Development and Integration of Enterprise GIS

by

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ABSTRACT

GIS introduction in the City of Richmond, VA follows typical Management Information Systems implementation patterns. All implementation stages including infancy and maturity have required understanding and accepting GIS vision, choosing and enabling technology and management framework, and defining business processes and data types/models that GIS can support. Additional characteristics of the City Enterprise GIS development are characterized by interdepartmental cooperation, centralized spatial databases, spatial and non-spatial applications, inter-agency data integration and maintenance, senior management support for GIS, stable staffing, and multi-phase implementation.

INTRODUCTION

The City of Richmond, Virginia, is situated on the banks of the James River approximately 100 miles from Washington, DC and the Atlantic Ocean. The City has a $514 million general fund operating budget, about 4,500 employees and a population about 200,000.

In 1998 the City of Richmond realized the benefits of implementing GIS to support business processes. A steering committee was formed and an implementation plan was developed. This plan was devised for a few phases following a needs assessment. The plan outlined targeted departments, applications and data conversion projects, staffing, and budget recommendations.

The City of GIS foundation and related applications consist of standardized software, an integration of spatial information with the City's master address database, data warehouse, Internet mapping services, and centralized GeoDatabase (GDB).

Most agencies of the City are located in one place – City Hall, but there are a few of them that are geographically dispersed across the City – Department of Public Utilities (DPU), Police, and Fire departments.

The Enterprise GIS becomes an important concept in the City of Richmond - the concept that raises not only the level of analytical capabilities, but first of all, integration with business processes, applications and data. A set of four strategic goals was identified for the Enterprise GIS:

1. Multi-purpose – the system should be designed and implemented to satisfy various business requirements of many agencies
2. Centralized administration and management – the system should have centralized administration and management solutions to provide coordination, standards, support
3. Decentralized operations – separated agencies should have decentralized maintenance, data, applications and business processes specific to agency needs with centralized administration and management
4. Effectiveness and efficiency – the main goal of the system should be maximization of functionality and invested resources

PHASE IMPLEMENTATION AND FUNDING

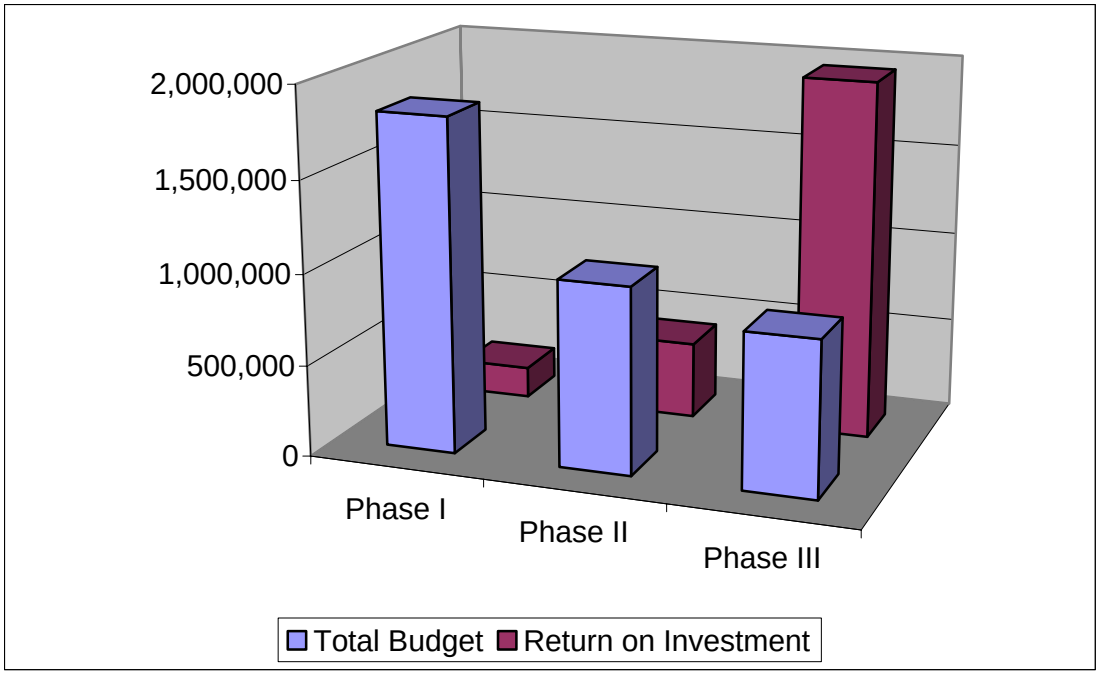
GIS Enterprise implementation was devised by few phases/modules. Each phase characterize by specific goals, including establishing target GIS business functions, policies and procedures, new databases, business units and budget. The following are two-year phases of the City of Richmond's GIS implementation:

- Phase I (1999 – 2001) – staffing, primary data layers development, establishing software and hardware architectures

- Phase II (2001 – 2003) – establishing centralized database, linking legacy systems initiation, further data layers development, dissemination GIS data and functions to public

- Phase III (2003 – 2005) - further linking of legacy systems, distributed databases

Historically, the GIS budget in the Department of Management Services has been used to fund all GIS projects in the City. All GIS funding comes from the general fund. The GIS budget for Phase I was about $1,826,250 (see Graph 1). Return on staff investment was about $170,000. This includes projects and tasks (mainly data development and integration) that were performed by in-house staff without the assistance of a consultant. This does not include the day-to-day mapping and/or analysis projects that were performed by the GIS Team or other City GIS users. The GIS Budget for Phase II was approximately $1,019,031. The total return on investment on in-house staff was about $420,000. The GIS budget for phase III was around $847,385 and return on staff investment was about $1,955,000 and included application development, GIS training and ArcSDE/GDB implementation.



Graph 1: GIS Budget and Return on Investment by Phase

EVOLUTION OF ENTERPRISE GIS

Since its origin, GIS is part of Information Systems (IS) and evolves from technological and organizational points of view towards full Management Information Systems (MIS). This “final”/mature stage of GIS is often called Enterprise GIS.

We define an enterprise system as GIS business processes, people, data and software, which supports a core business function and serves as the official source for information that is managed within a centralized database. A vision of an Enterprise GIS is with data use and maintenance, which are distributed to local data sources, but the storage and management of data are centralized.

There are many approaches to classify a growth of technology. We divide it into the three stages: infancy, intermediate and mature. It is assessed that the development of the Enterprise GIS in the City of Richmond is in the intermediate stage.

INFANCY STAGE

Generally, in this stage there are no plans for developing the Enterprise GIS, which operates independently of other information systems. Relationships between administrative units are uncoordinated, few stable processes are used, and data collection is not consistent. This stage is intuitive with unpredictable cost and quality of service. There is no unified architecture process across technologies and lines of business. Documentation of business processes and technology standards are informal and inconsistent, and reporting is rarely real-time. Projects and purchases are typically done in isolation, resulting in costly purchases and redundant development and training requirements. Some groups are unsupportive of the efforts.

The infancy stage of GIS in the City was merely apart of the implementation Phase I. In this stage GIS implementation focused on establishing a foundation from which the enterprise system would grow: data creation (Parcels, Orthophotography, Basemap, Contours), GIS training for City staff, establishing software and hardware architectures, and Computer Assisted Mass Appraisal system integration. A simple GIS Web site was developed to provide access to GIS and assessment data via the Internet.

While the infancy stage was successful in developing the City's base mapping and creating novice desktop users, no standards or maintenance guidelines were implemented. Additionally, the business processes for tracking Parcel changes in the Office of the Assessor and addresses in Department of Community Development were not defined and enforced. Approximately 50 employees were trained in GIS. Although an investment was made in internal training and GIS licenses, only half of these licenses were used regularly.

INTERMEDIATE STAGE

In this stage information management is formalized. Data definition and collection are standardized across the organization, and multi-departmental project groups start to work together. Slowly, the increase of maturity of GIS identifies it as an organizational source, and applications are modified to take advantage of GDB capabilities. Cost and quality becomes predictable. The organization has begun to develop a vision for Enterprise architecture. The need for Enterprise GIS is being communicated to senior management. Enterprise GIS is documented and strategic information has been identified.

During the intermediate stage enclosed in Phase II and part of Phase III, the GIS Enterprise implementation mainly focused on advancing into the next generation of a more object oriented GIS technology with centralized databases, linking legacy databases, and development of more effective dissemination of GIS data and functions to the public. In this stage we focused also on changing the skills and mindsets of the GIS user community.

The City's GIS implementation has databases of some business units connected through common identifiers and spatial relationships using GDB and the Data Warehouse (DW). Building from the infancy stage, there were further data refinements and additions, e.g., Parcels, Centerlines, Education or Census layers. Along with several ArcGIS applications and extensions that were created in-house (Parcel Editor, City Data, Label Maker, Zoning Editor, City Tool Box and Image Manager), GIS on the Web was also developed. Additionally, progress was made in the implementation of ArcSDE and ArcGIS. The hardware infrastructure for GIS was greatly enhanced. GIS implementation focused on educating and training City employees and GIS users. Preparations for data distributed environment were initialized. Field inventories, and hardcopy map conversions were also performed.

To facilitate those changes the GIS Team participates in the Information Technology Steering Committee, GIS/DIT Technical Committee and the Committee for the City's Asset and Work Order Management implementation. The GIS Team also participates in the Departmental Automation Plan development.

MATURE STAGE

In this stage the Enterprise GIS is well defined, architecture committees are defined, the lifecycle architecture processes have been defined and documented. Enterprise is integrated with strategic planning and budgeting process, standards are common practice throughout the enterprise, processes are continuously and systematically improved, a strong sense of teamwork exists across the organization. As the enterprise matures predictability, process controls and effectiveness increases. One of the characteristics of this stage is that GIS expenses are lower than in previous technology growth stages. Personnel throughout the organization have a good understanding of the architecture principals and participate actively, and new business models are developed. The organization works with other jurisdictions to share ideas with focus on improvements related to business and technology trends. Finally, the Enterprise GIS process drives continual reinvention throughout the organization.

Our goal for the mature stage is to make an effective and efficient Enterprise GIS.

ORGANIZATION

GIS TEAM

The group called the GIS Team leads the GIS implementation in the City. From its initiation, the GIS Team was not placed inside of Public Works, Community Development (DCD), Information Technology (DIT), or Public Utilities (DPU) departments, as is typical with most local governments. The City of Richmond placed the GIS Team under the umbrella of the Department of Management Services (see Figure 1). The GIS Team consists of four GIS professionals: Coordinator, Project Manager, Analyst and Technician. Almost each member of the team is capable of handling multiple tasks, including defining policies and procedures, project management, programming, data development and maintenance, training, and other duties.

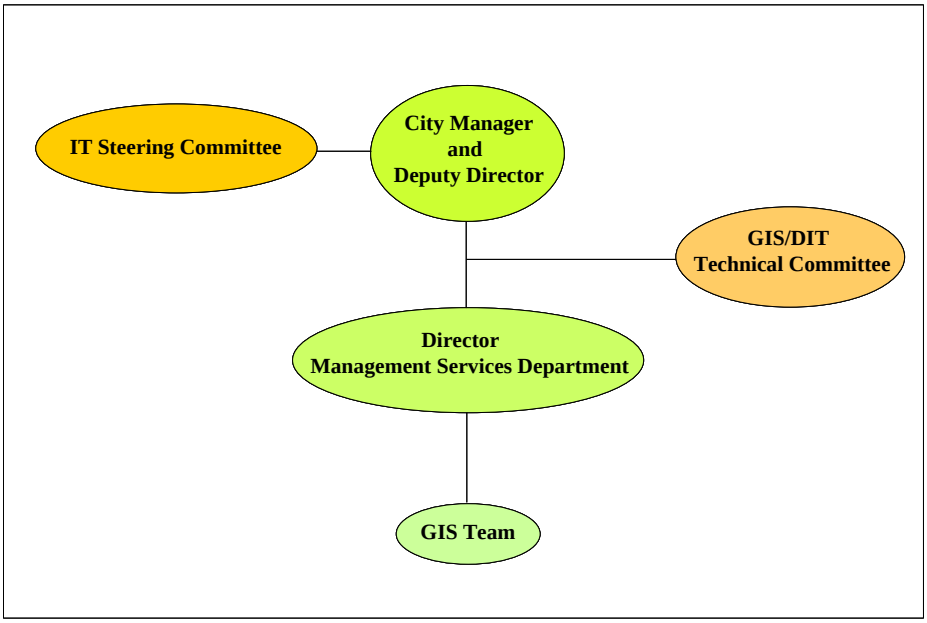


Figure 1: GIS Organizational Structure.

The GIS Team's relationship to other departments encompasses three areas:

1) To supply the stakeholders within City departments with the vision, knowledge, tools, applications, and GIS software training to use the technology. In many cases funding also is available for GIS projects. Typical things we have provided are: customized training, applications development, user support, software upgrades, and project management
2) To help identify where GIS can be used to solve problems or answer questions, increase sharing of or integration of data across the enterprise, and to make business more efficient.
3) To coordinate any GIS efforts with DIT.

One of our primary implementation goals is to document all GIS policies, procedures, and practices. The documentation includes descriptions of databases, applications, and work flows. For more efficient GIS implementation, the GIS Team adopted the following strategies of "sharing duties" with DIT:

1) Programming code and data are created and tested on a development server by GIS Team programmers, and are promoted into production by our DIT system engineers.
2) The Department of Information Technology plays an integral role with ArcIMS implementation, maintenance, and administration.
3) The GIS Team is the administrator of the SDE and SQL Server (DBA), while DIT is responsible for the system administration (SA).

PLANNING

GIS planning in the City of Richmond encompasses three levels of planning: strategic, operational, and annual.

The Operations Portfolio's Strategic Technology Plan represents the strategic level of planning. It states that GIS should be a supporting technology for the method in which the Operations Portfolio conducts business, particularly within the development of an asset/work order management system. Strategic planning is essential when trying to maximize return of Enterprise GIS implementation. As GIS continues to evolve, it is critical to foresee and plan for future directions to provide the foundation for the use of geospatial data in supporting an organization's business plan.

The operational level of planning is represented by the Automation Plan. The Automation Plan is a citywide approach to collecting, documenting and organizing the technology efforts in all departments. It includes all initiatives and projects that are multi-departmental, and require DIT approval and involvement. Beginning in FY04-05, the GIS Team's working plans follow projects outlined in the City's Automation Plan. A key component to getting an IT project included in the Automation Plan is the review process of the IT Policy Committee, which is chaired by the City Manager.

Our annual plans are based on the Automation Plan projects and some projects that for various reasons weren't placed in that plan, e.g., transportation model development or storm water data inventory.

DATA DISSEMINATION

The City of Richmond GIS Team encourages and promotes the use of GIS data. Access to the City of Richmond's GDB is unrestricted for 'data reading'. While anyone can have read access to the database, the GIS Team has applied security settings on all information, which protects all users even data custodians, from the 'default' data directly. The GIS Team categorizes GIS users into three tiers: Tier 1 - ArcInfo and ArcEditor users, Tier 2 - ArcView users, Tier 3 - Web-GIS users. Those tiers are used to define software type and data access requirements. There are few methods for distributing GIS resources to the end-user, but mainly a client-server method is used. To save resources we developed a strategy of data distribution between Tier 1 and Tier 2 users is used.

The client-server method is used to provide access to GIS software and data for Tier 1 users who develop and maintain data and perform analysis and modeling. There are two prerequisites for this type of implementation: high-power workstations and high-speed network with 100 Mb bandwidth.

Through the 'CityData' extension strategy, Tier 2 users are encouraged to work with personal geodatabases (PGDB) that are delivered to their PC from GDB and GIS data servers. Direct access to the database is discouraged to save resources, including network, server and database responding time. The CityData extension exports data from GDB and makes it available to users in the form of PGDB. The philosophy here is to limit the number of desktop users that would simultaneously interact with the geodatabase across the network.

To increase the usage and availability of the City's GIS investment, and promote the idea of open government, GIS data and some functions are available for anyone (Tier 3 users) by using web-based GIS – WebMapper. The WebMapper was designed to access information from the data warehouse and GIS servers. The idea behind the development of such a site was to provide a GIS that offers the kind of tools and abilities found only on desktop GIS software, and to make much of the City's information and GIS data available for use. This saves money in terms of limiting expensive GIS desktop software purchases and also provides increased citizens and city staff access to GIS.

The GIS Team believes that metadata documentation is a very important part of GIS. Following the National Spatial Data Infrastructure standards, we focus on three areas of metadata:

1) GDB metadata – data and data models/diagrams, database schema
2) In-line Programming/Code metadata – documentation
3) Process or Application metadata – documentation

VERSIONING

Versioning is a critical component of our Enterprise GIS business processes. Versioning is an RDBMS technique that plays a key role in terms of multi-user editing, data integrity, business practices and procedures, and project management. The adoption of versioning to edit GIS data supports our efforts to protect the information from direct editing of source data, which helps us ensure data integrity. Editors are prevented from working directly against their data. We apply the following versioning rules:

- The default version of GDB is the production level data, and each business unit has their own Editing Model and MASTER version for performing updates (see Figure 2)

- Versioning Models that limit branching of versions and employ direct lineage
- Reconciling edit changes are made in short time periods, rather than over long time periods.
- Conflicts are resolved only by a data owner and by the GDB Administrator

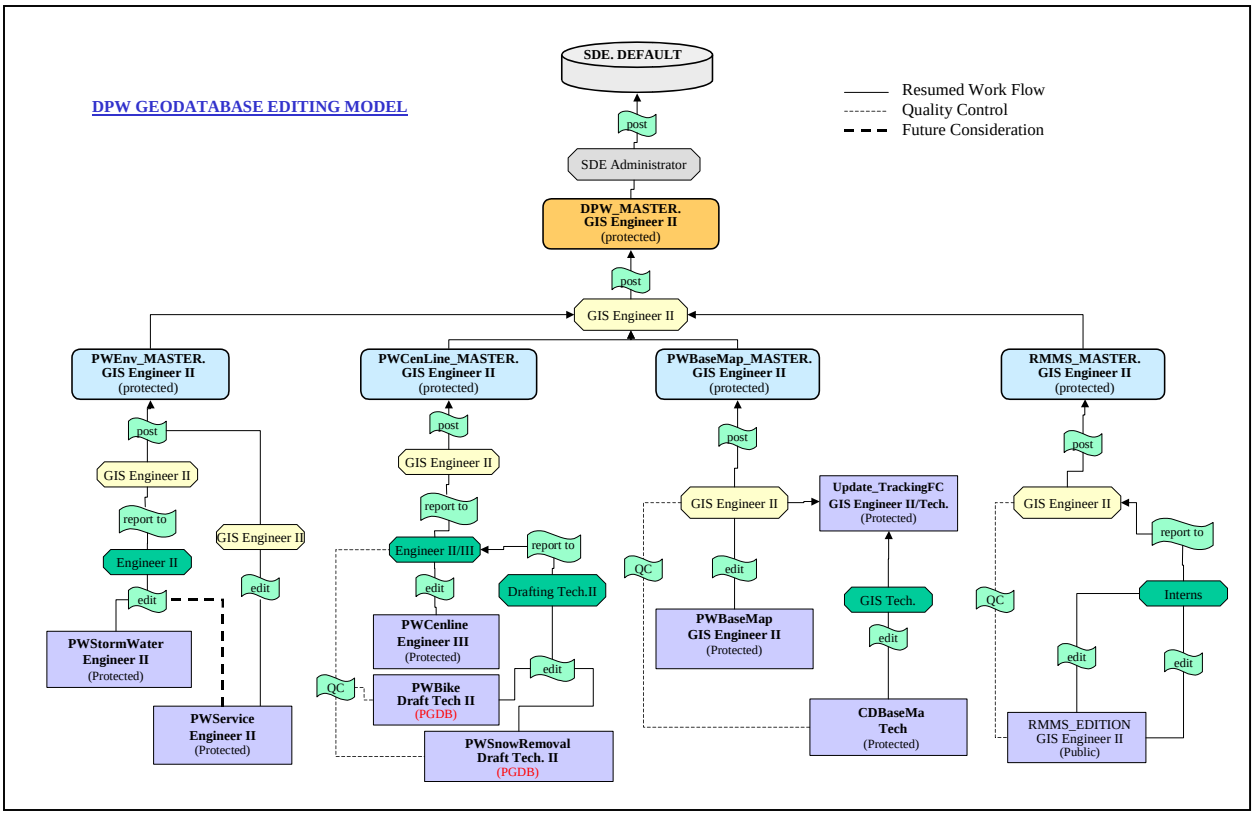


Figure 2: Department of Public Works Editing Model.

GIS INFORMATION TECHNOLOGY ARCHITECTURE

GIS hardware consists of a mixture of Windows and Unix based servers (see Figure 3), where the production servers contain the Redundant Array of Independent Disks (RAID). Following is our current GIS hardware architecture:

- 2 Windows development and production Web Servers
- 2 Unix Spatial Servers
- 2 Windows GIS Data Servers
- 1 Window SDE Server

The City of Richmond saves on software costs by utilizing a “floating” or “concurrent” licensing style for distributing GIS software. Forty floating licenses (and dissemination strategy) serve approximately 150 different types of GIS software users. Central license managers that are hosted within GIS, DIT, DPU and Police servers license all ArcGIS desktop and workstation products.

To avoid functional and data format problems, it was decided that GIS will be represented by the ESRI suite of products. All base modules and a few extensions of ArcGIS are used. Additionally, ArcSDE, ArcIMS, ArcReader, ArcPad, GRID, and TIN are utilized. Only the latest software release version is used. Erdas Imagine software is used for satellite imagery analysis.

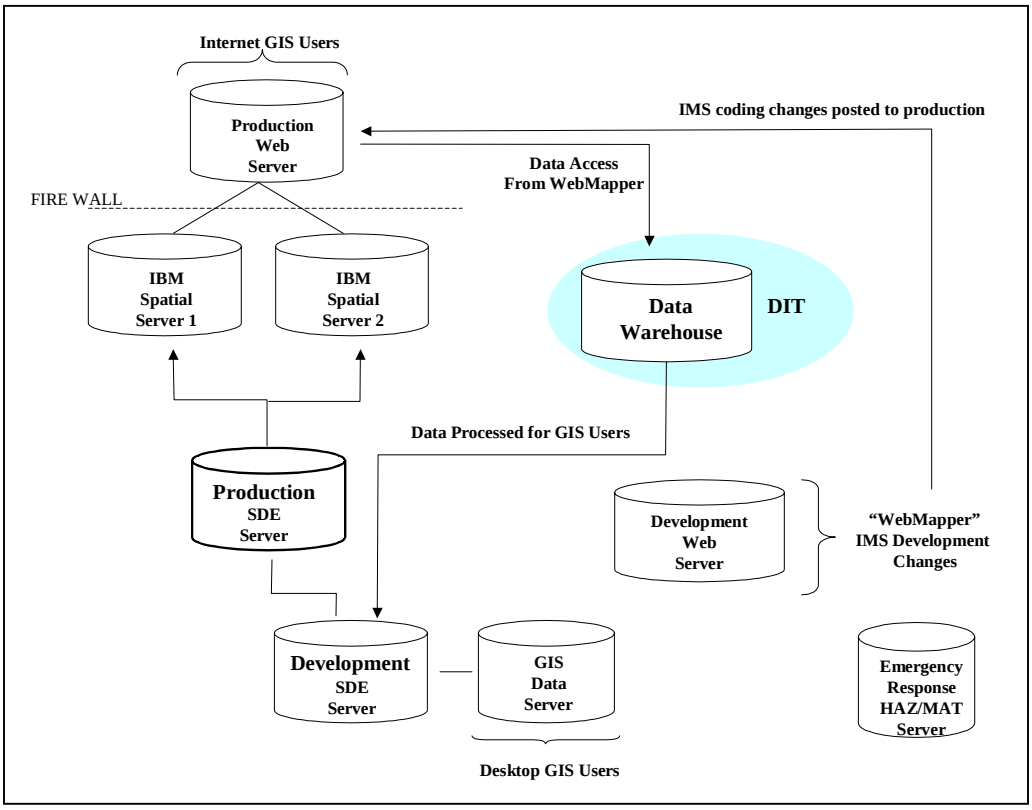


Figure 3: GIS Hardware Architecture.

GEODATABASE

ArcSDE and ArcGIS are essentially a shared technology solution for the City of Richmond. The GDB is used for storing and managing the City of Richmond's geographic information. The GDB is implemented in a Microsoft SQL Server environment. The City of Richmond's GDB is composed of 1) vector - geographic data and associated attribute data, and 2) raster – orthophotography and imagery. The vector branch consists of a few thematic databases.

Using CASE Tools and Object Oriented design methods, the GIS Team develops "Concept Models" in determining how the system works logically and how it meets user needs. The models are used, and are going to be used for storage of assets such as parcels, transportation, basemap, gas, water, sewer, and storm water utilities.

We have established custodianship and data access protocols. Data that are stored within the Geodatabase are owned by contributing departments. The role of the GIS Team is to support the creation and maintenance of such data, in partnership with

specifically identified departmental owners. Data may have an owner who is also the editor of the information, but there are owners who do not have the GIS skills necessary to perform editing or maintenance tasks. In such cases, the GIS Team takes over maintenance tasks, based on a request from the factual data owner.

The GIS Team has instituted a custodianship and documented a policy with each of the contributors and data custodians of the GDB. The owner, or data custodian is designated data editor. Under this rule, no other GIS user is allowed to perform either geographic or attribute changes of a GIS layer. Based on the database versioning function departmental editing models have been established. In this way, the GIS Team not only protects the production (default) version of the data, but also is able to track when data is changed.

FOUNDATION FOR ENTERPRISE GIS

Most information that is related to an address is also linked into GIS, which means that disparate data sets from different department systems can be spatially integrated. This cross-pollination of data could not have been accomplished without the master address database and data warehouse.

Central Address is the master address database and it is a main theme of the GIS implementation program. Many spatial and non-spatial applications are dependent upon address and its relationship to a parcel/property. A key challenge to developing a truly enterprise data system requires that the City's transactional business databases be connected/related. The best way to accomplish this is to use Central Address as the address database, and have the entered addressed data verify its accuracy against it in real-time. The advantages of this are two-fold: first, the database information will match all other City database datasets that are Central Address compliant, thus allowing for an accurate exchange of data across departmental lines. Second, GIS can be used to make any department's data spatial.

The data warehouse is another major keystone in the GIS Enterprise implementation. It is a complementary database to the corporate legacy databases. Data warehouse was a shared vision between DIT and GIS. The emphasis of Richmond's data warehouse is to make a copy of the source databases and reformat them into a simplified structure that makes reporting and analyzing the information easier and more powerful. A data warehouse is composed of a number of data "marts" of topical data tables designed to provide answers to business questions. The data warehouse succeeded in creating data marts for the following "types" of data: assessments, property sales, and up to forty other unique GIS-related data sets.

TRAINING

Training of GIS staff and users is one of the most important tasks of Enterprise GIS implementation. It builds upon existing staff resources and prepares for changes in technology. Training is a continuous process and can involve: self-paced online courses, reading technical books and manuals, participating in off site courses, workshops and conferences.

Core GIS users participated in all critical courses provided by ESRI. To customize the learning process to GIS users needs and to save money, the GIS Team had developed and continues to offer a few training courses. The first offering is the

"Introduction to ArcGIS" – a four-day class and a second class called, "Building and Editing Geodatabases." This second two-day class is particularly important for the training of Richmond GIS users that create and manage GIS information. The third class "Multi-User Geodatabase" was also developed. It resembles a workshop, which advance owners and custodians knowledge about versioning and editing. A few short training sessions were created, for example, "Migration to GeoDatabase" Part I and II. Additionally, during monthly GIS User group meetings 'How to do' sessions are conducted.

The GIS Team also seeks to spread the knowledge of ArcSDE, ArcIMS, and ArcObjects technology within the Department of Information Technology. Those technically minded and skilled staff is able to assist in making GIS a more efficient enterprise system.

It is estimated that since GIS deployment approximately 200 GIS users have been trained. We have provided GIS data and GIS training for approximately 15 City departments.

CONCLUSIONS

The Enterprise GIS in the City of Richmond is in the intermediate stage of technology evolution. The current Enterprise GIS characteristics are as follows:

- Offers departments with transparent access to spatial and non-spatial information
- Supports all relevant department business and decision making needs
- Supplies relevant documentation and metadata
- Provides custodianship responsibilities to departmental staff
- Integrates some non-GIS systems with GIS with Enterprise GIS
- Implements an organized framework of system security, access and protocols

Despite a few barriers, Enterprise GIS is expanding continuously in the City of Richmond. Today GIS serves the internal GIS users at maintenance, information management, and executive levels including the public and other external GIS users. The GIS Team has performed over $2.5 million worth of application/implementation projects that otherwise would be contracted to outside vendors. Richmond's GIS has a growing user base. We have converted all existing geographic information into GDB and are preparing a distributed environment. With the support of the Department of Information Technology and the master address database, a data warehouse is now able to cross-pollinate disparate data systems with GDB. GIS is becoming the asset management system of the City of Richmond. There are plans and preliminary activities related to inter-jurisdiction cooperation.

The challenges for Enterprise GIS in the City of Richmond are as follows:

1. GIS business plans improvement
2. Understanding and acceptance of GIS by middle-level management
3. Staff roles, responsibilities, and business processes need to be addressed
4. GIS budgeting need to be re-structured
5. Improvement of public and city employees' access to GIS IT infrastructure
6. Fully distributed databases among three IT centers: City Hall, Police and DPU
7. Improvement of cooperation and data exchange with neighboring jurisdictions

Despite challenges with budgeting and some planning constraints, the Enterprise GIS implementation is on a path to become a part of the City's Management Information System.

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