

***NITRATE LOADING MAP/REPORT FOR
SOUTHERN GILCHRIST AND NORTHERN
LEVY COUNTY, FLORIDA
(WAM ASSESSMENT OF FANNING SPRINGS)***



Submitted by

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WAM ASSESSMENT OF FANNING SPRINGS

INTRODUCTION

The purpose of this project was to simulate water and nitrogen discharges from Fanning Springs located within the Suwannee River Basin. The study area is 119 square miles in size and is located in portions of Gilchrist and Levy Counties. (see Figure 1).

Land use within the watershed varies from urban to rural and agricultural. The four most dominant land uses are agricultural (40%), rural upland (39%), wetlands (10%) and urban (8%). The dominant agricultural land use is pastureland (77%). The dominant rural upland land use is pine flatwoods (65%).

The study area was delineated by the Florida Department of Environmental Protection based on their estimated groundwater-shed or springshed for Fanning Springs. The springshed crossings two surface flow drainage basins. The western 72 percent of the springshed has surface runoff draining to the west toward the Suwannee River. The remaining 28 percent drains southeast and ultimately to the Wacassasa River. All groundwater within the study area was assumed to drain west to Fanning Springs, which is located east of and adjacent to the Suwannee River. It is common in this part of Florida for surface and groundwater to drain in different directions. Though surface runoff could flow two directions, very little surface runoff actually occurs within the springshed because the majority of the areas are closed basins, i.e. areas with high infiltration rates and depressions that traps runoff and percolates it to groundwater. Only areas near the Suwannee River and the southern portion of the Wacassasa River subbasin have surface runoff leaving the study area.



Figure 1: Fanning Springs Watershed Location

1. WAM Model Approach

WAM was utilized to estimate the flow and nutrient loads discharged from the Fanning Springs springshed because of its ability to assimilate both surface and groundwater flow and water quality by taking into account land source loads and appropriate attenuation processes along the flowpath. WAM is a Geographic Information System (GIS) based model that allows engineers and planners to interactively simulate and assess the environmental effects of various land use changes and associated land use practices.

WAM utilizes ESRI™ ArcView 3.2 with Spatial Analyst 2.0 to analyze and display model input and output using grids. Grid datasets, as opposed to polygon datasets, spatially represent

geographic data as a collection of raster cells. Each cell contains attributes of the dataset, e.g. land use code numbers that can be overlaid with cells of other grids. The benefits of using grids over polygons include computational speed and output resolution. Output can be displayed by grid cell as opposed to by subbasin polygon. The cell size is dependant on the desired resolution. A grid cell size of 1 ha was chosen with the intent that this would adequately characterize the land use and capture linear features such as highways.

The GIS based processing and user interface in the WAM model allows for a number of user options and features to be provided including:

- Source Cell Mapping of TSS and Nutrient Surface and Groundwater Loads
- Tabular Ranking of Land Uses by Constituent Contributions
- Overland, Wetland, and Stream Load Attenuation Mapped Back to Source Cells
- Accommodation of Point Source Information
- Adjustments based on WWTP Service Area locations
- Hydrodynamic Stream Routing of Flow and Constituents with Annual, Daily or Hourly Outputs
- User Interface to Run and Edit Land Use and BMP Scenarios

The water quality parameters (impact parameters) simulated within the model include: Water quantity, soluble nitrogen (N), particular N, groundwater N, soluble phosphorus (P), particulate P, groundwater P, sediment and biological oxygen demand (BOD). GIS datasets of land use, soils and rainfall are used to calculate the combined impact of the watershed characteristics for a given grid cell. Once the combined impact for each unique cell within a watershed is determined, the cumulative impact for the entire watershed is determined by first attenuating the constituent to the nearest stream or spring, and then calculating an area-weighted ranking/index for the attenuated load generated at each cell. Constituents are attenuated based upon the flow distances (overland to nearest water body, through wetlands or depressions and within streams to the sub-basin outlet), flow rates in each related flow path and the type of wetland or depression encountered. Figure 2 shows the conceptual routing schemes and flow distances that are calculated for each cell.

WAM estimate the fraction of water going to surface and groundwater based on the individual cell's land use and soil type. Surface flow that enters depressions is also converted to groundwater. Groundwater is routed to the nearest stream unless directed otherwise by the GWNODE grid.

The hydrologic constituent transport modeling is accomplished by first simulating all of the unique grid cell combinations of land use, soils, and rainfall by using one of several source cell models including GLEAMS (Knisel, 1993), EAAMOD (Botcher et al., 1998; SWET, 1999), a wetland module, and an urban module. These models are called by BUCSHELL.exe based on the land use of the unique combination. The time series outputs for each grid cell is then routed and attenuated to the nearest stream and then through the entire stream network of the watershed. Dynamic routing of flows is accomplished through the use of an algorithm, BLASROUTE.exe, that uses a non-linear reservoir technique (Jacobson et al., 1998). Figure 3 shows a flow diagram of the hydrologic contaminant transport modeling component of the overall WAM model.

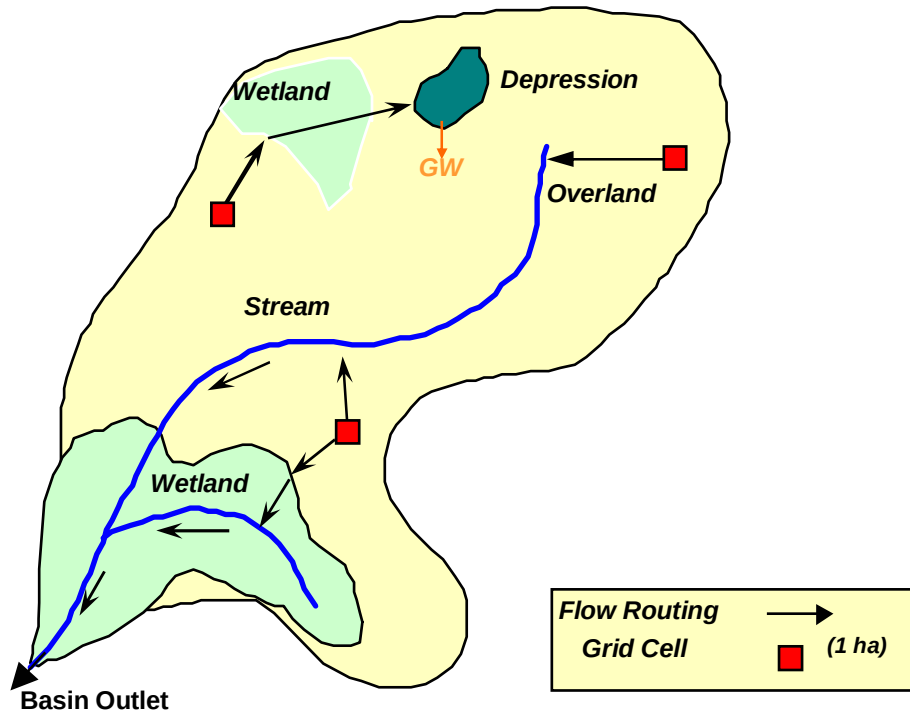


Figure 2: WAM Conceptual Routing Diagram

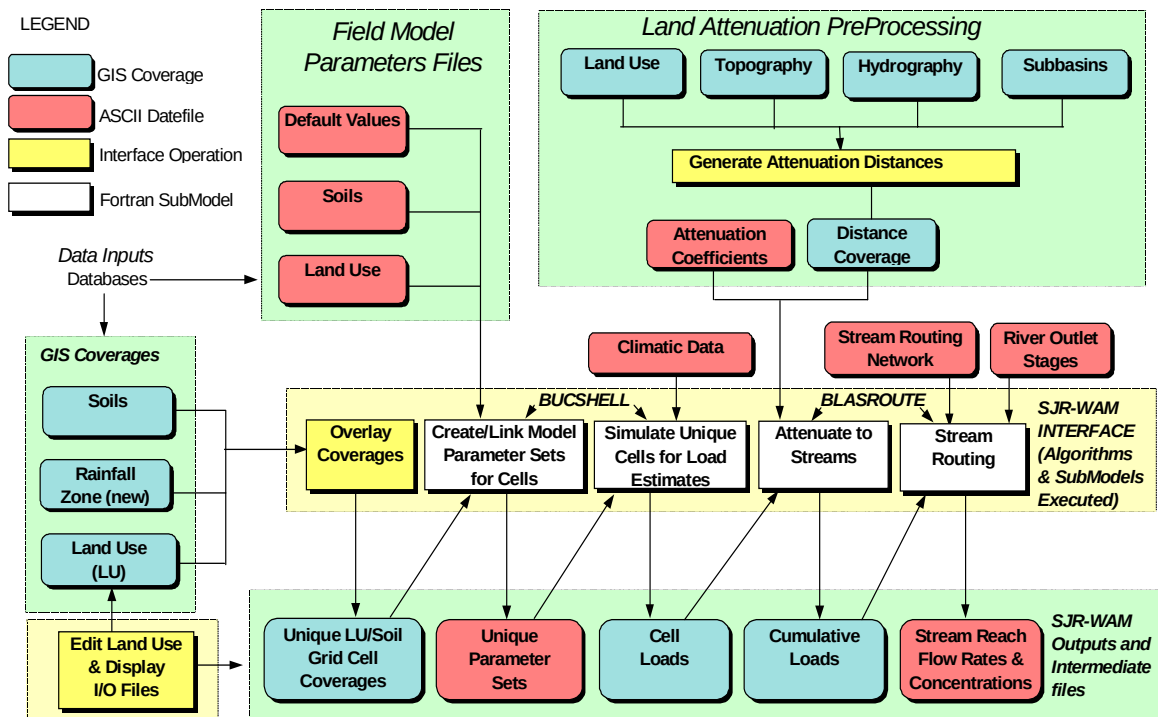


Figure 3: Dynamic Modeling Approach

2. WAM Setup

2.1 Overview

WAM utilizes the programming language known as Avenue™, which comes with ArcView™, to run the graphical user interface. A separate interface is also available for setting up WAM for a specific watershed. There were two setup procedures followed, as described in the WAM User Manual.

The Primary Basin Setup was used to create an ArcView project file for the primary basin, Fanning Springs. The term “primary basin” in WAM refers to a collection of subbasins or basins that discharge to a single receiving water body. In this study, the Fanning Springs basin is the only primary basin. The primary basin setup procedure was followed as described in detail in WAM’s User Manual. This procedure includes the following seven steps:

- Step 1: Create Project and View
- Step 2: Generate Reaches
- Step 3: Generate Depressions
- Step 4: Generate Distances
- Step 5: Re-assign Groundwater
- Step 6: Build Reach Sections
- Step 5: Create Default Output

The Watershed/Springshed Setup procedure was followed to create the main interface for WAM to reflect this geographic region. The main interface, when completed, provides project management tools and a means to select a primary basin to be assessed. In this case, there is only one basin to select. This procedure includes the following four steps, which are described in detail in the User Manual:

- Step 1: Select Base Maps
- Step 2: Select BMPs
- Step 3: Setup Watershed View
- Step 4: Customize Interface Layout

2.2 GIS Datasets

All of the GIS datasets necessary to set up WAM for Fanning Springs were obtained from a previous setup of WAM that spanned the entire Suwannee River Water Management District (SWET, 2003). The datasets are projected in Florida Department of Environmental Protection’s (FDEP’s) custom Albers projection in the HPGN (metric) datum. It was advantageous to utilize the previous datasets because they included modifications to expand poultry and dairy farms to represent more than just the barns, which is how they were represented in the original polygon coverage that SRWMD commissioned in 1995. The soil grids were originally created from polygon datasets obtained from NRCS and modified to include abbreviated Compname soil designations in order that these attributes would match WAM soils database established for the State. The topography was originally obtained from USGS. The above datasets were clipped to the extent of the Fanning Springs watershed as provided by FDEP.

National Hydrologic Datasets (NHDs) were used for the hydrologic stream network of the original WAM setup. However, the Fanning Springs watershed does not include any surface hydrologic features. Small “stub” reaches for both surface and groundwater flow were placed at the boundary of the watershed to form collection points whereby the discharges could be quantified. The Primary Basin Setup procedure available in WAM was utilized to layout and code these reaches. The selected segments, when finished, are referred to in WAM as model reaches within the hydrologic network. The model reaches created for Fanning Springs are shown in a later section 2.4 (Figure 5).

2.3 Rainfall

Rainfall datasets were created for the original SRWMD WAM setup using monitoring data obtained from SRWMD. The stations were initially chosen based on their locations for adequate spatial coverage of the study area and for an appropriate period of record. A 24 year period between January 1980 and December 2003 is available in these datasets. The model uses, but throws away the first five years of data. These five years are used to reach an equilibrium with antecedent conditions.

Theissen’s method was applied to create rainfall zones for each station as shown in Figure 4. Fanning Springs spans two rainzones.

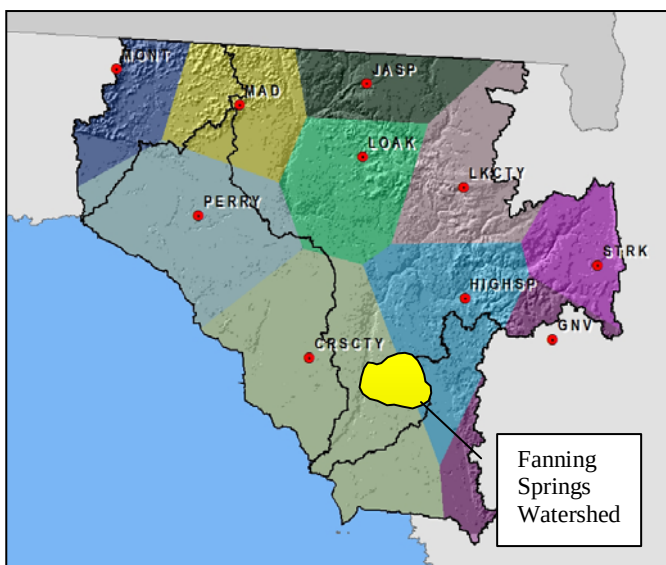


Figure 4: Rainfall Stations and Zones

2.4 Depressions

Depressions are one of the three geographic features (wetlands, streams and depressions) that WAM routes runoff to and attenuates constituents. Areas that drain to depressions are attenuated differently than areas that drain via surface water to the streams. Runoff entering depressions converts to groundwater with very little phosphorus and no suspended solids re-emerging in the streams.

Depress.asc is an ASCII grid of topographical and potential isolated depressional areas that is created by an algorithm in the WAM Primary Basin Setup. This algorithm utilizes wetlands from the land use dataset, depressional soils, such as Surrency, from the soils dataset, hydrography, and topography. The first step is to produce a grid of topographical depressed areas based on the topography grid, which was created from the USGS DEMs in a previous task of this study. Grid functions available in ArcView™ Spatial Analyst, that are intended to find and correct topographic sinks, are used to locate these depressions and determine their minimum elevation and depth at which runoff overflow would occur. The depth is added to the minimum elevation to determine the overflow elevation. All elevations equal to less than this elevation in the region of the sink are identified and converted to a new grid of topographic depressions.

The next step is to create a wetland and depressional soil grid by selecting and merging those features from their respective source grids. These areas represent potentially depressional areas as opposed to topographic depressions. Both grids are then converted to polygon shapefiles where they are subjected to screening processes.

The first screening process includes removing potential depressions that lie in areas where land slopes are sufficient to generate runoff discharge. The topography grid is used to create a grid of slope values. Polygons of potential depressional areas that lie over an area with an average slope that is above a set minimum slope are then removed.

The hydrography dataset is used in the algorithm to eliminate areas that are on or near “connected” hydrologic features. Connected features represent those line segments of the hydrography that form a contiguous drainage network including boundaries of lakes and wetlands. Any such boundaries that are isolated away from the connected system are not utilized in the analysis. Polygons that are within a set distance from the connected system are removed in both the topographic and potential depression shapefiles. This is based on the assumption that if the depression is close enough to the stream network, it is most like connected to the network somehow.

Default input was utilized as shown in Figure 5. This input was established by the software developers, Soil and Water Engineering Technology, Inc., for other similar projects in the State of Florida (SWET, 2002). Figure 6 shows the results of the overall analysis for depressions. The abundance of depressions and lack of surface hydrologic features implies that a significant amount of the runoff in this watershed go to groundwater.

The model reaches are setup as follows: Reach 1 is the Suwannee stage boundary reach which is an input. Reach 2 is simply the overall accumulation reach of all surface and groundwater flows from all the indicated reaches in Figure 5. Reach 3 collects whatever surface runoff occurs from the western portion of the springshed. Reach 4 and 6 are groundwater reaches to represent the actual spring (Fanning) outflow. The reason two groundwater reaches are used is to be able to show the difference of the size of the springshed would make. Reaches 4 and 6 represent the originally springshed as provided from FDEP. However, it was found that the original springshed produced too much flow and therefore was split where the new reach 6 represented a more appropriately sized springshed to produce the observed flow. Reach 5 collects whatever surface runoff occurs from the eastern most subbasin.

Create Depression Grid

This script will produce a grid of topographical and other potential depressions. Topographical depressions include closed sinks of a specified depth or greater that are located away from streams. Other potential depressions include wetlands and/or depressional soils that exist in flat areas away from streams. A grid of topography must be available in order to execute this script. If topography is unavailable, press Cancel - depressions will not be built and the model will assume that depressions do not exist. Otherwise, enter the information below:

ADAMSVILLE
ALAGA
ALAPAHA
ALBANY
ALLANTON
ALPIN

Select One or More Depressional Soils:

Add >
< Remove

SURRENCY

Minimum Size to be Considered a Depression: 4 Hectares
Minimum Depth for Topographical Depressions: 1 Feet
Minimum Setback From Rivers, Streams, Etc.: 200 Meters
Maximum Slope for Potential Depressions: 1 Percent

Proceed Cancel

Figure 5: WAM Depressions Setup

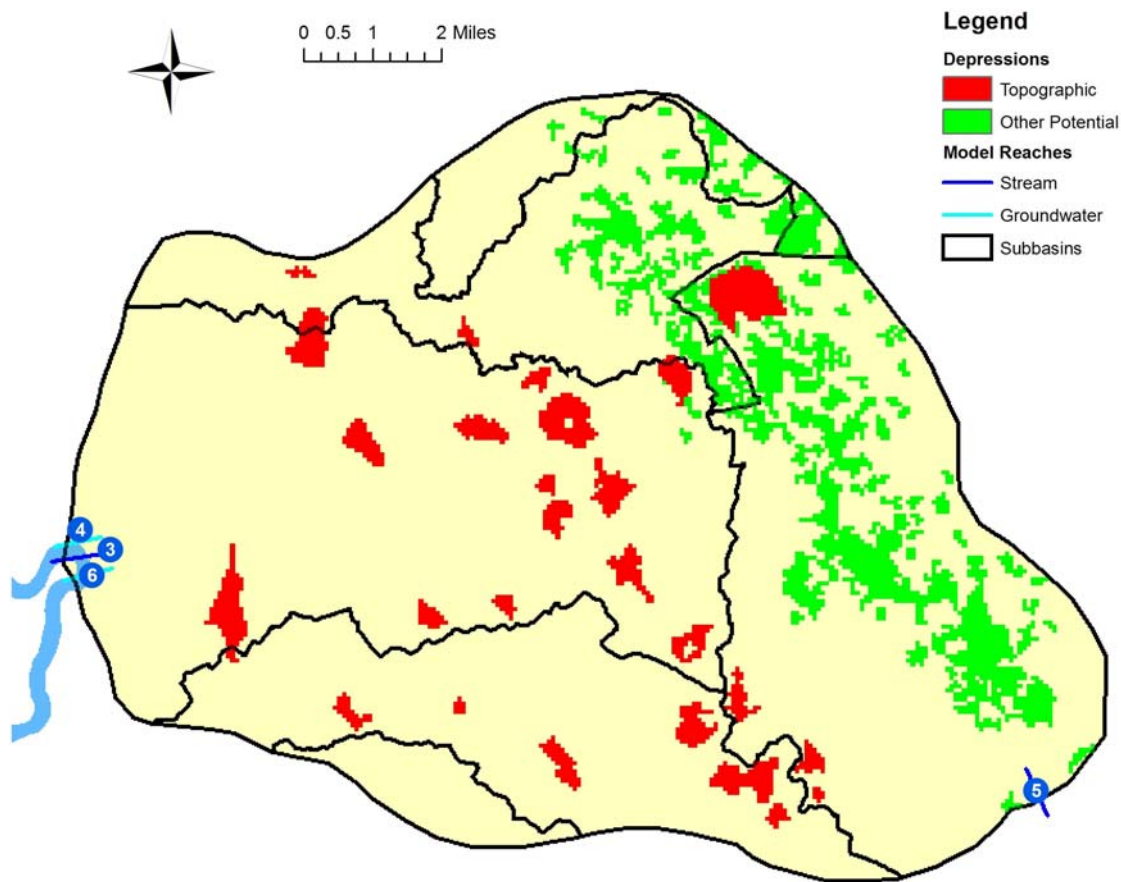


Figure 6: Model Reaches and Estimated Depressions

2.5 Attenuation Distances

WAM attenuates water quality parameters in the runoff based on distances and the type of geographic feature the runoff passes through such as upland, wetland, depression and stream. The WAM Primary Basin Setup includes an algorithm to develop a series of ASCII grids for this purpose. ArcViewTM Spatial Analyst cost distance functions are employed to both determine distance and attributes of the feature that is found. For example, when the closest wetland is found, the wetland FLUCCS number can also be returned. In addition, a grid of wetland distances to streams can be accessed to return the distance to the next feature. The distance and attribute grids created in this process are described below:

CellDist1.asc:	Grid of distance from land cell to closest stream reach.
CellDist2.asc:	Grid of distance from land cell to closest wetland.
CellDist3.asc:	Grid of distance from land cell to closest depression.
CellDist5.asc:	Grid of distance from wetland to closest stream reach.
CellDist6.asc:	Grid of distance from depression to closest stream reach.
CellDist7.asc:	Grid of distance from land cell to closest groundwater outflow stream
StreamNode.asc:	Grid of stream reach closest to land cell.

DepressNode.asc:	Grid of stream reach closest to depression.
WetlandNode.asc:	Grid of stream reach closest to wetland.
WetLandUsecode.asc:	Grid of land use codes for wetlands for calculating attenuation of surface flow.
GWNode.asc	Grid of stream reach# for groundwater outflow, i.e. spring reach

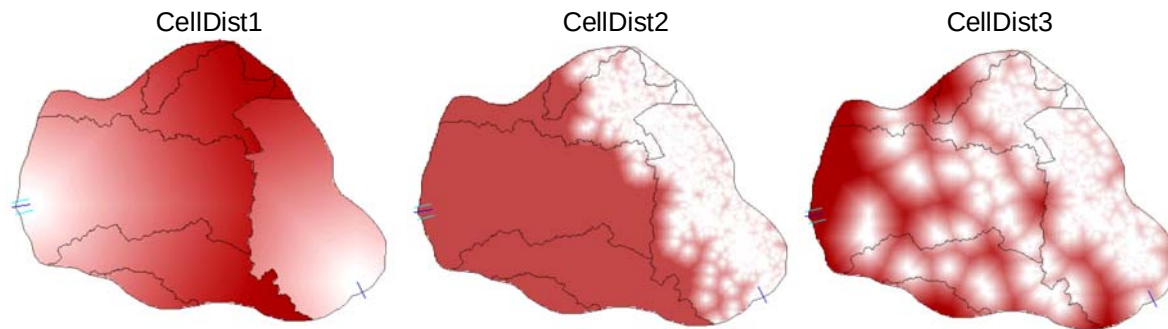


Figure 7: Sample Distance Grids (shaded light to dark, low to high distances)

2.6 Groundwater

An option in WAM allows groundwater to be routed to specified locations/reaches that are not necessarily the closest downstream waterbody, which is how surface water is routed. Springsheds indicate the areas that contribute groundwater to individual spring reaches. Fanning Springs is located in the western portion of the study area adjacent to the Suwannee River. The area corresponding to this springshed was designated with a stream reach number specifically created to represent the spring. For this project, initially the entire study area was assumed to contribute groundwater to the spring and, therefore, was designated as a single groundwater zone despite the fact that surface runoff in the easternmost subbasin drains elsewhere. However after preliminary runs it was clear that the provided springshed was probably too large, i.e. produced more flow than was observed in the spring. Therefore, as indicated in Section 2.4, the springshed was split into two groundwater zones as shown in Figure 8 after the initial modeling results were reviewed (Section 2.7).

2.7 Model Runs and Verification

This section provides the results and verification of the WAM simulations for Fanning Springs. As previous indicated the original springshed provided by FDEP appeared to be too large for the amount of flow measured at the spring. Figure 9 shows the simulated flow for the original and the two split springsheds (inner and outer) against the observed flow for Fanning Springs (FLOWCFS). As seen the smaller inner springshed more closely matches the observed flow. Figure 10 shows the simulated versus the measured total nitrogen concentration in the spring. As can be seen, the inner springshed clearly has higher nitrogen source areas than the outer area, but still does not reach the nitrogen levels observed in the spring though the trend in the last few years is similar. The discrepancy between the observed and simulated nitrogen level are likely

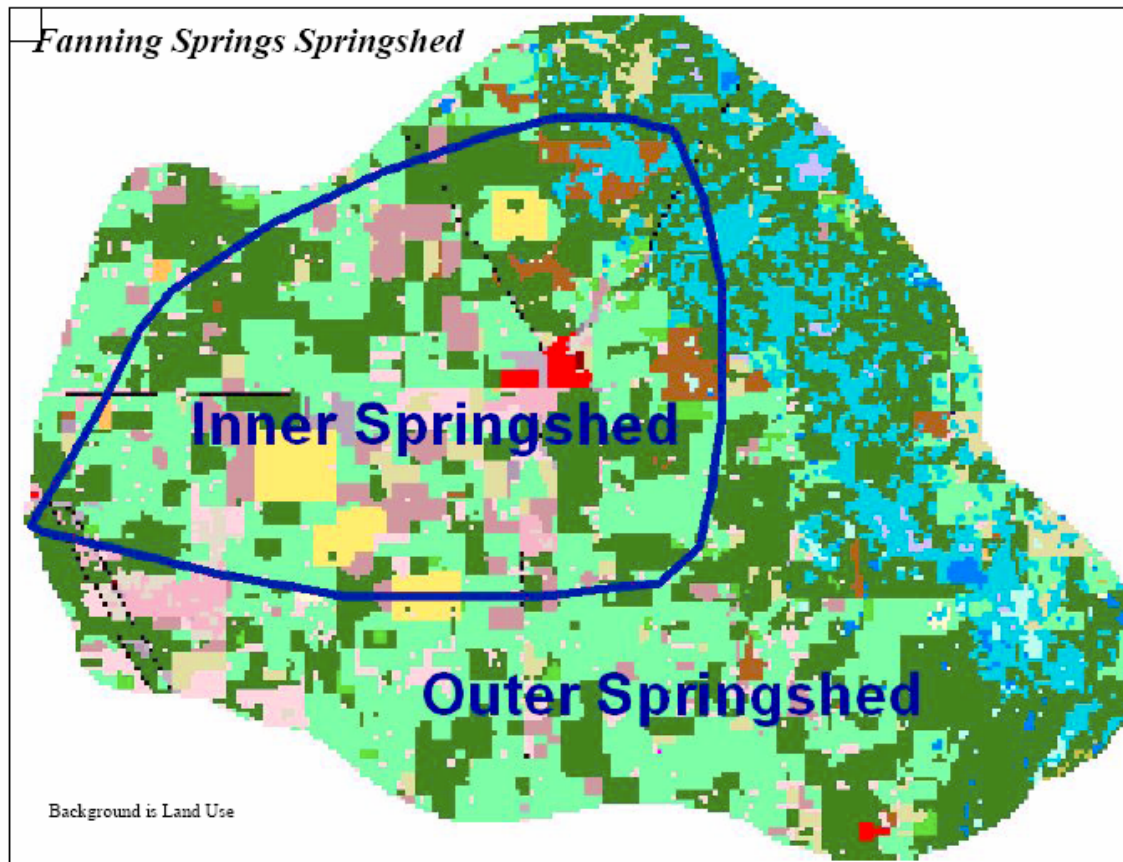


Figure 8. Diversion of Original Springshed into Two Smaller Springsheds.

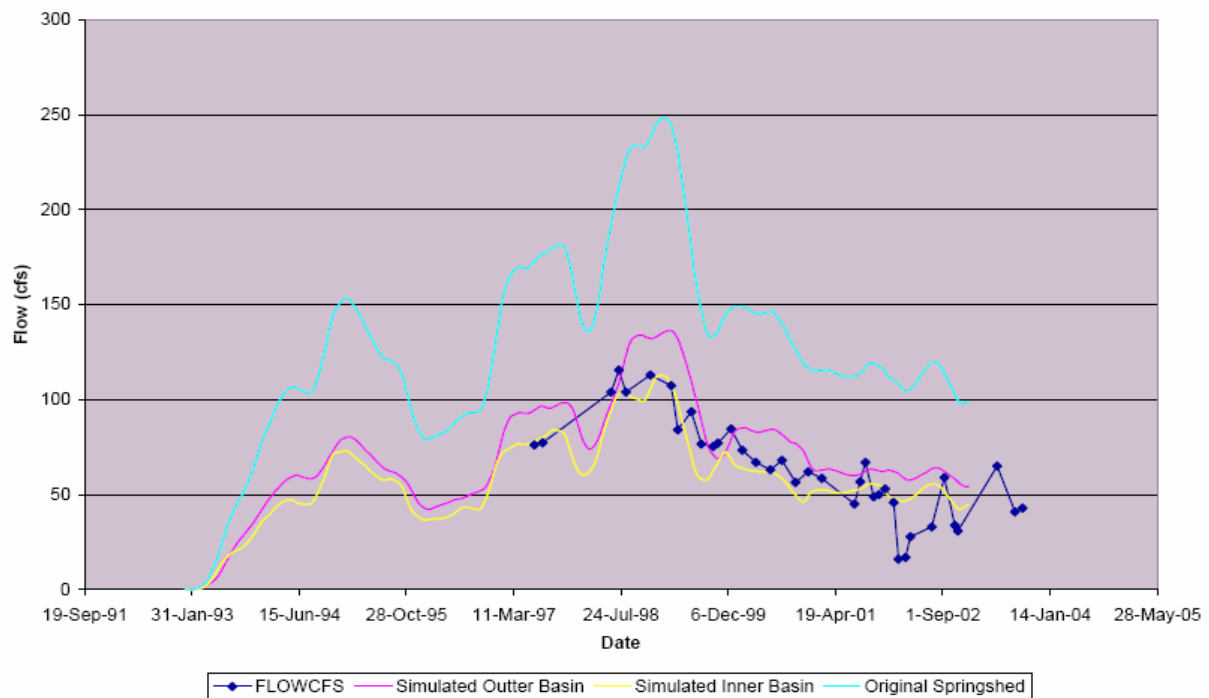


Figure 9. Simulated Flow for Fanning Springs for the Original and Two Split Springsheds

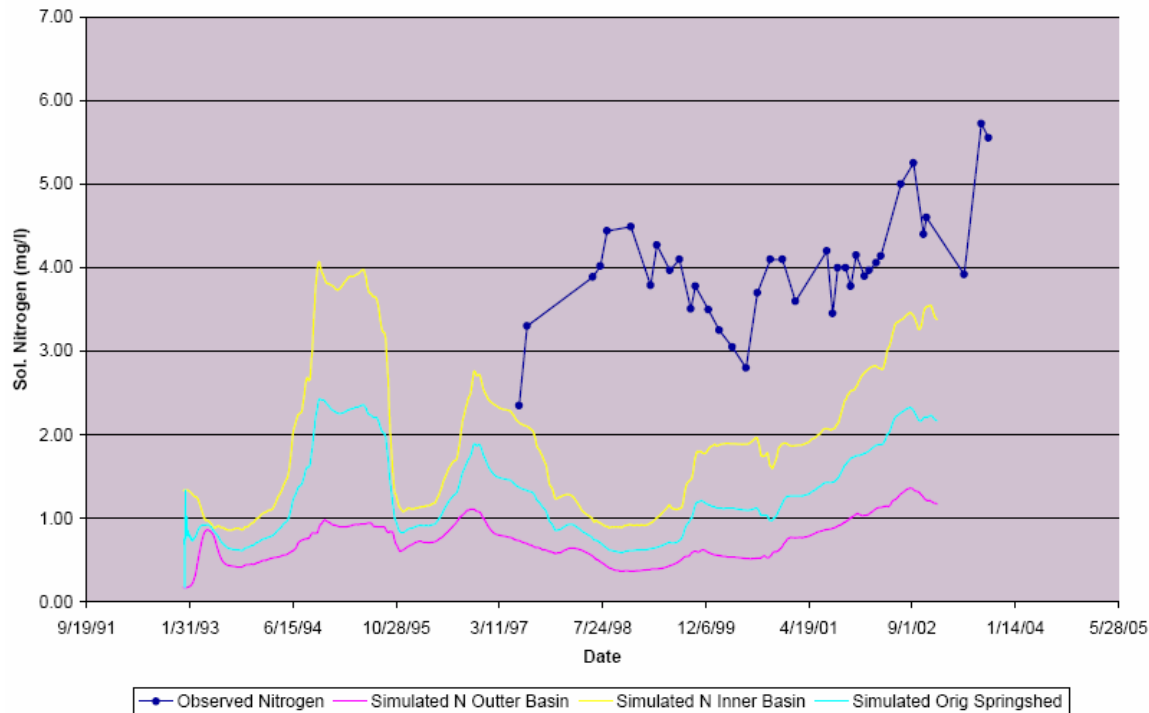


Figure 10. Simulated versus Observed Nitrogen Concentration in the Fanning Springs.

due to land use changes within the springshed since the 1995 coverage used in this study, actual fertilizer use and animal densities for mapped land uses are higher than assumed by the model, or the springshed area is not appropriately mapped.

3. WAM Interface and Example Results

As indicated the WAM interface uses ArcViewTM. ArcViewTM comes with many features that experienced users have become proficient with and accustomed to using. The concept of WAM interface, however, was to leave the functionality of ArcViewTM for the more experienced users, but also include simplified WAM functions that allow inexperienced ArcViewTM users to made full use of WAM.

The interface is described in detail along with tutorials in the User Manual/Help file. The intent of the interface is to allow users to 1) review model input datasets, 2) create and run modeling scenarios with modified land use and/or land use practices and 3) review output for existing and modified land use scenarios in the form of maps, tables and graphs. The following figures illustrate how WAM can be used to view model input and output grids. For this project, the ability to modify and run land use scenarios was not needed. The project goal was to only run the model for the existing land use scenario.

Figures 11 through 14 show input grids of subbasins, land use, soils and topography, respectively for the study area. Figure 15 shows the results for soluble nitrogen and sediment nitrogen for surface runoff. However, most if not all of the surface generated nitrogen shown in Figure 15 will flow to depressions and enter groundwater through recharge. Figure 16 shows the results direct groundwater nitrogen recharge.

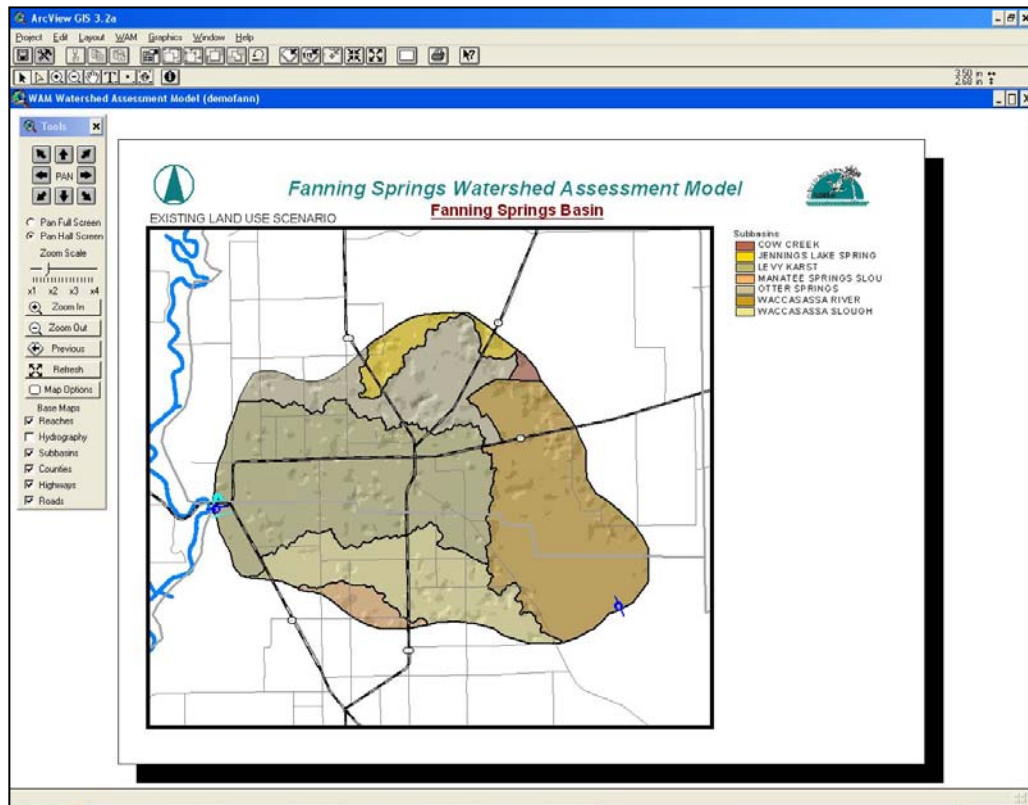


Figure 11: Subbasins

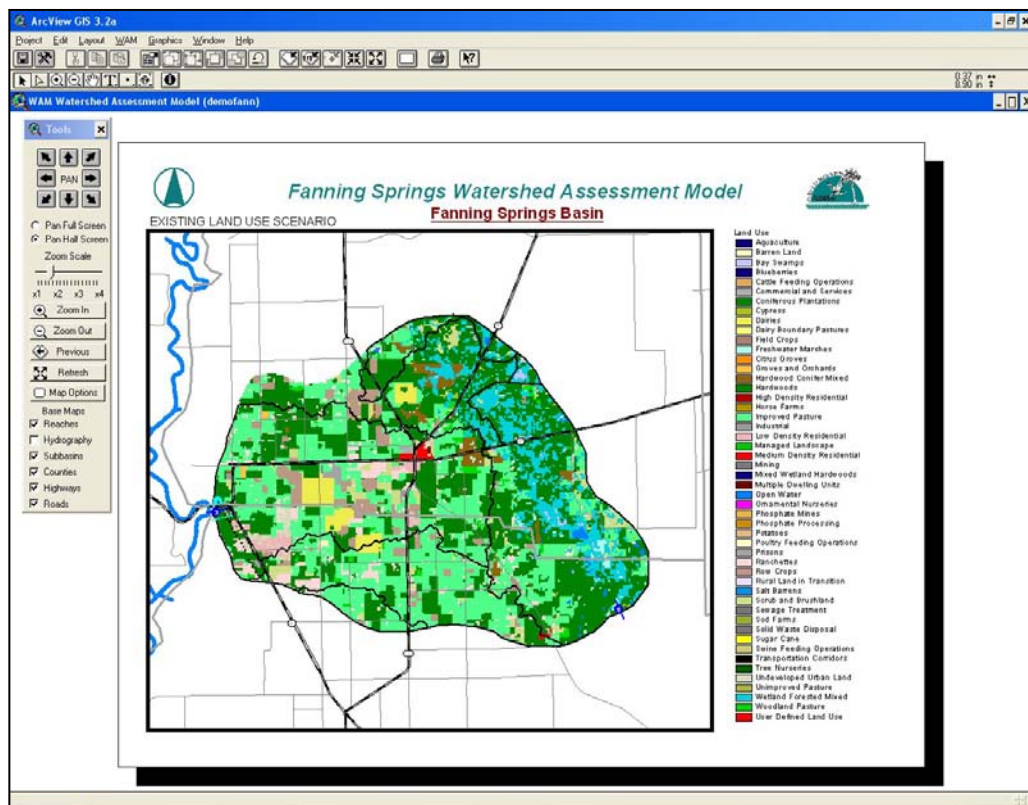


Figure 12: Land Use

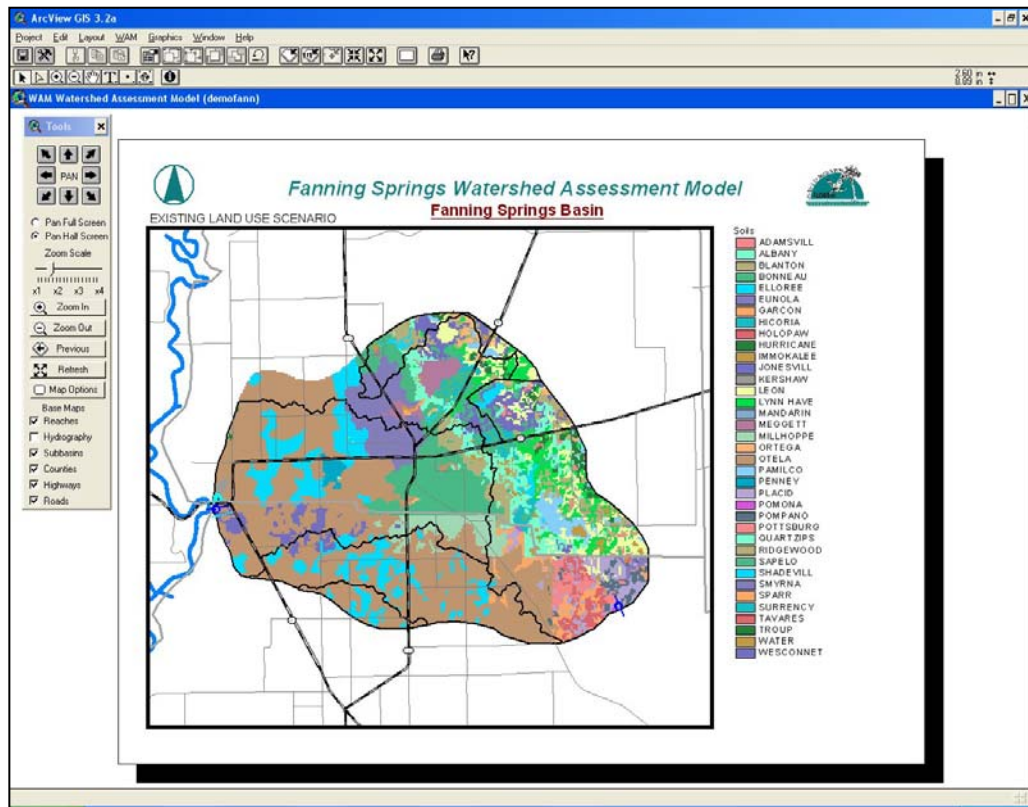


Figure 13: NRCS Soils

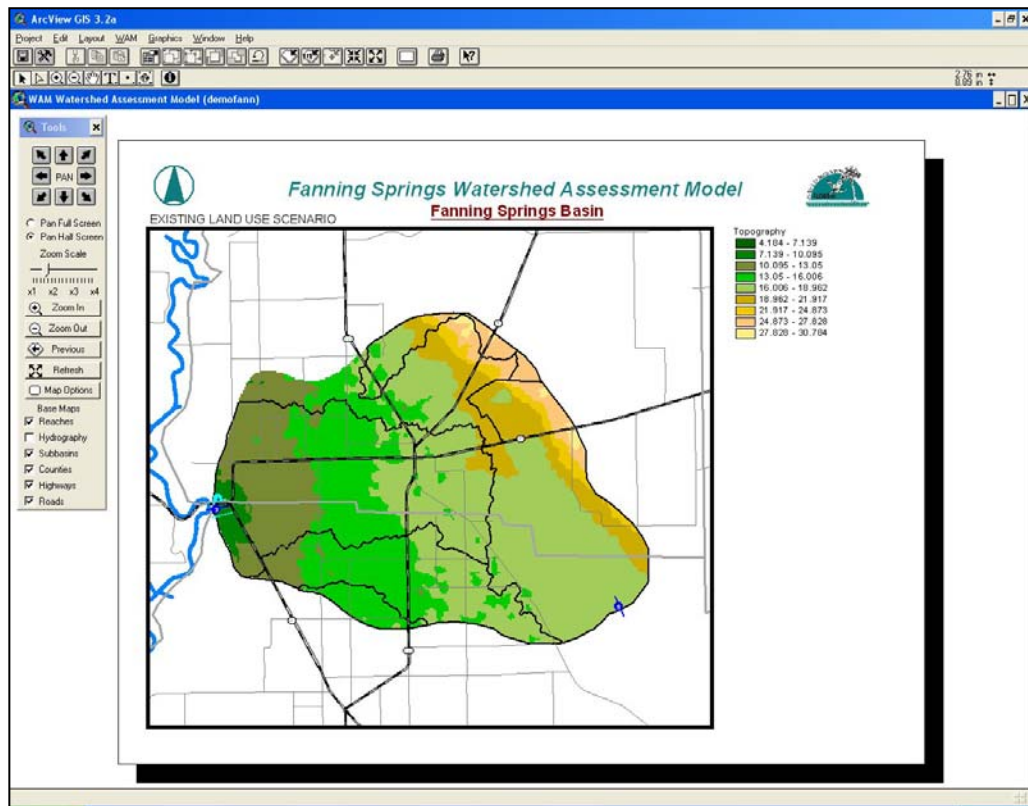


Figure 14: USGS Topography

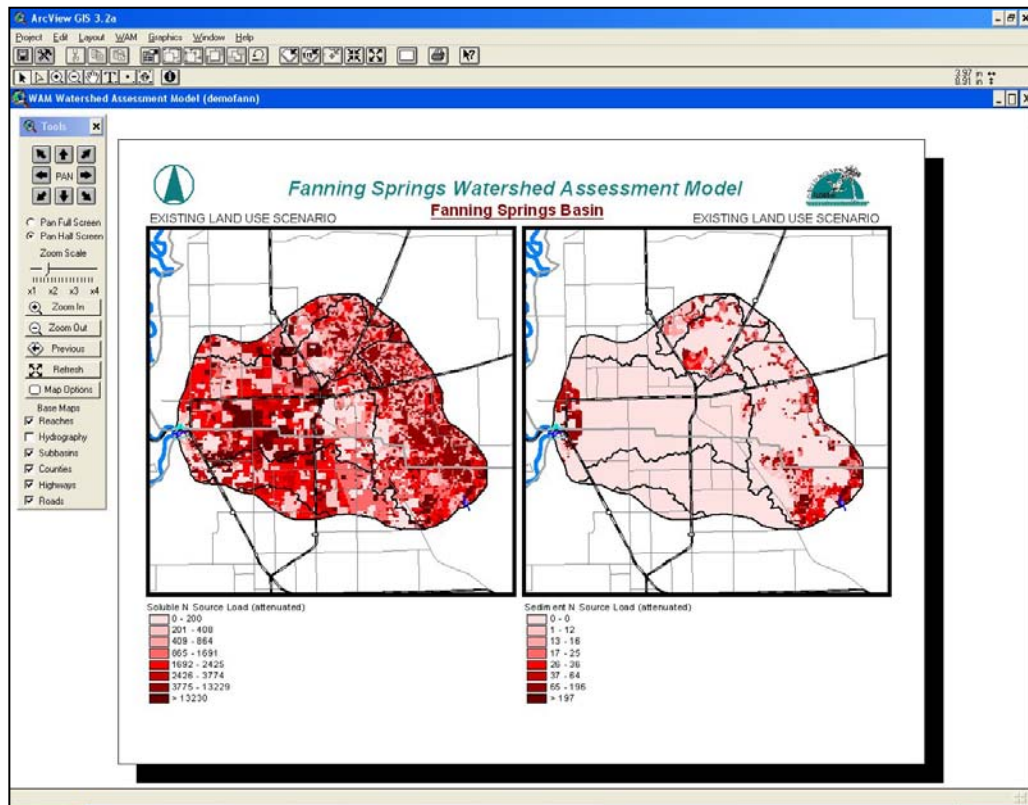


Figure 15: Soluble and Sediment Nitrogen Model Results

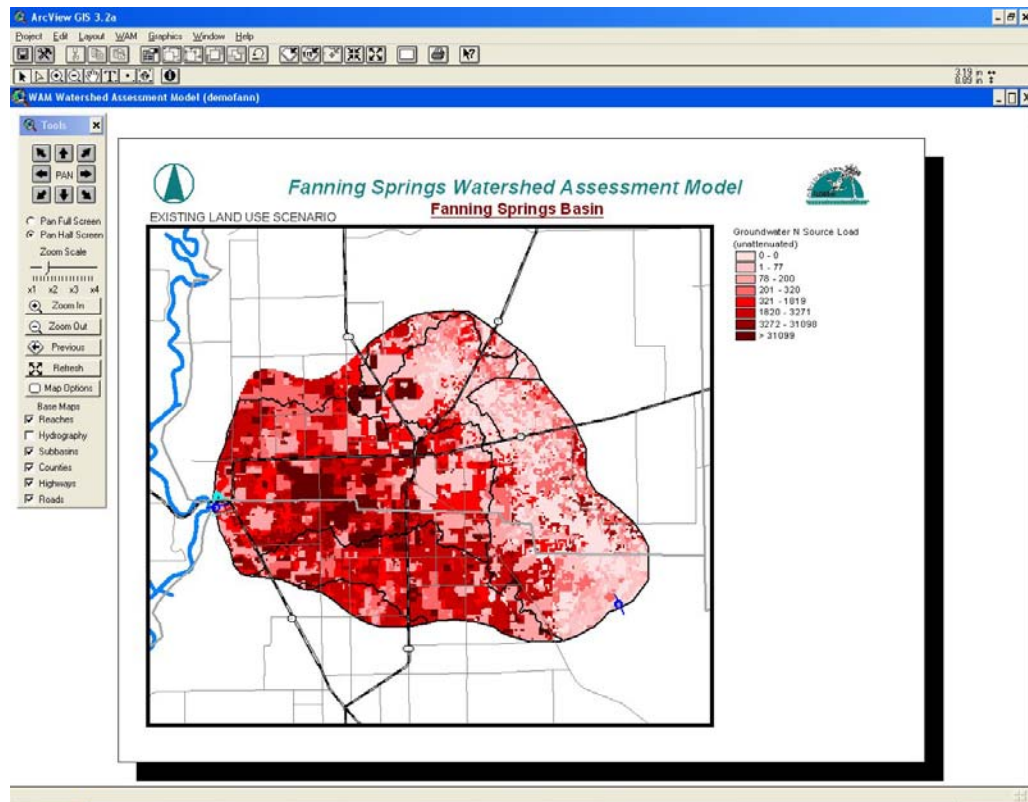


Figure 16: Groundwater Nitrogen Model Results

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