Building a Public Works Information System

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An ESRI White Paper

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Executive Summary

Public works and geographic information system (GIS) technology have a long and successful history together. GIS has provided public works departments with the data management and visualization tools necessary to support daily operations from mapping to data collection to analysis—helping plan, implement, and maintain the critical infrastructure of the community. However, in recent years, information management has become an equally crucial function of local government, requiring a parallel infrastructure of computerized systems to help meet demand, track progress, and plan for the future.

Public works rely on a variety of computerized systems to support daily operations. These systems are used to plan work, complete tasks, update databases, and provide public access to government information. Staff engage with work orders, asset inventories, permits, 311 and call center requests, and so on, with each system offering a different assortment of procedures and types of datasets. Likewise, many public works applications present (to external constituents and internal users) a variety of faces (or interfaces) that give the appearance of disconnected functions and responsibilities, while in reality, it is one department handling many tasks.

What if public works were able to consolidate these multitudes of systems into a common set of services and applications? What if these services and applications were based on a single development platform that didn't replace but, rather, augmented existing systems and databases? What if the value of existing technology and data could be elevated from basement obscurity, reinvigorated, and extended throughout different levels of government and to the public with minimal investment? What if this new system helped public works be more agile, responding quickly to information demand and service requests?

This paper presents the idea of a consolidated geocentric system that will help public works provide a common operating picture for most, if not all, of their information needs. Examples of blended technology implementations will be given, and the supporting concepts of a public works information system will be discussed.

What Is GIS?

GIS is a geographic information system. It is used to create, edit, import, map, query, analyze, and publish geographic information.

GIS allows you to analyze information. It is used to answer questions like the following:

- Where are the shutoff valves that will isolate the water line leak?
- What is the most cost-effective route for trash pickup during the winter?

- Who are the nearest property owners that must be notified before a sewer repair project begins?
- What is the density of service requests by district?
- How many streets, properties, people, and businesses will be affected by a street repaving effort, and what are the alternatives?
- Where are the critical mosquito breeding areas that require immediate treatment?

You use a GIS to manage all your spatial (location-based) information. Street maps, utility networks, facility locations, digital aerial photography, terrain data, and more are all stored and managed in geographic databases (also called geodatabases). Even non-GIS information, like computer-aided design (CAD) files, can be managed and integrated seamlessly with GIS. The geodatabase becomes your ultimate destination for data digitized in the field with global positioning system (GPS) or survey equipment.

GIS has also evolved into a content development and management system. Geographic content—on the Web and in the media—is becoming ubiquitous, and the demand for it is rising at an incredible rate. You use GIS to make maps for Web applications, books, public display, and many different types of publications. The results of analyses, such as change over time or relationships between seemingly unrelated events, can be documented; processes can be illustrated; and what-if scenarios can be modeled. People with little or no GIS experience are becoming consumers of GIS content, and those with experience are finding it easier to author GIS content quickly.

Geographic content can be visualized two-dimensionally, as in traditional maps, but also displayed in 3D or on a globe. The content can be static or interactive and customized to meet the needs of specific audiences or purposes. GIS functionality can be embedded within geographic content, exposing simple, intuitive tools that perform complex tasks such as creating new data from analysis or solving problems like defining service areas by evaluating a variety of factors.

GIS also serves another important purpose: it allows organizations to bind systems together by providing a common platform for interoperating with different technologies and data. This binding ability, often referred to as *integration*, makes GIS a logical core component for a unified information system, providing solution opportunities for the different aspects of public works.

Figure 1
GIS Connects Business Drivers and Technology

A public works information system utilizes GIS to bind programs and systems together to facilitate the flow of information. Public works and IT departments are motivated by different drivers, but GIS forms a seamless connection between them.

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GIS for Public Works

GIS technology plays a central role in helping public works professionals do their jobs.

A public works department can be made up of people from diverse disciplines and levels of training or experience. GIS plays an important role in helping public works professionals and support staff accomplish their individual tasks. It also improves internal communication between groups and with others in different departments.

- Engineers working with new municipal developments and infrastructure use GIS for site design and construction management, topographic mapping and boundary surveying, and environmental analysis and compliance.
- GIS is used by project managers to coordinate and visualize field data collection activities ranging from GPS data to survey measurements to digital imagery including large terrain datasets based on mass point collections of 3D data such as lidar.
- GIS routing software improves the effectiveness of road maintenance programs for street sweeping and snow removal and helps schedulers plan trash and recycling pickup, litter control, pavement repair, and landfill operations.
- Parks and recreation staff rely on GIS to maintain valuable inventories of community assets, such as the location of trees, landscape features, park furniture, and facilities, as well as to monitor weed and pest abatement projects and plan new park locations.
- Traffic engineers employ GIS to study traffic flow and intersection geometrics as well as make congestion management plans; design road striping; ensure work zone safety; and perform traffic impact analysis, road sign inventories, and transportation modeling.

GIS Solutions for Public Works

GIS strengthens public works information technology through blended technology solutions that work in desktops, on the Web, and with mobile applications. These solutions leverage information resources that are managed by other departments on different systems. They also present a means to create focused solutions. For example, a GIS combined with another system, like an asset management system, is used to create a set of easy-to-use composite applications that improve daily workflows or provide new, time-saving capabilities.

These types of solutions are effective in providing public works with numerous opportunities to infuse established systems with geospatial intelligence.

Work Order Management

When GIS is integrated with a work order management system, automated processes enable public works managers to provide incident maps, optimize job routing for field crews, and perform jurisdictional overlay and proximity analyses for customer and business notification. GIS and work order management can be tied to 311 or call centers to help expedite citizen requests and improve project management. To learn more about GIS and work order management, read *Building a Server-Based Public Works Information System* at www.esri.com/library/reprints/pdfs/publicworks_building-server-based.pdf.

Figure 2
GIS and Work Order Management

The New York City Department of Parks and Recreation uses Azteca's Cityworks® and ESRI's ArcGIS Server to fuse service requests, work orders, maps, and imagery and provide GIS functionality to its forest management system. (Screen shot courtesy of Azteca Systems, Inc.)

Asset Management

Public works departments significantly improve their ability to conduct, track, and maintain valuable aboveground and underground inventories by blending GIS with asset management. Inspectors create activity lists from spatial queries; field staff inspect, verify, and update databases; and analysts track down problems and map their locations. GIS and asset management can be combined to facilitate service calls as well as predictive and preventive maintenance and control overhead costs. To learn more about GIS and asset management integration, read *City of Mesa: Enterprise GIS Improves Workflow and Data Management* at www.esri.com/library/fliers/pdfs/cs-city-of-mesa.pdf.

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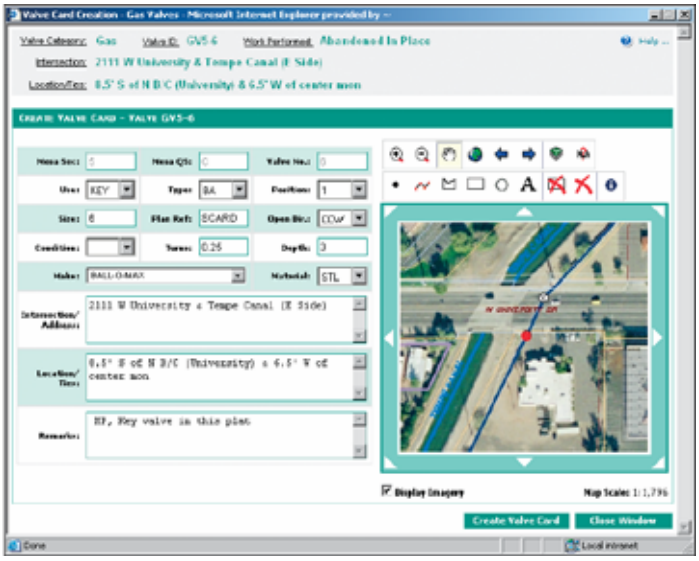
Figure 3
GIS and Asset Management



With ESRI's ArcGIS Server integrated with Tidemark Advantage and an Oracle® database, City of Mesa utility field staff members can map the locations of gas valves and track the condition of assets.

Customer Relationship Management

Improved citizen satisfaction and better access to government occurs when public works managers use GIS with customer relationship management (CRM) to review and analyze customer requests, monitor complaints by location, target resources more effectively, eliminate resource duplication, and allocate funds based on location. GIS and customer relationship management can be used to communicate problems, demonstrate success, and model potential outcomes of policy decisions. To learn more about GIS and customer relationship management, read *City of Indianapolis, Indiana: Enterprise GIS at a City Level* at www.esri.com/library/fliers/pdfs/cs-indianapolis.pdf.

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Figure 4
GIS and Customer Relationship Management

The City of Indianapolis uses its enterprise geodatabases and ArcGIS Server with the Siebel CRM to validate addresses and populate fields such as Trash Day and Incident Address.

Mobile Data Management

Public works happen in the field, and when GIS is integrated with mobile technologies, public works managers have an interactive system for on-site verification of field data accuracy and a tool for updating asset databases and assessing and tracking the conditions of roads, repairs, and incidents. Field-workers gain access to GIS datasets, current imagery, and georeferenced drawing files as well as addresses and geographic locations. GIS and mobile data management go hand in hand with infrastructure maintenance, asset inventories, customer service, and land development projects. To learn more about GIS and mobile data management, read "Frederick County Uses Mobile GIS for Roadway Asset Data Collection" at www.esri.com/industries/public-works/docs/frederickcounty_gm_2006.pdf.

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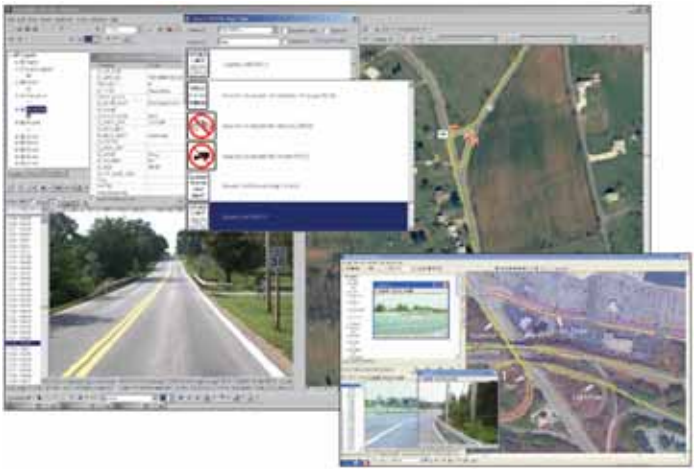
Figure 5
GIS and Mobile Data Management

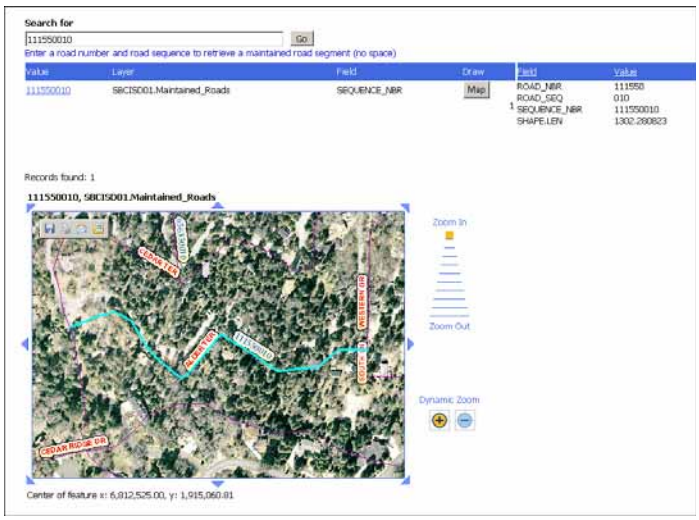


The Frederick County Division of Public Works uses a system that includes EnterRoadInfo, a mobile GIS data collection system and ArcGIS extension; GPS; digital cameras; a distance measuring instrument; and an inertial navigation device.

Map Book Production Management

When GIS is used in map book production, public works departments improve quality control and their ability to search for, locate, and inspect roads and other map features as well as keep map books up to date. Staff can take advantage of legacy databases and procedures and employ the cartographic sophistication that GIS offers to give map books a fresh, new look. GIS and map book production management make it possible to coordinate timely and accurate changes to paper and digital map information—from small, incremental edits to wholesale revisions. To learn more about GIS and map book production management, read *County of San Bernardino, California:* Traffic Road Book *Quality Control Using ArcGIS Server* at www.esri.com/library/fliers/pdfs/cs-sanbernardino.pdf.

Figure 6
GIS and Map Book Production



The San Bernardino County Traffic Road Book *reporting system integrates GIS with an online automated reporting tool that references a SQL table. The report includes a hyperlink that launches an ESRI ArcGIS Server Web mapping application.*

Document Management

GIS and document management system integration provides a mechanism for making supporting information accessible within the GIS without data conversion and redundancy. Scanned documents including maps, as-builts, CAD drawings, and legal documents (e.g., deeds and title records); equipment manuals and schematics; and survey records take on special significance when they are associated with geographic features. GIS and document management system integration makes it much easier to retrieve scanned documents by interacting with an intuitive, map-based user interface. To learn more about GIS and document management system integration, listen to the GIS and Document Management Integration podcast series at www.esri.com/news/podcasts/speaker_series.html.

These and many other types of solutions are examples of how people and organizations benefit when GIS is blended with other systems to support the city or county enterprise. In these cases, GIS represents the common framework for building a unified information system that supports operations at multiple levels of management: it forms the basis for a public works information system. GIS delivers a value-added solution to services and applications by enabling the people who use them with geospatial intelligence to possess a critical factor for critical infrastructure.

Building a Public Works Information System

When geospatial intelligence is added to the normal decision framework for an organization, geography becomes the focal point for services and data. This geoenabled framework helps link systems, consolidate workflows, and present a common operating picture for the people using the services and applications. A public works information system combines the benefits of GIS technology with advances in information technology (IT) to provide flexible solutions for public works.

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What Makes a Public Works Information System?

A public works information system is a geospatial system of services, applications, and solutions that allows public works to respond quickly and cost-effectively to the demand for information. The system is designed to provide access to public works projects and data through a variety of interactive content mechanisms such as maps, Web services, and customized applications.

At its core is desktop and server-based GIS, which provides the services and application development framework of the system. The GIS elements supply the primary functions for mapping, spatial data management, content development, and analysis.

The system is built on the concept of service-oriented architecture (SOA), which makes it possible to connect various resources and make them (their data) reusable. The SOA concept allows public works to respond faster to information demand, plus it provides opportunities to reinvigorate the value of existing systems and technology. Additionally, the SOA approach is modular in character, which allows for the rapid development of services and applications that reflect workflows and operational requirements (the business) of public works.

A public works information system relies on standards and interoperability. The GIS must be built on open and interoperable commercial off-the-shelf software products. It should support a number of standards for IT and Web services, including those from the Open Geospatial Consortium, Inc. (OGC); the International Organization for Standardization (ISO); and the Federal Geographic Data Committee (FGDC), as well as metadata (ISO 19139) standards. The GIS must support Data Exchange Format (DXF)—for storing vector data in ASCII or binary files—and Keyhole Markup Language (KML).

For public works departments, this means a flexible yet consistent system for data and application management. This basic framework allows public works to develop Web and mobile applications that directly correspond to business functions. For example, a road repair program can make use of a Web application for scheduling repairs that consolidates different information resources, such as project management, optimized routing maps for repair crews, and work order management, into a single user interface. This makes it possible to facilitate the business of road repair by tapping different supporting systems, including GIS, to provide managers, road repair crews, and others outside public works with accurate, up-to-date information.

In a public works information system, an application like this would serve as a template for other applications that required similar capabilities and resources. With only minor changes to the underlying code, the road repair scheduler application could become a tree inventory application or a solid waste collection routing application.

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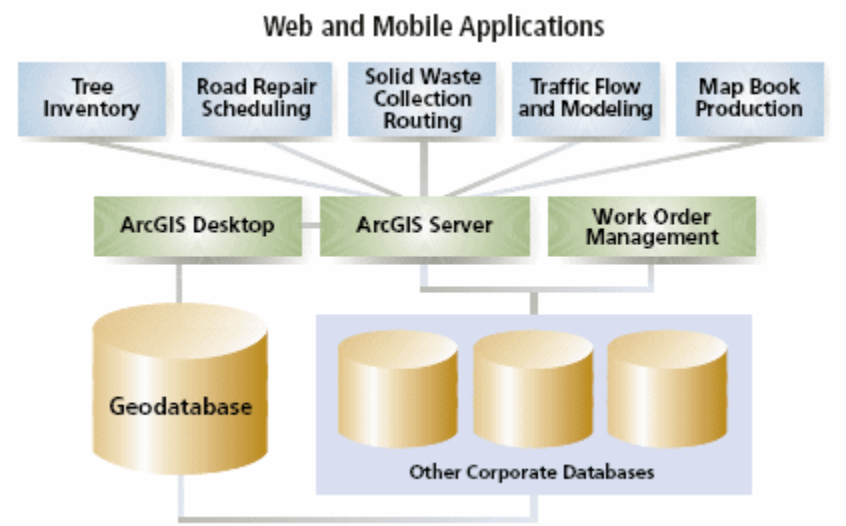
Figure 7



GIS standards and interoperability allow organizations to fuse systems, like a work order management system, and other enterprise databases with ArcGIS technology to create Web and mobile applications that work in the office and in the field.

Other characteristics of a public works information system are

- Easy-to-use applications that require little or no previous experience with GIS
- Focused applications that reflect or enhance well-documented user workflows and business processes
- Applications that seamlessly fuse information from multiple data stores
- Applications that reuse legacy systems or reinvigorate static data stores

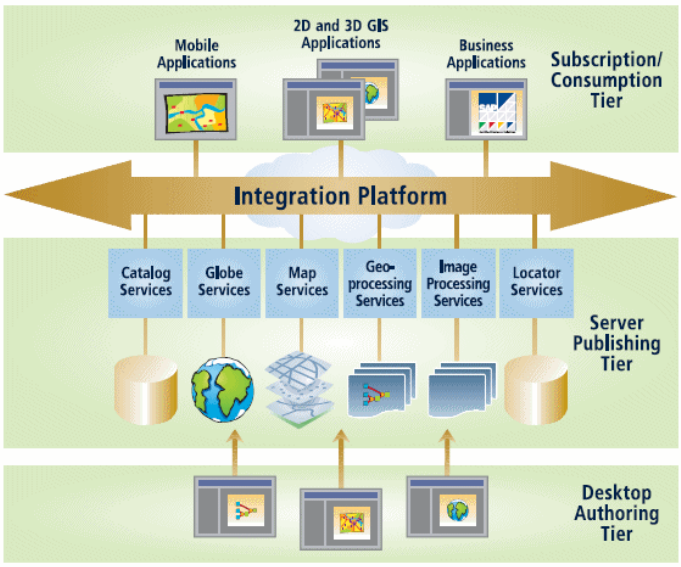
A public works information system is not a replacement for existing systems. Rather, it is an inclusive use of technology that encourages organizations to make better use of the data they have by eliminating redundancy, taking advantage of existing information technology architecture, and dissolving the barriers that block information flow.

Make Better Use of Data

Eliminating data redundancy simply makes data management more efficient and helps clear up any confusion about who is responsible for maintaining various datasets. Data stewardship is a policy issue that affects most government agencies and, in the case of public works, has special importance in terms of critical infrastructure and homeland security. With a public works information system, departments that normally maintain datasets continue to do so, but they allow different aspects of the data to be processed and published as services to be used in Web applications. For example, the public works department might publish the water/wastewater network data as a geoenabled Web service. The service can be used in a maintenance scheduler application for water/wastewater but also incorporated into a public safety application for homeland security—two focused applications taking advantage of one service.

In this way, legacy systems and data can be leveraged and blended with new systems to create practical solutions for the entire organization. For example, in a public works information system, people can author geographic content, such as maps, and publish that content as a service. Those services can be used by anyone connected to the network or Internet, and they can be used by other services. People who interact with these services don't have to know anything about GIS or geoprocessing because the applications are designed with a specific business function in mind.

Figure 8
ArcGIS: A Platform for Custom Enterprise Applications



Through close alignment with the IT infrastructure, a public works information system provides a more consistent and higher-quality approach to data and services, making it more receptive to reuse in custom enterprise applications.

Additionally, whenever possible, a public works information system consolidates all location and address information to the GIS database. This means that other systems that require an address or geographic location are tied to the GIS database either programmatically or by way of an integration platform (sometimes referred to as an enterprise service bus). The linkage between GIS and other systems adds the potential for location-based queries and analysis of data that existed previously. For example, when an inventory of fire hydrants kept in an asset database is linked to a GIS database that manages the location of those hydrants, a new, more powerful level of investigation is possible. Records selected in the asset database can be highlighted in an interactive map. Likewise, hydrants can be selected in the map based on geographic characteristics such as proximity or overlap with a boundary.

Consider the case where a municipality discovers that a particular hydrant model was shipped with a defective gasket. Within seconds, a public works information system could be used to query the asset database by hydrant model number and locate all the

hydrants with the defect. GIS could then be used to efficiently route inspection and repair crews.

Take Advantage of Information Technology

A public works information system is designed to be flexible and adapts readily to changes in technology and business processes. Because it is based on the principles of an SOA, the connection between data and applications is "loosely coupled," which means even incompatible system technologies can be joined to create composite services. A public works information system doesn't break down when a new application is added or an old application is improved on. Services can also be disassembled without negatively affecting the system.

A geospatially enabled SOA helps address the specific business functions of the organization by delivering geospatial content and capabilities via Web services. In turn, Web services provide the building blocks on which broader IT strategies are based such as the implementation of service-oriented architecture. It is a reciprocal arrangement that provides information stability for the organization while at the same time making it possible to respond to changes in technology and service requirements, facilitating rapid application development and centralizing the management of critical enterprise services. These benefits provide organizations with cost-saving and cost-avoidance opportunities.

A public works information system doesn't necessarily mean new equipment and software; it simply means paying attention to how equipment and software are aligned with IT plans and the organization's system architecture. For example, GIS desktop systems may be underutilized if they are distributed according to multiple departmental plans when, in fact, the functionality those different departments require is nearly identical. The system would be much more cost-effective and easier to implement if that functionality were distributed from a centralized location as a Web application.

Dissolve Data Islands

Many organizations maintain "islands" of data that simply don't fulfill their potential value. This is because data islands don't integrate well with enterprise business processes. A public works information system solves the problem of data islands by using GIS interoperability and service-oriented architecture to revitalize and extend data value throughout the organization.

A common example of a data island is a department that maintains computer-aided design files. These types of files are usually stored indiscriminately on individual desktop computers or in project folders with little or no metadata. The files don't conform to a common schema and the draftspersons (the originators of the data) often end up serving as gatekeepers—retrieving and interpreting the files for requesters.

Unfortunately, the organizational disarray of files, folders, and machines of a data island make it difficult to connect the work with enterprise applications. As a result, the public works department cannot effectively share or reuse the information stored on data islands or use it for other purposes such as spatial analysis.

Additionally, data islands interrupt business processes in several ways:

- Data islands contribute to the fragmentation of information. Data that is highly personalized and isolated from standard business practices has a tendency to lose relevancy and cohesiveness as pieces of the information are shared and dispersed. It

becomes difficult to know which version of a dataset is correct, how accurate or complete it is, or who is responsible for its "care and feeding." When users incorporate the wrong data into their analysis, it wastes time and leads to poor decision making.

- Data islands represent inert resources. Information is a corporate asset: it is the currency that makes businesses and governments successful. Information resources that are not easily consumed by enterprise applications or languish unused in isolated archives only have the potential for reusability.

- Data islands necessitate separate management efforts. Data management is expensive to begin with, but when the software and processes that create information become resistant to IT efforts to consolidate databases and centralize applications, a portion of the management workforce must set aside time or be relegated to support the information's upkeep. Still more staff may be needed to serve as go-betweens, personally shepherding the information to requesters and translating its meaning.

A public works information system dissolves data islands and facilitates moving information into the mainstream. The data management and metadata capabilities of the GIS help prevent data fragmentation, ensuring continuity and schema integrity. Through interoperability, a public works information system encourages the flow of information from data islands to the GIS database. The original data remains intact, but the information is given more universal context with respect to geography and made available to enterprise users and applications.

ArcGIS: The Complete GIS

The key to a successful public works information system is a fully integrated, interoperable GIS that adheres to important, emerging IT and GIS standards. ESRI® ArcGIS® technology meets all these criteria.

ArcGIS Server

ESRI's ArcGIS Server is a complete and integrated server-based GIS. It comes with out-of-the-box, end user applications and services for spatial data management, visualization, and spatial analysis. It supplies the foundation for geospatially enabling a service-oriented architecture. When combined with ArcGIS Desktop, ArcGIS Server provides an entirely new, overarching workflow for public works professionals: author, serve, and use.

ArcGIS Server also makes it easy to build Web applications without programming. It can be used to create Web applications for mapping, editing, geocoding, geodata management, and much more.

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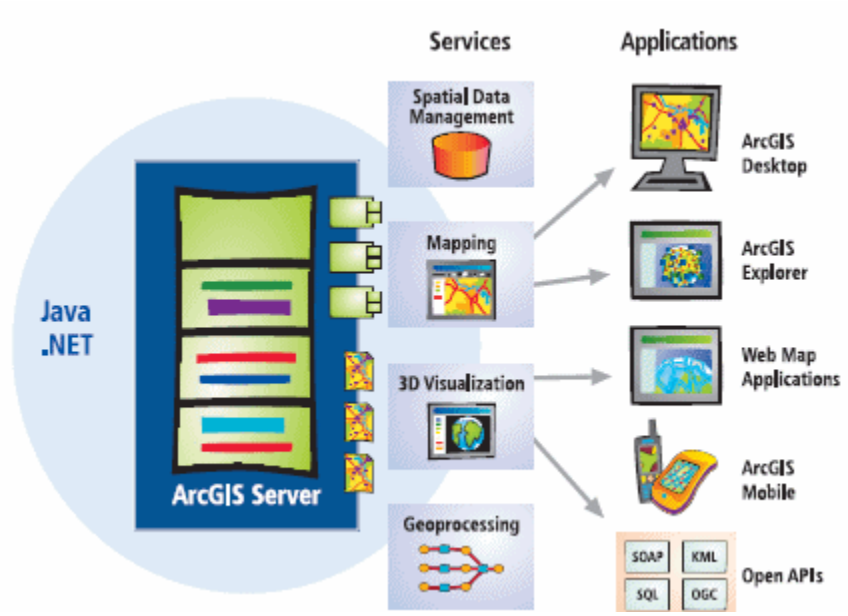
Figure 9
ArcGIS Server



Additional benefits of ArcGIS Server are

- Lower cost of ownership through centrally managed, focused GIS applications that can scale to support many users
- Browser-based access to GIS
- Integration with other enterprise systems using industry-standard software
- Support for interoperability standards in both the GIS domain (Open Geospatial Consortium) as well as the broader IT domain (World Wide Web Consortium [W3C])
- Ability to create custom applications using .NET or Java

For more information on ArcGIS Server, visit www.esri.com/software/arcgis/about/server.html.

ArcGIS Desktop

ArcGIS Desktop is a complete and fully integrated desktop GIS. In a public works information system, ArcGIS Desktop can be used to author geographic content for ArcGIS Server and to construct 2D and 3D maps, globes, toolboxes, and models that can be published as Web services.

With ArcGIS Desktop, you can

- Build powerful geoprocessing models for discovering relationships, analyzing data, and integrating data.

- Automate complex workflows and analysis models.
- Perform vector overlay, proximity, and statistical analysis.
- Generate events along linear features and overlay events with other features.
- Automate data conversion.
- Produce customized, accurate, publication-quality maps.

For more information on ArcGIS Desktop, visit www.esri.com/software/arcgis/about/desktop.html.

ArcGIS Mobile

ESRI provides three product solutions for mobile applications that address both simple and sophisticated mobile requirements and help extend the public works information system into the field. These include the following:

- **ArcPad**® is a mobile GIS application for taking GIS to the field. ArcPad is GIS-centric and focuses on field tasks that require relatively simple geographic tools. These tasks are typically performed on handheld computers (running Microsoft Windows CE or Pocket PC). ArcPad is in wide use today.
- **ArcGIS Desktop and ArcGIS Engine** products provide tools for high-end mobile GIS with sophisticated mapping, display, and editing tools. These solutions focus on field tasks that require more sophisticated geographic tools, typically running on high-end Tablet PCs. Often, the map displays used in the field on Tablet PCs must contain detailed information in high resolution.
- **ArcGIS Mobile Developer Kit** is included with ArcGIS Server. Field GIS often relies on custom applications that run on a range of devices (mobile phones, Pocket PCs, and Tablet PCs) and can work in a sometimes-connected mode to GIS servers.

These applications—which focus on fieldwork tasks and the need for productive, simple-to-use interfaces that work well in the field and help avoid errors in data collection—often need to be engineered to support the special workflows and tasks for a select group of mobile workers. Similarly, the ability to send and receive updates from the field is also a key requirement.

To support these requirements, the ArcGIS Mobile Developer Kit can be used to build simple, focused mobile applications, which can support wireless access to real-time data feeds from central GIS Web servers.

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Figure 10
ArcGIS Mobile

ArcGIS Mobile is designed to address these and many other field GIS needs. For example:

- **Mapping and navigation systems:** Provide low-accuracy, low-cost solutions to enable a mobile application for map use in the field. This often includes the ability to capture map notes.
- **Data collection systems:** Provide accurate and professional solutions for field data collection that ensure the accuracy of your GIS data layers.
- **Survey systems:** Provide highly accurate and higher-cost solutions for field survey data collection. Traditionally, spatial information has been taken to the field using paper maps, often in the form of map books, and surveying has not been considered a common part of GIS workflows; however, this is rapidly changing.

For more information on ArcGIS Mobile, visit www.esri.com/software/arcgis/about/mobile.html.

Summary

A public works information system is a geospatial system of services, applications, and solutions that allows public works to respond quickly and cost-effectively to the demand

for information. A public works information system relies on standards and interoperability and serves as the basic framework for developing and using geoenabled Web and mobile applications that directly correspond to the business functions of public works. In addition, a public works information system

- Makes better use of data by eliminating redundancy through consolidation of location-based information and leveraging legacy systems
- Takes advantage of information technology through the creation of a geoenabled service-oriented architecture that makes it easy to deliver geospatial content and capabilities via Web services
- Dissolves data islands and facilitates movement of information into the decision-making flow of public works

For more than 30 years, ESRI has built open, interoperable, commercial off-the-shelf software products that set the standard for GIS and productivity. ESRI's ArcGIS technology provides a completely integrated set of server, desktop, and mobile products that you can use to build, manage, and customize your own public works information system.