Sanitary Sewer Exfiltration Model Proposal

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- Humans convert food to wastewater

- And we depend on sanitary infrastructure to contain and treat this nitrogen source

Bernhardt et al.: *Urban Impacts on Surface Water Nitrogen Loading*

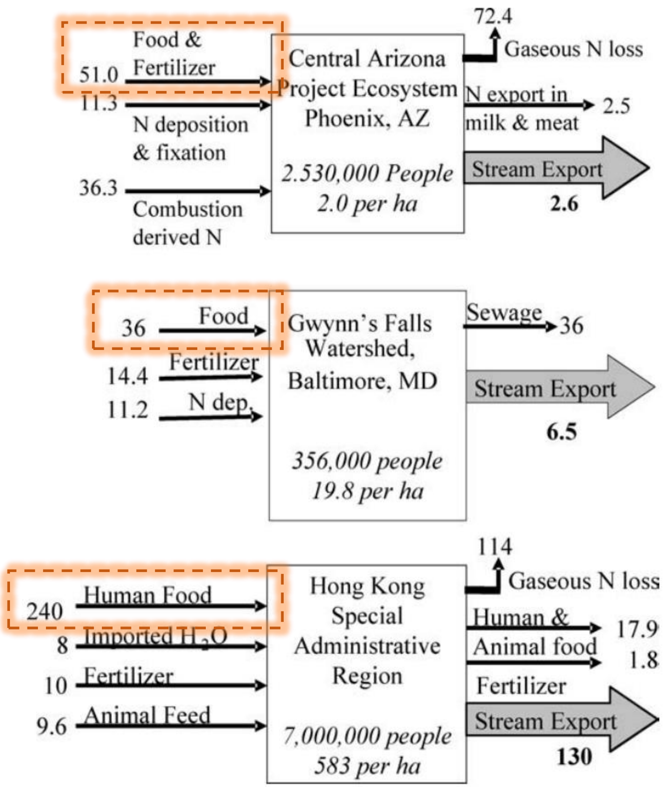
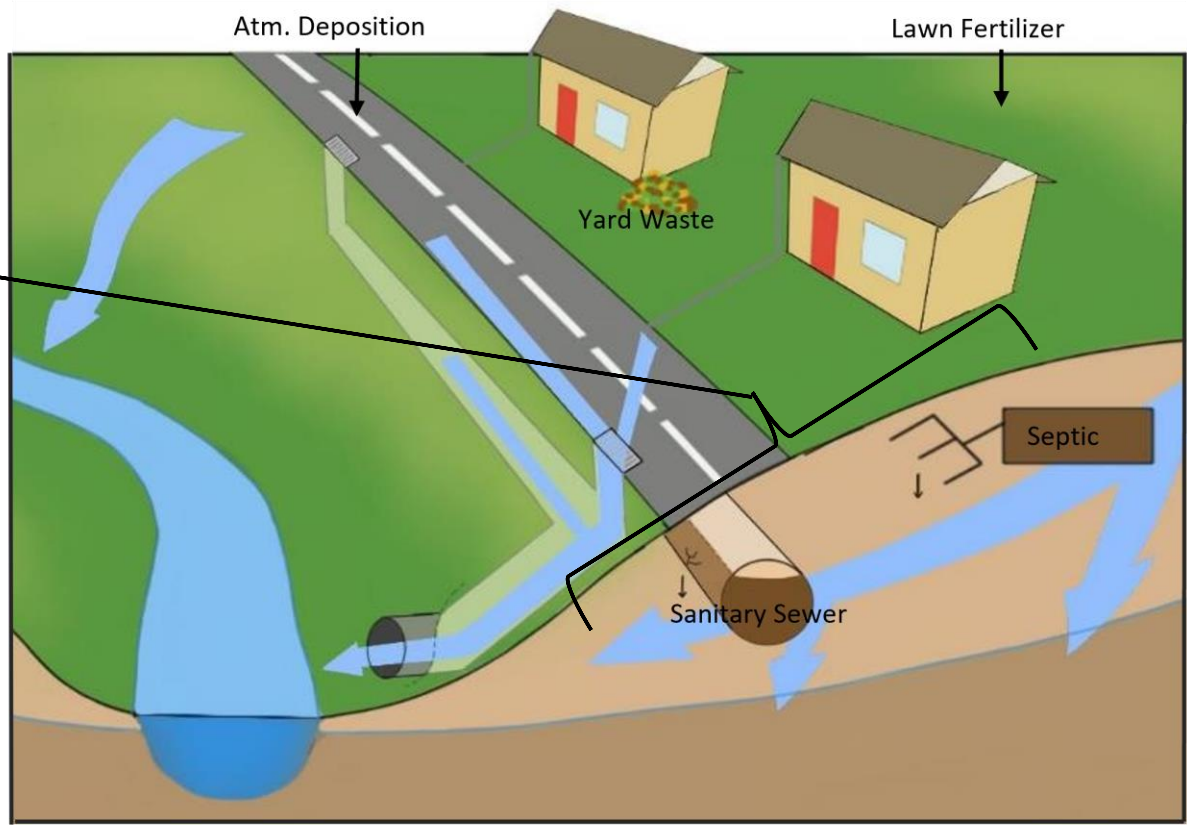


Figure 2. Compiled mass balance estimates for three cities (data in kg N ha^{-1} y^{-1}) arranged in order of increasing population density. Data for Phoenix from Baker *et al.* 2001, for Baltimore from Groffman *et al.* 2004, and for Hong-Kong from Warren-Rhodes and Koenig 2001. Note the discrepancies between the types of fluxes measured in each study.



Bernhardt, E. S., Band, L. E., Walsh, C. J., & Berke, P. E. (2008). Understanding, managing, and minimizing urban impacts on surface water nitrogen loading. *Annals of the New York Academy of Sciences*, *1134*, 61–96.

Baker, L. A., Hope, D., Xu, Y., Edmonds, J., & Lauver, L. (2001). Nitrogen balance for the Central Arizona-Phoenix (CAP) ecosystem. *Ecosystems*, *4*(6), 582–602.

Groffman, P. M., Law, N. L., Belt, K. T., Band, L. E., & Fisher, G. T. (2004). Nitrogen Fluxes and Retention in Urban Watershed Ecosystems. *Ecosystems*, *7*(4), 393–403.

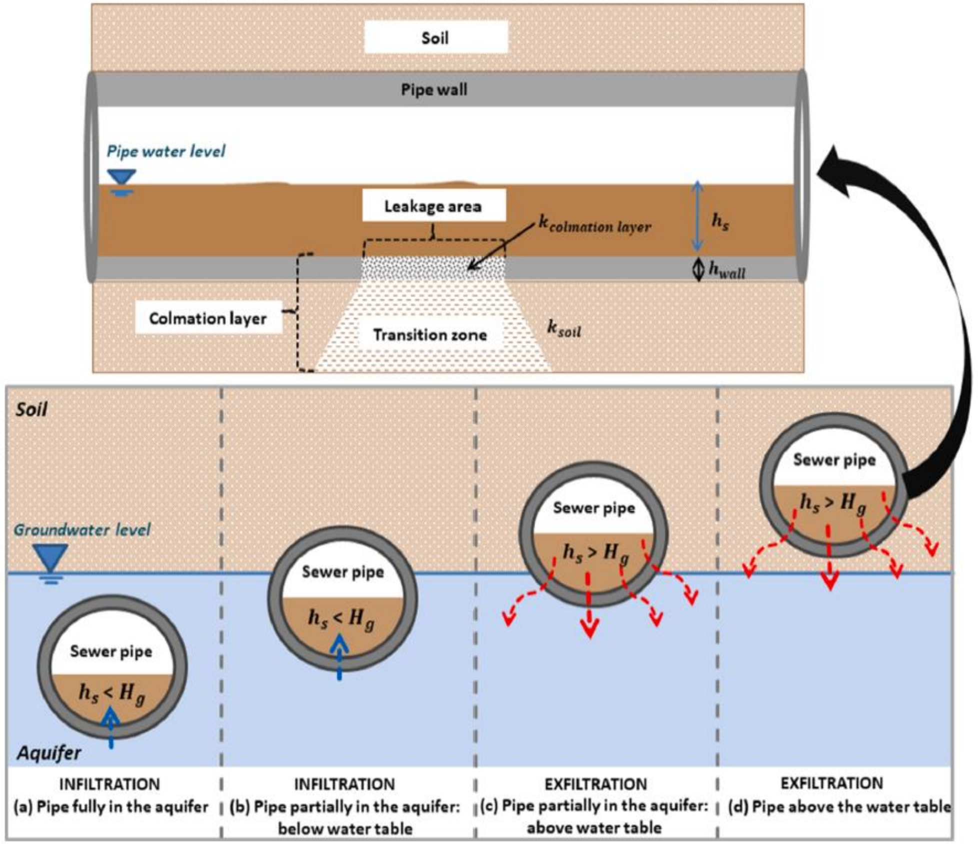
Warren-Rhodes, K. & A. Koenig. (2001). Ecosystem ap- propriation by Hong Kong and its implications for sustainable development. Ecol. Econ. 39: 347–359.

"**Sewer pipes are not designed to be watertight.** Sewer design sets a standard for allowable leakage during construction, which averages 125 gallons per 400 feet of pipe, which is the standard distance between sewer manholes (ASTM, 2009), or about 1,650 gallons per mile of standard sewer pipe."

Chesapeake Bay Program, (2014). "Final Expert Panel Report on Removal Rates for the Elimination of Discovered Nutrient Discharges from Grey Infrastructure"

If it can infiltrate, it can exfiltrate.

- Net system infiltration does not exclude areas of exfiltration
- Segments may infiltrate in wet periods and exfiltrate in dry periods
- Because WW nutrient concentrations are 2 orders or magnitude greater than background, small amounts of exfiltration can represent large loads



Nguyen, Hong Hanh, Aaron Peche, and Markus Venohr. "Modelling of sewer exfiltration to groundwater in urban wastewater systems: A critical review." *Journal of Hydrology* 596 (2021): 126130.

Why does this matter for the model?

- Proper appropriation of loads
- Improved targeting and crediting of management actions
- Scenario analysis (E.g., remediation, pipe ageing, etc.)

This load is in the bay, the load is in the model, but it is currently misappropriated.

Potential impacts of SS Exfiltration in the CBW

Conservative estimated contribution to the CBW from literature:

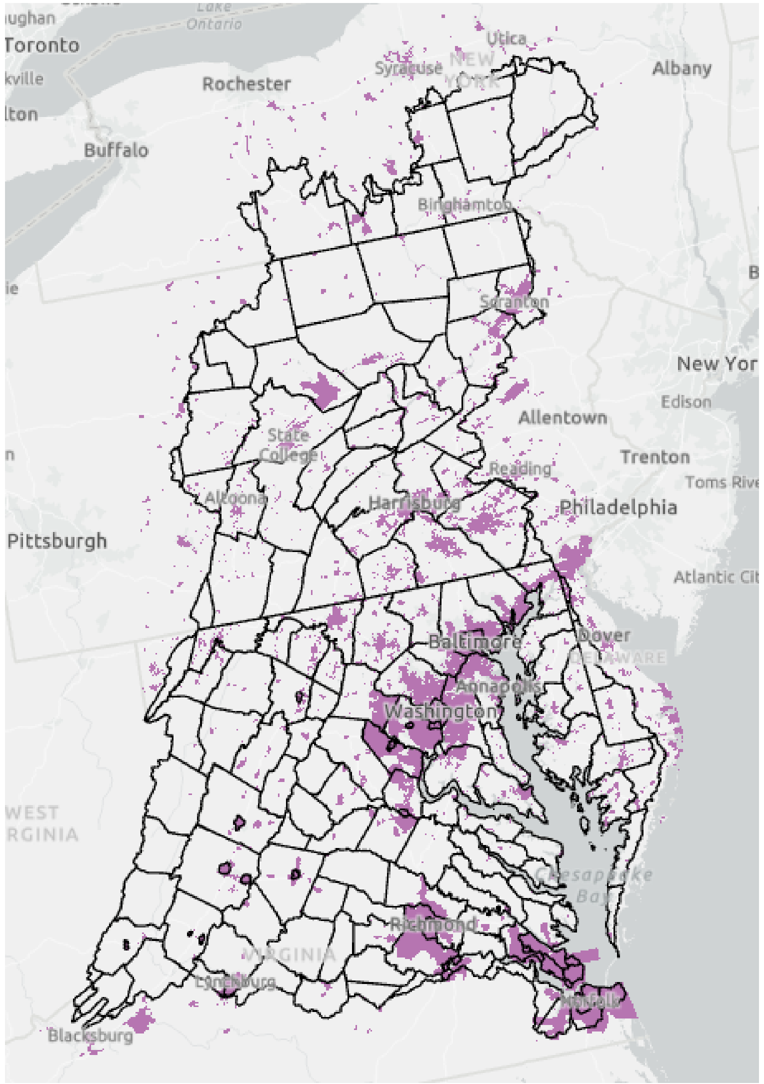
- 665,392 – 2,217,974 lb N/year
- 0.23 - 0.76% of the total N load to the CB
- 1.51 - 6.04% of the WW load to the CB
- 3.28 - 10.93% of the urban load to the CB
- 0.60% – 48.9% of the load from individual urbanized catchments to CBW**
- 13 - 47.5% of the measured load from individual urbanized residential catchments in the NC Piedmont*

Note: Values derived from the mean of studies or study regions (Delesantro et al., 2022; Nguyen and Venohr, 2021)
Assuming 30mg/l N in raw WW
Delesantro et al., 2022: Assuming NO_3^- proportion from WW ~ TN proportion from WW
*Assuming stormflow WW exfiltration loading from mean of Delesantro et al., (in review) urban catchments and baseflow WW exfiltration from Delesantro et al., 2022
** using full range in exfiltration values reported from Nguyen and Venohr, 2021

Potential modeling of sanitary sewer exfiltration

Option A

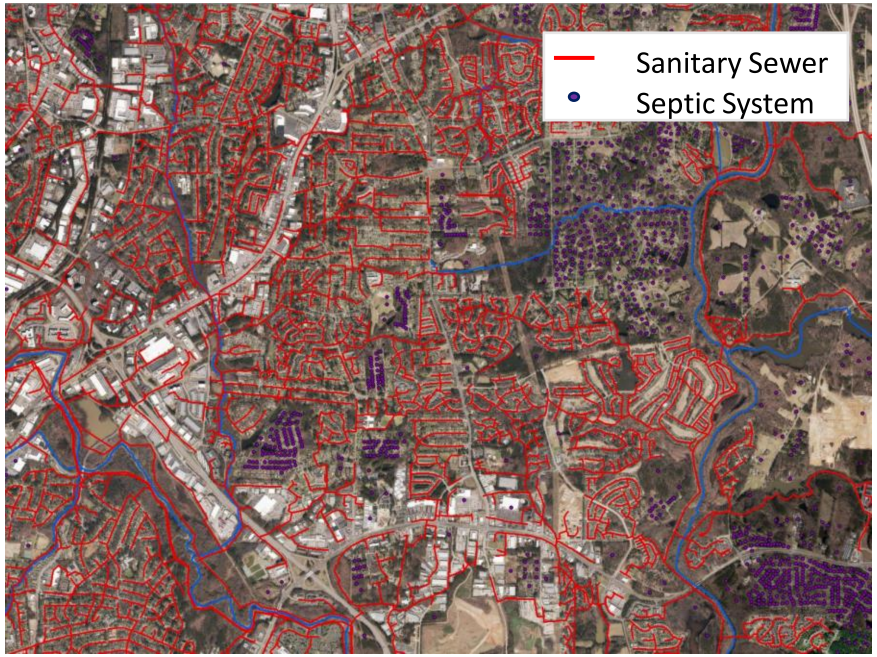
- Use per unit area or per capita exfiltration estimates from the most relevant literature
- Apply load to urban land use within service boundaries
- Requires no additional data collection
- Requires literature review and WG approval of exfiltration values



Potential modeling of sanitary sewer exfiltration

Option B

- Use exfiltration per unit length of gravity pipe estimated from the literature at watershed or system scale
  - These values generally have good agreement
- Apply load to urban land use within service boundaries
- Requires gravity pipe length from each utility
- Requires literature review and WG approval of exfiltration values



Potential modeling of sanitary sewer exfiltration

Option B

Load exfiltrated (N and P) within the service area mass N and P/ year = Exfiltration per unit length of pipe Vol/year/length × Length of pipe in the service area Length × N and P per unit vol raw WW mass N and P/Vol

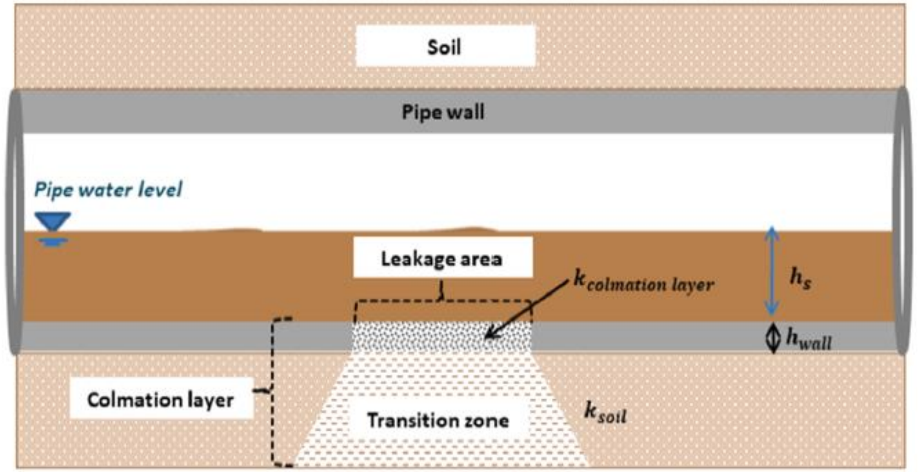
Load can be evenly proportioned to developed LU within the service boundary
Or
Proportioned to model units based on the relationship between sewer length density and sewer served population density.

Derived from studies of system or network averages or solicited from utilities.

Potential modeling of sanitary sewer exfiltration

Option C

- Model exfiltration as a function of pipe location, soils, groundwater depth, topography, and age.
- Spatially and temporally (potentially) explicit
- Requires detailed mapping and attribute data for sanitary sewer lines
- Requires greater modeling effort
- Requires literature review and WG approval of model parameters



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Potential modeling of sanitary sewer exfiltration

Option D

- A hybrid option where utilities or states opt for Option A, B, or C depending on the data they can provide and the level of detail they want accounted in exfiltration estimates.

Potential modeling of sanitary sewer exfiltration

Option E

- No action

Crediting Sanitary Sewer Rehabilitation

Final Expert Panel Report on Removal Rates for the Elimination of Discovered Nutrient Discharges from Grey Infrastructure, N-6, pg. 57-59

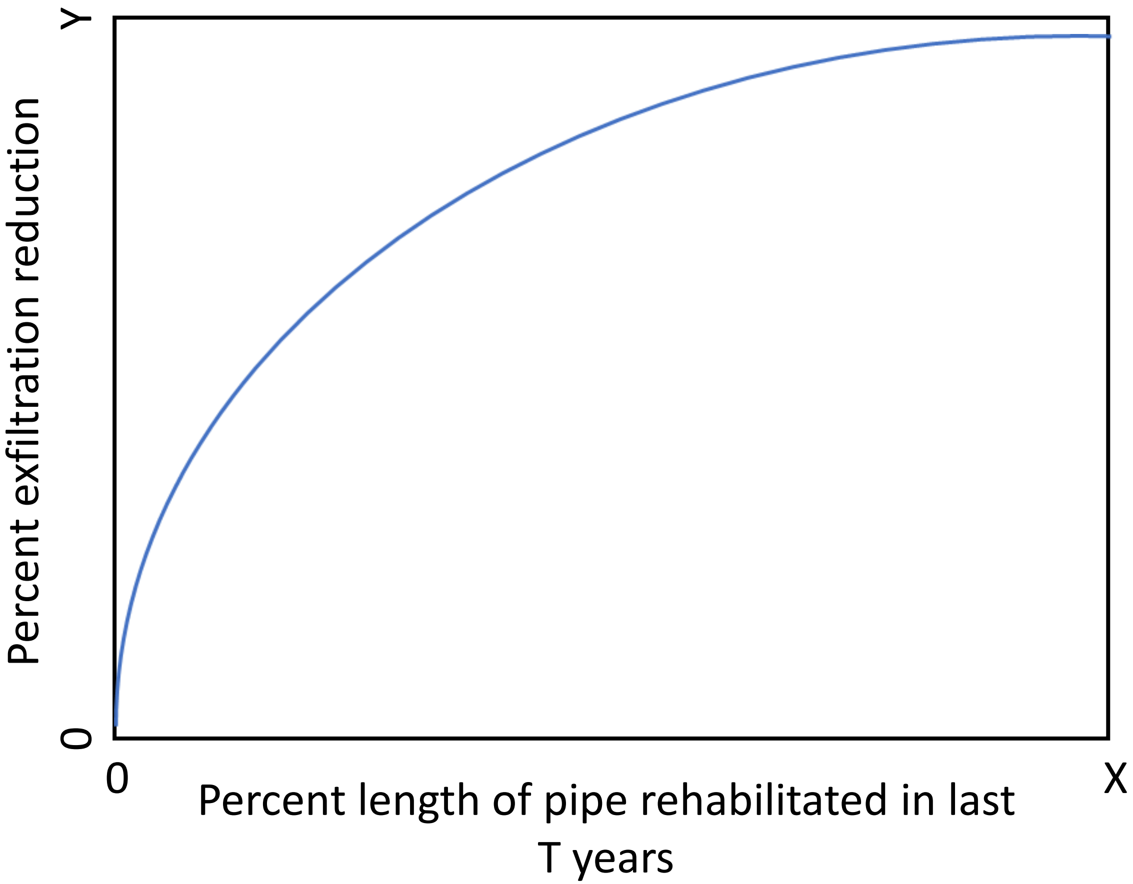
"…requires before and after flow metering in the pipe to determine the change in sewage exfiltration as a direct function of the sewer repair, based on the decline in flow rate associated with the capital project. While it is allowable to use the sewage concentration default values, the credit is also subject to a discount factor.

Discount factors:
- 50% if project is within 150' of stream or within 10 feet of a lower elevation storm drain pipe,
- 10% if project is greater than 150' away from the stream or greater than 10' feet from a lower elevation storm drain pipe to account for losses during groundwater migration

Walch, M., Brosh, M., Lilly, L., Tribo, J., Whitehurst, J., Brumbaugh, B., ... & Katchmark, W. (2014). Recommendations of the Expert Panel to Define Removal Rates for the Elimination of Discovered Nutrient Discharges from Grey Infrastructure FINAL PANEL REPORT.

Crediting Sanitary Sewer Rehabilitation

A possible whole system approach



Y: 36% to 70% in the I/I literature. Requires additional investigation.

X: A small percentage of pipes may account for the vast majority of exfiltration.

T: How often should pipes be rehabilitated?

Values of T and the characteristics of the curve should reflect and prioritize targeted rehabilitation.

End