

Elevating GIS to an Enterprise Solution at Otay Water District

Ming Zhao & Geoffrey Stevens

Abstract: The concept of the GIS as a centralized enterprise asset rather than a cartographic tool is gaining acceptance. Enterprise GIS takes an organizational approach for sharing and managing spatial information. At the Otay Water District, we are integrating departmental projects and data into a centralized GIS. To make sure the new GIS system can serve the best business needs at Otay, GIS staff first reviewed the ESRI's water model and then conduct a series of interviews with the end users in the District. A detailed user need assessment document was created as the guideline for the geodatabase model development and customization. The implementation of enterprise GIS will serve as the foundation in integrating other tabular database systems within the district.

1. Introduction

The purpose of this paper is to share Otay Water District's experience in upgrading their enterprise wide IT software and databases to meet the challenges that faces today's water utility company in terms of evolving technology and competing markets. The paper starts by providing brief background information on Otay Water District, history of the IT and GIS development and integration. The paper then outlines the District's experience in establishing their enterprise GIS systems and briefly goes through the driving motives to upgrade the existing system and how they have selected ESRI's geodatabase technology to be the central database to keep and maintain their potable and reclaim network assets. The paper also outlines how they intend to integrate the central geodatabase with other databases and 3rd party software.

2. Background

Otay Water District (OWD) is a publicly-owned water and sewer service agency, more specifically, a California special district. The district is located in south San Diego County and encompasses approximately 129 square miles with a parcel base of approximately 50,000 parcels. Otay facilities serve the water and/or sewer service needs of approximately 144,000 people living in the surrounding communities. The district is responsible for the design, construction, operation, maintenance and update of potable water, reclaimed water and wastewater facilities within its boundary. Otay is one of the fastest growing districts in San Diego County adding approximately 50,000 customers since 1999.

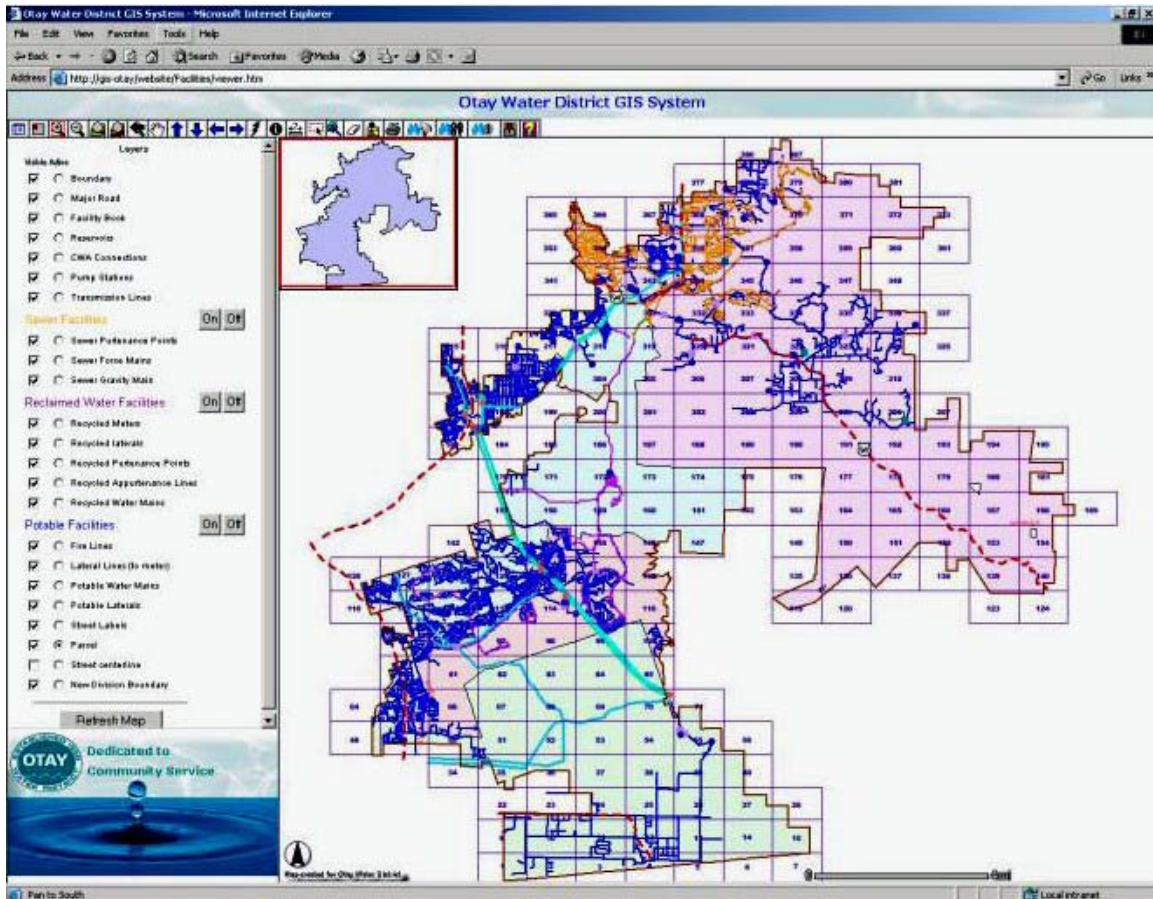
Otay also owns and operates a wastewater collection and reclamation system, providing public sewer service to approximately 5,000 homes and businesses within the Jamacha drainage basin. Through a dedicated pipeline system, the reclaimed water is transported into the eastern Chula Vista area where it is used to irrigate a golf course, elementary and high school playing fields, public parks, roadway landscapes and various other approved uses.

3. GIS history in Otay Water District

In 1994 PlanGraphics, a GIS consultant company was hired to conduct a study towards a practical GIS implementation plan that addresses all operational and technical issues. The outcome was a report titled “Otay Water District GIS conceptual design and implementation plan”. The report defined and proposed the scope of the GIS system, the schedule for implementation and budget. The document served as a preliminary guideline for the District’s GIS data collection, data structure as well as a conceptual guide for application developments.

Since then, the cadastral and facilities data have been GPS collected by another engineering survey consultant. Facility data, cadastral base map and the high-resolution digital orthophotos are the major GIS data needed within the District. The data has been delivered and stored at the District’s data server. The database is significant in size, approximately 20 Gigabyte, and captures major attributes of the facility infrastructure such as diameter, material, as-built number, facility page number and etc, and has become a major asset for the District. The AutoCAD based data were then converted into shape file format for further applications.

An ArcIMS based GIS web application has been developed and has been utilized by the District staff through an intranet. Since the GIS database was composed of both geographic data and tabular data, the ODBC connection along with ASP technology were adopted in developing and querying the relational database. A customized ArcIMS application was developed with similar GUI of desktop ArcView providing the consistent user interface for field laptop and other desktop applications for ArcView3.2 users. Distributing geographic information over the web allows real time data integration in a cost-effective manner. Furthermore, the interactive maps allow users to query the data to derive more information. In addition, the web GIS provided a new mean of quick access to geographical data and related information.



At Otay, the searching of the paper maps which used to be a standard procedure has been replaced by searching through the interactive GIS map to get the engineering drawing, record drawing, survey map etc. The web portal is a cost efficient way to distribute geographic information to the GIS end user. The website came at the right time to present the high accuracy data for the district and clarified the confusion how GIS can help the engineering workflow and procedures. The GIS web site in Otay does lead the District staff to the conception of centralized data and has been widely recognized and utilized.

To streamline data capture, the Otay Water District had taken a major strategic decision to move the GIS services group into the IT department to provide GIS services and technical support a couple of years ago. Furthermore, the GIS data collection and update tasks have been transferred from external consultants to the GIS service group. Since the GIS group will be responsible for the maintenance of the cadastral and facilities base maps, the GIS Group was also tasked with the management of all work load involved with project tracking including the scanning, microfilming and cataloguing of As-built drawings and maps. Scanning and cataloguing the notice-to-proceed projects, SIR's, record maps and APNs also fall into the GIS service group's responsibility.

After detailed study and discussion among Otay management, it was evident that the business processes and information shared between the departments are not streamlined or interfaced among the systems. Thus, the District's enterprise solution called "Otay Information System" (OIS) project was launched in June of 2002. The project is an ambitious effort to replace several of the Districts critical business systems, including the customer billing system, and the District's water sewer order system as well as the financial systems. The project will also add two new major components – a system that tracks work in progress for routine tasks, and a "web portal".

One of the key and challenging elements of the enterprise solution is the ability to organize, manage and distribute data, including geographic information, from various databases while still maintaining the data integrity. GIS integration serves as the foundation for enterprise database solution. It is, therefore, required to have a data model that is flexible enough to fit the overall information technology architecture of a modern utility company through the use of open databases, industry-standard programming environments and COM architecture.

4. Integrating departmental projects and data into a centralized GIS database

Although the GPS collected data have been centrally stored in the shapefile format, the attribute data were spread over the departments. The district staff currently performs multiple tasks of data entry and constantly passes papers among departments to gather information. The limitation of the existing GIS data management in term of different access right also makes the data centralization hard to satisfy end users' need. For instance, in the engineering department, engineers calibrated part of the GIS attribute data for modeling purpose but the newly updated data can not be shared within the district due to the lack of the update procedure to keep the data integrity. Another example, engineering front counter staff is continuously experiencing a high volume of plan checks, filing documents and permits. With the growing demand for information to support engineering dailywork, operations, and administration management, Otay Water District sees the need to keep pace with constantly changing regulations and requirements in technology.

As Otay is the fastest growing water district in the San Diego County, the ability to cope with the constant growing demand of service is the top priority for maintaining the data integrity. The proper database structures need to be established to really achieve the goal that GIS system is a joint district's asset and provide the institutional setting and data exchange mechanism so that each department can minimize its own individual expense and maximize contribution to the District. How GIS can serve as the foundation of Otay's other enterprise systems such as Custer Information System (CIS), Permit System, Parcel Manager, Service Request System, Work Order System (WO) and Infrastructure Management System is the major focus during our model design and integration implementation.

The GIS service group, which is responsible for the electronic facility and cadastral data update, is facing the challenge of making the update procedure appear seamless and most

efficient. While the GIS end users start enjoying the GIS's high quality graphic display and partially link to other RDMS, the GIS and IT professionals are already strategically taking the next step: GIS integration and enterprise database management.

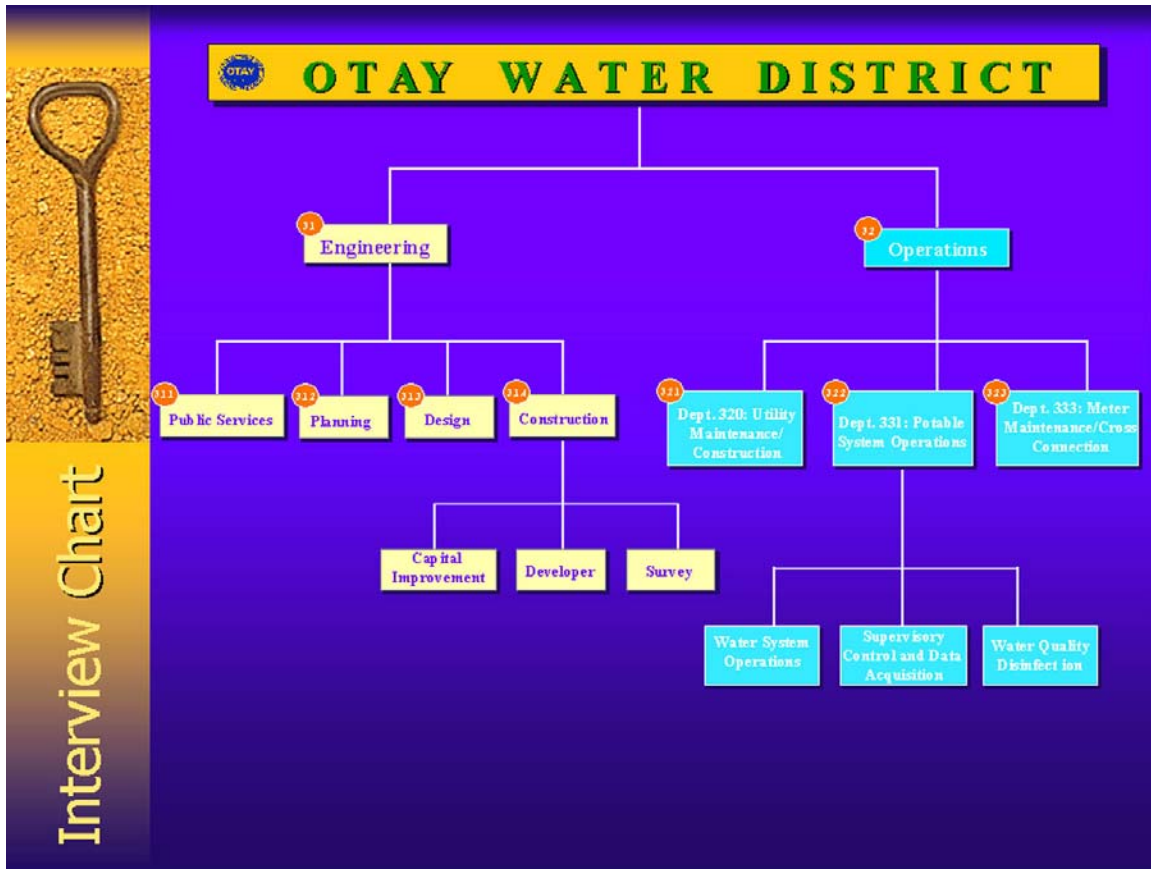
5. Data model design to fit Otay's need

The Otay Water District realizes that the needs of information system solutions that go beyond automated mapping and will become part of the foundation of the enterprise business procedures in order to work seamlessly across platforms and to manage water system in an enterprise environment.

ESRI's geographic database (Geodatabase) ensures the data accuracy, efficiency and decreases the long-term costs associated with updating information and systems maintenance. The geodatabase, which stores data in a commercial off-the-shelf DBMS , allows the organizations to have an integrated data management policy covering all data. Furthermore, geodatabase allows multi-user access to continuous database editing and update through the use of versioning and long transactions.

The district chose ESRI's water modeling as the basis for Otay's water network database considering that the ArcFM water object model was developed with the interviews of a large number of water and wastewater utilities and professionals with detailed knowledge of water and wastewater industry. The water model aids in visualizing and understanding real-world engineering and business problems. This system provides operational efficiencies and business benefits that transcend traditional geographic information system (GIS) and mapping boundaries. The goal is to have a central water network geodatabase that is linked to other associated databases maintained by the Otay Water District. The object-oriented data modeling allows features to be characterized more naturally by letting users define the types of objects, including topological, spatial, and general relationships and by capturing how these objects interact with other objects in the water network and related tabular data in the same or other databases.

Prior to the data model design activities, a series of interviews were conducted with departments within the District to determine how the new GIS system can serve the District's best interest. The following diagram shows the departments in which the staff has been interviewed.

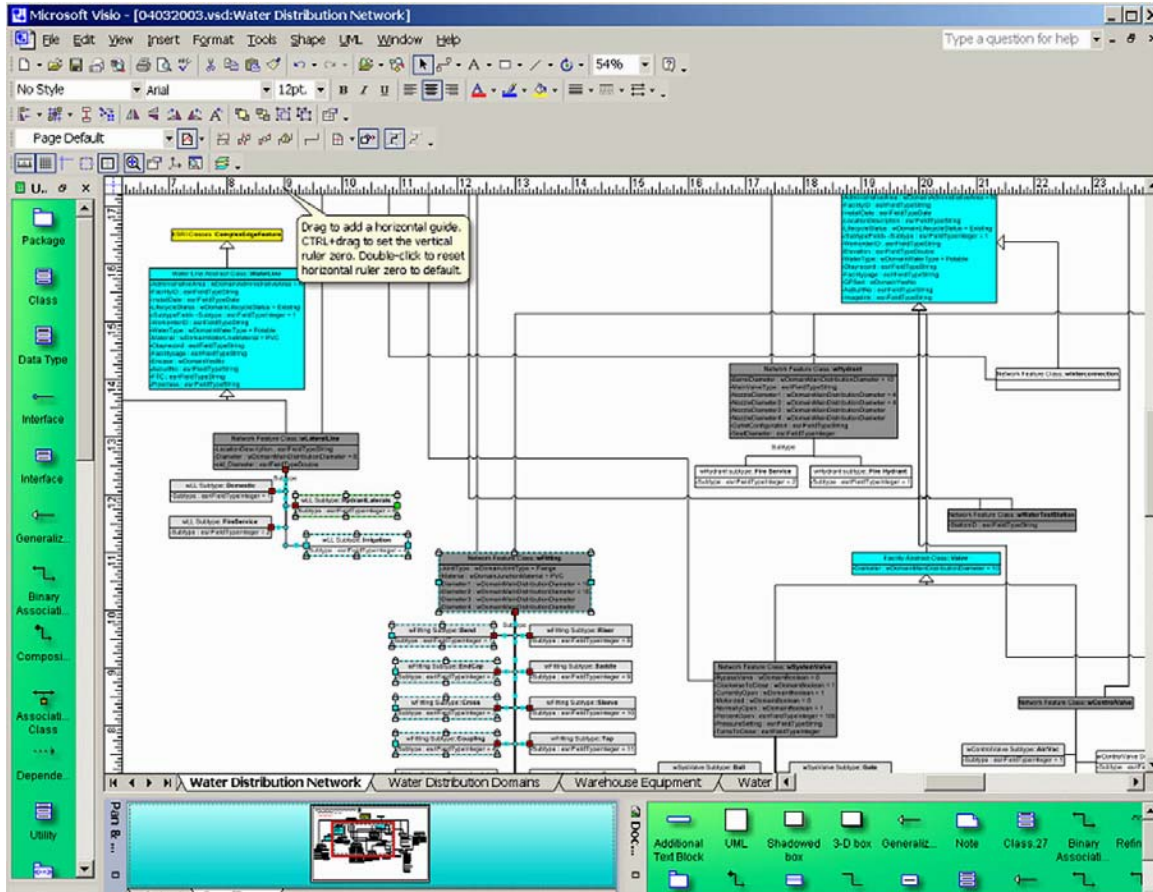


After the completion of the departmental interviews, a detailed user need assessment report was created and consisted of two major parts: first part outlines the required data model changes and the second part lists the functional requirements. The functional requirements refer to the applications or the custom tools that are required to automate the day-to-day activities in the new geodatabase environment. Meanwhile a detailed comparison between Otay's existing data dictionary and the ESRI's water model has been documented for reference to the UML design.

Based on the user need assessment documentation and data dictionary, the customized water data models were created. Since Otay not only maintains potable water system but also owns and operates the wastewater collection and reclamation system, each system requires its own network analysis function. The geodatabase model includes three geometric networks: potable system, recycled system and sewer system to accommodate the District's current operation structure. Each network system was designed to simulate the real entity by collecting different facilities. These files have been converted to shapefiles or some special feature class.

Further customization of ESRI's existing water model was conducted by Otay GIS professionals teaming up with ESRI's Database Services Group. The customization of Otay's geodatabase considers several sources of information and data needs. The most important source of data is Otay's existing data which is the GPS survey grid data;

secondly, the new application data when the development needs to meet the specific requirement from the end users of Otay; and the enterprise database from OIS which will contain information that should be used and linked to GIS.



Microsoft Excel - Attribute_decision_support.xls

File Edit View Insert Format Tools Data Window Help Acrobat

75%

Arial 10 B I U

S378

Field Name	Field	Le	DV	Domain	Field	Field	Pre	Sc	Len	DY	Domain
OBJECTID	OID	4									
Shape	Geometry	0									
Enabled	Integer	2	1	EnabledDomain							
AdministrativeArea	String	200	N	wDomainAdministrativeArea							
FacilityID	String	20									
InstallDate	Date	8									
OperationalArea	String	200	D1	wDomainOperatingArea	strstatus	char				8	Existing/ Abandoned/ Proposed (see note 2)
LifecycleStatus	String	20	Active	wDomainLifecycleStatus							
Subtype	Integer	4	2								
WorkorderID	String	20									
FlowMeasurementID	String	255			strwatersy	char				8	Potable/Recycled(See note 3)
WaterType	String	255	Potable	wDomainWaterType	strmatena	char				3	See note 3

Notes:

1.

From Existing Data Source : SV.shp --> Subtype = 1
 FL.shp --> subtype = 2; IL.shp --> subtype = 4 and
 HL.shp --> subtype = 6

wLateralLine (Complex Edge) (PolyLine)

Ready NUM 3:50 PM

To make sure the GIS database will be useful in a reasonable timeframe our strategy is to design a scalable data model by customizing UML water model, converting the customized UML into schema through ArcCatalog and loading Otay's existing data. Further modification of the model will be conducted through ArcGIS's CASE tool.

6 Geodatabase implementation at Otay

The primary geodatabase implementation has been completed. The geodatabase will help to ensure the quality of data entry and maintenance and also help to establish the procedure. Here are the activities lined up for the next stage:

- Loading the data into the geodatabase.
- Water network tool development and applications
- Development of versioning workflow
- Creating symbology and layer files
- Establishing the link between GIS and other databases

Each of the above activities will be discussed separately.

6.1 Loading the data into the Geodatabase.

Using ESRI's add on in Visio to export the XMI file and ArcGIS's built in CASE tool, the customized UML model was imported into SDE where SQL Server was chosen as the RDMS database which is also the other Enterprise Database Platform for Otay Water district.

A pilot project was launched to understand the existing GIS data and the new geodatabase structure. By using the loading tool in ArcGIS to load the shapefiles into the geodatabase, the different categories of shapefiles were loaded into a different data set for further creation of the geometric network. The tool allows the mapping of the old attributes into the new attributes and thus preserving the integrity of the data.

During the loading process, some of the historical data that were reported GPS collected were mapped on the wrong side of the pipe. Further study of the data and how to calibrate the GPSed above ground appurtenances to the network is required. Keeping the visual location is a the new challenge for the District.

6.2 Water network tool development and applications

Without the functionalities of enhancing the efficiency of the daily activity at a utility agency, a GIS software might be downgraded to a mapping tool. Geodatabase's functionality of having a geometric network where individual customers can be traced to the nearest valve, source or water supply is a plus to help field staff to improve daily service to the customers. For example, queries to tell who is connected to this valve down stream and the functionality to flag the isolating valves if a leak occurs are innovative features to address typical field issues in the water utility industry.

In addition, the geometric network maintains the connectivity and provides a means to ensure the integrity of the network. The connectivity means no over shoots or under shoots for the water lines, no hanging valves or disconnected pipes. For data integrity, connectivity rules can be established; a T or a Tap connection can be automatically added as soon as the lateral is connected to the main; reducers are automatically added when two pipe pieces with different pipe sizes are connected. Therefore, not only the integrity of the data is preserved, but quality assurance is also inherently provided.

Similar to other water utility agencies, Otay Water District utilizes a network simulation and modeling packages such as H₂O_Net, H₂O_Map. These packages are used for planning purposes to estimate the pressures and flows in the water network, given the rate of consumption and head potentials available. When GIS data are not available, the users of these packages need to enter the lengths, the material of the pipes and the elevations. The location of all valves, bends, customers' points are also required to be entered. This task is quite time consuming, especially for the Otay water district with its rapidly expanding water network.

However using GIS the strict connectivity rules that this software requires is already provided by the geometric network. Most of these software packages can now import all the geographic and tabular information from GIS and thus provide more up-to-date

information to the water modelers to spare the valuable time of reconstructing the network in the modeling package. In addition, the information imported from GIS can also provide consumption information from the Customer Information System in order for the modeler to achieve better and more accurate simulation results.

6.3 Development of versioning workflow

In the utility industry, especially a fast growing agency like Otay, data maintenance is the key. One of the main reasons ESRI software was selected is the multi-user editing tools and versioning features that come with the full license of ArcGIS. Because Otay's GIS group is responsible for the maintenance of the Facilities and Cadastral Base Maps, it's very critical to setup the procedures to bring GIS facility data up to date by communicating with different departments including getting the GPS data from survey group, obtaining the as-built and NP from engineering front counter, sharing modeling data with planning department, getting feedback from field crew and eventually releasing the new update data to Otay's staff.

The versioning function allows the District end users to be the 'owners' of their data. It will allow them to be responsible for updating their own water features or updating the tables they are required to maintain, and at the same time, provides the GIS administrator the capability to scrutinize and to detect any conflicting entries well before these changes are committed to the network. It allows the engineers to use the most up-to-date data available to expand the network and study the alternative network expansion options and their effect on the water Network. All this is done in their own 'versioned world' and without disrupting the system or having to check out or copy the network information into another 'sand box'. Versioning also helps GIS group itself to organize and track the work flow. Different version level is setup, after QAQC, the data is edited by different users, the GIS technicians submit their own version to the supervisor by the end of the day and the supervisor then reviews the edited secessions and consolidates them into the SDE.default.

This structure help to release the overwhelming work load from the GIS stuff and reduce the redundant paper work for updating or correcting the GIS facility data. The engineers, technicians and field crew who know the facility extremely well and rely on the accuracy of the GIS data, get the chance to be involved in the maintenance of the data in a safe way. Well-maintained data will be used, will earn the trust of those who use it and will be used more frequently as time goes by.

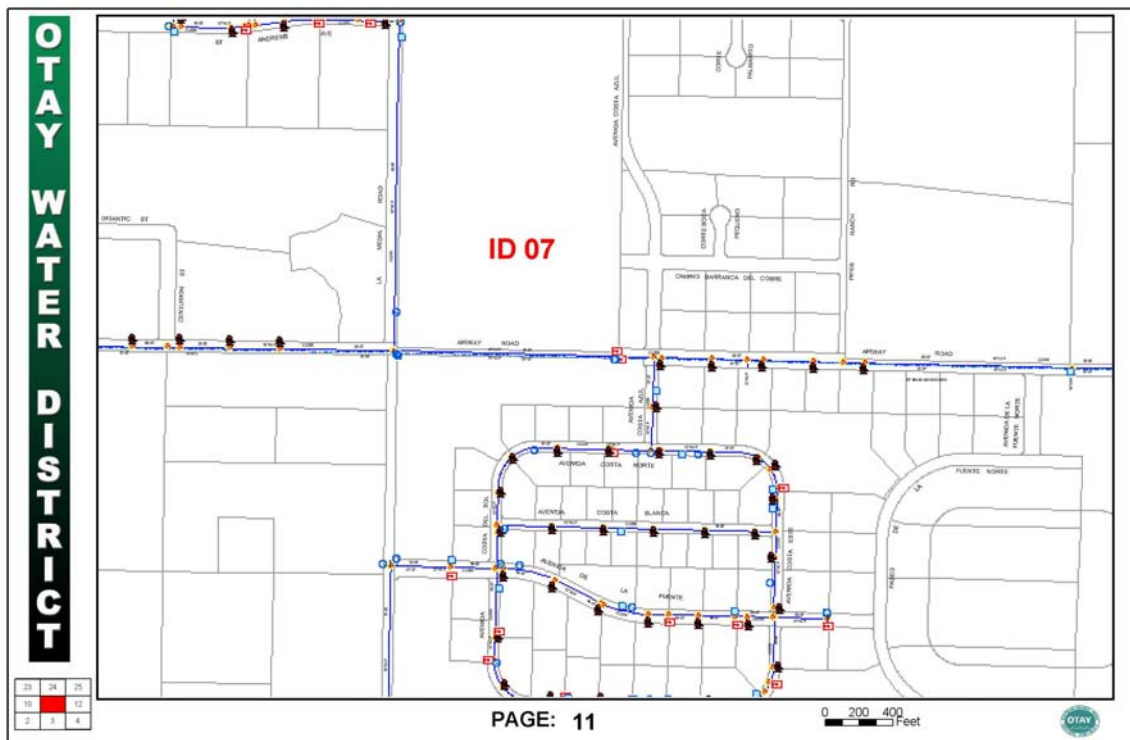
The Notice-to-precede documents from developers were entered into a version and the effects on the system studied and feed back to the contractors provided on the required changes (if any). Once the construction is finished, then the version is committed to the database, and thus eliminating delay and the need to update the system after construction is done.

Still, the end users were not satisfied with the fact that they have to be connected to the database in order to edit their data and wanted to take the GIS system on the field. The ‘Disconnected Editing’ function is used where the area of interest can be ‘checked out’ in a personal geodatabase and taken out of the network and edited. Once the edits are complete, the area of interest is checked back in and Arc GIS is able to detect the changes and update the version.

6.4 Creating symbology and layer files for facility map books in ArcMap

The success of any system, including the GIS enterprise solution, is determined by the degree of acceptance by its end users and their satisfaction with it. A key element towards this goal is that to make the new GIS have the same look and feel of the old paper maps the engineers and the field groups are accustomed to.

By utilizing the functionality to create identical symbols and annotation of what is available on the paper maps, the map production in ArcGIS is high quality and becomes close to a real time update. This functionality can be implemented using layer files. The layer files point to a particular geodatabase feature class (the meters, for example) and maintains the meters symbology that the GIS administrator creates.



This process can be repeated for all the network features and can be combined in an almost unlimited number of permutations to create a number of map products that suit the end user specific needs. For example, a map product can be created for the Engineering department and includes the link to specific databases or tables that they used in their daily activities. Another map product can be created for the customer information system

staff that links the features to the customer information system with a customized query tool so that the user can find the customer location and retrieve all the associated information.

6.5 Establishing link between GIS and other Database.

The Otay Water District has made a strategic decision to select Microsoft SQL Server as the Enterprise DBMS and it was our vision that the chosen GIS software must be easily customizable using off-the-shelf programming language, like VB and VBA. ESRI Enterprise Arc Catalog product fits these needs adequately. However, Otay Water District management believes in a phased migration from the old ways towards an Enterprise Solution. They also understand the need to gradually transition the existing workflows to the new environment. This approach is more acceptable by the end user rather than shock them with an overall rapid transition; a key element in the success or failure of this implementation.

As it was mentioned earlier, each department was comfortable developing their own databases using either Excel sheets or Access database to help them in their daily activities. At the same time, the web based ArcIMS application was introduced. That allowed the end users in Engineering and Operation departments to appreciate GIS and its utility, which they have welcomed and incorporated into their daily activities. However, they continued to use their databases in addition to the corporate databases.

In the short term, the users should be able to use ArcMap to view the water network features stored into enterprise GIS system on SQL Server. At the same time, provided there are common fields between the 'private' databases and the water network features, the information can be linked or related to each other. For Example, there is a meter database in Access format that is maintained by the meter maintenance and installation department. This Access database is located on the network. Each water customer has a unique water meter code, which is common code between the Access database, the Otay's geodatabase and the Customer Billing System which is stored in another SQL Server Database. Therefore, the Water meter users can display the meter features graphically and at the same time, they can link the meters to their own Access database using the common field –the meter code- and therefore, enabling them to see the meter detail in addition to their data for each feature they select. A custom Arc Map documents (*.mxd) and can be prepared for the Meters department so they do not have to do relates and links.

As another example, ArcCatalog allows a connection to any relational database (SQL or Oracle) using OLE DB Connection. Thus the Customer Information System staff not only can view the tabular data in the CIS database, but they can view the actual customer location graphically by, again, using the link or relate functionality in Arc Map. Again, a pre set map document can be prepared so that the users don't have to create these links.

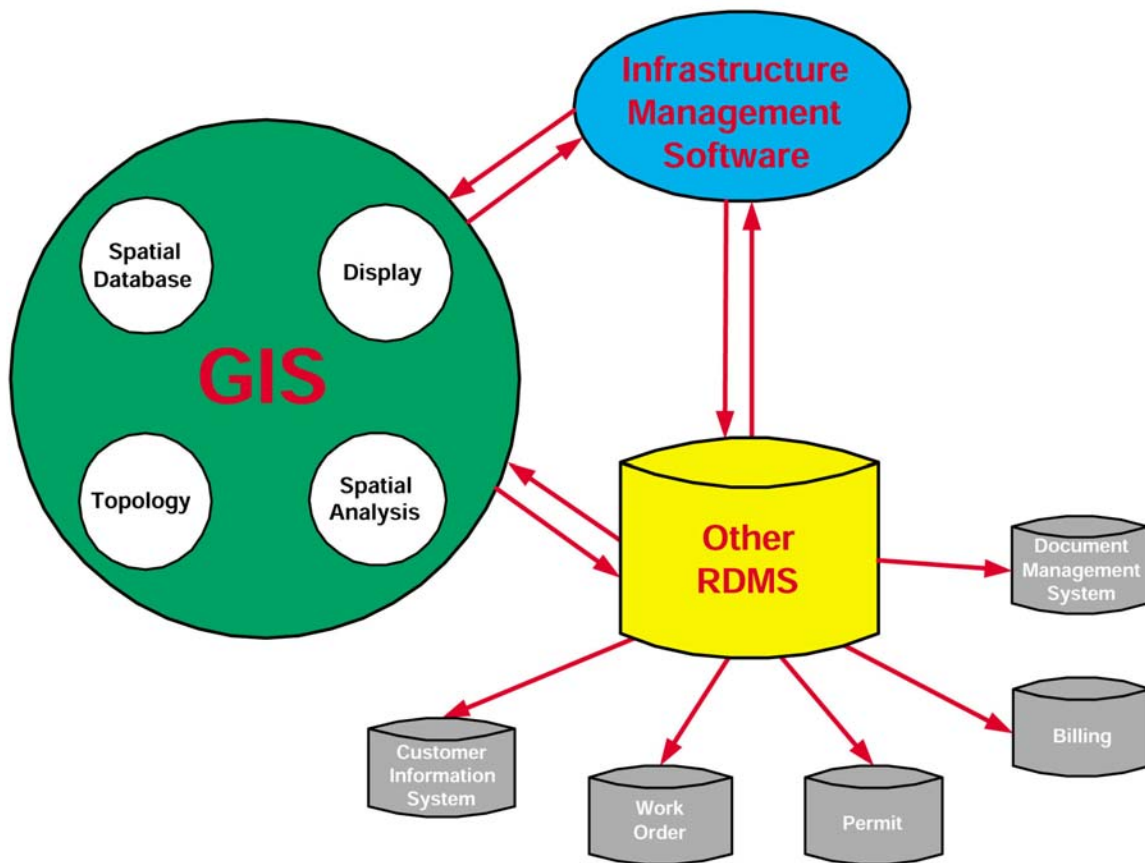
Within the next couple of years, all these databases will be migrated to the central SQL Database. However, it is envisaged that the users, like the meter maintenance groups will

continue to update their tables as they did when they had the Access database. Having these tables in an RDBMS will provide another layer of data protection using database roles and permissions. Furthermore, having both GIS and IT services under the same management umbrella will make this transition much easier; another testimony to the wisdom of this decision.

6.6 Geodatabase for infrastructure management

The infrastructure management has been an important concept in the water utility industry. "The infrastructure is a collection of public assets that can be managed to maximize public profit, the return on these assets invested in the region's economic and social enterprise". Sewers, water pipes, reservoirs, pump stations and other facilities are among the most of the important elements of the civil Infrastructure. The challenging features of managing the infrastructure are going to influence the services to our customer. The improvement of techniques for management of assets could facilitate reduced spending on assets that are functionally obsolete. GIS as a cutting edge technology that will help to improve the quality of infrastructure management by taking advantage of the data modeling and the relational database structure

The two basic components of the infrastructure management is "data collection and analysis" and "performance modeling" in identifying the assets. To obtain the accurate data is the most challenging tasks for infrastructure management in order to get the accurate location and current conditions of facilities. With the new technology, remote sensing and GIS, it facilitates the identification and analysis of interactions among infrastructure sub-system. As Otay already successfully set up the business procedures for GIS data collection, maintenance and update, it is absolutely feasible and doable to take advantage of this solid foundation to expedite the infrastructure management.



The Otay's geodatabase model is designed in consideration of the further infrastructure and asset management requirements. The facility specifications, material parameters, installation and replacement dates, the location and the connectivity within the water network and .etc are being stored in Otay's geodatabase. The geodatabase modeling enhances the robust system of the facility network, captures the business logic (rules for editing, and so forth), and generate the symbology that pertain to water and wastewater networks. Currently in the utility software market, infrastructure management software has been developed and deployed. In order to seamlessly integrate the existing Otay's geodatabase that specifies the District's own need with the infrastructure management software, an open API that can access both spatial data and tabular database needs to be developed or purchased. Otay's IT and GIS staff are working hard on doing the research to find the right software vendors and the proper mechanisms to reconcile the geodatabase data structure with the vendor's data structure.

Challenges

As Otay's enterprise solution is on the way to being the foundation for other RDMSs, the static linkage between geodatabase and the tabular database can be defined in a relatively easy way. The challenge is how to keep the geographic features and tabular data that reside on other database synchronized. The synchronization is quite crucial in term of

keeping the new projects or facilities installed up dated in the electronic system both in the geographic and tabular format, especially for a fast growing agencies like Otay. The proper business procedures need to be defined in order to make the software and the database works efficiently. On the other hand, the software and data model need to have the scalability to adjust according to the normal business procedures.

In the detailed level of geodatabase database loading and maintenance, GPS collected appurtenances were collected based on the caps that sit above ground. ArcGIS's snapping functions allows the appurtenances (valves, for instance) to snap to the built geographic network by specifying the tolerance. This automation release staff from the manual entry, but also might cause the wrong results that for instance, the valves can be snapped to the wrong pipes. In order to take the advantage of the geometric network and keep the data integrity, a certain level of manual QAQC or more robust QAQC tool need to be deployed.

The enterprise solution means two levels of integrations, both for the backend database and for the presentation tiers. Without the fundamental integration in the database structure level, any kind of interface integrations is not robust and efficient enough. Once the database migration is accomplished, without the enterprise wide and user friendly interface, the end users can't enjoy the true beauty of the integrated database.

Conclusion

The right design and structure of the database has enormous potential for saving money in the long term. Accurately maintained data will ensure that the investment in both application software and data continues to pay off. The benefits are many-- instant retrieval of information and associated documents, time saving to avoid the redundant data entry and paper work, smoother business process, improve quality of decision making and increased the levels of customer satisfaction.

It is also envisaged that extending the web portal services will provide an interface for our customers to have access to their customer bills, consumption history, and account status. This interface will serve as the basis for even more services in the future, so it is a platform we can continue to add to and improve upon. In addition, the status of major projects, including capital and development projects will be accessible to customers. For example, customers will be able to check on the status of their plans. To supply our customers, both residential and developers, "one stop shopping" is the goal.

As a public agency, Otay is constantly looking for the solutions that can improve services and efficiency. Under the guidance of the District Strategic Plan, GIS integration, along with the implementation of other enterprise database solution is expected to significantly contribute to the District. The GIS's special capability of graphic display, relational management and association make it the unique foundation of water utility management.

Acknowledgements

The authors would like to acknowledge and thank the following professionals Nader Al-Alem, Komam Diabate and Kevin Cameron for their precious inputs and participation.

Author information

Ming Zhao

Senior GIS Analyst at Otay Water District

2554 Sweetwater Spring Blvd, Spring Valley, CA, 91978

Phone: 619-670-2240 Email: mzhao@otaywater.gov

Ms. Zhao has over 9 years experience in project management, application development, database design analysis and development in both the private sector as a senior GIS developer and the public sector as senior GIS analyst. She holds two master degrees in Civil Engineering and Transportation Engineering specializing in computer simulation and GIS application developments.

Geoff Stevens

Chief Information Officer at Otay Water District

2554 Sweetwater Spring Blvd, Spring Valley, CA, 91978

Phone: 619-670-2717 Email: gstevens@otaywater.gov

Mr. Stevens has over nineteen years of senior level technology and utility project management experience. Prior to his tenure with OWD, Mr. Stevens provided fifteen years of service to San Diego Gas and Electric as Manager of Systems Development and the Information Technology Manager. Mr. Stevens also held the position as Director - Chief Information Officer at Consolidated Edison of New York. He holds a Masters of Arts in Communications Research and a certificate in Business Applications Programming.