Geosyntec consultants

3415 South Sepulveda Blvd., Ste 500
Los Angeles, CA 90034
PH 310.957.6100
FAX 310.957.6101
www.geosyntec.com

Memorandum

Date:	September 2015
To:	Darla Inglis, PhD, Central Coast Low Impact Development Initiative (LIDI)
From:	Geosyntec Consultants, Inc.
Subject:	Drywell Stormwater BMP - Drywell Information, Detail, and Specifications for Enhanced Infiltration Geosyntec Project: LA0339

INTRODUCTION

This memorandum introduces a combined stormwater "Best Management Practice" (BMP) consisting of a biofiltration system (for flow-through treatment of stormwater, such as where infiltration is restricted) and drywell (to enhance infiltration). It also provides the justification and description for a standard design detail and specification for this type of system. Section 1 of this memorandum explains the need for engineering details and specifications for a system that will enhance the infiltration of captured stormwater, while also ensuring a minimum standard of water quality treatment to protect groundwater sources. This section explains why biofiltration is one of the most effective means of natural passive pretreatment available. Section 2 provides a summary of literature characterizing the risk of groundwater contamination from drywell injection of treated stormwater. Section 3 describes system components to address concerns of groundwater pollution and maintenance. Section 4 lists recommendations for further research to address knowledge gaps highlighted by this assessment.

1. THE NEED/VALUE OF THE ENGINEERING DETAILS AND SPECIFICATIONS

Biofiltration (also referred to as bioretention with underdrains) is a highly effective type of stormwater treatment BMP that is designed to detain, filter, treat and release stormwater. Primarily used to address urban stormwater runoff, biofiltration BMPs can reduce the volumes runoff rates and pollutant loads that can otherwise adversely impact receiving waters such as rivers, lakes, streams and the ocean. Recognizing that stormwater runoff is an underutilized water supply, there is growing interest in furthering the development of stormwater infiltration systems to help replenish groundwater resources (Los Angeles and San Gabriel Rivers Watershed Council, 2010; CASQA, 2015). Biofiltration systems are typically designed to allow infiltration in suitable conditions, however the amount of infiltration achieved by these systems may be limited by the footprint area of the biofiltration system and the infiltration rates of near-surface soils. Excess water is typically discharged through an underdrain into the storm sewer system and not infiltrated. Incorporation of a drywell component provides an opportunity to significantly increase the infiltration capacity of these systems. Drywells are designed to enhance infiltration and are commonly used for runoff management in various landuse settings. Drywells enhance infiltration by penetrating clay and other less permeable soil layers that otherwise limit infiltration at the surface, thus providing the potential for significantly greater stormwater runoff volume reduction and aquifer recharge. The term "injection well" is commonly used to describe both drywells and also mechanically powered injection wells. The engineering details and specifications described herein provide an important reference defining how "enhanced infiltration" configurations differ from injection wells. Most importantly, wells with mechanical injection can include direct injection into an aquifer with no vadose zone treatment, whereas the system described in this memorandum features additional vadose zone treatment. This additional treatment is important for a number of pollutants described below. Current injection well regulations as defined by the Environmental Protection Agency may require users to register and monitor the facilities, which may create a disincentive for use in stormwater management. Evaluation of dry wells for stormwater management may be warranted to better understand their context regulatory context. Having a clearly defined system is particularly important in the context of the California Office of Environmental Health Hazard Assessment's (OEHHA) ongoing efforts to develop a regulatory framework for this type of work (OEHHA, 2015).

Combining biofiltration BMPs with drywells provides a system which helps optimize the multi-benefits of stormwater management (i.e. improved water quality and increased local water supply). Well-designed biofiltration systems can also provide pre-treatment for drywells, including providing treatment for suspended solids, particulate-bound pollutants, dissolved metals, pathogens, dissolved organics, and other constituents. Other BMPs such as vegetated swales, sediment basins, and permeable pavement also have potential to provide effective pre-treatment in combined BMP/drywell designs. This memorandum however only assesses the opportunities and risks specifically concerning the use of biofiltration systems with a drywell, and specifically within the context of typical pollutant loads found in urban stormwater runoff. It is important to note that other landuses such as heavy industry or agriculture may pose additional risks to groundwater contamination for which this system may not adequately address.

Conversely, in certain watersheds where low pollutant loads have been demonstrated, other BMP types such as vegetated swales may suffice in providing adequate pre-treatment.

Biofiltration alone provides water quality benefits including runoff volume and rate reduction and removal/treatment of common urban pollutants. By combining a biofiltration and dry well design, water resource benefits are optimized. As with any BMP design, the biofiltration/dry well technical details and specifications need to address potential risk. For example, as with any dry well design, care must be taken to limit the amount of sediment that enters the dry well. If media is not adequately retained in the biofilter, particles can wash out of the media and pose a clogging risk to the drywell. Second, removal of nutrients from stormwater is strongly dependent on the properties and sources of biofiltration media, and export of nutrients from media (i.e., negative removal efficiency) is a significant concern if materials are not carefully selected (Geosyntec Consultants and Wright Water Engineers, 2011; Roseen and Stone, 2013; Herrera, 2014, Herrera et al., 2015a, Herrera et al. 2015b). Finally, export of other pollutants, such as dissolved copper, has also been observed but is less common (Geosyntec Consultants and Wright Water Engineers, 2014; Roseen and Stone, 2013; Herrera et al. 2015b). Engineering details and specifications can help limit the potential for export of pollutants and associated impacts to drywell maintenance and groundwater quality.

2. PERCEIVED AND ASSESSED RISK OF GROUNDWATER CONTAMINATION FROM INFILTRATING STORMWATER.

While many stormwater BMPs are designed to infiltrate urban stormwater runoff, concerns have been raised as to whether there is an added risk of groundwater quality impact with drywells which provide a more direct conduit to groundwater. Therefore there is a need to provide a standardized BMP design that specifies pre-drywell treatment components to provide a minimum standard pollutant removal for the pollutants that are typically found in urban stormwater runoff. Priority pollutants in urban stormwater runoff generally include nutrients (i.e., nitrogen and phosphorus), heavy metals (e.g. cadmium, copper, lead and zinc), organics (i.e., petroleum hydrocarbons), pathogens (i.e., fecal coliforms, enterococcus), and suspended solids. The dissolved and colloidal (or planktonic, in the case of bacteria cells) fraction for each of these priority pollutants represents the greatest threat to groundwater quality given the effectiveness of biofiltration for removing particulate bound pollutants. However, typical dissolved concentrations of most urban stormwater pollutants are below drinking water standards (which are typically applicable to the beneficial use of underlying aquifers). An exception to this is bacteria and pathogens, where biofilter effluent concentrations are not expected to consistently meet drinking water standards, therefore vadose zone treatment is required to further mitigate this water quality issue.

Acknowledgment of the contamination risk to groundwater as a potential barrier to using enhanced stormwater infiltration techniques has prompted a number of studies to investigate contamination risks associated with stormwater infiltration BMPs, including drywells. Over all, studies however have found that treated stormwater infiltrated from BMPs does not pose a significant risk to impairment of groundwater quality and in some cases found to improve the quality of groundwater (Jurgens, 2008; Weiss, 2008, Los Angeles and San Gabriel Rivers Watershed Council, 2010). Studies found that nitrates in drinking water can pose human health risks, and tend to be poorly retained in BMPs due to high solubility (Pitt et al., 1999), however the amount of nitrates typically found in stormwater is less than the drinking water standard (U.S. EPA, 1999), and therefore nitrates are not considered a concern as long as nutrient hot spot areas are avoided (e.g., agriculture, nurseries) and sources of nitrates within biofiltration media are limited and controlled. Metals were found to largely be absorbed by BMPs, however there is a potential for breakthrough if the soil becomes saturated with contaminants, and satisfactory treatment depends on soil replacement at set intervals (i.e. a dedicated maintenance regime); typically maintenance intervals will be controlled by surface clogging of the biofilter rather than pollutant accumulation (Pitt and Clark, 2010). BMPs are known to remove bacteria through straining in the soils (Diez and Clausen, 2005; Rusciano and Obropta, 2007), however the treatment efficiency, and migratory potential for pathogens is highly variable (US EPA, 1999), and contamination of groundwater by pathogens has been documented (Pitt, 1999). However, any groundwater consumption as a potable water source requires treatment, and therefore bacteria contamination from stormwater infiltration is not deemed a threat to human health. Organic pollutants such as hydrocarbons are a concern for groundwater contamination since they are found to typically occur in quantities above regulatory levels (Shepp, 1996), have been shown to migrate into groundwater (Pitt et al, 1999), and can cause acute toxicity (U.S. EPA, 1999). Most hydrocarbons will be attenuated by soil in biofiltration systems (Hsieh and Davis, 2005), however, Wilson et al (1990) found that while undetected in stormwater samples, volatile organic sediments were present in dry-well sediments and groundwater samples, though at levels below the EPA human health criteria. Therefore the expected risk of groundwater contamination from stormwater infiltration is considered to be low for typical stormwater pollutants of concern.

3. OVERVIEW/DESCRIPTION OF THE ENGINEERING DETAILS

The following section describes the function of each component of design in terms of either addressing the water quality objective, the groundwater augmentation objective, and a “system fail” risk mitigation objective.

3.1 DESIGN ELEMENTS TO HELP PROTECT GROUNDWATER RESOURCES (BMP)

The biofiltration system consists of “soft infrastructure” and “hard infrastructure” components. The soft infrastructure includes vegetation within a filter media (e.g., bioretention soil media), and storage media (e.g., aggregate). The hard infrastructure includes an underdrain to discharge treated water to the drywell, an overflow control and hard engineered structures defining the boundary between the BMP and adjacent urban infrastructure. Other hard engineered structures such as inlets and curb retrofits relate to the site conditions and catchment hydrology but do not have a significant nexus to how well a BMP performs for protecting groundwater resources. The hard infrastructure elements are governed by local standard specifications and are not detailed in the following discussion.

- Vegetation used in biofiltration systems are typically reed species such as *Juncus* spp. and *Carex* spp. These species can tolerate extended wet and dry periods, help maintain porosity of media, provide uptake of nutrients and some other pollutants, and can play a role in symbiotic role with other organisms in media (i.e., microorganisms, fungus) (Read et al 2008). LIDI biofiltration technical specifications (LIDI 2013a) provides further details on irrigation and planting guidelines.

- The media bed supports plant growth, infiltration and provides treatment. The single media layer, often topped with a specified mulch, provides for planting and filtering. In other designs, a separate layer of planting media is placed in the top of the bed and is underlain by filter media which also provides treatment. Where planting media and filter media are the same layer, this layer should adhere to the more stringent of the LIDI technical standards for planting media and filter media.

    - Filter media, which is placed below the planting media in a layered design, is an engineered filter material known as the biofiltration soil media (BSM). Detailed specifications are contained in the LIDI Biofilter Technical Standards (BTS) (LIDI 2013a). The biofiltration soil media features a ratio of organic and inorganic material which allows suitable infiltration, and also the required chemical, biological and physical pollutant removal processes. The specified combination provides an important filtering function for metals and nutrients. Cation exchange capacity is known to be an important process in metal removal and nutrient retention (Jurries, 2003). Additionally, other treatment processes, such as sorption and precipitation can be provided by the components used in the filter media.

  - The abundance and solubility of contaminants in the soil media is a key factor in determining the potential for pollutant export. This can be controlled by utilizing minimum organic material quantities needed for plant survival (typically 5 percent or less), utilizing stable organic materials (a well-aged leaf-based compost or compost alternative such as coco coir pith should be considered), and conducting initial leachate testing on all materials that are used.

- The storage layer is the base layer of the biofiltration system and consists of an open graded aggregate to optimize the porosity of this layer. This layer includes the underdrain which drains treated water to the drywell. Since the system objective is to infiltrate treated water through the drywell, optimizing storage volume in this layer is not required. Therefore this layer only needs to be sized to cover the underdrain and provide the required distance between the drain and BSM as per LIDI specifications. This minimum depth between the drain and BSM has not yet been determined according to the BTS (LIDI 2013a) and warrants further research. A bridging layer of at least 6 inches is preferred. Alternatively, a well screen pipe with very fine slots can be buried directly within the filter media layer to eliminate the need for a bridging layer and storage rock. Connected to the drain are maintenance and ventilation riser pipes which are proposed in this design. These PVC pipes require a bent connection to the under drain to facilitate directional cleaning.

- To achieve lower pollutant concentrations in treated biofilter effluent, an outlet control device attached to the underdrain of the biofiltration system may be desirable to control the rate of flow through the filter media. This has the benefit of increasing the contact time of water in the media pores, reducing the potential for short circuiting, and reducing pore velocities. Most critically, if pore velocities are high through the media or preferential pathways form, export of fine particles from the soil media can result. The conventional way to control filtration rates is to limit the hydraulic conductivity of the media. However, this approach can be challenging to execute reliably in practice given sensitivity of media filtration rate to minor variations in particle size distribution and compaction - a high level of quality control is needed to "dial in" media filtration rates in this manner. This also results in a media that is closer to clogging failure at the time it is place. The preferred outlet control approach allows the media to be specified with a higher initial hydraulic conductivity and wider allowable range that is easier to specify and achieve. The actual rate of flow through the media is then controlled by a more precise hydraulic control structure (i.e., orifice or weir) affixed to the underdrain or outlet pipe rather than the surface of the soil media. This approach can also allow the water level retained in the biofiltration system to be adjusted; for example it may be desirable to pool water within the underdrain or filter media layer of the biofiltration system to improve residence time for small storms and provide a reservoir of water for plant roots.

3.2 DESIGN ELEMENTS TO ENHANCE INFILTRATION OF STORMWATER AND TO LIMIT ADVERSE IMPACTS AND SYSTEM FAILURE

The drywell is a relatively straightforward design and a system commonly used in stormwater management. The drywell typically consists of a gravel and stone backfilled slotted well which accepts treated stormwater for infiltration is drilled to at least 10 feet below any impermeable layers. A number of important design guidelines, design changes, and maintenance routines should be followed to enhance groundwater infiltration function.

Design Guidelines

These guidelines are based on common standards of the Los Angeles County LID Standards Manual (2014), the San Diego County LID Handbook (2014) and the Orange County Technical Guidance Manual (2013). The most important of these are:

- Maintain a 10 foot minimum separation between drywell bottom and seasonal high water table; in constrained hydrogeologic conditions (i.e., limited groundwater gradient; confining layers or faults), an evaluation of potential groundwater mounding may also be needed;
- Do not use in soils with >30% clay or >40% silt because these soils are not conducive to infiltration.
- Penetrate the drywell at least 10 feet into permeable porous soils;

- Conduct facility-specific infiltration testing at the location and depth of the proposed drywell facility, using standardized methods acceptable to the local jurisdiction, to estimate the long term capacity of the drywell;
- Apply appropriate factors of safety to address uncertainty in testing methods, long term operational conditions, and potential for clogging;
- Maintain at least a 100 foot minimum setback from public supply wells and septic systems;
- Maintain a 100 foot minimum separation between drywells unless the interdependency of multiple wells in close proximity has been evaluated to determine the reliable long term drywell capacity (the groundwater dispersion mounds from multiple drywells in close proximity may interact and reduce the rate of each well, if placed in close proximity);
- Maintain at least 250 foot setback from sites of potential soil or groundwater contamination (such as sites found in the Geotracker or EviroStor databases (http://geotracker.swrcb.ca.gov/; http://www.envirostor.dtsc.ca.gov/public/), unless a site specific study demonstrates that infiltration would not adversely impact groundwater conditions. Higher setbacks may be necessary depending on the direction of flow of groundwater and the level of certainty of the contaminant mapping. Consultation with parties responsible for nearby contaminated sites is encouraged, where applicable.
- When past uses of a site indicate potential for contamination, it may be prudent to assess the site for soil or groundwater contaminant levels even if the site is not currently listed on a contaminated sites database. The introduction of stormwater infiltration into an area of contamination can significantly complicate later cleanup efforts.
- Maintain appropriate setbacks from slopes, foundations and other structures; the project geotechnical engineer should provide site-specific criteria that relate to drywells.
- Avoid infiltration from pollutant hot spots, including:
    - Roads greater than 25,000 ADT
    - Heavy and light industrial pollutant source areas,
    - Automotive repair shops
    - Car washes

  - Fleet storage areas
  - Nurseries, agriculture, and heavily managed landscape areas with extensive use of fertilizer
  - Fueling stations

- Projects that propose to infiltrate stormwater are encouraged to consult with the applicable groundwater management agency to the extent necessary to ensure that groundwater quality is protected.
- Drywells[1] must be registered as a Class V injection well through EPA Region 9 (http://www.epa.gov/region9/water/groundwater/uic-classv.html).

Design Modifications

Several important modifications to a typical design are presented here to address system failure risks. Failed systems will achieve neither water quality treatment nor groundwater recharge objectives. At worst, a failed system becomes a public nuisance contributing to increased pollution pathways to groundwater aquifers, impaired surface water bodies, a negative perception of emerging BMP technologies, and wasted capital investment. These design modifications are:

- While a typical drywell used as a stormwater BMP should incorporate a pre-treatment device for sediment control, the coupling of a biofilter to the front end of a drywell, as described in the memorandum, is sufficient to manage and control sediment from reaching the drywell and clogging the infiltration system.
- Include a shut off valve with a manually operated switch or actuator to prevent water from the biofiltration system from entering the drywell in the event of an acute pollutant exposure, such as an oil spill within the BMP's catchment. This feature can be integrated with the outlet control structure that is recommended in biofiltration design.

---

[1] Stormwater drywells have a variety of designs and may be referred to by other names including stormwater drainage wells, bored wells, and infiltration galleries. A Class V well by definition is any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension, or an improved sinkhole, or a subsurface fluid distribution system (an infiltration system with piping to enhance infiltration capabilities).

- Include an alternative backup discharge location for biofiltered water, typically to the storm drain. This would allow the biofilter to continue to treat water and drain completed in the event that the drywell is offline, at capacity, or clogged.
- Route overflow from the biofiltration area directly to the storm drain and not to the drywell. This helps prevent unfiltered water from entering the drywell.
- Locate the drywell at the surface, adjacent to the biofilter, and not directly below it. This allows the inclusion of maintenance access in the form of an access hatch without the need to dismantle the biofilter. This alignment also allows for the inclusion of the shut off valve described above.

Maintenance Suggestions

Aside from the important design elements outlined above, and guidelines for their implementation, adequate maintenance is required to maintain a functioning system:

- Periodic replacement of the soil media is required to ensure that BMP soils feature low metal concentrations. Literature suggests that the soil adsorption of pollutants will eventually be saturated and soil material will need to be replaced. Unmaintained BMPs can result in breakthrough of metals and possible increased risk of groundwater contamination. This risk cannot be eliminated through design, and requires a dedicated life cycle maintenance program to ensure the system continues to project the groundwater resources form contamination risk. In general, biofiltration systems are expected to clog before pollutant accumulation reaches levels of concern (Pitt and Clark, 2010). Scraping the top 3 to 6 inches of media periodically can help extend life and minimize the risk of pollutant accumulation at levels of concern.

- Other common maintenance issues are vegetation die-off, which reduces the biofiltration function since they play an important role in long term permeability and pollutant uptake. Vegetation within a biofilter actively maintains the hydraulic conductivity of the planting media and vegetation die-off increases the risk of the BMP clogging. Vegetation should be maintained and should be actively replaced if it dies off.

- Sediment and debris accumulation which limits hydrologic connectivity to the BMP is another issue that can only be addressed through maintenance. Periodic removal of sediment and debris is recommended. This will also typically require replacement vegetation and the top layer of media if the entire surface of the biofiltration system is excavated.

Sediment capture pretreatment is considered a standard component of typical drywell construction to reduce the risk of clogging. In the proposed standard design, the biofiltration system provides appropriate sediment capture to protect the drywell, provided that export of particles from the biofiltration media itself is controlled with an effective separation layer. On average, biofilters outperform sediment basins because biofiltration BMPs filter much smaller sized particles (Geosyntec and WWE, 2014).

If desired, a sediment capture pretreatment BMP could be a useful component upstream of biofiltration since they protect the engineered biofilter media from excessive sediment fluxes which can affect plant growth and clog biofilters. Therefore, while not incorporated into this standard design, a pretreatment sediment capture system, such as a sedimentation chamber or forebay, is recommended to improve the longevity of the biofilter component of the treatment train. For larger biofiltration systems, an engineered pre-treatment system such as a sedimentation basin or hydrodynamic separator (where space constraints are an issue) could be considered for enhanced protection from clogging.

4 REGULATORY BARRIERS AND TECHNICAL DESIGN GUIDANCE OBSTACLES

The following regulatory and technical issues represent potential existing barriers to widespread implementation of drywells in California. It is recommended that these barriers be addressed to facilitate approval and use of drywell in the state.

- **Statewide drywell pretreatment standards or guidance**. Currently no regulatory framework exists in the State of California for permitting drywells or providing practitioners with guidance on pretreatment needs based on drainage area or soil conditions. For example, heavy industrial land uses with elevated metal and organic concentrations may require more advanced pretreatment or prohibition on drywells. Similarly, shallow groundwater or highly transmissive soils may require the same. Research is required to develop minimum standards (e.g., BMP unit process selection) for drywell implementation based on these site specific conditions. In addition there may be a need for specifications on contact time for pretreatment within the biofilter.

- **Appropriate infiltration test methods and factors of safety for drywells.** Infiltration testing methods are often approximations of full scale infiltration processes. Retrospective analysis of measured or estimated vs. actual infiltration capacity of drywells would be beneficial to evaluate which infiltration testing methods are most reliable and what factor of safety is needed to reliably develop capacity estimates from testing data.

5 REFERENCES

California Stormwater Quality Association (CASQA) (2015). "Stormwater infiltration wells – Studies, regulations, EPA registration". Water Quality News Flash. Number 2015-06. March 16, 2015.

Datry, T., Malard, F., Gilbert, J. (2004). "Dynamics of solutes and dissolved oxygen in shallow urban groundwater below a stormwater infiltration basin" *Science of the Total Environment.* 329 (1-3): p215-29

Dietz, M., Clausen, J., (2005) "A field evaluation of rain garden flow and pollutant treatment". *Water, Air, & Soil Pollution.* 167, p123- 138.

Geosyntec and Wright Water Engineers (2010). International Stormwater Best Management Practices (BMP) Database Technical Summary: Nutrients. Prepared under Support from EPA, WERF, FHWA and EWRI/ASCE. (accessible at www.bmpdatabase.org)

Geosyntec and Wright Water Engineers (2014). International Stormwater Best Management Practices (BMP) Database 2014 BMP Performance Summaries and Statistical Appendices. Prepared under Support from EPA, WERF, FHWA and EWRI/ASCE. (accessible at www.bmpdatabase.org)

Geosyntec Consultants, Inc. & Wright Water Engineers, Inc. (2014). "International stormwater best management practices (BMP) database pollutant category statistical summary report."

Herrera (2014b). Final Report: 185th Avenue NE Bioretention Stormwater Treatment System Performance Monitoring. Prepared for City of Redmond, by Herrera Environmental Consultants, Inc., Seattle, Washington. March 6, 2014.

Herrera (2015a). Interim Project Report: City of Redmond Six Bioretention Swales Monitoring. Prepared for City of Redmond, by Herrera Environmental Consultants, Inc., Seattle, Washington. February 20, 2015

Herrera (2015b). Analysis of Bioretention Soil Media for Improved Nitrogen, Phosphorous and Copper Retention, Final Report, Prepared for Kitsap County by Herrera Environmental Consultants, Seattle, WA, July 17, 2015. Project team: Kitsap County, City of Seattle, Washington State Department of Transportation, Geosyntec Consultants.

Hsiech, C., Davis, A.P. (2005) “Evaluation and optimization of biofiltration media for treatment of urban storm water runoff.” *Journal of Environmental Engineering*. 131, p1521-1531.

Jurgens, B.C., Burow, K.R., Daglish, B.A., Shelton, J.L, (2008). “Hydrology, water chemistry, and factors affecting the transport of contaminants in the zone of contribution of public-supply well in Modesto, eastern San Joaquin Valley, California”. *National Water Quality Assessment Program, U.S. Geological Survey, Scientific Investigation Report 2008 – 5156.* http://pubs.usgs.gov/sir/2008/5156/pdf/sir20085156.pdf

Jurries, D., (2003). “Biofilters (bioswales, vegetative buffers, & constructed wetlands) for stormwater discharge pollution removal.” *State of Oregon Department of Environmental Quality*.

Los Angeles & San Gabriel Rivers Watershed Council (2010). “Water augmentation study; Research, strategy and implementation report”.

Low Impact Development Initiative (LIDI) (2013a) “Bioretention technical specifications (BTS)”.

Low Impact Development Initiative (LIDI) (2013b). “Low impact development stormwater management standard details. Version 3/6/2013”

Office of Environmental Health Hazard Assessment (OEHHA) (2015). “Dry wells. Uses, regulations, and guidelines in California and elsewhere. Fact sheet to the City of Elk Grove, CA.

Pitt, R., Clark, S., Field, R., (1999). “Groundwater contamination potential from stormwater infiltration practices”. *Urban Water*, 1: p217-236

Read, J, Wevill,T., Fletcher, T., Deletic, A. (2008). “Variation among plant species in pollutant removal from stormwater in biofiltration systems”. *Water Research*. 42. P 893-902.

Roseen, R.M. and Stone, R.M. (2013). Bioretention Water Quality Treatment Performance Assessment. Technical Memorandum. Prepared for Seattle Public Utilities.

Rusciano, G.M., Obropta, C.C., (2007) “Biofiltration column study; Fecal coliform and total suspended solids reductions.” *Transactions of the ASABE*. 50, p1261-1269.

Shepp, D.L., (1996) “Petroleum hydrocarbon concentrations observed in runoff from discrete, urbanized automotive-intensive land uses”. *Metropolitan Washington Council of Governments, Washington DC.*

U.S. EPA (1999). “Preliminary data summary of urban storm water best management practices”, *Report EPA*-821-R-99-012, Aug.

United States Department of Agriculture, Natural Resources Conservation District, 1994. Part 633, National Engineering Handbook: Chapter 26 Gradation Design of Sand and Gravel Filters. October.

Weiss, P.T., LeFevre, G., Gulliver, J.S., (2008). “Contamination of soil and groundwater due to stormwater infiltration practices – A literature review”. *University of Minnesota, Stormwater Assessment Project.* Project Report No. 515.

Wilson, L.G., Osborn, M.D., Olson, K.L., Maida, S.M., Katz. L.T., (1990). “The ground water recharge and pollution potential of drywells in Pima County, Arizona”. *Groundwater Monitoring and Remediation*. 10(3). p 114-121