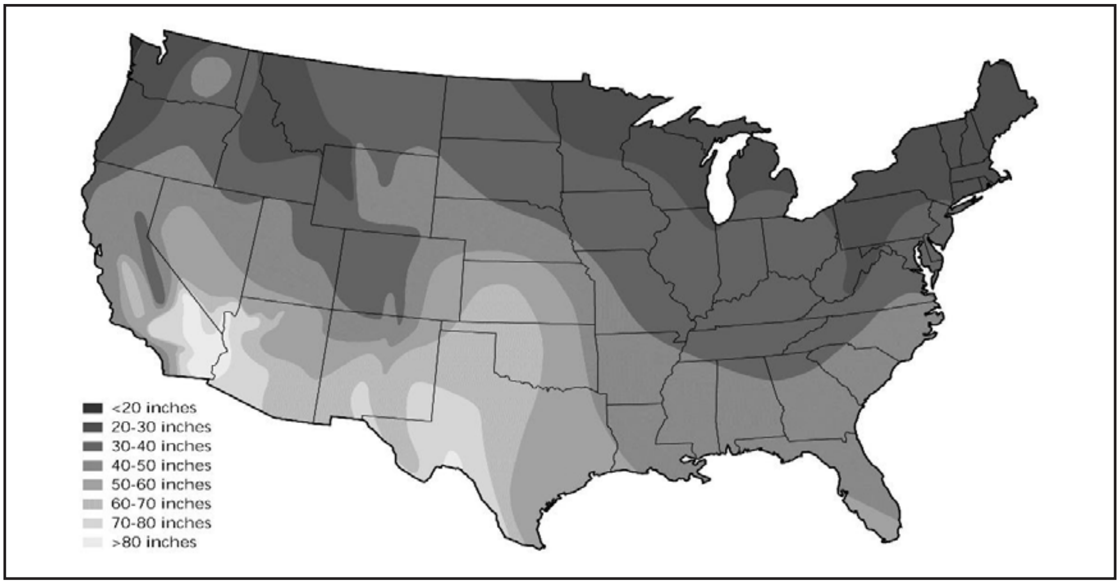

Figure 2. Map showing Mean annual lake evaporation for the period 1946-1955 in the contiguous U.S. (Source: FISRWG 1998).

and Denver represent the highest hourly rainfall intensities in the region. Although Las Vegas has the lowest average annual rainfall, the city's intensity of hourly rainfall is higher than that of Boise, Reno, and Seattle. Similarly, despite having the highest annual precipitation, Seattle has one of the lowest hourly rainfall intensities in the Western U.S. Although the annual volume of rainfall in the Desert Southwest is the lowest, the potential evapotranspiration rate (Figure 2) is the highest in the country.

Runoff Response. Runoff response of a watershed depends on land use/land cover, soil type, topography, geology (section 2.2), and antecedent moisture conditions, among other factors. Sparse vegetation, sprawling and rapid land development, and general geology can contribute to relatively higher runoff Curve Numbers (CN, a measure of runoff response of a watershed) in the Desert Southwest. The table of estimated curve numbers reported by Osterkamp and Friedman (2000) shows very high CN values for arid desert watersheds (Table 2). Similarly, CN values in G.C. Wallace Inc. (1997) for urban watersheds, as well as readjusted (reduced) CN values for some watersheds contributing to the Las Vegas Wash (Reilly and Piechota 2005), are also relatively high compared to those typically observed in humid watersheds.

An important feature that affects the runoff response of watersheds in the Desert Southwest via land use/land cover change is the rapid pace of urbanization. The Desert Southwest hosts several of the most rapidly developing cities within the U.S., including Las Vegas, Tucson, and Phoenix. The massive extent of urbanization is associated with increased paved surfaces, thus decreased infiltration, increased surface runoff, and reduced time of concentration. Green landscaping has contributed to additional management problems, including a rise in the shallow groundwater table and increased pollution loads to receiving waters. Outdoor water use accounts for the majority of

Table 2. Select curve numbers for arid and semi-arid U.S.

State	Location	Curve Number	Comments
AZ	Tombstone	89	Grassland
AZ	Tuscon	86	Desert Brush
CO	Boco Mountain	88	Sagebrush
CO	Badger Wash	91	Desert Shrub
NM	Albuquerque	90	Range; average of two sites
NM	Dona Ana County	86	Range; average of four sites

Source: Osterkamp and Friedman (2000).

residential water use in most parts of the arid West. About 40 percent of Tucson's potable water is used for landscaping (Gunderson 2009). Similarly, other studies have shown that outdoor water use accounts for over half of all residential water in several western cities, ranging from 57.5 percent in Boulder, Colorado, to 72.3 percent in Scottsdale, Arizona (Western Resources Advocates 2003). These outdoor uses in the arid West have raised significant concerns for stream water quality. For example, the water table in some parts of the Las Vegas Valley has risen significantly, limiting the natural soil barrier and filtration opportunities. Similarly, a number of natural washes in the region have undergone severe channel erosion in the recent past. Moreover, increased populations result in increased water use and return flows, which have additional implications such as turning ephemeral channels into perennial streams (e.g. Las Vegas Wash in Southern Nevada).

These hydroclimatic characteristics of arid regions have a number of implications for the design of BMPs including:

1. The size of the storage area needed to treat quality and quantity of water is much smaller.
2. Since annual depth of rainfall is extremely low, convincing stakeholders of the necessity of such systems (public outreach for non-structural BMPs) is very challenging (Brzozowski 2007).
3. The high evaporation rate combined with the demands of sustainable water use render common structural BMPs that are often used in humid regions (e.g. wet detention ponds) unsuitable for the arid regions.
4. The increased impervious areas and associated reduced time of concentration caused by rapid urban growth can significantly increase flow rates from the natural condition. This usually increases erosion in the natural washes (Buckingham et al. 2004) that are used as flood conveyance facilities.
5. The runoff from landscape irrigation and other outdoor uses (nuisance flows) are common. This can impact BMPs that rely on recharge as a treatment mechanism. Moreover, it can have the cumulative effect of turning ephemeral streams into perennial streams, as is evident with the Las Vegas Wash in southern Nevada.
6. Pollutant volumes vary from one storm event to the next in the same watershed and depend on the frequency of storms and the number of rainless days between two rainfall events. The build-up of pollutants can increase over longer periods of time, which may result in high concentrations of pollutants in the stormwater during the initial stage of the storm runoff. Given the low frequency of storms in arid regions, pollutant concentrations can be expected to be higher than those in humid regions, particularly the first flush of stormwater. Thus the "first flush concept" is exacerbated in the region, and this concept should be carefully considered while designing BMPs for arid regions.

Soil, Vegetation, Geology, Topography, and Geomorphology

Soils and Vegetation. Humid soils typically support a great deal of plant life and hence have a high level of biological activity. The top two layers (Horizon O and A) of humid soils are comprised largely of organic materials. Horizon O is characterized by decomposing plant matter and Horizon A is characterized by organic matter mixed with the eroded underlying material (Eastbrook 1999). In contrast, soils in arid regions are typically comprised of the erosion products of the underlying rock and do not have an overlying layer of organic matter marking the absence of O or A Horizons. The relative absence of organic matter, litter, and vegetation on the surface has implications for hydrological processes and flow pathways.

Soils and vegetation exert a strong influence on surface runoff generation. Osterkamp and Friedman (2000) found that although semi-arid parts of the U.S. have lower 100-year 6-hour rainfall intensities and smaller depths of 100-year probable maximum precipitation for 26-km^2 areas, the maximum flood peaks, flash-flood potentials, and runoff potentials are generally larger in semi-arid areas compared to humid areas. They attributed this disparity between rainfall and runoff to the soils and vegetation. The relatively scant vegetation cover in the arid environment increases the erosion potential of the soil. Moreover, the difficulty in maintaining vegetation cover makes bioremedial BMPs from

Table 3. Geomorphology and vegetation in the arid land of the Southwest.

Regions (U.S.)	Geomorphology type	Vegetation types
Great Basin	Basin and mountains	Artemisia-Atriplex steppes and pygmy open woodland
Sonora	Plateau, crystalline mountains	Thorny succulent savanna
Baja California	Diverse, coastal, sand	Thorny succulent savanna and dwarf shrubs

Source: Adapted from Mays (2001).

wet regions unsuitable in arid regions. In some parts of the arid West, the desert soils consist of the silty low permeable vesicular A (Av) horizon (Ritter et al. 2002). The discontinuous porosity in such soil, aided with their platy structure, leads to low infiltration rates, which have implications for aquifer recharge capacity and stormwater management BMPs.

Geology. The presence of naturally occurring minerals, mines, and trace elements in the Desert Southwest region is also a major water quality concern. For instance, the high concentration of selenium and mercury in the Las Vegas Wash is linked with the sub-surface geology and shallow ground water table in the area resulting from landscape irrigation (Clean Water Coalition 2008).

Topography and Geomorphology. Arid lands in North America are mainly in the tectonically active mountainous region. Their features are described in Table 3 (Mays 2001).

The soil, vegetation, and topography of the Desert Southwest are conducive to soil erosion and increased sediment transport due to storm events as well as wind action. The increased flow in ephemeral channels due to nuisance flows, stormwater, and treated wastewater accelerates the erosion of the channels.

Are Stormwater BMPs Important for the Desert Southwest?

Contrary to the general perception of the relatively low need for stormwater BMPs in the Desert Southwest, there is actually a strong need for such an approach. For instance, stormwater BMPs in Las Vegas are critically important to protect the water quality of Lake Mead because Las Vegas draws most its drinking water from Lake Mead. Similarly, BMPs are important for states like Arizona where groundwater is a valuable resource and aquifer recharge is being considered as an option in view of long term sustainability. Both stormwater management and recharge BMPs are thus important for the region.

A recent study (CCRFCD 2008) contained a comparison of wet-weather monitoring results from storms in 1992-2008 with additional dry-weather sampling data from 1991-2008 at the same locations. The study concluded that most of the indicators show greater water quality degradation in wet-weather flows compared to dry-weather flows (e.g. Total Suspended Solids concentrations are about 73 times higher, turbidity 133 times higher, bacteria counts 46 time higher, total nitrogen about 1.5 times higher, and total phosphorous 32 times higher in wet-weather flow compared to dry-weather flows). This demonstrates why stormwater BMPs are needed to protect the water quality of the receiving waters (i.e. Lake Mead and the Lower Colorado River).

BMP Design for Desert Southwest – The Path Forward

There are a number of differences between the nature of humid and arid environments. Differences in rainfall patterns, soil characteristics, patterns of urbanization, and general climate contribute greatly to differences in the stormwater generation process and thus to differences in the design and performance of stormwater BMPs. As discussed above, the frequency of rainfall events has a direct impact on the concentrations of pollutants in stormwater runoff.

Many BMPs developed in humid regions are directly applicable to arid regions. In some cases minor modifications are required. Generally speaking, the BMPs listed by the U.S. EPA (U.S. EPA 2006a, 2006b) are effective to some degree for removing construction and post-construction pollutants generated within an urban watershed, although there may by distinct differences in the effectiveness of the various types of BMPs depending on the region. Given the unique features of the Desert Southwest, in many situations the options for structural measures are either limited or very expensive; thus, non-structural BMP measures are important irrespective of the climatic zone. Such measures are focused on source reduction and thus help to minimize the volume of waste generated.

Several considerations are outlined here for the application of stormwater BMPs with a focus on the Desert Southwest.

BMP Strategies

BMP Strategies should be based on sustainable land use, water conservation, and water reuse. In the arid Southwest, water is an extremely limited resource. Water demand continues to increase due to rapid urbanization. Based on U.S. Bureau of Census 2001 data (Perry and Mackun 2001), the fastest-growing states in the nation were all located in the West: Nevada (66.3 percent growth), Arizona (40.0 percent), Colorado (30.6 percent), Utah (29.6 percent), and Idaho (28.5 percent). The severity of droughts and potential climate change impacts have further contributed to water scarcity and have clearly put stormwater conservation and water reuse in the forefront of regional priorities for the arid Southwest. Thus, the best strategy for effective BMPs for the arid Southwest would be developed based on stormwater conservation and water reuse. Such conservation practices should be based on rainwater harvesting, local ground water infiltration when feasible, and minimization of evapotranspiration losses.

The following four recurring principles for arid and semi-arid stormwater management (Caraco 2000) provide the guiding factors for stormwater management and BMP design:

1. Stormwater practices should be carefully selected, and adapted for arid watersheds.
2. Stormwater practices should avoid irrigation needs.
3. Ground water resources need to be protected from contamination and augmented through recharge practices where feasible.
4. Channel erosion and sediment generation in the watershed should be minimized.

Not all reported stormwater management practices of arid regions cited in the literature are suitable to this region. Some of these are being used in an unsustainable way. For example, Caraco (2000) concluded that 65 percent of the stormwater managers in his study reported that irrigation is being used to maintain vegetation cover for stormwater management practices. Given the strong and complex (oftentimes inseparable) link between surface and ground water, ignoring ground water quality and quantity issues while designing stormwater BMPs can often result in more harm than good. Similarly, even though upstream watershed erosion might be controlled through various stormwater BMPs, there is a need to consider downstream channel erosion, which can negate all of the efforts in the upstream region. Thus, stormwater BMPs in arid regions should incorporate considerations from both upstream portions of the watershed and downstream channel processes. Caraco's (2000) study also reported that 75 percent of arid stormwater managers found that sediment clogging and deposition problems were a major design and maintenance problem for their stormwater practices. In view of this, upstream erosion and sediment control were a major emphasis of stormwater plan review.

Since water quantity is a dominant priority in arid regions, water harvesting is being promoted in many cities in the Desert Southwest. Cities like Tucson and Phoenix in Arizona and Santa Fe and Albuquerque in New Mexico are promoting water harvesting practices, which address water quality and quantity in an integrated fashion. Water harvesting reduces the volume and peak flow of stormwater reaching receiving streams. Designs in Tucson's water harvesting guidance manual target both water harvesting for reducing storm runoff and improvement of stormwater discharge quality (Gunderson 2009). In terms of long-term sustainability, integrated approaches such as low impact development

(Dietz 2007, Low Impact Development Center 2007) could be ideally useful for the arid Southwest. By reducing impervious areas and limiting the directly connected impervious surfaces, low impact development designs can be helpful for the arid Southwest. This might also require a major shift in landscape design away from wide roads, large cul-de-sacs, and unnecessary impervious areas. However, BMP components in low impact development must be individually evaluated and adapted considering the local climate, soil, and geology. For instance, local geology in the Las Vegas area may not be conducive for groundwater recharge due to the presence of selenium (Clean Water Coalition 2008). In some semi-arid western states (notably Colorado), water harvesting meets a significant obstacle: water rights. Recent legislation in water rights states appears to make water harvesting more acceptable.

Pilot Scientific Studies

Pilot scientific studies are needed to evaluate the effectiveness of BMPs and design improvements. There is a conspicuous lack of scientific research and pilot projects related to BMP design in arid desert environments despite some efforts of implementation in semi-arid environments (Northern Nevada, Southern California, Colorado, etc.). The project information, success stories, and lessons learned are thus not widely known. In the following, we enlist the need of a few specific pilot scientific studies in the region.

1. Ideally, infiltration techniques are an excellent method for stormwater volume reduction, disconnection of the potential surface runoff plots in the urban area, and enhancement of ground water recharge. However, many experiences in the arid Southwest have revealed that these techniques are highly prone to clogging and demand high maintenance (Caraco 2000). Some studies (Lindsey et al. 1992; Schueler et al. 1992) have shown that clogging is a major problem in a majority of infiltration basins. As an alternative, bioretention techniques that include vegetation in the infiltration media are suggested as an improvement over the infiltration approaches. Despite an extensive literature search in this study, we did not find evidence of BMPs using techniques like bio-retention in the arid Southwest. Although the U.S. EPA BMP manual and other studies (Caraco 2000) report the possibility of modifying these techniques for use in the arid Southwest, there is no field-based research guidance or evaluation. In the absence of focused scientific studies, a clear picture of problems, constraints, and effectiveness of these techniques cannot be revealed. Furthermore, pilot studies with focus on design should help revise design parameters (e.g. size and type of soil bed, gradation of filter, types of vegetation, etc.) for the arid Southwest. Although water limitations can hinder the maintenance of vegetation in such systems, proper design can take advantage of the water-collecting nature of such facilities to support native desert plants (e.g. creosote bushes, mesquite trees, and cactuses).
2. Another research gap is to reduce maintenance and operations costs in components of low impact development projects. Since vegetation is a main element of some components of such projects, how the benefits can be accrued by adapting to the use of native desert plants is a major research challenge in the arid Southwest.
3. Studies evaluating the effectiveness of BMPs need to be carried out with specific climate sub-zoning with arid and semi-arid regions. For example, despite being located in a desert region, issues in semi-arid Northern Nevada are different than those of arid Southern Nevada. In contrast, Southern Nevada will share several commonalities with the arid desert of Arizona, despite some differences in local geology and climate.
4. The study in Las Vegas evaluating detention basins (which were designed mainly as flood control measures in the past) as a part of structural BMPs has shown inconsistent results (CCRFCD 2008). A specific study to inform design improvements of detention basin retrofit techniques is needed from the standpoint of water quality in the arid Southwest.

5. While designing structural infiltration amenities, water table elevation is often a factor even in arid regions. For instance, the Southern Nevada Water Authority Depth to Water Contour Map (Zikmund 1996) shows that in some areas of Las Vegas the shallow aquifer is only 5 feet below the existing ground surface. This can present a challenge when designing sufficient volume for the retention basin in a confined area. Additionally, variable water table elevations could put the water surface above the invert of the retention pond at certain times of the year. Infiltration of industrial pollutants into the shallow aquifer has been a problem in areas such as Las Vegas in the past. Moreover, soil type and the level of pollution in the soil determine the feasibility of infiltration BMPs. Considering such local situations, studies that identify suitability of different stormwater BMPs even in the same hydroclimatic location may be recommended. Geospatial analysis could be applied to prepare Geographic Information System (GIS) maps of BMPs' suitability for each city adhering to the basic philosophy and needs of the Desert Southwest.

Improved Representation and Workshops

Improved representation of and periodic workshops for stormwater managers in the Desert Southwest are needed. There is a need for separate representation of the Desert Southwest in stormwater management and BMP studies. Such representation that addresses the specific needs of the Desert Southwest is necessary in view of the regional differences in hydroclimatology, geology, topography, and other issues as described above. Moreover, rapid urbanization, growing economies, a very high rate of population growth, and the threat to ground water and surface water sources in the region make the case stronger for the need of such representation.

We believe that proactive participation is needed from the stormwater management community and environmental scientists and engineers in order to disseminate the results of their experiences and case studies to the broader community. Incorporating these findings into the existing ASCE/U.S. EPA International BMP Database will be a key future tool for spreading information (http://www.bmpdatabase.org).

Also, there is a need to bring arid Southwest stormwater managers, whose issues and concerns are climatically similar, together on a regular basis. Within such an organization, it is important to segregate the experiences and techniques of stormwater managers from arid and semi-arid regions. For example, swales and biofilters have received a high priority among stormwater managers of arid and semi-arid regions (Caraco 2000). However, there is a high probability that this opinion is highly influenced by the presence of a large number of participants from the semi-arid region where relatively more water is available. Hence, future workshops should be able to identify the issues, concerns, practices, and recommendations in the implementation of stormwater BMPs according to the hydroclimatic nature of the areas of interest.

Summary and Conclusions

This paper represents an initial attempt to describe the challenges facing stormwater managers in the region and to prioritize efforts to improve stormwater BMPs for this unique setting. Despite having a low annual volume of precipitation, rainfall intensity is generally high in the Desert Southwest. The runoff response in the Desert Southwest is also considerably high due to both intense precipitation and watershed characteristics. Stormwater BMPs for the Desert Southwest are an important tool for preserving the water quality of the region's precious water resources. These BMPs should be designed based on the unique features (vegetation, soil type, and geology) and needs (water conservation, reuse, and sustainable land use management) of the region. Since many, if not most, stormwater BMPs have been initially developed for humid regions, a number of pilot studies are recommended to adapt BMP design components to arid regions. Workshops targeting stormwater managers that include separate representation for the desert Southwest are needed so that opinions and solutions are not biased towards other relatively water-rich regions in the Southwest.

Acknowledgements

This study was funded by U.S. Corps of Army Engineers (USACE), Department of Defense under Urban Flood Demonstration Program of Arid and Semi-Arid Regions (Agreement # DACW42-03-2-0003).

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