Spatial and Temporal Variability of Runoff Chemistry

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Abstract
Spatial and temporal heterogeneity are inherent features of all ecosystems, and the scales of resource variability can be used to understand the processes driving patterns over a range of spatial and temporal scales. Human activities routinely change the spatial and temporal distribution of resources. Some of these changes are intentional; e.g. control of flood waters and drinking supplies. Others are unintended; e.g. the fragmentation of landscapes increases variability at that scale. Much work has been done regarding the effects of human land use changes on spatial variability of soil nutrients, showing decreased variance at the patch scale, and increased variance between sites. These changes in soil chemistry have implications for the distribution of runoff chemistry to streams and rivers. I use a 15 years of stormwater data collected by the USGS and the Flood Control District of Maricopa County to address the following questions. What are the scales of spatial and temporal variability of runoff chemistry and volume in Phoenix, AZ, an arid urban ecosystem? How do these patterns relate to land use and land cover? Finally, how do these patterns compare with those found in semiarid and mesic regions? Temporal variability is assessed for each catchment seasonally, annually, and over the entire dataset. Patterns are compared across land uses and catchment sizes.

Study Sites

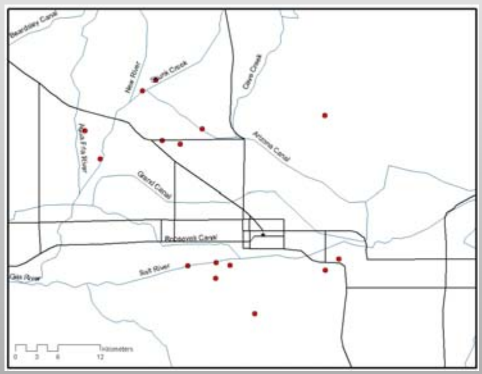


Figure 1. Stormwater collection sites. Dataset was collected by USGS and Maricopa Co. Flood Control District. 15 watersheds in the Phoenix metro area over 12 years (1994-2005), with a range of land use, imperviousness and catchment size.

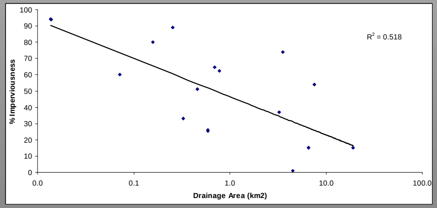


Figure 2. Imperviousness is inversely related to catchment size.

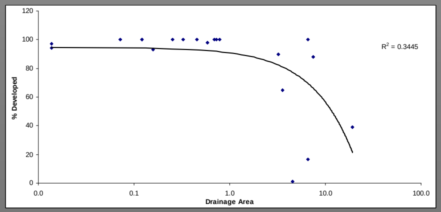


Figure 3. % development is inversely related to drainage area.

Introduction

Stormwater runoff chemistry results from interaction of precipitation with the land surface and soils. Urbanization changes land cover – soil type and chemistry and replaces soil completely with impervious surfaces – and alters drainage patterns, changing how precipitation interacts with the landscape. Previous work has shown that mesic and arid catchments demonstrate inverse scaling relationships (Acuna and Dahm 2007, Temnerud and Bishop, 2005; Stutter et al., 2006; Buffam et al., 2007), where discharge and water chemistry in large arid catchments are temporally more variable than smaller catchments and where large mesic catchments are temporally less variable than smaller catchments. The arid urban Phoenix metropolitan area has qualities similar to both undeveloped arid and mesic regions and therefore offers and opportunity to test the importance of climate and land cover as drivers of temporal and spatial variability. Precipitation patterns here are highly seasonal, with most rain falling during two distinct rainy seasons. However, human management results in more constant soil conditions seasonally, with consistent irrigation and fertilizer application. These soils may be more similar to those characteristic of mesic climates rather than unaltered desert soils. However, urbanization also creates an extremely heterogeneous landscape which may lead to unique scaling relationships.

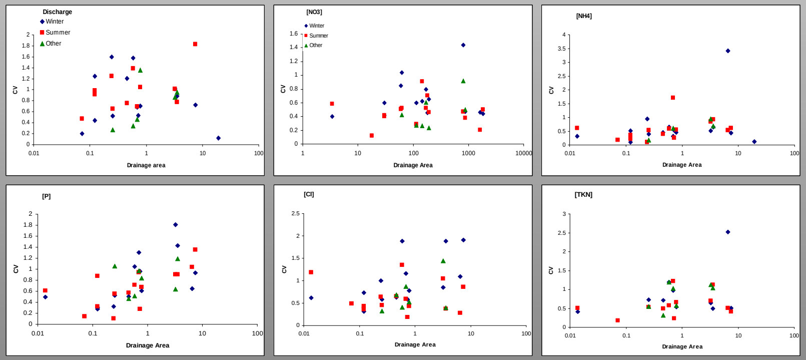
Goal To characterize the spatial and temporal scales of variability in urban stormwater runoff discharge and chemistry.

Questions

1. How does temporal variability scale with catchment size?
2. How do these relationships change with temporal scale?
3. How do these relationships change with land use type?

Spatial Scale of Seasonal Variability

Scaling relationship for nutrient concentrations inverses when temporal scale of data is refined: seasonal variation increases with catchment area.



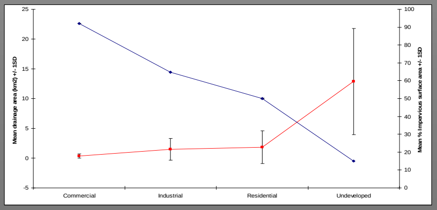
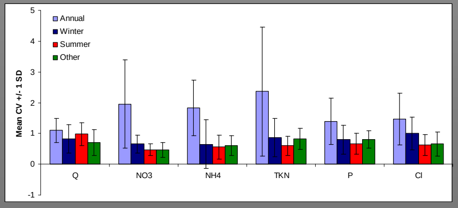


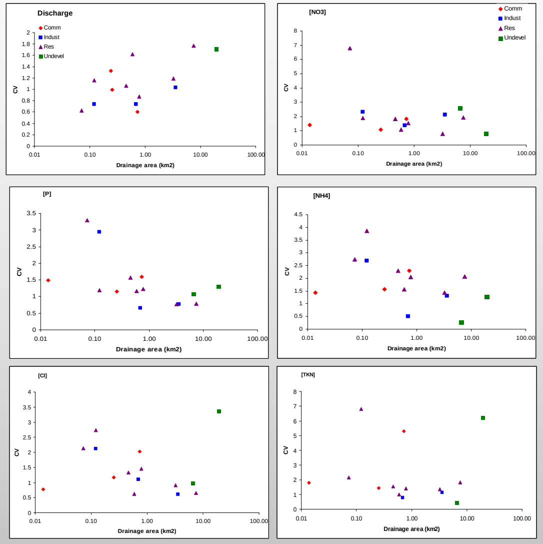
Figure 4. Imperviousness and catchment size vary with land use.



Within site temporal variation is higher for all data pooled together than when separated by seasons.

Spatial Scale of Annual Variability

When data are pooled across seasons, discharge variance increases with catchments size and nutrient concentration variation decreases with catchment size.



Conclusions

Spatial patterns of variation can be influenced by many factors, and these factors may or may not be important at different scales.
We expected that Phoenix stormwater would demonstrate scaling relationships similar to either mesic or arid regions. However, we found that scaling relationships for nutrient concentrations changed dramatically depending on the temporal resolution of the data. When data are pooled across seasons, variability decreases with catchment size. When data are separated by season, the relationship is reversed and variability increases with catchment size. Mean within site coefficient of variations (CV) for most parameters were also much larger for all data than for each season.

These patterns may be driven by the nature of urban development and watersheds. For these sites catchment size was strongly related to imperviousness, development, and land use. Therefore more work is needed to understand what is driving these patterns and what they mean for biogeochemical processes occurring in urban watersheds.

References

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