

Title: Implementing an Advanced ArcIMS Application for a Water/Wastewater Utility

Author: Philip Campman, City of Austin, Austin Water Utility

Abstract: In 2003, the Austin Water Utility upgraded its Geographic Information System (GIS) from ArcInfo 7.x to ArcGIS 8.x. Highlights of the upgrade included conversion to SDE/Enterprise Geodatabase, integration of GIS with Hansen Maintenance Management System (MMS) and upgrade of existing web application to ArcIMS. The upgrade of the web application takes advantage of several new capabilities including network tracing, advanced symbology and SDE storage of data layers. It also leverages the integration between the GIS and the MMS. This paper discusses the decisions that were made concerning the upgrade of the web application, the crucial questions that needed to be answered, the technical problems encountered and an overview of the web application functionality and the value it provides to Austin Water.

Table of Contents:

Origins.....	2
The Upgrade Project	6
Business Process Analysis	6
Software Upgrade and Data Migration	11
Web-based Application Upgrade.....	11
Business Information System Creation.....	15
Usage.....	28
Conclusion	33

Table of Figures:

Figure 1: Spatial Information System Transformation	3
Figure 2: Web Application Interface	13
Figure 3: Correction Submission Tool Interface	16
Figure 4: Full Isolation Trace Results.....	17
Figure 5: Wastewater Downstream Trace Results.....	18
Figure 6: Profile Generate Tool Results	21
Figure 7: Hansen Identify Tool Results	22
Figure 8: Hansen Select Interface	23
Figure 9: Hansen Select Tool Results	24
Figure 10: Hansen Query Tool Interface	25
Figure 11: Hansen Query Tool Results.....	26
Figure 12: Auto Pressure Calculator Tool Results	27
Figure 13: Austin Water GIS Access Site Usage Chart.....	29
Figure 14: Web Application Tool Usage Chart	31
Figure 15: Web Application Advanced Tools Usage Chart	32

Origins

The City of Austin's Austin Water Utility converted a legacy AM/FM system (Synercom) to ArcInfo in the mid-1990s. The conversion was very difficult for a variety of reasons and took a number of years before Austin Water was able to resume all of the tasks that it used to do with its legacy system. However, once complete, the conversion to ArcInfo opened up access to a system that previously had only been accessible to a handful of individuals; the legacy system was dependant upon specialized hardware and expensive software licenses and was not available for wide use. Since ArcInfo was able to be run on standard high-end Intel-based PCs using Windows NT, even though the cost of the software and the hardware were still high relative to average PC-based software, it was now possible for a wider (though still small) group of users to access the data for purposes other than map book production.

The idea of converting from an electronic mapping system to a GIS was viewed by many in Austin Water as the first step in a long-term process to expand and extend the role of the mapping system within Austin Water. The goal was to be not just a map-making machine but to be an information purveyor and decision support tool. The process would involve moving the mapping system through increasingly more complex but beneficial changes to evolve into a system that could add value to many different aspects of Utility management and decision making.

In general, these steps have been thought of as follows:

1. Electronic Cartography: Utilizing a mapping software to reproduce hard-copy maps using an electronic production method for graphical line rendering and hand-placed labeling
2. Automated Mapping: Producing graphically accurate map products electronically using simple database attributes to drive graphical formatting (such as line weights and coloration) and label valuation (derived from attribute values stored within simple associated attribute fields).
3. Geographic Information System: Storing and manipulating spatial and attribute data for the purposes of map production, spatial analysis and spatial database query.
4. Business Information System: Storing of spatial data with associated attributes in a fashion to allow beneficial database interaction between the spatial database and tabular database(s). Benefits of database interaction include querying of tabular database using spatial queries, combining spatial database features and attributes with tabular database attributes to support specific business unit needs and cross-population of attribute information between databases.
5. Management Information System: Storing multiple spatial and tabular databases within a data warehouse to provide support for standardized and on-the-fly database queries (both spatial and tabular) to support organizational and management decision-making.

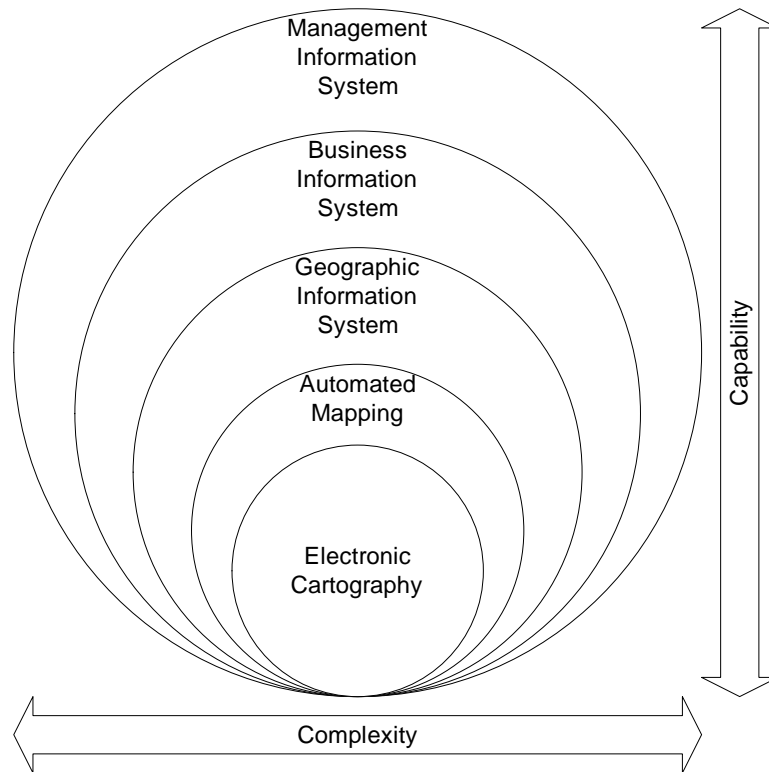


Figure 1: Spatial Information System Transformation

Figure 1 illustrates the capability versus complexity when advancing from Electronic Cartography to a full-scale Management Information System. Complexity necessarily increases due to the amount and types of information stored and the necessary coordination between differing database systems, applications and user groups with differing business needs. However, the capability derived from this complexity is the desired benefit. With most transitions from one stage to the next, the balance between complexity and capability fluctuates. Typically, complexity is higher at first at the expense of capability due to the establishment of new business processes and associated work efforts to support the new level. But once business process efficiencies have been obtained, complexity and capability tend to balance out.

Bolstered by a small but vociferous group of users who wished to utilize the data for purposes other than standard map production, Utility GIS management was at a crossroads: it could proceed along the path towards recreating its legacy automated mapping system within the ArcInfo environment and resume production of its previous list of mapping products or it could choose the more difficult path of attempting to move the data set from the next step to a true Geographic Information System capable of not only producing maps but also supporting sophisticated spatial analysis and query.

The choice was not unanimous. One of the strongest arguments against moving the mapping system to a GIS system was the amount of money that had already been spent on the mapping system. Estimates of the cost expended to date were in the millions of dollars; the cost of moving to a GIS system would be added to this amount. The cost spent on the system to date became one of the most cogent reasons to *continue* investing in the system to convert it to a true GIS. So much money had already been invested in

the system already, it was fiscally responsible to maintain and expand the system to not only continue to receive the benefits from the system that were expected and taken for granted but also to leverage the investment and provide even greater return for Austin Water. Conversion of the mapping system to a GIS was viewed as an ongoing investment with increasing returns rather than a fixed asset with a static set of returns.

Once the decision was made to go forward with a conversion to a true GIS, tasks were outlined to make this possible. Conversion to a GIS system was painful and time-consuming however it brought unexpected benefits. The employees which implemented the conversion developed into a very functional team. This team was able to examine the existing business processes for data entry and map production and restructure them for greater efficiency. Also, greater efficiency was achieved through customized in-house programming. With a revised mission for the data set, data quality needs were addressed with massive database enhancement project aimed at raising data quality and adding features needed for function as a true GIS.

However, creating and maintaining a GIS would be meaningless if it were not used. Since a GIS is more sophisticated than a mapping system, it is more difficult to maintain and extend and, thus, more *costly* to maintain and extend. The justification for its existence is driven by the value derived from its use. As the conversion went into full swing, teams were set up to start looking at new uses of the system when it was complete. Three of the most promising uses were to use the data as input to drive the development of hydraulic water and sewer models, as input for project-specific GIS analysis projects and as the basis for a new web-accessible on-demand mapping system.

Austin Water launched its “HotLinks! GIS Access Site” in 1998 following a pilot project used to gather requirements. The same reasons which made the Internet so popular with other businesses drove the decision to concentrate on a web-accessible GIS site: the need for a widely accessible system with a common user interface and no software costs for the end-user. The initial roll-out of the web site concentrated on providing electronic access to scanned images of existing Utility construction plans and standard map products however it offered also for the first time offered an electronic mapping system which allowed seamless access to Austin Water GIS through a web application front end.

The original web application was created using one of ESRI’s first attempts at marketing a server-based web GIS product: ArcviewIMS (Internet Mapping System). ArcviewIMS functioned as an extension to the Arcview 3.x desktop application environment. Essentially, an Arcview project was created to contain user data layers. A set of custom Avenue script files were loaded when the extension was registered along with a dynamic link library (DLL) which provided the connection from the Internet Java applet to the Arcview session. The DLL handled request traffic and queuing as well as redirecting the Java applet for the appropriate reply data. The Avenue scripts within the Arcview session handled any higher level requests such as processing any map redraws, attribute lookup and display as well as custom programming implemented by the web developer/programmer.

The web application was capable of doing rudimentary viewing and querying of GIS data. It was designed from the beginning as an entry-level web application to familiarize Austin Water with the concepts of web-accessible GIS. The application was capable of

out of the box functionality such as zoom, pan and legend control as well as identification of features and printing of simple maps. Some additional capability was added including an enhanced hotlink to raster image capability, simple geocoding functionality and rudimentary linkages between GIS features and Hansen MMS tabular attributes.

Austin Water extended this software as much as possible to add desired functionality. However after a few years, it had reached the point of diminishing returns. It was recognized that the application needed to be moved along the ESRI upgrade path before investing more time and effort into it.

This need to upgrade the web application resonated with a general theme playing out in all of Austin Water's GIS efforts. With the release of ArcGIS 8.x, ESRI took a decided step away from its installed base of applications, programming APIs and server products. The ArcGIS product line (ArcGIS Desktop, ArcIMS 4.x, ArcSDE 8.x, etc.) no longer emphasized coverage/shapefile file-based formats, Avenue/AML proprietary programming languages and Librarian tile-based data storage methods. Instead, the new paradigm with ESRI products was to work with general information technology industry standards when possible and extend (or set) standards only as a last resort. This meant commercially available database development software for database definition, establishing a spatial storage format based on Microsoft Access format database structure, establishing Visual Basic (VB), Visual Basic for Applications (VBA) and C++ interfaces for customizing and extending its desktop products and using off-the-shelf database packages, such as Oracle and SQL Server, for data storage. Austin Water recognized the need to continue to develop its GIS data set and processes however, as with development of the web application, it was reluctant to invest additional resources into obsolete formats, applications and programming standards. In addition, to go further along the road of integration with Austin Water's other database systems and applications, it could not do so while it continued to use ESRI proprietary data storage technology and programming APIs. The need for a major upgrade was clearly established.

While Austin Water GIS staff understood the inherent benefits of an upgrade project as it related to the GIS directly, Austin Water as a whole better understood the need to upgrade as a means to facilitate the point-to-point integration of the GIS with the Hansen MMS (as a Business Information System). The Hansen MMS had been sharing data with the GIS on a limited basis for a few years. The data shared allowed the GIS to populate the Hansen database with new features and the GIS could store the Hansen database keys in attributes carried on appropriate features. The upkeep of this system was difficult and there was no provision for keeping the databases synchronized as features were changed or deleted (in either system). The limited data sharing did allow the web application to retrieve and display some relevant Hansen attributes for features which were shared between systems but queries based on spatial selection and other more sophisticated tasks were too difficult to attempt due both to the limited nature of the data sharing between the GIS and Hansen and to the limited programming capabilities available for the web application.

While the move from an automated mapping system to a full-fledged GIS had been accomplished by 1998, by 2001 Austin Water was ready to make the next step from a GIS to a Business Information System.

The Upgrade Project

When the decision to upgrade the GIS had been made, the work began to turn resolve into action. A plan was created to upgrade the GIS and link the GIS and Hansen databases. The plan entailed:

- A. Business Process Analysis: Perform a detailed business process analysis of work groups within Austin Water who would be affected by the GIS upgrade and subsequent business information system implementation.
- B. Software Upgrade and Data Migration: Create a database model to support the recommended business processes and migrate the existing data to the new data structure.
- C. Web-based Application Upgrade: Upgrade and enhance the existing web application to restore functionality lost during the data migration and to enhance the application to take advantage of the new environment
- D. Business Information System Creation: Implement a point-to-point integration of the upgraded GIS and the existing Hansen MMS and leverage this integration with new web application modules.

Once a plan was created, a Request for Proposal (RFP) was released and vendors were chosen. ESRI was selected as the prime vendor for the business process analysis, software upgrade and data migration and web-based application upgrade. Marshall and Associates, Inc. was contracted on as a sole-source to create the point-to-point integration of the GIS with the Hansen MMS and the web application modules designed to leverage the integration. The Austin Water GIS team played a very active role on each part of the project.

Although many aspects of the upgrade and integration are germane to the discussion of implementing an advanced web application, much of the work involved is beyond the scope of this paper. Therefore, this paper will focus on the portions of each section of the plan which directly relates to the application development.

Business Process Analysis

Often, effective business process analysis is not completed for major information technology projects. This is a common cause of failure for many of these projects, particularly when the project involves a major automation effort or changes in existing automation processes. Simply put, a good business process analysis mean the difference between success or failure of a project. It can derive the information that a team needs to know about not only what processes will be changed but also *why* the processes need to be changed. In the case of the upgrade project, it was not enough for the GIS team to understand their own professional reasons to initiate an upgrade. The GIS team also needed to understand how effecting an upgrade would benefit the current (and future) users of the systems involved and to communicate this to the affected parties. It is only through this process that buy-in can be achieved with all of the parties involved and the project can be successful.

A good business process analysis will provide the following information to the team for use in later stages of the project:

- a) **Information Gathering:** Gather information to support business process analysis tasks including identification of major user groups, identification of important business processes dependent upon existing web application and existing business processes used to support the web application. The business process analysis portion of the project collected information on the major users of the existing application. Sessions were set up with these major users (or their representatives) to discuss the proposed changes and to get insight on what currently worked well and what needed improvement. These sessions were some of the most productive portions of the project. They allowed the development team to interact one-on-one with its installed user base and get first-hand feedback. It also provided the users with a sense of inclusion in the process which contributed to project buy-in. Key users were also kept in the loop throughout the project and were asked to help test the final product towards the end of the project.
- b) **Define Existing Functionality:** A list of functionality to be retained in the new application was developed. The list was created by the GIS team from technical documentation created for the application and from training materials which the GIS team used when training Austin Water employees. (ESRI team members actually sat in on a live training session which gave them a good introduction to the functionality of the existing application and also exposed them to the questions and comments from Austin Water employees who were being trained at the time.)
- c) **Define Constraints:** Trying to ascertain external constraints which could affect application development was one of the most challenging aspects of the project. Since the project team may or may not have any control over these external constraints, defining them was very important to the project. Some of the more important constraints imposed on the project:
 - i. **Time:** The project team was attempting to complete the upgrade and point-to-point integration in eight months, a very ambitious time frame for such a large project.
 - ii. **Project Quality and Performance:** While time was a constraint, it was by no means the overwhelming constraint; project quality and performance were valued higher than timeliness, which affected the overall project timeline to some degree. It was understood that the project would be considered a failure if it was completed on time and on budget but the applications were of low quality or if the performance of the systems involved was adversely affected.
 - iii. **Maintainability:** Since the web application was destined to be maintained by the GIS team following the conclusion of the project acceptance period, it had to be programmed with maintainability in mind. This meant choosing programming languages which the GIS team was familiar with and approved, such as Javascript and Active Server Pages (ASP).
 - iv. **Application Interface:** The existing web application used a Java applet embedded within the web browser to display the application interface. At the time of development, this was thought to be the best method of

implementing this application. However, several options were available for the development of the new application including an HTML-based viewer, a Java applet viewer, an ActiveX viewer, etc. Two important goals for Austin Water were to provide an application that used open web standards whenever possible and that the application be “light” enough (i.e. low bandwidth) that in the future it could be used by employees in the field utilizing some sort of wireless or cellular technology. The most obvious choice was to produce the application as an HTML-based viewer due to the low bandwidth requirement of HTML/Javascript and the relative ease and power of Javascript programming.

- v. Compatibility with Citywide IT Policies: Since the new web application was to be used Citywide, it needed to conform to Citywide IT policies. In addition, it was initially planned that the web application would be accessible on the Internet. It was originally thought that a single application, residing on a server placed in the City’s Demilitarized Zone (DMZ) would be available to the public. Security concerns were raised though about allowing access to the public to some of the more advanced tools which were proposed for inclusion in the new web application. This led to the concept of an internal viewer (with full functionality) and an external viewer available on the Internet which would have reduced capability.

However, further restrictions were placed on the development of the Internet-accessible application: it had to reside on a server running the Linux operating system, the web server needed to be Apache and the web server programming language needed to be Java Server Pages (JSP). The current intranet application server was an Intel server running Windows 2000 and Internet Information Server (IIS) utilizing ASP. Since programming the application to fit two different environments was not an option, Austin Water was faced with a decision. Either creating the application to fit City Internet requirements and also convert its existing base of other web applications to this new standard or programming the application to fit Austin Water’s existing GIS web server environment with instructions to the web application programmer to limit the amount of code used which would not be portable between the two environments when Austin Water was able to move to the new environment. Austin Water chose the latter with the intention of revisiting the web application in a future project to make it Internet accessible.

- d) Diagram Processes: Existing and proposed processes were diagrammed to document flow of information and the parties responsible for maintaining that flow. Much of the flow of information associated with the web application revolved around keeping the data layers up to date. With the existing application, this was part of a larger arduous and time-consuming process used to keep all of the data sets used for display and analysis up to date. Since Austin Water GIS data sets and supporting land-base data sets had to be stored in shapefile format to work with the web application, lots of processes were created just to convert data

to the proper format, adjust coverage annotation to work properly with the web application, index data layers for faster response time, etc. Also, since the data used for the web application was a copy of the original data sets (along with copies made for use by Austin Water as layers for Arcview users as well as copies made for distribution on the intranet site *and* the Internet), there was significant amounts of data redundancy. Data redundancy not only contributed to the complicated update process but also wasted disk storage and fostered confusion concerning which data repository was used for what purpose.

Many of the more interesting processes which were discussed involved how the web application was used by various work groups within Austin Water. For example, Austin Water's dispatch group used the existing application to determine the City grid map and Mapsco (map book) page number for each work order that they processed. This information could be retrieved manually but the application did the same work in a fraction of the time. It was a very important piece of their work flow which allowed them to operate as efficiently as possible. Other workgroups, both at Austin Water and within the City of Austin organization, used the web application to determine ID numbers assigned to features before opening work orders against them. Certainly, discovering all of these existing processes and maintaining them if possible was very important to the success of the new application.

- e) Detect Inefficiencies: Bottlenecks and inefficiencies in existing business processes and proposed solutions were also detected during the business process analysis. This particular task was crucial to the application specification process since many of the new tools added to the application were to address some of the inefficiencies and bottlenecks uncovered by the analysis.

Many of the problems associated with the existing application were a direct result of the product with which it was created (ArcviewIMS). Most of the positive aspects of the software were reasons why it was originally chosen as the development platform for the existing web application; many of the negative aspects were drivers for replacing it.

Positive aspects of ArcviewIMS:

- + The product was an ESRI product and worked well with ESRI-format data sets (shapefile, coverage, etc.)
- + It was server-based which made it easy to maintain
- + It used Arcview 3.x as the back-end which was familiar to the GIS team
- + Avenue programming language could be used to add custom functionality
- + What was displayed in the back-end Arcview session was exactly what was delivered to the customer (i.e. WYSIWYG) in the web front end
- + It was affordable with maintenance costing about the equivalent of maintenance on a single ArcInfo seat
- + Most of the functionality available to an Arcview session was also capable of being exposed to the web client (with the proper support programming) including table joins, product extensions and customized programming

Negative aspects of the product:

- The product became obsolete with the release of ArcIMS technology
- ESRI discontinued development of the product which instantly made it a dead-end technology
- Web viewer front end used a Java applet which required Java programming coding to add additional tools or to do anything more than simple modifications
- Server side customizations were created in Avenue programming which was unsupported by newer products from ESRI
- The product was not scalable – all users shared the same data channel
- The web server on which the product ran needed to have a user account logged in at all times which posed a security risk to the machine

Several manual processes which were prime candidates for automation were identified during this stage of the analysis. For example, Austin Water has a very active TV inspection program which is responsible for videotaping the interior conditions of wastewater mains on a scheduled basis. To schedule the work efficiently, sections of the wastewater system are designated for inspection during a work period. This type of work is done most efficiently when subsets of a wastewater drainage basin are completed at once. Existing processes were devoted to delineating these subsets by hand and highlighting the areas on a map to create a work packet. To speed this process, a tool was proposed which would leverage the new wastewater network topology to allow discovery of upstream branching sets with a single click in the web application.

When the business process analysis work had been completed, the results were presented to the Austin Water organization in a high-level presentation. The presentation explained the process that had been completed, why it had been done and gave an overview of the major findings of the process. An additional presentation was given to the Austin Water Executive team which covered similar topics however with a greater focus on the benefits to Austin Water that would be derived when the proposed business processes were implemented. These presentations were important to the project for several reasons. First, since a presentation was given Utility-wide, employees in the organization who may not have been directly involved in the analysis were offered an opportunity to participate to a degree in the project. Since most of these employees were interested in simply being informed of what was being done, the presentations were an effective means of satisfying this “need to know”. Second, by providing extra attention when explaining the benefits to Austin Water in the Executive team presentation, the target audience was not overwhelmed by technical minutia and could instead concentrate on the value the project would bring to the organization. With a history of mixed levels of understanding about the GIS team’s goals and mission, this presentation provided a common understanding to the Executive team about the value of the project.

As a final task, the raw data files created during the business process analysis were turned over to the GIS team at the completion of the project. These raw data files can be maintained by staff to keep them current with the state of the GIS, allowing them to be updated in the future to reflect continuing changes in business processes.

Software Upgrade and Data Migration

The results of the business process analysis were used to begin the web application development. On a separate track, the upgrade project began developing a new database design. Using the public domain water/wastewater data model as a starting point, ESRI and the GIS team began an intensive effort to tailor the model to suit the unique needs of Austin Water. Data model development began with a rough draft which was modified to a great degree in a round table session. Present at the round table session were the ESRI team, the GIS team and several key players within Austin Water and the City who had a stake in the new database design.

When changes from the round table session were completed, the GIS team began tuning the data model. Many of the items added to the data model came from a “wish list” created by the GIS team. Other items were added to support additional application functionality, such as an ArcSDE network topology. Still other changes were made to support the point-to-point integration which would occur later in the project. In total, the project team went through thirteen draft data models before the process was complete.

This process alone caused some delay in the project. However, the benefit derived was invaluable. Since Austin Water played such an active role in the database design, team members were empowered to take the database design into their own hands rather than be a passive recipient of work performed by an outside consultant. Of course, this was somewhat disconcerting to the ESRI team since most of their clients do not take a very active role in database design. However, to their credit, they were extremely supportive and willing to let Austin Water participate in this expanded role.

Web-based Application Upgrade

Tool Set Definition: With data model development underway, the web application development began in earnest. As stated before, ESRI had a fairly good understanding of what the web application’s current functionality entailed. A high-level list of its capabilities included:

- Zoom In/Zoom Out/Pan/Refresh/Legend control (out of the box functionality)
- Identify features including Simple linkage between some GIS features and corresponding Hansen MMS information (out of the box functionality)
- Print map function (out of the box functionality)
- Search for features by ID number (added functionality)
- Hyperlink to scanned images of water detail (intersection) images, wastewater plans and wastewater profile images (added functionality)
- Locate address point with centerline fallback (added functionality)

Based on results from the business process analysis, this existing list of functionality would be recreated within the new application along with a host of additional functions. New functionality to be added to the application included:

Basic Functions

- Tabs to switch between water and wastewater specific web application interfaces
- Selection tools (select by rectangle, select by polygon, select by box, clear selection)
- Measure and set units tools
- Address geocoding tool with simplified user input
- Print enhancements including user title and legend suppression
- “i+” tool which allowed display of attributes for multiple selected features
- Buffer tool to buffer selected features with optional selection creation from another layer and attribute display
- Secured access to the web application to allow selective activation and deactivation of tools based on security groups defined and maintained using the built-in web server operating system security settings
- Grouped data layers in the legend

Advanced Functions

- Correction submission tool for electronic submission of error reports to the GIS entry team
- Water shutout tool to identify which valves need to be turned to effect a shutout (including a print of valve IDs, pipes which would be out of water and a graphic selection of the valves and pipes)
- Wastewater upstream trace to select upstream wastewater branching from point selected (with optional export to a shapefile extract)
- Wastewater downstream trace to trace wastewater flow from selected point to downstream outfall
- Wastewater overflow reporting tool to analyze user selected point to determine if overflow occurred in an environmentally sensitive area which would require a public notification (with optional notification map creation)
- Wastewater profile select/create tools which allow the user to select contiguous wastewater mains and generate a wastewater profile on-the-fly
- Hansen Identify tool which links on-the-fly to the Hansen MMS database to retrieve maintenance attributes for the selected feature and builds a graphical report to display the information including links to existing work orders associated with the feature
- Hansen Select tool to query the Hansen MMS database for service request and work order information associated with the initial selection set of GIS features (with optional export to a shapefile and database extract for offline analysis)

- Hansen Query tool build and execute queries against the Hansen MMS database to determine service request and work orders associated with GIS features (with optional export to a shapefile and database extract for offline analysis)

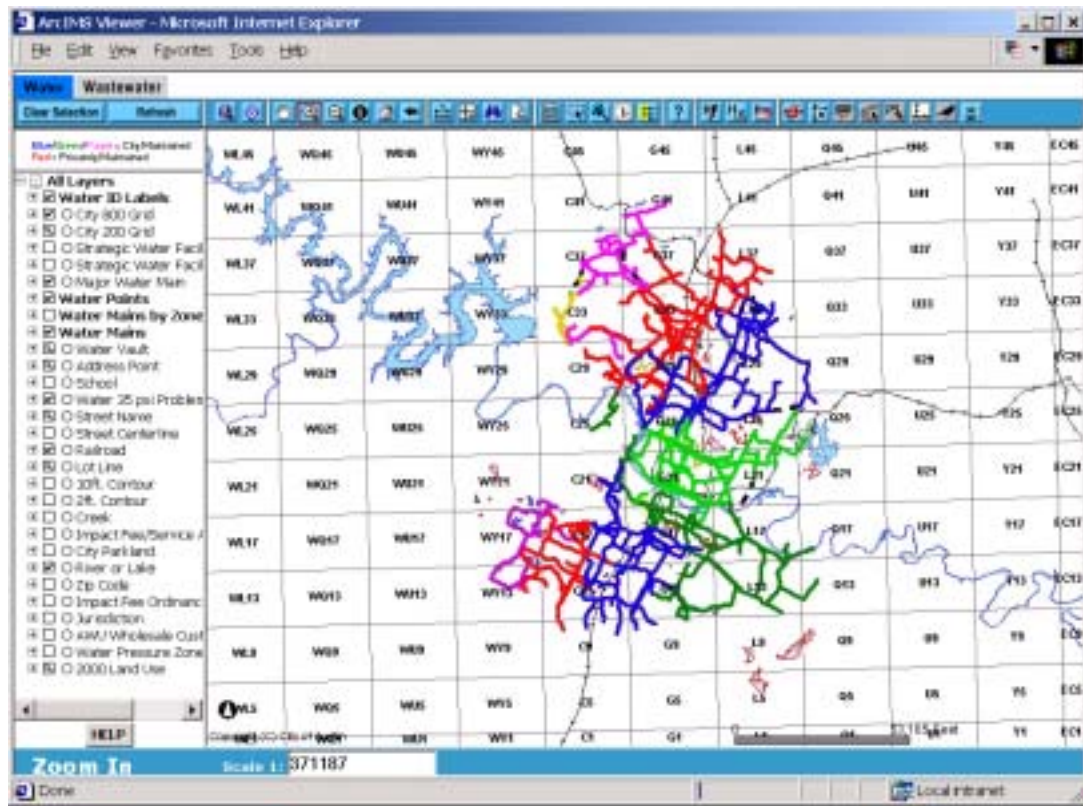


Figure 2: Web Application Interface

Coding: Initial coding of the web application was done by the ESRI team; Marshall and Associates, Inc. were responsible for programming the three Hansen-specific tools; Austin Water coded subsequent changes. Austin Water was responsible for turning user needs into application specifications. Since most of the work to create the application was accomplished at ESRI offices in Redlands, California, Austin Water accessed the application for much of the testing by connecting to the ESRI development web server over the Internet. Figure 2 shows the startup screen of the new web application.

Much of the basic functionality added to the application was already available in the public domain at the start of the project, such as the group layer capability and the print enhancements. Other functionality was simply out of the box functionality from ArcIMS 4.x, such as the measure tool and the selection tools. Most of the advanced functions were programmed from scratch.

Development of the advanced tools was separated from the basic tools for several reasons. First, these tools were thought to be the most resource-intensive tools. Second, most of these tools were candidates for selective access and were programmed to be enabled or disabled depending upon individual users security levels. Third, most of these tools would take advanced programming to implement including a mix of Java, C++ and .NET technology.

One technique that ESRI used to enable these tools was the use of a secondary application server to act as a geoprocessing server. Essentially, a separate physical server running Windows 2000 was set up to run ArcGIS 8.x ArcMap. Using a separate piece of “listening” software, ArcMap attached to a network socket and waited for incoming geoprocessing requests. Once a request was initiated, complex GIS tasks were performed in ArcMap, including tracing tasks, profile creation, etc., and the results were shipped back to the waiting web client for display. When a request was completed, the socket was reset and ArcMap resumed “listening” to the network port for additional requests.

Using a separate application server complicated testing of the new application. While it was relatively easy for ESRI to develop a web application and place it on an external server for testing by Austin Water, setting up the web server/application server link to be functional on the Internet would have posed a security risk for ESRI. Therefore, all testing of any advanced tool which utilized the application server link would have to occur onsite at Austin Water. Since the GIS team would not be able to test these portions of the software at all stages of development, communication between the GIS team and ESRI was critical. It became crucial that ESRI understood what Austin Water’s needs were for the tools and effectively communicated their development strategy throughout the process. Likewise, Austin Water needed to be very clear about its expectations to avoid recoding. It was never a good idea to make assumptions about functional details. It was painful at times but many long technical conversations had to take place to make sure that each team was on the same page when it came to even the smallest detail.

Testing: Official testing of the application occurred at two points in the project: Prototype Review and Final Acceptance Testing. At Prototype Review, the goal was to demonstrate all functionality of the web application even if it was not completely fleshed out. The purpose of Prototype Review was to make sure the direction and scope of tool development were correct; it did not focus on the quality of the tools since the development stage was too early. Final Acceptance Testing was to be completed after ESRI delivered the final code and the code had been installed on the production servers in preparation for final rollout. Testing at this state focused on software quality since by then feature scope had been clearly established and was for the most part complete.

Of course, testing of individual pieces of the application happened throughout the course of the project. These two test points focused on testing the entire web application as a unit. Between Prototype Review and Final Acceptance Testing, there were several test installations of the web application which were installed on a development server at Austin Water. This process was very helpful because it allowed the GIS team to test the functionality of the web application in a local environment, including the advanced tools, and it familiarized the team with the installation, configuration and removal of the web application. By Final Acceptance Testing, most of the major bugs in the software had been identified and fixed. ESRI was very responsive to bug reports and usually provided a patch within a few hours for most bugs reported.

Internal tracking of bug reports was done using a web-based database maintained by Austin Water. When a new bug was discovered in the application, it was logged into the database along with a description, date/time, etc. and a bug report was sent to the ESRI development team. When a response was received, it was tested on the development server. If the bug was corrected, the database record was closed and the patches were

archived. During the final weeks of testing before and during Final Acceptance Testing, the GIS team logged, reported and patched approximately sixty bugs. A handful of bugs were discovered during final rollout and were quickly dispatched.

During Final Acceptance Testing, a scripted set of actions was used to go through each tool and check it for functionality. Any bugs discovered were documented and sent to ESRI. Additionally, a subset of users was allowed access to the web application for testing.

Training: Training for the new application was done using a “train the trainer” method. ESRI provided hands-on training to the Austin Water team using training materials that they created. The training materials were then delivered to Austin Water as one of the project submittals. Austin Water in turn modified the training materials to adapt them for use in training classes for general Austin Water employees. Two classes were offered: a custom “What’s New” class which covered the new web application and an updated standard GIS web site class which covered the new web application in addition to other unrelated parts of the Austin Water GIS web site. The “What’s New” classes were approximately 1.5 hours long and were offered several times over the course of a two week period following final rollout. Attendance was fairly heavy at each section of the class with about 15% of Utility employees attending in total. The standard GIS web training class is 2 hours long. It has been offered several times since final rollout and has had steady attendance at each offering.

Training for the tools attempts to achieve three main goals. The first goal is to acquaint the user with tools in the new application that were in the old application. Since many users have personal or workgroup work processes that they have become familiar with, letting them know how they would do these tasks using the new application allows them to be productive with the new application immediately. The second goal is to progress from simple tools to the more advanced tools. This allows the users to acclimate themselves to the way things are done in the new application without getting too confused early on. Since some of the tools in the new application can be used together in interesting ways, it is important to present them in a logical fashion which builds progressively in terms of functionality. One example of using tools together would be to use the Water Shutout tool to identify water mains out of water during a shutout followed by a buffer to determine affected addresses near the water mains. The third goal was to apply real world situations during the training sessions to help users understand how the tools can be useful to them. For example, when demonstrating the “i+” tool, which allows the user to display attributes for multiple selected features, it was important to show a relevant example of its use. In the training class, a set of address points are selected using one of the selection methods and then the “i+” tool is invoked to bring up a textual listing of the addresses that were selected which could be saved or printed.

Business Information System Creation

While many of the tools added to the new application are general purpose tools or tools which are meant to be used in conjunction with other tools, several tools were designed with specific purposes and, oftentimes, users in mindⁱ.

Correction Submission Tool: This tool was designed to be used by all users. The business process analysis identified a gap when it came to field crews having an easy method of submitting field corrections to the GIS team. Existing methods relied upon printing or copying sections of a Utility map and marking changes on it. This was then forwarded to the GIS entry team for correction. Since this was often time-consuming, crews often did not submit this information. Also, corrections were sometimes submitted to the wrong personnel and the correction could easily fall through the cracks. An easier, paperless method was recommended. Since the correction could be submitted online, it could be done by any City employee from any data terminal running a web browser and connected to the City network. When the tool was activated, a separate Java applet is initiated to handle the correction. The applet captures the Windows login information and domain of the user who was logged in when the web application was started. The current date, feature data set and grid numbers are also captured automatically. The user



Figure 3: Correction Submission Tool Interface

is able to add points, lines and polygons to a screen capture of the current area. Coloration of each feature added can be changed to help distinguish each correction if multiple corrections are submitted at the same time. The user can also clear the display of all drawing and start again if so desired. Textual description information can be entered in a free-form text field. When the Submit button is pressed, the graphical drawing constructs are converted into features and stored in a special SDE layer along with the textual comments and other captured information. A complementary correction processing tool was written to be run within ArcMap. The correction processing tool can download new corrections to a work session for processing. It also marks the correction database to show that the corrections have been downloaded so they are not downloaded again the next time the processing tool is invoked. The correction information can be displayed in an ArcMap edit session so that a data entry person can make the correction to the database. If additional information is needed, the contact information is stored on the actual correction features themselves.

Water Shutout Tool: Designed as a tool to be used primarily by Austin Water valve operations, this tool also has secondary users in the Engineering division as well as the

Systems Planning division. The business process analysis identified problems Utility personnel had when planning or effecting shutouts. Since most shutouts had historically been planned manually, they were often time-consuming and prone to error. Also, field crews in emergency situations were known to inadvertently close unnecessary valves

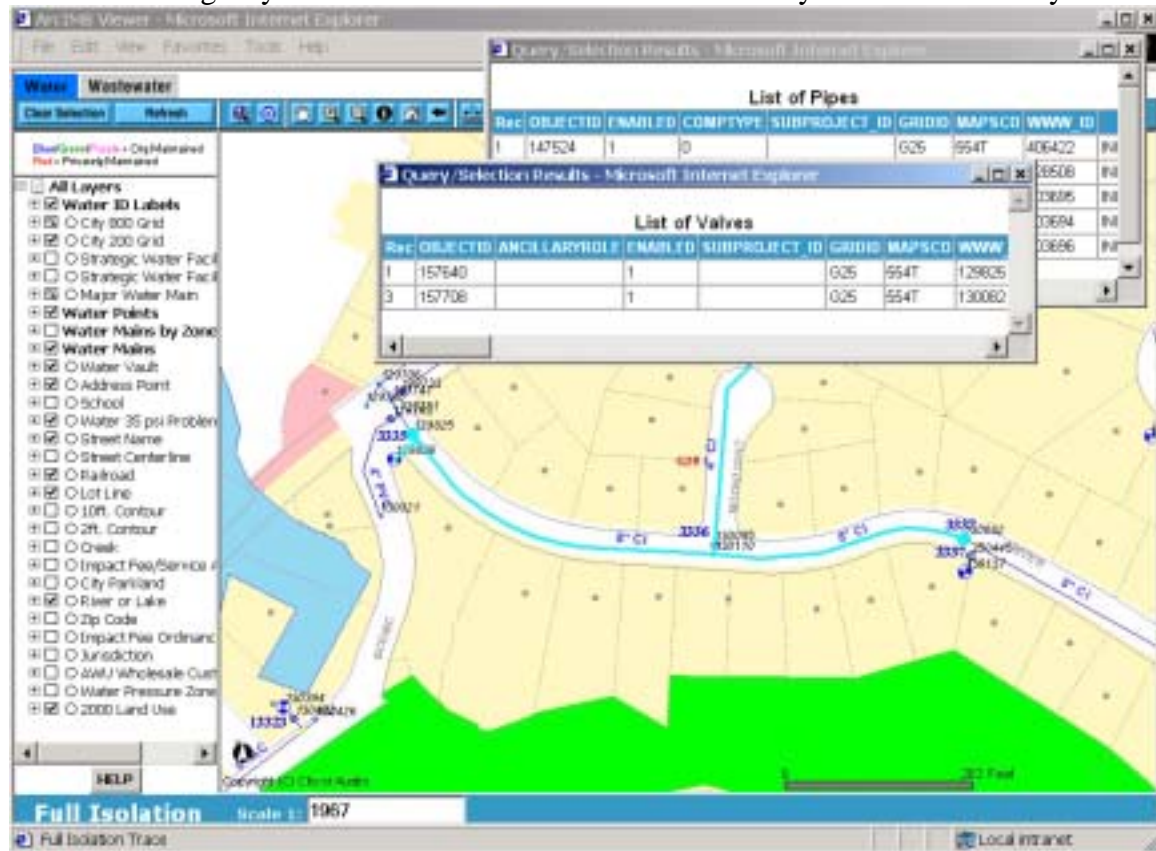


Figure 4: Full Isolation Trace Results

when attempting to stop the flow of water. A tool was recommended to help plan shutouts and reduce the number of unnecessary valve closures during planned and unplanned maintenance. The tool is invoked by pressing the button to activate the tool and then clicking on a water main on the map display. The tool then follows the following steps:

- The selected coordinates are captured and relayed to the web server
- The web server determines if there is a water main located at the coordinates
- If a water main is found, a connection is made between the web server and the application server and the information is relayed to the application server
- The application server uses the pipe information to initiate a water trace
- Trace results are sent back to the web server for formatting
- The web server formats the results and returns them to the user in the form of an HTML form displaying the list of valves to turn to effect the shutout, an HTML form displaying the list of water pipes which will be out of water when the

valves are closed and a map zoomed to the affected pipes/valves with the pipes and valves highlighted

This tool relies upon the processing capabilities of the separate application server. As stated earlier, the application server runs an ArcMap session which listens for requests from the web server. The ArcMap document contains several special tools which were created in VBA to respond to each special request. For this tool, a tracing function was created and stored in the ArcMap document which is used to trace and return the desired information.

As mentioned earlier, during training this tool is demonstrated along with the buffer tool to exploit the selection set created during the trace as input to the buffer command to select address points within a user specified distance.

Wastewater Upstream and Downstream Trace: Since the wastewater GIS main had been

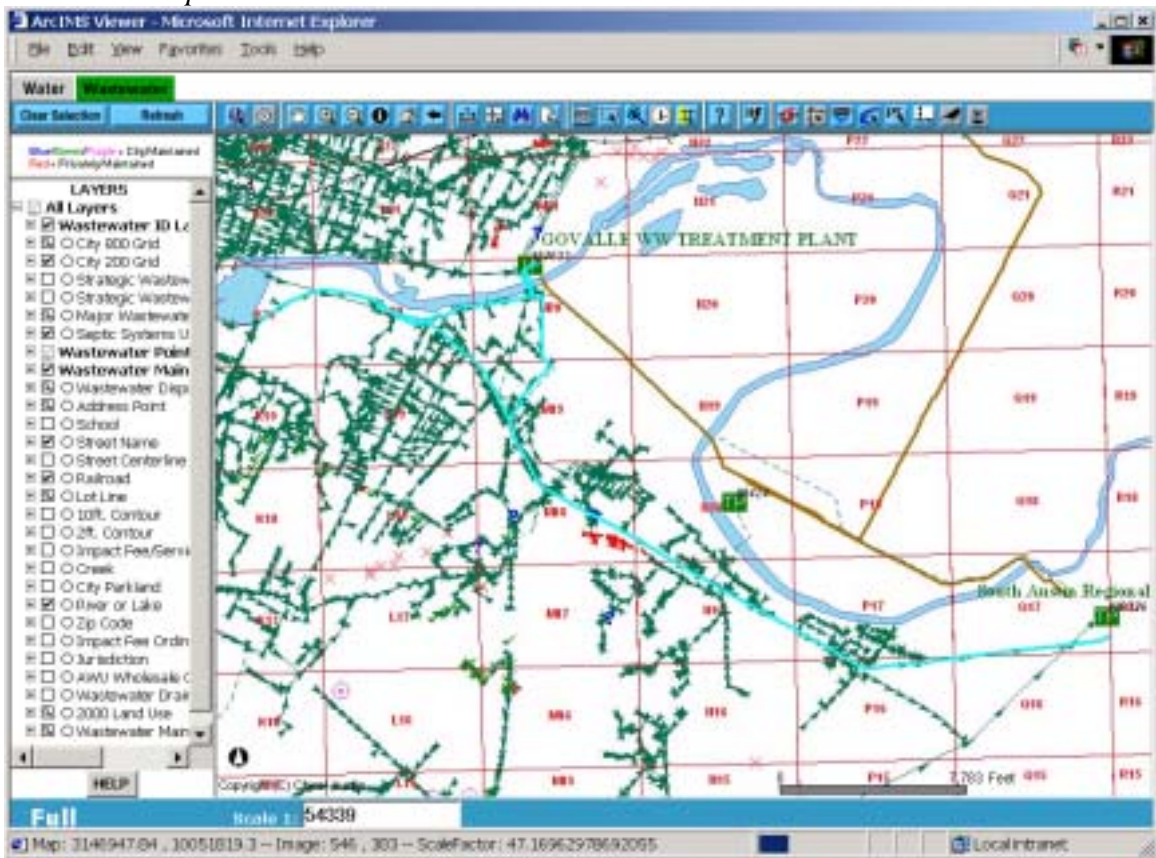


Figure 5: Wastewater Downstream Trace Results

entered using digitized direction to represent flow direction, it was easy to exploit this information for upstream and downstream network tracing. Since ArcIMS does not have tracing functionality, the application server is again utilized to carry out tracing tasks and return the information to the web server. The business process analysis identified users who needed an upstream tracing capability. It also identified a set of users who could benefit from a downstream trace capability. Two uses identified were to trace flow downstream of a point to help in placement of wastewater flow monitoring equipment. Another use identified was to pinpoint downstream flow of industrial waste contaminants that may inadvertently enter into the system. Additional benefits of the tool include help

in identifying wastewater mains with incorrect flow directions (exhibited by an abnormal stop in a downstream trace) and help in detecting weir and overflow manhole locations.

A user clicks on the Wastewater Trace button to invoke the tool. Once activated:

- a. The user chooses to initiate an upstream or down, determines whether the final view should zoom to the selected set of mains (default) or leave the existing view scale and location untouched, and whether to export the results as a shapefile or not. By default, a shapefile is not created.
- b. The user clicks on the wastewater main on the map display
- c. The selected coordinates are captured and relayed to the web server
- d. The web server determines if there is a wastewater main located at the coordinates
- e. If a wastewater main is found, a connection is made between the web server and the application server and the information is relayed to the application server
- f. The application server uses the pipe information to initiate an upstream or downstream wastewater trace, depending on the user selection
- g. Trace results are sent back to the web server for formatting
- h. The web server formats the results as a map display with the traced mains highlighted and selected. Alternatively, the user is prompted to save the shapefile that was created from the selection.

Since this tool has such varied use, examples of how to use the tool are generally done on the fly during training based on suggestions from employees attending the training.

Wastewater Overflow Reporting: Austin Water obviously takes wastewater overflows very seriously. For health and public safety reasons as well as environmental safety reasons, the organization has a formal response pattern when an excursion is reported. Following State of Texas mandated guidelines, Austin Water must report all wastewater overflows. In addition, if an overflow occurs within a set of specifically designated zones representing public drinking water supplies or environmentally sensitive features such as karst zones, or if the flow is of a particular triggering amount, a public notice must be issued within a designated time frame. The task of determining if the excursion was located within one of these designated zones originally was performed by a staff member experienced in planning with a good knowledge of GIS. When this function was transferred to the field support personnel, the task was no longer performed using a desktop GIS. Rather, paper maps representing all of the zones were plotted out and personnel had to determine from these maps if the overflow was in a zone of interest. To simplify this process, a tool was created in the new web application which does much of this work. The tool is clicked on to activate it and the user selects a location on the map where the overflow was reported. The nearest manhole to that point is selected and point-in-polygon routine is processed to determine if the point falls within one or more of the zones in question. Results are returned in a tabular format with an indication of “No” for not within a zone or “Yes” for within a zone. The user is then able to create a standardized map suitable for printing which shows the zone boundaries, the wastewater

manhole which overflowed, street lines and names and a legend/north arrow/etc. This map can be issued along with any public notification.

Wastewater Profile Select/Create: A significant gap in data accessibility within Austin Water has been the lack of a unified source for wastewater profile information. A wastewater profile is an engineering drawing showing the profile, or side view, of a wastewater main in relation to the ground elevation and sea level. Profile information is typically used by work crews to determine the depth of a main when attempting to repair it. Profile information is also useful for determining correct flow of sewage in a gravity-flow system. Austin Water historically documented wastewater profile information on a set of 11"x14" hard-copy maps. These maps were discontinued in the late 1970's in favor of including profile information directly on construction plans. The GIS tracks these old wastewater profile index numbers and newer project numbers and can be used to help research which document to pull to find profile information. However, trouble arises when research is being performed in places where the two different storage systems overlap or when a newer project superseded information stored on the older paper profile.

The business process analysis identified this as a gap which the GIS could potentially fill. For approximately 10 years, Austin Water had been entering the elevation information contained on new projects directly into attributes on the wastewater mains stored in the GIS. When combined with accurate ground elevation information, it was possible to create a program to create wastewater profiles on the fly.

Two tools were necessary to implement this feature: a profile selection tool and a profile generation tool. The profile selection tool, when clicked on, allows the user to select one or more wastewater main segments which are contiguous and non-branching. Once all desired mains have been selected, the profile generation tool is clicked on and a wastewater profile is created on-the-fly.

The tool relies upon work performed by the application server to produce the results.

- a. The selected set of mains is sent by the web server to the application server
- b. The application server checks for a proper selection set
- c. Relevant values for upstream and downstream invert elevations are retrieved from the wastewater mains. Also, manhole IDs, manhole ground elevations, main diameter/material, lengths, etc. are retrieved from the database and from overlay functions. A line representing changing ground elevation is created based on a highly accurate Triangulated Irregular Network (TIN).
- d. Once all of the relevant values have been assembled, they are exported using DDE to Microsoft Excel, where they are combined to form a chart representing the profile.
- e. The chart is imported into ArcMap for final formatting.
- f. The profile is saved to PDF format
- g. The PDF document is sent to the web server, which forwards the document to the client.

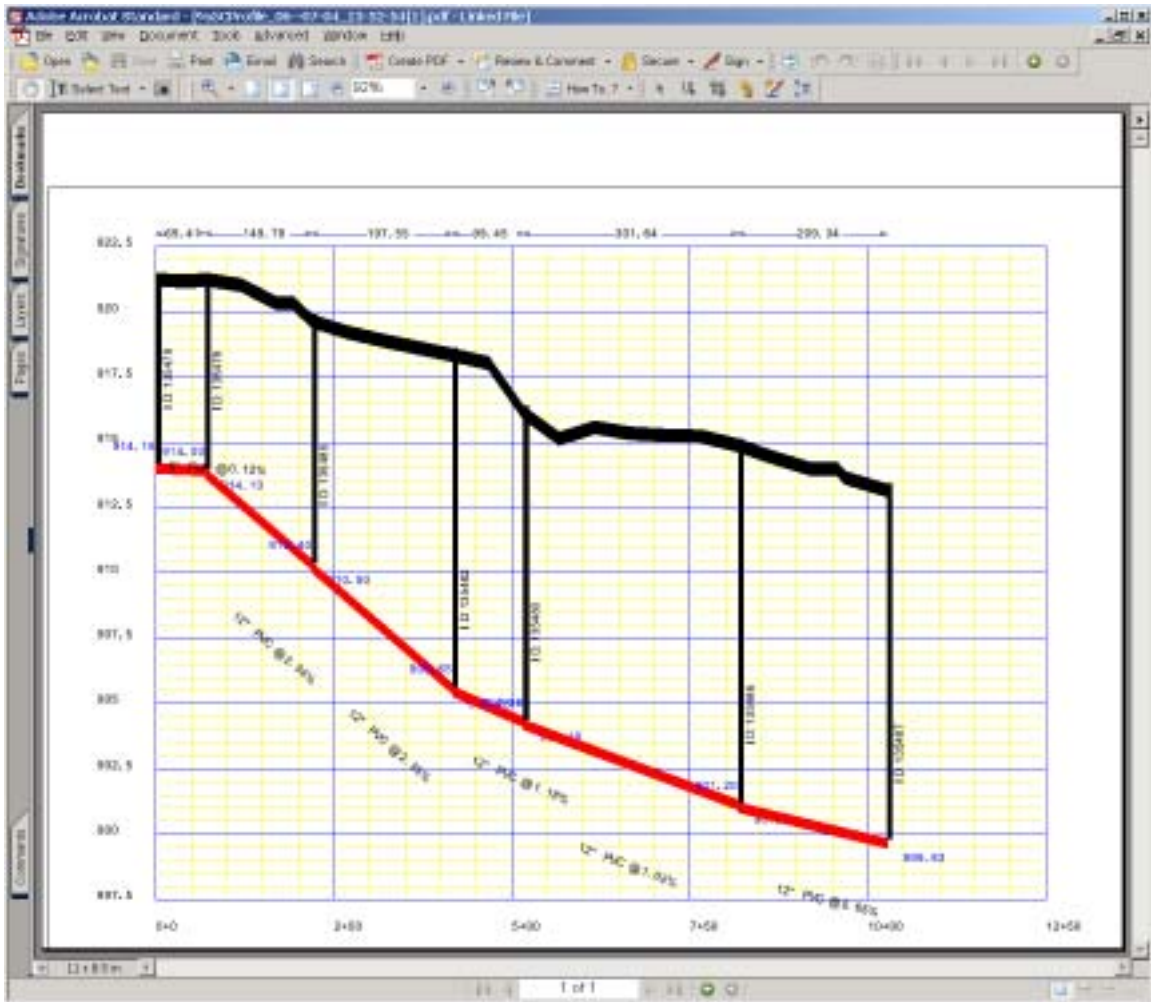


Figure 6: Profile Generate Tool Results

At the start of the upgrade project, only about 13% of wastewater mains contained within the GIS elevation attributes necessary to create a profile on the fly. Austin Water expects to populate this information more fully in the coming years through several efforts. Chief among these efforts are the Sanitary Sewer Evaluation Studies (SSES) that are currently underway and an effort to capture highly accurate elevation information stored within hydraulic modeling databases maintained by Austin Water’s Systems Planning workgroup. The current estimate of attribute completion stands at approximately 20% and rising. As the population of this attribute rises, this tool will become more and more useful. In the interim, the tool simply assigns a zero value to missing attributes so that at least a partial profile can be created if possible.

Hansen Identify Tool: The Hansen Identify tool was based on a feature present in the old web application. Leveraging the commonality of feature identifiers in the GIS and the Hansen MMS, the old web application was able to pull descriptive information from the Hansen database related to a GIS feature when said feature was selected by the user. The report generated was crude however. It lacked much of the information that was displayed in the Hansen desktop client. In particular, service request and work order information associated with features was not displayed. Also, since not all utility GIS features were linked with Hansen records before the upgrade, only selected features were

enabled with this capability. Finally, the popup which displayed the results was slow and rather ugly. To address these shortcomings, three things were done to enhance this tool in the new application.

1. All tabs that are displayed on the feature listing using the Hansen desktop client were replicated as faithfully as possible in web versions. Since the Hansen desktop client displayed its results in a complex tabbed display, .NET programming language was used to recreate these displays for the web client. The most important information contained on the History tab (service request and work order information) was now accessible.
2. All features linked with the Hansen database following the point-to-point upgrade were enabled for the Hansen Identify toolⁱⁱ.
3. The displays were recoded in .NET and streamlined, which made them speedier. Also, producing the displays in .NET allowed a more faithful rendering of the original displays used by the Hansen desktop client.

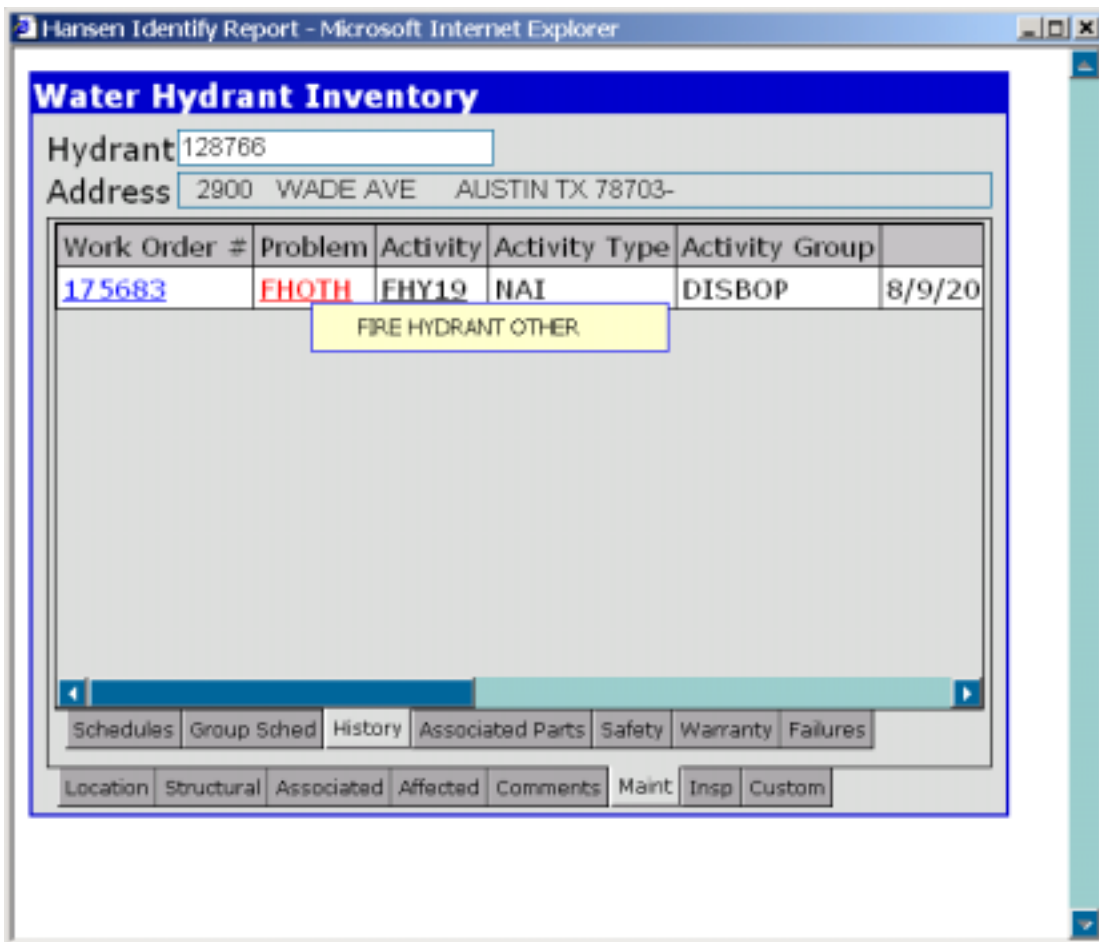


Figure 7: Hansen Identify Tool Results

To use the tool:

- a. A layer of interest must be activated in the web application layer listing. Only Austin Water GIS layers which have been integrated with the Hansen database

are eligible; if a non-Hansen layer is active when the tool is utilized, a default GIS feature layer is assumed and searched.

- b. Once a valid layer has been selected, the user clicks on the desired feature.
- c. The feature's UnitID number is retrieved along with its COMPTYPE value (which are used to link to the tabular data within the Hansen database).
- d. The web server sends the necessary information to a .NET DLL running in application server mode. It retrieves the information, parses the request and invokes the correct subroutine to pull information from the Hansen database and format it as a display screen.
- e. The display screen handle is returned to the web server which passes it to the client which opens the display screen.

Work order numbers are hyperlinked in the Maint tab History. If the work order number is clicked on, it will open a separate window to show work order details. Several of the fields also have pop-up help associated with them. In Figure 5, the Problem code "FHOTH" is converted to the descriptive value "FIRE HYDRANT OTHER". These descriptive popups are used throughout the display.

Hansen Select: Again, building on the point-to-point integration between the GIS and the Hansen system, the Hansen Select tool uses the inherent spatial power of the GIS to apply spatial constraints to queries directed at the Hansen database.

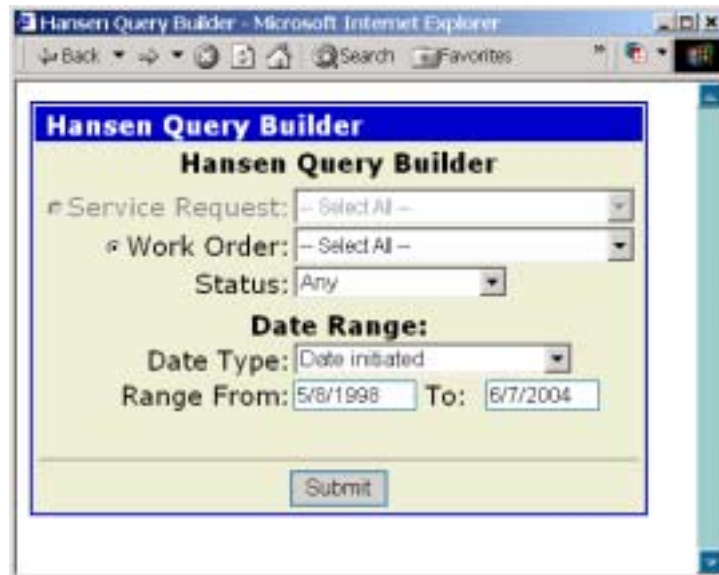


Figure 8: Hansen Select Interface

The Hansen Select tool begins with a selected set of utility GIS features (hydrants, manholes, water mains, etc.). Once invoked, the Hansen Query Builder is instantiated based on that selection set: If no Service Requests or Work Orders are available for the selected features, these dropdowns will be grayed out; Work Order dropdown is limited to the current range of work orders associated with the selected features; etc. The user can choose to return results of any status (default) or may limit the results to Open or

Closed. Various date range types can be specified as well along with a From and To date.

When the query is submitted, the web server collects the information requested and forwards it to the .NET DLL. The .NET application service queries the Hansen database using the supplied criteria, formats the results and forwards a handle to the results to the web server which supplies the handle to the client. Figure 7 shows the results of a Hansen Select query based on a selected group of two fire hydrants. The query criteria are reported with each result listing to document what query criteria produced the results. If a Service Request listing is selected in the query criteria, service requests are listed in the results along with any associated work orders attached to them. Work order numbers are also hyperlinked to allow detailed drill-down for work order details.

The report also has buttons to print the report, display a map of the features represented in the report and to download the data from the report. Pressing the Download Data button causes a separate ArcIMS extract server to extract and convert to shapefile the features represented in the report. These features are then zipped together with a database file containing the results of the Hansen report and sent to the user. A message is displayed which informs the user of the number of GIS records extracted since this can differ from the number of records in the report.

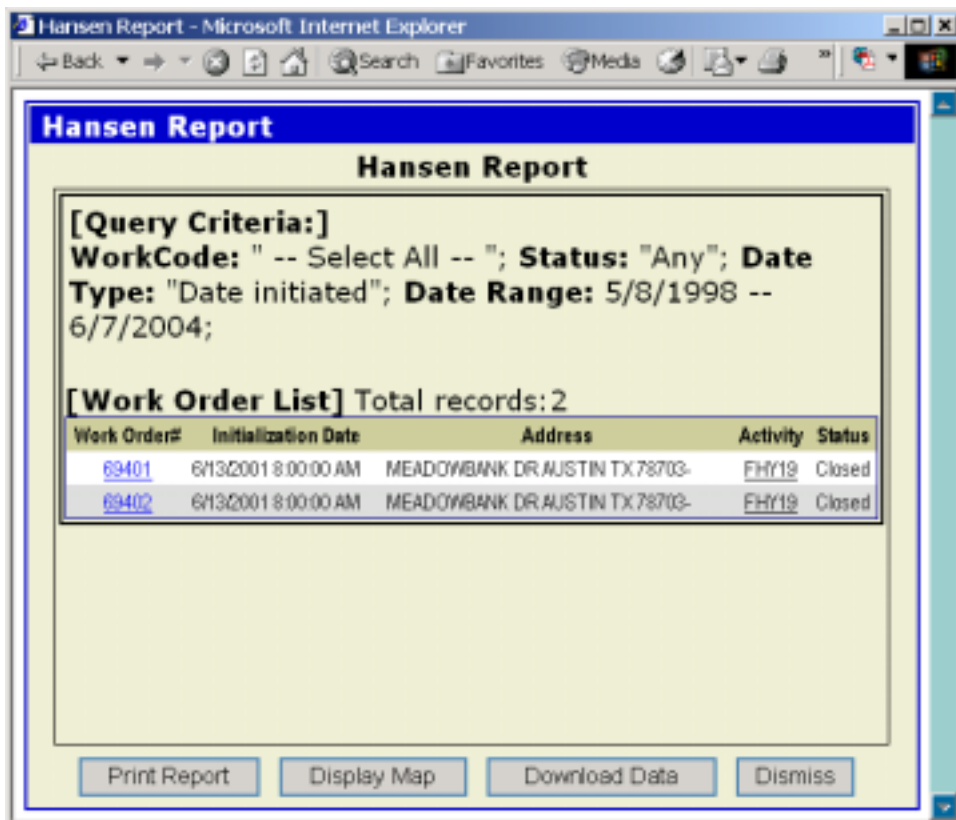


Figure 9: Hansen Select Tool Results

Hansen Query: While the Hansen Select tool relies upon an initial selection set of GIS features before a query can be performed, the Hansen Query tool has no such restriction.

It may be invoked at any time during a web application session. When invoked, the user has a wide range of criteria with which to narrow a search.

Figure 10: Hansen Query Tool Interface

- Asset Type: Type of feature in the Hansen data set. Common types include Water Valve, Wastewater Manhole, Water Hydrant, etc.
- Service Request: List of valid service request types from which to search (mutually exclusive with Work Order dropdown)
- Work Order: List of valid work order types from which to search (mutually exclusive with Service Request dropdown)
- Status: Choose to search for any records (default), Open or Closed records
- Date Type: Select a date type (Initiation Date/Problem Date, Inspection Date, Resolution Date, Scheduled Start Date, Start Date)
- Range From/Range To: Date range to search for records. Defaults to one month previous to the current date
- Geographic Area: Choose from a report that searches the entire City, a Mapscos page book grid number or a City grid letter/number combination

When submitted, the query is processed by the web server to collect the information requested, which is forwarded to the .NET DLL. The .NET application service queries the Hansen database using the supplied criteria, formats the results and forwards a handle to the results to the web server. The web server reports the handle to the client. Figure 9 shows an example of the results returned by the Hansen Query tool.

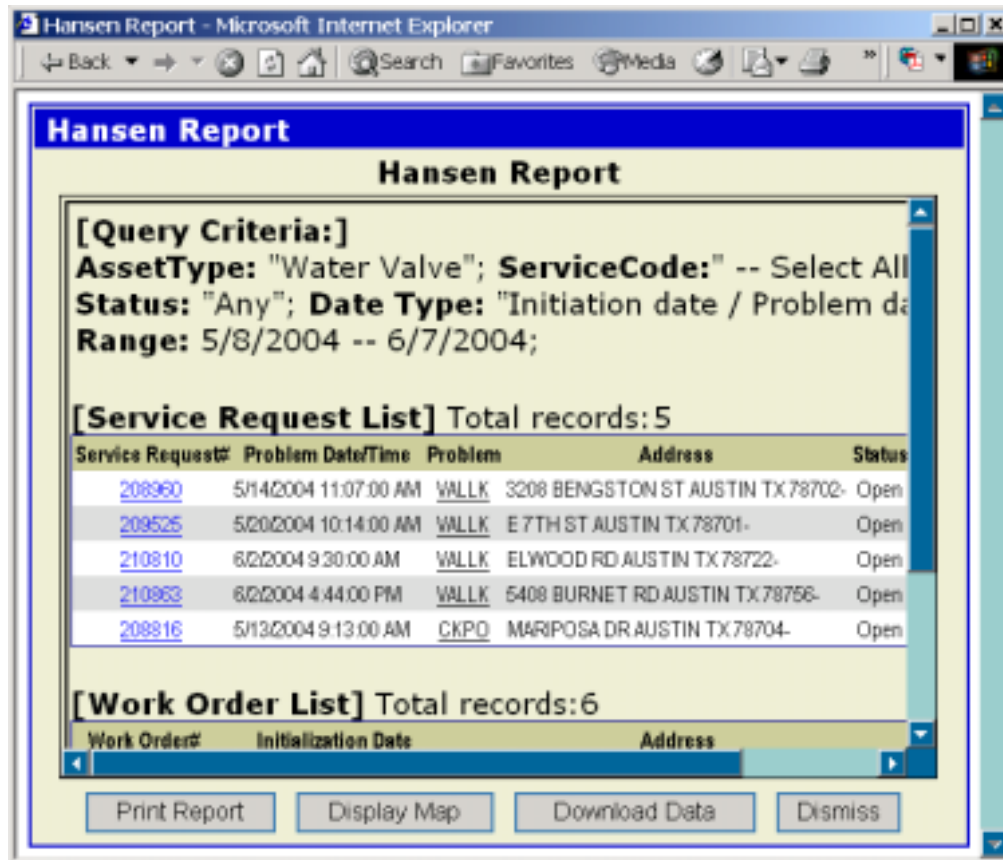


Figure 11: Hansen Query Tool Results

The results of the Hansen Query and Hansen Select tools are virtually the same. This is because the same .NET code is reused to process both requests to the Hansen database once a selection set has been created. In Figure 9, five service requests meeting the criteria were found. In addition, six work orders were found which are tied to the five service requests.

Both the Hansen Select and Hansen Query tools were designed with restricted access. The tools are extremely resource intensive on the web server, application server and Hansen database server. Careful query creation needs to be employed to narrow query criteria and return results within a decent period of time and to keep from over utilizing the servers CPU capacity.

Pressure Calculator: Although not technically a tool that was created for the initial rollout of the web application, the pressure calculator has quickly become one of the most used advanced tools provided. The tool was added by Austin Water six months after the initial rollout of the application. Utilizing water pressure zone hydraulic grade line (HGL) values and elevations derived from the TIN, this tool calculates Low, Typical and High

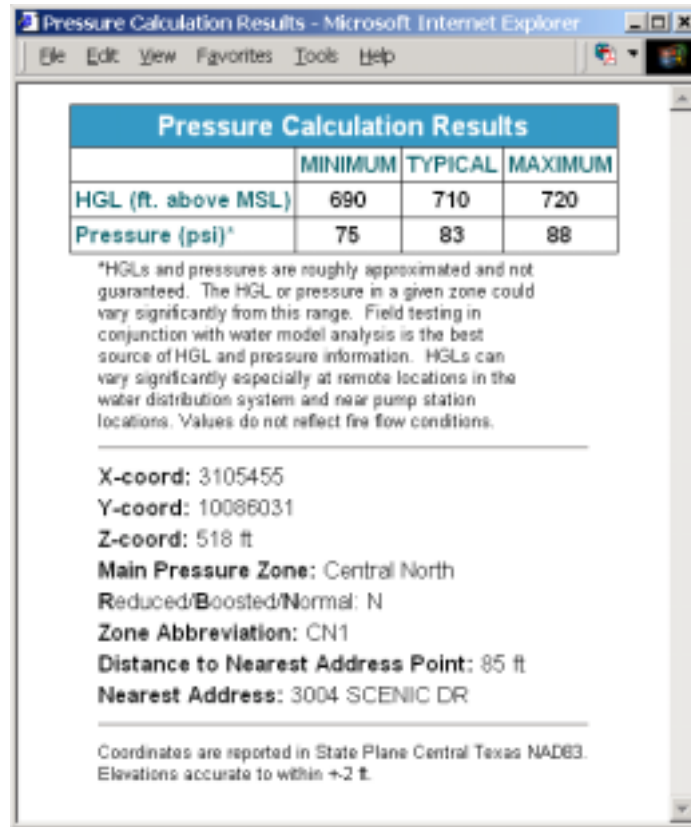


Figure 12: Auto Pressure Calculator Tool Results

HGL and water pressure values for a point selected by the user. In addition, attribute values describing the point entered are reported including X, Y and Z-coordinates; the pressure zone that the point is in; whether the pressure zone is reduced, boosted or normal; the pressure zone abbreviation; and the nearest address to the point entered along with the distance to that address point. Since the HGL values used in the calculation are approximated, the results can vary depending on the time of day and field conditions, hence, the results contain a disclaimer.

Environmentally Sensitive Area (E.S.A) Tool: Another tool that was added post-rollout, the E.S.A. tool is used to query a parcel to determine if any portion of it falls within a defined boundary representing the environmentally sensitive area in northwest Travis county. This tool has been provided to show due diligence of informing developers of possible endangered species requirements which need to be met when developing the parcel. The tool is used by Austin Water staff responsible for approving service extension requests. The same tool is being developed for use within the City of Austin's web GIS viewing application as well.

Usage

Austin Water's "HotLinks! GIS Access Site" has been in operation since 1998. The web site fulfills a dual purpose: it acts as a document resource center where employees can search for and retrieve utility location information and it hosts the web application. As a document resource center, the site provides electronic versions of water, wastewater and reuse standard maps, water valve location detail (intersection) images, wastewater profile images, as-built images and various other image sets. The site also provides various indexing and searching tools for locating the desired document. The original web application focused largely on becoming a geographic indexing tool for these document sources. The sites moniker "HotLinks!" originally referred to the web application's ability to link features with the appropriate documents associated with them. For example, the hyperlink tool could be used to click on a valve to bring up the associated valve location detail image. As the complexity of the GIS has progressed from GIS to business information system, the web site offers more sophisticated tools. While the site still offers the same documents and document retrieval tools, the web application has moved from a dynamic map viewing tool to a spatial document retrieval tool to a business information tool.

As use of the tool has grown within the organization, how the organization perceives its value has changed as well. When the tool was introduced, it was viewed as somewhat of an oddity – an experiment by the GIS team members who always seemed to be doing something different. As the tool gained ground within the organization, it was seen as a useful application which could supplement the other applications which were available. Today it has almost reached "appliance" stage: people are so used to using it (and in many cases dependant upon using it) that it is taken for granted and not missed until it is unavailable. This "always on" view has been spurred by the ability of the Hansen desktop client to display the web application as its own application background.

Application Environment: With dependence has come responsibility. When the site was first implemented, it was not unusual to take the site down for minutes or hours at a time to fix problems. There was a single server running the site and all data and images were loaded onto that server. The server was not actually a server at all, rather it was a high-powered PC located in the office of the main site developer. Today, the production site resides on a dual CPU Dell PowerEdge 4400 server. The server has a dual RAID 5 configuration with approximately 300GB of storage available and backed by a UPS. Supporting the site is a Dell PowerEdge server acting as the application server. Image data is stored on the web server however ArcIMS accesses a separate SDE server for its spatial data. All production servers are housed in the Austin Water computer center with controlled climate and fire suppression. Development now occurs on a set of independent development servers; testing of application changes and web site changes occurs on another independent set of test servers. And uptime has become crucial. While the system has not reached "critical" status yet, it has been designated as a "highly available" system. (As a comparison, Austin Water's email system has been designated as a "highly available" system as well.) The web application has now been embedded in dozens of business processes throughout the organization as well as the City of Austin in general. Major users, outside of Austin Water, include Street and Bridge, Austin Fire Department, Public Works, Austin Energy and Stormwater Protection.

Web Site Usage Patterns: One thing that separates the web application from most other organizational applications is that its use has never been mandated. While the organization chooses to use a particular email client or a certain maintenance management system, the GIS web site has had to establish itself as a compelling destination – people only use the site because they want to. Its competition has been the existing hard-copy maps that are still available, desktop GIS, other web GIS viewers within the City, etc.. Therefore, the success of the site has been gauged by increase in usage. If a compelling site has been produced, it will get used. The more compelling the site becomes, the higher usage will climb.

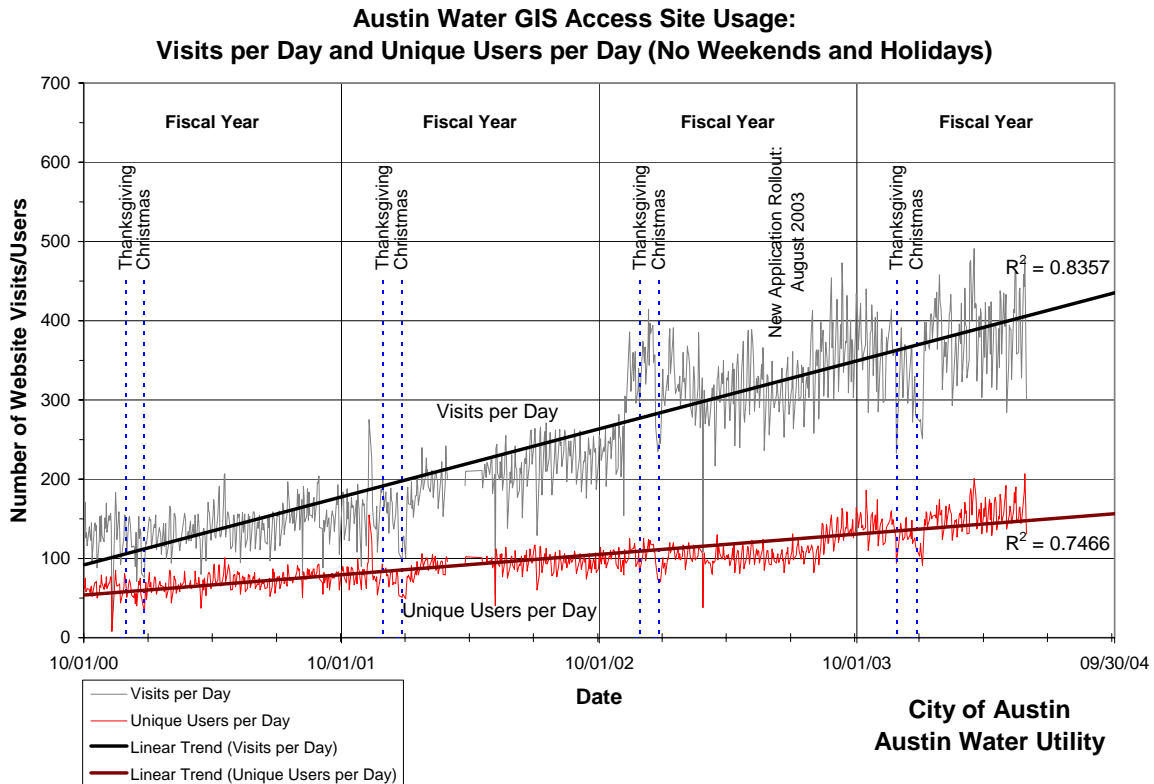


Figure 13: Austin Water GIS Access Site Usage Chart

Two measures of usage have been tracked since shortly after the introduction of the web site: visits per day and unique users per day. Visits per Day represents how many times individuals fire up a web browser and engage the web site in a session. A visit encompasses all transactions that an individual completes during the session. Unique Users per Day tracks the first appearance of a unique user connection on a daily basis. (Uniqueness is based on machine IP address not on user name.) Figure 11 charts Unique Users per Day and Visits per Day.

Unique Users per Day has risen from approximately 60 per day to approximately 150 per day. The growth is fairly linear overall. Most of the rise has been attributed in greater interest in the web application; more users appear to be using it every day. Unique Users per Day grew at a moderate pace from October 2000 to October 2002 at which time it flattened out at around 100. When the new web application was launched, it jumped significantly (approximately 40%) and resumed a moderate growth.

Visits per Day continues to grow steadily as well. The growth in this trend has been more linear as evidenced by the fairly good fit of a linear trend line to the growth pattern. An increasing value for Visits per Day also signals rising usage for the web site. However, when comparing Visits per Day to Unique Users per Day, Visits per Day is rising at a faster rate than Unique Users per Day. This indicates that not only are more unique users making visits to the site, but also they making more return visits each day. In other words, in October 2000, 50 unique users made up approximately 90 web site visits, a 90/50 ratio or 1.8 visits per unique user). By June 2004, this ratio had climbed to a 400/150 or 2.7 visits per unique user. This ratio is expected to rise to 440/160 (2.75 visits per unique user) by October 2004.

Three factors play a role in the increasing use of the web application:

1. Austin Water employees increasing familiarization with technology
2. New capabilities offered by the web application
3. Increased training opportunities

In 1998, half of the facilities where Austin Water employees were located had little to no network connectivity. When the existing VAX-based email system was retired in favor of Microsoft Exchange, it was crucial that all sites were connected to the City network. This not only allowed the use of the new email system, it also allowed access to other network-centric applications, including the GIS web site. As employees have become more familiar with personal computers, the World-wide Web and other technologies, their abilities have become more sophisticated. Now, it is assumed that all new information technology projects will have a web-accessible component; it is no longer considered a novel approach but rather a standard approach to doing business. Finally, the organization has stretched itself significantly in the last decade in an attempt to fulfill the business mantra of “do more with less”. Most frequently, this means automation of manual processes to increase productivity with no increase in work. It is just plain easier to bring up a visual display of utility infrastructure, click a tool on a facility and retrieve construction plans, maintenance history, shutout information, flow information, etc. rather than visit several different sources of information which may or may not reside in the same building.

Influence of Training on Usage: This increasing reliance upon automation to increase worker productivity is reflected in the increased capabilities offered by the web application (and all applications). These applications really do more work with less effort which leads to an increase in productivity. Tasks such as shutout planning, which used to take minutes or longer to complete (once all of the relevant documents were tracked down and assembled!), now takes seconds using the Water Shutout web tool. Building a list of addresses for customers that are expected to be out of water is as simple as buffering the results of the previous query rather than an exhaustive search in the customer billing database for all addresses on certain streets with certain address ranges; or sending workers out in the field to hang tags on all doors in the neighborhood; or not informing customers at all.

However, placing a computer on an employee’s desk and running a new web application on it will usually only benefit the very curious and the self-starters who like a challenge.

To sure that staff are capable of using the tools that are given to them, adequate training needs to be offered. Since June 2000, 22 training opportunities have been offered. Over 350 employees from Austin Water and the City of Austin have attended. These training opportunities explained each and every tool available at the web site and in the web application (both old version and new). Twice as many training opportunities have been offered for the new web application versus the old one.

Tool Usage: Statistics on tool usage in the application shows a healthy mix of standard tools and advanced tools usage. As expected, map viewing utility tools such as zooming and panning and refresh are used the most since these tools are used to move around within the application. The use of tools which were available in the old application, such as Print and Identify, has dropped. This probably does not mean that users need to print less or identification of features is less important; it is likely that users are utilizing these tools to the same degree in the new application as they did in the old application. Rather, the decreased percentage of use is a reflection of the availability of a larger tool set. They may still be using tool X a certain number of times per month but they are also doing other things with the application that they could not do before. Therefore, the total use of tool X goes down relative to the total tool usage even though use of that tool may have stayed the same (or increased).

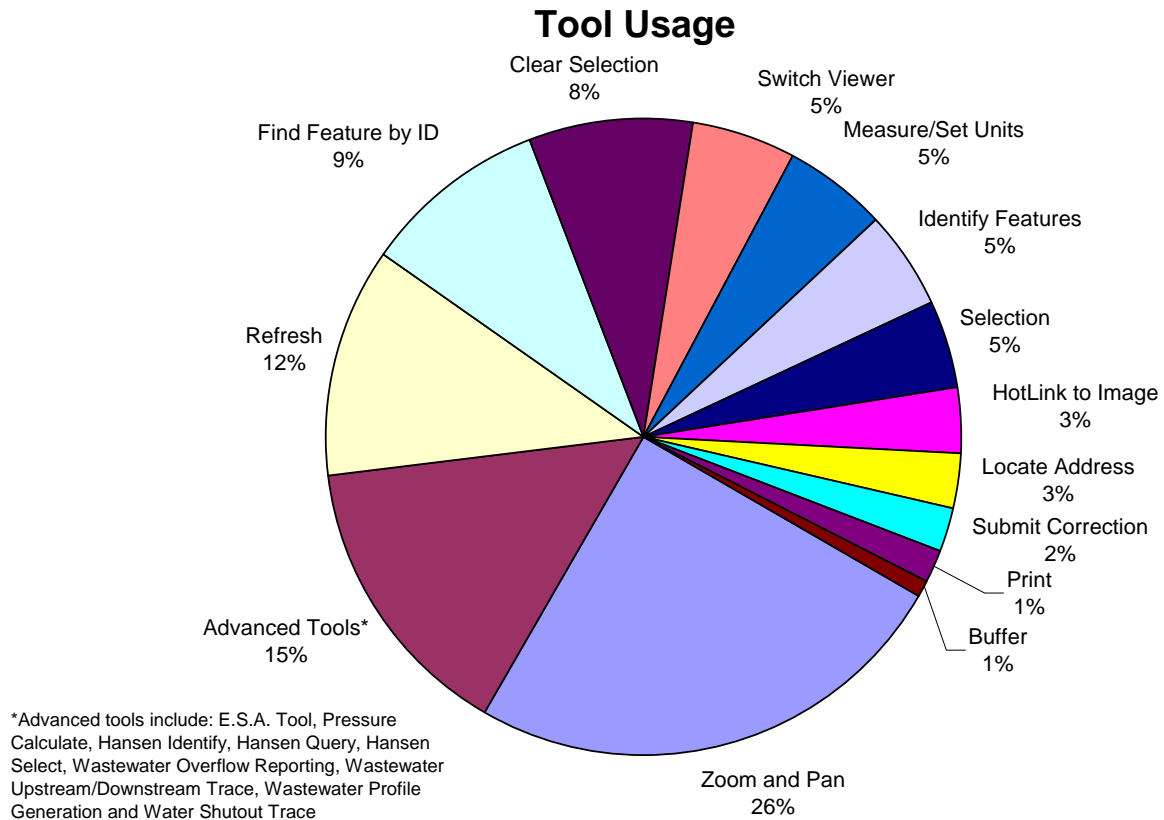


Figure 14: Web Application Tool Usage Chart

When viewed individually, most of non-utility tools (zooming, panning, etc.) are used in roughly the same amount – from 1% - 5%. This includes the advanced tools when broken down individually. The Find Feature by ID tool clearly shows a higher use than

the other tools. This is most likely a reflection of the GIS/Hansen MMS interaction. Since the GIS and Hansen systems share feature identifiers and the Hansen system has limited visual representation of features, the GIS is used as a means for staff to easily locate features which have had work orders issued against them in Hansen. The alternative method is to pull a standard grid map and search for the feature on the map. While this tool is one of the simplest to implement from a programming perspective, it exploits the most complex aspect of the upgrade project, the point-to-point integration of the GIS and Hansen MMS.

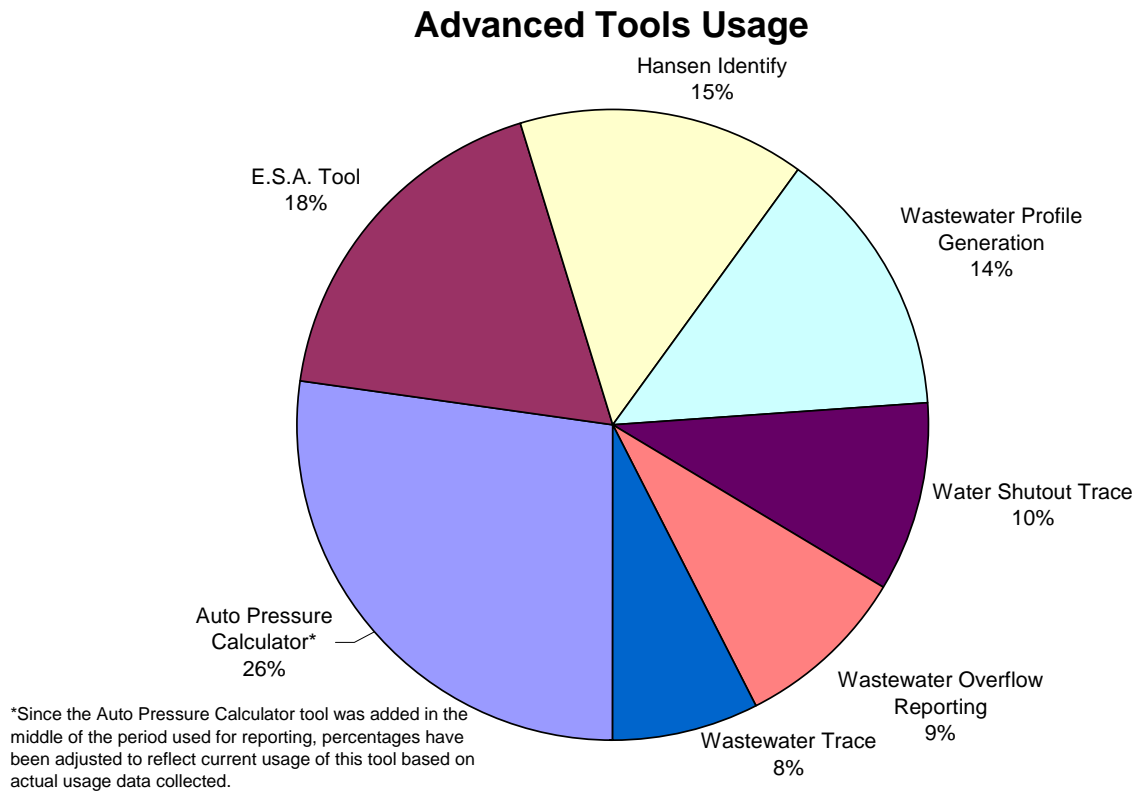


Figure 15: Web Application Advanced Tools Usage Chart

The advanced tools as a group account for 15% of all tool usage. Figure 13 shows a breakdown of the advanced tools according to how much each tool accounts for total advanced tool use. The Auto Pressure Calculator tool was added by Austin Water staff approximately six months after initial rollout of the web application. To provide an apples to apples comparison of its use to the other tools, usage data was extrapolated for the first six months based on actual data obtained during the five months of actual use following its introduction. It was important to include information about this tool since its popularity has far surpassed the other advanced tools. The E.S.A. tool was released shortly after the initial rollout. Its usage has not been adjusted since it was released at roughly the same time. Combined, the two new tools account for 44% of advanced tool use. While the popularity of the E.S.A. tool is most likely due to the fact that it has been embedded within the service extension request review process (a required step), the popularity of the Auto Pressure Calculator tool is most likely due to the fact that it is very

easy to use and is extremely handy. Advanced tools such as the Water Shutout Trace or Wastewater Trace may have a more limited audience than the Auto Pressure Calculator tool and therefore they experience less use. It is not assumed that they are any less valuable however.

Conclusion

While a web application is certainly not the answer to all questions, it can be a very good way of getting better use out of existing databases. As always, planning is the key to good application development. A few key points to make:

- Development of a database is almost never a destination; rather, it is an ongoing process. Continual development of a database to add value is often more cost effective than to develop a completely separate database with overlapping functionality.
- As such, a database should be recognized as not just a repository of data but as a mutable business process which constantly needs to be reassessed to determine if it still meets an organization's needs. Business process analysis is the most effective way of determining organizational needs, current processes and the gaps that may exist between them.
- A web application may seem like the "cherry on the sundae" at first glance. Keep in mind that no matter how good a database is, it is useless if users cannot get information out of it easily. A web application is an excellent method of providing access to the knowledge locked inside the database.
- When developing an application, it is crucial that good lines of communication exist between the customer and the supplier. Be sure that both parties are on the same page no matter how detailed and long the conversations must be to assure mutual understanding. One hour spent in discussion can save hours of rework later.
- Planning for web application development is equal (if not greater) in importance to coding. While mediocre code can be tinkered with to make it run better, if your programmers and analysts are unaware of the organizations needs or don't effectively communicate these needs to the consultant developer, code may need to be rewritten entirely and scope changes become unavoidable.
- If a web application is being upgraded, try to leverage the existing training investment within the organization by only changing the way existing tools are used in the new application when absolutely necessary. Placing existing tool buttons in familiar places, providing similar input screens and similar processes allows users a smoother transition to the new application and allows training to concentrate on new functionality.
- Training is one of the keys to a successful application. Application functionality may be obvious to the developer and to staff members who created the application specification; it may not be as obvious to employees using the application for the first time.

- It is important to keep track of how the application is being used after it has been rolled out. This can include analyzing web logs, user surveys, training feedback and follow-up meetings with key user groups. Feedback on the application can identify ways to improve the current tools and offer opportunities for expansion with new modules to fulfill new business needs.

By keeping these thoughts in mind, an ArcIMS web application can be implemented quite effectively and help to improve efficiency and productivity at a Utility.

Acknowledgements:

Environmental Systems Research Institute, Inc. (ESRI)

Marshall and Associates, Inc.

Jim McKibben

Austin Water GIS Upgrade Team members: Leeanne Pacatte, Steve Hutton, Paul McKnight, Donn Lorbiecki

Author Information:

Philip Campman

Business Systems Analyst

City of Austin, Austin Water Utility

P.O. Box 1088

Austin, TX 78767-8859

Ph.: (512) 972-0167

Fx.: (512) 972-0168

Philip.Campman@Ci.Austin.TX.US

ⁱ A Microsoft PowerPoint presentation used for internal training which contains detailed descriptions of all tools and functionality is available upon request.

ⁱⁱ Marshall and Associates, Inc. created Hansen Identify reports only for the features which were originally linked in the old version of the application. Austin Water completed the linking of new features added during the upgrade and point-to-point integration project.