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Groundwater in Urban Areas

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Kuprianov (2009) defines urban hydrology as "a science, part of land surface hydrology investigating the hydrological cycle, water regime and quality in urbanized territory." Urban hydrogeology is that part of the hydrological cycle focusing on urban groundwater processes and groundwater exchange with other parts of the hydrological cycle. By the year 2000, about half of the Earth's population lived in urban areas (Kuprianov 2009). Urbanization is projected to increase even more proportionally in the next fifty years, and urban development and urban sprawl will impact and increase dependence on groundwater systems while altering groundwater processes locally and regionally (Hibbs and Sharp 2012).

Physical changes associated with urbanization include increasing recharge from leaky utility systems, changes in irrigation and delivered water return flow, and modification of subsurface flow paths due to underground urban infrastructure. Chemical changes include groundwater and soil contamination from point and non-point sources, water quality impacts from storm-water control systems, and both modern and legacy pollution from urban development (Johns and Pope 1998; Rose 2007). Understanding these changes, their causes, and effects is necessary to address the critical and growing environmental and water resource issues of urban areas (Hibbs and Sharp 2012).

In an early paper on urban groundwater, Lerner (1990) discussed effects of urban infrastructure on groundwater budgets (Table 1). Water budgets in urban areas are modified by installation of "impervious" cover, widespread use of import water, construction of soakways and drainage swales, concentration of septic tanks, over-irrigation, and groundwater leakage to and from sewer and water pipes. These groundwater flow terms and associated water budgets in urban areas are difficult to quantify (Lerner 2002; Vazquez-Sune et al. 2010). Pipe leakage and delivered water return flow, for example, are frequently extrapolated from coefficients taken from often limited studies in other urbanized basins.

Modification of natural landscapes by urban sprawl provides many avenues of new and expanded research for groundwater scientists. Considerable work needs to be done to develop more reliable groundwater budgets in urban settings. Groundwater scientists are as important now as ever for providing these and other practical and theoretical contributions in urban hydrogeology. This is especially true where urban infrastructure is being retrofitted. Many new initiatives in stream restoration, for example, have been proposed in recent years in areas where concrete stream linings are targeted for removal and replacement with unlined channel. Classical engineering design posits that concrete stream linings protect urban areas by sending urban runoff quickly downstream away from urban developments (Farassati 2016). Experience has shown that the high velocity of runoff along lined channels sometimes causes unlined channel below the lined section to be damaged and destabilized due to erosion, leading to loss of land along the streambank (Colosimo and Wilcock 2007; Farassati 2016) (Figure 1). As a result, multi-objective planning in urban storm water control now considers a different, more comprehensive engineering approach. With appropriate and comprehensive engineering retrofit, removal of channel lining can be achieved as part of a comprehensive watershed restoration effort. Simultaneous placement of on-site retention facilities in urban areas, such as dry wells, green belts, or local recharge basins reduces the volume of urban runoff while providing distributed points of recharge to aquifers. The urban retrofit creates a partial return to more natural recharge conditions.

Stream restoration projects also open up many avenues of research for groundwater scientists. An emerging area of research is the study of biogeochemical cycling during hyporheic zone interactions while the stream is recovering after restoration (Hester and Gooseff 2010). Another area of research requiring extensive hydrogeological expertise relates to large-scale artificial recharge projects that are developing in urban centers. Evaluation of sites for artificial recharge factors in many levels of analysis, such as characterizing aquifer permeability, storage properties, and continuity of aquifer strata. Hydrochemical analysis is equally important and includes studies on the possible impacts of mixing waters of different sources on trace element mobilization in aquifer sediments. Evaluating proximity of recharge facilities to legacy contaminant sources is another area of concern, as is persistence of emerging contaminants where treated recycled water is the recharge source.

Numerous opportunities are available for groundwater scientists to engage in these and other levels of hydrogeological analysis in urban centers. Accordingly, the goal of this theme issue is to bring together a collection of papers to showcase ongoing research and policy as these relate to groundwater flow systems in and near urban areas. I am indebted to the authors of this theme issue for their efforts in this endeavor. The general scope and diversity of their eight papers is summarized herein.

Several papers focus on water budget analysis and modeling in and around urban centers. Schnaar et al. describe integrated water budget analysis to quantify groundwater inputs and outputs to San Diego Creek and Newport Bay Watersheds, California. Hauwert describes stream gain/loss studies to recalculate forms of recharge in the Barton Springs Segment of the Edwards Aquifer, Texas. Granados et al. perform rainfall/runoff modeling of desert catchments in and near Ciudad Juarez, Mexico, to support groundwater recharge augmentation projects in the Hueco Bolson aquifer.

Other papers focus on environmental tracers and hydrochemical analysis for evaluating recharge sources, groundwater residence time, and trace element mobilization. Eastoe and Gu use stable water isotopes and radioisotopes to evaluate long-term changes in perched and regional aquifers in the Tucson Basin, Arizona. Larsen et al. use multiple environmental tracers and integrated modeling to evaluate modern water contributions to the Memphis aquifer, Tennessee. Darling evaluates possible arsenic release from aquifer sediments due to mixing of native groundwater and recharge water at an artificial recharge site near Clearwater, Florida.

The remaining papers emphasize policy and methodology. Hodder discusses regulatory compliant decommissioning of water wells in urban areas in California and elsewhere, while Hibbs et al. discuss stream/aquifer interactions along grout-lined channels in urban catchments and describe opportunities for future research along lined channels.

I wish to acknowledge the reviewers of the papers published in this theme issue. Several reviewers have more than two decades of experience conducting groundwater assessments in urban zones. The reviewers include, in no particular order, Peter Van Noort, Stephen Osborn, Bruce Darling, Benjamin Hagedorn, Thomas Meixner, Claudia Espinosa Villegas, Michael Harrison, M. Hassan Rezaie Boroon, Anna Doro-on, John Sharp, Carlos Gutiérrez Ojeda, and Radu Boghici. A few reviewers asked to remain anonymous. Karl Williard and Jackie Crim, co-editors of *Journal of Contemporary Water Research and Education*, provided many helpful suggestions and assistance throughout the process.

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Table 1. Urban controls on groundwater recharge (adapted from Lerner, 1990).

Urban Factors Increasing Recharge	Urban Factors Decreasing Recharge
Impervious cover reducing evapotranspiration[1]	Impervious cover limiting rain recharge
Changing urban microclimate (+)	Changing urban microclimate (-)
Urban runoff drywells and catch basins	Infiltration to sewer and water pipes
Artificial recharge wells and basins	Infiltration to storm sewers
Concentrated density of septic tanks	Extraction and export to other basins
Exfiltration from sewer and water pipes	
Exfiltration from storm sewers	
Import water return flow	

[1] Wiles and Sharp (2008) noted that leakage through impervious cover must also be considered.

Figure 1. Erosion of unlined channel below a lined section of Barranca Channel, San Diego Creek Watershed, California (photo credit, Henry Jones).

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References

Colosimo, M.F., and P.R. Wilcock. 2007. Alluvial sedimentation and erosion in an urbanizing watershed, Gwynns Falls, Maryland. *Journal of the American Water Resources Association* 43(2): 499-521.

Farassati, A. *A Project Report, Las Virgenes Creek Restoration Project, Healing a Stream*. Available at http://www.cityofcalabasas.com/pdf/documents/environmental-services/Healing-a-Stream.pdf. Accessed November 20, 2016.

Hester, E.T., and M.N. Gooseff. 2010. Moving beyond the banks - Hyporheic restoration is fundamental to restoring ecological services and functions of streams. *Environmental Science & Technology* 44(5): 1521-1525.

Hibbs, B.J., and J.M. Sharp. 2012. Hydrogeological impacts of urbanization. *Environmental and Engineering Geoscience* 18(1): 3-24.

Johns, D.A., and S.R. Pope. 1998. Urban impacts on the chemistry of shallow groundwater, Barton Creek Watershed, Austin Texas. *Gulf Coast Association of Geological Societies Transactions* 48: 129-138.

Kupriyanov, V.V. 2009. Urban hydrology. In: *The Hydrological Cycle*, Volume III, The Encyclopedia of Life Support Systems, I.A. Shiklomanov (Ed.). pp. 141-160.

Lerner, D.N. 2002. Identifying and quantifying urban recharge, a review. *Hydrogeology Journal* 10(1): 143-152.

Lerner, D.N. 1990. Groundwater recharge in urban areas. *Atmospheric Environment, Part B. Urban Atmosphere* 24(1): 29-33.

Rose, S. 2007. The effects of urbanization on the hydrochemistry of base flow within the Chattahoochee River Basin (Georgia, USA). *Journal of Hydrology* 341(1-2): 42-54.

Vazquez-Sune, E., J. Carrera, I. Tubau, X. Sanchez-Vila, and A. Soler. 2010. An approach to identify urban groundwater recharge. *Hydrology and Earth System Sciences* 14: 2085-2097.

Wiles, T.J., and J.M. Sharp Jr. 2008. The secondary permeability of impervious cover. *Environmental and Engineering Geoscience* (14)4: 251-265.