Investigating Peak Flow Effects of Tile Drainage in the Beaver Creek Watershed Using a Physically Based, Coupled, Surface Water/Groundwater Model

IOWA STATE UNIVERSITY Department of Geological and Atmospheric Sciences

Minnesota Ground Water Association
April 24, 2013

A.K. Morrison, W.W. Simpkins, K.J. Franz, A.D. Wanamaker, and Ö. Acar

1. Introduction

Recent large-scale flood events in Iowa have suggested to many that drainage alteration, specifically through tile drainage and ditches related to intensive agriculture, has affected peak flow events and streamflow hydrology. We are investigating these relationships in the South Fork watershed, a 78000-ha watershed in north-central Iowa that was recently included as an Upper Mississippi River Basin LTAR site. Approximately 80% of the watershed is tile drained. It was chosen in part for its long data record – more than 15 years of streamflow and tile data – and groundwater monitoring wells. The physically based, coupled surface water/groundwater model, HydroGeoSphere (Fig. 1, Therrien et al., 2007), will be used to simulate the hydrology of the watershed. The goal of the study is to observe and simulate the contributions of tile drainage to streamflow under varying hydrologic conditions.

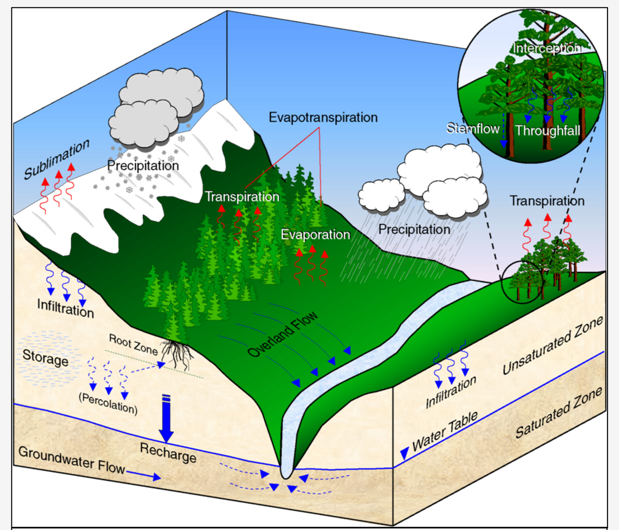


Figure 1. Diagram showing the range of hydrologic processes modeled in HydroGeoSphere.

2. Methods

Sample collection in the watershed began in November, 2011, in cooperation with the National Laboratory for Agriculture and the Environment (NLAE). Surface and tile water are collected weekly and precipitation samples (wet and dry) are collected usually the day following the event (Fig. 2). Groundwater samples are collected and water levels are measured monthly in monitoring wells at 11 sampling locations.

Water samples are analyzed for $\delta^{18}O$ and $\delta^{2}H$ using a Picarro L1102-i Isotopic Liquid Water Analyzer in the Stable Isotope Laboratory in the Department of Geological and Atmospheric Sciences at ISU.

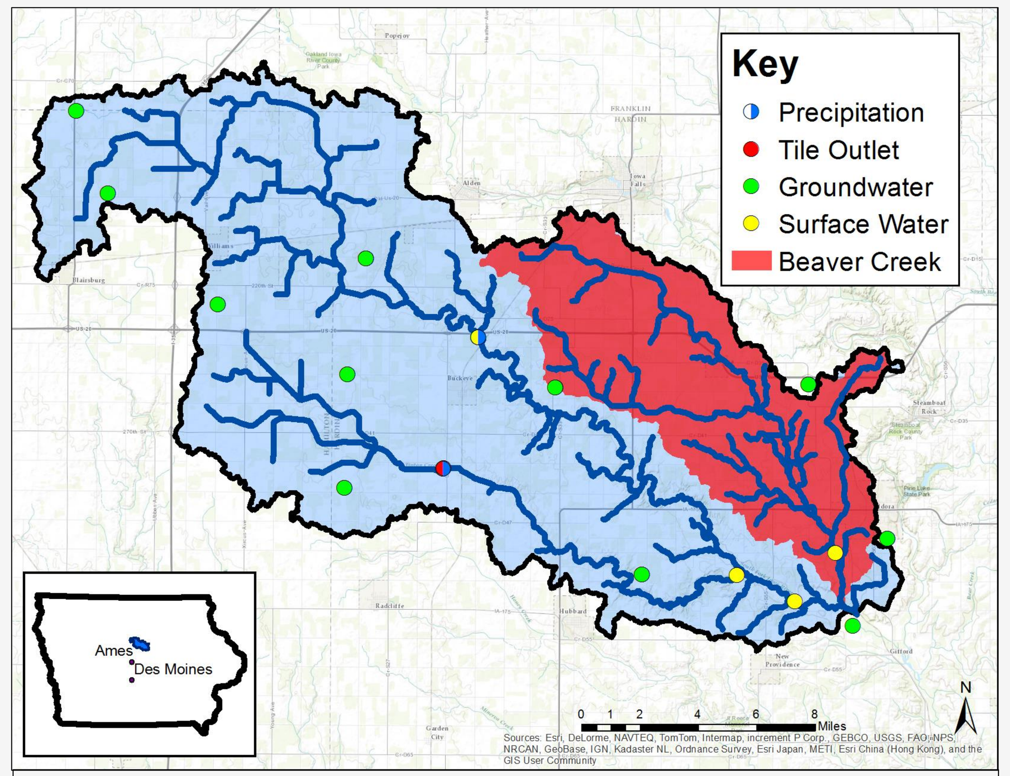


Figure 2. Map of the South Fork watershed showing the Beaver Creek subwatershed and sampling locations.

The results will be used both as model inputs (as an additional calibration tool) and to determine input of baseflow, tile flow, and precipitation to streamflow through hydrograph separation. Streamflow has been recorded for the past 15 years at some sites (SF450, Fig. 2). Subsurface geology is being constructed in GMS from borings from a previous student in the watershed and strip logs available through the Iowa Geological Survey's GeoSAM website.

3.1 Results – Model Construction

A 3-D subsurface model is being constructed in the groundwater modeling software GMS for eventual import into HydroGeoSphere (Fig. 3). The geology consists of four main units: the Wisconsinan Dows Formation (till), Peoria Formation (loess), Pre-Illinoian Formations (till), and Mississippian bedrock (limestone). When this model is complete, the surfaces of each geologic layer will be exported from GMS as an ASCII file. These layers will then be used to build 3-D finite-element mesh in HydroGeoSphere.

Generation of the initial 2-D finite-element mesh involves the use of multiple applications: ArcGIS software (ArcMap), Python scripts to convert between data formats, and the finite-element mesh generator (Triangle). Watershed boundaries and rivers are imported into ArcMap and ultimately discretized into a series of points of preferred spacing. ArcGIS files are prepared for Triangle using a series of Python scripts which then allow Triangle to produce a 2-D mesh (Fig. 4), including mesh refinement near rivers, areas of high topographic change, hydraulic head measurements, and tile drains. For example, the 2-D finite-element mesh for the Beaver Creek watershed has a boundary node spacing of 200 m and a river node spacing of 100 m (Fig. 4) .

To create the 3-D finite-element mesh, data describing the 2-D mesh are entered into the HydroGeoSphere preprocessor, Grok, which combines the 2-D mesh with a DEM or LiDAR-based ASCII elevation file. This produces a 3-D finite-element mesh which can then be directly loaded by HydroGeoSphere. Grok also discretizes and applies model parameters to geologic layers. An initial 3-D, finite–element mesh for the Beaver Creek subwatershed is shown in Figure 5.

Figure 3

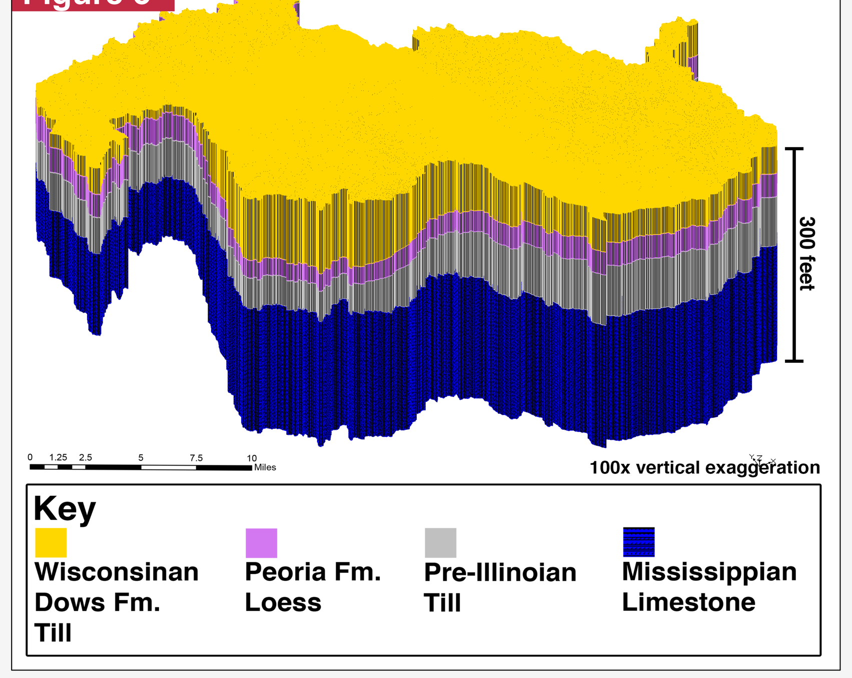


Figure 4

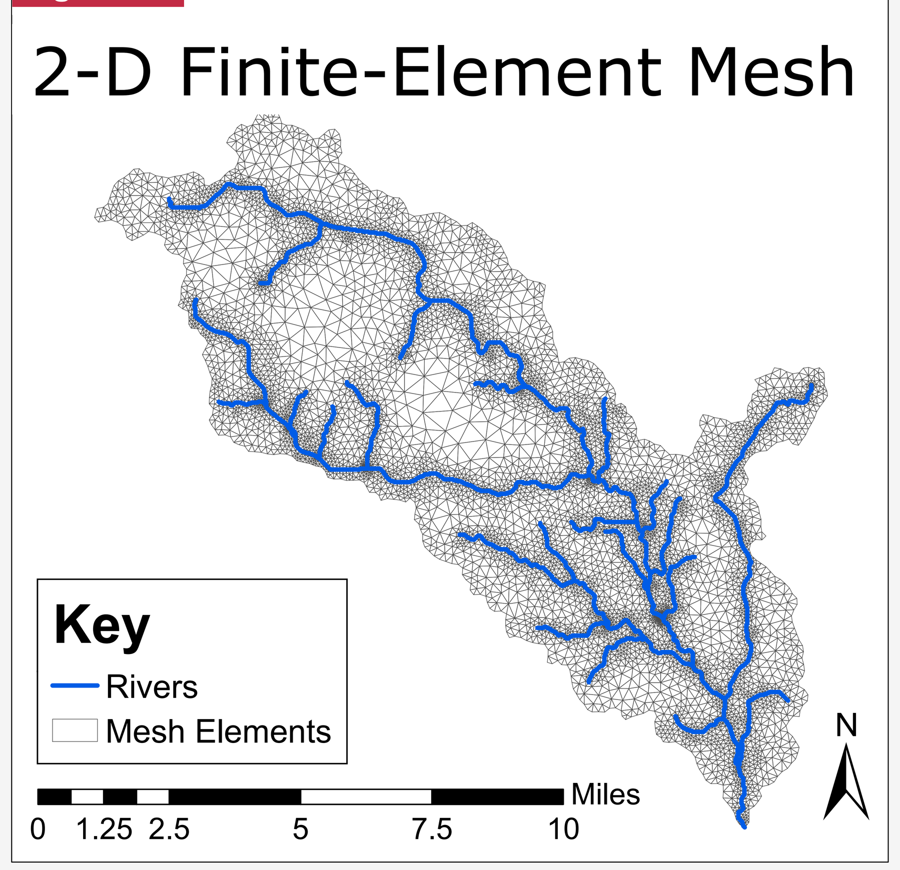
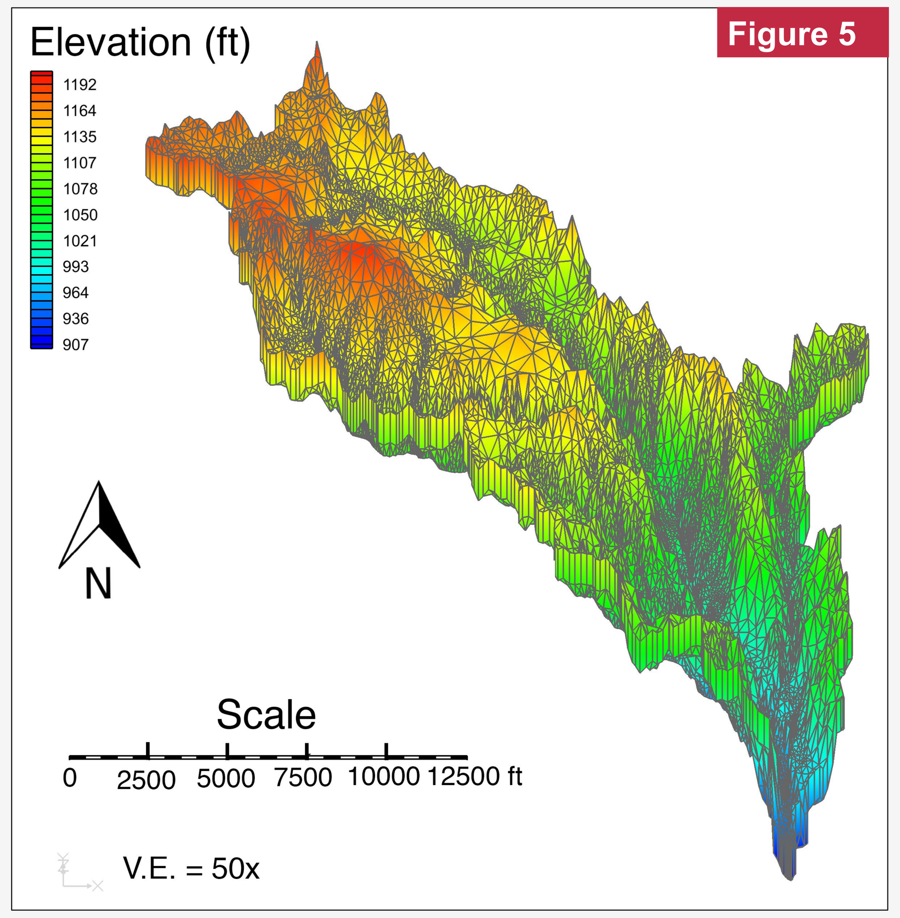


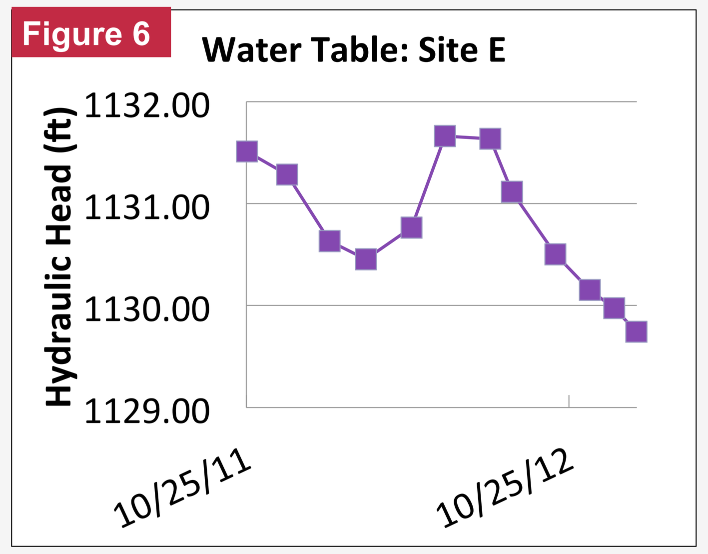
Figure 5



3.2 Results – Monitoring

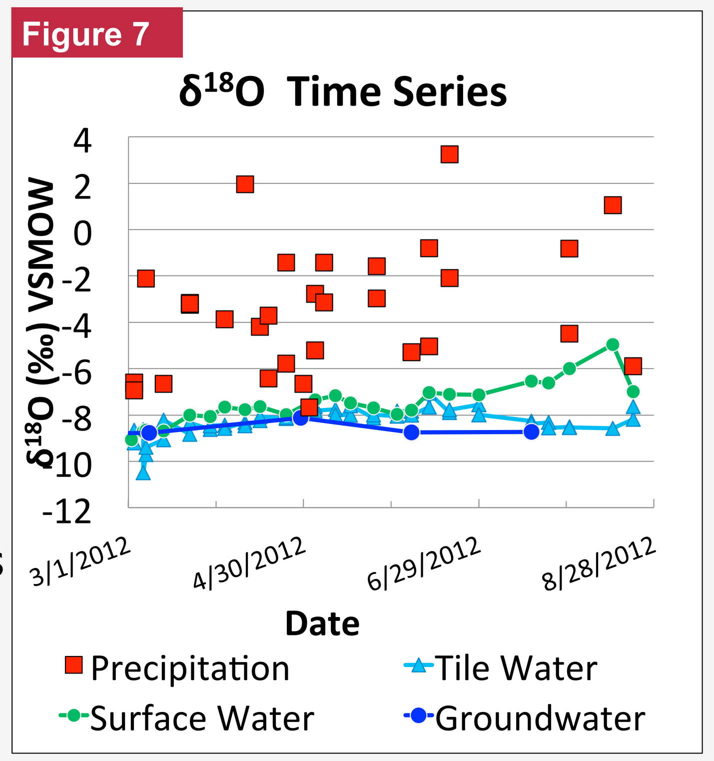
Unfortunately, instead of observing flood events, we witnessed extreme drought in South Fork watershed in 2012. Water table elevations in till at some sites were depressed 2 ft since measurement began, with a maximum drop in water table elevation of more than 5 ft by January 2013 (Fig. 6).

Figure 6



Stable isotope data collected during 2012 show a very dynamic relationship between the hydrologic components of the tile-drained system (Fig. 7). Surface and tile water values largely overlap in March, but an evaporative trend in $\delta^{18}O$ occurs in surface water as the summer progresses. Tile water shows the opposite trend, showing depletion in heavier isotopes, and approaching values of groundwater. This could suggest that water flowing in the tiles accesses only deep groundwater during this time. Such relationships are useful to establish baseline isotopic signatures for model calibration and hydrograph separation (e.g., Sklash, 1976)

Figure 7



4. Future Work

Work on the HydroGeoSphere watershed model and sample collection will continue into summer of 2013. Samples to date were collected under increasing drought conditions, representing only one end of the climate continuum. The rains this spring will hopefully provide an opportunity to experience a real peak flow event so that the model can be calibrated under those conditions prior to simulating future events.

Acknowledgements: Funding was provided to PI's Simpkins, Franz, Helmers and Cruse by the Iowa Economic Development Authority. Additional funding was granted to M.S. student Alex Morrison through a Geological Society of America Student Research Grant. We thank the USDA National Laboratory for Agriculture and the Environment for contributing both knowledge and water samples as part of their ongoing research in the watershed.

References: McLaren, R.G., Sudicky, E.A. 2007. HydroGeoSphere—a three-dimensional numerical model describing fully integrated subsurface and surface flow and solute transport (Draft ed.). Groundwater Simulations Group, University of Waterloo.; Therrien, R.; McLaren, R.G., and Sudicky, E.A. http://hydrogeosphere.org/images/watershed.png. Groundwater Simulations Group, University of Waterloo. Accessed October 26, 2012.; Sklash, M.G. 1990. Environmental isotope studies of storm and snowmelt runoff generation. In Anderson, M.G. and Burt, T.P., eds. Process studies in hillslope hydrology. Chichester. Wiley, p. 401-35.; Therrien, R.; Jonathan Richard Shewchuk, Triangle: Engineering a 2D Quality Mesh Generator and Delaunay Triangulator, in "Applied Computational Geometry: Towards Geometric Engineering'' (Ming C. Lin and Dinesh Manocha, editors), volume 1148 of Lecture Notes in Computer Science, pages 203-222, Springer-Verlag, Berlin, May 1996. (From the First ACM Workshop on Applied Computational Geometry.)