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Enterprise GIS for Local Government

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Introduction

Geographic information system (GIS) technology has been in use in local government (e.g., municipalities, townships, cities, counties) organizations for decades. In most, the GIS started in one department then gradually gained acceptance and was adopted in others. However, this expansion frequently resulted in isolated or, at best, loosely related departmental systems throughout the organization. Although efficiencies were gained within individual departments, the full potential of GIS to the organization as an enterprise did not materialize. Both technical and operational impediments yielded this result. This white paper introduces a set of best practices that has been shown to minimize and often eliminate those impediments and allow end users to benefit from an integrated GIS that serves the entire organization as an enterprise.

GIS and other information technology (IT) vendors have been working to address the technical barriers that have hampered the seamless integration of GIS throughout an organization. Advances in technology, particularly software interfaces and methods; the variety of hardware platforms (e.g., mobile devices, multicore processors); and service-oriented architecture have all positively impacted the implementation of GIS as an enterprise technology, or EGIS. The term *enterprise* refers to looking at the entire governmental structure as a single entity supported by information systems that can be used in combination to produce the information products required by end users while minimizing data and process redundancies. The role of an EGIS is to deliver spatial data and software tools as one of the enterprise IT systems used to provide information products to a large number of potentially varied users. The data and software tools of the EGIS may be delivered independent of other information systems but most frequently are integrated with the data resources and software tools of those systems to add value in support of departmental and organizational business functions. In particular, EGIS provides a framework for collaboration and communication by organizing and sharing data and information based on a common frame of reference—location.

Over a period of time, an alternative approach to delivering software and information products to the enterprise has been gaining acceptance. This approach is based on the concept of delivering software functionality and/or data on demand as a service rather than redundantly housing the same software function or data resource in multiple locations where they may be needed. This approach or model is referred to as a service-oriented architecture (SOA). GIS has taken hold of this model and is now providing spatial data analysis, visualization, and reports as services over the Web. As services, the data and tools may reside in one or more locations, either internal or external to the organization, and can be accessed and used to support business functions of all end users. This services-based GIS technology is an important enabling technology for governments. It allows them to be more efficient and provide consistent business functions and information products across the enterprise. These products support better

decision making and operational efficiency, regardless of the organization's physical structure.

What Is Involved in the Enterprise GIS Approach?

The goal of an EGIS is to distribute GIS functions and data throughout an organization while leveraging and integrating the functions and data offered by other technologies. Accomplishing this requires adherence to standards and use of uniform methods to define the GIS data, service, and information product components of business functions. The new or revised business processes and information products provide internal efficiencies as well as improved services to the public. For example, a standard geocoding service ensures all departments receive consistent address information and provide uniform response to public inquiries. When government departments integrate their GIS with other IT solutions, business process functions and information products, such as permitting and inspection routing, are enhanced through the use of spatial data and analysis tools. Often the use of GIS to apply location to a business function occurs behind the scenes.

In implementing EGIS, it is important to focus on

- Developing an organization-wide GIS approach using standards and consistent methodologies that address the needs of all units of the organization
- Migrating existing GIS applications and data to current GIS technology capable of supporting all potential users in a cohesive manner
- Integrating GIS data and services with other information systems within the organization as part of an overall enterprise information systems solution
- Adapting the GIS staffing structure to support the enterprise approach
- Training the IT and GIS staff to design, develop, and maintain the enterprise GIS resources
- Training staff in the departments new to GIS in the effective use of GIS specific to their business needs

Establishing the EGIS requires several years to work through budget or other influencing factors. The actual implementation timeline and sequence depend on a variety of factors such as prioritized areas of need for EGIS, availability of funding, organizational priorities, and the ability of the organization to adapt to and leverage evolving technology.

Organizations usually prepare a strategic plan, either internally or with the assistance of a consultant, to direct the creation of the EGIS. An important element of a GIS strategic plan is the multiyear work plan containing vision, annual priorities, and rough order estimates of resources required. The work plan provides this information for each of the four components of the EGIS: applications, database, infrastructure resources, and organization/staffing, each of which is discussed in greater detail below. Implementing an EGIS commonly includes migrating from an existing departmental GIS to the new organization-wide system architecture. During the migration, government business processes that rely on the GIS today must be assured of continued operation as their more

modern replacements are developed, tested, and deployed. Therefore, the work plan usually identifies activities and resources needed to ensure a smooth migration.

Enterprise Applications Based on Shared Services

Local governments, whether large or small, have departments that perform hundreds of business functions in providing services to the community. Most of these business functions have location as an aspect of their operation. The effectiveness and efficiency in the delivery of information and services can be improved by taking advantage of GIS. For example, a recent study of a midsized California city identified more than 300 business functions performed by 24 departments that currently or potentially could make use of GIS applications. Furthermore, analysis revealed that in excess of two-thirds of the business functions identified for this city shared common patterns of information processing, analysis, reporting, and management. Evaluations of other local government organizations have also revealed that a similar percentage of their business functions are characterized by these same shared patterns.

As a result, local governments are ideal candidates for an EGIS approach. By taking advantage of the services model to deliver the full spectrum of GIS and IT functionality, the business needs of a diverse group of end users can be met. This approach results in Web-based GIS applications and services that are developed and managed once but packaged and made available to multiple government departments in a manner tailored to each one's particular needs.

For those specific business functions that require intense levels of GIS-based editing and analysis, typically not well suited to a 100 percent Web services solution, desktop or mobile GIS solutions can be implemented. These implementations focus on the specific needs of the individual departments and are designed to leverage the applicable components of the enterprise Web-based solutions.

A conceptual EGIS design that takes advantage of the SOA model is shown in figure 1. This conceptual design requires multiple application and technology components arranged in several tiers to deliver Web-based desktop and/or mobile services as well as applications. As shown in the figure, these components provide GIS functionality and information in a consistent, integrated, extensible, and efficient manner to all applications regardless of the underlying software platform.

The tiers that comprise the application concept for an EGIS include the following:

- **User Access Tier—**The user access tier contains the end user application interfaces as determined by the underlying technology platform. Each of these interfaces is an entry point for department staff and, where appropriate, the public to gain access to GIS application functionality and data resources.

- **Business Logic Tier—**The business logic tier consists of the business rules and programming logic for using GIS and other software capabilities to fulfill the step-by-step requirements of each business function. The content of this tier directs the use of the service components and server and data infrastructure tiers to perform the business functions. For example, the business logic for creating a mailing list would exist in this tier and be used by all departments in creating their respective mailing lists.

- **Service Components Tier—**The service components tier contains the GIS-based services used by Web-based applications. It also provides service-based capabilities for desktop and mobile applications. Several types of services are identified in the figure including

  - Framework services that provide the most commonly used GIS functionality and data services such as geocoding

  - Public access and commercial services that provide easy access to available data and Web services from external sources such as federal government sources and ArcWeb℠ Services

  - Business application services and service adapters that enable the integration of the GIS with other business systems, such as building permits, within the organization as well as authorized external systems such as those of other government entities

- **Server and Data Infrastructure Tier—**The server and data infrastructure tier provides management of and access to GIS and other data resources needed to perform the departmental business functions. It is sometimes referred to as the *authoring* tier because GIS data creation and editing occur on this tier.

Also shown in the figure is a development and integration framework. This framework provides the communications infrastructure for binding together the components of the other tiers. This framework can take many forms and is sometimes referred to as an enterprise service bus (ESB).

As mentioned previously, the majority of local governments' GIS functional requirements can be met using the Web services approach. This includes services such as vehicle routing, query and display, and geocoding. However, there are some business functions that warrant the dedication of GIS computing resources such as parcel editing. These business functions continue to be met using desktop GIS applications even as part of an EGIS. These desktop GIS applications are designed as an integral part of the EGIS solution, enabling them to take full advantage of the GIS Web service functionality to perform many GIS operations, such as geocoding, as part of a multistep business process.

Mobile GIS applications can be developed to provide access to GIS data and geoprocessing capabilities for staff working in the field. Deployment of mobile applications increasingly takes the form of providing wireless access to the services-based tools and applications. Mobile applications that require specialized software functionality or that do not require real-time connectivity to the EGIS may be developed specifically for use on field computers. For example, disconnected editing of parcel or utility features using a Tablet PC could be performed in this manner, with the data entries and updates then uploaded to the EGIS.

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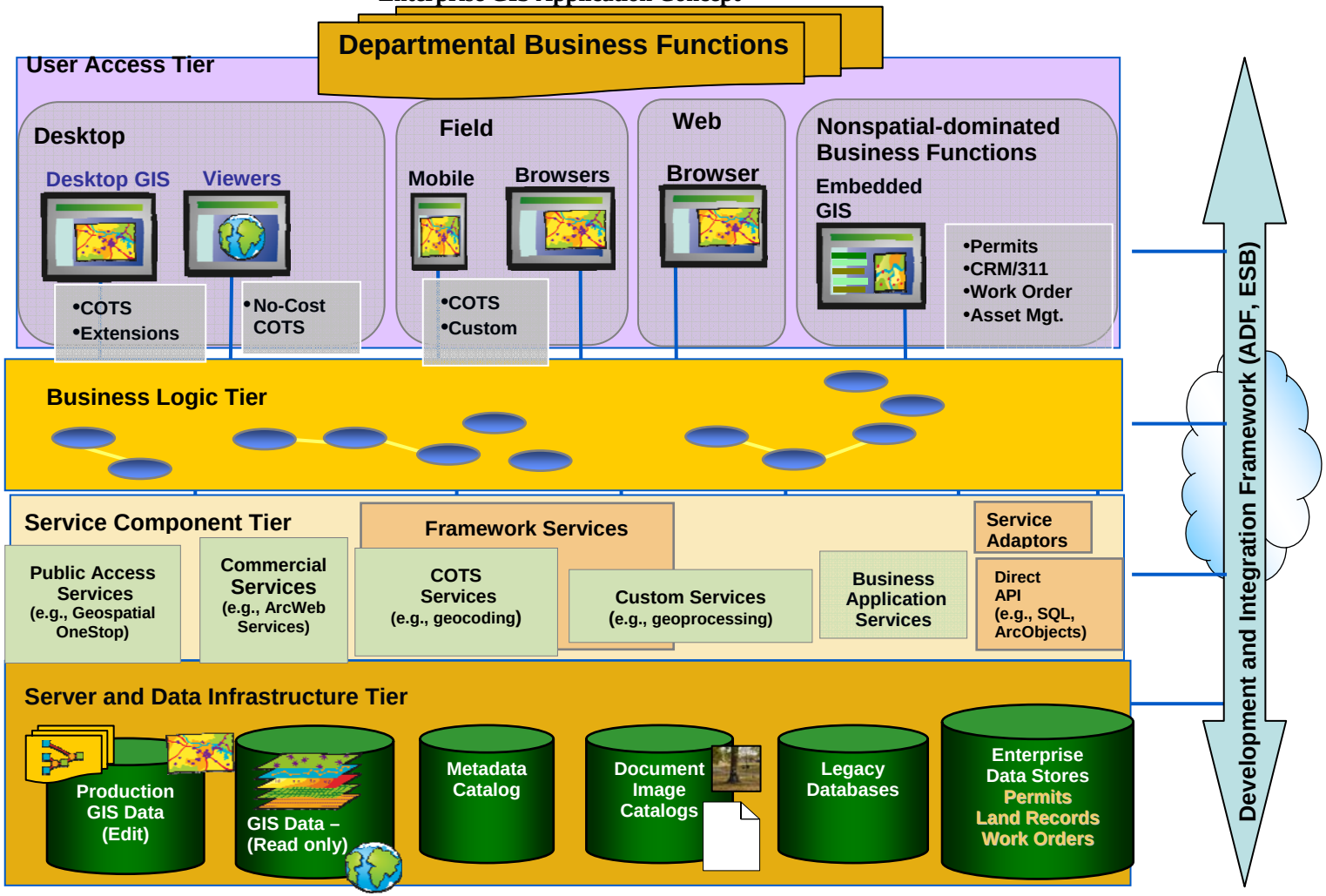
Figure 1
Enterprise GIS Application Concept



Migration to a Services-Based EGIS

Implementing an EGIS usually involves a phased migration from the organization's present GIS applications to the new services-based applications for a large proportion of its business functions. Figure 2 illustrates the typical GIS migration process. Section A is a generalized depiction of a nonservices-based GIS application environment that consists of a mixture of custom GIS desktop and Web-based applications. Extraction, transformation, and loading (ETL) tools are frequently used to reformat data for use in the different GIS environments. This creates data redundancy and data consistency problems. Shown in section B is a generalized depiction of the transitional phase from the predominantly per-seat and client/server-based GIS shown in section A to a predominantly server-based GIS. During this migration, the departments will become less dependent on the old per-seat applications and increasingly dependent on services-based GIS.

Important in this transition is the introduction of applications or other software resources that enable data and functionality of non-GIS applications to be accessed in real time by the GIS. This integration with non-GIS applications, such as work order, customer relationship, and asset management, may occur in different ways depending on the overall IT infrastructure of the organization. For example, GIS services may be accessed using an ESB or similar SOA technologies. Individual application programming interfaces (APIs) may be used for direct connectivity between specific applications. Also, ETL processes may continue to be used for non-real-time connectivity and the movement of data from the respective business system to a central database location. The appropriate technology to accomplish integration depends on the types of interfaces supported, the standards established by the organization to structure these system interfaces, the workflow requirements of the end user application, and the response time needed.

In section C of the figure, the completed SOA-based enterprise GIS conceptual design is shown. In this design, the GIS needs of all current and future users are met primarily through the shared services and application resources. These shared Web-based services and other resources are configured or may have their functionality extended, as needed, to meet special needs of individual users.

The transition from an existing GIS environment to an EGIS takes time. A common aspect of the migration is creating an interface application to synchronize GIS databases to ensure that the requisite data is available in the needed format to support the old and new GIS environments during the transition. This requires data replication to and from both the old and the new GIS environments. Such an application is depicted in section B of the figure. This application will be discontinued once all of the legacy GIS functions are migrated to the new EGIS architecture as shown in section C.

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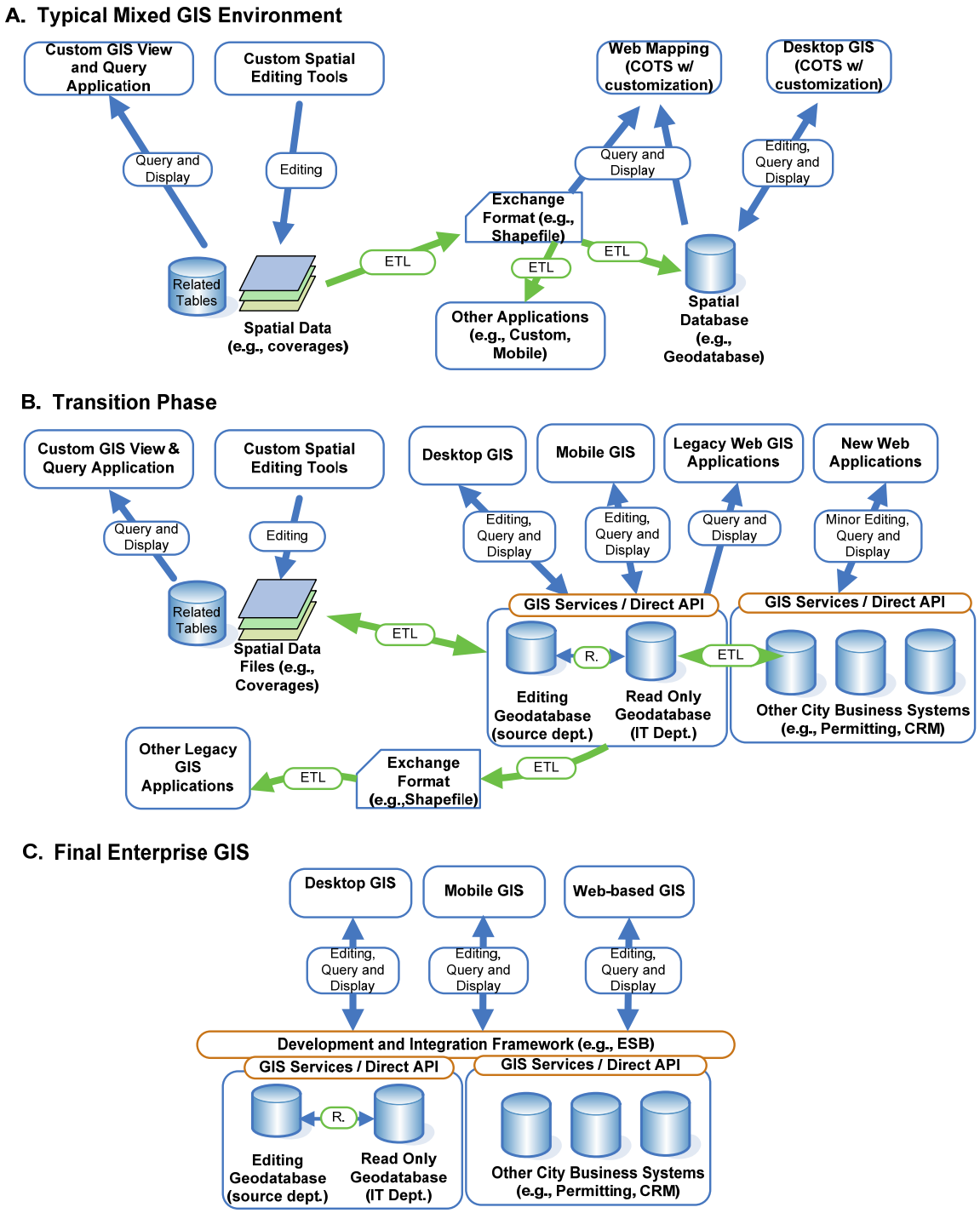
Figure 2
Migration Concept



Geodatabase Built on Geodata Models

A mature GIS (a GIS that has been developed over several years and supports a variety of departments) is characterized by a large volume of GIS and GIS-related data resources (spatial data). The spatial data in combination with the spatial applications and services-based tools enable departments to apply spatial analysis, reporting, and display to their business functions. This is true for all business functions for which location is a consideration whether the result is a map product, such as exhibit maps for public hearings, or a tabular report, such as an aggregation of capital expenditures by neighborhood or councilmanic district. The investment in creating the GIS data resources typically represents more than 50 percent of the initial and ongoing GIS investment. Therefore, ensuring these existing spatial data resources are formatted and managed in the best manner possible to work within the EGIS is a critical component of EGIS success.

Like other data types, geographic data is typically stored in an RDBMS and can be managed as a geographic database (geodatabase). ArcGIS® 9.x is one GIS software that provides this spatial data management capability for geodatabases. The geodatabase represents an evolution of geographic data structure from the coverage and file-based spatial data formats still in use at many localities. A geodatabase needs to support the wide variety of spatial data types typically used by today's GIS applications. Importantly, a geodatabase also includes directly in the database the rules that govern the behavior of these data types. This eliminates the need for separate custom programming to define even the simplest of data behaviors, such as the relationship between a parcel and the subdivision of which it is a part.

To support the implementation of geodatabases, spatial data model templates have been developed by software vendors such as ESRI by continually working with the GIS community (see http://support.esri.com/datamodels). These models represent the current best practices and strategies for structuring, managing, and maintaining spatial data in the geodatabase. As an agency moves forward with its migration from coverage/file-based to geodatabase format, these models provide a basis for planning and completing the transition of existing spatial data resources as well as automating additional spatial data themes. Figure 3 illustrates the data formats managed in a geodatabase and identifies some of the data layer themes for which templates relevant to local government business functions have been developed.

An EGIS database is a multiuser geodatabase designed to support all the business functions of organizations that require spatial data. At the conceptual design level, the enterprise geodatabase is viewed as a single database. The actual physical implementation of the enterprise geodatabase typically occurs in a variety of deployment approaches. For example, it may be managed as a single central database, or it may be distributed to several physical locations but operated "virtually" as though it were a single data resource. Important benefits of an enterprise geodatabase are the following:

- Supports small to extremely large, continuous spatial data layers and themes (i.e., does not have to be divided into segments for data management purposes)
- Supports virtually unlimited numbers of simultaneous users
- Supports the long transactions and versioned workflows, such as subdivisions and capital improvement projects, that characterize the business functions of local government

- Highly scalable (can manage multiple terabytes of data)
- Incorporates advanced spatial data models and behaviors as part of the data itself, eliminating the need for custom application programming to define data behavior
- Provides advanced and complete capabilities to maintain spatial data integrity
- Usable within a heterogeneous software environment
- Provides raster data retrieval

Development of the geodatabase concept considers the data resources, the departmental responsibilities for data update, and the guidance provided by the related data models. The models can be readily adopted regardless of the organization's system architecture. Although the geodatabase models provide a strong starting point for creating an organization's geodatabase, each government entity has characteristics that result in unique aspects of its geodatabase. The geodatabase design process is one of achieving a balance between complexity and robustness in the data model. Throughout the design process, trade-offs between these two considerations are needed to ensure the EGIS geodatabase supports user needs and is sustainable through the business processes of the organization. When designing the geodatabase, the organization must consider organizational issues such as workflows, stewardship, staffing, and training.

The Role of System Infrastructure

The hardware, software, and communication network(s), collectively referred to here as the system infrastructure for an EGIS, deliver to each end user the specific spatial capabilities and resources needed to support their business functions. A conceptual configuration for the EGIS system infrastructure can be established based on the characteristics of existing system infrastructure; required information products and spatial and nonspatial data resources; essential spatial analysis, display, and reporting functions; needed data management resources; and the anticipated number of end users within the departments. This conceptual configuration describes a long-term picture of the system infrastructure resources needed to support EGIS operations. This concept provides the basis for detailed system infrastructure planning and budgeting by the IT and end user departments.

Implementation of the EGIS system infrastructure resources occurs as defined within the organization's IT guidelines. This may entail reuse of existing hardware and network resources to the extent these resources continue to fulfill the organization's standards. Introduction of accurately specified servers to deliver the enterprise applications, data, and services is an important component of the transition to an EGIS.

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Figure 3
Extending the Geodatabase Model

Basemap Themes
- contours
- control points
- PLS grid

Land Records Themes
- lots
- parcels
- tracts
- easements

Transportation Themes
- centerlines
- bike paths
- bus & transit routes

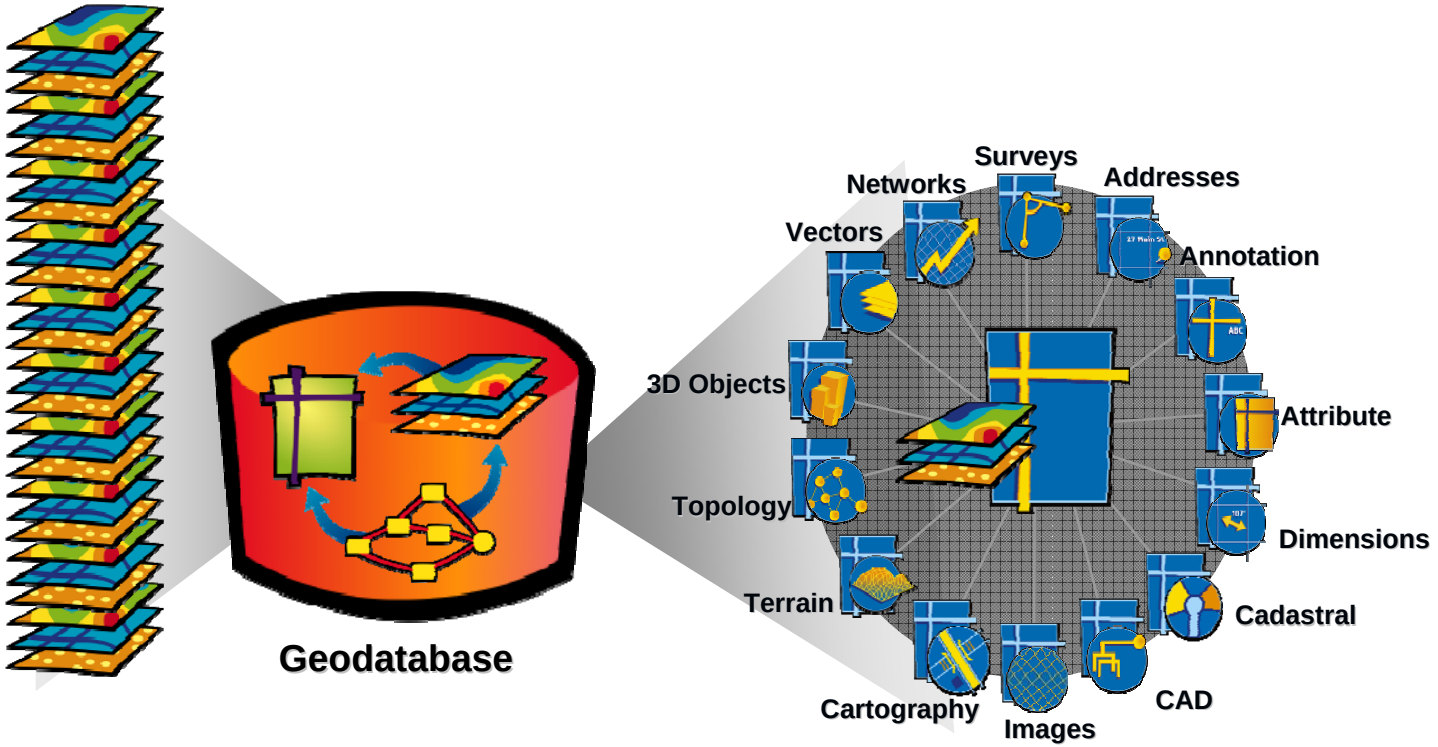
Land Use Themes
- comprehensive plan
- zoning
- demographics

Environmental Themes
- water features
- floodplains
- soils
- vegetation

Administrative Themes
- service districts
- voting precincts
- neighborhoods

Infrastructure Themes
- water
- wastewater
- electric
- storm water

Operational Themes
- crime statistics
- calls for service
- work orders



As mentioned previously, in an EGIS, applications are increasingly developed based on a services model. Web-based services are hosted on one or more designated servers and delivered via the network, wireless communications, or the Internet to end users and the public. The benefit of the server-based approach is that rather than having to deploy core software and custom application code on individual desktop computers, local governments can maintain these software resources centrally. This makes delivery of GIS capabilities to users much more cost-effective.

Figure 4 illustrates a generalized system infrastructure concept for an EGIS. In this system concept, centralized spatial and nonspatial data and applications environments are used to support the EGIS operations. A distributed server environment is also depicted for supporting GIS end users with special security or other requirements. A mixture of desktop, mobile, and services-based platforms for delivering EGIS resources is provided depending on the system infrastructure requirements of the business function being supported. Data, application, and communications servers are all components of an EGIS system infrastructure. Among the other major EGIS system infrastructure characteristics shown in the figure are

- A separate production database to support read access to the spatial data
- One or more separate maintenance databases for use in creating and maintaining geodatabase changes
- Geodatabase replication procedures to retain consistency between the production and maintenance geodatabases
- Migrating existing Web services to take advantage of current GIS software and hardware capabilities
- Compliance with existing organizational IT security standards through provision of appropriate firewall, demilitarized zone (DMZ), and other measures
- The use of desktop GIS software on those business functions, such as data editing and other computer-intensive analytical functions, that require more computing resources while minimizing the load placed on the communications network
- Wireless use of Web-based and service-based application for mobile or business processes as the organization shifts to wireless technology
- An SOA that enables Web-based access to GIS services and data for use by other organization-wide and departmental information systems
- Off-site and redundant systems to provide failover capabilities for critical systems

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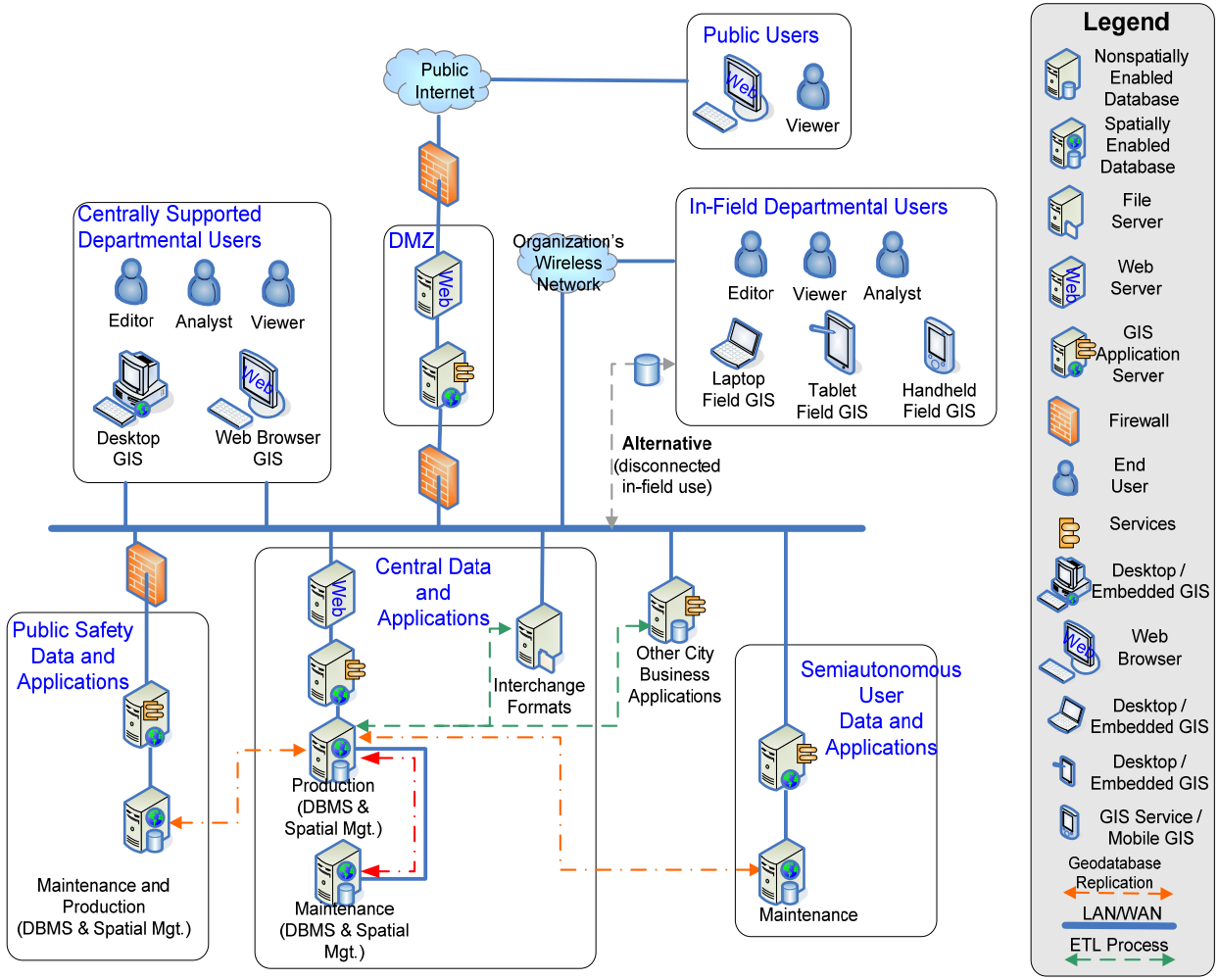
Figure 4
Enterprise GIS System Concept



EGIS Success Requires a Supportive Organizational Structure

Successfully organizing and managing an EGIS requires communication and coordination among all affected departments. To accomplish this, additional organizational elements are required. These elements typically include a policy committee, a technical committee, and various subcommittees on an as-needed basis. A policy committee consisting of representatives of all departments that currently and potentially will use GIS is essential and plays the role of approving projects and establishing annual budget priorities. A technical committee serves to refine the annual work plan and review it with the policy committee for approval. Subcommittees are needed to focus on defining and implementing application, data, metadata, and other standards and policies essential to the success of the enterprise system. Development and enforcement of these organization-wide GIS standards is a central element of EGIS success. Through this committee process, awareness of common needs for GIS functionality and opportunities for shared benefits is raised. Also, the essential need to integrate the EGIS with other organization information systems becomes apparent.

A major consideration from the organizational perspective is determining the most suitable manner to adequately staff EGIS support. Personnel dedicated to system maintenance and operation as an enterprise resource are needed. Additionally, departments that have a primary role in capturing new spatial data need staff trained in the use of these specialized GIS applications. The GIS staffing plan needs to be coordinated with overall information services staffing to ensure the most effective use of staff resources.

A critical component of the governmental EGIS program is providing the training needed to develop staff skills and capabilities to maintain and extend the EGIS solution framework. Accomplishing this necessitates a comprehensive training program for all levels of staff. This training includes a combination of standard training in the GIS software used as well as specific training in the use of organization-wide applications that are developed.

Use of a Step-by-Step Work Plan

Designing and implementing an EGIS is a multiyear effort. A work plan that provides an incremental approach to migrating from the existing GIS to the enterprise GIS is an essential tool for achieving success. The incremental approach recognizes the substantial investment in GIS made to date and provides a path forward that sustains and enhances the prior investment. In particular, the work plan identifies how the GIS data, system resources, and to a lesser extent, GIS application investments can be brought forward as parts of the new EGIS. As these prior investments are sustained, the addition of further GIS capabilities enables the value of these investments to be leveraged for further benefit to departments and the public.

Different implementation approaches are possible and need to be tailored to specific conditions and priorities of the organization. The ultimate goal of the chosen incremental approach is to build the core capabilities of the EGIS to benefit all departments. In particular, this includes the services-based tools that can be developed once but combined as needed to create multiple Web-based applications that support a diverse set of business functions throughout the organization. Additional single- or multidepartment application capabilities are added to the core capabilities as determined by breadth of benefit, overall priorities, and budget availability. The goal of the work plan is to establish a foundation that brings widespread use of GIS, ensuring success is built on at each step in the implementation process. Within the work plan, it is important to set reasonable goals for each step and to produce tangible results. The advantages of the incremental approach

include lower startup costs, lower risk, better knowledge of requirements gained through experience, ability to keep up with the latest technology because the initial investment is smaller, less disruption to the existing organization, and greater acceptance by staff because introduction of EGIS is gradual.