FEDERAL INTERAGENCY HYDROLOGY AND HYDRAULICS GIS APPLICATIONS WORKGROUP

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Abstract: The GIS data community is well developed and organized and the use of GIS data and applications by water resource modelers is growing steadily. However, hydraulic and hydrologic model developers and users do not have an efficient way to exchange and learn relevant technology, including coordinating application development within GIS environments and expressing needs for new tools specific to water resource applications. Numerous federal and non-federal employees would also like to learn about both GIS data and its application in hydrology and hydraulics. To meet this need, the Hydrologic and Hydraulic GIS Applications Workgroup was authorized by the Federal Subcommittee on Hydrology (a subcommittee of the Advisory Committee on Water Information, ACWI). The Workgroup consists of application developers and users working in the field of water resources. The Workgroup is charged with communicating to the GIS and water resources modeling community the variety of data and applications that are available, how to access the data and applications, and how to receive training and support.

The Workgroup is directing its efforts to 1) reporting availability and efficient access of GIS-based applications in a web environment, 2) identifying and summarizing existing GIS-based applications, and 3) promoting interagency development and use of GIS applications in relation to hydrology and hydraulics. Toward these ends, the Workgroup has set up a web site through Texas A&M University to summarize information on these GIS applications. Goals, guiding principles, and progress on the activities of the Workgroup are included in the paper.

Detailed information on the Workgroup can be accessed from the web site: http://acwi.gov/hydrology/h2gisa/ . Information on activities is posted periodically.

INTRODUCTION

The Hydrologic and Hydraulic GIS Applications Workgroup consists of application developers and users. Growing use of GIS data and applications is resulting in the increasing need for federal and non-federal employees to learn about both GIS data and its application in hydrology and hydraulics. The Workgroup communicates to the GIS user community the variety of data and applications that are available, how to access the data and applications, and how to receive training and support. The focus is on applications which are in the public domain (accessible to the largest number of people at the least cost). The workgroup was established in July 2007 and currently has ten members representing a spectrum of federal agencies.

The Workgroup has a very broad scope which includes data sources and GIS applications. Information exchange concerning GIS applications and GIS data are important items. The Workgroup holds teleconferences every 1-2 months. The first priority of the Workgroup has been to gather and publicize information on GIS applications in hydrology and hydraulics. This step is described in the next section of the paper.

INFORMATION TO BE COMPILED ON EACH APPLICATION

A questionnaire was designed to gather limited but key information about particular GIS applications in order for a potential user to decide if the application fits his/her computer system, data requirements, and physical system to be modeled. Some of the information that has been compiled includes a brief description, data requirements, operating system, and software dependencies (for example, is the application dependent on other software such as Environmental Systems Research Institute, ESRI, products). Twelve applications are currently in the list. More are being sought.

A more detailed questionnaire is desirable for further investigation of GIS-based models. In addition to describing the computer system, data requirements, operating system and software dependencies of the GIS-based models, the new questionnaire is also attempting to describe a GIS-based model from a hydrologic or hydraulic perspective. This would provide the user with more detailed information on practical applications. These items are shown as follows:

Model Type: this sections states the types of model developed. For example, hydrological models can generally be classified as event-based precipitation-runoff models, continuous precipitation runoff models, snowmelt runoff models, steady-flow flood routing models, unsteady-flow flood routing models, reservoir regulation models, flood frequency models, watershed/water resources management models, etc. These categories are basically defined on the basis of the nature of a hydrological model, its physical mechanism and in part application purposes. There is no doubt that some models bear a series of application purposes, such as simulations of water quantity, water quality, and sedimentation. In this case, a category termed general purposes would be listed. On the other hand, with a rapid development of digital images and data (from scanner, digital video, digital camera, sensors mounted on balloon, aircrafts, space shuttles, satellites) and relevant GIS database, newly developed hydrologic models are increasingly assimilating these data sources based on a GIS platform. Describing a model in a hydrologic manner would however provide the user with an essential scope about its physical mechanism and application purposes.

Model Objective (s): describe purpose of the model, like the simulation of hydrologic processes for designing flood damage reduction projects.

Model Structure or Mathematical Basis: describe the type of the basins for which the model has been developed. For example, the basins may be rural, urban, agricultural, mountainous, etc; describe the size of the basins for which the model applies. For example, the basins may be small ($<10^3$ km^2), medium (10^3-10^4 km^2), or large ($>10^4$ km^2); the nature of simulation that the model undertakes. For example, the simulation may be event-based or continuous; components of the hydrological cycle represented in model formulation, for example, precipitation, infiltration, evaporation, interception, detention storage, overland flow, channel flow. Mathematical formulation of the model components, for example, lumped, distributed, deterministic, and probabilistic.

Model Parameters: this section describes the number of parameters involved in each model component process and then of the model.

Spatial Scale: this section describes the spatial representation used in the model. For example the watershed can be treated as a single unit or as a network of sub-watersheds.

Temporal Scale: this section describes whether the model is an ‘event based’ model or a daily, weekly, monthly, yearly model.

Input Data Requirements: this section describes the data required for application of the model. The data may pertain to the following elements as needed by the model, like watershed characteristics data (topographic map, drainage area, channel lengths, drainage areas of channels, slope, etc.), climatic data (rainfall intensity in time, temperature, humidity, vapor pressure, wind velocity, etc.), stream flow data (measured discharge in regular time steps), soil data (type, structure, texture, infiltration characteristics) and land use data (cropping patterns, vegetation, percent imperviousness, etc.).

Model Output: this section describes the type of output of the model procedures.

Model Testing & Verification: this section describes whether the model has been tested and verified extensively using split sampling data and split sampling watershed techniques, involving other watersheds than calibration watersheds. Are test data sets available to the user for modeling use training and model operation confirmation?

Model Sensitivity: this section describes the sensitivity of the model to its parameters and its components. Has a sensitivity analysis been performed for the model and shared to the general user community?

Model Reliability: this section describes the confidence in the model results. Consider a) the repeatability of the model, b) accuracy of output as compared with real observations, and c) the Probability of obtaining consistently accurate model predictions.

Model Application/Case Studies: this section describes where the model is / has been typically applied. How does the user community apply the model to real world problem settings?

EXAMPLES OF GIS APPLICATIONS WHICH ARE INCLUDED IN THE WEB LIST

The following seven high-profile GIS applications in hydrology/hydraulics/water quality/watershed assessment are examples of software applications included in the web list. Pertinent information on these applications is included so a potential user can decide if a particular application is suitable for his/her purposes.

HEC GeoHMS, U.S. Army Corps of Engineers (USACE, 2007). Geo-HMS is a GIS graphical user interface to the Corps of Engineers Hydrologic Modeling System (HMS) model. Geo-HMS is designed to operate with ESRI ArcView and the Spatial analyst extension. Using digital elevation, land use and soil layers, a number of inputs to the HMS flood event model are generated.

HEC GeoRAS (USACE, 2007). Geo-RAS is a GIS graphical user interface to the Corps of Engineers River Analysis System (RAS) model. The interface allows the user to prepare geometric data to be imported into the HEC-RAS water surface profile model. After completing the HEC-RAS computations, an export file is opened by the GIS interface and various outputs may be displayed geographically, such as flood plain limits. The primary input to HEC GeoRAS is digital elevation data in the format of a digital terrain model (DTM). Cross sections, reach lengths, and other hydraulic data are generated through the interface. The most recent version of HEC GeoRAS operates with ESRI ArcGIS version 9.1 with the Spatial Analyst and 3-D Analyst extensions.

EPA BASINS (US EPA, 2007) is a multi-purpose environmental analysis system that integrates a geographical information system, national watershed data, and state-of-the-art environmental assessment and modeling tools into one convenient package. BASINS 4.0 is the latest version available. It operates with an open source GIS software system. This system makes it possible to quickly assess large amounts of point source and non-point source data in a format that is easy to use and understand. Installed on a personal computer, BASINS allows the user to assess water quality at selected stream sites or throughout an entire watershed. BASINS may be used to develop input data for the Hydrologic Simulation Program – Fortran (HSPF) and Soil and Water Assessment Tool (SWAT).

StreamStats, U.S. Geological Survey (USGS, 2007). StreamStats is a web-based GIS application which solves the USGS peak flow regression equations for 13 states which have been implemented. The user selects the watershed outlet interactively on a map of the state. Basin characteristics (such as drainage area) and peak discharges for a series of return periods are calculated. No GIS software or data need to be installed on the user's computer.

Automated Geospatial Watershed Assessment Tool, (AGWA), USDA Agricultural Research Service and US EPA, (Goodrich, et al, 2008). AGWA is a GIS interface which uses widely available spatial datasets to develop input parameters for two watershed models: KINEROS2 and SWAT. KINEROS2 is a watershed model which analyzes hydrology, erosion, and sedimentation. SWAT is a continuous simulation model which analyzes hydrology, erosion/sedimentation, nutrients, and pesticides. Both models allow for distributed processing of a discretized watershed. AGWA utilizes generally available digital datasets of elevation, soil, land use, rainfall, and others.

NRCS Geo-Hydro, USDA Natural Resources Conservation Service, (Merkel, 2007). NRCS Geo-Hydro is a work station application which is a complete GIS interface to the NRCS WinTR-20 flood hydrology model. It is an extension which operates with ESRI ArcGIS Version 9.1 and Spatial Analyst and ArcHydro Tools extensions. The required GIS grid data layers are digital elevation, soil, and land use. The required polyline layer represents stream locations (such as National Hydrography Dataset, NHD). The data may be

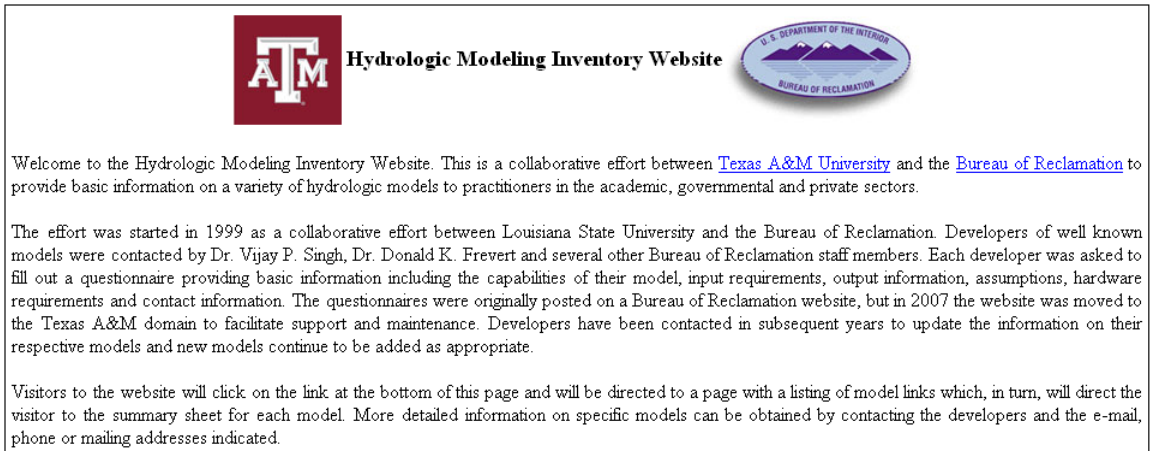
in English or SI units and any cell size (though data are most commonly available at 30 meter and 10 meter resolutions).

Soil Water Assessment Tool, (SWAT), USDA Agricultural Research Service (ARS), (Arnold, 1998). SWAT is a river basin scale model developed to quantify the impact of land management practices in large, complex watersheds. Application of the model (ArcSWAT 1.0 for ArcGIS 9.1 version) requires prior installation of ESRI software package including ArcGIS-ArcView 9.1 with service pack 2 (Build 766), ArcGIS Spatial Analysis 9.1 extension, ArcGIS Developer Kit (usually found in C:\Program Files\ArcGIS\DeveloperKit\), and ArcGIS DotNet support (usually found in C:\Program Files\ArcGIS\DotNet\). The required GIS grid data layers are digital elevation models, soil map, and land use map.

More recently developed GIS-based hydrologic models with their latest versions and their performance and development could be obtained from the user group or hotline-type support, or from online academic database, such as ISI Web of Knowledge, and Engineering Village. The questionnaires will be disseminating to the developer at a certain period. If they are not well aware of the sensitivity and reliability of the models, the Workgroup would search for relevant information and summarize it. Development of the original models will also be traced for providing the hydrologic community with latest information.

GIS APPLICATIONS WEB SITE

The web site where the list of GIS applications resides is associated with the list of hydrologic models maintained at Texas A&M University. The web site is http://hydrologicmodels.tamu.edu



Hydrologic Modeling Inventory Website

Welcome to the Hydrologic Modeling Inventory Website. This is a collaborative effort between Texas A&M University and the Bureau of Reclamation to provide basic information on a variety of hydrologic models to practitioners in the academic, governmental and private sectors.

The effort was started in 1999 as a collaborative effort between Louisiana State University and the Bureau of Reclamation. Developers of well known models were contacted by Dr. Vijay P. Singh, Dr. Donald K. Frevert and several other Bureau of Reclamation staff members. Each developer was asked to fill out a questionnaire providing basic information including the capabilities of their model, input requirements, output information, assumptions, hardware requirements and contact information. The questionnaires were originally posted on a Bureau of Reclamation website, but in 2007 the website was moved to the Texas A&M domain to facilitate support and maintenance. Developers have been contacted in subsequent years to update the information on their respective models and new models continue to be added as appropriate.

Visitors to the website will click on the link at the bottom of this page and will be directed to a page with a listing of model links which, in turn, will direct the visitor to the summary sheet for each model. More detailed information on specific models can be obtained by contacting the developers and the e-mail, phone or mailing addresses indicated.

From the introductory page, go to the list of hydrologic models. The models are grouped in categories, one of which is GIS applications.

Geographic Information System (GIS)-based models

- Automated Geospatial Watershed Assessment Tool
- eCoastal Program
- BASINS version 4.0
- GIS Weasel
- HAZUS-MH
- HEC-GeoRAS
- MapWindow
- NHDPlus Append Tool
- NRCS Geo-Hydro ArcGIS
- NRCS Geo-Hydro ArcView
- StreamStats
- Soil and Water Assessment Tool (SWAT)

By clicking on one of the applications, the questionnaire with pertinent information is available. This includes a link to the developer's web site.

SUMMARY AND CONCLUSIONS

The purpose of the Workgroup is to gather and disseminate information on GIS data and applications related to hydrology and hydraulics. The focus is primarily on data and applications of federal agencies which are in the public domain. These are of great interest to the general GIS user community because of easy access, acceptance, good documentation, and in some cases, user support. Progress is being made towards accomplishing these goals and setting a course for future developments. Progress is posted on the Workgroup web site.

REFERENCES

Arnold, J.G., Srinivasin, R, Muttiah, R.S., and Williams, J. R., 1998. Large Area Hydrological Modeling and Assessment: Part I. Model Development. JAWRA, 34(1):73-89.

Goodrich, D.C, and Hernandez, M., USDA-ARS, 2009. Automated Geospatial Watershed Assessment Tool, http://www.tucson.ars.ag.gov/agwa , 2009.

Merkel, W.H., 2007, NRCS Geo-Hydro – ArcGIS Interface to WinTR-20 – User Guide, USDA-NRCS, Beltsville, MD.

USACE, HEC-GeoHMS, 2007, http://www.hec.usace.army.mil/software/hec-geohms/index.html , 2007.

USACE, HEC-GeoRAS, 2007, http://www.hec.usace.army.mil/software/hec-ras/hec-georas.html , 2007.

US EPA, 2007. Better Assessment Science Integrating Point and Non-Point Sources (BASINS), http://www.epa.gov/waterscience/basins , 2009.

USGS, 2009. StreamStats, http://water.usgs.gov/osw/streamstats/ , 2009.