Title of Paper : Enterprise GIS to Manage Water Resources Simulation Models

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Abstract :

Agencies responsible for regulations and management of watersheds often handle a multitude of water-resources simulation models with multiple input and output files. Managing updates, relating information, and distributing the most up-to-date models can quickly become overwhelming. The proposed approach uses specialized data models to store all the parameters in the water resources simulation models in an ArcSDE/SQL Server Geodatabase. Specialized applications then use the model's files in their native formats as the source Geodatabase updates instead of GIS data files. Once the geodatabase contains all the modeling information, the simulation files can be re-created from the geodatabase structure and exported for efficient and up-to-date distribution, while also allowing the simulation information to be analyzed, related, and manipulated from a spatial perspective.

Paper Body

Introduction

The San Antonio River Basin is located in South Central Texas and encompasses approximately 4,100 square miles, with the bulk of the urban area concentrated in Bexar County and the City of San Antonio. The northern half of the basin is rolling Texas Hill Country which then begins to transition into relatively flat coastal plain in the southern basin. This transition occurs along the Balcones escarpment which is in the most populous part of the basin, Bexar County.

Due to the geomorphology of the basin and the fact that Central Texas experiences some of the most intense rainfall in the nation, the basin has frequently experienced significant loss of life and property. In 1998 and 2002, the basin experienced record storms. The damages sustained in these storms prompted the City of San Antonio, Bexar County and the San Antonio River Authority to enter an Interlocal Agreement (ILA) which formalized the desire of the three agencies to approach flooding issues on a regional basis as well as finding a method for sharing 'flood' data between the agencies.

A comprehensive Regional Watershed Management System (RWMS) was envisioned by the ILA partnership to meet those goals. The RWMS is envisioned to be an enterprise system where hydrologic and hydraulic flood models would be stored, retrieved and updated. Once the RWMS has become the repository for all the flood models in the basin, it will be a natural place to keep existing and ultimate development flood models for the basin for use by each agency.

The base functionality for the RWMS will allow the ILA partners to select a portion of the existing conditions flood model for editing on their desktop. The RWMS will automatically calculate the extents of the required hydrologic and hydraulic models required by the requesting parties. The information is then compressed into a zip file for the client to retrieve. Editing of models by the end user will be performed on their own systems and will not specifically require any specialized software other than the basic models.

After the requestor modifies the flood model to reflect the proposed conditions, it will be resubmitted to the RWMS for validation and inclusion in the existing conditions model. This portion of the workflow has proved to be a significant hurdle in the RWMS development because all edits to the individual models may be performed in non-ESRI software and therefore, out-of-the-box disconnected editing could not be used to manage the non-exclusive data check-outs and check-ins.

The System Design

Prior to RWMS implementation, the ILA partners evaluated and selected standardized tools for modeling. The tools selected were HEC-HMS for hydrologic modeling and HEC-RAS for hydraulic modeling; they were selected due to their availability as freeware, maturity and extensive documentation. Future plans for the RWMS (currently in prototype) include the integration of USGS HSPF water quality models.

HEC-HMS and HEC-RAS models store the information about the environment in a series of ascii files which are not directly read by standard GIS applications. Even when the models are created with the assistance of a GIS preprocessor such as GeoHMS or GeoRAS, only a subset of the modeling information is considered. Since one of the RWMS goals is to act as a central/shared repository of models, it was

necessary to develop an enterprise geodatabase with the capability of storing every potential model element and parameter, as well as functionality to transfer that data back and forth between models and geodatabase. Two data models representing HEC-HMS and HEC-RAS were initially developed as the core of the enterprise geodatabase.. The early prototypes for those data models and tools were created by University of Texas Center for Water Resources Engineering and Texas A&M.

While GIS preprocessors can be of great value for model creation, significant portions of models which will be submitted for approval and storage in the RWMS are not created using GIS tools. Requiring the engineering community to use GIS-based tools exclusively would place an excessive burden on those users that don't currently use GIS. For that reason, the RWMS must be preprocessor independent and not require users to purchase or learn a GIS software in order to create HEC-HMS and HEC-RAS models that can be successfully imported into the system. Whether a model is created using a GIS-based preprocessor or strictly HEC-HMS and/or HEC-RAS is completely up to the engineer.

The model-to-geodatabase/geodatabase-to-model translation tools rely on a model element naming scheme and on standardized HEC-HMS and HEC-RAS files in order to transform model elements into Enterprise Geodatabase features, tables and fields. For HEC-RAS models, the geometry and spatial information is obtained from the geometry file. It is assumed that the engineer has entered this information manually in HEC-RAS or with the assistance of a GIS preprocessor. For HEC-HMS models, the geometry and spatial information can be provided in AutoCAD® drawing (dwg) or Microstation® design (dgn) files as well as ESRI® shapefiles or personal geodatabases, if those are available.

Models are submitted into the system through a series of steps that includes the regulatory review of the floodplain studies. Submittal of a floodplain study into the system by internal users may be done directly on the ArcGIS system management user interface. External users (such as land developers) will submit study data through the RWMS Web Portal.

The RWMS Workbench is system administration application used by the internal engineers. It is accessed in ArcMap through a custom table of contents where users with appropriate permissions can manage floodplain studies in a modified

implementation of the ArcSDE/SQL Server cyclical version tree versioning workflow. The floodplain study goes through the workflow (and versions) of checkout, submittal, approval and construction. Each version corresponds to a phase the models in a study must go through before the drainage conditions they represent is “published” for distribution. Each version stores a historic snapshot of the phase’s activities. Checkout records the status and availability of modeling data when the study started, Submittal records the modeling edits as submitted, Approval records the interaction between the regulatory entity and the submitter and Construction records as-built modifications.

External users interact with the system through the RWMS Web Portal which includes functionality such as model/data extraction, submittal, study status tracking, notification and regulatory review (depending on user category).

The first step in loading models that are submitted into the system (through the web portal or directly in the RWMS Workbench) is to verify that they are valid. Therefore, each model goes through a series of validation checks which range from basic data/format requirements such as required values, naming of model elements and required files to H&H specific rules that determine if the model adheres to modeling standards established by the ILA Partners. A model is only passed on to the assigned regulatory agency for review after it has passed this validation step, thus adding an extra layer of quality control and facilitating the job of the regulatory reviewers.

Once the model is reviewed and approved by the regulatory agency it is then ready to be imported into the system and merged into the existing modeling information. An important consideration in this step is how individual models are combined into the regional geodatabase. Business rules were specified in order to facilitate merging and replacement of models independently of its extents (such as watershed or reach) while ensuring that overlapping and adjacent models can be integrated without losing their engineering integrity. These rules inspect models being imported in the context of the existing data. For example in the case of a submittal of a HEC-RAS model that is a tributary to a main stem stream already stored in the Enterprise Geodatabase. The RWMS provides functionality to incorporate a confluence into the existing data and split the main stem HEC-RAS reach and it also ensures that HEC-RAS flow input locations are properly handled at the new confluence.

Models that are successfully imported are then reconciled against their target drainage-conditions “master” version. There are two “master” versions: Existing drainage conditions and Proposed drainage conditions. When a models in a study submittal is imported, the target master is specified and it controls the workflow of the model based on whether edits represent existing or proposed (not yet constructed) conditions.

Unlike traditional reconciliation processes, where individual conflicts can be resolved on a row/field basis, the RWMS must enforce a “winner-takes-all approach”. If a submitted model is in conflict with the master drainage-conditions data, either the entire model must be accepted (all conflicts resolved by using the new version) or the model must be corrected to match the “master” conditions and then submitted again. This approach is necessary since modeling information is validated in the context of a full model, but not necessarily as individual features or field values. A model that is approved with a certain set of cross sections would generate significantly different results with a different set of cross sections. Therefore, selectively resolving some conflicts with the new version and some with the target version would cause both models to lose their integrity.

Once the model is successfully reconciled it can then be posted to its respective master drainage-conditions version and when ready, the master version is then posted for publishing in the RWMS Web Portal.

As mentioned earlier, the RWMS Web Portal allows external users of the system to view, query and request models stored in the regional geodatabase. Since there is no fixed model extent, the user can request a HEC-HMS model by outfall location and additional contributing area. The system determines the appropriate model extents based on the HEC-HMS schematic network and exports a HEC-HMS model for that extent. A similar process applies to HEC-RAS: the user specifies the desired reaches and an additional length, the appropriate extent is then determined and a single HEC-RAS model is exported.

Besides serving as a central repository for the collection and distribution of models the RWMS’s ability to store and export full modeling information also has significant benefits to flood forecasting. Once an area of the river basin is modeled, engineers within the ILA partners’ network with access to the RWMS Workbench can generate

automated floodplain delineations. Precipitation information from NEXRAD is applied to the desired HEC-HMS models where a simulation is run to generate peak flows at combination points. The peak flows from the combination points are then passed to the respective HEC-RAS model's cross sections and the hydraulic simulation is performed. The output of the hydraulic simulation generates water surface elevations which are intersected with the terrain dataset and then converted to the floodplain delineation polygon. The initial prototype to demonstrate this concept was developed by University of Texas Center for Research in Water Resources in 2003, and received nationwide recognition.

Conclusion

The current implementation of the RWMS is the culmination of the vision of the ILA partners, cooperative efforts with the ILA partners to define the requirements for the system, the pioneering work of the University of Texas and Texas A&M University, an the efforts of PBS&J information solutions professionals and water resources engineers.

The RWMS provides an efficient, enterprise system for the management, maintenance and distribution of models and supporting data. It also provides a solid framework upon which additional functionality such as flood forecasting or topographic data management can be built.

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Appendixes

None

End Notes

None

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