A Case Study: San Antonio River Authority Enterprise GIS Implementation

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Abstract. The San Antonio River Authority (SARA) has established a Geographical Information System (GIS) program to implement an Enterprise GIS. This involves an enterprise database, web components and associated standards, applications and tools to provide spatial data, metadata and standards related to the San Antonio River Basin. The Enterprise GIS database will store the San Antonio River Basin spatial data with an emphasis on water resources at a centralized database for various uses and users. The pilot scale systems have been developed for several departments to demonstrate the capabilities of the system, to provide hands-on experience to internal users, to test various implementation alternatives, and to refine the process of the implementation, so that a streamlined, cost and time efficient full-scale system implementation will be achieved. The system will form the spatial data framework for evaluation, assessment, selection, prioritization and implementation of the projects throughout the river basin. The system will provide cost and time savings by facilitating informed decisions for San Antonio River Basin projects and their implementation.

1. Introduction

The San Antonio River Basin is located in south central Texas and covers approximately 1,1380 square kilometers (Figure 1). The basin is bordered on the west by the Nueces River Basin and on the east by the Guadalupe River Basin. Most of the San Antonio River Basin is rural, particularly in the southern half. The San Antonio River is sub-divided into upper and lower segments receiving five major tributaries according to environmental classification. The river basin is divided into four hydrologic units as Medina River, Cibolo Creek, Lower San Antonio River, and Upper San Antonio River. The basin drainage area includes all or parts of 14 counties with Bexar County being the largest and most populated. The central part of the basin includes the City of San Antonio and surrounding areas. Total population living in the basin area is around 1.8 million.

Average elevation of the basin area is 229 meters, and the lowest and the highest elevations are 2 meters and 710 meters, respectively. The basin has low elevation except in the northwest upper basin (Figure 2). Average slope of the basin is 1.38 degrees and average aspect of the basin is 133.56 degrees (southeast).

2. San Antonio River Authority and GIS

The San Antonio River Authority (SARA) generated and stored paper maps, survey plots, CAD files, terrain elevation data, projects data, aerial photos, water quality, environmental sampling and many other format spatial data related to San Antonio River Basin since its establishment in 1937. The authority has the equivalent of more than 100 gigabytes of spatial data in various formats. Most of the digital format data has been generated using

traditional drafting, CAD software such as AutoCAD and newer integrated versions (i.e., Land Desktop), ESRI GIS software (i.e., ArcView 3.x, ArcGIS 8.x) and some using GPS/Survey tools (i.e., Trimble, Leica). There are many non-digital hardcopy maps as well.

GIS data was stored in directories and project folders scattered all around the network and replicated on many drives. Additionally, due to the existing file structure, storage mechanism and lack of organization, standards, and naming conventions, it is very difficult to identify and locate the original and current spatial data to be stored in the database. Since file storage is based on project, and the project generated data and the original data has not been documented properly, it is hard to differentiate the spatial data generated for/by the project from already existing data.

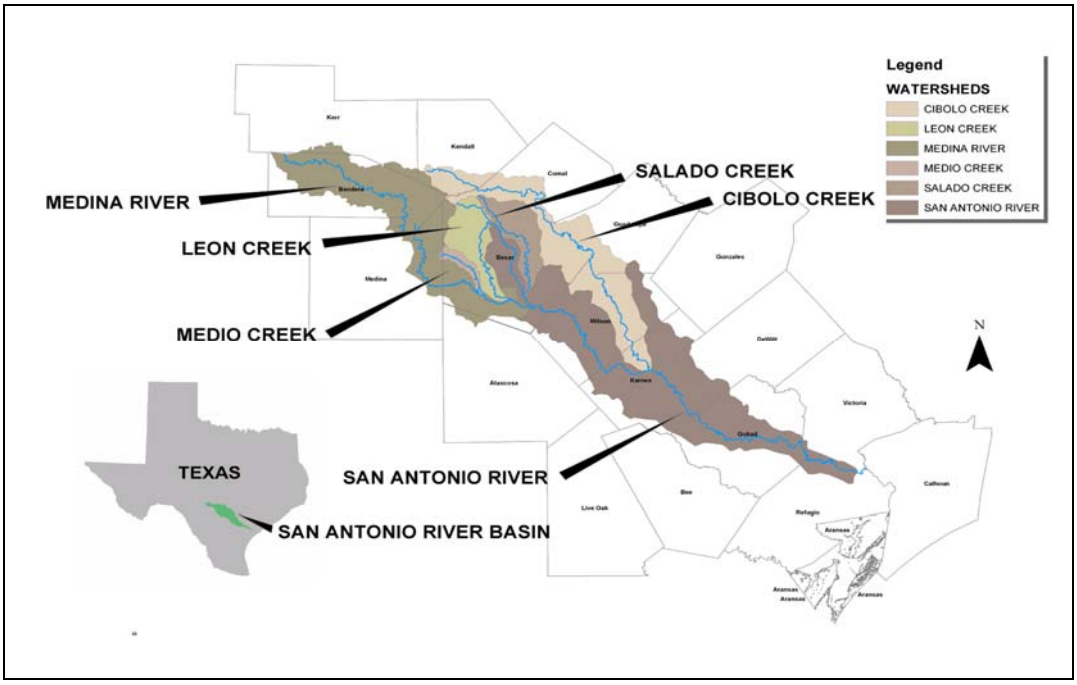

Figure 1. San Antonio River Basin location map.

There were no organization-wide spatial data quality assurance, quality control procedures, data consistency/integrity rules/regulations, standards, or metadata. The access and use of the data was limited to a couple of users, and mounting amounts of data replication, duplication and reproduction were made due to the existing lack of organization and structure for GIS and spatial data.

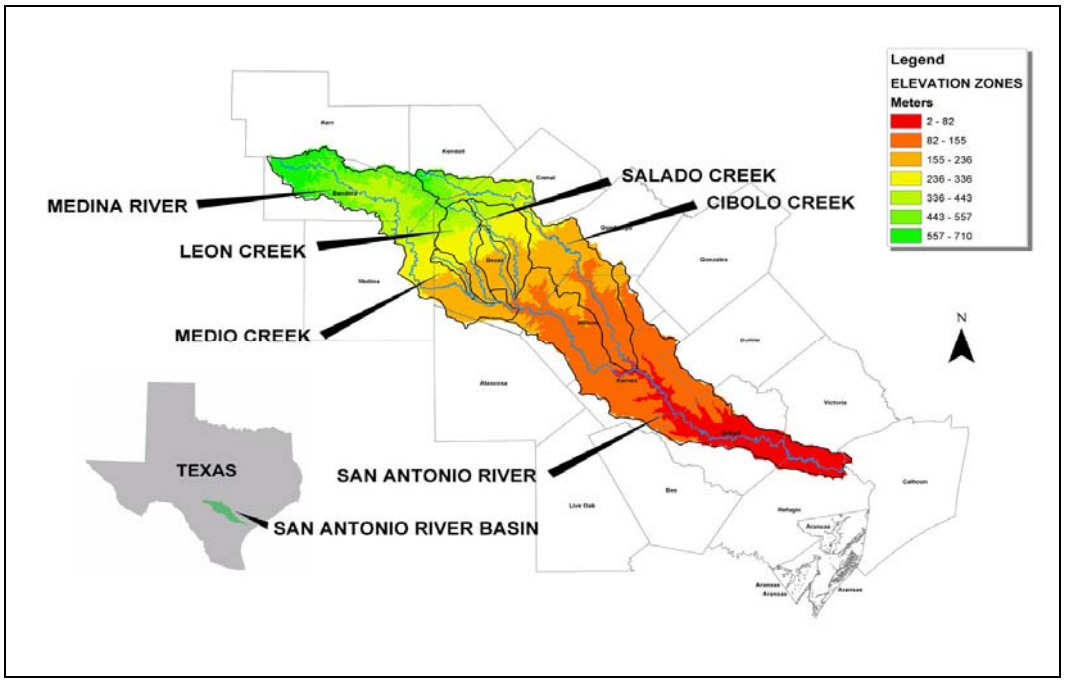

Figure 2. San Antonio River Basin elevation map.

3. San Antonio River Authority GIS Program

The SARA GIS Program was established in 2003 to develop policy for GIS, GIS data and its serving and to implement a regional GIS database and associated components that would be the centralized hub (source) for the most up-to-date data. The GIS program is responsible for promoting and developing strategies for organizational/departmental GIS/spatial data standardization, automation and integration, and for ensuring consistency between the departments of SARA and other state/federal and private organizations/companies working on water/GIS related issues in the San Antonio River Basin area. Existing personnel includes a GIS/Database Program Manager, technicians, and collaborating departmental personnel.

The GIS program is primarily responsible for supporting the formation of a base GIS database including river, regional tiger files, elevation data in various details, and many other regional data that are used by all departments of the organization. Additionally, the program is responsible for defining, guiding, planning and supporting the implementation of the departmental GIS databases inclusive of GIS training. GIS organizational structure and responsibilities established by SARA GIS policy provides mechanisms to have inter-departmental, organization-wide communications, feedback, and collaboration related with the organizational Enterprise GIS.

The GIS program is led by a GIS/Database Program Manager who developed GIS policy for SARA, completed the inventory of regional SARA related data from federal/state/local sources, developed/implemented all of the fundamental critical quality assurance and quality control standards, standard of procedures, guides, training materials for spatial data/metadata,

specialized geodatabase models for water resources (Arc Hydro). The program has carried out SARA users training. Additionally, the program guided departmental GIS database projects and completed planning of departmental GIS database implementation projects since its inception.

The program established MS SQL – ArcSDE Enterprise GIS database together with relevant documentation and established connections using various client tools such as CAD (AutoCAD 2000, Autodesk Land Desktop 3 etc.), ArcView 3.2, ArcGIS 8.2/8.3, ArcExplorer 2.0/4.01 to the database, and migrated the database from its temporary Windows 2000 server to permanent Windows 2003 server, and has set-up and configured intranet and Internet web sites for data/metadata serving. Currently, loading the spatial data using standard of procedures established to database and customizing web sites, and implementing pilot scale projects for the departments. In this paper, the progress in Enterprise GIS implementation for SARA has been summarized.

4. Enterprise GIS Database and Internet Serving

The GIS organization and Enterprise GIS system implementation for SARA initiated with establishing general guidelines for GIS and its use. This is documented in SARA GIS policy. The policy stated the vision, objectives, organization, general standards for data quality/consistency, metadata, software, hardware requirements, accessibility, technical support and funding sources for SARA GIS.

The next step was to formalize the regional GIS database implementation process, necessary steps, funding and other issues using project management principles. Formal project management documents were prepared by the relevant department together with the program manager and approved by the SARA management. After the approval, the next step was taken to determine the requirements for GIS, and the collection of federal/state/local data for SARA. A GIS coordination committee has been established by the GIS policy through the participation of departmental representatives, existing and prospective GIS users, and surveying/CAD personnel. All the basin-related federal/state and to the extent possible local/organizational spatial data and metadata have been collected from various internal and external sources and the data inventory has been formed.

A GIS Database was set up and configured using MS SQL 2000 and ArcSDE 8.3. First, general database storage structure, filegroups, and security and backup mechanisms were identified/explored and implemented (ESRI 2003b; ESRI 2002d). Test data standardized using developed standard operating procedures (SOPs), modeled using Visio, and loaded into the database using simple or object loader tools of ArcGIS. Database and operating system tuning were carried out by adjusting parameters specifically related with buffer size, checking for CPU usage and disk I/O, for better performance with the sample data and limited users (ESRI 2002c; ESRI 2003e).

For GIS base database standards/guides/manuals and simple geodatabase modeling schemes were developed and implemented using

various tools and Visio 2002. Geodatabase models are developed using Visio 2000 are used to generate the structure for datasets stored in ArcSDE/MS SQL database. Many geodatabase model templates were tested to find the best model to capture features and attributes of spatial data layer/layers in concern comprehensively and collectively and to serve them efficiently over the network/intranet/internet. The selected/finalized visio geodatabase model was documented and used to build geodatabase for the storage of the data. Data layers were standardized according to the established standards, guides for spatial data. The standardization process included data conversion, projection to SARA accepted projection (i.e., State Plane, South Central Texas, Feet with horizontal datum NAD83 and vertical datum NVD88), mosaicking and/or tiling and/or cataloging for raster data, raster/vector or raster format, vector format conversions, clipping, generalization, feature location and attribute accuracy checking/conciliating and adjustments, metadata entry or importing and many other processes depending on the original data (ESRI 2003g) . The loading is carried out after the standardization by using object or simple data loading methods in general. During loading spatial indexes were determined using mean/mod/median feature sizes for a vector data or using data type (bit depth), database and client/network settings for a raster data and these indexes were assigned while loading the data (ESRI 2002c; ESRI 2003d; ESRI 2003e; ESRI 2003g). At the same time data compression schemes were applied.

The metadata, and data dictionaries have been generated/finalized for the data migrated to the enterprise GIS database. Currently, the loading process has been completed for some of the data sets and client tool connections for various user software environments have been established for the GIS database users. The departmental GIS database support projects were initiated to form department specific databases. The GIS program not only formed the general outline of the support projects but also detailed the outline in the planning phase, and established the mechanisms/documentation templates for the communication of progress/process and issues, data modeling, dictionary and others.

GIS program established the ArcIMS, and metadata server web sites together with associated tools, utilities using ArcIMS, Tomcat, IIS, over the Windows 2003 server before it has been endorsed by ESRI, and served sample metadata documents for pilot scale projects.

5. Spatial Data Standardization

Data standardization process has been carried out according to the standards, guidelines established for SARA using the ArcGIS/CAD tools, and custom developed scripts and programs. The QA/QC and standardization steps in general included data importing, projection to SARA accepted projection, mosaicking or cataloging for raster data, raster/vector or raster format, vector format conversions, clipping to the standard spatial reference frame, generalization, data mapping, feature location and attribute accuracy checking/conciliating/clean-up/documenting and adjustments, spatial and

attribute index assignment/adjustments, compression, analyzing and many other processes depending on the original data and the migration method used. The loading (i.e., loading data to geodatabase model templates) is carried out after the QA/QC and standardization by using object or simple data loading methods. During loading spatial indices were assigned. At the same time data compression schemes were applied specifically for raster data. After loading compress and analyze commands are used to compress the database and to update the statistics of business tables, feature tables, and delta tables, along with the statistics on those tables' indexes (ESRI 2002a; ESRI 2002c). Metadata, have been imported or generated and when necessary modified for the data migrated to the enterprise GIS database. Database models, data dictionaries, and standard of procedures, quality assurance and control procedures were formed.

The process of migration for each type (i.e., with certain unique format) of data (e.g., DOQQ to ArcSDE or shapefile to ArcSDE) has been documented in standard of procedure documents. Set-up and configuration documentation, user manuals for the enterprise GIS database and ArcIMS and Metadata intranet/internet servers have been generated. Many hours have been spent for standardization and quality assurance/quality control of the data layers to have consistent/integral/accurate/current GIS database.

After the data migrated to ArcSDE/MS SQL GIS database, metadata was imported, and in some cases generated and/or modified for ArcSDE layer. User manuals for SARA users will be developed to document the procedures and issues related with enterprise database access/editing.

6. Quality Assurance and Quality Control for GIS

Development of standard operating procedures (SOPs), quality assurance/quality control (QA/QC) procedures and timely updates were determined as a necessary and integral part for well-organized, efficient GIS database development/management. The SOP/QA/QC procedures should include steps taken to standardize and the clean-up of original data and modeling/documentation of geodatabase items (geodatabase model with database dictionary) and the specific data related issues. Custom queries/scripts/programs and QA/QC were developed to check accuracy/correctness of the data sets. Generation of QA/QC procedures was time consuming, however, developing and using them provided feedback on database users' abilities and ensured the quality, currency and accuracy of GIS data. SARA is still in the development stages of Enterprise GIS database; a major portion of the feature and attribute data entry will be carried out by departmental personnel specifically related with the departmental spatial data. The SARA GIS program has already gathered and standardized some of the data that would be used as a starting point for departmental GIS database formation. The departmental database will be formed by the relevant departments with the guidance, and technical and training support of the GIS Program.

7. Communication for GIS

One of the first things need to be accomplished in the organization for successful implementation of GIS database is to establish mechanisms and platforms for communication with organizational personnel on GIS and its uses together with full management support/endorsement. As proposed by GIS policy, the GIS coordination committee, together with the regularly held monthly meetings and departmental GIS database support project meetings, have formed the GIS users platform and mechanism to communicate/feedback on GIS development and relevant issues/problems within SARA. Setting up the formalized project plan for the Enterprise GIS database and presentation/justification, endorsement of this plan to/by the management, and later on follow-up on the issues related with the plan at departmental level through departmental GIS support meetings was crucial for GIS implementation at SARA. SARA personnel has been trained in GIS fundamentals and further training plan has been prepared with the observations of SARA personnel's needs/requirements and difficulties/problems encountered by the personnel related with GIS. At the same time, formal/informal information meetings on GIS with counties within SARA's jurisdiction specifically with the ones having technology or personnel difficulties in implementing GIS are conducted.

8. Departmental GIS Database Support Projects

Departmental GIS database support projects have been initiated to identify, gather and store the spatial data needed specifically by the departments of SARA for daily works/tasks or projects of departmental personnel. The database support projects were formed mainly by the departmental personal for spatial data identification, locating, attribute entry and CAD/Survey division personal for mapping, geometry entry, data clean-up and migration currently. The support projects' objectives, needs, requirements, resources, challenges have been documented using SARA project management documentation. SARA GIS support project departments included (Figure 3):

1. Watershed management
2. Engineering
3. Real estate
4. Utilities
5. Environmental services
6. Planning and development and others

And the following supporting departments:

1. Information Technology-GIS/Database
2. Finance
3. Intergovernmental and Community Relations

And one program:

Lower Guadalupe Water Supply Project

The general outline of the GIS support projects based on established project management principles has included the following steps in general:

A. Definition Phase:

This phase initiated the departmental GIS support projects by preparation of project management definition documents indicating objective, needs, resources, challenges and endorsement from the sponsors and approval of SARA general management.

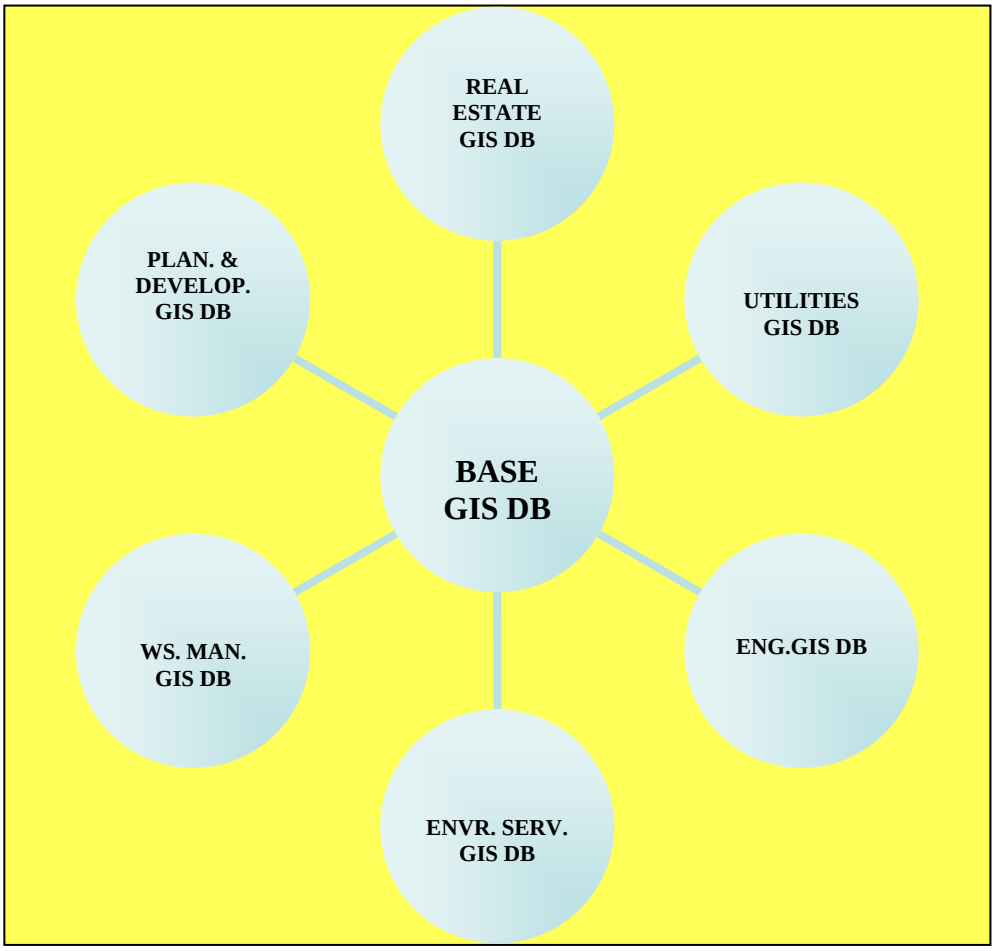

Figure 3. Departmental GIS database support projects.

B. Planning Phase:

1. Functional and operational requirements identification
2. Basic Training for Data collection, modeling and standardization
3. Data Collection
4. Standards/guides and QA/QC procedures development for departmental data

5. Metadata finding, exploring and populating
6. QA/QC- Missing data/metadata completion, units, projections, coverage standardization Database conceptual model development (schema development)
7. Migration and loading of data into the personnel database – comes with the software used Jet Engine (Access) at the background (pilot scale)
8. Documenting database schema for approval
9. Migration and loading of data into the personnel database (full scale)

C. Enterprise Database Implementation Phase:

1. Integration of departmental data to main GIS database
2. Training for Enterprise GIS Database
3. Data sharing/responsibilities for maintenance of departmental data SOP/Guides for maintenance and future updates

D. Closing phase

1. Operation and maintenance (updates, automation, application development)

Depending on the departmental GIS needs/requirements, details of the planning and implementation has been modified/adjusted. For example, for watershed modeling items related with real-time and near-real time modeling support through GIS database and water resources specific geodatabases (ArcHydro, HECHMS/HECRAS geodatabase models) and items related with interagency/inter-organizational/regional coordination/communication/data sharing activities/standards as well added. For environmental services database communication with state environmental quality organization (i.e., Texas Commission on Environmental Quality, TCEQ) and adaptation of the state defined standards are included.

9. Training for GIS

The GIS training is considered as an essential and integral part of Enterprise GIS development for SARA. SARA's GIS program has laid out the plan for training of the GIS support projects personnel to elevate their knowledge to the level that they would be able to establish the GIS databases for their department with minimum help from outside. The training program included the classes starting with basic-introductory level classes and continuing with database modeling, building, and ending with a class on enterprise database/GIS systems issues, customization and automation. SARA personnel have been trained in GIS concepts, processes, uses, GIS database and connection and carried out hands-on exercises using relevant GIS tools. The training program included department specific GIS training classes as well, such as a class on CAD to GIS conversion focusing on ArcSDE CAD client tool and conversion issues, and a class on ArcSCAN to cover conversion of scanned paper maps to vector format GIS data etc (Gaudet et al. 2003; Wear 2002; Wikle 2002). Additionally, for department specific databases such as Arc Hydro training materials together with sample

data has been prepared and presented to users. For ArcSDE/MS SQL database client tools training materials were prepared. ESRI training class has been carried out, and the training for departmental specific databases/database models, enterprise database, standards and other relevant issues are planned/outlined for the future (i.e., training program to accommodate the user needs to use GIS effectively, and efficiently and to establish departmental GIS databases have been established). Additionally, training schedule and details (syllabus) have been laid out. The training will be carried out as indicated in the GIS project plans.

10. Pilot Scale Projects and SARA GIS Future Phases

SARA has established the Enterprise GIS database and currently standardizing/loading data layers for base GIS database and set-up ArcIMS web site and developing/customizing the web site. At the same time departmental level GIS database formation process has been initiated and first pilot scale projects were implemented. In the pilot scale implementations, the relevant geodatabase models and geodatabases based on them were developed together with associated data dictionaries, standard of procedures (SOP), QA/QC procedures, guides, specifications and reports using representative data. Pilot scale GIS implementations at SARA facilitated to:

a. Test hardware, software and other tools/data to be used
b. Test and refine conceptual and physical database design and generate sample representative database
c. Identify appropriate data conversion approach, and develop relevant SOP, management and maintenance procedures, QA/QC and technical specifications, guides
d. Identify and test potential alternatives for full-scale implementation and develop relevant documentation
e. Develop management strategy to market system to end users and the management
f. Provide hands-on experience and exposure to key personnel
g. Evaluate and quantify results
h. Estimate data volumes, costs, production and maintenance scheduling, system management and staff training needs for full-scale implementation

User requirements for additional functionalities, advanced tools and real-time capabilities will also be identified, prioritized and implemented with enterprise full-scale GIS database. As a future step, enterprise database will be made available to the field personnel who work on data gathering. The mechanisms will be developed to allow the field personal to make edits to the geodatabase during the workday through disconnected editing etc. At the same time, the applications developed for departments for real-time or near-real time flood modeling, data acquisition, and others will also be

integrated with the GIS database. Additionally, the fully implemented GIS database will be served over the intranet and internet with varying levels. Currently, SARA web site for serving of GIS Data/maps/metadata/tools over the intranet and internet has been formed and being tested and tuned and used for pilot scale implementation disseminations.

Conclusions

Development of GIS policy provided the direction and vision for GIS in SARA. The establishment of ArcSDE/MS SQL database had streamlined spatial data management and maintenance process for SARA related with GIS. As the development and implementation of the geodatabases continues and matures, it is expected to have more interest and extensive use of GIS database by SARA managers and departmental staff as a spatial data management, manipulation, analysis, modeling and decision making tool on a regular basis including the daily works/tasks. During the development intensive training for GIS, spatial databases, and migration and enterprise database issues will be carried out, to facilitate the development of departmental GIS databases by GIS support project personnel. Additionally, the training will be diversified to accommodate departmental needs for GIS. The development of the enterprise database and associated web components and implementation will ensure the spatial data quality and increase the productivity of SARA personnel related with their daily works/tasks, and will increase the organization-wide efficiency. The database and relevant documentation/SOP/guides developed will form basis for spatial data sharing/communication for local, state, federal level collaboration. The database will support real-time, near real time and other applications/programs specifically built for flood control, management, forecasting, basin-wide water resources, water quality planning, capital improvement projects management and prioritization. The database will form the backbone of the intranet and internet serving of regional/local spatial data using ArcIMS, Metadata server. The database and associated applications will enhance public awareness/support on regional water resources/environmental issues by serving as a centralized one stop information hub on spatial data and related issues and will improve the role/presence of SARA as a regional water/environmental management organization.

The investment in GIS will improve efficiency at SARA by providing timely and reliable information to address regional issues, concerns, problems such as flood control, flood mitigation and planning, environmental assessment and monitoring and so on. SARA GIS database and associated components will facilitate better planning, management, implementation decisions by provision of proper information, analysis and visualization capabilities. SARA GIS will also provide tools to generate future opportunities and add value to SARA services.

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