

# **AUTOMATED GEOSPATIAL WATERSHED ASSESSMENT (AGWA): A GIS-BASED HYDROLOGIC MODELING TOOL FOR WATERSHED MANAGEMENT AND LANDSCAPE ASSESSMENT**

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## **Abstract**

The Automated Geospatial Watershed Assessment (AGWA, see: [www.tucson.ars.ag.gov/agwa](http://www.tucson.ars.ag.gov/agwa)) tool is a GIS interface jointly developed by the USDA-Agricultural Research Service, the U.S. Environmental Protection Agency, the University of Arizona, and the University of Wyoming to automate the parameterization and execution of the Soil Water Assessment Tool (SWAT) and KINEmatic Runoff and EROSIon (KINEROS2) hydrologic models. By employing these two models AGWA can conduct hydrologic modeling and watershed assessments at multiple time and space scales. AGWA uses commonly available, national, GIS data layers to fully parameterize, execute, and visualize results from both the SWAT and KINEROS2. Through an intuitive interface the user selects an outlet from which AGWA delineates and discretizes the watershed using a Digital Elevation Model (DEM). The watershed model elements are then intersected with soils and land cover data layers to derive the requisite model input parameters. The chosen model is then run, and the results are imported back into AGWA for visual display. This allows managers to identify potential problem areas where additional monitoring can be undertaken or mitigation activities can be focused. AGWA can difference results from multiple simulations to examine relative change over a variety of input scenarios (e.g. climate/storm change, land cover change, present conditions and alternative futures). The AGWA tool is being further developed for online decision support to provide ready access to environmental decision-makers, resource managers, researchers, and user groups. In addition, a variety of new capabilities have been incorporated into AGWA. They include handling FAO soils for international application; pre- and post-fire watershed assessments; and, multiple options for user defined land cover change. An overview of AGWA and these capabilities will be presented.

## **INTRODUCTION**

The Automated Geospatial Watershed Assessment (AGWA) tool is a multi-purpose hydrologic analysis system for use by watershed, natural resource, and land use managers and scientists in performing watershed- and basin-scale studies. AGWA ([www.tucson.ars.ag.gov/agwa/](http://www.tucson.ars.ag.gov/agwa/)) uses widely available standardized spatial datasets that can be obtained via the internet. The data are

used to develop input parameter files for two watershed runoff and erosion models: KINEROS2 ([www.tucson.ars.ag.gov/kineros](http://www.tucson.ars.ag.gov/kineros); Smith et al., 1995; Goodrich et al., 2006) and SWAT ([www.brc.tamus.edu/swat](http://www.brc.tamus.edu/swat); Arnold et al. 1994). AGWA can then execute either model and import the results from the hydrologic modeling environment back into AGWA for visual display. The results from multiple simulations can be differenced by AGWA to evaluate and display the relative change over a variety of input scenarios (e.g. climate/storm change, land cover change, present conditions and alternative futures).

The initial release of AGWA coincided with the Second Federal Interagency Hydrologic Modeling Conference in 2002 (Miller et al., 2002). AGWA 1.2 was released as an ArcView 3.x extension (trade names are mentioned solely for the purpose of providing specific information and do not imply recommendation or endorsement). Since that time, AGWA has steadily evolved and has been used in a wide range of applications. Due to the abbreviated nature of this paper, extensive references describing AGWA and supporting research are not included herein. The AGWA tool; documentation; and, many of the supporting references can be found at [www.tucson.ars.ag.gov/agwa/](http://www.tucson.ars.ag.gov/agwa/) and [www.epa.gov/nerlesd1/land-sci/agwa/](http://www.epa.gov/nerlesd1/land-sci/agwa/). This paper focuses on describing a number of new features that have been incorporated into the AGWA toolkit. The primary improvements include: 1) The ability to use FAO soils data layers to enable greater international application; 2) The ability to use high resolution SSURGO county level soils data layers; 3) Several options for user-defined land cover change; 4) The ability for users to insert buffer strips adjacent to stream channels; 5) Multi-watershed delineation and discretization of all watershed within a political boundary (e.g. county, park); and, 6) The ability to rapidly compare post-fire to pre-fire simulations. In addition, AGWA, with its new features, is being migrated to ArcGIS and an internet-based version (DotAGWA; Cate et al., 2006)

## **NEW AGWA FEATURES**

### **FAO and SSURGO Soils**

AGWA was originally developed for applications within the United States, and was designed to use the State Soil Geographic (STATSGO) database. STATSGO is available for the entire United States, including Alaska, Hawaii, and Puerto Rico, and is organized by state. These maps are generalizations of the detailed county soil series data and are most effective for broad planning and management uses covering state, regional, and multi-state areas (Soil Survey Staff, 2005). STATSGO maps are at a scale of 1:250,000.

Since AGWA's inception, two additional soils datasets have become available: the Soil Survey Geographic database (SSURGO), and the Food and Agriculture Organization of the United Nations (FAO/UNESCO) Soil Map of the World (FAO). Both datasets are now incorporated into AGWA, greatly increasing its functionality. SSURGO is currently available for selected counties and areas of the United States and its territories. These maps were digitized from the original county wide soil survey maps, and are generally the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. They are most useful for landowners, townships, and county natural resource planning and management. The SSURGO maps are at scales ranging from 1:12,000 to 1:63,360 (Soil Survey Staff, 2005).

The STATSGO and SSURGO soils data sets are available only for the United States. As a result, analysis of basins that straddle the U.S. border, such as the San Pedro River basin in Southern Arizona, or those outside of the United States was not possible. In January 2003, version 3.6 of the FAO/UNESCO Soil Map of the World was released. This digital soils data set includes soil maps and properties for the entire world and was added to AGWA in 2004 (Levick et al., 2004).

### **Land Cover Change Tools**

One of the main focuses of AGWA is the impact of land cover change on water quantity and quality across a watershed. The previous version of AGWA, 1.4x, introduced the Land Cover Modification Tool (LCMT), allowing users to modify land cover surfaces to examine the effects of different management practices and environmental factors within AGWA (Scott, 2005). Enhancements to the LCMT include the integration of a multifractal surface generator, the Land Cover Modification Fractal (LCMF) tool, to create more realistic land cover surfaces for multiple land cover classifications than those created with the completely spatially random surface generator in the tool. The multifractal surface generator, based on a two-dimensional midpoint displacement algorithm (Saupe and Peitgen, 1988), allows users to specify multiple land cover classifications, the proportion of each class to be found in the new surface, the degree of clustering, and the boundary of the modification area. The modified surface contains land cover patches (size determined by the degree of clustering) randomly distributed within the boundary area. The process of creating a multifractal surface is illustrated in Figure 1.



Figure 1. The LCMF process. (left) The modification area; (middle) the multifractal surface generated from the 2D midpoint displacement algorithm; and (right) the final randomly distributed, patchy land cover surface for 3 land cover classes.

### **Best Management Practice (BMP) Tool**

The BMP tool allows users to parameterize KINEROS watersheds with the U.S. Natural Resources Conservation Service's ecological sites database and the state and transition models contained within it (Scott, 2005). Like the LCMT, the BMP tool provides several options for modifying land cover surfaces; however, the modifications for the BMP tool are based on the defined plant transitions and the management practices driving them. The distribution of the new plant state within the modification area can be adjusted by defining a level of success for the BMP. For example, if herbicide application and reseeding in an area is 70% percent successful, then the final surface is created with a combination of 70% of the new land cover class and 30% of the current class. The distribution of the two types is generated using the Land Cover Modification Fractal tool included in AGWA 1.5.

### **Buffer Strip BMPs**

New to AGWA 1.5 is the capability to simulate the most widely used best management practice, riparian buffer strips, through KINEROS2 (Scott, 2005). The tool discretizes buffer elements, provides options for modeling the watershed before and after buffer installation and compares the simulation results. The tool can be used to examine the effects of buffer location, buffer geometry and land cover changes on water quantity and sediment yield. The parameters that affect buffer effectiveness, including buffer width, roughness, slope and vegetation parameters, are modifiable through the AGWA interface. Each buffer is discretized as distinct watershed elements to allow for run-off/run-on simulations. Using an existing KINEROS2 watershed, users determine the length, width and placement of the buffer elements within the watershed. Buffer elements can correspond to the entire length of a given channel, bisect the channel and terminate at a channel endpoint or occupy some internal channel segment as defined by the user. A new watershed is created containing the newly configured buffer elements, including the buffer and its upland plane (Figure 2).

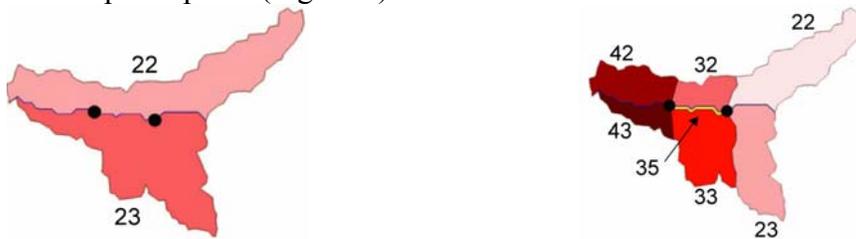


Figure 2. KINEROS2 Buffer discretization for an internal channel buffer. (left) The unbuffered plane elements with buffer location and length defined by points. (right) The buffered plane elements, with buffer element (35) selected. Note the increased complexity of the watershed due to the discretization process.

Buffered watersheds can be parameterized and simulated for the pre-installation state and the post-installation state. To account for the increased complexity, the land cover and soils parameters obtained for the original watershed elements are applied to the new buffer elements. The new elements are thus parameterized as a uniform surface identical to the original plane for pre-installation simulations. For post-installation simulations, new land cover parameters, selected by the user, are applied to the buffer element to reflect the change in land cover associated with riparian buffer treatments. For example, in Figure 2, plane elements 23, 33, 43, and 35 would be assigned the weighted parameters from plane element 23 in the original watershed for the pre-installation simulation while only plane elements 23, 33, and 43 would be assigned those parameters in the post-installation simulation. Plane element 35, the buffer, would receive parameter values based on the selected land cover class. AGWA 1.5 automates much of the buffer discretization and simulation process, allowing users to focus on assessing the impacts of different buffer geometries and characteristics on a watershed.

### **Multi-Watershed Delineation**

In previous versions of AGWA, users have been limited to creating and simulating individual watersheds. A new feature in AGWA 1.5 allows users to create a watershed group that is parameterized, simulated and viewed as one unit (Scott, 2005). A watershed group can be defined explicitly by the user through the identification of watershed outlets prior to delineation, similar to the identification of the single outlet. Alternatively, a watershed group can be defined

by a user-specified area of interest. Outlets for this type of watershed group are interactively located such that the entire area of interest will lie within a watershed. Watershed groups can be defined for both KINEROS2 and SWAT and utilize the same input surfaces required in previous versions.

Area of interest watershed discretization provides users with a unique process of creating and simulating watersheds. The area of interest can be defined by county borders, parks, islands and other boundaries to facilitate watershed modeling and assessment in these areas. To create a watershed group with this method, the user supplies the boundary of the area to be modeled and an analysis extent to limit the search area for the potential outlets. AGWA uses these datasets, with the stream network, to locate potential watershed outlets. Watersheds are delineated for each potential outlet and intersected with the area of interest. If any region of the area of interest is not covered by a watershed, the affected outlets are moved downstream and new watersheds delineated. This is repeated until the entire area of interest is contained in a watershed. Watershed delineation and discretization for explicitly defined outlet locations repeats the current AGWA processes for each provided outlet (Figure 3). Contributing source areas are defined for each watershed delineation.

Regardless of the method used to create a watershed group, the parameterization and simulation of the group is the same. The parameterization is essentially unchanged from all previous versions of AGWA; all of the land cover and soils options are available. Simulation is undertaken as a batch processing task, with each watershed in the group simulated separately. Watersheds can be extracted from a group and simulated separately through AGWA. Watersheds can also be appended to the group.

AGWA 1.5 also provides users with the option to create nested watersheds, a commonly used research tool. A nested watershed uses internal breakpoints to differentiate areas of varying complexity within a watershed. The delineation of a nested watershed is similar to that of the watershed group where each point serves as an outlet; however, for nested watersheds, the internal watershed delineations are used only to define the analysis mask for the discretization process. The discretization process moves downstream towards the watershed outlet, discretizing and merging each watershed to create the final watershed. This watershed is parameterized and simulated as a normal AGWA watershed.

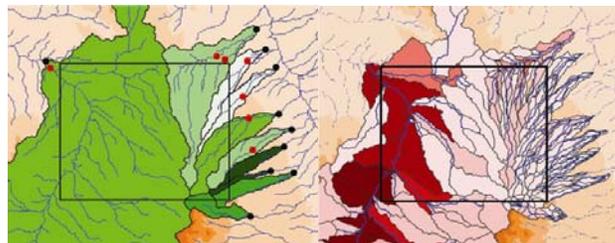


Figure 3. (left) Area of Interest outlet identification and delineation for the boundary. Red points indicate a potential outlet; black points final watershed outlets. (right) Area of Interest watershed discretization.

### **Pre- and Post Fire Assessments**

Rapid assessment of post-fire hydrologic watershed response can aid forest and watershed managers in locating and applying mitigation and rehabilitation resources. Pre-fire AGWA simulations of a watershed can be made at anytime. By doing so, the necessary basic DEM, soils, and land cover data sets for the watershed of interest can be acquired and initially processed in AGWA prior to the urgency of a fire situation. In a post-fire situation, a burn-severity map is typically produced by Burned Area Emergency Rehabilitation (BAER) teams. Research was conducted by the AGWA team (Canfield et al., 2005) to derive post-fire model parameters for both SWAT and KINEROS2 based on pre- and post-fire hydrologic observations over a wide range of watersheds in the Western United States. An application of AGWA-SWAT was conducted by Goodrich et al. (2005) using available data sets and a burn-severity map from the 2003 ASPEN fire near Tucson, AZ. The estimated changes in SWAT Curve Numbers (CNs) were smaller than those derived from experience and used in many other post-fire BAER analyses. However, simulations using the smaller CN resulted in post-fire runoff volumes that agreed more closely with observed post-fire volumes. Post-fire watershed response from many of the other data sets examined indicated that the change in runoff volume is small relative to the large change in post-fire peak runoff. Therefore, a second modification in AGWA was implemented to drastically decrease hillslope roughness. This increases peak runoff rates without a large increase in runoff volume. An application of KINEROS2 to the Starmer Canyon post-fire dataset at Los Alamos, New Mexico (Canfield et al, 2005) indicated that hillslope roughness approximates bare conditions following the fire, and rapidly recovers with time. Post-fire parameter look-up tables are now available in AGWA 1.5 and will be available in both AGWA 2.0 (ArcGIS) and DotAGWA.

### **AGWA MIGRATION TO ARCGIS AND THE INTERNET**

An Internet based version of AGWA is being developed in order to broaden AGWA's potential user base to a larger community. The Internet version of AGWA is called DotAWA. Features of DotAGWA will include specially designed components that will enable local managers to evaluate the potential costs and benefits associated with management strategies and best management practices. Users will be able to define management activities like watering points, vegetative buffers, and other common best management practices. Users will not be required to have specialized scientific training or extensive experience using watershed models. The application is also expected to serve as an invaluable learning tool for students. AGWA and DotAGWA are being developed in parallel to minimize duplication of effort. Geoprocessing features in AGWA are being packaged into re-usable components that can be accessed by the web-based application. Both applications share the same system architecture which means the work required for adding future components will be minimized. Basically, AGWA and DotAGWA serve as a framework for incorporating additional models, tools, and data to promote ongoing Federal and academic research in earth sciences.

### **CONCLUSIONS**

The Automated Geospatial Watershed Assessment (AGWA) GIS-based hydrologic modeling toolkit has been enhanced with a variety of features to aid in watershed assessment and analysis. Resource and land managers can utilize AGWA to rapidly identify potential problem areas where additional monitoring can be undertaken or mitigation and management activities can be

focused. While AGWA can be applied to ungauged watersheds, it should be stressed that in the absence of good hydrologic observations to conduct calibration and validation, AGWA results are best suited for relative change analysis or watershed to watershed comparisons. It is our intent that AGWA evolve to assist model users in model parameterization using GIS tools and in-situ or remotely sensed (RS) data. As SWAT or KINEROS2 (Goodrich et al., 2006) (or additional models that may be added to AGWA) provide increasing modeling complexity, parameter look-up tables, based on widely available watershed GIS or RS data layers, will be developed based on field data, published literature, expert experience, and calibration/validation experience where sufficient data are available. As AGWA evolves it will be incorporated into new releases of the BASINS (Better Assessment Science Integrating point and Nonpoint Sources) modeling suite maintained and distributed by EPA ([www.epa.gov/OST/BASINS/](http://www.epa.gov/OST/BASINS/)).

In summary, the integration of FAO soils into AGWA provides international users a convenient means of assessing the impacts associated with land cover/use change for environmental planning efforts. The enhanced AGWA tool can be an important component of a protocol to determine the optimal placement of buffer strips in a watershed to maximize its efficiency in removal of sediment and nutrients load and improve its impact on water quality. The combination of KINEROS2 with SWAT will allow us to evaluate the effectiveness of buffer strips at each location. After identifying potential buffer strips location using SWAT, the effectiveness of buffer width on sediment loads will be evaluated with KINEROS2. In addition, the LCMT can be an important tool for decision-makers to assess the relative hydrologic impacts of several alternative sets of landscape choices for a desirable future environment. Major post-fire concerns include increased erosion due to loss of the protective forest floor layer, loss of water storage, and the creation of water repellent soil conditions. The AGWA tool allows the use of readily available spatial datasets to perform pre-fire hydrologic analysis using SWAT and KINEROS2. If a burn-severity map is available, estimates of post-fire watershed response can be made using the hydrologic models in AGWA. The migration of AGWA from its original form as an extension for ArcView 3.x to one for ArcGIS 9.0 is designed as a means to keep pace with rapidly evolving GIS technologies while accommodating the largest potential user audience. The development of DotAGWA (Cate et al., 2006) is intended to broaden AGWA's potential user base to include anyone with a connection to the Internet. Specially designed components will enable local managers to evaluate the potential cost and benefits associated with management strategies and best management practices, and foster community involvement in environmental management. Also found in this issue is a paper describing a channel characterization tools that is being developed to enable AGWA to derive necessary channel geometry parameters from LIDAR data (Semmens et al., 2006). Additional improvements to AGWA 1.5 include support for SWAT hydrologic response units, improved SSURGO soils handling, enhancements to the simulation results display, notably additional comparison options and simulation time step views, and support for the USGS GAP vegetation datasets.

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