Managed Aquifer Recharge
using Stormwater as a Drought Mitigation Strategy

urban flood resilience

FACTSHEET

Project area: *SuDS, Managed Aquifer Recharge, Water Supply, River Augmentation*
Intended audience: *LLFA, EA, government, practitioners, developers, academia*

Summary

Managed Aquifer Recharge (MAR) involves artificially recharging and storing water into an aquifer to recover it during times of drought. This water can also serve to raise local water table levels in aquifers connected to rivers, thus having the potential to augment low river levels through baseflow. Considering that a significant proportion of rainfall falling over urban environments is converted into runoff, it is worth exploring the opportunity and feasibility of using MAR with urban runoff as the recharge water source. In this process, stormwater must be captured, stored and pre-treated before it is recharged into the subsurface. Sustainable Drainage Systems (SuDS) are ideal for this purpose and, therefore, a SuDS/MAR scheme can be envisaged in an urban setting. Barriers and opportunities arising from implementing such a scheme are explored for the Cray catchment, South London. The analysis follows a stepwise methodology examining whether (i) sufficient quantity can be captured, (ii) a suitable aquifer is found locally, (iii) there is sufficient space for SuDS development and (iv) water quality constraints can be dealt with given aquifer protection regulation. Schemes under favourable conditions might become increasingly needed in a context of future climate uncertainty where the marginal environmental and economic costs for additional storage capacity in surface reservoirs are expected to rise sharply.

Concept. In the UK, Defra (2016) has pointed to a population increase of 10 million by 2050 coinciding with increasing summer temperatures and decreasing rainfall leading to the likelihood of short duration droughts. This situation will require new water resources to safeguard public supplies, particularly in light of population growth in metropolitan areas. Expansion of surface water storage, treated water reclamation, trans-basin transfers and desalination comprise potential, but expensive, solutions.

Where the geology is suitable, an alternative approach might involve Managed Aquifer Recharge (MAR) as part of wider integrated water management strategies, a technique involving artificially introducing and storing water into the ground to supplement groundwater stocks. Different types of Managed Aquifer Recharge exist using dry wells, injection wells, infiltration ponds or galleries [1]. This technology has proved successful in many parts of the world including India, South Africa, Australia and the USA [2,3,4], but has had limited practice in the UK. Thames Water already performs recharge using drinking water at the NLARS scheme [5].

Reusing urban stormwater in this way can provide an alternative water supply to reduce pressure on existing water supply systems. Urban areas are subject to increasing rates of development which add to the high levels of impervious areas and the generation of substantial quantities of urban runoff. Actively managing such runoff not only lowers urban flood risk but captures a vital resource which otherwise is lost in downstream receiving water bodies. Coupling to Sustainable Drainage Systems (SuDS) can support stormwater collection and retention prior to injection (Fig. 1).

Risks and Uncertainties. The Groundwater Directive [6] requires that hazardous substances are prevented from entering groundwater. Water quality is a major concern and, although SuDS provide a preliminary treatment, pre-treatment will be required for different types of organic and inorganic contaminants. Technical, financial and regulatory feasibility need to be assessed through a case-by-case analysis (see Fig.2).

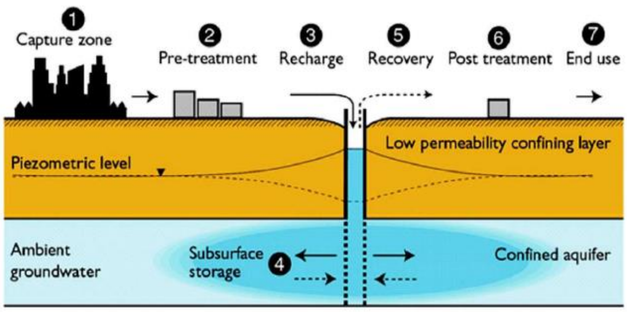

Fig. 1: Stages in Aquifer Storage and recovery process [2]

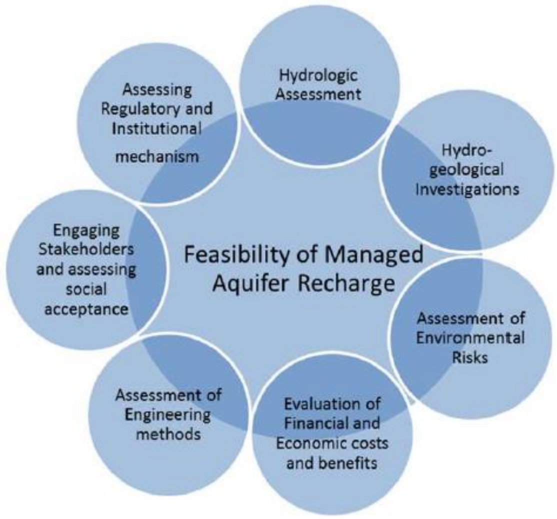

Fig. 2: MAR feasibility framework [7,8,9]

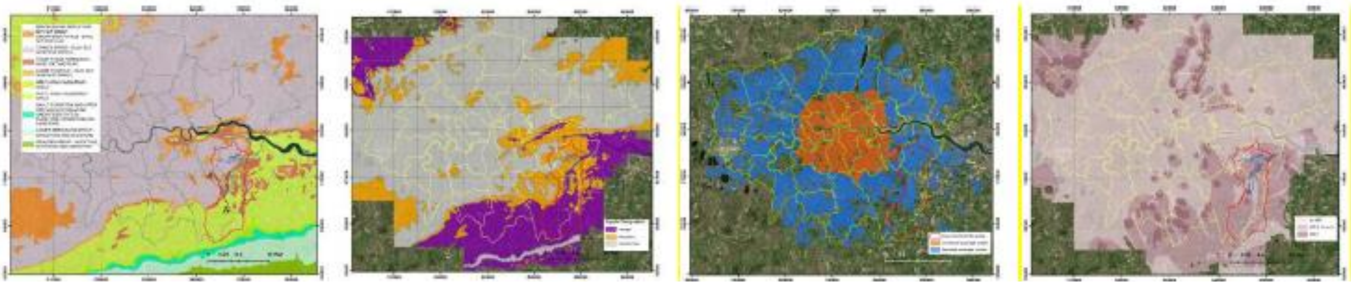

Fig. 3: Overlaid spatial information to identify opportunities within the London Catchment: From Left to Right: Outcrop Geology, Aquifer Designation, Combined/Separate Sewers and Groundwater Source protection Zones.

Case analysis. An opportunity assessment for locating potential MAR sites in London was carried out using GIS (Fig. 3). Layers included a land cover base map, London geographical boundaries, rivers, geology, hydrogeology, aquifer designation, urban catchments, and groundwater source protection zones. The analysis revealed the Cray catchment was suitable for detailed investigation (Fig. 4). The River Cray supports a high-quality biological diversity, but it is susceptible to pollution due to its interaction with the urban environment. The Cray catchment is covered by a considerable amount of Source Protection Zones (SPZs) ranging from risk level I to IV (from high to low risk). Slightly less than half of the catchment is urbanised with the rest of the land being greenspace. The catchment of the tributary River Shuttle, however, has a higher degree of impermeability with 82% of the area considered impervious (Fig. 4b). The Chalk outcrops cover about half the catchment area while the Harwich Formation, Woolwich 39 Beds, London Clay and Thanet Sands, occupies the other half, overlying the Chalk in the northern basin. The geology under River Shuttle is mainly composed of a sand and gravel formation known as the Harwich Formation. Superficial deposits also exist in the area. The Shuttle catchment is protected with groundwater zones ranging from I to III and therefore water of potable quality will need to be recharged in the aquifer to prevent degradation of groundwater quality.

Results. Stormwater amounts to approximately 8.6 Mm3/year. The available volume captured and treated will be lower however it can contribute significantly to local water demand (6,6 Mm3/year) (see Saleh et al. for details [10]). Two applications, namely river augmentation and water supply, were assessed as two possible end-use options for the Shuttle sub-catchment. The limited thickness of the recharge aquifer (30 m), as well as the fact that it is unconfined, limited significantly the injection rate and, by extension, the total injected volume to the system. Based on the selected recharge point (Fig 3), travel time is approximately 120 days and water injected in the winter will supply the river in the early summer. The storage capacity and operating rules of the retention pond can allow some flexibility with respect to the selection of injection time in a year to meet low flow augmentation requirements.

Extended findings. Recharge water needs to be of sufficient quality meeting regulation and end-user requirements, therefore pre-treatment is part of the system design. Raised water levels should not increase the risk of groundwater flooding. For this reason, limits to injection rates and periods are expected to apply. Adequate monitoring is therefore required for the safe operation of the scheme. The financial viability of the system is higher when combining it with planned or existing infrastructure. Wetland and retention ponds are standard approaches to flood risk management, which would require limited adaption to perform the additional function. In this case, early co-design is critical from the start - rather than attempting a retrofitting approach. Future challenge to find alternative surface water sources due to physical and climatic limiting factors or low social acceptance of large-scale water supply infrastructure can make SuDS/MAR systems more relevant.

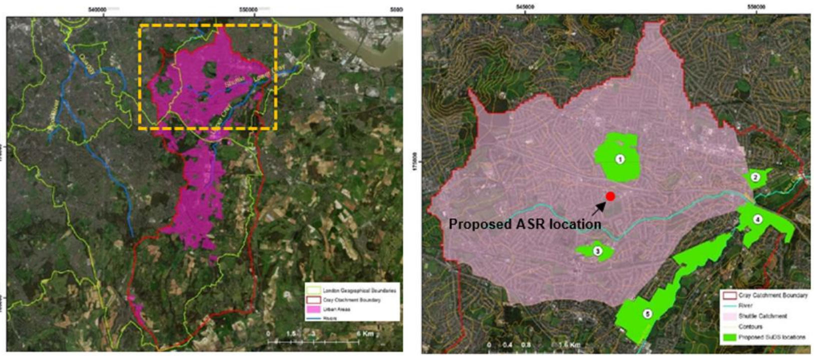

Fig. 4: (a) The Cray catchment and its impermeable coverage, and (b) Potential SuDS locations in the Shuttle subcatchment and recharge (ASR) point. Yellow frame in "a" represents the magnified area in "b".

References: *1. Dillon, P., Pavelic, P., Page, D., Beringen, H. (2009). Managed aquifer recharge: an introduction. Waterlines Report Series no. 13, February 2009, National Water Commission, Canberra. Australia.*

2. Jordan R (2016). Stanford Researchers reveal cost effective path to drought resiliency. https://news.stanford.edu/2016/07/21/cost-effective-path-drought-resiliency/

3. Shuster, W.D., Gehring, R., and Gerken, J. (2007). Prospects for enhanced groundwater recharge via infiltration of urban storm water runoff: A case study. Journal of Soil and Water Conservation 62(3):129-137.

4. Gale, I.N., Williams, A.T., Gaus, I. & Jones, H.K. (2002). ASR -UK: elucidating the hydrogeological issues associated with Aquifer Storage and Recovery in the UK. UK Water Industry Research Limited (UKWIR), 54pp. (UKWIR Ref: 02/WR/09/2, CR/02/156N). http://nora.nerc.ac.uk/id/eprint/512266/

5. North London Aquifer Recharge Scheme, URL: https://www.thameswater.co.uk/help-and-advice/water-quality/where-our-water-comes-from/north-london-artificial-recharge-scheme

6. European Commission, 2006, Groundwater Directive

7. Page D.W., Peeters L., Venderzalm K., Gonzalez B.D. (2017). Effect of aquifer storage and recovery (ASR) on recovered stormwater quality variability. Water Research. 117 pp1-8

8. Rawluk, A., Curtis, A., Sharp, E., Kelly, B.F. (2013). Managed aquifer recharge in farming landscapes using large floods: an opportunity to improve outcomes for the Murray-Darling Basin? Australasian journal of environmental management. 20 (1), 34–48.

9. Arshad, M., Guillaume, J.H.A. & Ross, A. (2014). Assessing the Feasibility of Managed Aquifer Recharge for Irrigation under Uncertainty. Water. 6 (9), 2748– 2769. doi:10.3390/w6092748

10. Saleh, H., Fenner, R.A., Kapetas, L., 2019. Managing aquifer recharge using stormwater as a drought mitigation strategy in London, in: Proceedings of the 38th IAHR World Congress. IAHR, Panama.

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