Surface Water Flow Modeling of Kalamazoo River Basin
Under Current and Future Conditions

Rabi Gyawali and Dr. David Watkins
Civil and Environmental Engineering, Michigan Technological University, Houghton MI 49931

Introduction
Surface water flow modeling of Kalamazoo River Basin is a part of NSF-funded MUSES (Material Use: Science, Engineering, and Society) project: "Modeling and Analyzing the Use, Efficiency, Value and Governance of Water in the Great Lakes Region." The project focuses on water quality and use in the Great Lakes Basin, on a watershed-by-watershed basis. Given that the coverage of all watersheds in detail is ambitious, "characteristic watersheds" are selected to be studied in depth (Fig. 1). Cluster analysis was used to classify similar watersheds, based on land use and climate/hydrology. Surface water availability, Ground water availability, Water quality and Embodied energy studies are being done in Michigan Technological University and System Dynamics studies are being done in Yale University.

Kalamazoo River Basin
The Kalamazoo River Basin is selected as the first watershed to be studied in detail. It is located in south-west Michigan and drains 2036 sq. miles from 10 counties. The watershed is 162 miles long and 11 to 29 miles in width drains to Lake Michigan near the town of Saugatuck. Several large and historic towns lie Kalamazoo and Battle Creek lie within the watershed. Parts of the river have become EPA Superfund sites due to polychlorinated biphenyl (PCB) polluting from de-inking process used in paper mills located around the area. (Axt, 2001)

Surface Water Flow Modeling
Data (from years 1994 to 2009) of USGS stream gages and NOAA rain gage stations (from years 1961 to 2008) are available at a daily time step (Fig. 2, Table 1). Delineated sub-watersheds within the Kalamazoo River Basin are obtained from Michigan DNR. The sub-watersheds that drain to the stream gages are merged and color coded (Fig 5). Theissian polygons are drawn (Fig 5) and weights assigned based on watershed area intercepted by the polygons. The model will be calibrated and verified in HEC-HMS (Fig. 3) based on the data for 10 year period (1997 to 2008). Semi-distributed water availability models are being developed to better simulate rainfall runoff characteristics, ground water flow, snowpack and soil moisture. The water quantity modeling will allow us to make predictions of water availability under various scenarios of land use, population and climate changes.

Data Processing and Analysis
Precipitation and stream flow data are being processed and converted into HEC-DSS (Data Storage System) input format (Fig. 4) in HEC-HMS. Missing rainfall data which limit the hydrological study are identified and efforts are being made to compute a continuous time series of stream flow and rainfall data by replacing missing data from gages nearby (Fig 6a). Seasonal and monthly variability are identified (Fig 6b). Other methods of replacing missing rainfall data is being reviewed in literature.

Table 1: Stream gage stations with drainage area

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Drainage Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalamazoo River near Marshall, MI</td>
<td>649</td>
</tr>
<tr>
<td>Kalamazoo River near Mattawan, MI</td>
<td>260</td>
</tr>
<tr>
<td>Kalamazoo River near Coldwater, MI</td>
<td>4,033</td>
</tr>
<tr>
<td>Kalamazoo River near Battle Creek, MI</td>
<td>824</td>
</tr>
<tr>
<td>Battle Creek at Battle Creek, MI</td>
<td>245</td>
</tr>
<tr>
<td>Kalamazoo River near New Richmond, MI</td>
<td>1994</td>
</tr>
</tbody>
</table>

Figure 3: Schematic of HMS model

Figure 4: An example of HEC-DSS input format

Figure 5: Schematic of stream network and delineated sub basins with rain and stream gages in HEC-HMS

Figure 6a): Cumulative Precipitation of all rain gages from 1997 to 2008

Figure 6b): Cumulative January Precipitation of all rain gages from 1997 to 2008

Modeling Land Use and Climate Change Impacts
National Land Use Scenarios for Climate Change Impact Assessment and Adaptation developed by U.S. EPA/Global Change Research Program will be used to model land use change impacts. Two approaches will be taken to model climate change scenarios:

1) Constant Change scenario
The model will simulate constant changes (e.g. 10% increase or decrease) in precipitation and temperature.

2) Downscaling of GCM outputs
Variables essential to watershed modeling such as precipitation and soils, are not modeled in GCMs at the necessary scale. (Fig. 7) Statistical downscaling GCM output less large scale predictions to local variable responses. (Wibby and Dawson, 2004)

References
4. Michigan DNR –Centre for Geographic Information

Acknowledgements
The authors acknowledge support provided from U.S. National Science Foundation through the Modeling and Analyzing the Use, Efficiency, Value and Governance of Water as a Resource in the Great Lakes Region Project (CMMI-0725636).

Figure 1: Characteristic watersheds based on land use, climate, and hydrology

Legend
Great Lakes Shoreline
USDA Watersheds
Canada Land Use
Undeveloped
Open Water
Developed
Agriculture
US Land Use
Agriculture
Historically Developed
Lesser Developed
Open Water
Undeveloped

Figure 2: Kalamazoo River Basin showing USGS stream gages and NOAA rain gages

Figure 7: General Approach to GCM Downscaling