Oregon’s Experience with Dry Wells:
The Underground Injection Control Program

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Background

While over a dozen states around the country oversee dry well programs, one of the most developed programs is in Oregon. The Oregon Department of Environmental Quality (DEQ) issues permits to municipalities to operate underground injection control (UIC) devices or dry wells. Portland manages about 9,000 public UICs which collect stormwater in a catch basin, filter it through a sedimentation manhole, and release the runoff into a dry well for infiltration 20—40 feet below the ground. Portland developed UICs as a best management practice to minimize the damaging effects of increased stormwater runoff volumes on the aquatic ecosystem as well as to recharge the aquifer. In Portland, the public UICs typically collect stormwater in drainage inlets along the side of the street from the public rights-of-way. In some areas of the City, UICs are the only form of stormwater disposal. Portland’s program stands out among others around the country due to the extensive oversight and monitoring performed in an effort to protect groundwater quality. This fact-sheet describes Oregon’s UIC Program.

The role of stormwater monitoring in Oregon’s UIC Program

The protection of groundwater in Oregon’s program rests on monitoring the quality of stormwater. Drinking water standards such as MCLs (maximum contaminant levels) are used to determine the maximum allowable concentration of contaminants in stormwater. Oregon assumes that if stormwater entering the UIC does not exceed drinking water standards, groundwater quality is likely to be protected. Municipalities in Oregon operate their UIC Program under a permit from the Oregon DEQ. In June 2005, the DEQ issued a 10 year permit to Portland, which allowed stormwater discharges into city-owned UICs – the first permit of its kind in the nation. The permit established construction, operation and maintenance, and monitoring mandates for the UICs to ensure contamination prevention and groundwater replenishment.

Figure 1. A UIC located in a public right of way. *Source: Oregon DEQ UIC program.*

UICs: Construction and Design

The main component of a UIC is the dry well, which is typically a precast, reinforced, concrete cylinder that contains numerous perforations, allowing stormwater to infiltrate into the surrounding subsurface (Fig. 1 & 2). Specific features of UICs can vary by site to account for local geologic and hydrological conditions. The drywell is not filled with gravel or other material that might impede the flow or become clogged with fine sediment over time. Most have a solid bottom to permit periodic vacuuming of accumulated sediment. The size and depth of the dry well depends on the amount of infiltrating stormwater, subsurface conditions, and distance to the water table.

A second component of the UIC is the sedimentation manhole, a solid concrete cylinder generally 3-4 feet in diameter and 10 feet deep, 4 feet of which extends below the pipe that transfers stormwater to the dry well (Fig. 3). The sedimentation manholes provide pretreatment by allowing sediment in stormwater to settle, thus minimizing suspended solids, and the pollutants they carry, from entering the dry well.

The third component of the system is a catch basin. The design of catch basins vary, from a street gutter to a vegetated swale or bioretention cell or some combination of the two (Fig. 3). The function of this portion of the UIC system is to collect water and, in some cases, provide additional pretreatment.

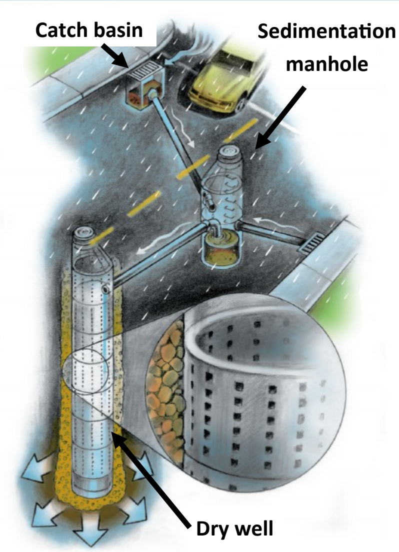

Figure 2. Schematic of typical city UIC system in Portland. *Source: Portland Bureau of Environmental Services*

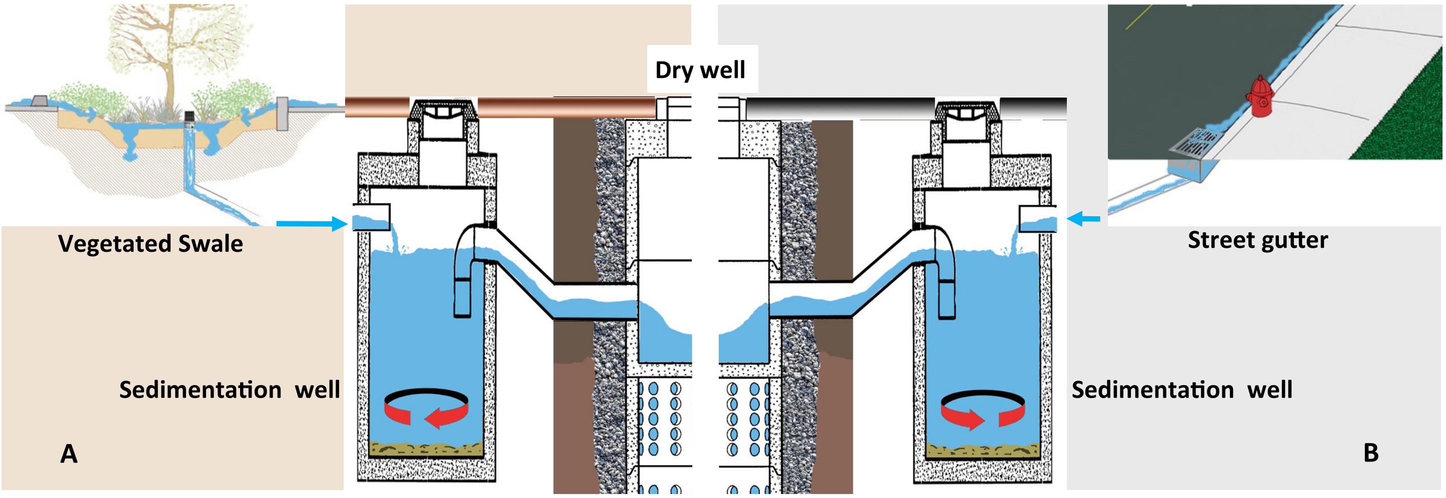

Figure 3. Typical UIC systems used in Oregon. In Oregon, the drywell (center) can extend up to 40 ft. below ground surface, depending on the depth of groundwater. Panel A shows a system more commonly seen in Bend, OR with a vegetated swale collecting stormwater, followed by a sedimentation well, where particulates in the water can settle to the bottom. This promotes an efficient and sustainable system because sediment and associated pollutants are removed as runoff passes through the system. Panel B shows a system commonly seen in Portland. Street gutters collect the stormwater runoff and transport it to the sedimentation well directly. Because Portland receives much more rain than Bend, concentrations of contaminants in stormwater are diluted. This two part UIC has been shown to efficiently remove pollutants from runoff.

Regulations and Permitting

Both public and private UICs must comply with a common set of restrictions. These restrictions affect the placement of UICs, including prohibition of UICs near vehicle maintenance areas and gas and fire stations, as well as within 500 feet of a water supply well. Permit holders must conduct a minimum of two years of stormwater monitoring to verify that run-off entering the UIC does not exceed criteria values. Permittees also must perform groundwater fate and transport modeling to ensure groundwater quality will not be compromised. Lastly, an annual report must be submitted to Oregon DEQ describing the location and monitoring results. If exceedances do occur, source control measures are the first corrective action, followed by retrofitting the UIC to capture the contaminant(s) of concern. If neither is effective, the UIC is decommissioned. There are no requirements for pretreatment, although the majority of UICs include some type of sediment trap (e.g., manhole or swale).

Monitoring Program

The monitoring program in Oregon focuses on analyzing stormwater samples collected after pretreatment, just prior to entering the dry-well (Table 1). Groundwater monitoring is not an active component of Oregon's UIC programs. Instead, vadose zone modeling is used to estimate the migration of contaminants through the subsurface. Portland, for example, monitors a randomly selected set of 30 UICs five times each year. Contaminants that are analyzed include metals, volatile and semi-volatile organics, polycyclic aromatic hydrocarbons, and pesticides/herbicides, as well as others. Owners of private UICs are also responsible for monitoring and ensuring the safety of groundwater. They must identify pollution sources, prevent stormwater pollution from reaching groundwater, and ensure UIC stormwater discharge receives the appropriate pretreatment. Results of the stormwater monitoring suggest that, in almost all cases, pretreated stormwater met federal, state, and local standards .

Analyte	MCL (µg/L)	Exceedances
Antimony	6	1
Arsenic	10	2
Benzo[a]pyrene	0.2	2
Cadmium	5	8
Chromium	100	3
Di(2-ethylhexyl)	6	30
Lead	50	78
NO3-N	10000	2
Pentachlorophenol	1	79
Zinc	5000	1

Table 1. Number of Exceedances of the Maximum Contaminant Level (MCL) in Stormwater. Over 25,000 runoff samples were collected prior to entering the dry well between 1990-2008 throughout Oregon. Of the 45 analytes tested, 10 exceeded screening levels. Pentachlorophenol, lead, and phthalate were the most common exceedances.

Modeling the Risk of Groundwater Contamination

Each UIC permit holder has to assess the potential risk to groundwater posed by the discharge of urban stormwater into UICs. Part of this process involves using a solute-based, one-dimensional model, known as the Groundwater Protectiveness Demonstration Tool (GWPD), that estimates how much a pollutant's concentration in stormwater will decrease as stormwater flows out of the UIC and infiltrates through the vadose zone to the water table. Physical, chemical, and biological characteristics of both the pollutants and the unsaturated soil are used as input parameters. Porosity, soil moisture content, percent organic carbon, and degradation rate, gathered from literature values for the area, are some of the input parameters (Fig. 4). The pollutants selected for analysis were chosen based on their frequency of detection, mobility, persistence, and toxicity. Because hydrogeological systems are highly complex, scenarios depicting average and worst-case conditions were created.

The values used for the various parameters are conservative. By using a one-dimensional equation for fate and transport, the tool assumes that the stormwater pollutants migrate vertically, whereas lateral movement often predominates, resulting in significant pollutant attenuation. The use of a one-dimensional model both simplifies the calculations as well as assumes a worst-case scenario. Additionally, the pollutant concentrations used in the model were equal to or 10 times higher than those actually measured. Data from Bend and Portland show that modeled pollutant concentrations in stormwater were often 10 to 1000 fold lower than the MCL. Lastly, the GWPD tool input assumes a 5 foot separation distance from the bottom of the UIC and the groundwater. In some cases, the separation distance was 5 feet, but in many others it was as great as 100 feet. Taken together, numerous highly conservative factors have been built into the model to promote protection of groundwater quality.

Modeling results for a variety of locations produced similar findings—even with a 5 foot separation distance and highly permeable geologic material, the great majority of pollutants would be reduced by more than 99% before they reach the water table. There were a few pollutants that commonly varied from this general finding, notably 2,4-D and toluene.

Modeling results can best be understood by examining output from two cities: Bend and Portland. Table 2 summarizes key findings of the modeling efforts worst-case conditions. For each of the measured stormwater concentrations (Col. A), a safety factor was applied (Col. B). The model input concentration represents the theoretical concentration of the contaminant discharged from the UIC (Col. C). Most of these values are equal to 10 times the contaminant's MCL, while others are equal to the MCL. The model output concentration reflects the theoretical contaminant concentration 5 feet below the bottom of the UIC (Col. D). Most concentrations of pollutants would be less than the reporting limit (RL). Notably, for 2,4-D and toluene, the concentrations 5 feet below the UIC were measurable. The percent reduction (Col. E) refers to the change in concentration of each contaminant from samples collected as runoff entered the dry well (immediately after pretreatment) and at 5 feet below the UIC.

In Bend, for example, the concentrations of 2,4-D and toluene were reduced by 44% and 47% respectively. Although their output concentrations were still far below the MCL, the concentrations of these pollutants would actually be attenuated below detection limits within 40 feet of the bottom of the UIC (based on modeling). The majority of UICs in Bend have greater than 100 feet of separation from the water table.

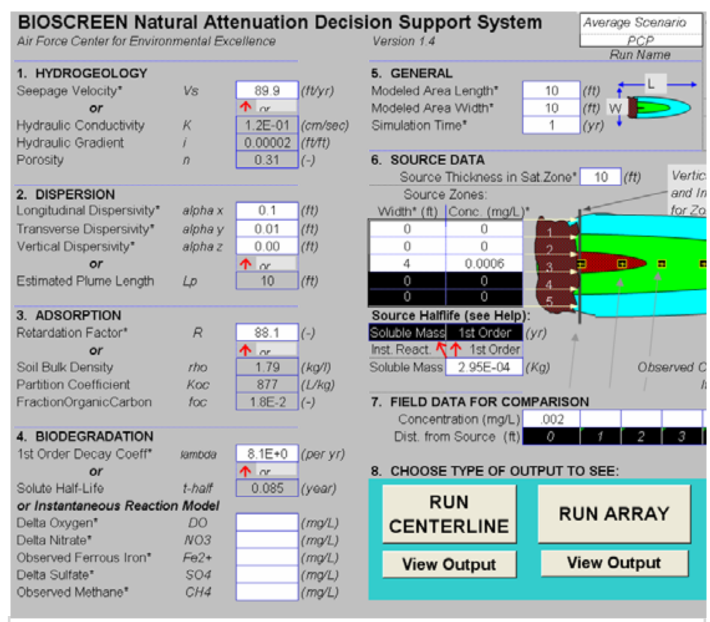

Figure 4. Screenshot of modeling input parameters. This model factors advection, dispersion, adsorption, and aerobic decay into the analysis. It is based on the advection dispersion equation programmed in an Excel spreadsheet. An example is posted at: *http://www.deq.state.or.us/wq/uic/docs/template/ClackamasCoReport.pdf*

		A	B	C	D	E
Analyte	**Study City**	**Estimated Conc. in SW (µg/L)**	**Safety Factor Applied for Modeling**	**Model Input Conc. (µg/L)**	**Model Output Conc. @ 5 ft. below UIC (µg/L)**	**Percent Reduction**
Copper	*Bend*	43.6	30	1300	<RL	100
Lead	*Bend*	10.1	50	500	<RL	100
Benzo(a) pyrene	*Bend*	No Detections	-	2	<RL	100
	Portland	0.02	100	2	<RL	100
Napthalene	*Bend*	No Available Data	-	10	<RL	100
	Portland	0.05	1240	62	<RL	100
PCP	*Bend*	0.05	200	10	<RL	100
	Portland	0.6	17	10	<RL	100
DEHP	*Bend*	0.6	100	60	<RL	100
	Portland	3.8	16	60	<RL	100
2,4-D	*Bend*	No Detections	-	70	39.2	44
	Portland	0.68	1029	700	2.5	99.6
Toluene	*Bend*	2	500	1000	525.7	47
	Portland	2.1	476	1000	76.7	99.2
Methoxychlor	*Portland*	0.1	4000	400	<RL	100

Table 2. Estimated Maximum Concentration of Key Contaminants in the Vadose Zone. The estimated concentration of each contaminant was multiplied by a safety factor in the modeling to account for uncertainty. Bend data represents the mean value over 5 years while Portland data is the 95th upper confidence limit of the mean.

Conclusions

Oregon's UIC Program is a regulatory program designed to oversee the use of UICs for stormwater infiltration. Active UIC programs are found throughout the state: from wet, rainy areas with a high water table, such as Portland and Eugene, to the high desert areas with low amounts of precipitation, such as Bend. Through a combination of monitoring and modeling, the Dept. of Environmental Quality, which oversees these programs, endeavors to protect groundwater resources while benefitting from the value of UICs. Recently, Portland's monitoring data was reviewed by the DEQ and their permit to continue to operate UICs was renewed for another 10 years. Some of the keys to the success of Oregon's UIC programs appear to include both thoughtful UIC design and verification components. The use of a variety of pretreatment facilities, designed to capture pollutant-laden sediment, is a key design feature that has led to the low levels of pollutants entering the UICs. Extensive monitoring of stormwater is performed to ensure it meets regulatory levels. Lastly, the use of a conservative one-dimensional model to estimate subsurface fate and transport of pollutants helps to verify that the handful of pollutants that are not removed by pretreatment will not contaminate the aquifer. The combination of these three program components, as well as other requirements and restrictions, has led to the widespread use of one of the newer low impact development practices - drywells.

OEHHA Note: While Oregon uses the MCL as the criteria for contaminants entering a dry well, other health-related, risk-based criteria might be appropriate for this use.

Useful Links and References

Portland UIC Program Overview
http://www.portlandoregon.gov/bes/48213
City of Portland Underground Injection Controls (UICs) Factsheet
http://www.portlandoregon.gov/bes/article/436258
Groundwater Protectiveness Demonstration Tool
https://www.portlandoregon.gov/bes/article/430383
UIC Management Plan *http://www.portlandoregon.gov/bes/article/250334*

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