National Ground Water Association Comments
submitted to the
EPA Environmental Financial Advisory Board

February 11-13, 2020 Meeting

- Comments to EFAB Regarding Stormwater Infrastructure Funding Task Force Recommendations to Improve the Availability of Public and Private Sources of Funding for Stormwater Infrastructure (Submitted: November 7, 2019; Updated December 16, 2019)
- Comments to the EFAB Stormwater Financing Task Force, December 18, 2019
- *Stormwater Management: When is Green Not So Green?* Guest Editorial (Groundwater, May-June 2018)
- The Influence of Green Infrastructure Practices on Groundwater Quality: The State of the Science (Excerpt) (EPA/600/R-18/227, August 2018)

NGWA The Groundwater Association
Address 601 Dempsey Road, Westerville, Ohio 43081-8978 U.S.A.
Phone 800 551.7379 • 614 898.7791 Fax 614 898.7786
Email ngwa@ngwa.org Websites NGWA.org and WellOwner.org

National Ground Water Association

Comments to

Environmental Protection Agency Environmental Financial Advisory Board

Regarding Stormwater Infrastructure Funding Task Force Recommendations to Improve the Availability of Public and Private Sources of Funding for Stormwater Infrastructure (Section 4101, America's Water Infrastructure Act of 2018)

Submitted: November 7, 2019; Updated December 16, 2019

Summary of Action

The USEPA Environmental Financial Advisory Board is preparing a report to improve the availability of public and private sources of funding for the construction, rehabilitation and operation and maintenance of stormwater infrastructure to meet the requirements of the Federal Water Pollution Control Act, as required under Section 4101, America's Water Infrastructure Act of 2018. The Task Force plans to deliver to USEPA a report in February 2020 on this matter.

Comments of the National Ground Water Association

NGWA supports affordable financing availability to communities to assist them in responding to managing stormwater impact. NGWA's main concern is to adequately protect groundwater beneath proposed stormwater infiltration facilities and, in doing so, we suggest that <u>financing for any strategies that consider or incorporate infiltration be conditional on designs and their implementation that address adequate protection of groundwater quality</u>. Each site's soil zone and geology possess unique characteristics and value to communities, and the uses of groundwater from beneath each site may be different and, as such, these circumstances must be taken into account in engineering natural degradation of pollutants and protection of groundwater. Our comments below elaborate on this concern. Attention to groundwater-protective design will affect cost of facilities which in turn will affect financing capacity and affordability.

Stormwater as a Resource

Stormwater is a resource for capture, use and groundwater recharge that can be managed in much of the arid western United States and elsewhere in the nation for water supply. To use stormwater for aquifer recharge and safe water supply, federal, state and local governments and the private sector should continue collaboration to protect groundwater and improve total water management. NGWA appreciates EFAB's consideration of the need of communities, in particular small communities, to obtain financing for infrastructure to properly manage stormwater. Given that 62 percent of community water systems serving 10,000 or fewer people are groundwater supplied,[1] it is crucial that stormwater reuse methods used in these communities be proven protective of groundwater supplies. Additionally, nearly 42 million people live in communities relying on private wells.[2] Groundwater is a water source needing

[1] U.S. Environmental Protection Agency. 2019. Drinking Water Government Performance and Results Tool. https://www.epa.gov/ground-water-and-drinking-water/drinking-water-performance-and-results-report (Accessed December 10, 2019).

[2] U.S. Geological Survey. 2018. Estimated Water Use in the United States in 2015. Circular 1441. https://pubs.er.usgs.gov/publication/cir1441 (Accessed December 10, 2019).

protection for them and these systems. Small communities have few resources or expertise to protect their groundwater sources of water supply.

Response to Urban Runoff

Uncontrolled stormwater discharges contain a variety of pollutants such as sediment, nutrients, chlorides, pathogens, metals, petroleum hydrocarbons, and trash, and are a significant cause of water quality impairment for surface waters.[3] EPA has promoted green stormwater infrastructure as a principal method to respond to urban runoff to be controlled under the Clean Water Act National Pollutant Discharge Elimination System (NPDES) permitting. EPA has identified a range of methods to mimic the hydrologic cycle in nature including: reduction of impervious areas, downspout disconnection, rainwater harvesting, rain gardens, planter boxes, bioswales, permeable pavements, green streets and alleys, green parking, green roofs, urban tree canopy, and land conservation.[4]

Effects of Stormwater Practices on Groundwater Quality

The National Research Council did a thorough review in 2008 of urban stormwater practice. The report raised concerns about stormwater quality impacts on groundwater quality. While no specific research recommendation was made relative to groundwater quality, it noted "To ensure that groundwater is not compromised when surface water is routed through infiltrative practices, municipalities must establish where appropriate conditions do and do not exist and spot infiltration opportunities accordingly"[5], pointing to a need for sound guidance. The Center for Watershed Protection's 5-year research agenda focused on actions to protect surface waters needing attention relative to pollutants from stormwater and did not include groundwater quality concerns.[6] The International Stormwater Best Management Practices Database Final Report maintained by the Water Environment and Reuse Foundation contained minimal information on groundwater quality as a result of stormwater management.[7] In general, there is a lack of microbial removal performance for green stormwater infrastructure. The fecal indicator pollutant summary noted "Where infiltration is used, it is important to recognize that groundwater pollution can also occur, if adequate sorption and filtration do not occur prior to the infiltrated flows reaching groundwater." While some studies of permeable pavement suggest that additional performance reporting would be useful, other studies have shown improvement in their water quality performance.[8]

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[3] U.S Environmental Protection Agency. 2017. Municipal Separate Storm Sewer System Permits Compendium of Clear, Specific & Measurable Permitting Examples. EPA-830-S-16-002. https://www.epa.gov/sites/production/files/2017-01/documents/final_compendium_intro_document_508.pdf;

[4] U.S Environmental Protection Agency. 2017. What is Green Infrastructure? https://www.epa.gov/green-infrastructure/what-green-infrastructure.

[5] National Research Council. 2008. Urban Stormwater Management in the United States. The National Academies Press, Washington, D.C., www.nap.edu.

[6] Center for Watershed Protection. 2017. Five-Year Research Agenda https://www.cwp.org/~cwporg/Oldsite/wp-content/uploads/2015/09/cwp_researchagenda_10.18.16.1.pdf "The goal of our research is to synthesize the best available science to develop tools that work to protect and restore our streams, rivers, lakes, wetlands and bays."

[7] Water Environment and Reuse Foundation. 2017. International Stormwater BMP Database Final Report: 2016 SUMMARY STATISTICS 2017. http://www.bmpdatabase.org/Docs/03-SW-1COh%20BMP%20Database%202016%20Summary%20Stats.pdf

[8] Roseen, Robert M., Thomas P. Ballestero, James J. Houle, Joshua F. Briggs , Kristopher M. Houle, 2012, Water Quality and Hydrologic Performance of a Porous Asphalt Pavement as a Stormwater Treatment Strategy in a Cold Climate, ASCE Journal of Environmental Engineering, vol. 138, no. 1, pp. 81-89.

A review of the database results found for the more than 400 studies included that groundwater was mentioned in summary results 30 times, while retention ponds/basins/cells were mentioned 440 times and wetlands, 583 times. Retention structures and wetlands are typically associated with groundwater. Even in hydrologic soil group C (sandy clay loam), infiltration can be significant.[9] This observation reflects that groundwater protection has received less attention in design and testing, while methods for removal of pollutant loads from surface water has commanded stormwater management efforts.

Guidance to States and Communities

A review of stormwater guidance of selected federal, state and municipal governments[10] with significant groundwater and stormwater challenges found that the major concern relative to groundwater quality was checking for "hotspots" that were already contaminated. In these "hotspot" locations, caution should be exercised not to infiltrate stormwater to them since additional subsurface water could cause the contamination to spread to groundwater users and to streams. Nearly all the references included setbacks for infiltration sites to ensure that wells or other subsurface conditions or structures were not adversely affected. Some references importantly cited the need for precautions in wellhead protection areas to protect water supply safety. State documents provided direction on hotspots and areas of high water tables to avoid or be setback from and on special steps to take in areas of karst and permeable geology. Two state documents indicated that soils may exist at sites or be amended to adjust organic matter and pH to provide pretreatment for infiltrated water that may have metals and organic contaminants that could be adsorbed.

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[9] Houle, James, T. Ballestero, and T. Puls, 2018, Stormwater Runoff Study helps Determine Sizing Criteria of Control Measures, Stormwater Management, WEF, V. 6, No. 1, Alexandria, VA.

[10] City of Los Angeles (California). 2011. Development Best Management Practices Handbook; Low Impact Development Manual. http://www.lastormwater.org/wp-content/files_mf/lidhandbookfinal62212.pdf; Maryland Department of the Environment. 2009. Maryland Stormwater Design Manual , Volumes I and II. http://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/stormwater_design.aspx; Minnesota Pollution Control Agency. 2016. Minnesota Stormwater Manual https://stormwater.pca.state.mn.us/index.php?title=File:Contamination_screening_checklist_for_stormwater_infi l tration_July_2016.xlsx and Stormwater and Wellhead Protection. https://stormwater.pca.state.mn.us/index.php?title=Stormwater_and_wellhead_protection; New York City Department of Environmental Protection. 2012. Guidelines for the Design and Construction of Stormwater Management Systems. http://www.nyc.gov/html/dep/pdf/green_infrastructure/stormwater_guidelines_2012_final.pdf; Philadelphia Water. 2017(accessed online). Stormwater Retrofit Guidance Manual. https://www.phila.gov/water/PDF/SWRetroManual.pdf; US Environmental Protection Agency. 2009. Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects under Section 438 of the Energy Independence and Security Act. EPA 841-B-09-001. www.epa.gov/owow/nps/lid/section438 and https://www.epa.gov/sites/production/files/2015-08/documents/epa_swm_guidance.pdf; US Environmental Protection Agency. 2003. When Are Storm Water Discharges Regulated As Class V Wells? https://www.epa.gov/sites/production/files/2015-08/documents/fs_storm.pdf; West Virginia Groundwater/UIC Program. 2006. Stormwater Management Structure Guidance Document. https://dep.wv.gov/WWE/Programs/gw/Documents/14469_gw_Stormwater_Management_Structure_Guidance_Combined.pdf; Wisconsin Bureau of Watershed Management. 2017. Site Evaluation for Storm Water Infiltration Technical Standard 1002. http://dnr.wi.gov/news/input/documents/guidance/TS1002Final.pdf; Wisconsin State Legislature. 2017. Chapter NR 151, Runoff Management https://docs.legis.wisconsin.gov/code/admin_code/nr/100/151/III/12/5/c.

Generally, the stormwater management guidance provided significant detail on stormwater capture, infiltration and facility development and relatively little focus on long-term considerations for groundwater quality which would require significant resources to deal with if degraded over time. One state guidance specifically provided the option for monitoring groundwater that receives stormwater infiltrate and would be used as a source of drinking water – a significant acknowledgement that the larger hydrologic cycle being intervened with needs attention. Additionally, "EPA has set minimum standards to address the threats posed by all injection wells, including stormwater drainage wells [which may include dry wells, bored wells and infiltration galleries]. Stormwater injection is a concern because stormwater may contain petroleum or other organic compounds that could harm USDWs [Underground Source of Drinking Water]. Other potential harmful contaminants include: sediment, nutrients, metals, salts, microorganisms, fertilizers, and pesticides."[11]

While drainage wells are regulated, they must be registered with the state to provide for control of stormwater, but could potentially be a pathway for stormwater contaminants if regulations are not adequately enforced. These wells could exist in rural areas as well as in urban and suburban locations.

Research on the cumulative effect of stormwater infiltration on groundwater quality is needed to protect the resource for the future and provide further guidance to states and communities, including: stormwater pollutant effects on groundwater in a range of subsurface environments, engineering studies of stormwater facility hydraulics, development of monitoring approaches, and modeling stormwater pollutant infiltration, migration and degradation. Communities should avoid moving society's contaminants from one water source to another to avoid paying the full cost of today's water use for near-term benefit, but potentially resulting in negative long-term consequences. We should understand the effects and the costs and incorporate that understanding in guidance to communities.

EPA's report "The Influence of Green Infrastructure Practices on Groundwater Quality: The State of the Science" [12] indicates that effects of stormwater infiltration on groundwater quality are largely not understood and need research, but the EPA research program has been reduced in funding to track groundwater quality at only three existing stormwater infiltration sites that do not reflect the complexity of the subsurface environment and its geologic matrix across the nation. Ten research were identified in the original EPA research plan. The intent of this research program is to provide guidance to states and communities to protect groundwater from effects of stormwater infiltration. The subsurface environment is complex and different from place to place, even within the same watershed.

Regulatory Process as a Basis for Incentives

In the absence of concerted efforts to protect groundwater resources when implementing stormwater management strategies, EFAB should be encouraging stormwater BMPs that deal directly with the source of contamination through positive financial incentives. While UIC standards in practice are relatively limited as applied to stormwater management, disposal to shallow groundwater through Class V "wells" should only be incentivized if the disposal by Class V wells receives authorization via the UIC Class V program (either EPA or delegated state) using UIC standards on the quality of the injected water so that the USDW is not "endangered."

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[11] U.S. Environmental Protection Agency. 2016. Stormwater Drainage Wells. https://www.epa.gov/uic/stormwater-drainage-wells (Accessed December 10, 2019).

[12] Brumley, J., C. Marks, A. Chau, R. Lowrance, J. Huang, C. Richardson, S. Acree, R. Ross, AND D. Beak. The Influence of Green Infrastructure Practices on Groundwater Quality: The State of the Science. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-18/227, 2018.

If a community is using UIC standards for its storm water disposal and cannot meet the nonendangerment standard, financing should be contingent upon the USEPA granting an aquifer exemption for the impacted aquifer/groundwater. If a delegated UIC program is in place, that program would also review and, if appropriate, approve the aquifer exemption request and submit it to USEPA where it will go through the aquifer exempting process laid out in 40 CFR 144.7 and 146.4. The use of an aquifer exemption would only be appropriate if a large scale/regional Municipal Separate Storm Sewer System (MS4) permit is involved due to the expense to the permittee and the amount of time involved for the review and approval by the delegated authority and USEPA, which may include modeling flow, inventorying wells that are using the same aquifer, and other key steps. If the aquifer is currently in use or is potentially usable, the granting of the aquifer exemption would not only be in question, but unlikely.

Stormwater Infiltration Design Approach

The vast majority of stormwater infiltration systems are not regulated under the UIC program. In general, it is not prudent or wise to discharge polluted waters to any of our natural systems. So whether it be stormwater discharge to surface water or to groundwater, some minimum amount of treatment should occur first. Treatment becomes complex because some pollutants, such as chloride, are not removed by green stormwater infrastructure. For each site and setting, a conscious effort to understand the consequences to all receiving natural resources should occur and design the stormwater collection, treatment and infiltration process accordingly. Ideally, this design should stem from regulatory guidance, but in general this guidance is incomplete and mainly focuses on volume rather than quality. A more effective approach is to reduce and/or eliminate the sources of pollution, but this may not always be practical.

The importance of the soil zone for stormwater infiltration treatment is considerable. EPA's State of the Science report states on pages 69 and 70[13]:

> "The chemical interactions between surface water and groundwater are controlled by the type of geologic materials present and the amount of time the water is in contact with these materials. The various chemical reactions that affect the biological and geochemical characteristics of the basin are acid-base reactions, precipitation and dissolution of minerals, sorption, ion exchange, oxidation-reduction reactions, biodegradation, and dissolution and exsolution of gases. It is concluded that when implementing green stormwater infrastructure for infiltration, the properties of the unsaturated and saturated zones interacting with the infiltrating water need to be considered. These considerations encompass the understanding of the native soil texture, structure, and organic matter content of the unsaturated zone, as well as considering the porosity and permeability of the saturated zone and the flow of the groundwater. Kinetics and mixing relationships also require examination. Colloidal transport also needs to be considered as a mechanism that can transport contaminants through the soil, by either being a contaminant itself or having a contaminant sorb to a benign colloid. Colloids

[13] Brumley, J., C. Marks, A. Chau, R. Lowrance, J. Huang, C. Richardson, S. Acree, R. Ross, AND D. Beak. The Influence of Green Infrastructure Practices on Groundwater Quality: The State of the Science. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-18/227, 2018.

> can be restricted by capture, sorption and static interaction. . . . [C]olloid-facilitated transport could be an important mechanism for the movement of contaminants into groundwater."

Any design that does not incorporate an adequate soil zone for some level of natural treatment and bypasses this zone enables contaminants to move into the lower unsaturated zone with minimal mitigation, potentially contaminating groundwater.

Monitoring and Modeling

Predictive methods followed by monitoring groundwater quality at stormwater infiltration sites is important to establish groundwater quality and safety, similar to monitoring surface water effects of discharges. Monitoring demonstrates the efficacy of the stormwater infiltration at any location. Monitoring also provides the basis for determining if another stormwater management approach should be considered. Monitoring is not included in most research on stormwater quality impacts to groundwater.[14] Groundwater quality effects have a significant lag time to be observed at distances away from the stormwater infiltration site and therefore long-term effects need to be observed over decades.[15] Long-term monitoring is a necessary investment to understand the effects and how stormwater infiltration should be modified to deal with them. Monitoring is also needed to determine whether remediation is required for safe groundwater use. Data from monitoring can be used for modeling stormwater effects on groundwater quality and potential costs on receptors at risk. Modeling is a cost-effective approach for groundwater impact assessment.[16]

As an example, monitoring in Delaware identified eleven groundwater-supplied water systems with wells between 75 and 450 feet deep receiving stormwater in their groundwater capture area to have statistically significant trends of increasing chloride. Four systems have radionuclide problems due to the high chloride concentrations. At current rates of increase, groundwater serving two systems will reach the 250 mg/L SMCL for chloride in about 10 years. With no suitable alternative sources of supply, these systems will need expensive treatment to remain viable. [17] While policies relating to deicing may need attention, this example points to the interactive nature of chemicals carried by stormwater infiltrated to the subsurface with the ability to change groundwater chemistry adversely.

Conclusions about Current Understanding of Stormwater Infiltration

- Small communities need significant attention and support for stormwater management with most small communities relying on groundwater for domestic water supply.
- The focus of most federal and state guidance to communities is primarily on reducing the volume of stormwater runoff, not on the effect of infiltrating stormwater on groundwater quality.
- EPA's State of Science report on green stormwater infrastructure effects on groundwater quality indicates that effects largely are not understood and need research, but the EPA research program has been reduced. Other research avenues should be pursued.

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[14] Brumley, J., C. Marks, A. Chau, R. Lowrance, J. Huang, C. Richardson, S. Acree, R. Ross, AND D. Beak. The Influence of Green Infrastructure Practices on Groundwater Quality: The State of the Science. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-18/227, 2018.

[15] *Ibid.*

[16] Anderson, M.P.; Woessner, W.W.; and Hunt, R.J. 2015. Applied Groundwater Modeling. Academic Press/Elsevier Publishing, London, UK. P. 468.

[17] Communication from Delaware Geological Survey, October 21, 2019.

- Infiltration facilities do not all provide treatment and do not all use natural soil zone treatment.

- Due to potential long-term effects on groundwater, stormwater management is an intergenerational equity and environmental justice issue; if groundwater becomes contaminated, it is more costly to remediate, affecting affordability of facilities to water systems already having limited fiscal resources.
- Training and education are needed for both communities and consultants on contaminant treatment to be addressed in design, cost and affordability of stormwater infiltration options.
- The Underground Injection Control (UIC) program under the Safe Drinking Water Act provides one regulatory process for managing stormwater; states may have other standards that apply.
- Research is still needed on stormwater infiltration effects on large areas over the long term which may affect types of facilities needed and their cost to be financed that in turn affects affordability.
- Surface and ground waters are one shared natural resource that deserve all the protections that can be provided, including monitoring to ensure that intended uses can be met.
- Regardless of funding options for stormwater disposal, the approaches need to ensure that we protect groundwater resources when implementing stormwater solutions to provide safe water supply to communities and aquatic life relying on groundwater and its interaction with streams.

Implications for Financing Options

Financing arrangements should be conditioned on addressing design of stormwater facilities that is protective of groundwater quality and reference the following points that will affect stormwater facility costs that may need to be financed:

(1) Guidance to communities for engineering stormwater infiltration should clearly address, and be revised if necessary to address, groundwater quality effects and their mitigation. Guidance must recognize and incorporate the complexity of the subsurface and the differences in geology from location to location, even within a community.
(2) Existing regulatory processes for underground injection control, where applicable, should be drawn on as a first step in design if wells are used for stormwater disposal to the subsurface.
(3) Groundwater modeling can provide a view of the subsurface and the affected aquifers for communities evaluating stormwater infiltration alternatives to project effects of stormwater on groundwater quality.
(4) Monitoring must be a part of any stormwater infiltration project to ensure that groundwater quality is safe for its intended use.

Basis for the Interest of the National Ground Water Association (NGWA) in Stormwater Infrastructure Financing

NGWA, the largest trade association and professional society of groundwater professionals in the world, represents over 10,000 groundwater professionals within the United States and internationally. NGWA represents four key sectors: scientists and engineers, employed by private industry, by the consulting community, by academic institutions, and by local, state, and federal governments, to assess groundwater quality, availability, and sustainability; water-well contractors responsible for developing and constructing water-well infrastructure for residential, commercial, and agricultural use; and the manufacturers and the suppliers responsible for manufacturing and providing the equipment needed to make groundwater development possible. NGWA's mission is to advocate for and support the responsible development, management, and use of groundwater.

Over 42 million people in the United States rely on private wells and nearly 90 million people are served by groundwater from community water systems. Seventy-one percent of groundwater withdrawn is for irrigated agriculture. Additionally, forty percent of baseflow of streams is contributed from groundwater discharge through streambeds.

NGWA views groundwater and the subsurface as a significant natural resource that should be sustainably managed for current and future use. The subsurface environment should be considered from an integrated resource perspective. The resources extant in the subsurface environment with proper management can provide fresh groundwater for drinking, industrial and manufacturing applications, food production, and ecosystem support.

A concise summary of the position of the National Ground Water Association on groundwater protection related to potential sources of contamination is:

- Control of potential and active sources of contamination should be a national objective, reducing the need for remediation of groundwater.
- Aquifers should be protected from degradation recognizing that nondegradation may not be economically and technically practical in many circumstances.
- Groundwater quality should be protected for existing or potential beneficial uses.
- Methods available to control point source contamination include land-use controls while remediation approaches should be flexible and practical to recognize different situations.
- Waste reduction, education, and technology transfer are important to protect groundwater.
- Increased scientific research can provide the basis for land-use control decisions.

The NGWA appreciates the opportunity to comment on financing alternatives, capabilities and adequacy for stormwater infiltration.

For further information, please contact:

Charles Job, Regulatory Affairs Manager
National Ground Water Association
601 Dempsey Road Westerville,
OH 43081 cjob@ngwa.org
202-660-0060

NGWA The Groundwater Association
Address 601 Dempsey Road, Westerville, Ohio 43081-8978 U.S.A.
Phone 800 551.7379 • 614 898.7791 **Fax** 614 898.7786
Email ngwa@ngwa.org **Websites** NGWA.org and WellOwner.org

National Ground Water Association
Comments to the
USEPA Environmental Financial Advisory Board Stormwater Financing Task Force
December 18, 2019

The National Ground Water Association supports federal and state financial assistance to communities needing stormwater infrastructure.

1. Response to EFAB/Stormwater Financing Task Force Recommendations: Of the EFAB Stormwater Financing Task Force recommendations addressed on the December 18, 2019, conference call, #2 (Educating public officials and the public on stormwater infrastructure need), #7(g) (multiple benefits including green infrastructure projects), and #9(B) (green project reserve) could be modified to include wording to the effect that "the design and implementation of stormwater infiltration projects should provide adequate protection and monitoring of groundwater quality to protect human health and minimize future remedial costs and financing needs."

2. Factors Contributing to the Response

   a. The MS4 permit program under the Clean Water Act allows infiltration of stormwater as one technology approach using collection drains, dry wells, infiltration basins, LID and other means to reduce discharges to surface waters, but potentially impacting groundwater quality because there are no groundwater discharge standards or treatment required and may result in changed groundwater chemistry and release of contaminants to groundwater. The UIC Class V regulations might apply in some circumstances but are not often used for municipal stormwater control. Stormwater may be used as an important source of water for managed aquifer recharge projects.

   b. The EPA review of research by EPA/Office of Research and Development has concluded that the effects of stormwater infiltration on groundwater quality are not well understood. EPA's own research program on this subject only started in 2015, is incomplete and has been cut to the point of monitoring at 3 infiltration sites not representative of the variable and complex subsurface conditions that may exist within a community nor across the country.

   c. 80 percent of community water systems serving 10,000 or fewer people and nearly all nontransient and transient noncommunity water systems are groundwater supplied with larger surface water systems often having backup groundwater wells as an alternate source.

   d. Designing and implementing stormwater infiltration projects to protect groundwater quality may affect their cost for contaminant degradation and reduction and their affordability. Impacts to groundwater quality may not be observed more immediately as in surface water but, if they occur, the impacts will be costly to remediate in the longer term.

For followup, contact: Charles Job, NGWA Regulatory Affairs Manager., cjob@ngwa.org, 202-660-0060

Groundwater

Guest Editorial/

Stormwater Management: When Is Green Not So Green?

by A. Scott Andres[1], Thomas P. Ballestero[2], and Mary L. Musick[3]

Current national stormwater policy may have adverse effects on public and private water supplies. Shallow groundwater, which is increasingly being relied on for drinking water, irrigation, stream baseflow, and drought relief, is now becoming a sink for unwanted stormwater contaminants to avoid direct discharge to surface water. This policy of infiltration without properly considering implications for groundwater quality should be improved so that society's contaminants are not transferred from one water resource to another just to avoid paying the full cost of today's stormwater management.

Stormwater regulatory programs and green infrastructure practices focus first on reducing pollutant loads to surface water, with minimal consideration of pollutant load diverted to groundwater. Best management practices, which provide direct recharge, such as porous pavement, retention ponds, shallow injection wells, as well as agricultural and roadway drains, are commonly used. Frequently the only design criterion for stormwater infiltration is the infiltration rate. Infiltrated stormwater can carry pollutants (nitrogen; pesticides; metals, oil, and grease from road surfaces and gas stations; hazardous waste spills; and salts used in road deicing) as well as cause hydraulic problems (mounding, slope stability, and subsurface flooding of infrastructure).

Governmental and professional organizations, including the National Research Council (https://doi.org/10.17226/12465), USEPA Underground Injection Control Program, and Water Environment & Reuse Foundation (www.werf.org), have examined the groundwater impact issue, but issued often vague, general cautions about the risks. For instance, the guidance for the Underground Injection Control program only notes that infiltration through stormwater drainage wells has the potential to adversely impact groundwater supplies. State and local stormwater infiltration guidance typically focuses on avoiding "hotspots" already contaminated so as not to move contaminated groundwater in unanticipated directions.

Most guidance documents recommend fixed-distance setbacks for infiltration sites instead of empirically determined or engineered structures to preclude adverse subsurface effects. While these structures may initially function as designed, without guidance and implementation of routine maintenance, they will not continue to do so. Guidance and regulation rarely include mention of groundwater monitoring. We understand that USEPA is starting to identify some key concerns regarding groundwater impacts. These include recognizing aquifer complexity and long-term groundwater monitoring needs near stormwater facilities.

Finally, using shallow groundwater for the disposal of todays' stormwater problems may only be delaying a problem rather than solving it. Hydraulic loading by managed stormwater infiltration can overload natural treatment processes. Impacted groundwater can ultimately discharge to surface waters resulting in long-term degradation, especially under low flow conditions. This concept was recently addressed in a U.S. Ninth Circuit Court of Appeals decision (February 1, 2018, *Hawaii Wildlife Fund v. County of Maui*). The panel found that the disposal wells were "point sources" that discharged "pollutants" into groundwater, that eventually entered surface water and therefore these wells fell under the purview the National Pollutant Discharge Elimination System. On February 20, 2018, the U.S. Environmental Protection Agency issued a request for comment regarding the adequacy of its regulatory programs under the Clean Water and Safe Drinking Water Acts addressing stormwater discharges to groundwater "in direct hydrologic connection to surface water" (83 FR 7126 comments due May 21, 2018).

[1]Delaware Geological Survey, University of Delaware, Newark, DE 19716.
[2]University of New Hampshire Stormwater Center, 238 Gregg Hall, Durham, NH 03824.
[3]Corresponding author: Consulting Geologist, Ground Water Protection Council, 1605 Flite Acres Rd., Wimberley, TX 78676; mmusick@gwpc.org

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With the complexity of the subsurface, a single approach to managing stormwater infiltration and protecting groundwater quality will not be appropriate. Most guidance documents do note that additional research into groundwater contamination is warranted. Scientific research is needed to identify less risky stormwater infiltration practices, quantify impacts on groundwater quality and quantity, develop appropriate monitoring practices, improve pollutant removal prior to infiltration, and discern sound hydrogeologic and engineering design practices in the siting and design of stormwater facilities. Research is also needed to understand the future effects and costs of stormwater disposal practices and to develop a more advantageous and desirable policy for all water users.

The Influence of Green Infrastructure Practices on Groundwater Quality: The State of the Science

Contact

National Risk Management Research Laboratory
https://www.epa.gov/aboutepa/about-national-risk-management-research-laboratory-nrmrl

Citation:

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Impact/Purpose:

Green infrastructure (GI) is increasingly being used to manage urban stormwater runoff. How the soils and subsurface geology/sediments interact with the stormwater runoff constituents has received little attention and the possible risks of groundwater quality impairment is poorly understood. The goal of literature review is to provide the current understanding of potential impacts or impacts to groundwater quality that could result from the use of GI to manage stormwater runoff. The results of the literature review were mixed; in some cases, there were impacts or potential impacts, and in other cases there were no impacts found. Many of the studies' results were problematic. In most cases, the results—reflected only what occurs in the vadose zone or the infrastructure—were extrapolated to predict what may occur to the groundwater. This extrapolation ignores other processes that could facilitate the transport of contaminants to the groundwater, such as preferential flow. In other cases there was no attempt made to measure concentrations of contaminants in aquifers or deeper in the vadose zone, and therefore, no definitive evidence for changes in groundwater quality. These results indicate that more research is needed to address potential risk of groundwater contamination that could result from the use of GI. These results will inform decision makers in EPA Office of Water, EPA Regional Staff, States and Local Governments of the potential for groundwater impacts resulting from the use of GI for stormwater management.

Description:

Green infrastructure (GI) technologies applied to stormwater are developed to mimic natural infiltration and hydrologic processes. GI is a design strategy that enhances runoff storage volume, infiltrates runoff, and contributes to groundwater recharge. Urban development often leads to the removal of vegetation and soil, and replacing them with large stretches of impervious surfaces. This disturbance of the natural hydrologic cycle due to urbanization is closely connected to deteriorating urban water quality and enhanced flood risks. When GI is used for urban runoff, there are concerns as to how the soils and subsurface geology/sediments interact with the stormwater runoff constituents, thus providing possible risks of groundwater quality impairment. Groundwater can be contaminated by many constituents: nutrients, metals, dissolved minerals, pesticides, other organics, and pathogens. This review provides insight into the current state of knowledge of the influence of GI on the subsurface environment and groundwater. All types of GI were assessed, both surface and subsurface infiltration infrastructures from peer-reviewed literature, published reports, and conference proceedings. Issues addressed include: 1) pollutant risks that need further research, 2) new infrastructure that has not been researched in depth, and 3) determining local considerations when planning for green infrastructure. When managing water resources, the tendency for contaminants to move between the ground and surface water needs to be considered. This requires an understanding of the native soil characteristics in the unsaturated zone and saturated zone as well as the hydrology. The primary geochemical processes that need to be considered as stormwater infiltrates are dissolution and precipitation, redox, ion exchange, adsorption/desorption, complexation/chelation, kinetics, mixing relationships, and colloid-facilitated transport. Simulation models are a potentially affordable way to predict risk as well as provide a decision-making tool for implementing GI. While many models are used to assess surface water and groundwater transport, few integrate GI; those that do integrate GI do not address groundwater contaminant transport. The biology of the system can have various impacts. Microorganisms such as bacteria, viruses, and parasites can be a contamination risk depending on the unsaturated and saturated zone conditions, incubation time, and native microbial populations. Macrobiological organisms can enhance or cause complications for green infrastructure, but research on these is limited. Riparian zones do not have any studies specific to urban GI, but previous studies on riparian zone restoration show they could restore denitrification to urban streams, induce recharge, and serve as a less manipulative approach for enhancing infiltration into alluvial groundwater. Overall, a better understanding of the risks associated with GI is needed to recognize the implications of GI on a longer temporal scale and wider spatial scale. When implementing GI, the local geology, climate, hydrology, biology, geochemistry, type of infrastructure, and contaminant loads need to be carefully considered to reduce risks to groundwater.

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The Influence of Green Infrastructure Practices on Groundwater Quality: The State of the Science

by

Jessica Brumley†, Christopher Marks‡, Alexis Chau*, Richard Lowrance‡, Junqi Huang‡, Cassie Richardson#, Steven Acree‡, Randall Ross‡, and Douglas Beak‡

†NRC Post Doctoral Research Associate
Ada, OK 74820

‡U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory
Ada, OK 74820

*ORAU Student Contractor
Ada, OK 74820

#Environmental Research Apprenticeship Program
Ada, OK 74820

8.0 Conclusions/ Future Research Needs

8.1 Conclusions

Stormwater reclamation for eventual reuse is triggering a paradigm shift from stormwater seen as a contaminant and a flood risk to a resource that can solve these risks. GI design strategy retains storage, infiltrates runoff, and contributes to the renewed groundwater recharge to more closely resemble the hydrology before urban development. The disturbance of the natural hydrologic cycle due to urbanization is closely connected to deteriorating urban water quality. This creates an increased risk to groundwater quality because of new pathways for contaminant introduction into groundwater, chemicals associated from anthropogenic activities, and wastewater exposure. This literature review determined what research that has been done on GI practices with respect to groundwater quality and the risks and impacts to the subsurface environment. The issues addressed include: 1) contaminant risks that need further research, 2) new infrastructure that has not been researched in depth, and 3) determination of local considerations when planning for green infrastructure.

Any pollutant found in stormwater could be a potential groundwater contaminant when used with GI infiltration technology. GI can return the urban hydrology to a more natural hydrologic cycle through retention and infiltration methods. Surface and subsurface infiltration can influence the impact the infiltrating stormwater has on the groundwater chemistry. Retention techniques can influence the water table depth through mounding, which have been seen in restoration projects, bioretention cells, and regenerative stormwater conveyance systems. Concern with GI for stormwater infiltration include fluctuations in groundwater levels, limitations with large precipitation events, clogging, and soil limitations. The infiltration is dependent on the clogging rate of the infrastructure.

Depending on the water's chemical, biological, and physical conditions, there is the risk of potential contaminants leaching from native soils and geology. When it comes to managing water resources, the tendency for contaminants to move between the ground and surface water needs to be considered. Urbanization can introduce contaminants that are otherwise not an issue in natural stormwater hydrology. Groundwater can be contaminated by many constituents: nutrients, metals, dissolved minerals, pesticides, other organics, and pathogens; the sources of which include residues from automobiles, lawn treatments though fertilizers and pesticides, sewer overflows, and road deicing salts. Due to risks affecting groundwater quality, it is suggested that infiltrating GI not be implemented in areas with potentially high contaminant loading, i.e. recycling centers, gas stations, and brownfields. When infiltrating devices are installed and used for urban runoff, there are concerns as to how the soils interact with the stormwater runoff pollution while infiltrating into the subsurface, thus providing possible risks of groundwater quality impairment from areas with potentially high contaminant concentrations.

The chemical interactions between surface water and groundwater are controlled by the type of geologic materials present and the amount of time the water is in contact with these materials. The various chemical reactions that affect the biological and geochemical characteristics of the basin are acid-base reactions, precipitation and dissolution of minerals, sorption, ion exchange, oxidation-reduction reactions, biodegradation, and dissolution and exsolution of gases. It is concluded that when implementing green stormwater infrastructure for infiltration, the properties of the unsaturated and saturated zones interacting with the infiltrating water need to be considered. These considerations encompass the understanding of the native soil texture, structure, and organic matter content of the unsaturated zone, as well as considering the porosity and permeability of the saturated zone and the flow of the groundwater. Kinetics and mixing relationships also require examination. Colloidal transport also needs to be considered as a mechanism that can transport contaminants through the soil, by either being a contaminant itself or having a contaminant sorb to a benign colloid. Colloids can be restricted by capture, sorption and static interaction. As discussed previously, colloid-facilitated transport could be an important mechanism for the movement of contaminants into groundwater (de Jonge et al., 2004).

The potential and actual impacts to groundwater quality as the results of GI practices were reviewed. The results presented were mixed; in some cases, there were impacts or potential impacts, and in other cases there were no impacts found. Many of the studies' results were problematic for several reasons. In most cases, the results—reflecting only what occurred in the vadose zone or the infrastructure—were extrapolated to predict what may occur to the groundwater. This extrapolation ignores other processes that could facilitate the transport of contaminants to the groundwater, such as preferential flow. Since there was no attempt made to measure concentrations of contaminants in aquifers or deeper in the vadose zone, there is no definitive evidence of changes in groundwater quality.

In studies that did include groundwater monitoring, it is unknown in some cases if the sampling strategy would detect changes in groundwater quality. Information on groundwater flow direction was not included, therefore the relationship of monitoring points to the potential transport of contaminants could not be ascertained. Another potential problem was that the studies did not account for lag between the time of water infiltration and the time it takes to transport the infiltrated water to the aquifer. In most studies, that sampling occurred at or very close to the precipitation event. Because lag time was not considered, transient changes to groundwater quality were not accounted for, even in systems that were monitored for decades.

The only system that consistently showed impacts to groundwater quality was ASR. The ASR impacts fell into one of two categories: unintended consequences, or the mixing of two waters with different composition and characteristics.

Simulation models can be an affordable way for predicting quality and quantity changes, as well as a decision-making tool for implementing green infrastructure. While there are many models in use for surface water and groundwater transport, there are few that integrate green infrastructure, and those that have do not address groundwater contaminant transport. Green infrastructure models have been implemented in various formats, but none specifically addressed groundwater contamination from this infrastructure. Problems associated with implementing models for assessing green infrastructure technologies and influence on groundwater include the amount of data available for calibration and validating these models, indicating a need for more field research to obtain this data.

Microbiological organisms such as bacteria, viruses, and parasites can be a contamination risk depending on the unsaturated and saturated zone conditions, incubation time, and native microbial population behavior. Microbial contaminants are a concern primarily if they present a public health threat from consuming contaminated groundwater, with the most common waterborne disease being acute gastrointestinal illness. While gut-associated microbial contaminants are not expected to grow and thrive within the groundwater environment, their rates of removal are affected by several, often interdependent, environmental factors. Research has shown there is a general trend of differential survival for the various contaminant organism types. Viruses tend to have the longest persistence times within any groundwater environment; enteric eukaryotes (*Cryptosporidium* spp. and *Giardia* spp.) and enteric bacteria typically have die-off rates of five to ten times, and over one hundred times larger than enteric viruses, respectively. Pathogen removal or die-off rates are typically reported based upon first order decay models; however, field and laboratory experiments have shown that biphasic models better approximate the removal behavior of fecal eukaryotes and viruses within groundwater systems. Hence, these studies have shown that there is an initial rapid removal phase for the first few days after introduction, followed by a slower phase two to hundreds of times less than the initial phase that can lead to months or years of persistence.

In saturated zones, factors influencing pathogen survivals in groundwater are temperature, water chemistry, and biological processes. Aquifer hydrogeology can influence the mechanical filtration, adsorption, wedging, and straining processes that can remove pathogens. There is also the potential of competition for nutrients and predation by indigenous microorganisms can play a significant role in the removal of introduced enteric pathogens. In unsaturated zones, the same processes from the saturated zone can apply but the air phase within the unsaturated zones can create two new interfaces, air-water and air-sediment that do not exist in saturated conditions which can both adsorb and entrap organisms. The decreased moisture can subject microorganisms to die-off or inactivation through desiccation. The highest native microbial populations are going to be in the rooting zone of the soil profile. Below the rooting zone, microbial populations and activity decrease with depth.

Macrobiological organisms can enhance or cause complications with green infrastructure. Vegetation is often used to retain nutrients and metals, enhance ecosystem service, increase filtration, and mimic the natural hydrology. The selection of the plants is important because they need to survive potentially toxic contaminants and the perturbations of the GI systems. There are few studies on how various macroorganisms can influence the green infrastructure. Bioturbator species that live in the sediment can increase the possible risk of nutrient contamination, and burrowing activity of worms can increase the macropores in the sediment and influence the infiltration. Macrobiological organisms can enhance or cause complications for green infrastructure, but research on these effects is limited.

Urban riparian zones can function as green infrastructure, but few studies have been done on their influence on groundwater. Previous studies on riparian zone restoration show that they could be useful to restore denitrification to urban streams. By serving as "natural filtration," the practice may have beneficial effects on surface water if the water is discharged back to surface sources. This induced recharge can also be used for either drinking water supply or to re-water floodplains. This is also a less manipulative, more feasible way to create opportunities for filtration into alluvial groundwater.

8.2 Future Research

Analogous to what the Pitt et al. (1999) and the recent Kabir et al. (2014) reviews concluded, we concur that more research is required to understand the potential groundwater quality impacts that can result from the implementation of GI. Apart from conservative chemical species such as chloride, a more complete understanding of what conditions are likely to cause groundwater quality impairment is necessary to mitigate or prevent these potential impacts. This review also indicates there is an apparent risk to the vadose zone "quality." Stormwater infiltration is causing the soil and vadose zone sediments to degrade, and the potential future impacts and risks to groundwater quality because of this are unknown—making long-term GI studies crucial.

Since land use and environmental conditions are likely to change, future groundwater risks are possible at many current GI sites if the infrastructure is not properly maintained. Further research is needed to determine the best monitoring methods for groundwater at these sites throughout their lifetime. Changing conditions will likely change the chemical and physical properties which can alter the retention properties in the soil/vadose zone. These potential land use changes and maintenance problems need to be addressed in future research. Another issue encountered is that, once the GI system is no longer functional or is "decommissioned," what practices should then be implemented to mitigate the potential environmental issues created by trapping the contaminants in the vadose zone. This emphasizes the need for long term monitoring methods that addresses placement of sampling points and timing of sampling to determine the long-term impacts to the subsurface. Currently GI performance standards are not included into the National Pollutant Discharge Elimination System (NPDES) permits, including impacts on groundwater. Including this into the NPDES system may be benefitial to protection groundwater quality.

Additional research is needed to understand the impacts and benefits that various macrobiological organisms have on GI, and how these affect the hydrology, fate, and transport of contaminants in GI systems. Vegetation is the most common addition to GI, but there is an inadequate understanding as to how this vegetation influences groundwater quality over time. Addressing whether preferential flow increases over time or if nutrient and metal concentrations change over time is a necessity. Previous studies on riparian buffer zones have shown various benefits to restoring these in non-GI situations, but further studies are needed to determine the benefits and potential issues with implementing them as part of urban GI.

Simulation modeling of GI systems needs to be addressed to help users understand the potential groundwater impacts. Further research of simulation models is needed to address the location and spacing of GI stormwater practices to determine if there are diminishing returns on the quantity of stormwater controls. Simulation models are necessary to determine how large GI projects can be designed to effectively reduce runoff and have the least environmental impact (Brown et al., 2012; Eckart et al., 2017). Research on the use of models to demonstrate how GI performs under different temporal scales, spatial scales, and climatic conditions is needed since there is a lack of data on the performance of these technologies. Simulation research and improvements in modeling techniques are also needed so that they can assist in understanding the role of GI in restoring the water balance, reducing contaminants over the long term, evaluating various GI performance, as well as acting as decision support tools (Dietz, 2007; Ahiablame et al., 2012; Fletcher et al., 2013; Eckart et al., 2017).

Overall, there are several research areas necessary for a better understanding of the risks of a GI infiltration technology that have been proposed as the result of this effort. There needs to be more investigations looking at the GI interactions on a longer temporal scale and wider spatial range. When implementing GI, the local geology, climate, hydrology, biology, geochemistry, type of infrastructure, and contaminant loads need to be carefully considered to reduce the risk to groundwater quality.