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Review papers

Assessing the effectiveness of drywells as tools for stormwater management and aquifer recharge and their groundwater contamination potential

Emily C. Edwards [a,*], Thomas Harter [a], Graham E. Fogg [a], Barbara Washburn [b], Hamad Hamad [b]

[a] University of California Davis, Department of Land, Air, and Water Resources, 1 Shields Avenue, Davis, CA 95616-8627, USA
[b] California Environmental Protection Agency, Office of Environmental Health and Hazard Assessment, 1001 I Street, Sacramento, CA 95814, USA

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SUMMARY

Drywells are gravity-fed, excavated pits with perforated casings used to facilitate stormwater infiltration and groundwater recharge in areas where drainage and diversion of storm flows is problematic. Historically, drywells have predominantly been used as a form of stormwater management in locations that receive high volumes of precipitation; however the use of drywells is increasingly being evaluated as a method to supplement groundwater recharge, especially in areas facing severe drought. Studies have shown that drywells can be an effective means to increase recharge to aquifers; however, the potential for groundwater contamination caused by polluted stormwater runoff bypassing transport through surface soil and near surface sediment has prevented more widespread use of drywells as a recharge mechanism. Numerous studies have shown that groundwater and drinking water contamination from drywells can be avoided if drywells are used in appropriate locations and properly maintained. The effectiveness of drywells for aquifer recharge depends on the hydrogeologic setting and land use surrounding a site, as well as influent stormwater quantity and quality. These parameters may be informed for a specific drywell site through geologic and hydrologic characterization and adequate monitoring of stormwater and groundwater quality.

Contents

* Corresponding author.
E-mail addresses: ecledwards@gmail.com (E.C. Edwards), thharter@ucdavis.edu (T. Harter), gefogg@ucdavis.edu (G.E. Fogg), barbara.washburn@oehha.ca.gov (B. Washburn), hamad.hamad@oehha.ca.gov (H. Hamad).

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1. Introduction

1.1. Background

The natural hydrologic cycle has been altered in much of the world due to climate change and human land development (Maloney et al., 2014; Rusu et al., 2012). Urban development limits the permeability of ground surfaces; precipitation that would normally reach natural land surface and infiltrate into the underlying aquifer instead runs off, traveling over paved areas or areas with low surface soil permeability until it evaporates, or enters surface water bodies or stormwater management facilities (Clark and Pitt, 2007; Rusu et al., 2012). Rapid human population growth is further stressing the allocation of water resources, and groundwater usage in some areas is occurring at potentially unsustainable rates (Gorelick and Zheng, 2015; Rusu et al., 2012). One of the ways to address the challenges of managing stormwater runoff and replenishing depleted groundwater resources is through the use of deep infiltration practices such as drywells. Drywells are vadose zone infiltration wells that end before the water table and are used extensively throughout the United States and other parts of the world to dispose of stormwater in areas with low ground surface permeability. However, more recently their potential to provide additional aquifer recharge has been recognized (Natural Resources Defense Council, 2014). There is some concern that drywells allow stormwater pollutants more direct passage to the water table without undergoing surface soil and near surface sediment attenuation processes. In some cases, drywells have been linked to groundwater and drinking water contamination events (Environmental Protection Agency, 1999a,b). This has created controversy over their use and made some regulatory agencies reluctant to support further installations (EPA, 1999a,b).

1.2. Rationale

While drywells are a prevalent form of stormwater infiltration device in some parts of the world, relatively few studies have been performed to quantify either the quantity of recharge entering aquifers from drywell infiltration, or the potential for this infiltration to contaminate groundwater and drinking water. Groundwater contamination events associated with the use of drywells have been reported, however in many cases these events are the result of mismanagement of the facilities and can be traced to surface pollutant spills or illicit dumpings (Adolfson, 1995; EPA, 1999a,b; Jurgens et al., 2008). Some regulations pertaining to drywell installation, design, and usage were instated before many comprehensive drywell studies had been performed, and therefore can be lacking quantifiable basis and may mandate separation distances that are based on those set for other forms of stormwater or wastewater management (EPA, 1999a,b; Minnesota Department of Transportation, 2009). In some locations where successful full or pilot scale drywell studies have been performed, preexisting regulations or permitting processes have been reformed based on the studies' conclusions (Brody-Heine et al., 2011; City of Portland Bureau of Environmental Services, 2014; Wilson et al., 1992). It has been shown that drywells can offer an effective solution for both stormwater management and aquifer recharge; however, little has been done to synthesize these findings. The purpose of this paper is to review the available literature pertaining to drywell performance in terms of both stormwater management and groundwater quality control. General stormwater quality will be summarized along with the findings of studies focused on the impact of drywells on groundwater recharge quantity and quality and their performance compared to other forms of stormwater infiltration devices. We use the information reviewed to discuss the factors that affect the potential for drywells to cause groundwater contamination, and the possible means by which to predict the timescale and magnitude of contamination.

1.3. Drywell design and usage

A drywell by simple definition is a well that is deeper than its widest surface dimension and is used to transmit surface water to the subsurface (EPA, 1999a,b). An important distinction must be made between drywells and soakaways. Soakaway is a term commonly seen in European stormwater management literature, and refers to an infiltration system that transmits stormwater to the subsurface; however, soakaways are not necessarily deeper than they are wide, and so while some soakaways may be classified as drywells, some are too shallow and wide to qualify. In this paper, soakaway will be used as a broad term, and the specification will be made whether or not a described soakaway is also a drywell. A typical drywell design consists of a perforated precast casing, usually made of concrete but in some cases PVC, with an average diameter of approximately 1.2 meters (m), and a depth of anywhere from 0.6 to 26 m, usually backfilled with gravel and/or sand (Adolfson and Clark, 1991; Adolfson, 1995; Bandeen, 1984, 1987; Barraud et al., 1999; Chen et al., 2007; City of Portland, 2008; Clark and Pitt, 2007; Dallman and Spongberg, 2012; Izuka, 2011; Jurgens et al., 2008; Lindemann, 1999; Pitt et al., 2012; Wilson et al., 1990; Wogsland, 1988). Fig. 1 depicts the design of a typical drywell. Drywells are also referred to as underground injection control wells (UICs), and are classified by the United States Environmental Protection Agency (USEPA) as class V wells, which are defined as shallow wells used to place fluids directly below the land surface (EPA, 1999a,b). They are further categorized as stormwater drainage wells (SWDWs), which are bored and dug wells and improved sinkholes designed to manage stormwater runoff (EPA, 1999a,b). In 1999, there were an estimated 247, 522 SWDWs in the United States. A more current national estimate has not been made, and a worldwide estimate is not available.

As drywells have become more prevalent, their design has increased in complexity, and more modern drywells usually include some form of Best Management Practice (BMP) or pretreatment in their design. Sedimentation can be a major problem for drywells, and so sedimentation traps, manholes, filters, or settling chambers are often constructed to receive influent stormwater