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Reply to comment on "Suburban watershed nitrogen retention: Estimating the effectiveness of stormwater management structures" by Koch et al. (*Elem Sci Anth* 3:000063, July 2015)

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Abstract

We reply to a comment on our recent structured expert judgment analysis of stormwater nitrogen retention in suburban watersheds. Low relief, permeable soils, a dynamic stream channel, and subsurface flows characterize many lowland Coastal Plain watersheds. These features result in unique catchment hydrology, limit the precision of streamflow measurements, and challenge the assumptions for calculating runoff from rainfall and catchment area. We reiterate that the paucity of high-resolution nitrogen loading data for Chesapeake Bay watersheds warrants greater investment in long-term empirical studies of suburban watershed nutrient budgets for this region.

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We thank Dr. Walsh for his interest in this research and for generously sharing his knowledge as one of the 10 experts participating in our structured expert judgment (SEJ) elicitation. Like all of the experts, he provided a thoughtful rationale for predicting nitrogen (N) loads in the focal watersheds. In his comment, Walsh (2015) restates a portion of his rationale and highlights differences in rainfall versus discharge measurements for the Coastal Plain scenario as presented in the SEJ protocol document (Koch et al., 2015; Appendix S3). He suggests the differences may be due to inaccurate measurements of stream discharge or, alternatively, may indicate unique catchment hydrology.

Discharge measurements are typically highly variable in small catchments (Harmel et al., 2006). This variation is further magnified within the Coastal Plain physiographic province, where low relief, dynamic channels, and subsurface flows combine to limit the precision of streamflow measurements.

In addition, several features unique to lowland Coastal Plain watersheds challenge common assumptions for calculating surface runoff from rainfall volume and drainage area (CSN, 2009). First, the Coastal Plain is especially flat, which complicates catchment delineation. For example, most slopes within the Magothy watershed, which contains the focal study catchment of North Cypress Creek, are less than 14% (MDE, 2013). The Cypress Creek subwatershed itself has extremely low elevation and little variation in topography (AACDPW, 2010). Consequently, it is possible that not all runoff within the delineated drainage flows into the Cypress Creek channel.

Second, Coastal Plain soils can be highly permeable (Markewich et al., 1990). Soils in the Magothy River watershed are predominantly sand (67%; MDE, 2013), and the majority (82%) of soils in the Cypress Creek subwatershed are classified as having low or moderately low runoff potential when thoroughly wet (AACDPW, 2010). The combination of flat terrain and highly permeable soils reduces runoff potential in this catchment.

Third, although the Cypress Creek subwatershed is substantially urbanized, an unexpectedly large proportion of the land cover is permeable. Low- to medium-density residential areas account for 57% of the developed area while commercial property accounts for 29%, and transportation corridors for 2% (MDP, 2010). Of the residential land cover, more than half is vegetated with grass and second-growth trees (MDP, 2010), where water infiltration can be quite high, especially because of the flat terrain and dominance of sandy soils. Walsh assumed that impervious runoff is predominantly routed to the stream channel, however much of the impervious runoff in the residential zones drains directly to those vegetated areas.

Finally, water infiltration in the Coastal Plain can vary greatly through time, depending on storm frequency and season (Harder et al., 2007). As a consequence, storm size may poorly predict the magnitude of runoff. Logs from groundwater monitoring wells located close to the Cypress Creek subwatershed reveal a thick (>30m) zone of permeable material extending below the surface which may act as a reservoir for infiltrating surface flows (MGS, 2015). Surface runoff varies with the level of saturation within this reservoir. Furthermore, this extensive zone of permeable sediments can promote the conveyance of stream water via subsurface flow paths.

The hydrologic data we provided the experts represented the best available, and indeed the paucity of high-resolution N loading data for Chesapeake Bay watersheds is what motivated our expert elicitation in the first place. The purpose of our SEJ was not to present comprehensive, empirical case studies of watershed hydrology. Rather, we sought to leverage what little existing data there are on N budgets in suburban Chesapeake Bay watersheds to derive expert-informed estimates of BMP N retention performance in those watersheds.

Walsh suggests a way of improving expert-informed estimates by calibrating each expert against a "known uncertainty". This idea was explored in research leading up to the development of the "Classical Model" for structured expert judgment (Cooke, 1991); however it has not been implemented. The primary reason is that it is difficult to find such "known uncertainties" from experts' domains, in this case, hydrology. A secondary problem is that testing the hypothesis that an expert is statistically accurate against a distribution of outcomes is mathematically complex and would require knowing the sample size on which the "known uncertainty" is based. Because of these challenges, the simpler statistical test is commonly employed in SEJ studies (Cooke and Goossens, 2008), though this has the disadvantage of a "binary assessment" that Walsh notes. The best practical antidote is to simply query more quantiles in the elicitation, but this increases the burden on experts. The current compromise adequately accomplishes the main goal of assessing the statistical accuracy of the resulting combination of experts; however another approach, when a few independent realizations are available for an elicited variable, was used in Slijkhuis et al. (1998).

Despite the tremendous economic and environmental importance of the nitrogen problem in the Chesapeake Bay region, there are scant data and funding to empirically characterize N dynamics of BMPs, especially within the Coastal Plain. Nonetheless, millions of dollars are invested annually in constructing stormwater BMPs (AACDPW, 2015; NRC, 2009; USEPA, 2006), the benefits of which are largely unknown. Although expert-derived uncertainty in BMP performance can inform management actions, long-term empirical studies of suburban watershed nutrient budgets are needed to quantify the extent to which alternative stormwater BMP designs retain excess nutrients under different environmental conditions.

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Competing interests

The authors have no competing interests.