Enhanced Aquifer Recharge Using Stormwater: State of the Science Review

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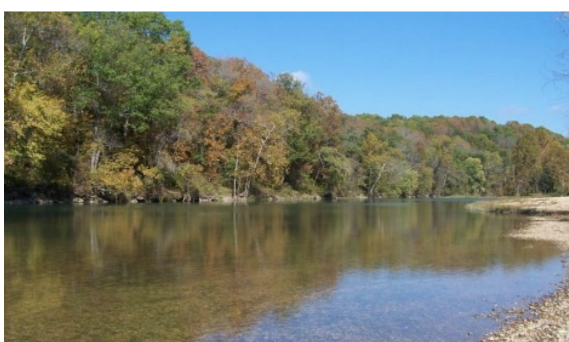
Problem statement

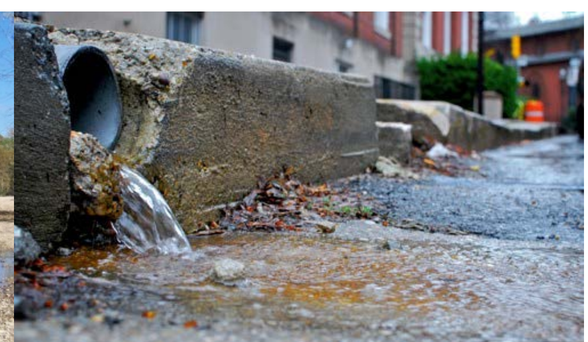
Enhanced aquifer recharge (EAR) has potential to augment water supplies, replenish groundwater, restore streamflow.

- EAR includes managed aquifer recharge (MAR), artificial recharge, ASR, other.

This report focuses on one aspect of EAR, the intentional recharge of aquifers using <u>stormwater</u> (urban/developed).

Stormwater EAR is increasingly attractive as urbanization increases. Also dovetails with infiltration-based stormwater management (treats stormwater as a resource).





Risk

RISK: Stormwater can contain chemical and microbial contaminants that could be detrimental to receiving aquifers.

- can pose risk of groundwater contamination

MITIGATION: Includes, soil/aquifer systems present opportunities for natural filtering and inactivation or removal of contaminants from recharging stormwater.

EAR BENEFIT: Decreases potential risk associated with local flooding.

Report goal

Summary/synthesis of available technical literature.

Goal is an improved understanding of the scientific foundation, including knowledge gaps, leading to best practices for effective, efficient, and safe EAR using stormwater.

Addresses the following questions:

- What practices are used for stormwater EAR?
- What factors affect stormwater EAR volume?
- What are the risks; particularly water quality degradation?
- What does current science suggest about best practices?
- What are key knowledge gaps which, when filled, would help advance the effectiveness, efficiency, and safety of EAR using stormwater?

Does not address policy or regulatory issues.

Conducted a keyword-based literature search:
- Web of Science
- Proquest
- Science Direct

Approximately 650 items returned

KEYWORD SEARCH	
TERM	**BOOLEAN MODIFIER = "AND"**
aquifer	stormwater OR storm water
aquifer recharge	contamin*
aquifer recharge	stormwater OR storm water
aquifer storage	contamin*
aquifer storage	stormwater OR storm water
aquifer storage and recovery	
artificial recharge	
artificial recharge	contamin*
artificial recharge	stormwater OR storm water
drainage well*	stormwater OR storm water
enhanced aquifer recharge	
green AND BMP*	contamin*
green AND BMP*	recharge
groundwater replenishment	
infiltration galler*	
in-situ infiltration	stormwater OR storm water
managed aquifer recharge	
managed underground storage	
recharge basin	aquifer
recharge basin	stormwater OR storm water
recharge basin	
recharge wel*	
recharge well	contamin*
recharge well	stormwater OR storm water
recoverable water	
stormwater OR storm water	contamin*
stormwater OR storm water	microb*
stormwater OR storm water	quality
stormwater recharge OR storm water recharge	
underground injection	contamin*
underground injection	stormwater OR storm water
underground injection control	
underground storage	contamin*
underground storage	stormwater OR storm water
water banking	
water capture	
water reuse	aquifer recharge
water reuse	aquifer recharge OR aquifer storage

Literature search results – Heat maps

Publication Date	Items
2016 - 2020	250
2011 - 2015	184
2006 - 2010	93
2001 - 2005	42
2000 or earlier	64

Region	Items
General (lab/review)	196
Northeast	19
Southeast	55
Midwest	5
Great Plains North	2
Great Plains South	26
Northwest	10
Southwest	107
Australia	94
Other International	119

Literature search results – Heat maps (cont)

Study Endpoint	Items
Volume/Hydrology	134
Quality - Microbial	32
Quality - Chemical	173
Quality - General	81
General	170
Aquifer - Microbial/Biofilm	11
Economic/Policy/Decision	32

Study Focus	Items
Design/Planning/Siting	90
Maintenance/Pre-treatment	78
Performance/Risk	228
General/Case Study	103
Review Paper	134

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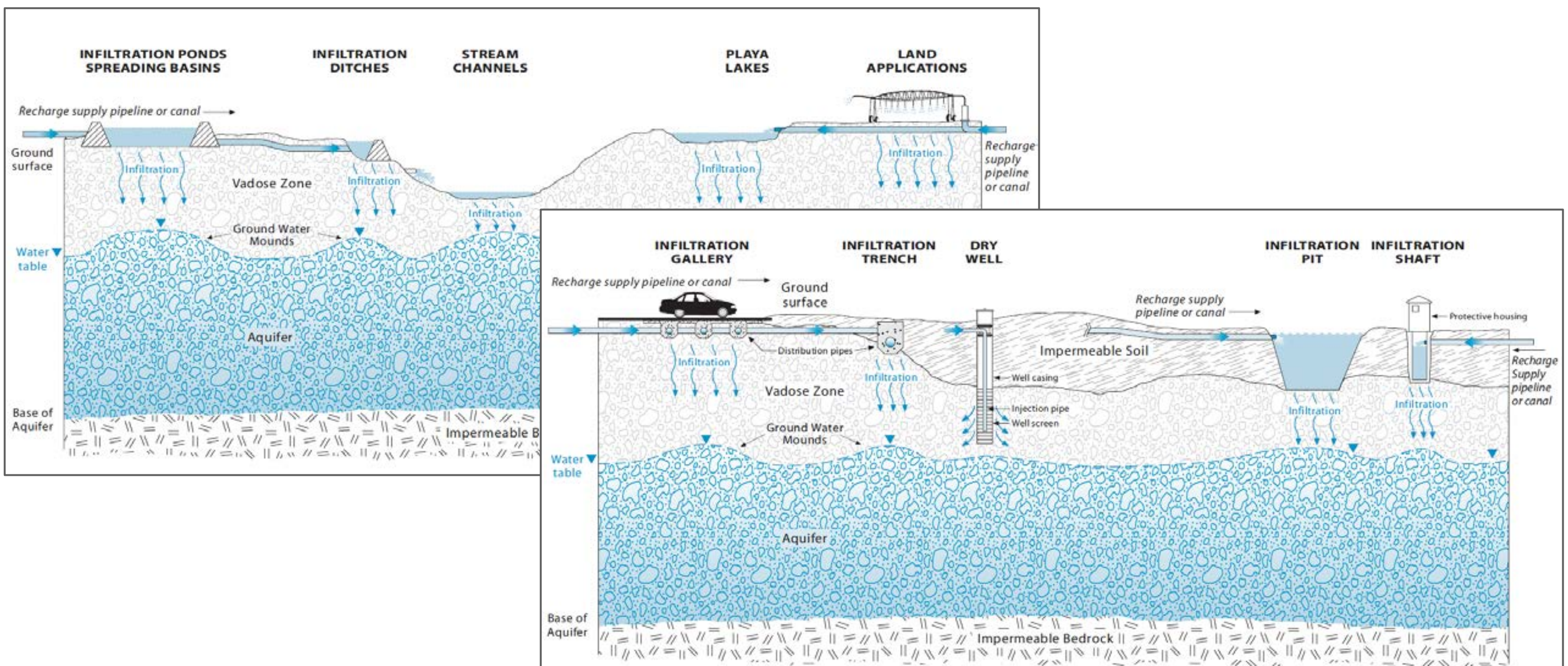
Stormwater EAR methods

Methods considered include:

- Infiltration ponds/basins
- Infiltration trenches and galleries; ditches
- Percolation ponds
- Dry wells
- Dry riverbeds
- Injection wells (including stormwater drainage wells and ASR wells)



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Physical factors affecting recharge rates

Factor	Relationship
Precipitation	In general, as the magnitude, frequency, duration, and intensity of precipitation events increases, runoff volumes increase, increasing potential EAR volumes
Evapotrans-piration	As evapotranspiration increases, soil moisture deficit, surface evaporation, and vegetative transpiration will increase, and EAR volume will decrease
Land Cover	More precipitation is converted to runoff when more area is covered by impervious surfaces
Geology	Clogging can lead to decreased EAR volumes. Conversely, dissolution of karst can result in increased permeability at the recharge site
Depth to Water Table	EAR volumes decrease when the depth to the water table is too small (i.e., shallow)
Alternative Source Waters	If alternative source waters are avaiable during dry seasons increases, the recharge system can be operated when stormwater is not available
Infiltration Basin or Injection Well	Increased hydraulic loading rates will generally increase EAR volumes, but can also increase physical and biological clogging rates
Climate Change	More flashy, intense or seasonal precipitation patterns can lead to exceedance of EAR system design, resulting in runoff losses to surface water bodies

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Potential effects on groundwater quality

Urban stormwater can contain a wide range of contaminants

- pathogens
- metals
- organic contaminants
- nutrients
- road salts (in areas with snow)

Differences between infiltrated stormwater and ambient groundwater can result in mobilization of subsurface contaminants

- precipitation/dissolution of minerals
- oxidation/reduction reactions
- sorption and cation exchange reactions
- clay swelling and dispersion

Towards best practices

While uncertainties remain, there is a growing scientific understanding we can use to characterize risk and inform strategies for risk reduction

Opportunities/constraints:

- Site selection
- Aquifer extent and hydraulic properties
- Pretreatment (e.g., for settling basins, constructed wetlands, green infrastructure, media filtration, chemical pretreatment)
- EAR operations and maintenance (e.g., for infiltration practices including stormwater BMPs, dry wells, injection wells)

Knowledge gaps

Potential for stormwater EAR to help meet local water supply goals?
- where in the U.S. are site physical conditions most suitable?

Are there specific location or design factors for EAR of stormwater that suggest increased risk, particularly risk of water quality contamination?
- occurrence and fate of pathogen and chemical contaminants in stormwater

How effective is pre-treatment for reducing risk of contamination?
- fit-for-purpose in different locations, for different contaminants?

Monitoring design to ensure compliance with regulatory requirements?

Some additional sources of information

EPA ORD Reports:

Effects of green infrastructure practices on groundwater quality (2018)
https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=342610

Case studies – Influence of stormwater/wastewater infiltration (2020)
https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=350152&Lab=CESER

National Academies Reports:

Using graywater and stormwater to enhance local water supplies (2016)
https://www.nap.edu/catalog/21866/using-graywater-and-stormwater-to-enhance-local-water-supplies-an

Prospects for managed underground storage of recoverable water (2008) https://www.nap.edu/catalog/12057/prospects-for-managed-underground-storage-of-recoverable-water

Work on the report initiated in August 2020

A draft report currently in technical peer review by experts

Final report available in late spring 2021

Thanks for listening!

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