Evaluating the influence of a stormwater exfiltration system on stormwater runoff reductions and potential groundwater contamination

Hamed Mohamadian, Christopher Power, Clare E. Robinson

Department of Civil & Environmental Engineering, Western University, London, Ontario, Canada (hmohama5@uwo.ca; cpower24@uwo.ca; crobinson@eng.uwo.ca)

www.eng.uwo.ca/restore

1. INTRODUCTION

- Stormwater Exfiltration Systems (ES) are a Low Impact Development (LID) stormwater management approach that use perforated pipes beneath storm sewers to infiltrate stormwater and reduce runoff volumes [1,2].
- Few studies have assessed performance ES in reducing runoff volumes particularly when ES are installed in low permeability soils.
- Potential impact of ES on groundwater contamination including chloride contamination from road salts, is unclear.

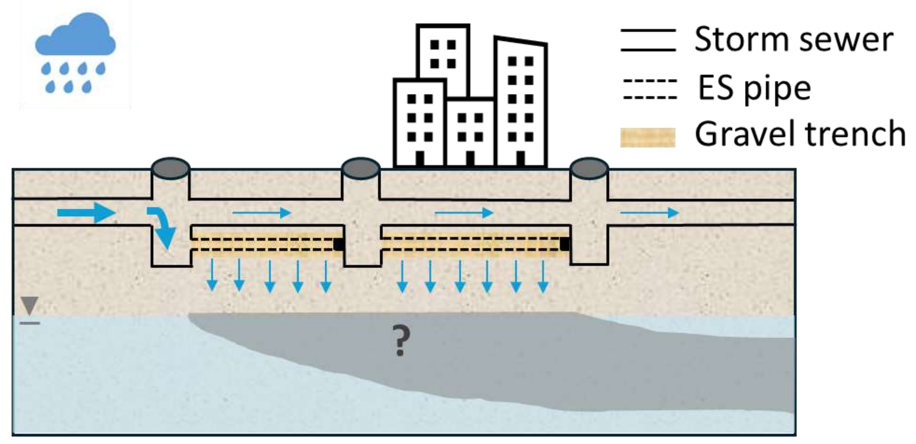

Fig. 1: Conceptual diagram of a stormwater ES.

- **Objective:** Evaluate performance of an ES installed in low permeability soils in decreasing stormwater runoff volumes and assess the impact of ES on surrounding groundwater levels and quality.

2. STUDY SITE AND METHODOLOGY

- Monitoring conducted over a 13 month period on an 80 m section of a 500 m ES installed under a major road in London, Ontario (Fig. 2).
- ES system installed in clayey and sandy silt substrate with measured hydraulic conductivity ranging from 1.8×10^{-8} to 6×10^{-7} m/s .
- Flow sensors and CTD divers (pressure, electrical conductivity [EC], temperature) installed in storm sewer (inflow, outflow, and ES pipe) to monitor stormwater volume reductions and estimate exfiltration into the subsurface (Fig. 3).
- Three piezometers, located between 5 to 18 m from ES (Fig. 2) were installed at 7 to 9 m depth for continuous measurement of groundwater levels and EC, and biweekly sampling (EC, chloride; Fig. 4b).
- Electrical Resistivity Tomography (ERT) surveys conducted along two lines (Fig. 2) to delineate surrounding geology [3]. Monthly time-lapse ERT to be conducted to examine temporal changes in groundwater quality.

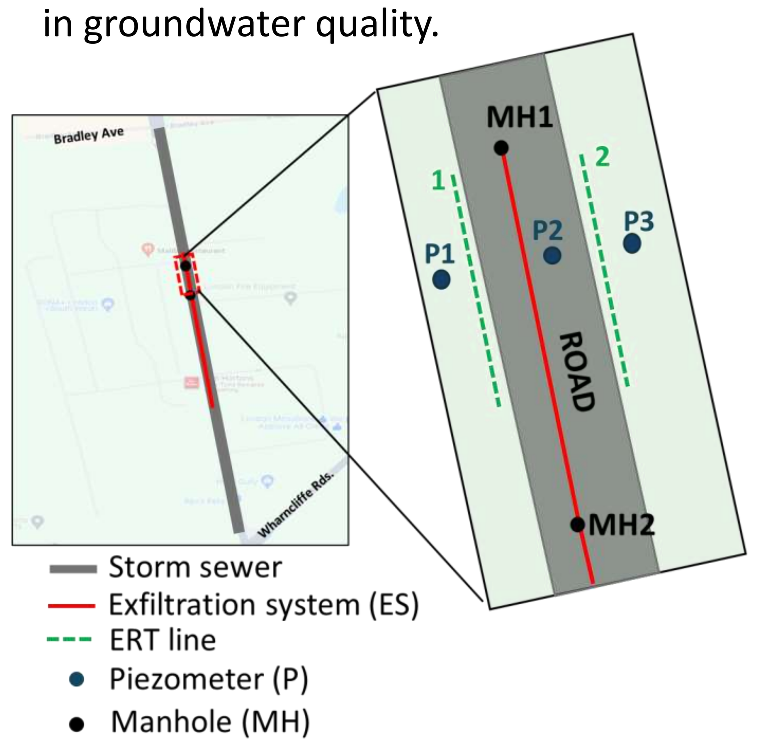

Fig. 2: Location of ES along a major road in London, ON.

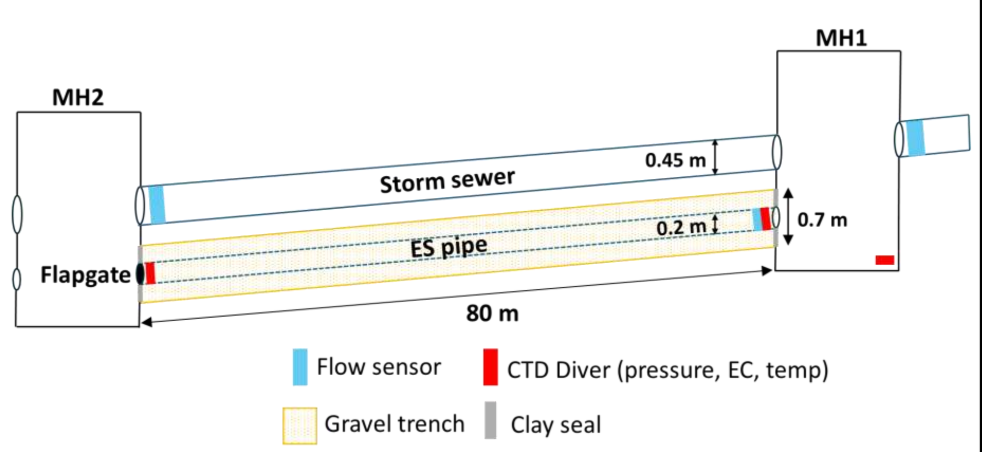

Fig. 3: Monitoring setup in storm sewer system between MH1 and MH2.

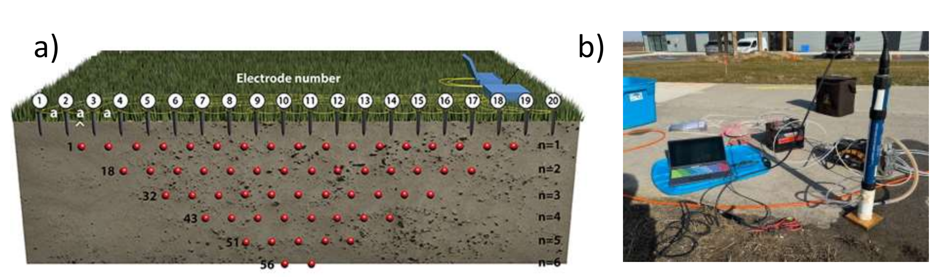

Fig. 4: (a) Conceptual model of ERT survey, and (b) photo of groundwater sample collection.

3. RESULTS

3.1. Stormwater Runoff Reduction

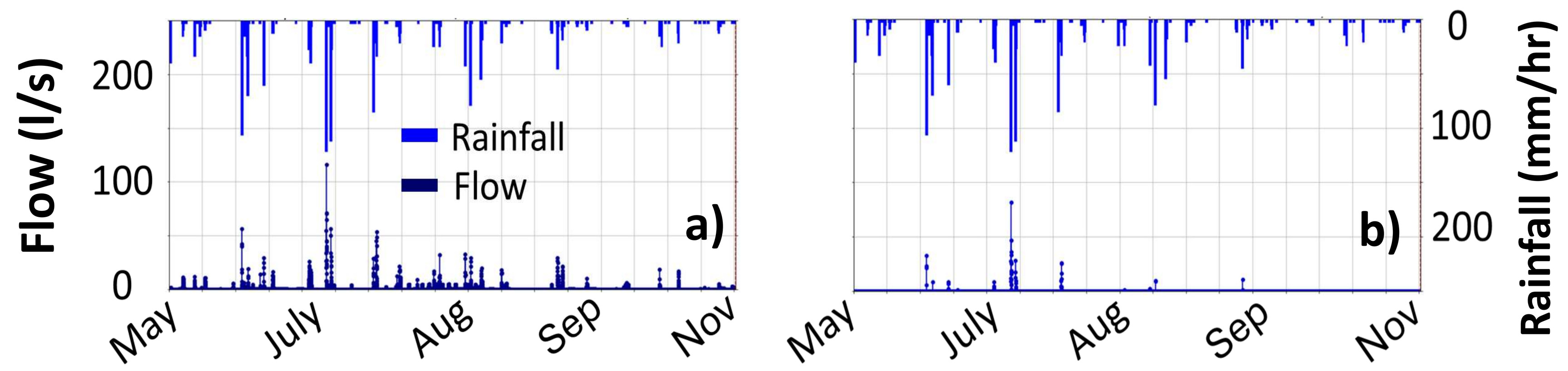

Fig. 5: Storm sewer flow and rainfall at (a) MH1 (upstream) and (b) MH2 (downstream) from May 29 to Nov 15, 2024.

- ES decreased stormwater runoff volume by 84% from May to Nov 2024 despite low permeability of surrounding soil and shallow depth to groundwater table (0.6–3.5 m).
- ES decreased event stormwater volumes by 23 to 100% with % reduction varying with rainfall depth and intensity (Fig. 6, Table 1).
- Estimated exfiltration rates (0.3–11.8 cm/hr; Table 1) consistent with silty soils which range from ~0.03 cm/hr to ~12 cm/hr for clay and sand [4].

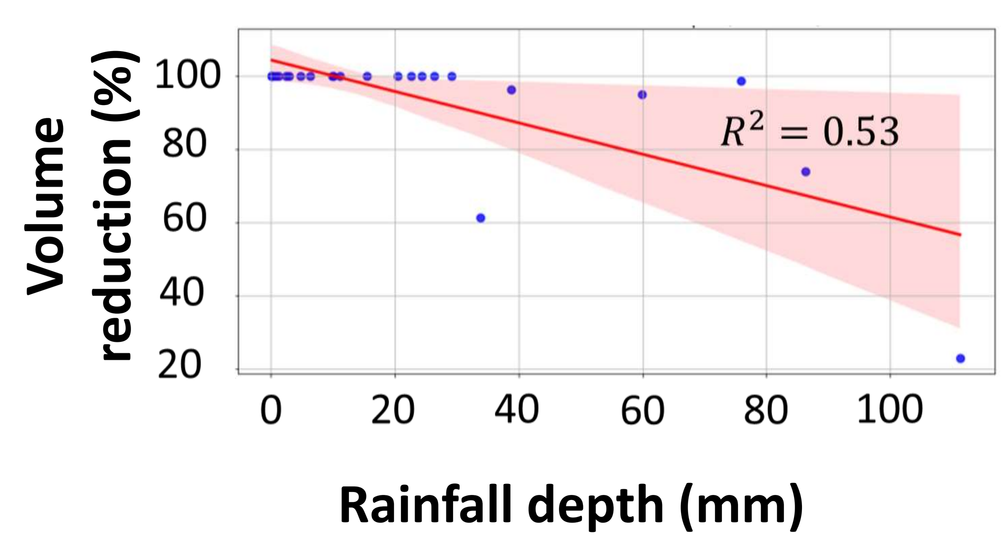

Fig. 6: Event runoff volume reduction vs. rainfall depth for 31 events over monitoring period.

Table 1: Runoff characteristics and percentage volume reduction for 7 large rainfall events.

No.	Rainfall depth (mm)	Event duration (hr)	Average rainfall intensity (mm/hr)	Volume reduction (%)	Average exfiltration rate (cm/hr)
1	86	325.4	0.27	74	0.4
2	59	21.5	2.74	95	7.8
3	111	58	1.92	23	0.9
4	34	25.2	1.34	62	2.6
5	34	202	0.17	97	1.1
6	23	8.5	2.66	93	6.8
7	12	3.6	3.26	100	11.8

3.2. Groundwater Level and EC Monitoring

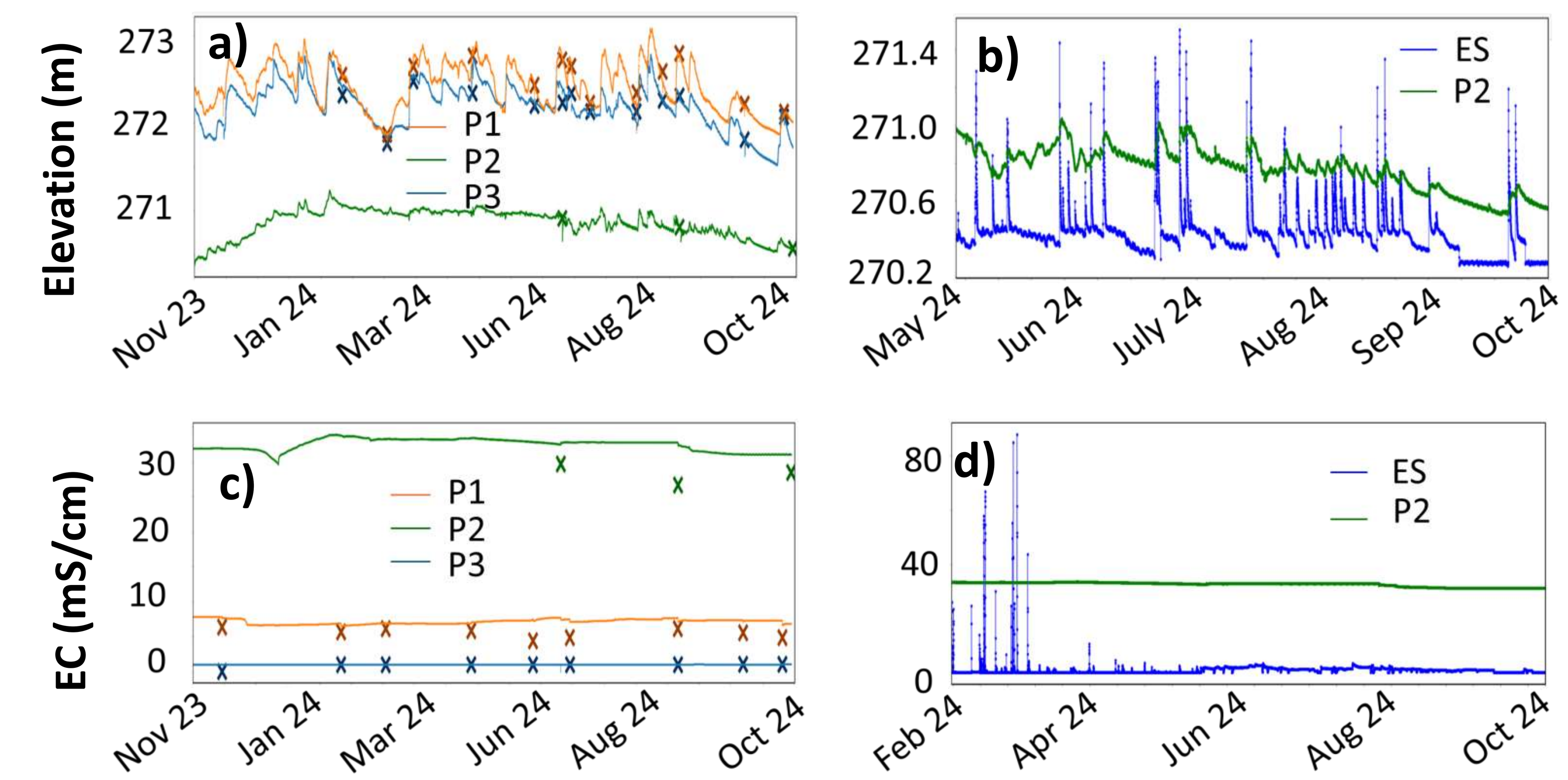

Fig. 7: (a) Groundwater elevation in three piezometers (P1, P2, P3), (b) Water elevation in ES pipe and P2 (c) EC in three piezometer (d) EC in ES pipe and P2.

- Groundwater levels fluctuated in response to rainfall events, with larger fluctuations in piezometers farther from ES (P1 and P3, Fig. 7a).
- Groundwater level at P2 generally above water level in ES pipe (except during heavy rainfall). Large difference in EC between ES pipe and P2 indicate groundwater is not infiltrating into ES (Fig. 7b).
- Groundwater EC shows no seasonal changes in response to high EC in ES pipe during winter (EC up to 30 mS/cm; 3500 mg Cl/L, Fig. 7d) although groundwater EC is highest in piezometer closest to ES (Fig. 7c).

3.3. ERT surveys

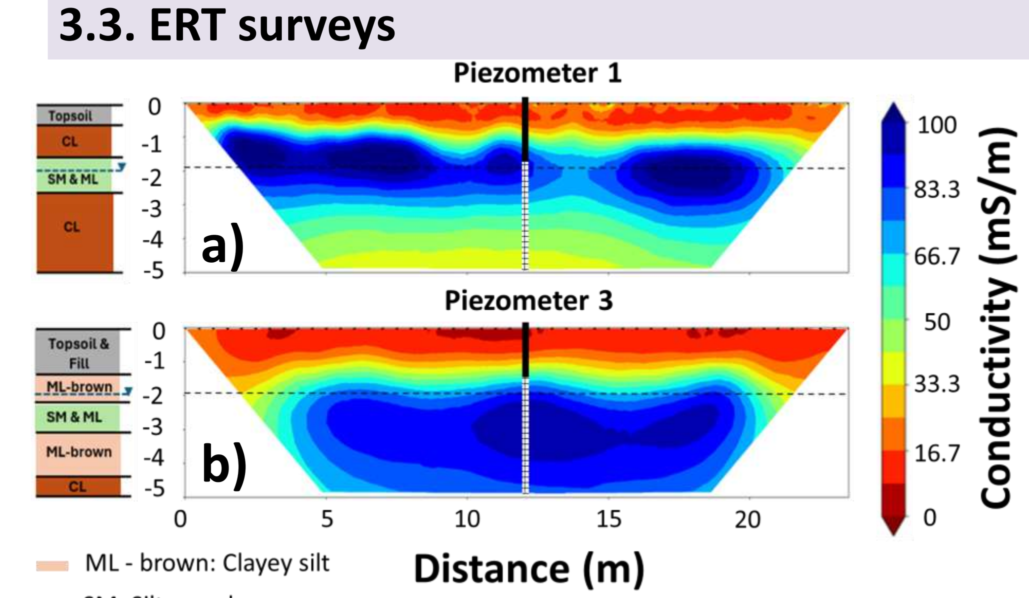

Fig. 8: Cross-sectional images of bulk EC from ETR surveys along a) Line 1 and b) Line 2 on Nov 1 2024.

- Bulk EC for Lines 1 and 2 (Fig. 2) show conductive zones (>60 mS/cm) which could be due to clayey materials or high porewater EC.
- Time-lapse ERT surveys needed to untangle influence of geology and water quality on bulk EC.

4. CONCLUSIONS AND IMPLICATIONS

- ES reduced stormwater volumes despite being installed in low-permeability substrate. Additional work to be conducted to further evaluate ES performance for chloride load and peak flow reductions.
- Groundwater monitoring data indicates complex hydrogeological conditions around ES with no clear evidence of groundwater Cl contamination at piezometer locations. Exfiltrating stormwater may possibly be short-circuiting to urban karst features associated with infrastructure.
- Time-lapse ERT surveys needed to provide insight into potential subsurface chloride plume from ES.

REFERENCES

[1] Joksimovic, D., Li, J.Y. (2018) Performance Modelling of Etobicoke Exfiltration System (EES):(035). In *WDSA/CCWI Joint Conference Proceedings* (Vol. 1).

[2] Ternier, S. (2012) Review Of Stormwater Management In Ontario And A Case Study On The Etobicoke Exfiltration System.

[3] Loke, M.H., Chambers, J.E., Rucker, D.F., Kuras, O., Wilkinson, P.B. (2013). Recent developments in the direct-current geoelectrical imaging method. Journal of Applied Geophysics, 95, 135-156.

[4] Tran, J., & Li, J. (2015). *Planning and Design Manual of the Etobicoke Exfiltration System for Stormwater Management*. Department of Civil Engineering, Faculty of Engineering and Architectural Science.