Hoque, Yamen M. Ph.D., Purdue University, August 2013. Risk Based Assessment of Watershed Health and the Role of Uncertainty. Major Professor: Rao S. Govindaraju.

The assessment of watershed health, as it related to water quality constituents such as sediments, nutrients and pesticides has been addressed primarily through deterministic procedures. The overall goal of this dissertation was to develop a probabilistic framework for assessment of watershed health by employing measures of reliability, resilience and vulnerability (R-R-V) indicators using stream water quality data. The methodology requires long term continuous water quality data. Since observed WQ are usually sparse, water quality time-series are often reconstructed using surrogate variables. A Bayesian algorithm based on relevance vector machine (RVM) was employed to quantify uncertainty in the reconstructed series, and a probabilistic assessment of watershed status was conducted based on established thresholds for various constituents. Observed water quality data for several constituents within the Cedar Creek watershed in north-east Indiana were utilized. Results indicated that such risk-based indicators show promise as a management tool for assessing watershed health. It was also found that ignoring uncertainty affected R-R-V values.

R-R-V calculations can become tedious when time-series data for several WQ constituents have to be evaluated individually. A dimensionality reduction technique called variational Bayesian noisy principal component analysis (VBaNPCA) was utilized to condense multi-dimensional WQ datasets into a one-dimensional time-series The VBaNPCA method also allows for model uncertainty information to be incorporated in the analysis. R-R-V values were calculated using the aggregate time-series for two Indiana watersheds. Comparisons with individual constituent R-R-V values showed that variability present in the original multi-dimensional WQ dataset propagates to the aggregate time-series, and subsequently to aggregate

R-R-V values as well. The data-driven approach to calculating aggregate R-R-V values was found to be useful in providing a unified picture of watershed health.

The spatial scaling behavior of R-R-V indicators was also explored for five agricultural watersheds in the midwestern United States. The study was conducted using two different measures of spatial scale based on drainage area and stream order. It was found that R-R-V indicators change with spatial scale, but a representative threshold exists for these indicators to achieve stable values. Also examined was the role of BMPs implemented via a cost-effective optimization scheme on the evolution of R-R-V values. While their placement achieved reductions in constituent loads, BMPs do not necessarily change watershed risk and reliability measures, but are likely to cause significant reduction in vulnerability.

Further, model-predicted impacts of several projected land-use and climate change scenarios on the health of the Wildcat Creek watershed in Indiana were assessed through R-R-V indicators. It was found that cultivation of bio-energy crops such as *miscanthus* and switchgrass has the potential to improve risk indicator values with respect to sediment, total nitrogen and total phosphorus. On the other hand, climate change scenarios that involved rising precipitation levels were found to negatively impact watershed health indicators. Trends of water quality constituents under risk-based watershed health assessment revealed nuances not readily apparent from deterministic considerations alone. Risk-based analyses coupled with deterministic methods are needed for a more comprehensive assessment of the health of a watershed.