INTRODUCTION

Geographic Information Systems (GIS) integrate hardware, software and data to analyze, manage and display many forms of spatially referenced, or “geospatial” information. An effective GIS provides the ability to view, question, interpret and visualize relationships; analyze patterns and anticipate trends; and employ various techniques and outputs to support business processes and inform decision making. In the modern GIS technology era, GIS analysts, developers and the community have many options available to collect, integrate, display and consume geospatial information.

The foundation of any GIS begins with a well defined, standards based GIS and data management framework. This can be extremely challenging in large organizations such as Caltrans that maintain both a corporate (Headquarters) and decentralized (Districts) organizational structure. This underscores the need for effective partnering, communication and the leveraging of talent and resources to support the entire corporate structure, or “enterprise”.

Understanding these fundamental concepts, and how they relate to the Department’s business processes and can be integrated into various workflows, is the first step in developing an effective GIS and geospatial data framework. Discovering where effective strategies and best practices exist within the Department will help educate and inform our GIS professionals, data stewards, and executive management.

The intent of this document is to explore the District’s GIS framework, and describe our business and technical workflows in order to share our approach with the Caltrans community. Our GIS foundation is built on the premise of developing integrated, repeatable solutions using commercial off the shelf (COTS) software, coupled with existing staff resources and collaborative internal/external partnerships. We view GIS as a system of integrated components that support data collection, integration and management, cartography and advanced visualization, and the interaction between people and technology.

Or put simply, GIS is much more than a map…..

GIS FRAMEWORK

The District 11 GIS/Project Development Support Branch (GIS unit) serves as the District's focal point for GIS management and innovation. This includes software deployment, geospatial data and imagery acquisition and maintenance, capital project analysis and mapping support, web map service development and functional unit technical support activities. The GIS unit is composed of GIS professionals with a wide array of education, knowledge and expertise performing activities to support the following initiatives:

- GIS analysis and mapping to support capital project delivery
- Development of models, tools and scripts to support workflow efficiencies
- GIS data collection, development, management and delivery
- Software technology and data integration with CADD applications
- Web mapping solutions using ArcGIS Server and flexible client interfaces
- Technical support for District GIS users
- Develop and maintain partnerships within the GIS community
- Coordinate with internal programs and functional units to meet Departmental goals

District 11 GIS uses a variety of geospatial technology tools including the Esri suite of ArcGIS software (ArcGIS Desktop, ArcGIS Server and Image Server, ArcSDE, ArcGIS Mobile and ArcPad), image analysis and compression tools, map catalog software, and flexible client viewers. The District's approach to implementing GIS solutions is to maximize the use of COTS software, tools
and existing staff expertise. This enables the District GIS unit to provide a wide range of geospatial strategies and solutions to our customers in an efficient, cost effective manner – avoiding the need for consultant services, custom programming and complex application development and maintenance.

This approach revolves around the use of the existing functionality within the Esri suite of GIS software for data management, analysis, cartographic products, web map services and mobile project deployment. The GIS unit consists of “professional” GIS analysts with a combination of education, GIS experience, GIS/CADD/Graphics/Web software expertise and knowledge of the Department’s business objectives.

INFORMATION TECHNOLOGY (IT) FRAMEWORK

The partnership between the District IT Chief, managers and support staff, and the GIS Manager and GIS support team is critical to ensuring the success of a secure, standards based, functional and sustainable GIS hardware and software framework. This ongoing consultation, collaboration and two-way education was initiated over twenty years ago when District 11 first began using GIS. Over time, information technology has evolved with respect to computing power, the complexity of software applications and data, expanded information sharing capabilities associated with the internet, social media and real time information, and GPS enabled field computers, smart phones and other devices. Geospatial technology has long been at the forefront of this evolution, and continues to be developed and used in ways that underscore the need for effective IT partnerships. This includes discussions regarding GIS and IT best practices, informing and educating on GIS principles and terminology, and understanding the State’s IT framework, standards and policies to not only ensure security and compliance, but support innovation, integration and efficiency. Maintaining a standards based approach to GIS technology deployment and program management ensures that solutions are sustainable, meet existing and future customer needs, and support business workflows.

Software Deployment:

ArcGIS software deployment is coordinated with the District IT Branch. A detailed inventory of GIS software users is maintained by the GIS unit, which includes software versions, workstation type and configuration, staff location, and any additional applications, extensions and tools installed for specific users. Prior to installing new releases of ArcGIS software, patches or service packs, the GIS unit goes through a testing phase to ensure that the software is stable and meets the needs of end users, including monitoring for conflicts with Microstation and other software. Once the software test phase is complete, the GIS unit coordinates closely with IT to develop a software image for deployment. The software deployment is done in phases, by functional unit, so that workgroups have a consistent and stable work environment, as well as to ensure that any issues are identified and corrected prior to further deployment. Additional, specialized applications, extensions and tools are installed and configured for workgroups or on a case by case basis on workstations or devices for users with specialized needs. The GIS unit also provides ongoing technical support for GIS software users. This includes troubleshooting, basic questions and answers, tips and tricks, promoting best practices, identifying user training resources and providing direct, hands on training.

Hardware Acquisition, Deployment and Maintenance:

Hardware acquisition, deployment and maintenance are also closely coordinated with District IT. This coordination includes developing workstation, server and disk space requirements and specifications. Through a collaborative effort, the District maintains two dedicated servers to support the GIS program. SV11PLAN1 provides the platform for managing the GIS data library. It is also used for software license management, and serves as the testing environment for ArcGIS Server and the deployment of image services. SV11GIS1 provides the platform for the ArcGIS Server,
ArcGIS Mobile and ArcSDE production environment. SV11GIS1 also serves as the web server (intranet) for deploying ArcGIS Server and Flex Viewer web map services to District and Department customers. IT maintains the responsibility for system security, patching, software upgrades (Change Control), etc., while GIS and IT staff coordinate the deployment of GIS server related software applications, data management, delivery and functionality.

Geospatial data and aerial imagery are extremely disk space intensive. To guarantee the availability of adequate disk space to support the GIS program and District customers, GIS and IT staff plan and coordinate the ongoing acquisition, deployment and monitoring of storage area network (SAN) and/or SUN Unix disk space configuration and backup requirements (specific to GIS program support). Current usage is monitored closely, and expansion requirements, funding needs and sources are forecasted each fiscal year and incorporated into the IT Acquisition Plan (ITAP). Local storage is also monitored on each of the two GIS servers to make sure operating system requirements are managed effectively, and any local storage needs are addressed.

GIS PROGRAM SUPPORT:

The District GIS unit performs core GIS support and development activities using ArcGIS. This includes a wide variety of data collection, development and management activities, analysis and mapping functions in support of capital projects, corridor and environmental studies, and asset management. The ArcGIS platform provides a robust environment for creating, editing and managing spatial feature data, and non-spatial or related tabular data. Various tools are available within the ArcGIS environment that can be easily accessed in order to perform sophisticated analysis, rendering and mapping. The open nature of the software allows users to develop models, tools and scripts that can be shared among many users to increase efficiency between workgroups.

Analysis and Mapping:

Analysis, mapping and visualization services support a wide range of business needs, including long range system planning, the Project Approval/Environmental Document phase (PA/ED), Design, Construction, Maintenance, Operations and asset management. ArcGIS provides powerful analytical tools to perform impact assessments for project alternatives, proximity analysis for planning studies, system monitoring and performance measurement, and a wide range of other tasks. The use of ArcGIS Model Builder allows analysts to develop custom tools and scripts that can be used to streamline workflows, schedule and perform geoprocessing tasks and can be shared across functional units within ArcToolbox via ArcCatalog. ArcGIS also provides cartographic and rendering tools to handle a wide range of map production needs. The use of map templates, specialized map book configurations, online base map services, custom stylesets, annotation layers and other cartographic strategies help to provide efficiencies, particularly for mapping large, corridor level projects and studies. Complimentary graphics, video and animation applications are used for specialized needs and product enhancements.
Data Collection and Development:

Data collection activities are performed by various functional units within the District. This ranges from the use of Global Positioning System (GPS) field computers for resource grade mapping, to the use of survey grade GPS equipment for higher precision and accuracy. The GIS unit, along with key functional units, is maximizing its ability to improve the real time accuracy of field collected (resource grade) data by partnering with the Surveys unit to access the Virtual Reference Station (VRS) network. This facilitates real time GPS correction, and helps to increase productivity, accuracy, and minimize or eliminate the need for post processing. This results in time savings and reduced post processing software costs.

Data development activities include spatially enabling tabular data (from existing databases or real-time data feeds), georeferencing files such as as-builts, manually digitizing data from hard copy or digital maps, data capture via image processing, and data conversion (to-from CADD/GIS). Additional data is derived through various geoprocessing and analytical tasks (input/output) during project or study analysis activities. Such data ranges in content, utility and accuracy dependent on several factors including the collection, development or conversion methodology, accuracy of source data, and the data’s intended use or life-cycle.

Spatially enabling the wealth of Department’s tabular data can be challenging due to the multitude of “databases” in various formats including Microsoft Access and Excel, FileMaker Pro, SQL Server, Oracle, etc. This is compounded by differences in how key data fields (County, Route, Postmile values, XY coordinates, and other attributes) are formatted, as well as the inherent limitations of the Caltrans Postmile Toolbar and underlying TSN postmile data. This leads to additional pre-
processing, error correction, and manual editing in order to develop a complete and accurate GIS dataset. Aligning program or workgroup level data so that spatially enabling it becomes more streamlined and efficient improves both the overall workflow and quality of spatial data. Developing minimum Departmental standards for database schemas would go a long way to improving how the Department manages and integrates this wealth of data.

Data Management:

Data Management is focused in three primary areas:

- The GIS data library
- Project folders that support specific analysis, mapping or asset management activities
- ArcSDE Geodatabase that stores feature datasets to support field data editing, web map feature and geometry services, and multi-user, check-in/check-out editing

The GIS data library houses a wide variety of internal and external data from many different sources. Statewide data resides within a “Caltrans” directory, and includes information such as the highway network, postmiles, index grids and other statewide information for use for general mapping at small scales. Regional and District data are maintained in separate directories and include more focused datasets such as custom boundaries, transportation assets and information, and other data developed for District customers.

Data from external sources is organized within the GIS data library by originating agency at the top level, then by data themes (transportation, land use, parcels, hydrology, elevation, assets, etc.), and varies in content depending on the primary focus of the agency. Data sources range from federal agencies (FEMA, USDOT, USGS, USFWS, etc.), state agencies (DFG, DWR, and State Parks), regional agencies (SANDAG, SCAG, and ICGIS), local agencies (County of San Diego, City of San Diego and other municipalities) and utility districts. Data updates are accomplished through ongoing coordination with agency counterparts and on regularly scheduled intervals dependent on agency update cycles.

Project folders are maintained on the GIS and SUN Unix servers depending on the type of work performed (capital projects, planning studies, etc.). Data developed to support these efforts, as well as asset management data maintained for functional units may be loaded into the data library for general use depending on the content, nature and value of the data and in some cases is based on demand. Maps, data, analysis tables, reports, and other output are typically maintained in project folders, and in some cases made available to customers through file or URL document links.
A focused ArcSDE geodatabase is maintained on SV11GIS1 to support Mobile GIS (ArcPAD, ArcGIS Mobile), web service editing, and feature and geometry services. This geodatabase currently supports production and concept development activities that require functionality above what is available in standard File Geodatabases.

Data management functions are performed using ArcCatalog, which has a user interface that allows analysts to connect to a variety of data sources and network locations. Spatial data in a wide array of formats, stored throughout the organization or on external agency sites, can be accessed through folder, spatial database, and standard GIS server (web services and image services) connections. Data management and delivery capabilities within ArcCatalog provide GIS unit analysts (data owners/administrators) the ability to create, manage and deliver data in various formats and spatial references. Such data include File Geodatabases, ArcSDE Geodatabases, Raster Datasets, map and image services, and tabular data.

Workgroups and end users can also take advantage of many of the same tools and methods, though typically at a more focused or general level. Data developed and maintained at the workgroup level can be rolled up into a larger geodatabase and delivered to a larger group of users to support various business functions through the Data Library, geoprocessing tools or web map services.

One of the recommended strategies of the GIS Branch is to develop such data (where appropriate) within a File Geodatabase so that feature creation and attribute updates can be accomplished in an effective, streamlined manner. This requires close coordination with functional units to define and maintain a schema that addresses their core business needs, streamlines field and office workflows, and allows for integration with tabular data or other feature classes. This includes the use of Domains, Subtypes, Relationship Classes and Topology rules. While the GIS unit routinely uses this approach, mainstream use has been slow in coming due to several factors including lack of understanding of the File Geodatabase structure and associated benefits, apprehension to change existing practices, and in some cases lack of necessary expertise. Through our user seminars and direct technical support, progress is being made in key areas such as Engineering, Environmental and Hydraulics to develop more efficient data management strategies.
One of the key data management principals supported within the District is that responsibility for source data remains with the data “owners”. This ensures that the integrity, currency and utility of the data is maintained by those with the responsibility and expertise to do so. Providing the GIS team direct access to view and pull from key District data sources is a necessary component to efficiently creating spatially enabled data. In many cases, minor adjustments can be made by the data owners that improve the data conversion process, so close coordination and active partnering are critical for success. A current example of a data “alignment” strategy is being undertaken by the District’s Program/Project Management (PPM) program. This is the result of coordination between GIS and PPM to develop a new schema that supports project management tracking and reporting needs and the efficient development of GIS data, making it much easier to expose this data through GIS web map services. Other examples of this approach include coordination with Construction, Maintenance and Operations with goals ranging from asset (data) management through the project development life-cycle, construction project monitoring, and streamlining workflows by enabling user input through web services or mobile devices in the field or office, with direct updates to the geodatabase.

It’s important to emphasize that not all programs or functional units have the need or desire to utilize a true GIS solution in managing their data. However, in many cases data that is managed by one group may have value to another, and in some cases it may have Department wide utility. Using minimum data standards and coordinating data development activities greatly enhances the Department’s ability to spatially enable such data for use in mapping and visualization, analysis, integration with desktop applications, and data/information sharing through web map services, CT-Earth and other methods.
GIS SERVER TECHNOLOGY:

ArcGIS Server:

ArcGIS Server is used as the “back-end”, or foundation for the development and deployment of web map services. Simply put, ArcGIS Server makes it easy to “publish” data and information from existing ArcGIS projects and normal workflows into a service that can be “consumed” by other clients. This is accomplished using the out-of-the-box settings and functionality provided with ArcGIS Server. Examples of the types of services published include KML, REST, WMS, WFS, etc. These service formats are Open Geospatial Consortium (OGC) compliant and standards based, ensuring such services can be accessed by clients and software applications throughout the Department. Symbology (icons, line widths, colors, shading, and transparency), attribute fields and values, document attachments, URL links and other characteristics in the ArcMap project and underlying geodatabase are retained in the published service. These services can be consumed (viewed) by a wide range of clients, such as CT-Earth, ArcGIS Viewer for Flex, Silverlight and Flex APIs, Google Maps API, Microstation and ArcGIS, and can also be accessed using more advanced web developer tools such as JavaScript or .NET. The ability to publish data as services greatly enhances delivery by leveraging existing data workflows. Having data maintained at the source, published as services, and consumed by clients eliminates redundant processes and overhead. Additional benefits include maintaining data accuracy and currency, improving server and client performance, reducing disk space requirements and expanding data accessibility.
ArcGIS Server also exposes functionality from the core ArcGIS software framework in order to make geoprocessing tools, editing environments, scripted models and tools and other capabilities available to users. This functionality can then be consumed by client applications for viewing information, performing search/query tasks, editing attributes or geometry, viewing linked documents and many other tasks.

As mentioned above, web map services published by ArcGIS Server can be consumed by many different client interfaces. However, there are pros and cons to the various approaches. For example, while CT-Earth provides a framework that facilities the sharing and display of vast amounts of data, imagery and information, it shouldn’t be considered as a data management or analysis tool, or as a portal for aerial imagery and elevation data consumption by CADD or GIS clients. For solutions that require client interfaces to have additional GIS functionality (analysis, data entry, attributes editing, clip-n-ship data exporting), a better option would be to use the ArcGIS Viewer for Flex, Flex or Silverlight APIs, or even a more advanced approach to fully take advantage of the underlying capabilities found within the GIS framework.
Web Map Service Clients:

Web map service clients (or thin clients) provide accessible, easy to use and functional environments for viewing data and information published by ArcGIS Server. District 11 currently uses ArcGIS Viewer for Flex to develop client viewer applications. Flex Viewer is a free, XML based set of tools that are easy to configure, customize, and deploy. No programming skills or additional costs are required – the framework is built around and takes advantage of the data and services being maintained and deployed as part of normal ArcGIS workflows. This approach brings customer and business oriented data and information into a focused, spatially enabled, internet browser based map service environment. This approach is particularly effective for a customer base consisting of non-GIS users, professionals and
management – customers who do not have a need to learn the heavier, more complex ArcGIS Desktop application.

One of the key benefits to using the Flex Viewer framework is that solutions are easily repeatable and reusable. The core functionality of readily available, online basemaps and imagery is retained across various configurations, while access to the specific map and feature data services and widgets (tools) that add functionality to the application can be easily tailored to suit the intended business solution. This makes deploying projects fast, simple and cost effective. The Flex Viewer structure is easy to understand, is well documented, and a large user community exists for collaboration. Public facing services from partner agencies can also be consumed in Flex Viewer, as can real or near real time information essential for emergency response and incident management.

ArcGIS Image Server and Image Services:

Aerial image services are being developed and published using ArcGIS Image Server under an Esri Developer Network (EDN) subscription. This effort was initiated in late 2008 as part of an Esri Government Mobile GIS grant project, along with a request by Headquarters Office of GIS (OGIS) to explore the feasibility of developing fast, efficient aerial imagery services for ArcGIS and Microstation customers. The current inventory of imagery includes multi-year data for the San Diego and Los Angeles regions, urban area imagery for Districts 3, 4, 5, 7, 8, 10, 11 and 12, along with statewide National Agricultural Imagery Program (NAIP) imagery. Elevation data, such as regional and statewide digital elevation models (DEM) and Light Detection and Ranging (LiDAR) data can also be published as services via Image Server. One of the primary goals of image service development effort was to determine the interoperability capabilities and efficiency of serving such imagery data to our CADD clients. This has proved successful particularly in advance of the Department’s rollout of new roadway design software, which has improved interoperability capabilities. These capabilities will allow CADD clients to easily access imagery and web map services, reducing time and costs associated with data conversion to-and-from CADD. This concept, from a technical standpoint, could effectively be used to replace the Department’s Digital Highway Inventory Photography Program (DHIPP) framework with a modern, standards based, accessible and flexible environment. The ArcGIS Image Server framework provides functionality that allows vast amounts of high resolution imagery to be consumed rapidly by clients, as well as accessing elevation data as services. Data viewing, extraction, reprojection, interpretation and other processing tasks can be easily configured to accommodate specific user requirements.
Mobile GIS:

For many years the District has been using Mobile GIS through the use of GPS field computers in conjunction with Esri’s ArcPAD and Trimble’s TerraSync for resource grade field data collection and inspection activities. Functional units including Environmental, Culverts, Traffic Operations and the GIS unit have made Mobile GIS an integral part of their workflow. With the advancement of GIS technology that now includes ArcGIS Mobile, ArcGIS Server editable web applications and Flex Viewer client interfaces, the demand for Mobile GIS capabilities to enhance workflow efficiencies has risen.

Mobile GIS plays an important role in the Department’s asset management and inspection efforts by placing tools into the hands of functional unit staff to define and collect information about assets such as drainage culverts, environmental habitat, species and mitigation sites, roadway signage and other fixed assets, and various other departmental assets. Mobile GIS efforts vary across the Department, though the utility, flexibility and affordability of equipment and supporting software have become both more robust and affordable.

Mobile GIS Goals & Objectives

The District 11 Mobile GIS program has five goals.

- Implement best practices and standards for an effective, long-term program through enhancement of current Mobile GIS concept projects
- Add innovative methods and technology to complement the established traditional methods for the development and delivery of critical state highway infrastructure information by placing state-of-the-art tools into the hands of District 11 GIS staff and field crews
- Demonstrate the importance of Mobile GIS technology in maintaining an organized, efficient, and prepared approach to the management of key assets for daily workflow and emergency response
- Deliver critical information in real-time to management and emergency response staff during regional disaster events
- Build upon District 11’s multi-disciplinary team-oriented approach between GIS services and Engineering and Operations functional units within Caltrans
GIS COORDINATION ACTIVITIES

The District GIS Manager and staff participate in regional and statewide user groups and technical committees, which greatly enhances our ability to respond to the needs of our internal and external partners and facilitate information and data sharing. District 11 GIS has been a long standing member of the San Diego Regional GIS Council (SDRGC). Currently, District 11’s GIS Manager serves as SDRGC Chair, and GIS staff have also served in various SDRGC capacities including Vice-Chair and Secretary in the past. This active participation has led to key local, regional, state, national, bi-national and public/private partnerships that have been beneficial to both the region and the Department.

Additional coordination activities include participation in statewide GIS coordination activities with CA GIS Council and CMCC, national agency coordination with USGS, DHS/CBP and GSA, and with international partners in Mexico including IMIP, IMPLAN and INEGI. Activities with regional partners include participating on technical proposal review and interview panels for partner agency and MPO projects, ad-hoc committees composed of fellow GIS professionals, demonstrations at various summits and seminars, and direct interagency coordination related to data and information sharing.

Internally, the GIS Branch holds bi-monthly seminars to provide focused support for District GIS users. These seminars cover a range of topics, including reports on significant current events in the geospatial field, tips and tricks for software users, best practices and standards, GIS data and services updates, and hands-on demonstrations. The seminars are user driven so that the District GIS community directly benefits from the topics, and can bring new knowledge back into their workflows.

The GIS Manager coordinates with Project Managers on the development of contract Task Orders to ensure that GIS related tasks are scoped properly, and that deliverables meet required specifications. GIS Manager or staff participation on Project Development Teams (PDT), Regional Transportation Plan (RTP) and Corridor System Management Plan (CSMP) efforts, and other key planning, operational and project development activities are important in order to focus current activities and anticipate future workload.
Emergency response/disaster preparedness is an essential GIS coordination activity within the District and the region. GIS support is an integral part of the District's response capabilities, including maintaining the Emergency Response Common Operational Picture (COP) web services. These services provide real or near real time data and information from both internal and external sources to support incident management. GIS staffing and technical support is incorporated into the District’s Emergency Operations Plan (EOP), including providing direct support in the District Emergency Operations Center (EOC) and District office complex during significant events. In addition, all GIS staff are trained to use and staff the County of San Diego’s Office of Emergency Service (OES) WebEOC to support countywide efforts.
CONCLUSION

The District’s approach to delivering geospatial data and technology solutions is centered on internal and external partnering and collaboration, and maximizing the use of existing hardware, software and staff resources. Supporting capital project delivery, transportation and environmental planning studies, and data/asset management remain the GIS unit’s highest priorities. Much of this is done using “traditional” GIS analysis, mapping and data interoperability approaches and techniques. However, advancements in geospatial technology, CADD interoperability, web map services deployment and Mobile GIS have provided new opportunities to tie project development, program and asset management, and operations and performance monitoring together. These advancements support improved information sharing, project workflows and decision making – leading to greater efficiencies in our business processes.

As is the case in most large organizations, both in the public and private sector, many tools exist to perform various tasks and processes within the corporate structure. Geospatial technology, and the District’s approach to GIS in particular, is best utilized when leveraged with these other tools, as well as the underlying talent pool. Using existing staff resources, standards based IT infrastructure and out-of-the-box COTS solutions as a base framework maximizes the ability to implement solutions, and reduces or eliminates costs associated with custom development, maintenance and re-engineering efforts.

An effective GIS program and geospatial technology deployment should be complimentary in nature to the suite of tools available to the District, and the Department as a whole. No singular solution exists that meets all Departmental needs. This underscores the need for effective partnerships between GIS professionals, programs, functional units and Information Technology. Further, building support at the executive management level through education, demonstration and awareness of how GIS principals, data management strategies, best practices and technology integration support the Department’s mission, vision, goals and objectives is critical. While the data and technology components are vital to develop and maintain an effective GIS framework, the interaction and collaboration by the people supporting the framework are ultimately what enables us to be successful.

After all – GIS is much more than a map....

Prepared By:

Pat Landrum, GIS Manager
Caltrans District 11
4050 Taylor Street
M.S. 256
San Diego, CA 92110
(619) 688-6476
pat.landrum@dot.ca.gov

Barbara Kent, GIS Coordinator
Caltrans District 11
4050 Taylor Street
M.S. 256
San Diego, CA 92110
(619) 688-6002
barbara.j.kent@dot.ca.gov