4-2005

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Recommended Citation

Rahim, Mustafa Rezaur, "Assessing Water Quality of the Davis Creek Watershed, Michigan using AnnAGNPS Model" (2005). *Master's Theses*. 4748.
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ASSESSING WATER QUALITY OF THE DAVIS CREEK WATERSHED, MICHIGAN USING AnnAGNPS MODEL

by

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A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Geography

Western Michigan University
Kalamazoo, Michigan
April 2005

ACKNOWLEDGMENTS

It is difficult for me to find appropriate expression to thank my committee members. First I want to thank Dr. Chansheng He who has not only provided proper directions and guidance for my study but also persistently motivated me to finish the research timely with high standards. He has also graciously provided me research opportunities to work with him at his facilities. I am also very grateful to my two other committee members, Dr. Gregory Veeck and Dr. James Biles who have given me their assistance whenever required. While no words can adequately express my deep appreciation, I have to say they are the best professors I have encountered during my study at Western Michigan University, thanks to all three of them.

I would like to thank all of the professors and staff at the Department of Geography, Western Michigan University for their encouragement and well wishes.

Finally, I am deeply indebted to my wife Amatun, my parents and my brothers and sisters for their support, encouragement, and love. Without them I would not be in this stage. Thanks everybody, once again.

Mustafa Rezaur Rahim

ASSESSING WATER QUALITY OF THE DAVIS CREEK WATERSHED, MICHIGAN USING ANNAGNPS MODEL

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Western Michigan University, 2005

The Davis Creek watershed is the most polluted tributaries of Kalamazoo River in Kalamazoo County, Michigan. This study applied continuous simulation AnnAGNPS model, developed by USDA ARS, to estimate sediment yield and nutrient loadings and simulate the effects of proposed land use scenarios on nonpoint source pollution in the Davis Creek Watershed. Daily climate data of 1998 to 2004, Digital Elevation Model, soil, land use, hydrography, and agricultural management information were used to derive the model input parameters. The model was run continuously for the period of 1998 through 2004. The simulated results showed that erosion and sediment loadings are high at the industrial zone in the downstream but phosphorus and nitrogen loadings are high in the croplands. The critical source areas were identified as areas near the downstream industrial area along with a few portions of adjacent residential area, and croplands in the upper and middle stream area. Three types of land use scenarios were developed and their effects on water quality were simulated. The results show that No-till would reduce sediment and nutrient loadings. Urbanization might increase nutrient loadings. Expansion of the wetland is likely to reduce nitrogen loadings significantly but might increase sediment and phosphorus loading.

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INTRODUCTION

Different pollutants enter surface waterbodies from various sources, often causing adverse impacts on the environment and ecosystem. The most recent national water quality inventory for the United States shows that, as of 2000, 39 percent of assessed stream miles, 45 percent of assessed lake acres, and 51 percent of assessed estuary acres are impaired (US Environmental Protection Agency 2003). The leading causes of impairment are excessive amounts of organic nutrients, siltation, metals, and a variety of pathogens. State inventories indicate that agriculture, including crop production, animal operations, pastures, and rangeland, impacts 18 percent of the total river and stream miles assessed, or 48 percent of the river and streams identified as impaired (US EPA 2003). Water can be polluted through point sources and nonpoint sources. Nonpoint source pollution generally results from precipitation, surface runoff, infiltration, drainage, seepage, hydrologic modification, or atmospheric deposition. As runoff from rainfall or snowmelt travels across ground surfaces, it picks up and transports natural pollutants as well as pollutants from human activity, ultimately depositing these materials into rivers, lakes, wetlands, coastal waters, and ground water. Point source pollutants generally enter receiving water bodies at some identifiable site(s) and carry pollutants whose generation is controlled by some internal process or activity, rather than weather. Point source discharges such as municipal and industrial waste water, runoff or leachate from solid waste disposal sites and concentrated animal feeding operations (CAFOs), and storm sewer outfalls from large urban centers are regulated and permitted at specific levels under the Clean Water Act (US EPA 2003). EPA legislation also identified several categories of nonpoint source (NPS) pollution.

These include pollutants from agriculture, forestry, hydromodification/habitat alteration, marinas/boating, roads/highway and bridges, urban, and wetland/riparian management. Nonpoint source discharges enter surface and/or ground waters in a diffuse manner at intermittent intervals related mostly to meteorological events. As a result, pollutant generation diffuses from an extensive land area and moves overland before it reaches surface waters or infiltrates into ground waters. The extent of NPS pollution is related to uncontrollable climatic events as well as to geographic and geologic conditions. As a consequence, pollution varies greatly from place to place and from year to year. The extent of NPS pollution is often much more difficult and expensive, to monitor at the point(s) of origin, as compared to the monitoring and control of point source pollution. As a consequence, abatement of nonpoint sources must be focused on land and runoff management practices, rather than on effluent treatment (US EPA 2003). During the first 15 years of the national program to abate and control water pollution (1972–1987), the EPA and related state agencies focused most of their water pollution control activities on traditional point sources. These point sources are regulated by EPA and the states through the National Pollutant Discharge Elimination System (NPDES) permit program established by Section 402 of the 1972 Federal Water Pollution Control Act (Clean Water Act). Discharges of dredged and fill materials into wetlands have also been regulated by the U.S. Army Corps of Engineers as well as EPA under Section 404 of the Clean Water Act (US EPA 2003). As a result of the above activities, the nation has greatly reduced pollutant loads from point source discharges and has made considerable progress in restoring and maintaining water quality. However, the gains in controlling point sources have not solved all of the nation's water quality problems. Recent studies and surveys by the EPA and by state agencies as well as those of indigenous tribes and other entities, indicate that the majority of the remaining water quality impairments in nation's rivers, streams, lakes, estuaries, coastal waters, and wetlands result from NPS pollution and other nontraditional sources, such as urban storm water discharges and combined sewer overflows (US EPA 2003). In 1987, in view of the progress achieved in controlling point source pollution and the growing national awareness of the increasingly dominant influence of NPS pollution on water quality, the U.S. Congress amended the Clean Water Act to provide a national framework to address nonpoint source pollution. Under this amended version, referred to as the 1987 Water Quality Act, Congress revised Section 101, "Declaration of Goals and Policy," to add the following fundamental principle: "It is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this Act to be met through the control of both point and nonpoint sources of pollution" (US EPA 2003).

Problem Statements

The Davis Creek watershed is located in the urban and urbanizing core of the Kalamazoo County, Michigan. Within this urbanizing core, the Kalamazoo River and its major tributaries (including Davis Creek) have recently received tremendous public attention and the river and its tributaries are now recognized as a valuable, shared resource for community economic growth and quality of life enhancements. The Davis Creek watershed came into public focus when the Nonpoint Source Pollution Advisory Committee of the River Partners Program identified this creek as the most polluted tributary in the Kalamazoo County (Forum of Greater Kalamazoo 1998). It quickly became clear that the degraded water quality of Davis Creek was due to nonpoint source pollution (Forum of Greater Kalamazoo 1998). The lower (downstream) reaches of Davis Creek are largely urbanized and contain large industrial/commercial tracts as well as several landfills and an oil refinery. The upper reaches are currently rural, agricultural lands with occasional, dense residential developments. The creek suffers from most known types of NPS pollution including: suspended solids and sediments, bacteria, nutrients, metals and petroleum hydrocarbons and trash and litter. This nonpoint source pollution is much more difficult to control. It is really hard to identify critical problem areas, estimating loading and developing and evaluating best management practices scenarios for decision makers to plan and manage the Davis creek watershed more favorably.

Porntip Limlahapun (2002) analyzed the impact of land use on NPS pollution in the Davis creek watershed by examining land cover changes between 1978 and 1996 and assessing the impact of these changes on nonpoint source pollution. Separate land mosaics were compared to determine types and magnitude of land cover changes between 1978 and 1996 (Limlahapun 2002). In this research, Limlahapun used ArcView Nonpoint Source Modeling (AVNPSM), an interface between Agricultural Nonpoint Source Pollution Model (AGNPS) and ArcView GIS to evaluate NPS pollution in Davis Creek (He et al. 2001, 2003). Finally the AGNPS was used to estimate soil erosion and sediment rates, nutrient (nitrogen and phosphorus) loading potential, and runoff rates across the entire watershed. It only simulated a single 25-year 24 hour range of storm and did not simulate precipitation event continuously over multiple years.

The AGNPS model used in that research, however, is a single event model. As such AGNPS has limitations; it does not allow the simulation of NPS over a continuous period of time. The major disadvantage of such a single event model is that it requires the specification of the designed storm and antecedent moisture condition, assuming equivalence between the recurrence interval of the storm and the recurrence interval of the associated runoff. This type of model cannot be used for estimation of long term loadings of pollutants to a receiving water body without difficulty and larger expenses

(Mulik 2000). On the other hand, the annualized version of AGNPS, AnnAGNPS, used in this research, is a continuous simulation model. This model allows the simulation of different scenarios over multiple years. In general, a continuous model usually operates with a time interval ranging from a day to fraction of an hour, allowing estimates continuously balanced water and pollutant volume in the system. Continuous modeling has the great advantage of providing results from long term series of water and pollutant loadings that can be analyzed statistically as to their frequency (Mulik 2000). AnnAGNPS is designed to read a climate input file. Daily climate data including variables, such as precipitation, the maximum and minimum of temperatures, dew point temperature, sky cover (cloud cover), and wind speed are considered as input parameters. Given these strengths, the AnnAGNPS model will be used to investigate the temporal distribution of NPS pollution over multiple years, thus enabling better understanding of NPS in the study area, Davis Creek Watershed.

Research Objectives

The goal of this research is to simulate hydrology and NPS loading in the Davis Creek Watershed in support of water quality management. The specific objectives of this study are:

1) to estimate sediments, and different pollutant (nitrogen and phosphorus) loadings from NPS

2) to identify critical NPS source areas in the Davis Creek Watershed

3) to evaluate the uncertainty of the AnnAGNPS model in the Davis Creek by comparing the observed (actual) data with simulated yields and nutrient loadings

4) and to develop and evaluate land use and agricultural best management practices scenarios for the Davis Creek Watershed.

Watershed Description

The Davis Creek Watershed is located in the most urbanized area of Kalamazoo County. Davis Creek alternatively referred to as Allen Creek or the Olmsted-Davis Drain, is a highly modified, predominately urban drainage corridor. The watershed encompasses portions of five local jurisdictions: the Cities of Kalamazoo and Portage, and the Townships of Comstock, Kalamazoo and Pavilion. The watershed has been urbanizing generally in a northwest to southeast direction which is roughly the inverse of the overall flow of Davis Creek. The lower (downstream) reaches are largely urbanized and contain large industrial/commercial tracts which include Wings Stadium, the former Cork Street landfill and the Lakeside Oil Refinery. The upper reaches (Pavilion Township) are still currently rural in nature, typically agricultural lands with occasional, dense residential developments. It is anticipated that this urbanizing trend will continue moving toward the origin of Davis Creek at East Lake (Forum of Greater Kalamazoo 1998). The watershed is approximately 9,251 acres. The length of Davis Creek is six miles, drains into the Kalamazoo River (Figure 1).

Figure 1: Location of the Davis Creek Watershed, Kalamazoo, Michigan

As a hydrologic component of the Kalamazoo River Basin, the creek eventually drains to Lake Michigan at Saugatuck, Michigan in Allegan County. Davis Creek flows northwest from its origin at East Lake, through agricultural areas of Pavilion Township, and into the City of Portage at the Lexington-Green neighborhood, then flows north through a densely populated mobile home park, and into the eastern parts of the City of Kalamazoo and Kalamazoo Township. During its northerly flow, the creek roughly parallels Sprinkle Road at a distance of 1/4 to 1/2 mile to the west. Finally, it joins with the Kalamazoo River (Forum of Greater Kalamazoo 1998).

Topography: Davis Creek is relatively flat in the upper half of the watershed, and outwash plains are the dominant topographic feature. The outwash plain contains a ponded area, known as East Lake, which is generally recognized as the source of Davis Creek. The topography of the lower half consists of irregular rolling till plains (Forum of Greater Kalamazoo 1998). The highest elevation occurs up to 270 meters and the lowest elevation goes up to 236 meters (Figure 2).

Soils: The soils of the watershed reflect the strong glacial influences. Contrasting soil types are commonly found in any given location due to the erratic nature of the glacial ice movement, and many of the soils are loamy. In the upper part the soils are mostly medium to moderately coarse textured (Forum of Greater Kalamazoo 1998). The dominant hydrologic soil group is group B (Figure 3). This means that most of the areas have moderate infiltration rate when thoroughly wetted. These are moderately deep to deep, moderately well drained to well drained soils that have moderately fine to moderately coarse textures. They have a moderate rate of water transmission. These are silt loam or loam soils. Along the stream, especially from middle of the watershed to the downstream, sand, loamy sand or sandy loam types of soils or hydrologic soil group A are found (Figure 3). This type has low runoff potential and high infiltration rates even when thoroughly wetted. Hydrologic soil group C exists in the middle of the watershed (Figure 3), with low infiltration rates when thoroughly wetted and soils are sandy clay loam. Hydrologic soil group D also exists in a very small area, just upper stream of East Lake (Figure 3). These soils have the highest runoff potential and clay in nature.

Land use/Land cover: Based on 1996 land use/land cover map (Figure 4) of the Davis Creek Watershed, it is estimated that almost 30 percent area is occupied as cropland. These croplands mainly exist at upper stream and in the middle of the watershed area. Residential land accounts for 12 percent. Major residential area is situated at northwest corner of the watershed (Figure 4). Residential areas are also sparsely distributed at the edge of downstream, and, scattered in the upper stream especially near the lakes and waters bodies. Industry also occupies a larger portion, 14 percent which mostly situated in the downstream area. There is a significant percentage of rangeland exists (13 percent). Forest and wetland consists of 7 percent and 8 percent respectively (calculated by author).

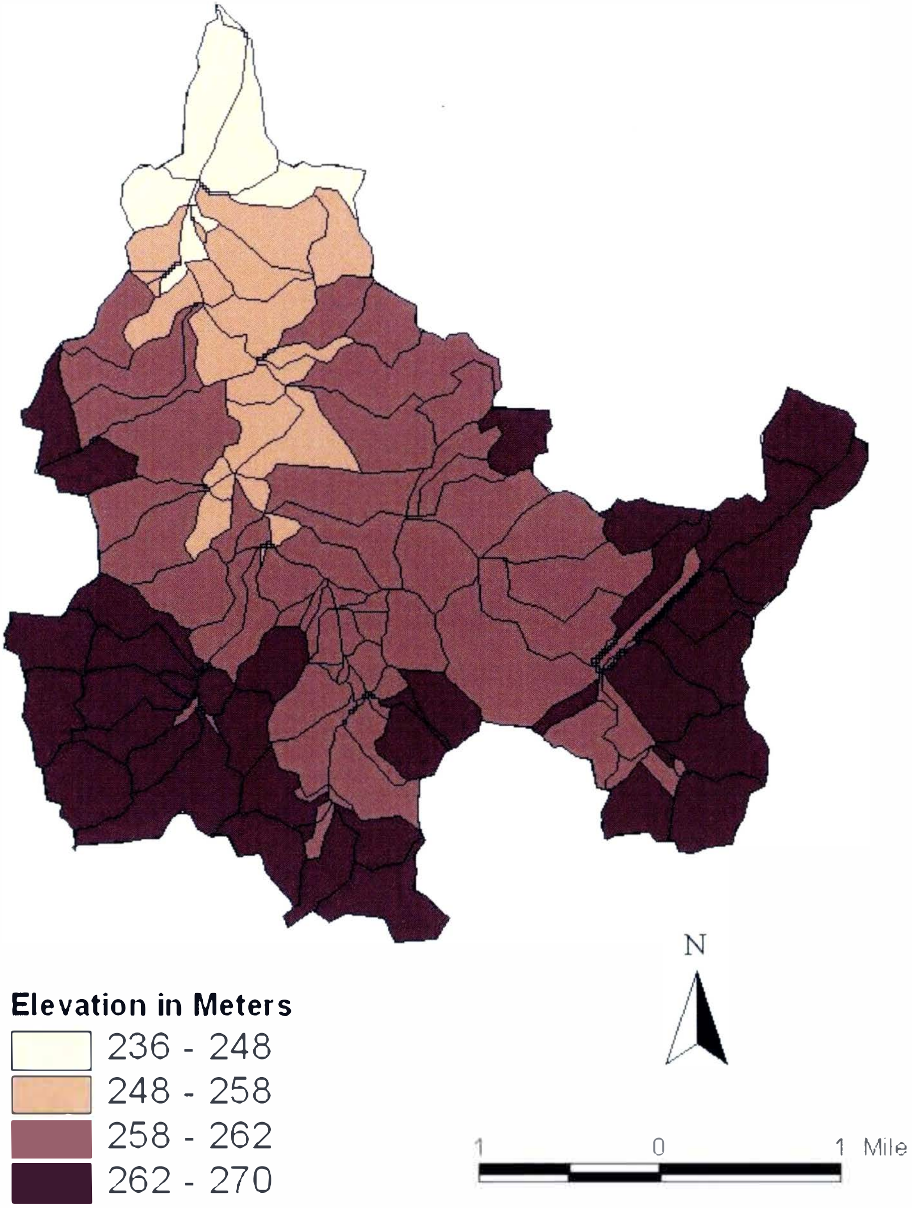

Figure 2: Elevation map of the Davis Creek Watershed

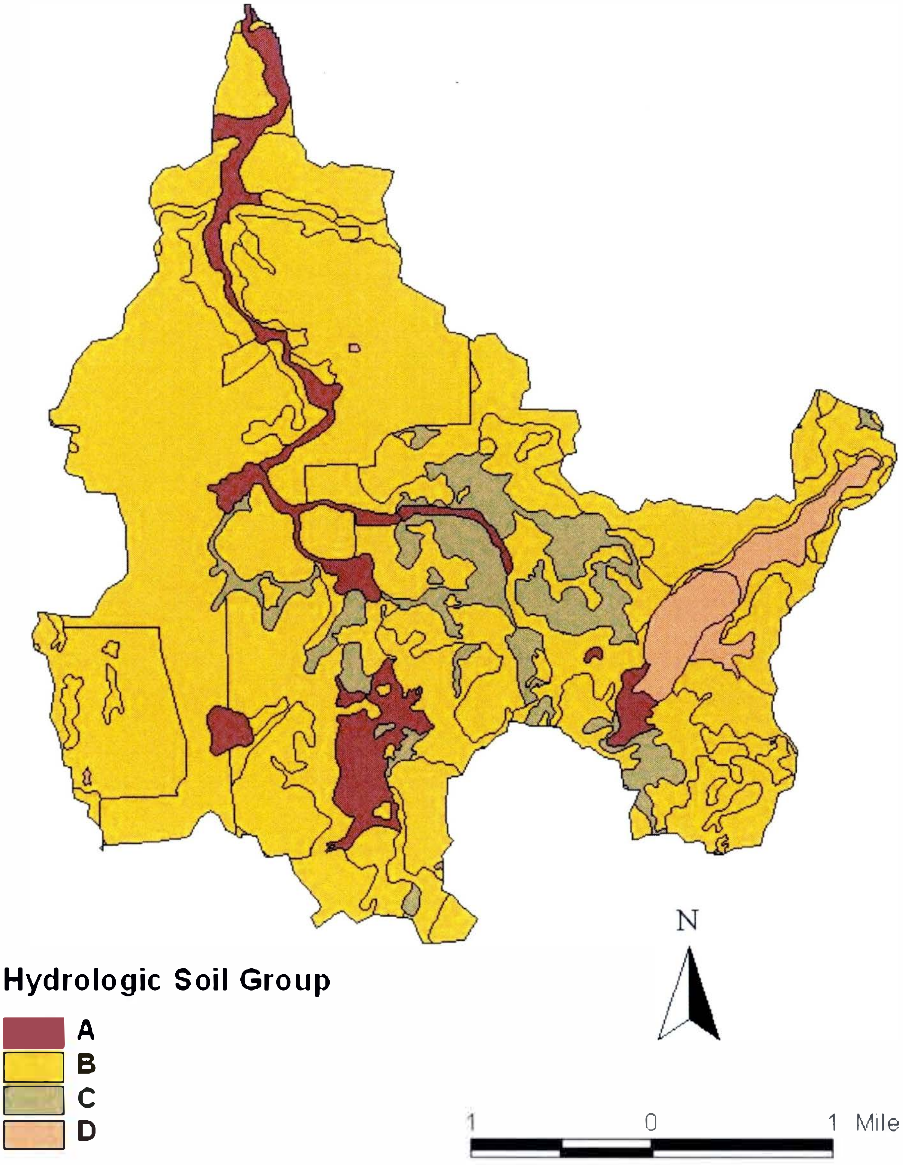

Figure 3: Distribution of hydrologic soil groups in the Davis Creek Watershed

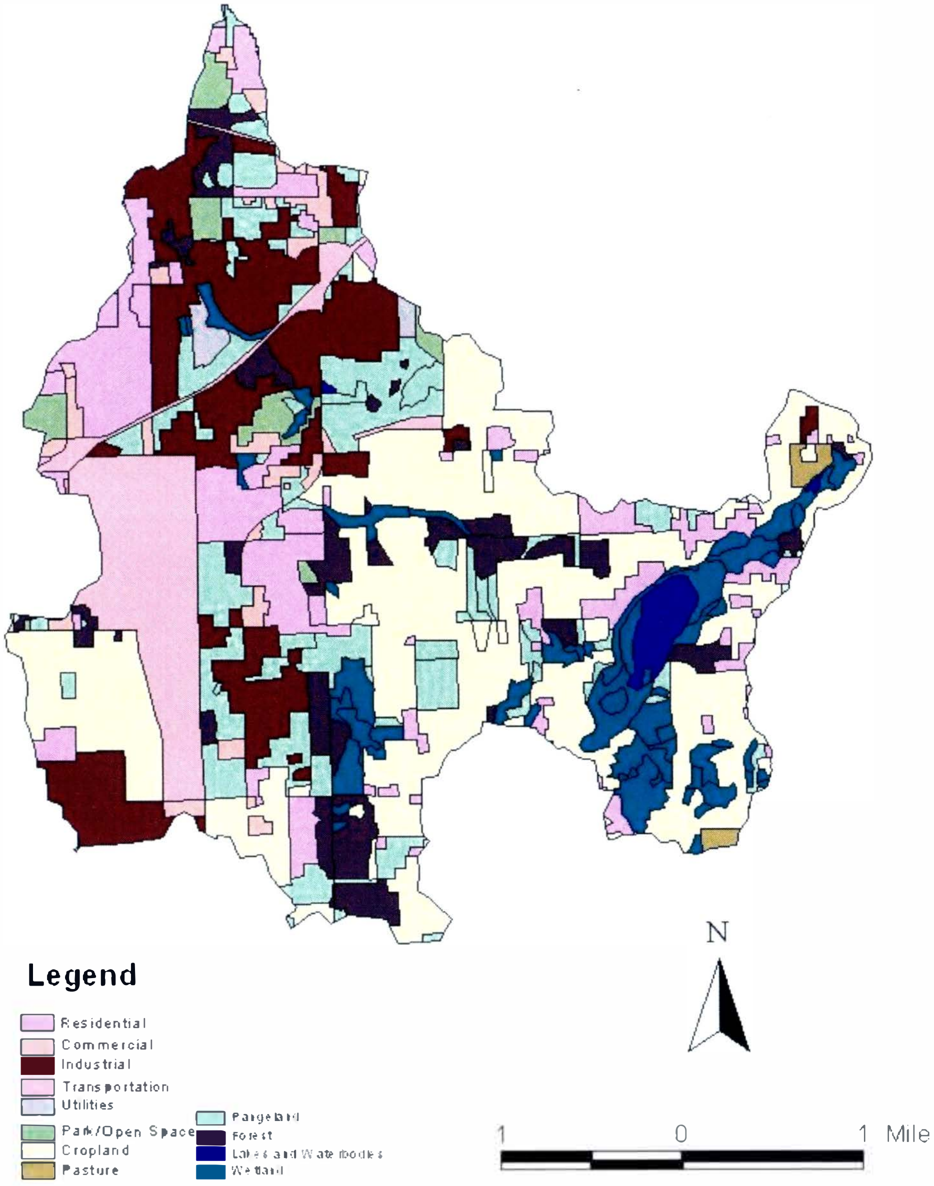

Figure 4: Land use map of the Davis Creek Watershed, 1996

CHAPTER TWO

LITERATURE REVIEW

Humans must cultivate the land for their food. They build houses for their shelter, factories for production and they make roads to connect all of their places. In short, everything occurs on land. As a result, land use is changing everyday. This land use/land cover change has several impacts on all surrounding ecosystems as well as on water, the most valuable resource in the world. Land use has significant impacts on both the quality and quantity of water resources. Surface runoff is a function of the soil type, topography, climate and land use. Land development without recognizing the conservation needs of a watershed leads to a reduction of ground water recharge, the degradation of streams, and the loss of aquatic life (Limlahapun 2002). Various methods and models have been developed to understand water quality by estimating pollutants from both point and nonpoint sources, their impact on water quality, developing and evaluating best management practices scenarios to adjust and coup with this issue in the real world.

The AGNPS (AGricultural NonPoint Source Pollution) model was developed by the United States Department of Agriculture - Agricultural Research Services (USDA-ARS), in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service (SCS) (Young 1989a). This distributed parameter model was developed to analyze and provide estimates of runoff water quality from agricultural watersheds, ranging in size from a few hectares to upwards of 20,000 hectares. Many studies have been conducted using AGNPS and indicate that the simulated results for runoff and sediment from AGNPS compare favorably with observed data (Young et al

1989a, Bingner et al 1989). Young et al (1989b) further tested the chemical component of the model using three year monitored data from seven different watersheds in Minnesota. They found that simulated nitrogen and phosphorus concentrations agree reasonably well with measured concentrations.

The Annualized AGNPS (AnnAGNPS) has been developed as a direct replacement of the single event model, AGNPS 5.0; but retains many of the features of AGNPS 5.0. Early in the development of the AGNPS, several serious model limitations were recognized. The AGNPS model handles only one storm event at a time to predict pollutant loading (PL) throughout a watershed (Baker et al. 1995). In the early 1990's, a cooperative team of ARS and NRCS scientists was formed to develop an improved annualized continuous-simulation version of the model, AnnAGNPS. It is written in standard ANSI FORTRAN 90. The model was developed to simulate long-term sediment & chemical transport from ungaged agricultural watersheds (Bingner et al. 2003). Version 1 of AnnAGNPS was released in February 1998 (Bosch et al. 1998). The AnnAGNPS model is a batchprocess, continuous-simulation, surface-runoff, pollutant loading (PL) model designed for risk and cost/benefit analyses (Cronshey et al. 1998). This model is able to run continuously with daily climatic data over multiple years. AnnAGNPS can be applied to evaluate NPS pollution from agricultural watersheds ranging in size up to 300,000 hectares. The AnnAGNPS model simulates quantities of surface water, sediment, nutrients, and pesticides leaving the cells and their transport through the watershed. This model can be used to examine current conditions or to compare the effects of implementing various conservation alternatives over time within the watershed. Alternative cropping and tillage systems; fertilizer, pesticides; and irrigation application rates point source loads and feedlot management can also be evaluated (Bosch et al. 1998). In short, this is a very sophisticated model. The amount of water, sediment yield by particle size class and source, soluble & attached nutrients (nitrogen, phosphorus, & organic carbon), and any number of soluble & attached pesticides from anywhere in the watershed can be predicted for anywhere within the stream network. Nutrient concentrations from large feedlots and other point sources can be modeled. Individual feedlot potential ratings for associated pollutants can also be derived using the model (USDA- ARS 2001a).

Mulik (2000) applied the AnnAGNPS model to the Horseshoe Creek Watershed located in Kansas to estimate runoff volume, sediment, and nutrient losses. The model was used to continuously simulate eight different scenarios in this watershed for four years (1994-1997). In that study four different land cover conditions such as the current condition (70 percent cropland at the time of model run), 100 percent pasture, 100 percent cropland with conservation practices and 100 percent cropland with no conservation practices were considered. That study also considered four different buffer strip practices that included 50 ft and 100 ft buffer strips at main stream sections and all stream sections. The output of the study indicated a high volume of runoff and sediment loss for all four years under the current scenario as well as for the 100 percent cropland condition. The highest volume of runoff, sediment and nutrient losses were observed for the years 1996 and 1997. The application of buffer strips had very little effect on sediment loss and there was no change in the runoff volume and nutrients loss.

Bingner et al (2001b) used the AnnAGNPS to predict runoff and sediment yield from a monitored sub-watershed of Deep Hollow Watershed in the Leflore County, Mississippi. Predictions were compared with actual field observations in order to test the AnnAGNPS model. Test results showed that AnnAGNPS adequately predicts long-term monthly and annual runoff and sediment yield and, in addition, can actually reflect the impact of BMP's[1]. Test results also showed that AnnAGNPS provides a reasonable estimate (±15 percent) of long term monthly and annual runoff and sediment yield without calibration. Bingner (2001a) also applied AnnAGNPS to estimate sediment yield by particle size for sheet and rill erosion in the Goodwin Creek Watershed, in the Yazoo River Basin, Mississippi. This study shows AnnAGNPS can successfully predict sheet and rill erosion's contribution to sediment yield from any field within the watershed at any location within the stream system. From this study, AnnAGNPS predicted values shows how well the relative behavior of the sheet and rill erosion responds to decreasing sediment yield as the sediment is transported downstream, i.e. continued depositions of sediment originating from within the fields-coarse sediment largely depositing in the fields and the fine sediments behaving predominantly as wash load. This capability of AnnAGNPS provides a powerful tool in assessing the sediment loadings related to best management practices within a watershed system.

Chaubey et al. (2001) applied the AnnAGNPS model to study long term nutrient transport assessment of animal manure from an agricultural watershed, the Crooked Creek Watershed in Cullman County, the largest poultry producing county in Alabama. The effects of three management practices on long term nutrient runoff losses included: soil test P, pasture management, and litter export from watershed were assessed. Results found that sediment attached and soluble nutrients transport was significantly affected by all three management practices.

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[1] According to EPA, Best Management Practices (BMPs) are methods that have been determined to be the most effective and practical means of preventing or reducing pollution. These practices are often employed in agriculture, forestry, mining and construction. The goal of developing BMPs is to increase efficiency while reducing pollution. (EPA, 2004http://www.epa.gov/ebtpages/envibestmanagementpractices.html)

Finney (2001) applied the AnnAGNPS model with CONCEPTS[2] to develop sediment budget and sediment routing at a sand gravel mining area. This study was conducted at the San Luis Rey River Watershed in the northwestern part of San Diego County, California. The purpose of that study was to describe a tool defined as a Dynamic Sediment Modeling and Analysis Process (DSMAP) that would allow regulators and gravel miners to assess the impacts of sand/gravel mining on streambed stability. This would allow for sediment production predictions, as well as determining the potential for adverse impacts from sediment mining based different land use and management practices scenarios. End products would include sediment budgets and streambeds profiles of selected streams showing either aggradation (streambed deposition) or degradation (channel erosion or incision). Finney (year unknown) also applied the AnnAGNPS model to Cold Creek watershed adjacent to Lake Tahoe, and modeled the surface nutrient budget for nitrogen and phosphorus while estimating surface sediment and nutrient loading to Trout Creek. This paper provides further support for the need for developing sediments and nutrients budgets for watersheds in the Lake Tahoe Basin and this work also describes the process for implementing the AnnAGNPS model and verifying outputs.

Yuan et al. (2001, 2002) used this model to evaluate the effectiveness of BMPs on sediment reduction. They applied the AnnAGNPS model at the Deep Hollow Lake Watershed located in the Mississippi Delta Management Systems Evaluation Area (MDMSEA) was used for evaluating the effectiveness of several BMPs for reducing sediment yield from a 12 ha sub watershed within the project area. Simulation results proved that the AnnAGNPS model is capable of simulating the effects of variety of

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[2] CONCEPTS or CONservational Channel Evolution and Pollutant Transport System was developed by the National Sedimentation Laboratory which simulates open channel hydraulics, sediment transport and channel morphology. CONCEPTS simulates unsteady, one-dimensional flow, graded sediment transport, and bank-erosion processes in stream corridors. It can predict the dynamic response of flow and sediment transport to instream hydraulic structures (Langendoen, 2000).

BMPs and BMP combinations. Yuan et al. (2003) further tested the performance of AnnAGNPS 2.0 on nitrogen loading using the data from the Deep Hollow watershed of the Mississippi Delta Management Systems Evaluation Area (MDMESA) project. Statistical tests showed that the predicted nitrogen loading was not significantly different from observed nitrogen loading at the 95 percent confidence level.

Baginska et al. (2002) examined the applicability and predictive capacity of AnnAGNPS in Australian conditions. They applied the AnnAGNPS model in Currency Creek at New South Wales, Australia. This model was applied to the prediction of export of nitrogen and phosphorus from Currency Creek, a small experimental catchment within the Hawkesbury-Nepean drainage basin of the Sydney region. Events flows were simulated satisfactorily with AnnAGNPS but only moderate accuracy was achieved for prediction of event based nitrogen and phosphorus exports. The biggest deviations from the measured data were found for daily simulations but trends in the generated nutrients matched observed data. AnnAGNPS was also used for source assessment of sediment and phosphorus water quality impairments of Hillsdale Lake, Kansas (Barnes 2002).

The AnnAGNPS model was also applied to an intensively cultivated watershed within the Canadian climatic context (Cluis D. et al. 2002). D. Cluis et al. conducted the research at the Boyer-Nord River, a well documented experimental agricultural watershed on the southern bank of the St-Lawrence River at Quebec, Canada. The objective of that study was to evaluate the suitability of AnnAGNPS to predict runoff, sediment yields as well as nitrogen and phosphorus loading under Canadian climatic and agronomic conditions. Using data for 1998 and 1999, simulated results were compared with observed data showing a good agreement.

The Channel and Watershed Processes Research Unit at the National Sedimentation Laboratory (NSL), in cooperation with the U.S. Army Corps of Engineers (CoE), Sacramento District, conducted the Sediment Loadings and Channel Erosion Study in the Lake Tahoe Basin of California and Nevada (Simon et al. 2003a). They determined a bulk loading value for sediment from individual streams including the relative contributions of fine- and coarse-grained materials for use in estimating the subsequent Total Maximum Daily Load (TMDL[3]). They evaluated the effect of the large runoff events occurring January 1997 on future suspended sediment loadings. The team simulated suspended-sediment loadings for the next 50 years for a minimum of three representative watersheds using the upland model AnnAGNPS and the channel evolution model CONCEPTS. Numerical simulations of suspended –sediment loadings from distributed and undistributed western streams and the Upper Truckee River for the next 50 years shows a trend of decreasing sediment delivery to Lake Tahoe. In this study, it was found that streambanks are the major source of sediment based on simulation results at the mouth of the Upper Truckee River: 49 percent of the fine suspended loads (clay and silt), 90 percent of the coarse suspended loads (sands), and 79 percent of the total suspended load. The 50- year simulation of the Upper Truckee River predicts that on average 770 tons/yr of sediment will be discharged to Lake Tahoe (Simon et al. 2003a). Simon et al (2003b) also applied the AnnAGNPS model with CONCEPTS once again to evaluate the severity of sediment transport condition at James Creek, Mississippi.

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[3] A TMDL or Total Maximum Daily Load is a calculation of the maximum amount of a pollutant that a waterbody can receive from both point and nonpoint sources, and still meet water quality standards, and an allocation of that amount to the pollutant's sources. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs. (EPA, 2004 http://www.epa.gov/owow/tmdl/intro.html#definition)

Srivastava et al. (2003) conducted a study on watershed optimization of agricultural best management practices: continuous simulation versus design storm, using the AnnAGNPS model. The specific objective of the study was to determine the differences in watershed pollutant loads, in an USDA experimental watershed, Mahantango Creek, located in Northumberland County, Pennsylvania, resulting from optimization analyses performed using pollutant loads from a series of five 2-yr 24-hr storm events, a series of five 5-yr 24-hr storm events, and cumulative pollutant loads from a continuous simulation of five years of weather data. For each of these three different event alternatives, 100 near optimal solutions (BMP schemes) were generated. Sediment, sediment nitrogen, dissolved N, sediment organic carbon, and sediment phosphorus loads from a different five-year period suggested that the optimal BMP schemes resulting from the use of annual cumulative pollutant loads from a continuous simulation of five years of weather data provide smaller cumulative NPS pollutant loads at the watershed outlet.

Suttles et al. (2003) applied the AnnAGNPS model to understand scale simulation of sediment and nutrient loads in Georgia coastal plain streams. Sediment and nutrient loadings in the Little River research watershed in south central Georgia were modeled. In this study nitrogen, phosphorus, sediment, and runoff were predicted over a seven year period. The simulation results were compared to seven years of actual monitoring data at the outlet of five nested sub watersheds and the outlet of Little river research watershed. The average annual predicted runoff in the upper part of the watershed was one third to one half of observed runoff. However, predicted runoff in the lower part of the watershed was close to observed, and at the watershed outlet was100 percent.

The AnnAGNPS model was used to develop a stormwater best management practice placement strategy for controlling stormwater runoff from highways and its other facilities, such as maintenance headquarters, storage areas, etc. This study was conducted by Yu Shaw L. et al (2003) for the Virginia department of transportation. For this study the AnnAGNPS model was used for a generic analysis, with the VAST VirginiA STorm model which was used for a specific highway case study.

In summary, the AnnAGNPS model has been used for a variety of practical applications, and has proven to be an excellent tool for the analysis of nonpoint pollution effects. The next chapter will introduce the current research that uses this model.

CHAPTER THREE

METHODOLOGY

Description of the AnnAGNPS Model

The implementation of AnnAGNPS requires three stages: data preparation, simulation process, and model outputs.

Input Data Preparation: The required input parameters include climate data, watershed physical information (geomorphologic data) and management information. The different categories of input data can be grouped into the following classifications:

Physical information includes watershed delineation, cell[4] boundaries, cell data (requires information on each cell regarding slope, area, aspect, average elevation, land use, soil type, time of concentration Tc, reach identifier) land, slope, slope direction and reach information. GIS and digital elevation models can generate some of the geographical inputs including cell boundaries, land slope, slope direction, and land use (Bosch et al.1998).

Climate data includes precipitation, maximum and minimum air temperature, relative humidity, percent sky cover (cloud cover), and wind speed.

Management Information includes land characteristics (soil characterization, curve number, Revised Universal Soil Loss Equation (RULSE) parameters, watershed drainage characteristics), crop characteristics (crop data information on each crop, root

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[4] In AnnAGNPS model, cell is different from traditional square cell. These cells are amorphous and based on homogeneous land area; represent the landscape characteristics within the respective cell boundary.

mass, canopy cover, rain fall, height, yield unit weights, unit harvested), field operation data (tillage operations, planting, harvesting, rotation and irrigation schedules; chemical operation data, feedlots and soil information (USDA-ARS 2001a).

Simulation Processing includes processing climate information for each day of the initialization period and the simulation period and calculation of these impacts on each individual cell. The simulation period data is furthered processed for: feedlots, gullies, point sources and reaches. Information concerning soil moisture, snow pack, crop growth, residue and chemicals are carried from one day to the next for each cell, as are manure pack and nutrients for each feedlot. Reach and selected source accounting component data are also accumulated from the events during the simulation processing. The SCS curve number technique (SCS 1986) has been using to generate daily runoff and RUSLE 1.05 technology (Renard et al. 1997) is responsible to generate daily sheet and rill erosion from fields (Geter and Theurer 1998). The parameters that are used for RUSLE are also used within AnnAGNPS. Each cell within AnnAGNPS can have different RUSLE parameters associated with describing the farm operations. This can provide a spatial and temporal variation of the management practices associated with a watershed system. Sheet and rill erosion is calculated for each runoff event during a user-defined simulation period and averaged for this same time period. A runoff event can occur from any combination of rainfall, snowmelt, and irrigation. All subsequent sediment is routed throughout the stream system down to the watershed outlet. An account of each individual field contribution to the sediment yield at any user-defined stream location can be determined (Bingner et al. 2003)

RUSLE is used only to predict sheet and rill erosion and not field deposition, therefore a delivery ratio of the sediment yield from this erosion to sediment delivery to the stream is required. The Hydro-geomorphic Universal Soil Loss Equation (HUSLE) is used for this procedure (Theurer and Clarke 1991). The procedure was initially developed to predict the total sediment yield at a user-defined point in a stream system using spatially- and time-averaged RUSLE parameters; and to ensure that sheet and rill-related sediment was properly calculated (Bingner et al. 2003).

RUSLE preprocessing

Erosion model RUSLE is designed to predict the long time average annual soil loss (A) carried by runoff from specific field slopes in specified cropping and management systems as well as rangelands (Renard et al. 1997). RUSLE computed average annual soil loss as

$$A = R * K * L * S * C * P$$

where,

A = computed spatial average soil loss and temporal average soil loss per unit of area

R = rainfall-runoff erosivity factor-the rainfall erosion index (EI) plus a factor for any significant runoff from snowmelt

K = soil erodibility factor -the soil loss rate per erosion index unit for a specified soil as measured on a standard plot

L = slope length factor

S = slope steepness factor

C = cover management factor

P = support practice factor

(Renard et al. 1997)

The K factor or soil erodibility is computed for each soil either as an annual value or a series of 24 15+ day values for a year depending on the specified Variable K-factor code and whether the EI[5] Number supports variable K factors. The C factor is computed as an annual value for non-cropland and as a series of 24 15+ day values for each year in the operation management schedule. The LS factor is computed for each cell. The RUSLE LS calculation is based on calculating slope steepness (S factor) and slope length sub factors (L factor) and finally combining them into single LS value. The P factor is computed as an annual value for non-cropland and as a series of annual values (one for each year in the operation management schedule) for Cropland. The P factor includes adjustments for contours, strip crops, and terraces contained in the cell as well as sub-surface drainage. The EI values used for the entire watershed are expressed as a series of 24 15+ day values in the calendar year (USDA-ARS 2001a).

Pollutant Loading Output analyzes variable accumulations over the simulation period at downstream reach locations to determine outlet contribution from specific user selected components (cell, feedlot, gully, point source, or reach). Variables analyzed are user selected from input source accounting codes or global source accounting codes (USDA-ARS 2001a). **Average Annual** and **Event** file files contain tables showing the average annual loading amounts for water, erosion, sediment yield, & sediment in transport and the event loading amounts for water, erosion, sediment yield, & sediment in transport for water runoff events in excess of ¼ in (6.35 mm). However, there is a limit of the first 120 events included in this event file so as not to overwhelm the file size. Event output can be rearranged by daily event date or monthly event or yearly event basis. Both files are designed to be used with MSWORD; and, when edited, can be printed on 8 ½ by 11 in standard size paper (USDA-ARS 2001a).

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[5] Erosion index (EI) —EI is a statistical interaction term that reflects how total energy and peak intensity are combined in each particular storm. EI indicates how particle detachment is combined with transport capacity (Renard et al. 1997).

Implementation of the AnnAGNPS to the Davis Creek Watershed

For the AnnAGNPS model physical and management information of the watershed is derived from digital elevation model (DEM), land use/land cover, and soil GIS layers. To derive the required input parameters for physical information and watershed information these GIS layers need to be collected and preprocessed within a GIS platform.

Databases:

The Digital Elevation Model used in this research was obtained from United States Geological Survey Seamless Data Distribution System (USGS 2004) at 30 meter resolution. It was processed with Arc/Info Workstation and ArcGIS software. The Soil Survey Geographic (SSURGO) Database from USDA Natural Resources Conservation Service was used for this study. However, spatial coverage for SSURGO data for Kalamazoo County is not available from NRCS; therefore digitized SSURGO data for Kalamazoo was acquired from the GIS Center at Geography Department of Western Michigan University (GIS Research Center 2004) and attribute data of SSURGO database was collected from NRCS Soil Data Mart website (USDA NRCS 2004). Then it was processed with ArcGIS. Land use/land cover of 1996 land cover data was also acquired from the GIS Center at Western Michigan University. Then it was processed into the appropriate format for AnnAGNPS using ArcGIS. All of the GIS layers were projected to UTM coordinate system.

After processing the required GIS data layers, all layers were imported into the AnnAGNPS ArcView Interface developed by the USDA ARS AGNPS team. This interface was used to delineate the watershed boundary, derive AnnAGNPS cell (AnnAGNPS homogeneous area) and AnnAGNPS reach files. Then cell and reach files were imported into the AnnAGNPS Input Editor for completing cell and reach data sections, respectively, later on this was used to complete the entire AnnAGNPS Input (AnnAGNPS.inp) file.

AnnAGNPS Input File:

After creating the "AnnAGNPS.inp" files, both the cell (AnnAGNPS homogeneous area) and reach data from the AnnAGNPS ArcView interface were imported into this input file. The AnnAGNPS Input Editor was used to assign the other parameters. Cell time of concentration (Tc) is also required which is calculated by the AnnAGNPS from sheet flow and concentrated flow variables for each cell. Therefore, sheet flow and concentrated flow variables are entered from AnnAGNPS Input Editor for each cell. Manning's n value for sheet flow was available from the Technical Release 55 (SCS 1986) report and also from AnnAGNPS reference documentation (USDA 2001a). For this study manning's n value for sheet flow was collected from both of the sources to get the values for all types of land use. Manning's n value for concentrated flow was collected from the Connecticut Department of Transportation report as they developed the values for paved and unpaved area (Connecticut Department of Transportation 2000).

Management field information contain field IDs or land use IDs and related information for each ID. AnnAGNPS can only recognize five categories of land use type including: cropland, pasture, rangeland, forest, and urban, therefore all of the land use categories were adjusted into these five categories. RUSLE sub P factor values were assigned as default values. An inter-rill erosion code was assigned for each filed ID based on land use and management practices. The Management schedule data section in the AnnAGNPS Input file mainly consists of the management schedule ID, an event date for the management schedule, the curve number ID, the management operation

ID, the new crop ID, and the non crop ID. This section of the AnnAGNPS input file mainly links the different sections within the management data file and with other data sections in AnnAGNPS input files (outside management data section such as soil) by these IDs. All of these IDs have been assigned using the Input Editor. The management operation data section of the AnnAGNPS input file stores effect codes for management operation and information about surface residues.

Fertilizer data (fertilizer name and application rate per unit area) was collected from Wilbur-Ellis, a local commercial fertilizer company which usually applies the fertilizer for the farmers in the watershed area (Wonders 2004). Fertilizer reference data such as the value of fertilizer organic and inorganic N, fertilizer organic and inorganic P, fertilizer soluble P, and fertilizer organic matter have been added from the AnnAGNPS reference documentation.

Reach related data focuses on hydraulic information for each reach ID which mainly comes from a reach file derived by the AnnAGNPS ArcView interface. Hydraulic geometry ID curve A, from built-in sets, has been chosen for the entire watershed. The reach vegetation code was assigned for each reach ID according to the land use along the reach. The default manning's n was used for each vegetation code.

According to local NRCS official, corn and soybeans are the prime crops in the research watershed area (Buckham 2004). Information of each crop i.e root mass, canopy cover, rainfall height, yield unit weight and yield unit harvested were collected from Michigan Agricultural Statistics and Agricultural Handbook 707 (Renard et al. 1997).

All non crop land was assigned with non crop land ID based on land use. The data for this section including variable such as root mass in the soil, annual cover ratio, rainfall height and surface residue cover have been obtained from Agricultural Handbook 707 (Renard et al. 1997).

According to the local NRCS official, there is no irrigation practice that impacts the watershed area (Buckham 2004). Pesticide information was not available. There are no feedlots and point sources within the watershed area. Therefore, these optional sections of the AnnAGNPS Input file were omitted.

Soil data was imported from the AnnAGNPS ArcView interface after assigning a soil identifier for each AnnAGNPS cell (AnnAGNPS homogeneous area). However, some of the soil parameters were entered and edited through the Input Editor. Physical and chemicals soil parameters include: hydrologic soil group, k factor, time of consolidation, impervious depth, layer depth, bulk density, clay ratio, silt ratio, sand ratio, rock ratio, very fine sand ratio, field capacity, wilting point, pH, organic matter ratio, inorganic N ratio, organic and inorganic P, and soil structure code.

The runoff curve numbers were obtained from the TR55 report which is based on the SCS Engineering Handbook (SCS 1986). For the AnnAGNPS model, the curve number was modified according to land use and different field operations.

Simulation year was selected for the period from 1998 to 2004 because of climate data availability for these years. Rainfall distribution code, RUSLE energy intensity for 10 year frequency rainfall (10 year EI), and the EI number were collected from the Agricultural Handbook 703 (Renard et al. 1997). The number of the initialization year was set to zero to get a full seven year simulation.

Climate Data (daily climate input file)

The daily climate data was obtained from the Kalamazoo Battle Creek International Airport weather station which is located within the watershed. Seven years of daily climate data for precipitation and daily minimum and maximum temperature were obtained from the weather station. Data for wind speed, the percentage of cloud cover and the dew point temperature were generated by AnnAGNPS complete climate program using monthly climate data for these three variables which were collected from the climate atlas. The 2 year 24 hour precipitation value was entered for this region from TR 55 (SCS 1986).

CHAPTER FOUR

ANALYSIS OF RESULTS

This study used the AnnAGNPS model to estimate sediment yield and nutrient loadings and simulate the effects of proposed land use scenarios on nonpoint source pollution in the Davis Creek Watershed. Daily climate data of 1998 to 2004, DEM, soil, land use, hydrography, and agricultural management information were used to derive the model input parameters. The model was run continuously for the period of 1998 through 2004. The simulated results were analyzed to estimate and understand the loadings of nonpoint source pollutants in the Watershed. Daily event data were also analyzed to determine the uncertainties of the model results with observed data. Subsequently, the simulated average yearly nonpoint sources loadings were used to identify the critical pollution areas in the watershed. Finally land use management scenarios were simulated in the model estimate their impacts on NPS loadings in the watershed and to provide information for support of water quality management programs.

Simulated Nonpoint Source Loadings

Simulated runoff results (in cubic feet per second or cfs) were shown in Figure 5. The highest runoff of 3.94 cfs was in 2001, corresponding the highest precipitation of 39.64 inches in that year. During the seven years of simulation period, the lowest runoff was of 1.44 cfs was in 1998 but the lowest precipitation of 24.57 inches occurred in the year 2002. Except the year 1998, the year 2002 has the lowest runoff. The year 1998 got the lowest runoff in spite of not having the lowest precipitation; this could be the problem of model initialization.

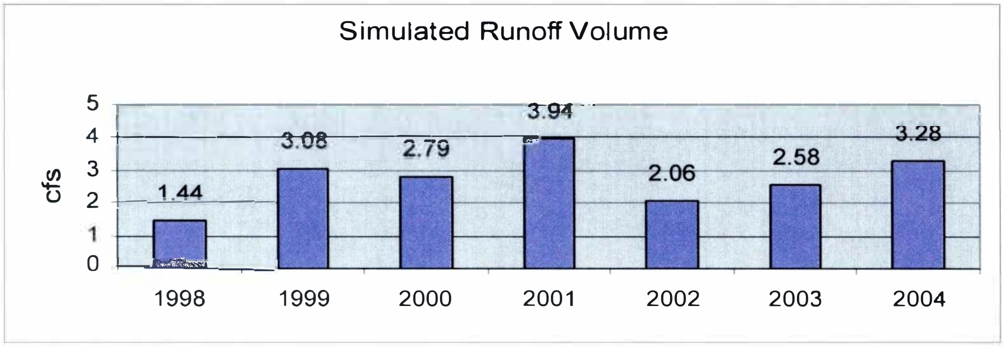

Figure 5: Simulated runoff (cfs) for the period of 1998-2004 in the Davis Creek Watershed

The simulated sediment yield at the watershed outlet is shown in Figure 6. The highest and lowest loadings of 2,297 tons per year and 421 tons per year were for the year 2001 and 2002 although the 1998 has the lowest runoff. Except the first simulated year 1998, the year 2002 has the lowest precipitation runoff. So by purge the first simulation year, model estimated the highest and the lowest sediment yield in the year 2001 and 2002 respectively, corresponding to the simulated highest and lowest runoff in those years. In spite of the lowest runoff rate (1.44 cfs), the year 1998 had a higher sediment yield because some large storms occurred in 1998 and produced higher sediment loadings, for example July 2 of 1998 was responsible for 433 tons sediment loading as a high precipitation event occurred (above 2.37 inches) on that day.

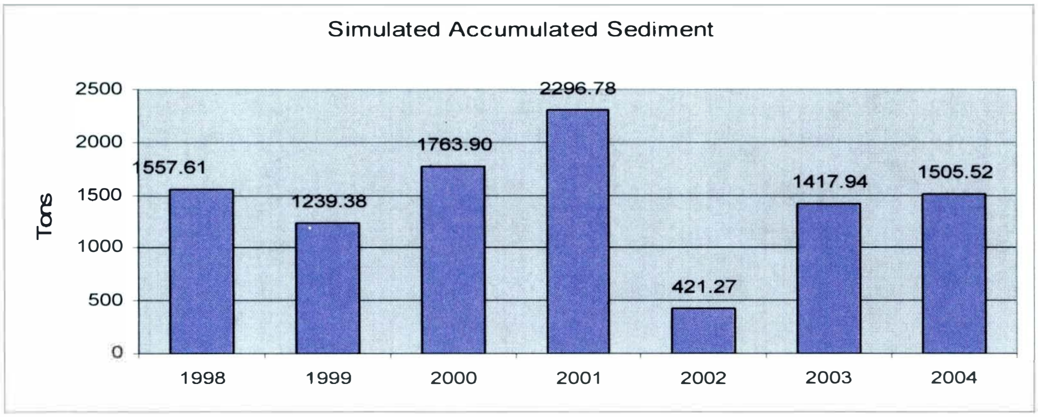

Figure 6: Simulated sediment yield (tons/year) at the Davis Creek Watershed outlet.

Simulated nutrient loadings including sediment attached N and P, soluble N and P and total N and P are shown in Figure 7. The highest simulated loadings for all sediment attached nutrients (N and P) occurred in 2001 and the lowest loadings were calculated for the year 2002, corresponding to the highest and lowest sediment loadings in 2001 and 2002 respectively.

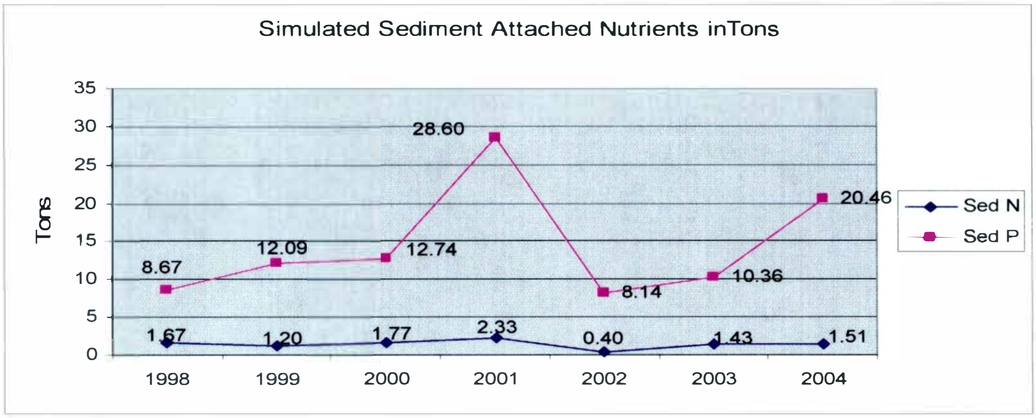

Figure 7: Simulated sediment attached nutrients loading in tons

For soluble nutrients, the pattern is somewhat different from the attached nutrients. For soluble nitrogen, the highest simulated amount (1.3 tons) was found for the year 1998 and the lowest loading (0.6 ton) for the year 2003 (Figure 8). For the soluble phosphorus loading, the highest value (451tons) was simulated for the year 2001 while the lowest (58 tons) was found for 1998 (Figure 8). Except the first simulation year 1998, the highest soluble loadings for both nitrogen and phosphorus occurred in the year 2001 as precipitation and runoff occurred highest in that year. The lowest phosphorus loading was found in 1998 as the lowest runoff was simulated for that year. But for soluble nitrogen loadings the lowest value was detected for the year 2003 despite of not having lowest runoff or precipitation.

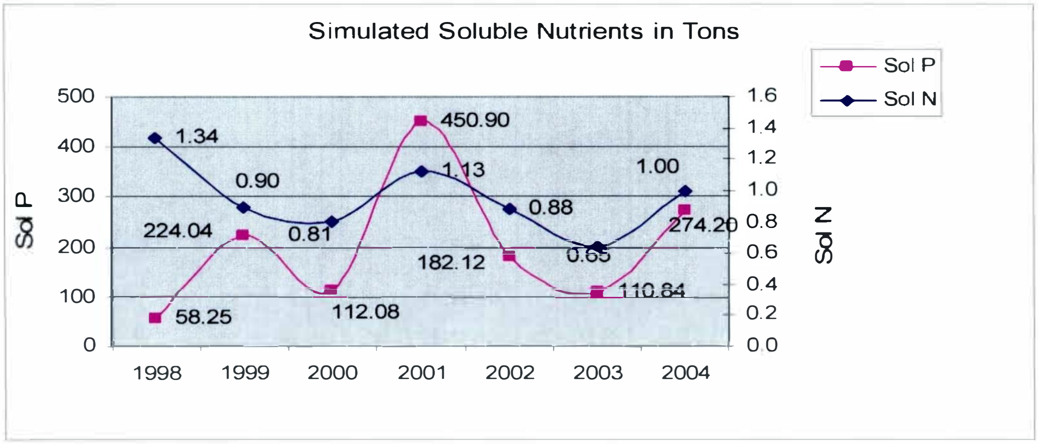

Figure 8: Simulated soluble nutrients loading in tons

For the entire simulated nutrient yield, the highest loading was for the year 2001(Figure 8) as highest sediment attached nutrients and soluble nutrients estimated highest for that year due to highest runoff volume and sediment yields. For total nitrogen and total phosphorus, the lowest values were for 2002 and 1998 respectively as sediment attached nitrogen was very low in 2002 and soluble phosphorus was very low in 1998. Total nutrient loading is calculated based on sum of sediment attached nutrient and soluble nutrient.

Table 1: Simulated nutrient loadings for the period of 1998-2004 in the Davis Creek

Year	**TOTAL Nitrogen (Tons)**	**TOTAL Phosphorus (Tons)**
1998	3.0	66.9
1999	2.1	236.1
2000	2.6	124.8
2001	3.5	479.5
2002	1.3	190.3
2003	2.1	121.2
2004	2.5	294.6
tons/yr	2.4	216.2
Kg/yr/ha	0.7	63.6

Determination of Uncertainty of the Simulated Results

The simulated runoff, sediment yield, and nutrient loadings were compared to the observed data to determine the uncertainties of the simulated results by AnnAGNPS in the Davis Creek. The observed data were from Dr. Chansheng He, Department of Geography at Western Michigan University (He 2005). Dr. He and his research team measured flows and collected water samples for analysis of discharge, sediment loading, and nitrogen and phosphorus concentrations in the Davis Creek for the period of 1999 to 2001. Dr. He kindly provided these data to this study for verifying the model results. However, the in situ data from Dr. He covered only part of 1999 (222 days), 2000 (306 days), and 2001 (177 days) and no complete yearly measurement was available. Thus these data were compared to the simulated estimated model results for the 1999 to 2001. Some simulated storm events were selected from AnnAGNPS daily event data, to compare with the observed data collected by Professor He.

Comparison of the simulated results to observed discharge is shown in Table 2. The comparison indicates that for some storm events the simulated discharges were very close to the observed ones, with differences ranging from 4 to 44 percent. However, for some storm events, the differences between the simulated and observed discharges were more than 100 percent (for example, 5/18/2000). These differences could be attributable to both errors in observed data and errors in the simulated discharge. Some simulated storm events have unrealistic values due to model error. Proper calibration might resolve this issue.

Table 2: Comparison of simulated versus observed runoff in cfs for selected event date.

Event Date	Simulated Runoff in cfs	Observed Runoff in cfs	Difference (percent)	Precipitation (inches)
5/31/1999	3.7	3.5	4.0	0.32
7/9/1999	28.2	13.6	107.1	1.62
12/5/1999	11.9	8.7	36.4	0.91
5/18/2000	254.6	3.1	8193.4	2.28
6/24/2000	59.7	2.2	2675.3	1.63
11/7/2000	4.04	4.5	-9.6	0.35
1/29/2001	3.3	5.9	-44.4	0.25
2/24/2001	195.3	14.8	1220.4	1.44
6/10/2001	9.0	19.9	-54.8	0.54

For sediment yield, some storm events have close values (20-80 percent) between observed and simulated results but some of them are absolutely not viable (Table 3). For phosphorus loadings, best match found for some storm event (66 percent) and some event have impractical values (Table 4).

Table 3: Comparison of simulated and observed sediment loading in Kg/ha at outlet

Event Date	Simulated Sediment (kg/ha)	Observed Sediment (kg/ha)	Difference (percent)
5/31/1999	0.0	6.5	-99.9
7/9/1999	57.6	11.3	409.5
12/5/1999	14.7	5.2	184.8
5/18/2000	132.4	1.5	8997.6
6/24/2000	56.6	2.8	1913.2
11/7/2000	0.0	12.6	-100.0
1/29/2001	0.8	16.6	-95.0
2/24/2001	50.3	41.8	20.5
6/10/2001	6.3	33.1	-80.9

Table 4: Comparison of simulated and observed phosphorus loading in Kg/ha at outlet

Event Date	Simulated P (kg/ha)	Observed P (kg/ha)	Difference (percent)
5/31/1999	0.0	0.1	-66.3
7/9/1999	1.0	0.3	207.1
12/5/1999	0.4	0.1	223.6
5/18/2000	1.6	0.7	147.1
6/24/2000	1.4	0.0	3722.4
11/7/2000	0.0	0.01	-61.4
1/29/2001	0.4	0.1	335.0
2/24/2001	1.4	0.2	569.2
6/10/2001	0.5	0.0	966.4

Yearly estimated data for 1999, 2000, and 2001 were also compared with the observed data for runoff, sediment loadings, total nitrogen and total phosphorus (Table 5 and Table 6). These data shows that estimated runoff can reflect the observed runoff. The simulated yearly nitrogen has good reflection of the observed data but the simulated phosphorus loading had a lot of discrepancy compare to the observed data (Table 6).

Table 5: Yearly comparison of simulated and observed runoff and sediment yield

Year	Simulated Runoff in cfs	Observed Runoff in cfs	Difference percent	Simulated Sediment (kg/yr)	Observed Sediment (kg/yr)	Difference percent
1999	3.08	2.84	8.3	1239381	4864	25380.6
2000	2.79	3.69	-24.3	1763902	14855	11774.1
2001	3.94	7.45	-47.1	2296777	53816	4167.8

Table 6: Yearly comparison of simulated and observed nitrogen and phosphorus loading

Year	Simulated Total N (kg/yr)	Observed Total N (kg/yr)	Difference percent	Simulated Total P (kg/yr)	Observed Total P (kg/yr)	Difference percent
1999	2097	1641	27.8	236134	306	77068.0
2000	2578	1585	62.6	124825	259	48095.0
2001	3461	5126	-32.5	479495	517	92645.6

Proper calibration of the model may give more accurate results. A longer period of in situ data would reduce uncertainties from the simulated results.

Identification of Critical Source Area

Spatial distribution of simulated nonpoint sources loadings are shown in Figures 9, 10, 11 and 12. These results (sediment, nitrogen, and phosphorus) are combined to identify the most seriously polluted areas in the study area. By GIS overlaying of most polluted or highest loadings areas from each pollutant, critical source area is delineated (Figure 13). It seems that higher erosion occurs near the downstream industrial and transportation areas especially at the AnnAGNPS homogeneous area or so called AnnAGNPS cell ID number 31, 33, 42, 43, 62, 63, 82, 83, 72 (Figure 9). This happens because the runoff is high in paved surfaces. The next higher erosion rates take place in some residential area near downstream (AnnAGNPS homogenous area ID 32, 552, 553, 561) and in the middle of the watershed (AnnAGNPS ID 115, 132, 133, 292, and

293). In most upstream areas erosion is low; most of these areas are croplands although erosion tends to be high in agricultural areas. It could be a problem of curve number, because higher curve number was selected for industrial area.

The spatial distribution of sediment loading has almost same pattern as erosion. The highest sediment loadings occur mostly in the downstream industrial and residential area (Figure 10). On the other hand, higher nutrient loadings occur mainly in the upstream agricultural areas and some small areas near the downstream. AnnAGNPS ID 232, 233, 241 in the upstream have the highest nitrogen loadings (Figure11). Phosphorus loadings are most severe mainly in croplands in northeast part of the upstream and downstream areas. AnnAGNPS ID 182, 212, 231, 232, 501, 503, and 51. In AnnAGNPS cell ID 22, which has major land use of rangeland and in AnnAGNPS ID 23 (major land use is open space or barren land) in upstream areas also have the highest phosphorus loadings (Figure 12). Simulated phosphorus loadings are also high in AnnAGNPS IDs 112, 113, 142, and 143, which are mainly, cropland and rangeland in the middle area of the watershed. This may be due to the application of compound fertilizers (NPK 18-46-0) in these regions.

These results are similar to Porntip Limlahapun's (2002) study. She used the single event AGNPS (V.5.0) model to simulate the effect of land use changes on NPS loadings in the Davis Creek Watershed and found that the highest amounts of runoff came from industrial and commercial area due to low infiltration as she identified. That study also concludes that land diverted to urban uses (residential, commercial and industrial area) had higher sediment loadings compare to other land uses as she identified due to construction or little vegetation. Porntip's study identified commercial areas as most responsible for the highest rate of nitrogen and phosphorus loadings in the Davis Creek watershed (Limlahapun 2002). On the other hand, this study concludes that croplands are more responsible for higher phosphorus and nitrogen loadings in the study watershed as fertilizer applies in the cropland provide more nutrients to the soil and water. Industrial and residential areas have higher runoff as because yarding and construction reduces infiltration capacity that produces higher runoff. Paved surface is also responsible for higher runoff. As a result erosion rate is also higher in these areas that also influences for higher sediment loadings.

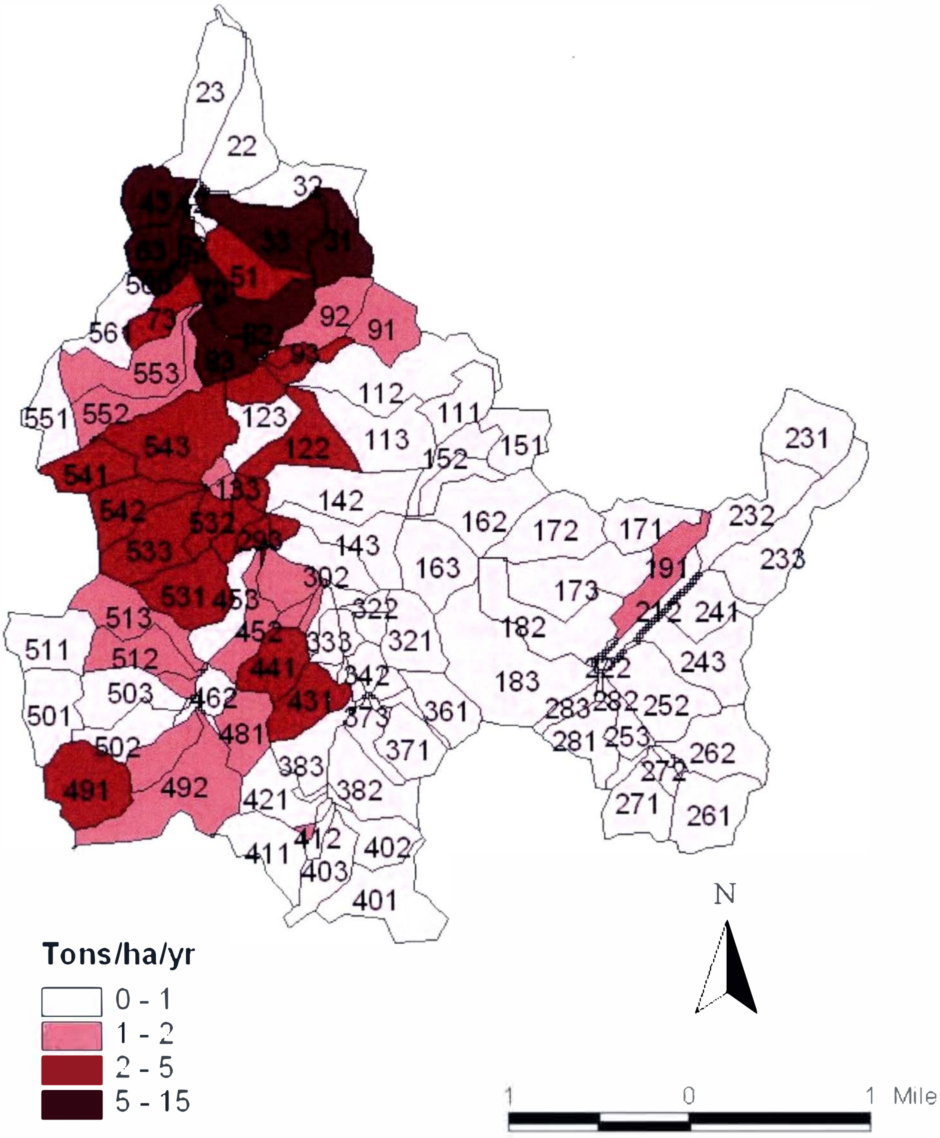

Figure 9: Spatial distribution of the simulated erosion in Davis Creek Watershed, (average annual of 1998-2004, in tons/ha/yr)

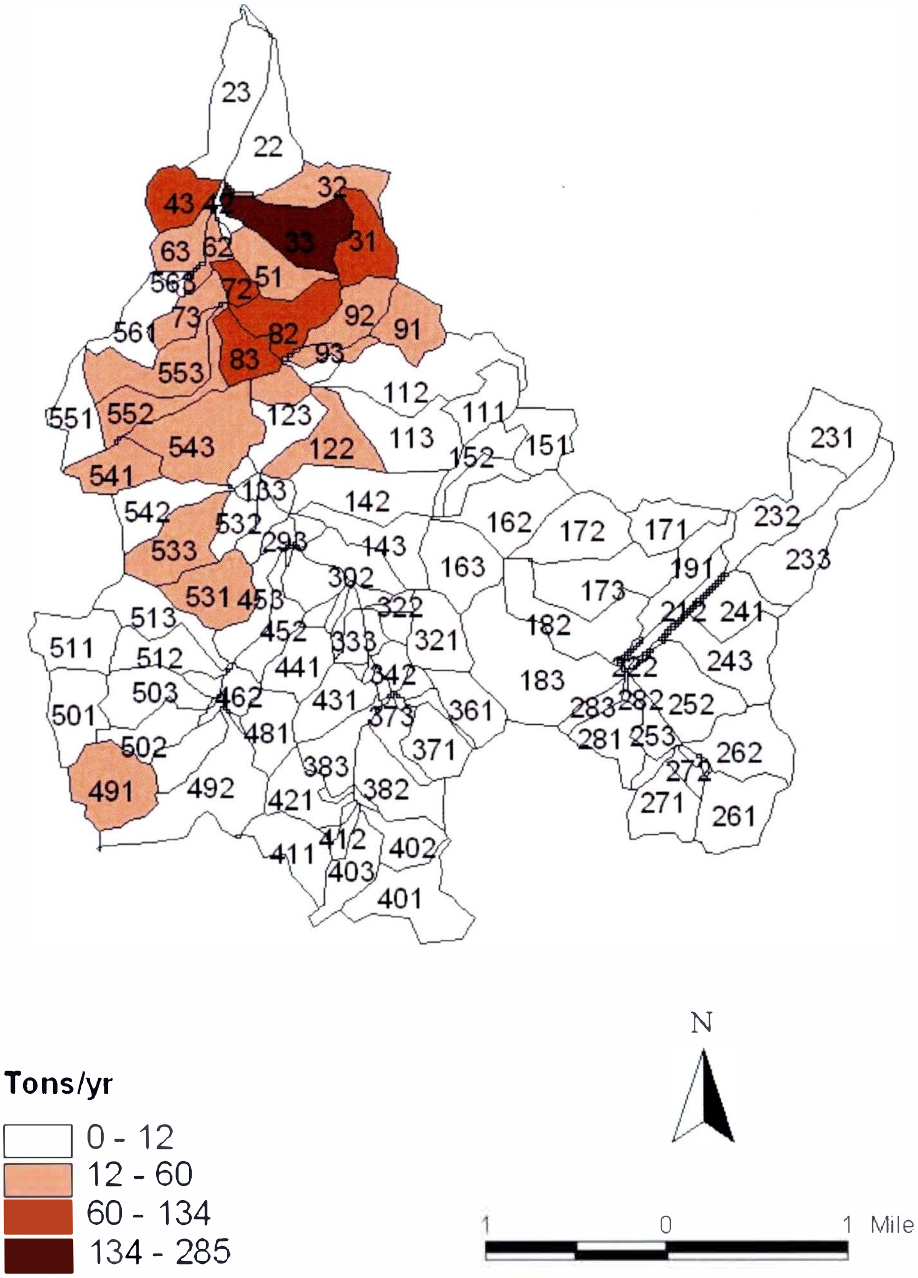

Figure 10: Simulated accumulative average annual sediment loadings (tons/yr) in the Davis Creek Watershed (1998-2004)

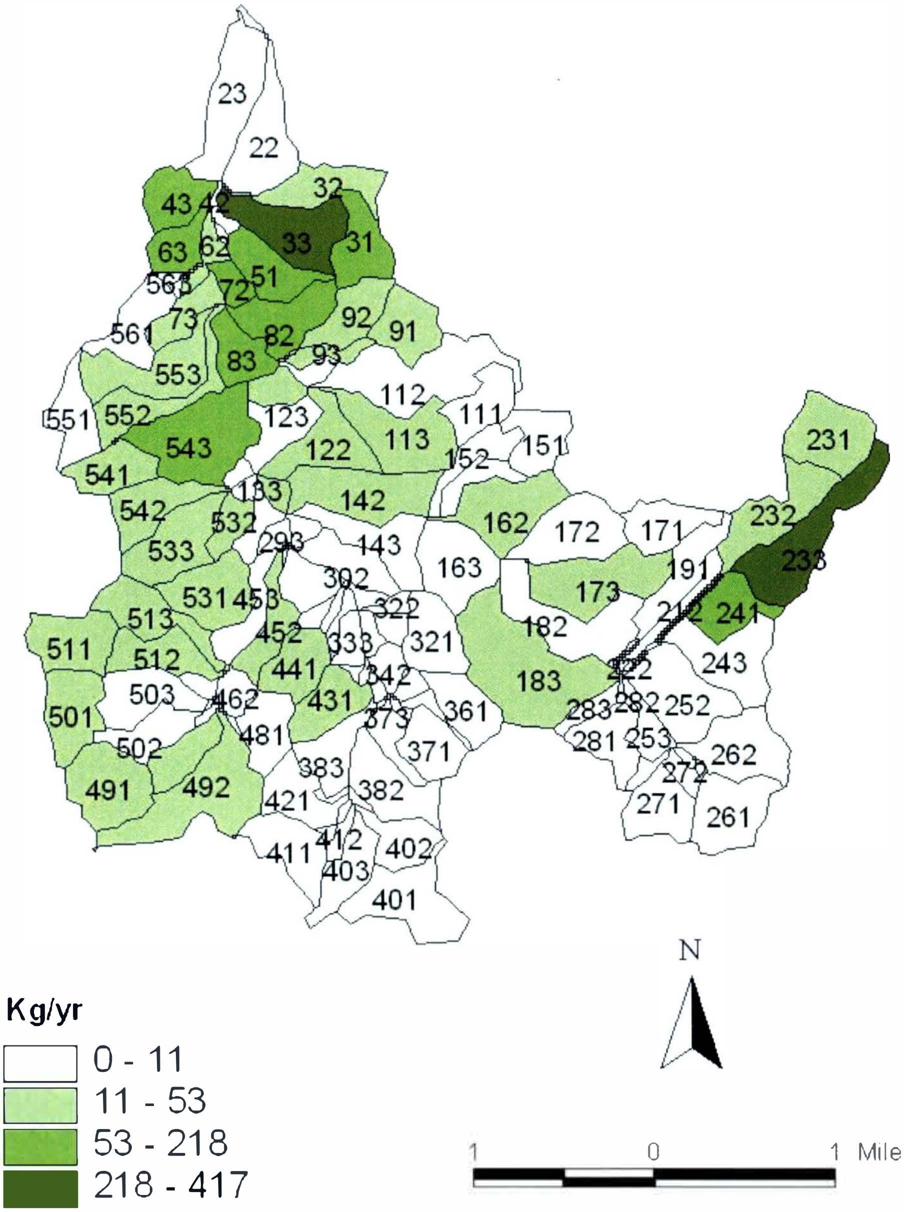

Figure 11: Simulated average annual total nitrogen loadings (kg/yr) in the Davis Creek Watershed (1998-2004)

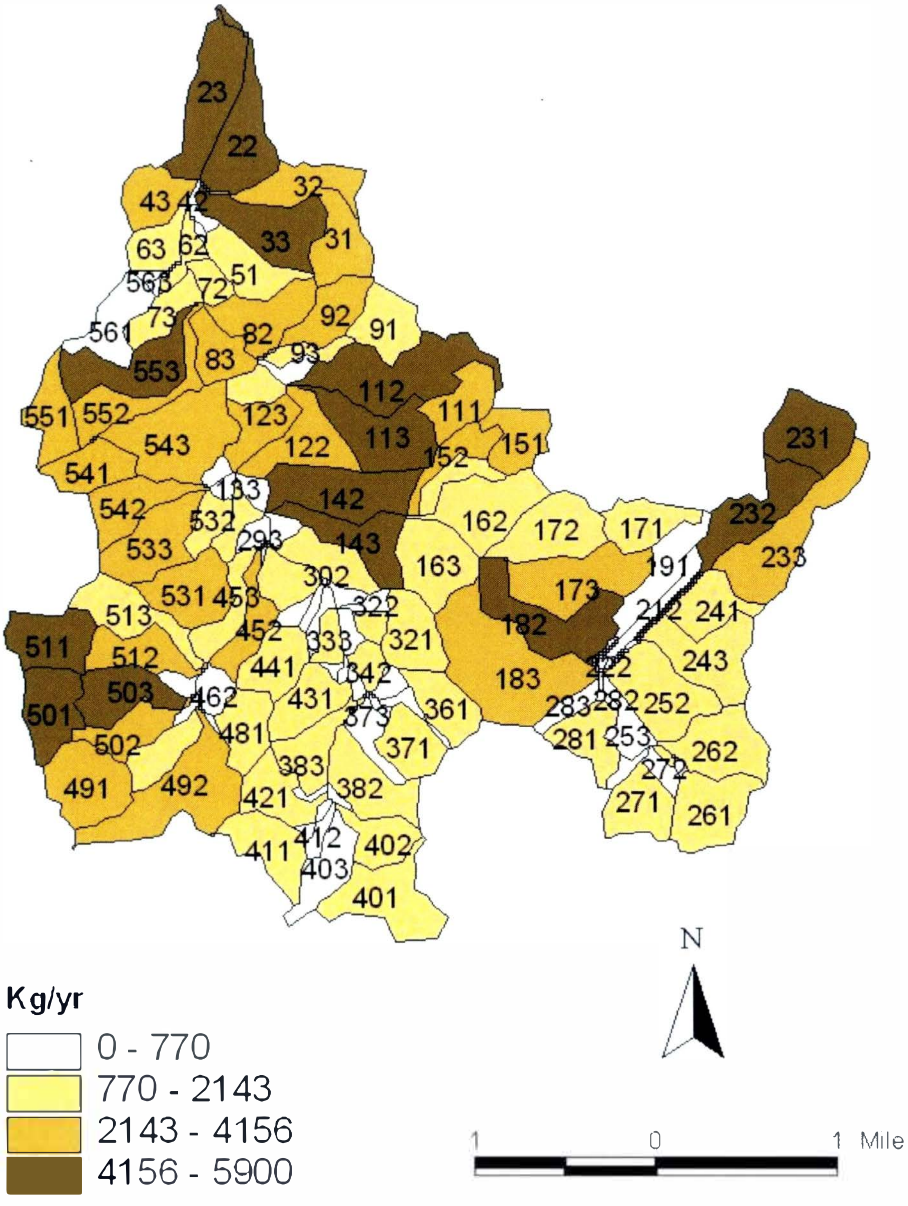

Figure 12: Simulated average annual total phosphorus loadings (kg/yr) in the Davis Creek Watershed (1998-2004)

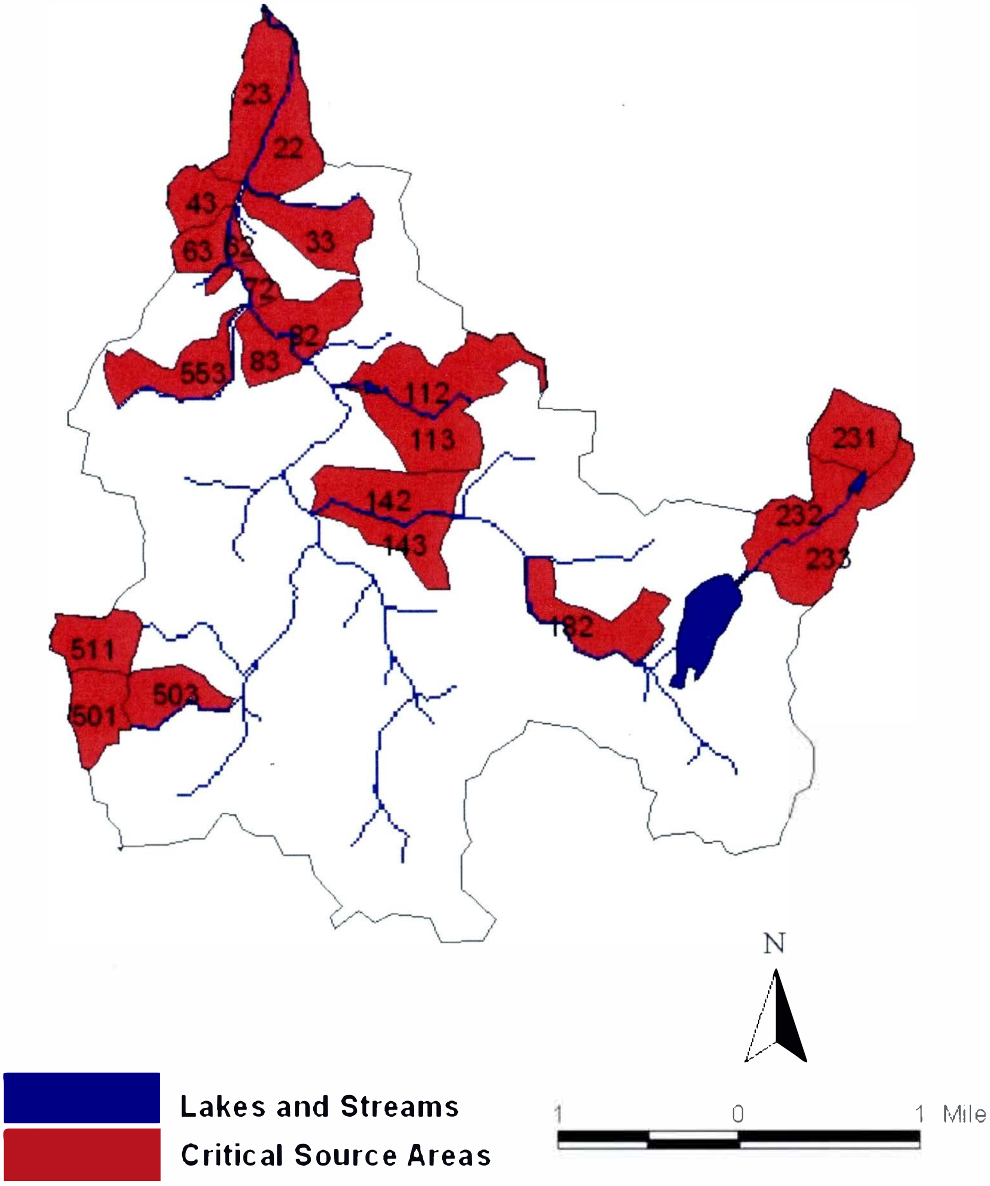

Figure 13: Identified critical source areas in the Davis Creek Watershed based on continuous simulation of sediment and nutrients loading (1998 to 2004)

Simulation of Management Scenarios

Once the critical source areas are identified, management scenarios are developed to simulate their effects on NPS loadings to support water quality programs in the Davis Creek. Three likely scenarios were developed and simulated for the period of 1998-2004 in addition to the current condition. These scenarios were developed based on the land use change between 1978 and 1996 (Limlahapun 2002).

Current condition: The year 2004 was used as baseline year.

No Till: The 2004 was used in this scenario with agricultural management practices changed to no till condition.

Agri-Urban: Assuming all agriculture land would be converted to urban land (industrial), since from 1978 to 1996, residential area was increased by 170 percent and industrial area was increased by 41 percent (Limlahapun, 2002).

Wetland: This scenario assumes an expansion of existing wetland by 432 hectares in the adjacent wetland located at upper stream.

The model was run with each scenario for the entire simulation period. The average simulated annual runoff, sediment yield, and nitrogen and phosphorus loadings were calculated and compared for each scenario.

Based on the simulation results, the Agri-Urban scenario agrees that it will increase runoff by 18 percent (Table 7), sediment loading by 2 percent (Table 8), nitrogen loading by 7 percent (Table 9), and phosphorus loading by 5 percent compared to the current condition (Table 10). The No Till scenario is simulated to produce some positive impacts on water quality. It is likely to reduce runoff by 7 percent (Table 7), sediment loading by 1 percent (Table 8), nitrogen loading by 2 percent (Table 9), and phosphorus by 3 percent (Table 10).

Table 7: Simulated surface runoff under different scenarios (cubic feet per second)

Year	Current	No Till	Change (percent)	Agri-Urban	Change (percent)	Wetland	Change percent)
1998	1.44	1.36	-5.2	1.75	21.6	1.77	23.0
1999	3.08	2.87	-6.6	3.50	13.9	3.41	10.8
2000	2.79	2.60	-7.1	3.32	18.8	3.23	15.7
2001	3.94	3.62	-8.2	4.77	20.9	4.57	15.8
2002	2.06	1.90	-7.4	2.41	17.2	2.32	13.1
2003	2.58	2.41	-6.7	3.01	16.8	2.94	14.0
2004	3.28	3.01	-8.2	3.98	21.5	3.85	17.2
Average	2.74	2.54	-7.1	3.25	18.7	3.16	15.6

Table 8: Simulated sediment load under different scenarios (ton/ha/year)

Year	Current	No Till	Change (percent)	Agri-Urban	Change (percent)	Wetland	Change (percent)
1998	0.46	0.45	-1.9	0.46	1.5	0.47	2.4
1999	0.36	0.36	-1.4	0.37	0.3	0.37	1.7
2000	0.52	0.52	-0.7	0.54	4.0	0.52	0.3
2001	0.68	0.68	1.3	0.69	2.2	0.68	0.8
2002	0.12	0.12	-0.5	0.13	3.0	0.13	1.6
2003	0.42	0.41	-2.8	0.43	2.1	0.42	1.2
2004	0.44	0.43	-2.0	0.46	3.7	0.44	-0.6
Average	0.43	0.42	-1.0	0.44	2.4	0.43	0.9

Table 9: Simulated total nitrogen load under different scenarios (kg/ha/year)

Year	Current	No Till	Change (percent)	Agri-Urban	Change (percent)	Wetland	Change (percent)
1998	0.88	0.87	-1.9	0.89	0.5	0.71	-19.6
1999	0.62	0.61	-1.4	0.69	11.5	0.47	-24.6
2000	0.76	0.75	-0.7	0.79	4.2	0.58	-23.3
2001	1.02	1.00	-1.6	1.04	2.3	0.87	-14.0
2002	0.38	0.37	-0.9	0.40	7.5	0.22	-41.7
2003	0.61	0.58	-4.8	0.67	9.9	0.46	-24.2
2004	0.74	0.71	-4.4	0.85	14.7	0.55	-25.8
Average	0.71	0.70	-2.2	0.76	7.2	0.55	-24.8

Table 10: Simulated total phosphorus load under different scenarios (kg/ha/year)

Year	Current	No Till	Change (percent)	Agri-Urban	Change (percent)	Wetland	Change (percent)
1998	19.68	19.12	-2.8	22.41	13.9	21.76	10.6
1999	69.43	69.36	-0.1	70.32	1.2	70.09	0.9
2000	36.70	35.02	-4.6	40.97	11.6	38.16	4.0
2001	140.99	135.47	-3.9	143.29	1.6	141.23	0.2
2002	55.94	56.72	1.4	58.76	5.0	57.02	1.9
2003	35.64	33.99	-4.6	39.82	11.7	37.16	4.3
2004	86.64	83.70	-3.4	91.90	6.0	84.57	-2.4
Average	63.57	61.91	-2.6	66.78	5.0	64.28	1.1

Note: Change is calculated for each scenario based on differences from the current scenario condition to each proposed scenario for each individual year

Restoring 432 hectares of agricultural land to wetlands will also have positive impacts on water quality as wetlands have important filtering capabilities for intercepting surface water runoff from higher dry land before the runoff reaches open water. As the runoff water passes through, the wetlands retain excess nutrients and some pollutants, and reduce sediment that would clog waterways (EPA 2005). In this study, the restoration will increases runoff by 15 percent because of higher curve number is used in model. As a result it increases sediment loading less than 1 percent. This restoration will reduce nitrogen load by one fourth (25 percent) but phosphorus will increase but only slightly (~1 percent).

If no till practices are implemented, the watershed's environmental health will be improved significantly. Even if current trends of industrialization continue in this area, it will not be so vulnerable for the water quality of the Davis Creek Watershed. Also wetland restoration might considerably recover water quality in the watershed.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The Davis Creek Watershed was identified as the most polluted tributary in the Kalamazoo County by the Nonpoint Source Pollution Advisory Committee of the River Partners Program (Forum of Greater Kalamazoo 1998). Using continuous simulation model AnnAGNPS, this study estimated sediment and nutrient loading (nitrogen and phosphorus), developed different management scenarios based on agricultural and land use practices, simulated the impacts of these scenarios on NPS loadings, and identified critical source areas. Erosion and sediment loading are high at the industrial zone in the urbanized core downstream but phosphorus and nitrogen loadings are high in the cropland throughout the watershed. The critical source areas were identified, which include areas near the downstream industrial area along with a few portions of the adjacent residential areas, and at upper stream croplands as well as cropland in the middle of the watershed area. Three types of agricultural management and land use scenarios were developed: No Till scenario, Agri-Urban scenario and Wetland scenario. Changing traditional agricultural practices to no till will reduce sediment and nutrient loadings. Urbanization or industrialization might increase sediment and nutrients in the watershed. Expansion of the wetland will reduce nitrogen loadings significantly but might increase sediment and phosphorus loading. This preliminary study is useful for water quality management in the Davis Creek Watershed.

Limitations of the Study

This study used multiple databases and AnnAGNPS to simulate the nonpoint source loadings in the Davis Creek Watershed. As shown in the model verification section, there are significant discrepancies between the simulated and observed identical variables in the watershed. The AnnAGNPS model requires a considerable amount of input data for some parameters. However, default values were used for some parameters as it was very difficult to determine the values for the watershed. In addition, then 1996 land use data was used for the entire simulation period of 1998-2004 as it was the most recent land use data available . A more current land use file might improve the simulation results. Further more, only three years of actual data from 1999 to 2001 were available to assess the simulation results. Even these data were not collected continuously throughout the year. A longer period and more frequent of in situ data could better calibrate the model for the study area. Finally, AnnAGNPS model is still in development stage and it has some limitations. For example, the AnnAGNPS model delineates watershed boundary based on DEM. It does not allow the incorporation of the existing or predefined watershed boundary. In this study, the DEM delineated watershed boundary was smaller than the official watershed boundary delineated by the Davis Creek watershed management team (343 hectare less than the official watershed boundary area, almost 9 percent). This may have effect on simulation results.

To improve the accuracy of the simulations, further studies should consider using most recent land use data and more accurate input parameters. In addition, a longer period of and more frequent in situ data should be collected to help better calibration in AnnAGNPS. Furthermore, other types of management scenarios can be developed and filed verified to provide more complete information of management in the Davis Creek Watershed.

BIBILIOGRAPHY

Baginska B., Mline-Home W., and Cornish P.S. 2003. Modeling Nutrient Transport in Currency Creek, NSW with AnnAGNPS and PEST. *Environmental Modeling & Software.* 18: 801-808.

Baker Kevin D., Theurer F. D., and Whitte J. 1995. AGNPS VERSION 5.00 VERIFICATION: Science, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi.

Barnes P. L. 2002. Hillsdale Lake (Kansas) Source Assessment of Sediment and Phosphorus Water Quality Impairments. Proceedings of the 2002 ASAE Annual International Meeting / CIGR XVth World Congress. Chicago, Illinois. July 28- 31, 2002.

Bingner, R. L., Murphree C.E., and Mutchler C.K. 1989. Comparison of sediment yield models on watershed in Mississippi. *Transactions of the ASAE.* 34 (2): 529-534.

Bingner , R. L. and Theurer F. D. 2001a. AnnAGNPS: Estimating sediment yield by particle size for sheet and rill erosion. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Reno, Nevada. March 25-29, 2001. p I1- I7.

Bingner R., and Yuan Y. 2001b. Evaluation of AnnAGNPS of Mississippi Delta MESA Watersheds. *Transactions of the ASAE.* 44 (5): 1183-1190.

Bingner R. L., Theurer F. D., and Yuan, Y. 2003. AnnAGNPS technical processes documentation, Version 3.3, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi.

Bosch D. D., Bingner R. L., Theurer F. D., Felton G., and Chaubey I. 1998. Evaluation of the AnnAGNPS Water Quality Model, ASAE paper no. 982195. Presented at the 1998 ASAE Annual International Meeting, Orlando, Florida, July 12-16, 1998. Online at http://www.cpes.peachnet.edu/sewrl/Papers/Paper003.PDF

Buckham K. 2005, Acting Administrator/Executive Director, Kalamazoo Conservation District. Portage, Michigan. Personal interview on December 15, 2004.

Chauby I. and Beck Jason M. 2001. Long-Term Nutrient Transport Assessment of Animal Manure from Agricultural Watersheds. Proceedings of the AWRA Annual Spring Specialty Conference on Water Quality Monitoring and Modeling, San Antonio, Texas, April 30 -May 02, 2001. p. 211 to 216.

Cluis D., Chardonneau G., Gangbazo G., and Proulx S. 2002. Testing the New AnnAGNPS Simulation Model on an Intensively Cultivated Watershed within the Canadian Climatic Context. Proceedings of International Conference on Management Information Systems Incorporating GIS and Remote Sensing, Chalkidikae, Greece, 2002, p. 389-400.

Connecticut Department of Transportation. 2000. ConnDOT drainage manual. Newington, Connecticut.
Online at http://www.ct.gov/dot/lib/dot/documents/ddrainage/6.C.pdf

Cronshey, R. G. and Theurer F. D. 1998. AnnAGNPS –Non-point pollutant loading model. Proceedings of the First Federal Interagency Hydrologic Modeling Conference, Las Vegas, Nevada, April 19-23, 1998. p. 1-9 to 1-16.

Darden, R., and Justice, V. 2003. AGNPS Input Data Preparation Model User's Guide, version 3.3. USDA-ARS, Nationa Sedimentation Laboratory, Oxford, Mississippi.

Finney, V. 2001. A Dynamic Process for Assessing the Impacts of Gravel Mining and Land Use Changes on the San Luis Rey River, CA. Proceedings of the Seventh Federal Interagency Sedimentation Conference, Reno, Nevada, March 25-29, 2001, p. XI 58 to XI 65.

Finney, V. L., and Abuin, A. (year unknown). Nutrient loadings to Lake Tahoe, CA from Cold Creek Watershed using the AnnAGNPS model. Printed from WWW. http://www.cal.net/~vfinney/banpaper/coldck.htm

(The) Forum of Greater Kalamazoo 1998. *Davis Creek Watershed Management Plan.* Online at: http://theforum.org/Docs/DCFullRpt.pdf

Garbrecht Jurgen, and Martiz L W. 1999. TOPAZ Overview, TOPAZ Version 3.1, USDA-ARS Grazinglands Research Laboratory, Oklahoma.

Geter W. F. and Theurer F.D. 1998. AnnAGNPS-RUSLE Sheet and Rill Erosion. Proceedings of the First Federal Interagency Hydrologic Modeling Conference, 19-23 April 1998, Las Vegas, Nevada, p. 1-17 to 1-24.

GIS Research Center. 2004. Land use data of 1996, Department of Geography, Western Michigan University, Kalamazoo, Michigan

GIS Research Center. 2004. Digitized SSURGO soil layer of Kalamazoo, Michigan, Department of Geography, Western Michigan University, Kalamazoo, Michigan

He C. 2005. Flow, sediment and nutrients data of Davis Creek Watershed, 1999-2001. Department of Geography, Western Michigan University, Kalamazoo, Michigan

He C. 2003. Integration of Geographic Information System and Simulation model for Watershed Management. *Environmental Modeling & Software.* 18:809-813.

He C., Shi C., Yang C., and Agosti B. P. 2001. A window-based GIS –AGNPS Interface. *Journal of the American Water Resource Association.* 37(2): 395-406.

Langendoen E.J. 2000. CONCEPTS- Conservation Channel Evolution and Pollution Transport System, Stream Corridor Version 1.0. Research report no. 16. USDA-ARS National Sedimentation Laboratory, Oxford, Mississippi.

Leon L.F., Lam D.C., Swayne D.A., Farquhar G. J., Soulis E.D. (2000). Integration of Nonpoint Source Pollution Model With A Decision Support System. *Environmental Modeling & Software*.15: 249-255.

Limlahapun, P. (2002). *Assessment of Land use/Land cover change Impact on Water Quality in The Davis Creek Watershed, Southwestern Michigan.* M.A. thesis, Western Michigan University, Kalamazoo, Michigan.

Mulik S. B. 2000. *Water Quality Assessment for a Kansas Watershed Using Continuous Simulation AnnAGNPS Model.* MS thesis, Kansas State University, Manhattan, Kansas.

Renard K. G., Foster G. R., Weesies G. A., McCool and Yoder, D.C., coordinators. 1997. Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Unified Soil Loss Equation (RUSLE). U.S. Department of Agriculture, Agricultural Handbook No. 703, 404 pp.

SCS. 1986. Technical Release 55: Urban Hydrology for Small Watersheds. Soil Conservation Service, USDA.

Simon A., Langendoen R., Bingner R., Wells R., Heins A., Jokay N., and Jaramillo I. 2003a. Lake Tahoe Basin Framework Implementation Study: Sediment Laodings and Channel Erosion. USDA-ARS, Oxford, MS.

Simon A., Langendoen R., Bingner R., Wells R., and Alonso V.V. 2003b. Combined Geomorphic and Numerical-Modeling Analysis of Sediment Loads for Developing Water-Quality Targets for Sediment. Proceedings of the First Interagency Conference on Research in the Watersheds. Benson, Arizona. October 27-30, 2003. p. 455-460.

Srivastava, P., Hamlett J. M., and Robillard P. D. 2003. Watershed Optimization of Agricultural Best Management Practices: Continuous Simulation Versus Design Storms. *Journal of the American Water Resource Association.* 39(5): 1043-1054.

Suttles J. B., Vellidis G., Bosch D. D., Lowrance R., Sheridan J. M., and Usery E.L. 2003. Watershed- Scale Simulation of Sediments and Nutrient Loads in Georgia Coastal Plain Streams Using the Annualized AGNPS Model. *Transactions of the ASAE.* 46 (5): 1325-1335.

Theurer F.G. and Clarke C.D. 1991. Wash Load Component for Sediment Yield Modeling. Proceedings of the Fifth Federal Interagency Sedimentation Conference, Las Vegas, Nevada, March 18-21, 1991, p. 7-1 to 7-8.

United States Environmental Protection Agency, 2004. Best management practices, http://www.epa.gov/ebtpages/envibestmanagementpractices.html

United States Environmental Protection Agency, 2004. Total Maximum Daily Load, http://www.epa.gov/owow/tmdl/intro.html#definition

United States Environmental Protection Agency 2003. *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. Office of Water, USEPA, Washington D.C. EPA-841-B-03-004

Unite State Geological Survey, 2004. USGS Seamless Data Distribution Center. http://seamless.usgs.gov/

USDA NRCS. 2004. Soil Data Mart. http://soildatamart.nrcs.usda.gov/

USDA ARS. 2004. AnnAGNPS v 3.4 input file specifications, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi.

USDA ARS, 2001a. AnnAGNPS Version 2: user documentation, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi.

USDA ARS, 2001b. AnnAGNPS Version 2: output file specifications, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi.

USDA ARS. 1999. Generating climate data for AnnAGNPS, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi.

USDA ARS. 1998. Run output processor model, USDA-ARS, National Sedimentation Laboratory, Oxford, Mississippi.

Young, R. A., Onstad, C. A., Bosch D. D., and Anderson, W. P. 1989a. AGNPS user's guide. Version 3.5. USDA-ARS North Central Soil Conservation Research Laboratory, Morris, Minnesota.

Young, R. A., Onstad, C. A., Bosch D. D., and Anderson, W. P. 1989b. AGNPS: A nonpoint-source pollution model for evaluating agricultural watersheds. *Journal of Soil and Water Conservation*. 44 (2): 168-173.

Yu Shaw L., Zhen J. X. and Zhai S. Y. 2003. Development of a stormwater best management practice placement strategy for the Virginia department of transportation, Final contract report, Virginia Transportation Research Council, Charlottesville, Virginia.

Yuan Y, Bingner R. L., Rebich R A. 2003. Evaluation of AnnAGNPS Nitrogen Loading in An Agricultural Watershed. *Journal of the American Water Resource Association*. 39(2): 457-466.

Yuan Y, Bingner R. L., Dabney S. M. 2002. Cost effectiveness of agricultural BMPs for sediment reduction in the Mississippi Delta (best management practices). *Journal of Soil and Water Conservation*. 57(5): 259(9).

Yuan Y, Bingner R. L Dabney S. M. 2001. Evaluation of Agricultural BMPs for sediment reduction using. Proceedings of the American Water Resource Association Annual Spring Specialty Conference. April 30-May 02, 2001. p. 275-280.

Wonders G. 2004. Location Manager, Wilbur-Ellis, School Craft, Kalamazoo, Michigan. Personal interview on December 23, 2004.