Geospatial Web Application Development to Access Irrigation Asset Data: Veterans Affairs Palo Alto Health Care System

by

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DEDICATION

To my mom, Carolyn Ann Eriksson, for everything. Gone too soon but forever in our hearts.

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I would like to thank my family for their continued support throughout my graduate coursework and thesis writing. Knowing the time you have allowed me to pursue my dream of finishing my master's degree resulted in time not spent with you all. I hope for my three boys that you can now see that going to school when you are passionate about something is worth all the hard work.

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List of Abbreviations

AGOL	ArcGIS Online
CAD	Computer-Aided Design
DOT	Department of Transportation
GIS	Geographic information system
GISci	Geographic information science
GISP	Geographic Information System Professional
GPS	Global Positioning System
LMD	Livermore Division
MPD	Menlo Park Division
PAHCS	Palo Alto Health Care System
PAD	Palo Alto Division
PC	Personal computer
PDA	Personal digital assistant
SDSFIE	Spatial Data Standards for Facilities, Infrastructure, and Environment
SSI	Spatial Sciences Institute
VA	Veterans Affairs
USC	University of Southern California
WYSIWYG	What you see is what you get

Abstract

Asset management systems can save organizations time and money by enabling staff access to well-organized and easily retrievable information. Visualizing the physical and contextual locations of these assets in a geospatial application increases the understanding and efficiency of staff. Often times, Geographic Information Specialist (GIS) analysts create and maintain asset information using specialized software programs, however these software platforms are often not user-friendly to non-GIS practitioners. Consequently, comprehension and adoption of GIS technologies requires special training and hands-on experience. The benefits of managing this information in GIS may not be realized if others cannot access the data. This thesis presents two easy-to-use GIS web applications developed for non-GIS staff at the VA Palo Alto campus to visualize and better understand the geospatial context and data of their 93-acre campus facility. The applications focus on irrigation infrastructure and include: irrigation controllers, back flow valves, gate valves, and all of their respective areas. Users can quickly locate shut off locations of irrigation pipelines when an immediate need arises such as a line break or a required maintenance activity. The applications developed for this thesis provide a template for managing other utility assets through web applications for the VA Palo Alto campus.

Chapter 1 Introduction

As technology has developed and become more accessible, software applications must have a spatial component tied to infrastructure to effectively manage assets (Halfawy, Vanier and Froese 2006; Stenstrom and Parida 2014). There are many firms, water districts, and government agencies, creating custom GIS web applications in the utility market such as IBM Maximo and Cityworks. A subgroup of this market addresses managing irrigation infrastructure, including pipelines, irrigation controllers, back flow location, gate valves, sprinklers, drip systems, as well as other mechanisms that may make up an irrigation system. Differing from custom-developed solutions, this thesis presents two web applications built using Esri's Web AppBuilder templates and widgets freely available to users. The applications allow non-technical users to view and query geospatial irrigation infrastructure with either a computer or mobile unit.

1.1 Asset Management and GIS

Managing assets and enabling easy-access of the data to staff is crucial for organizations to proactively plan and effectively administer the services they support. Aging infrastructure is causing huge costs within water and wastewater systems (Baird 2010, Booth and Rogers 2011). The breakdown of old pipes and irrigation systems can require entire systems to be shut down. Without a system in place to track the health of infrastructure, management has no way to determine which pipes require maintenance, or to identify a shut off location if a water line breaks. The US Environmental Protection Agency reported that by 2020 the capital required to fix or replace infrastructure may exceed 50% of capital infrastructure budgets for local communities (Booth and Rogers 2011). The American Water Works Association (AWWA) further supports this claim, stating that maintenance costs will total more than $1 trillion by 2035 (Mader 2012).

Asset management is defined as knowing what assets an organization has, precisely where they are located, the condition of the assets, how they should be operated, the development of a maintenance program, and performing all related activities in order to minimize costs (Davis 2007). Due to its spatial and information system capabilities, GIS technology becomes an obvious choice to assist in the management and tracking of irrigation infrastructure (Baird 2011, Schultz 2012).

In the past, asset management occurred with stacks of hard-copy construction drawings, and old financial information records. GIS provides the foundation for incorporating geospatial asset location information tied to robust databases which work with all aspects of asset management (Johnson and Goldman 1990). Not only does GIS provide attributes about the specific asset such as model, manufacturer and serial number, but can also be linked to construction drawings, maintenance records, or customer information.

1.2 GIS Implementation at the Palo Alto Health Care System

The U.S. Department of Veterans Affairs (VA), Geospatial Business Intelligence Service Line, adopted the Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE) for the development of Esri-GIS databases used for facility management in 2015. This standard was developed by the CADD/GIS Technology Center and has been adopted by many US federal agencies (Halfaway 2006). This is significant because it shows the commitment to GIS used for facility and infrastructure management. The VA's Palo Alto Division (PAD) campus of the Palo Alto Health Care System (PAHCS) completed a GIS base map for its 93-acre campus in early 2015, which includes general land cover types such as buildings, paved, or landscaped areas. Figure 1 on the following page shows the PAD campus, located in Palo Alto, California, containing approximately 93 acres of land. Originally established in 1960 with 15

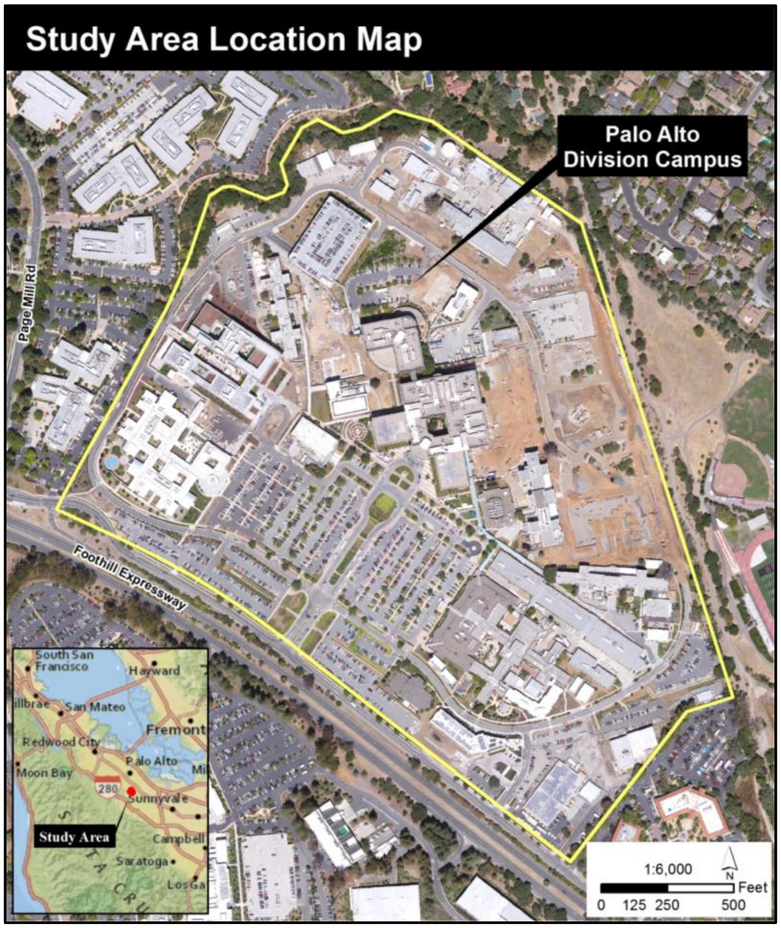


Figure 1 Study Area location. *Source*: Megan Gosch 2015

original buildings, PAD was the third major campus in the system. The main hospital was demolished after the Loma Prieta earthquake in 1989. In 2010, the PAHCS launched a $1.5 billion capital infrastructure investment program, spurring the major construction occurring at PAD ever since (Veterans Affairs 2010). Now employing approximately 4,000 employees, and providing care to over 500,000 patients, this immense amount of construction will help address the growing veteran population requiring health care. The campus needs an accurate asset management system due to the immense physical changes occurring from this construction.

The facility planning department at PAD has never previously used GIS. The campus is separated into two distinct sections: health care and facility planning. The two sections have very different responsibilities, goals and objectives. The health care section uses GIS, mostly in the form of paid consulting through Esri. Their work focuses on health care analytics regarding patients, location of facilities, and disease outbreaks. The facility planning department contracted for the creation of a campus GIS base map in February 2014, providing the foundation of this project. Being PAD's first foray into GIS, it was very important to illustrate to staff the benefits of GIS and how it could improve their workflow and tasks in a cost effective manner.

1.3 Project Overview

After completing the GIS campus base map, the benefits of including other facility information into the GIS database became apparent. Working closely with the site's landscape architect, we incorporated irrigation infrastructure into the GIS database. A landscape maintenance company is currently contracted to provide services to the campus. Their employees do not have direct access to the VA servers containing the digital CAD design or as-built irrigation drawings. Creating a system allowing users to view and identify irrigation shut off locations supports prompt action when leaks or breaks occur. Additionally, staff also benefit from the ability to monitor and locate irrigation controllers during the phases of heavy construction. This allows employees to determine which controllers require relocation or to discontinue their weather service subscriptions.

There are two objectives to this project. First, enabling non-technical employees' access to irrigation infrastructure in two easy-to-use GIS applications created with Esri products. And second, to demonstrate to the VA the benefits of utilizing GIS technology as part of their overall asset management system by increasing staff productivity and response times. The first application locates irrigation controllers and information about their respective areas. The second application focuses on shut off information including gate valve and back flow locations. The potential users include maintenance staff, landscape architects, mechanical engineers, and facility planners at PAD. As part of a larger asset management system, these applications can be expanded to include domestic water, electrical, gas, and steam pipelines information.

1.4 Application Technology

The two web applications were created within Esri's ArcGIS Online (AGOL) and Web AppBuilder for Developers environment. Esri provides a suite of products for creating GIS data, sharing the information as web services, and constructing web applications. Developing this application with the Esri product suite allows for the long-term use of this application, as the VA has committed to using Esri software for all GIS development. Accessing the VA's internal Esri GeoPortal server removes any costs associated with hosting this application. It also allows for the easy update of the irrigation infrastructure information.

1.5 Application Goals

Table 1 presents the goals of this project and how they were achieved.

Table 1 Application Goals

Application Requirement	**Achievement Parameters**
Provide an alternative to locating hard-copy paper or digital CAD maps to identify irrigation infrastructure assets	Build a web GIS application to manage and geographically locate irrigation infrastructure assets
Develop applications that are usable by staff with limited technology skills	Develop user-friendly applications which provide limited functionality focused on their primary tasks
Ensure that the applications meet the previous goal of being user-friendly and useful	Present the application to a small user group for testing and user feedback
Develop applications that can be transferred within the existing VA GIS technology environment	Create the GIS database and application with Esri technology including ArcMap, AGOL and Web AppBuilder for Developers
Illustrate the benefits of GIS technology to VA management and staff thereby increasing use of GIS for future projects	Capture user feedback with a user survey which identifies potential future GIS uses

1.6 Thesis Organization

This thesis is divided into 6 chapters. The project background is described in Chapter 2, and summarizes how GIS is used in asset management and irrigation infrastructure. Chapter 2 then compares and contrasts the irrigation infrastructure applications with other asset management applications illustrating the benefits of this project. Chapter 3 presents the application development process for the VA case study. Chapter 4 reviews the results of the user surveys and feedback from the testers of these applications. Chapter 5 discusses the technology transfer strategy. The applications are currently hosted on USC's SSCI AGOL environment, and will be transferred over to the VA’s Geoportal upon completion. Chapter 6 closes with the successes and failures of this project as well as how it may be further studied.

Chapter 2 Background

This literature review identifies the use of GIS and asset management in a variety of different formats: commercially-developed software, GIS ArcMap extensions, custom web-based solutions, and Esri-developed applications. Several commercial GIS applications provide access to GIS data in an approachable format, providing tools and information within web browsers. Similar to this project, these applications allow non-technical users the ability to visualize and query geospatial information previously inaccessible without a GIS analyst. Development of a number of the applications discussed here occurred within larger consulting firms with skilled application developers using proprietary software. These applications are different from this project in that they are custom software solutions and include more complex and comprehensive functionality.

Esri's AGOL is a platform for users to manage, create, store, and access, hosted GIS services and applications. This project developed its initial map services using AGOL. This chapter discusses several other applications that also used AGOL, and the end-results are visually similar to an ArcGIS Desktop environment. A more recent product developed by Esri is Web AppBuilder. Providing sophisticated templates and widgets to users, this technology creates applications that are more visually pleasing than previous versions. I developed the applications for this project using this Web AppBuilder. Including custom widgets allows the VA users quick access to the GIS data, and limited functionality keeps the application focused on each primary objective.

This chapter reviews GIS and asset management, GIS and irrigation infrastructure, web-based GIS applications, and applications created using Esri AGOL or Web AppBuilder. This project incorporates aspects of each of the reviewed topics, and summarizes their similarities or differences.

2.1 GIS and Asset Management

Historically, GIS has been used to collect, store, and document utility and infrastructure information. GIS use for asset and utility management grew as hardware and software became more affordable and user friendly (Hanson 2008). Custom-developed products and comprehensive solutions are available for users to manage their assets in a variety of applications.

Many well-known consulting firms create custom asset management software. However, they offer much more complex functionality than this project, and can include computerized maintenance management systems, and inspection and monitoring components (Cityworks 2015). Cityworks integrates their application with Esri ArcGIS, as well as open source software. Aqualogy, now known as Suez Environment, offers a suite of GIS-based asset mapping products called acqaCIS™. These tools cover a wide range of business processes from billing, customer service, work orders, asset management, and smart metering (Aqualogy 2015). The products are out-of-the box software packages and do not focus on one primary use, which differs from this thesis project.

Other firms provide enterprise asset management software that fully integrates with Esri ArcGIS. These custom software solutions manage assets, facilities, equipment, and personnel. Cartegraph markets software as easy to use, and claims that no technical savvy is required (Cartegraph 2015). In addition to a desktop version, this system is only available to run on an iPad tablet, and has not been developed for Android-based tablets. Field data collection, notes and photo attachments, and planning for follow-up task functionality is all included in this product. Cartegraph's software is much more robust than the applications developed for this project.

Custom extensions developed for ArcMap require users to be trained GIS specialists as opposed to general users. Futura Systems's custom extension, FuturaGIS, provides asset management of electric utility infrastructure data. The system also includes a browser-based version allowing staff to access information from the field. FuturaGIS integrates into other business applications including customer management systems and accounting because it was developed with an open architecture framework. Extensions for ArcMap are designed for an entirely different user-base than this project, and require experienced GIS staff to run the products. The two applications for this project are designed for users of all levels of technical ability – not only GIS specialists.

2.2 GIS and Irrigation Infrastructure

"Precision agriculture software" is a category of applications marketed to the irrigation industry. These software programs provide technology for both spatial and non-spatial field data, management, and analysis (Culibrk 2009). The technology is similar to this project because it creates GIS databases to document irrigation infrastructure. Providing integration with other systems such as maintenance and crop yields makes these programs different than the applications developed in this project. Precision agriculture technology assists in the spatial visualization of various factors affecting farming including crop yields, soil conditions, and water availability. Three precision agriculture platforms discussed by Culibrk include: Esri ArcGIS, MapInfo, and Integraph. Mainly the literature focused on Esri's suite of products (Culibrk 2009). SST Software develops two custom GIS applications for farming professions called SSToolbox and SSToolkit. These applications incorporate information related to the agricultural field itself: soil types and fertility, yield results, aerial photos, chemical applications, and hybrid/variety selections (Culibrk 2009). These two applications do not appear to include irrigation information into their databases and therefore are not similar to this project.

Additional farming-oriented custom applications provide management solutions for both the office and field, as well as cloud solutions (Farm Works 2015). FarmWorks™ developed software that is focused more on crop yields instead of irrigation. This software is compatible with Trimble's WM-Drain™, and analyzes surface and sub-surface drainage systems for water management. It determines pipe sizes based upon specific user input including topography, depth, and soil drainage (Farms Works 2015). Although it is similar to the applications developed in this project, it does not manage irrigation infrastructure. FarmWorks™ focuses predominantly on crop yields and is compatible with several precision farming displays such as John Deere, Trimble, and Ag Leader.

"Smart irrigation sytems" (SIS) focus solely on irrigation infrastructure, and not the larger farming-based solutions discussed previously. The VA uses WeatherTrak products for the majority of their controllers, which fall under the SIS category. These systems operate irrigation controllers based on existing soil or current weather conditions (Davis 2007). Specific adjustments or even stopping irrigation based upon this soil or weather information decreases the amount of over-watering. The WeatherTrak system, developed by HydroPoint, is focused on decreasing the amount of landscape irrigation water waste. Like other weather-based irrigation controller technology, these controllers offer zonal scheduling based upon the site's soil-type, sprinkler type, slope, sun exposure, and current weather (WeatherTRAK 2015). Their technology provides weather modeling of both historic and current conditions as well as evapotranspiration values. Although the VA uses WeatherTrak systems, they do not track where those controllers are located, or when their subscriptions will expire. One of this project's applications enables staff to visualize the spatial locations of these controllers as well as view the subscription date details.

Different from stand-alone products, customized interfaces managing irrigation infrastructure work directly in ArcGIS. In 1999, the Bureau of Indian Affairs (BIA) Division of Irrigation, Power, and Safety of Dams, created a customized interface to ArcGIS Desktop to manage their irrigation assets called Asset Map Viewer. The design of the application looked similar to other applications within their existing system (Richardson 2009). Similar to this thesis project, Asset Map Viewer allows staff members to view and identify various irrigation components. When Esri changed their GIS file structure from shapefiles to geodatabases, the Asset Map Viewer was updated to work with ArcGIS Server to utilize the new functionality. The Asset Map Viewer is robust and integrates with IBM's Maximo asset management software, providing work order and task tracking. ArcGIS provides the mapping component so users may view the spatial locations of the assets managed. The users of this custom-developed tool are highly technical and experienced with GIS software. Although very comprehensive and useful for the BIA, this application does not meet the needs of this project because it requires technically-trained staff. This project was designed for staff at all levels of technical ability, and to provide limited, focused functionality for each application.

2.3 Web-Based GIS Applications

There is much literature regarding GIS asset mapping as well as GIS web applications, but very few identified irrigation infrastructure web applications. The article "Web-GIS Solutions Development for Citizens and Water Companies" (Sercaianu 2013) discusses building web-GIS solutions for water-related data, and determining the interest and use of those tools by public citizens. Miner (2005) shows how water utilities can enhance workflows by using GIS not only to map water assets, but to also perform analysis and field-based editing. Tremendous changes in GIS application technologies available have occurred since this article was written in 2005; therefore the research requires updating. The assimilation of GIS into web applications now allows users to view, query, and update information without being GIS experts. Since late 2010, Esri's AGOL mapping program offers user-friendly, Java-based web application templates to its user community.

Published GIS web applications have grown exponentially over the last two decades (Haklay, Singleton and Parker 2008). In part due to vast use of the internet, the acknowledgement that GIS can add value to business processes has also contributed to this growth (Tait 2005, Veenendaal 2015). This literature review identifies GIS web applications created in a diverse range of areas: asset management, biological monitoring, climate change, ecological sensitivity for tourism development, land suitability index mapping, and even analyzing commercial motor vehicle crashes (Bapna and Gangopadhyay 2005).

The term "smart grid" originally referred to managing an electric power network with digital technology but now includes mobile and web-based GIS irrigation applications (ESRI 2009). Smart grid can be defined as "enabling data management, planning and analysis, field collection, and situational awareness (ESRI 2015, 2**)**. A custom smart-grid application from the China Agricultural University in Beijing utilizes a wireless sensor network to connect to GPS and GIS technologies through a host personal computer (PC) and personal digital assistants (PDA). The focus on this particular technology includes irrigation decision making, as well as basic farmland mapping and visualization. The systems developed by the China Agricultural University programmed custom mobile systems including PDAs instead of utilizing existing software and server environments, as do the two web applications presented in this thesis project. Another system developed at the China Agricultural University in 2010 also created their systems to run on customized PDA units (Zheng et al 2011).

2.4 Esri ArcGIS Online Applications

Developing applications utilizing Esri's suite of products including readily available templates and widgets was a goal of this project. Esri, the leading provider of GIS software, created a service called AGOL allowing users to create online maps or applications to incorporate their GIS data. AGOL provides the backbone of the two applications created for this project. AGOL for Water Utilities is a water-focused service Esri offers within their online platform. This service allows users to manage, create, store, and access, hosted services and applications. Users subscribe to this service, and then have access to a power-point template to create an AGOL home page banner, as well icons for each AGOL item. Additionally, a series of Python scripts are available to assist in creating groups and sharing content within a user's AGOL organization. The users are still required to build their data layers and create their services and applications, unless they contract with Esri to do so. This service did not provide any useful functionality for the applications of this project.

This literature review describes web applications developed in Esri's AGOL environment to compare their usability and functionality to the applications developed for this project. Several transportation-oriented applications exist including ones developed by the Utah Department of Transportation (DOT), the Texas DOT, and Bucks County in Pennsylvania. The applications all focus on primarily on one or two main functionalities for users to explore. These reviewed applications are similar to this project's goal because they present users with limited functionality thereby minimizing user confusion or frustration.

The Asset Management Group within the Utah DOT developed a series of online mapping applications based upon Esri's AGOL application. Maps available include bike lanes, billboards, driveways, intersections, and other highway-related assets. When the user selects the map, an AGOL map service is opened. These maps are very basic, have no custom widgets or functions, and are each focused on one asset type. For example, Figure 2 shows the driveways map and displays the driveway type and milepost symbols on the legend.

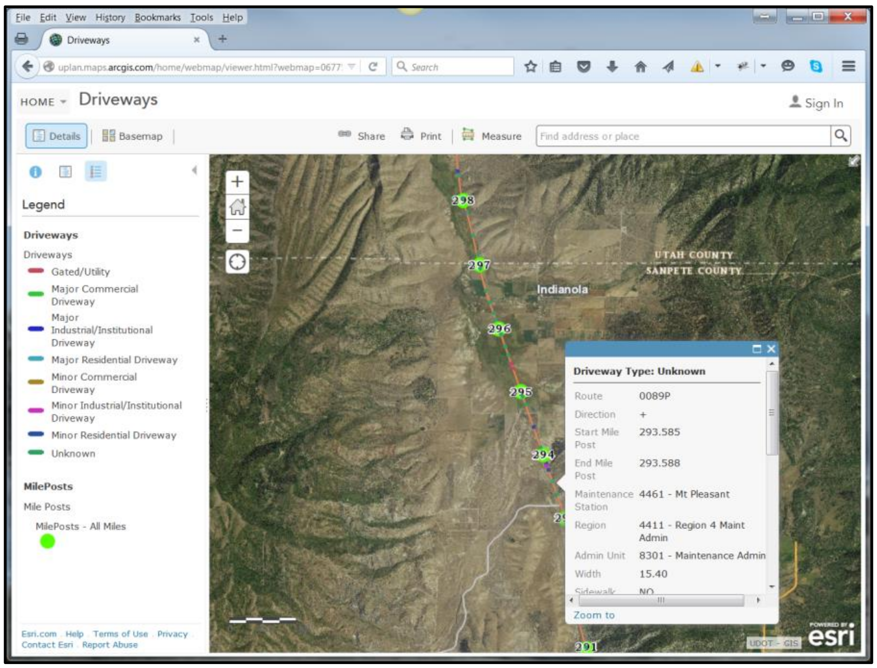


Figure 2 Utah DOT driveways map. *Source*: Utah DOT 2015

A user may click on any of the features and a pop-up box shows the attribute information for that asset. The Asset Management Group's web maps are similar to this project's applications because they are very simple and easy to use. The only functionality available to the users in addition to the attributes, is the ability to print a map, search for an address or place, or measure a distance. This study's application differs in that it will serve an AGOL map service into a web application interface using Esri's Web AppBuilder for Developers.

The Texas DOT also offers an AGOL map providing one main function – the ability to view real property asset information. Figure 3 on the following page shows the map, and it is similar to the previous example shown from Utah's DOT maps. The Texas DOT map offers multiple assets on one map, allowing users to view many items. Printing, measuring, or viewing attributes is also available to users. All of these examples utilized AGOL as their base development environment, were limited to freely available functions and tools, and maintain the same look and feel.

Esri's Web AppBuilder is a follow-up tool to AGOL, and makes the process of creating GIS-enabled web applications even easier for users. This application takes an AGOL map service and quickly converts it to a web or mobile application. Built-in widgets, or buttons, and themes make this application comparable to WYSIWYG-type web development software.

Esri's Web AppBuilder technology also provides a more polished application interface for developers to explore. Bucks County in Pennsylvania built two publically accessible web applications with AGOL and Web AppBuilder. The applications are very basic and provide the general public the ability to view information such as floodplains, land use, zoning designations, and parcels. Figure 4 on the follow page shows the straight-forward and easy to use viewers. Although the applications do not present asset or irrigation-related information, they are similar to this thesis project because they have very little functionality and one main purpose. The main difference is that these applications do not include custom widgets such as presenting popup information in a side-panel.

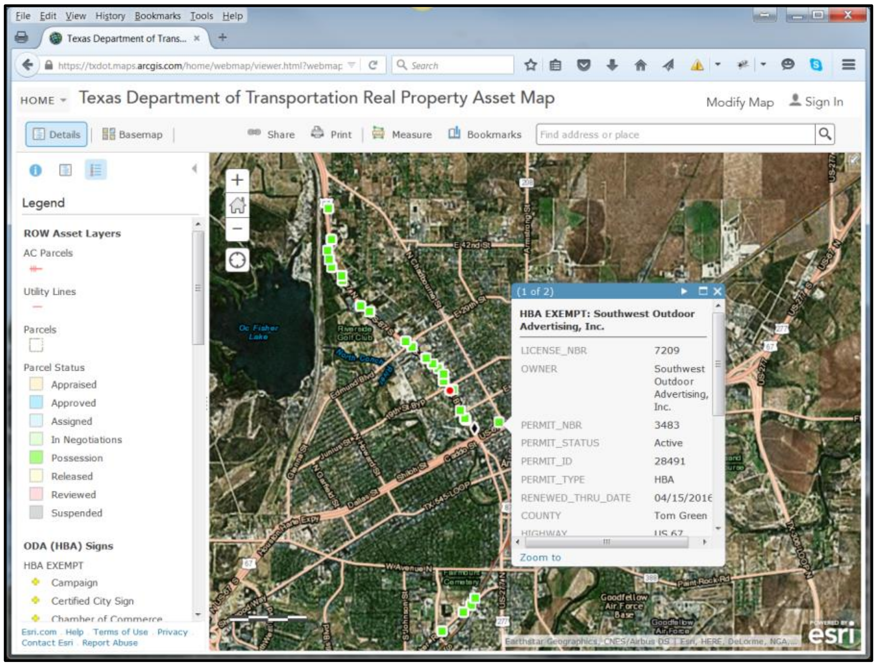


Figure 3 Texas DOT real property asset map. Source: Texas DOT

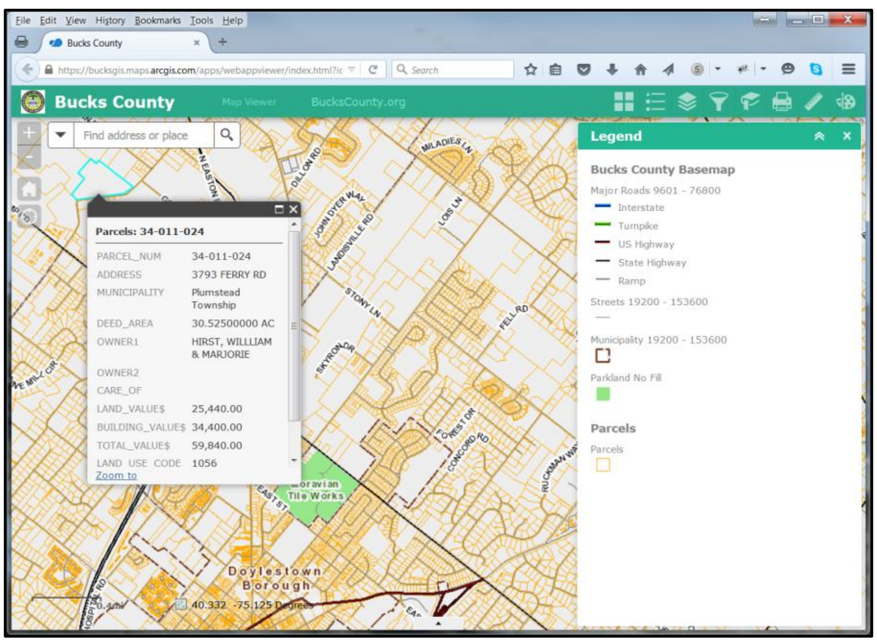


Figure 4 Bucks County map viewer. Source: Bucks County 2015

The City of Mountain View also developed an application offering GIS data to the public using Esri's Web AppBuilder environment. Figure 5 shows the City of Mountain View's zoning code application. Users can click on the map and view the zoning code for that specific parcel. The focused functionality of the City of Mountain View's application is similar to the irrigation infrastructure applications because they all support one main function. The look and feel of the City of Mountain View's application is also similar to those created by this thesis project.

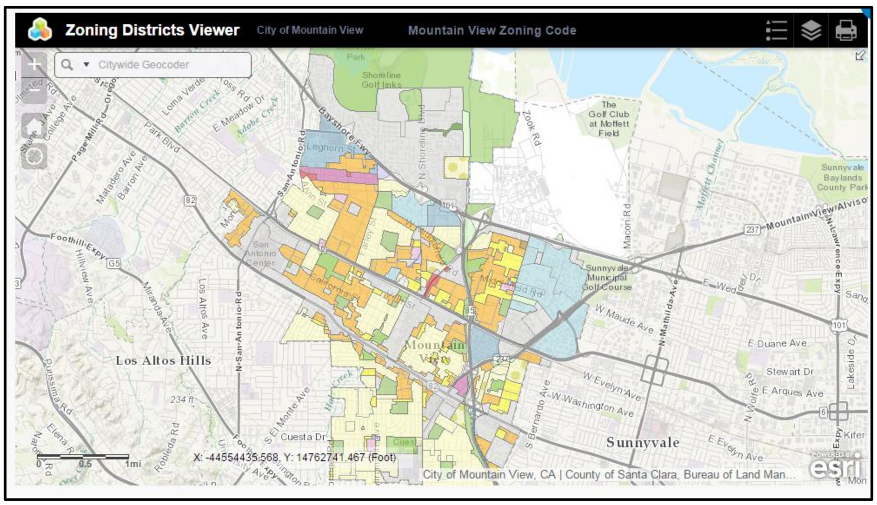


Figure 5 City of Mountain View Zoning Districts Viewer

Overly complex or all-inclusive applications, as discussed previously in this chapter, do not meet the objectives of this thesis project. This project provides stream-lined applications with one or two primary functions, a preference of the VA staff. As described further in Chapter 3, these applications adapted from one comprehensive application, into two specific function-based applications to better meet the stated needs of the users.

Chapter 3 Development

This chapter presents the development of two web applications for the VA's Palo Alto Division. Section 3.1 identifies the scope and objectives of this study, followed by Section 3.2 which documents the process of data collection. Section 3.3 explains how this data was used to create the irrigation infrastructure geodatabase. Lastly, Section 3.4 describes the development of the two web applications.

3.1 Scope and Objectives of Study

In January of 2014, Geografika Consulting was contracted by the U.S. Department of Veterans Affairs, Palo Alto Division (PAD) campus to build a campus GIS base map for their facility. In addition to the campus base map, freely accessible GIS data layers were compiled. The facility lacks trained GIS staff to access or update any GIS information. Staff needed access to web or mobile applications presenting this GIS data. Development tools available from Esri make it feasible to easily and economically create web applications serving GIS data to all levels of staff. These new tools eliminate the need to hire a large consulting firm or purchasing expensive software. This study created two irrigation infrastructure applications demonstrating to the PAD staff the benefits of GIS and how accessing updated and accurate information can save staff time and money.

Historically, GIS was used to collect, store, and document utility and infrastructure information. Using GIS to manage assets and utilities is more prevalent now as hardware and software are more affordable and user friendly (Hanson 2008). The main objective of this study is to enable non-technical staff access to view and locate irrigation infrastructure information in easy-to-use GIS web applications. The two applications are accessible on web browsers or mobile devices. The potential users include the maintenance staff, landscape architect, mechanical engineers, and facility planners at PAD. The PAHCS includes three main campuses, and PAD is the pilot study area for evaluating GIS web applications. Upon completion, a similar process will occur at the Menlo Park Division campus. The last campus, Livermore, is slated for closure so replicating this process there will not occur.

Developed as the first part of a greater asset management system, it is desired to incorporate domestic water, electrical, gas and steam pipelines into web-based applications. The VA’s internal Geoportal will host the applications. Esri’s Geoportal Server, introduced in 2012, enables organizations to manage and publish GIS data and metadata (Mitsova 2013). The VA introduced this environment nation-wide in January 2016.

The landscape architect identified the goal of tracking irrigation controller type and subscription information on a GIS web application. The first web application meets this goal by collecting irrigation controller locations, links to pictures and as-built construction drawings, and attributes regarding the controllers themselves. Staff members also requested the ability to quickly identify shut off locations to turn water off when there is a line break or leak. Employees need to be informed when lines have been or may be impacted by the major construction occurring on this site. The second web application fulfills this need by incorporating irrigation shut off information such as back flow locations, gate valves locations, and their respective areas. These applications allow staff members the ability to quickly and accurately locate irrigation equipment without relying on outdated CAD drawings, or inaccurate as-built drawings.

A backflow prevention device is used to protect potable water supplies from contamination due to back flow. A major back flow preventer located at PAD is connected where the irrigation pipe loop meets the city of Palo Alto’s water system. The back flow can be used to shut off the water supply to the loop. Smaller back flow preventers are used when the irrigation systems is connecting to an internal domestic water line on campus (instead of the irrigation loop). Gate valves are also used to control the flow of water, but they are not sufficient to stop back flow. They provide shut off at the next level within the hierarchy of a system after the back flow preventer. They are used to shut off the sub-sections within an irrigation area that receives its water off the irrigation loop. Back flow preventers can still be open, but a smaller area within the system is isolated by the gate valve. According to the landscape architect at the VA, there does not need to be a relationship set between back flows and gate valves (Fong 2016).

Both applications are publically accessible from a computer, tablet, or mobile device via a web-browser since the landscape maintenance crew does not have access to the secure VA server. Users who do have access to files within the VA firewall still face challenges when trying to identify irrigation infrastructure drawings. Both electronic and hardcopy file storage at the campus is not well organized and difficult to navigate, so it may be hours to days before the proper locations are identified. These applications address those challenges by providing up-to-date information and links to construction and as-built drawings.

Most of the irrigation controllers on campus are subscribing to a weather service through WeatherTRAK and maintenance engineers need to track those subscription dates. This is important because the subscription is fee-based. Several of the controllers are no longer connected to the service physically, yet the VA is still paying the associated fees. The second application of this project identifies the WeatherTrak irrigation controllers, as well as their subscription dates. Managing this information allows the VA to incorporate the subscription fees into their annual budgets.

3.2 Data Collection and Geodatabase Creation

PAD is currently undergoing an immense amount of construction which impacts the irrigation infrastructure system. Orthorectified aerial photography flown in mid-2014 provided the foundation for an accurate GIS basemap. From this first aerial, land cover types were digitized into 6 main types including: building, pedestrian or vehicular paved, improved or unimproved landscaping, or under construction. Orthophotography is scheduled to occur quarterly, to maintain the continuous revisions required to the GIS basemap.

3.2.1. Irrigation Controller Geodatabase

After creating the campus GIS basemap, the irrigation infrastructure database was designed with assistance from the VA's landscape architect. An existing irrigation controller spreadsheet developed by a maintenance engineer inventoried controllers and their associated numbers, manufacturer, serial number, and relative location on campus. No maps were associated with this information. Maintenance and engineering staff would benefit from knowing the actual physical location of the irrigation controllers. The database meets this need, storing the requested information in GIS. The landscape architect identified back flow information as an important data layer for inclusion in the geodatabase as well. Figure 6 on the following page presents the initial irrigation database structure.

The PAD campus was surveyed with a landscape architect and a maintenance crew member to gather the irrigation controller information. Using an Ike surveying system, attribute information, photos, and controller charts were collected at each irrigation controller location. The maintenance crew confirmed or updated the information collected, including manufacturer, model, and serial number. If the controller was manufactured by WeatherTrak, then the attributes included the service installation date. Importing the GPS points into a new file geodatabase

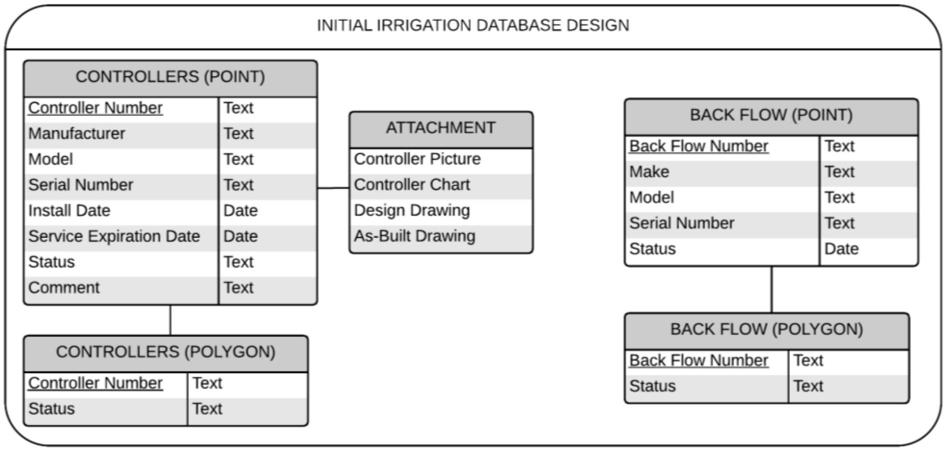


Figure 6 Irrigation Database Design

allowed feature attachments to be included. These attachments include irrigation charts, as-built drawings, and construction drawings. Creating links between the photos of the controllers to the GPS points allows users to view this information when clicking on a controller point. Staff sketched on a large map the areas controlled by each irrigation controller. Figure 7 shows a reviewed map. The hand-drawn irrigated areas were digitized into the geodatabase as

Figure 7 Staff member review document.

polygon features and attributed with their respective irrigation controller labels. Figure 8 shows the irrigation controller and areas developed map.

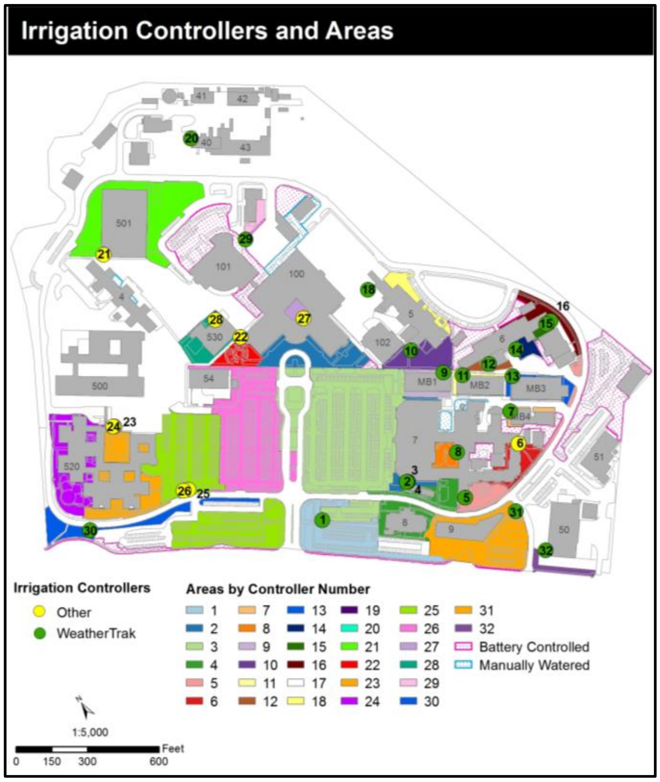


Figure 8 Irrigation controllers and areas. Source: Megan Gosch 2015

3.2.2. Gate Valve Geodatabase

Documenting the back flow valve locations differed from the irrigation controllers because GPS technology was not used. The maintenance crew mapped the point and polygon locations on a hard-copy plot, and these were digitized into the GIS database. Staff determined it was not necessary to include photos or .pdfs for the gate valves at this time. Figure 9 on the following page shows the back flow locations and areas digitized from the hand-drawn maps.

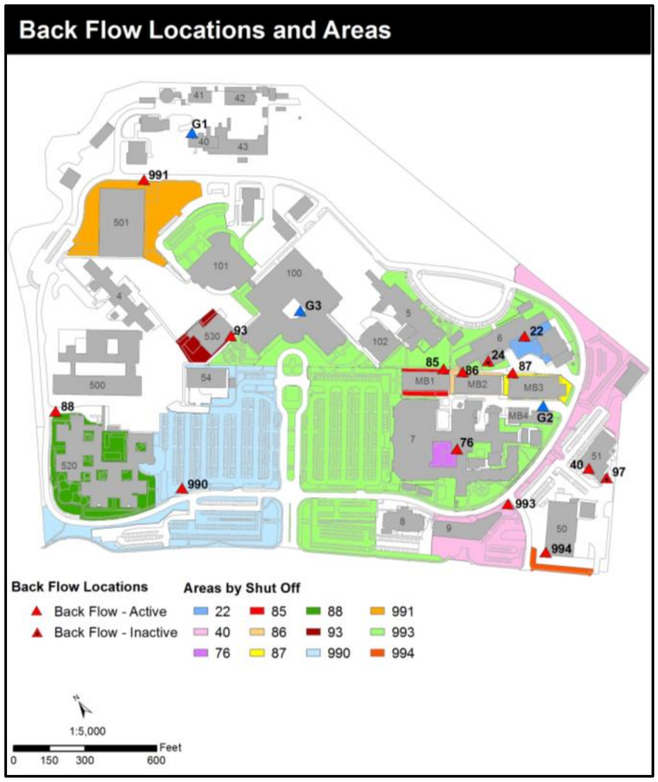


Figure 9 Back flow locations and areas. Source: Megan Gosch 2015

Presentation of the compiled data occurred to a large group that included the landscape architect, PAD maintenance supervisor, the Chief of Engineering and two engineers from PAD, as well as the maintenance supervisor and maintenance staff from the Menlo Park Division campus. The presentation was well-received as it was the first time this irrigation information was presented spatially. The maintenance supervisor recommended that another level of detail be included in the mapping project: gate valve locations. The landscape architect, the PAD maintenance supervisor and I met again to hand draw the gate valve locations and their respective areas onto a hard copy plot of the campus. After digitizing this information into the geodatabase, it was received for final review by staff members in December 2015. All subsequent edits were completed in January 2016. Figure 10 on the following page shows the gate valve database design. Figure 11 shows the Gate Valve Locations and Areas map.

GATE VALVE DATABASE DESIGN

GATE VALVE (POINT)	
Gate Valve Number	Text
Status	Date

GATE VALVE (POLYGON)	
Gate Valve Number	Text
Status	Text

Figure 10 Gate Valve Database Design

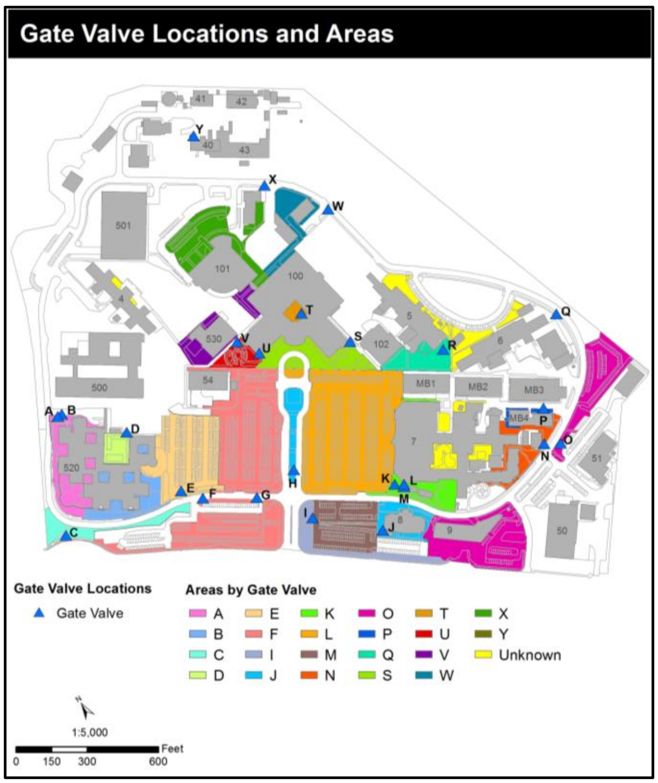


Figure 11 Gate valve locations and areas. Source: Megan Gosch 2015

3.3 Application Development

Compiling the irrigation infrastructure GIS into web applications for the PAD campus was important as they are the first GIS web applications created for this campus. The applications add much value to the client by enabling staff members to quickly access accurate and updated data. Previously maintenance crew requested information from engineers, most often in hard-copy map form. The engineers then navigated through a very complicated and unorganized CAD file structure to try to identify the information requested. Now this information will be available to everyone, in an easy-to-use format.

Creating two GIS web applications for the collected irrigation information was simplified by utilizing Esri's AGOL Web AppBuilder for Developers. The applications include: point data (irrigation controllers, back flows, and gate valves) and polygon data (buildings, and areas controlled by each specific irrigation controller, back flow, or gate valve). Designing the user interfaces for these applications for a very low technical skill level allows all employee the ability to use the tools. They are essentially a "point and click" application where the user only needs to move their mouse to the valve or area location, click on the point or polygon, and a list of attributes displays on the screen. Crew members with little technical experience can be easily trained in the use of these applications.

3.3.1. Programming

A USC GIST virtual machine provided the development environment for all the maps and applications. A single map document in ArcGIS Desktop version 10.3 includes all of datasets created for this study. During this process, I designed the display and labeling of each data layer. Additionally, identifying relates between layers allows for creating queries in the web applications. Sharing this map document as a service to USC SSI's Arc GIS On-Line account provides the input needed to create the two web maps: Irrigation Controllers – Map Viewer and Irrigation Shut Off Locations - Map Viewer.

Sharing these two map viewers enables development of the web applications in Esri's Web AppBuilder for Developers environment. Creating a development version on the virtual machine for building and testing the web applications resulted in a few problems. Esri technicians assisted and correctly installed the software and defined the development environment required.

3.3.1.1. Irrigation Controller - Map Application

Developing both applications from the same template provides a consistent look and feel to the users. Figure 12 shows how the Irrigation Controller – Map Application initially launches with the legend items displayed. This screen orients the user to the Palo Alto Division Campus and introduces the mapping data sets available in this application.

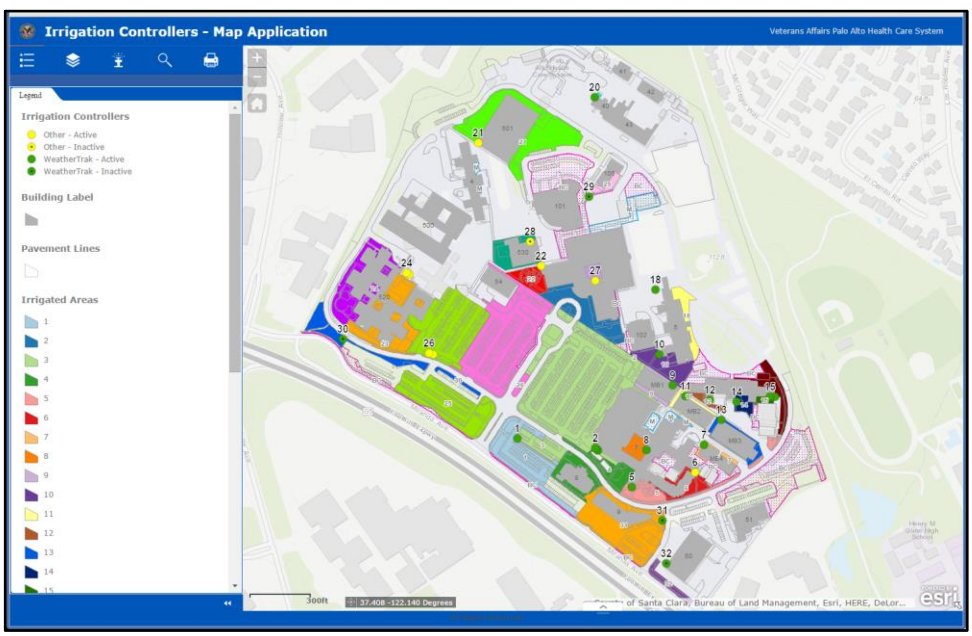


Figure 12 Irrigation Controller Map Application

Users may view the applications on a mobile device, causing the displayed map area to be quite small. Programming the pop-ups to open on the left-side panel of the application when a user clicks on a widget ensures that the entire map is viewable. Downloading a user-created custom widget identified on Esri's GeoNet community page allowed for this functionality (Scheitlin 2016). The second widget on the application is the Layers button. Clicking this button presents the available layers the user may view, including an image tile service created from the most recently flown aerial photography of this site. This is very useful because the Esri Image service base map is outdated, and doesn't reflect current conditions of this site. Figure 13 shows the aerial imagery on the map application.

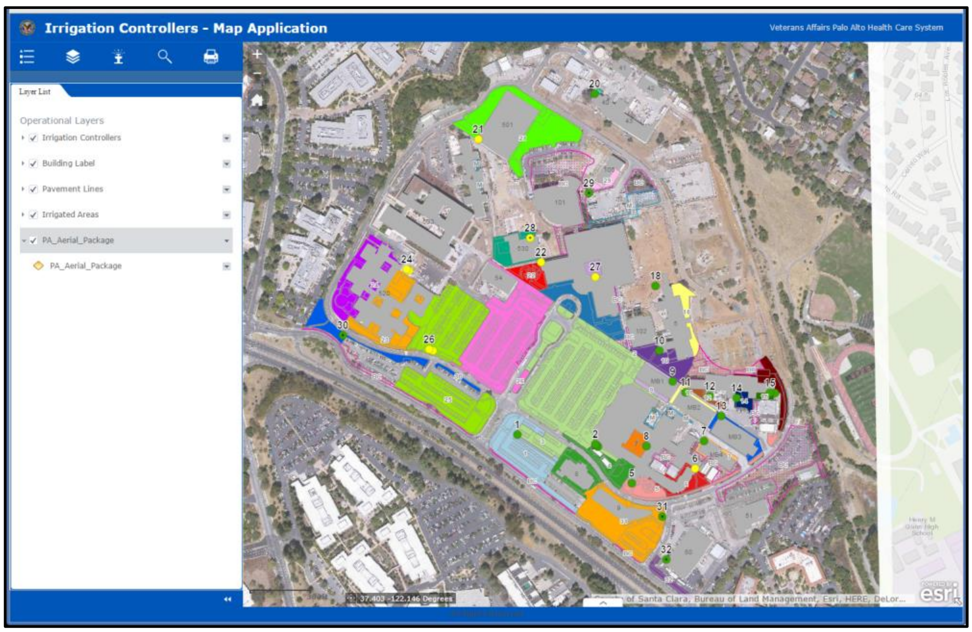


Figure 13 Aerial Imagery

The third widget, a custom-designed irrigation sprinkler icon, brings the user to the controller information page. From this location the user clicks on the map to view the attribute information of the feature selected. The side panel displays the controller number, all of the attributes collected for that item such as model and manufacturer, feature attachments associated with that controller, as well as an image of the actual controller. Figure 14 shows the information associated with irrigation controller number 21. Figure 15 on the following page shows the construction drawing feature attachment for controller 21.

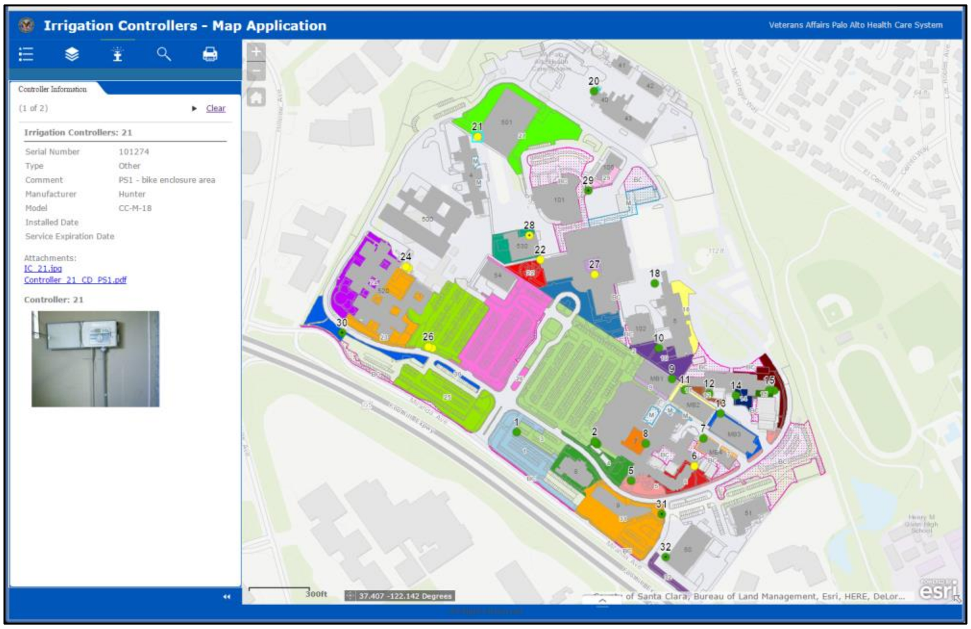


Figure 14 Controller Information

The fourth widget, controller search, performs a preset query on the controller manufacturer information. Configuring this query to provide a drop-down list of irrigation controller manufacturers allows the user to select a specific manufacturer and view the corresponding results on the map. This is useful function because all the WeatherTrak controllers require a paid subscription service. Knowing the locations of those controllers are located and whether or not they are currently being used in the appropriate capacity would save the VA money.

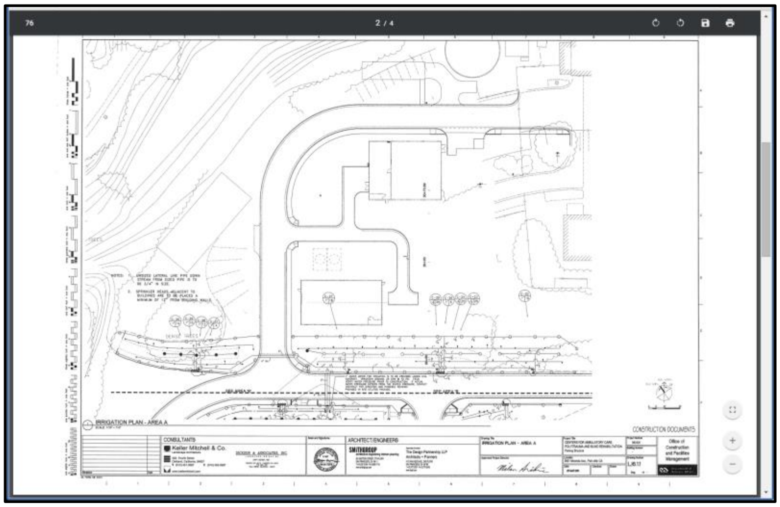


Figure 15 Construction Drawing

Figure 16 shows the results of applying this query. The information panel also displays the attribute information about each of those controllers. Clicking on one result will zoom the map into that specific controller location.

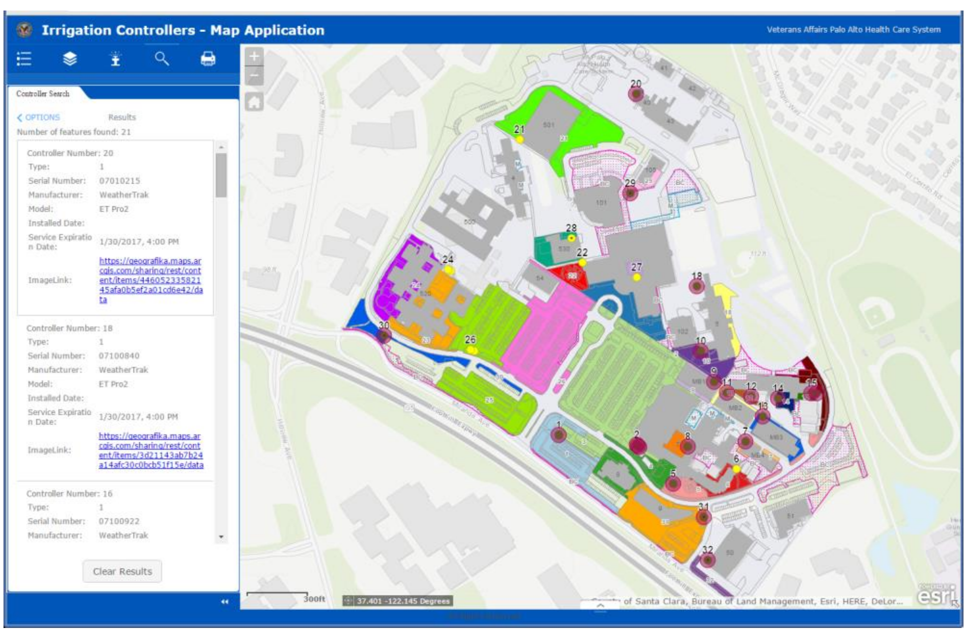


Figure 16 Controller Manufacturer Search Results

3.3.1.2. Irrigation Shut Off Locations – Map Application

As discussed previously, using the same template to create both applications provides consistency for the users. The Irrigation Shut Off Locations application launches with the legend items displayed. Figure 17 shows the home page of the Irrigation Shut Off Locations – Map Viewer.

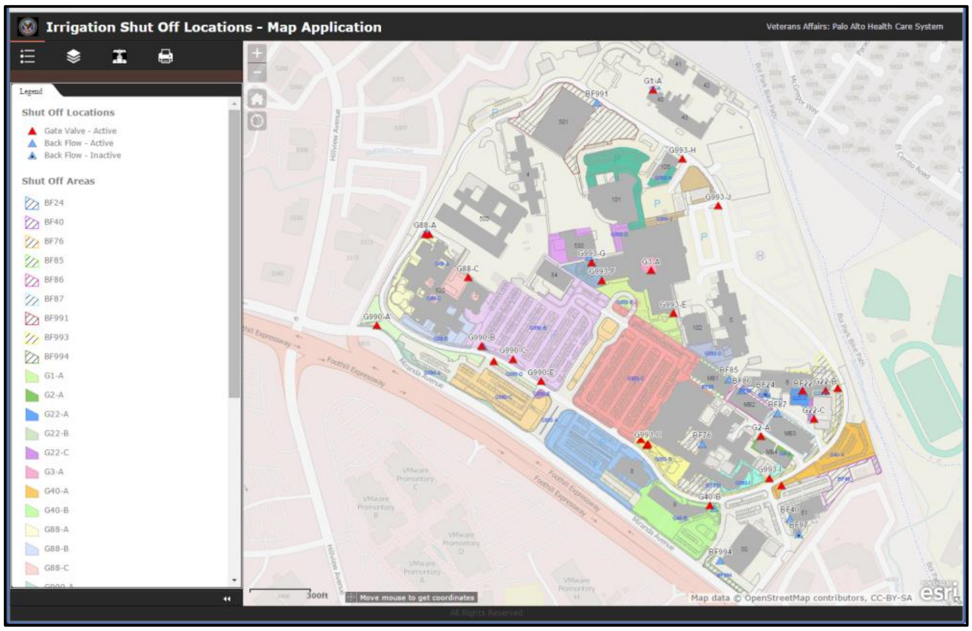


Figure 17 Irrigation Shut off Locations – Map Viewer

As both the layers page and the print page contain the same functionality as the Irrigation Controller application, those screens are not presented here. The third widget, depicting an image of a valve, identifies this as the shut off information widget. When a user clicks on this widget, they then click on a feature on the map to see the features attributes. Figure 18 on the following page shows the results of a user clicking on Shut Off G88-C.

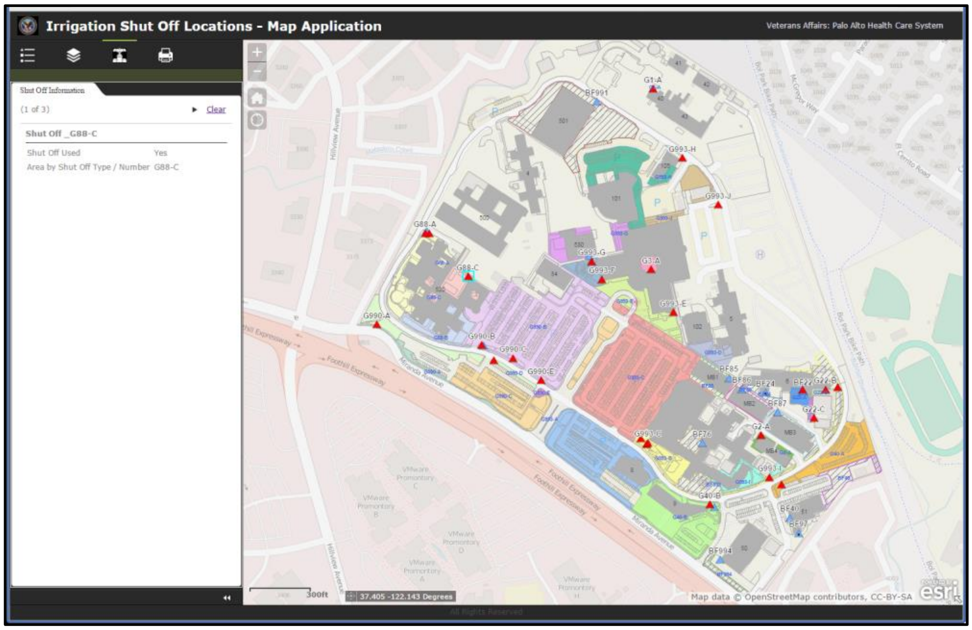


Figure 18 Irrigation Shut Off G88-C Click Results

3.3.2. Programming Challenges

One challenge immediately obvious was when users clicked on an area, the pop-up box covered up the map so they could no longer see the feature they were selecting. A custom widget was identified through the Esri Community Geonet website. The widget is called Popup Panel Widget Version 1.3, created by Robert Scheitlin, GISP. This widget was based upon the "Popup content in side panel" JavaScript API (Scheitlin 2015). The widget created a side-panel pop up so that the attribute information no longer covered over the map features. This was important because if the user is viewing the application on a mobile device, the map area is already smaller than on a computer's monitor. The application needs to allow for easy viewing of attribute information, and yet still provide a view of the geographic location of the features as well.

Another challenge encountered was the ability to have a user click on a polygon, and have its related point feature highlighted on the map. In a telephone conversation with Preeti Gupta, an Esri technical support analyst, on January 22, 2016, she acknowledged that this ability is not supported in the current version the Web AppBuilder. This known bug, BUG-000087466, states that applications built with Web AppBuilder do not support related tables, and two enhancements have been identified for the next release of the software: ENH-000091041 and ENH-000082871 (Gupta 2016). Additionally, a blog entry was created on the GeoNet Esri Community page (Gosch, Megan, post to “Identify Related Point by Polygon Feature,” January 18, 2016, Geonet.com, https://geonet.esri.com/thread/170960#comments). This documented bug is a bit misleading though, as the Query function does allow for related table information to be presented in the pop-up. However it is the functionality of the Identify command available in the ArcMap Desktop version that is required in this application. The Identify tool allows a user to click on a feature, and its related features are then presented in the pop-up box. If the user clicks on a related feature attribute in that pop-up box, that feature is highlighted on the map. Due to programming skill limitations, developing a custom widget allowing for this desired functionality did not occur.

Chapter 4 Application Evaluation

Chapter 4 presents the application evaluation process. Section 4.1 discusses the original intent of the project and how it changed over time. Section 4.2 describes the how individuals were identified to be evaluators of the application. Lastly, Section 4.3 presents the user survey form and summarizes the results of the respondents' answers.

4.1 Original Project Intent

Creating one web application allowing users to turn on and off layers for both irrigation controllers and shut off locations was the original intention of the project. Staff members preferred to have the functionality separated into two applications. As the two datasets are used for different purposes, it was more complicated requiring users to turn on and off the layers in order to query the information they wanted to view. Having the irrigation controller information in one application allows users to view information about those controllers and their respective areas. This application is used for more informational purposes.

The second application is used specifically for shut off information. When a shut off location needs to be identified, potentially during a water leak or line break, this application provides that functionality. Having one application for just this purpose makes it easier on the user so they do not have to ensure that the proper layers are turned on, or that they are selecting the appropriate query button. Each application has 2 or 3 widgets to query or view attribute information, minimizing the potential for user error or frustration. This also allows all staff, regardless of technical skill level, to use the applications.

4.2 Evaluator Identification

Identifying a user evaluation committee ensured that the two applications met the goals previously identified in Chapter 1. Throughout the entire process of developing the irrigation infrastructure databases and applications, the maintenance crew provided feedback and comments. Already familiar with the functionality of the applications, they declined participating in the committee. Three other individuals were identified to test and evaluate the two irrigation applications. The Associate Chief of Engineering was not involved in the development process but expressed interest in joining the user evaluation committee. This individual reports to the Chief of Engineering and was crucial in advocating this and future GIS applications to the Chief as well as other management at PAD.

The second committee member, the Supervisory Engineer from the Office of Facility Planning for PAD, also reported to the Chief of Engineering. This person is a long-time employee of the VA and is well-known and respected within the office. Additionally, as a larger supporter of GIS, he is another great advocate for these and additional GIS web applications.

Lastly, the landscape architect asked to be a user to test these applications. Although she had been involved throughout the entire process as well, she had a limited hands-on GIS knowledge so could provide important feedback about the usability of the applications.

On January 27, 2016, I presented both applications to the user group along with a user guide created for each application, included in Appendixes A and B, respectively. Presenting the background information about this project provided context to the user group. Reviewing the data creation process explained the reasoning behind including only specific asset types at this time. While demonstrating both applications step-by-step, users followed along with the user-guides. Reviewing the user survey forms at the end of the meeting ensured that there were no questions and that everyone understood the expectations.

The following day links to the application, the user guides, and the user survey forms were distributed by email to the user group. Users had one week to test the application, and return the user survey form by Friday, February 5, 2016.

4.3 User Survey Form

After researching user satisfaction and application usability questionnaires, the user survey form was developed. Two previous studies provided useful input about keeping the surveys short and to the point, as well as easy for the user to fill out (Chin et al, 1988; Lund 2008). Creating the user survey form in Adobe Form keeps everything digital and easy to retrieve. Appendix B includes full user survey form. The first set of questions focused on the usefulness of the applications, including their effectiveness, ability to save the user time, if they met the users' needs, and did everything the user expected them to. Figure 19 shows Question 1 and its responses.

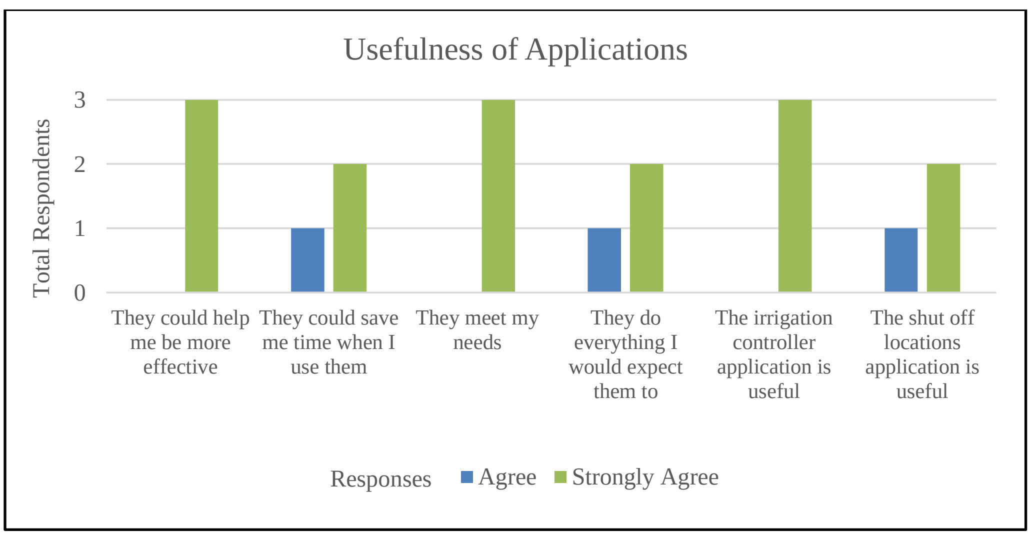
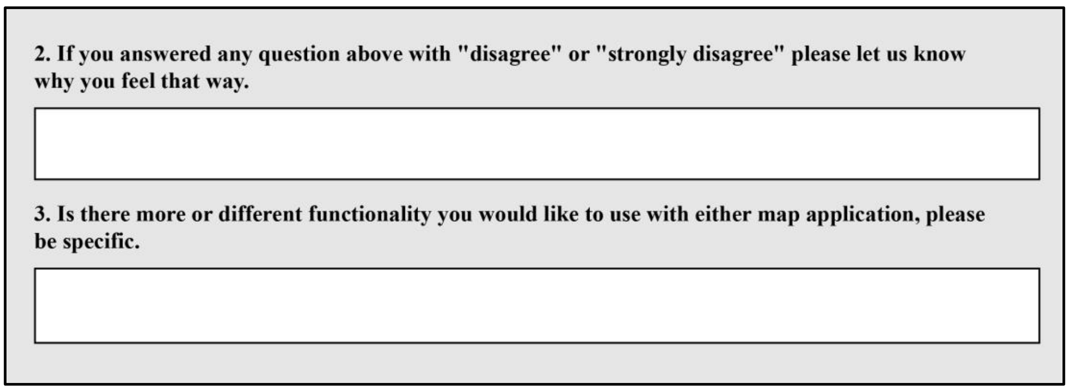


Figure 19 User Survey Form Question 1 and Responses

If users answered Question 1 “disagree” or “strongly disagree”, Question 2 requests more information. Question 3 asks respondents if there is more or different functionality they would like to see in the applications. Figure 20 shows Questions 2 and 3. These questions were designed to solicit more specific feedback from the users, as well allow for more information regarding enhanced functionality suggestions.



2. If you answered any question above with "disagree" or "strongly disagree" please let us know why you feel that way.

3. Is there more or different functionality you would like to use with either map application, please be specific.

Figure 20 User Survey Form Questions 2 and 3

No respondent answered Question 1 “disagree” or “strongly disagree”, so Question 2 was left blank. Question 3 answers included the ability to have an associated irrigation area highlighted when the user clicks on a controller, and vice versa. Also suggested was the inclusion of irrigation lines, pipe sizes and other pipeline information.

Question 4 inquired about the applications ease of use. Figure 21 on the following page shows the specifics of Question 4 and its responses. Question 5 focused on the users’ overall satisfaction with the application. Figure 22 on the following page shows the options of Question 5 and the results.

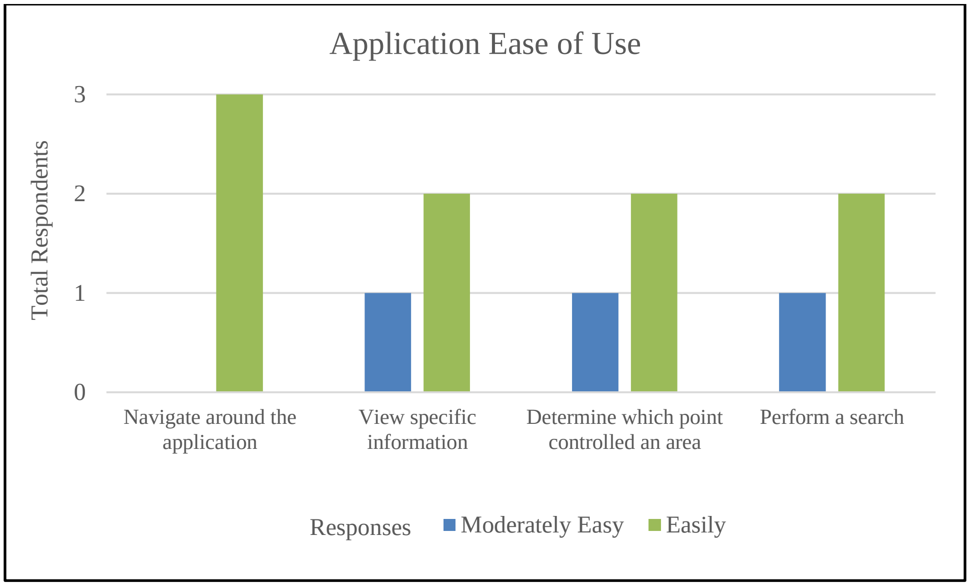
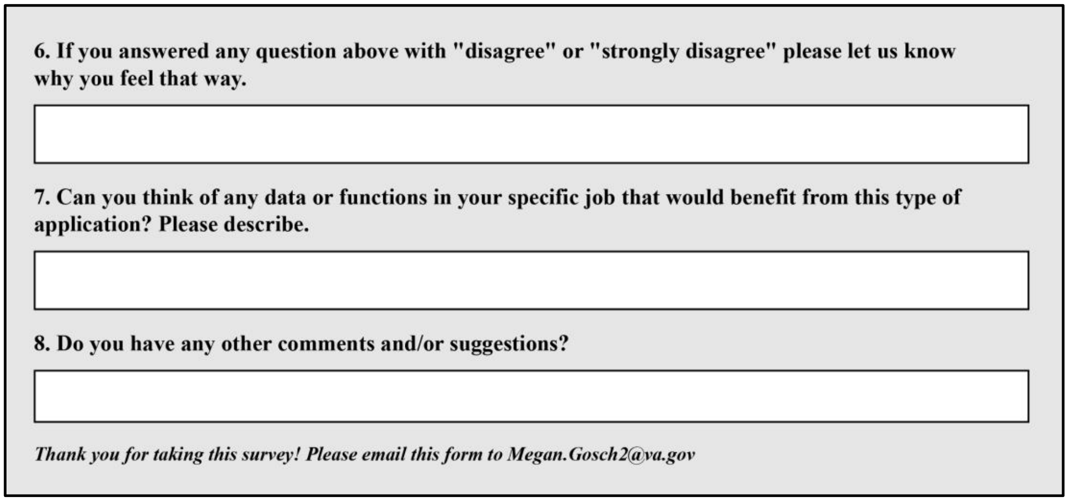


Figure 21 User Survey Form Question 4 and Responses

Figure 22 Question 5 and Responses

The remaining questions again asked for specific feedback if the user responded with a "disagree" or "strongly disagree" selection, as well as prompting the user to think of any other functions in their respective jobs that would benefit from this type of web application. An open ended question regarding any other comments or suggestions finalized this survey. Figure 23 shows Questions 6, 7 and 8.


6. If you answered any question above with "disagree" or "strongly disagree" please let us know why you feel that way.

7. Can you think of any data or functions in your specific job that would benefit from this type of application? Please describe.

8. Do you have any other comments and/or suggestions?

Thank you for taking this survey! Please email this form to Megan.Gosch2@va.gov

Figure 23 User Survey Form Questions 6 through 8

There were no “disagree” or “strongly disagree” answers for Question 5, therefore Question 6 was not answered. Question 7 responses included: a tree inventory and management application, as well the ability to isolate sections of water mains. Question 8 received several responses including: the inclusion of a HELP button or table to provide general information such as the naming system for files; and instructions for printing and the inclusion of the embedded data (pictures or charts) when printing. The most positive comment collected was: “Excellent application that is extremely useful, saves time and money and allows better service and response.”

Feedback supplied from the testing phase was into the final versions of the applications, when possible. For example, the main comment regarding the ability to “Identify” a related object has already been discussed in Chapter 3, section 3.2 Programming Challenges. Working with a GIS developer to create a custom widget to enable the "Identify" processes for these applications has not yet produced the proper functionality.

Including an information button in the final version of the Irrigation Shut Off Locations application addressed the feedback regarding labels and instructions. The information screen provides background information about the applications, how the datasets were created, as well as the naming system conventions. Also included on this screen are printing instructions. Figure 24 shows the added fifth widget and associated pop-up information.

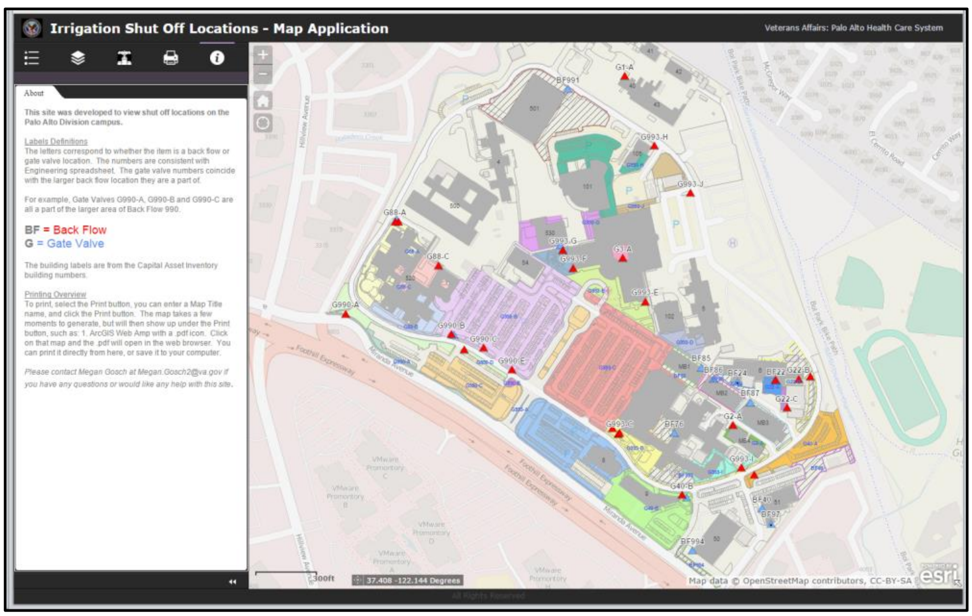


Figure 24 Information Screen

The feedback provided validated that the main objective of this project was met: creating an easy-to-use web application saving staff members time by increasing their efficiency in identifying shut off locations when needed. It also generated more interest in GIS and how it could be used for additional applications throughout the facility.

The applications are hosted on USC’s AGOL account, but will be transferred over to the VA’s internal Geoportal within their secure firewall, as discussed in Chapter 5 Technology Transfer. Updates will occur quarterly, or as construction necessitates, by myself.

Chapter 5 Technology Transfer

The VA PAD, Office of Facility Planning and Development did not have Esri's ArcGIS Desktop software installed when this project was initiated. As a consultant to the VA, Geografika Consulting made available an ArcGIS Desktop license, and this software was installed on February 17, 2016. This chapter presents how the technology will be transferred from USC SSI's AGOL and virtual machine environment where the two applications are currently hosted, to the VA's internal Geoportal environment. There is no plan to train other individuals in the data creation or maintenance of the applications at this time as Geografika Consulting is currently under contract until February 2018. Ideally there would be at least one person who will understand the technology and be able to assist in additional asset GIS development. The VA needs to hire an individual with GIS experience; however that has not yet occurred.

The VA has committed to using Esri products for all GIS mapping needs. In January 2016, the VA's Corporate Data Warehouse (CDW), based in Washington DC, rolled out a Geoportal Server environmental for certain identified staff members to utilize. Michael Villenueve, GIS/Data Manager of the CDW, has agreed to host the two irrigation infrastructure applications on the VA's Geoportal. Mr. Villenueve stated that he wanted the applications delivered as templates as well, so other VA staff may use them for their asset management applications.

All of the GIS data created, as well as the ArcMap .mxd and the Esri Web AppBuilder applications, are downloaded and saved onto the PAD VA server. The applications will be sent to Mr. Villenueve for inclusion on the VA's Geoportal. Updates to irrigation data will occur on the VA PAD workstation, at a minimum quarterly. If a major change in irrigation infrastructure occurs, such as a complete line being turned off or relocated, then the maintenance staff will notify me to make the changes accordingly. Updates occur within an ArcMap environment directly to the feature data, which are then shared as a map service to the VA's Geoportal, and finally the applications dynamically update as well.

The applications will be saved as templates on the VA's Geoportal, enabling other VA campuses to access them. By following the geodatabase structure used in this project, other offices can create their own geodatabase to populate these applications templates. For example, if the Loma Linda campus creates an irrigation controller database using the same naming structure and attributes, they can create a map service in Geoportal, and use this project's Irrigation Controller Map Application template to create a new application for their specific site.

Chapter 6 Conclusion and Future Work

This chapter discusses how implementing irrigation infrastructure applications contribute to work efficiency at the VA PAD campus, and how the project meets the goals identified in Chapter 1. Section 6.1 describes how the VA benefits from the development of these applications. Section 6.2 presents how this project met its goals. Section 6.3 discusses how these applications can be developed further to meet the suggestions collected from the user survey. Lastly, Section 6.4 discusses how the development of these applications can be implemented for other assets within the VA PAD.

6.1 Impact

The VA PAD is a large campus with a multitude of assets requiring management. Due in part to staff turnover, and partly due to an unorganized file storage structure, it is difficult and time-consuming to locate digital data (CAD) or hard-copy drawings identifying locations of various assets. Additionally, this campus is undergoing a significant amount of construction which impacts the existing infrastructure. A lack of staff knowledge about the location of irrigation infrastructure has caused water lines to be broken, and irrigation controllers to be unknowingly disconnected. The first application enables staff to quickly identify the locations of existing irrigation controllers and to determine if construction will require moving a controller, or discontinuing its fee-based subscription service of satellite weather information. By preventing the disruption of irrigation lines, cost savings can be realized.

The second application allows staff to view all the shut off locations for irrigation infrastructure on campus. If a water line break occurs, a user can very quickly visually identify the back flow or gate valve location to turn off the water to that area. Both of these applications build the knowledge of staff, thereby reducing the cost and time previously required to identify these asset locations.

6.2 Goals Achieved

These applications achieve the goal identified in Chapter 1 of providing an alternative to locating hard-copy paper or digital CAD maps to identify irrigation infrastructure assets. The development of two user-friendly and focused web applications helps achieve the goal of creating applications that are usable by staff with limited technology skills. Using the Esri suite of products allows for the easy transfer of the applications to the existing VA GIS Geoportal server. This provides for easy updates and management of these applications over time. Additionally, the VA has committed to using Esri products for facility mapping, so these applications are consistent with efforts occurring VA-wide.

The user responses and feedback provided through the survey indicated that the applications were easy to use and successfully met their desired purposes. Suggestions for other data types and attributes to include in additional applications were identified as well. Verbal feedback received during the presentation discussing additional assets that would benefit from these type of applications achieved the desired goal of illustrating the benefits of GIS technology to staff.

6.3 Future Improvements

The main functionality desired by the users is the inclusion of a widget to identify asset features. If a user clicks on a polygon, its related point feature would be highlighted. The application now requires users having to locate the point themselves by reading the attribute information on the side panel and finding the associated point. At the time this project was completed, Esri's Web AppBuilder did not support this function, and was catalogued as a known future enhancement by Esri.

Continued work with a GIS Developer will ultimately result in this functionality being added to the applications. At the time of this report, the custom widget is still being configured. The javascript code from Esri's Identity function was used as the starting point for this widget. A relationship has been set between the shut off points and polygons. The attributes are being returned by a related record query by creating a new feature layer object. The final stage will be writing code so that the related feature is highlighted on the map. Therefore, when a user clicks a polygon, a "on-click" query will occur returning the related features attributes, and ultimately highlight that feature on the map.

Additionally, incorporating the linear irrigation pipeline features into the GIS database will improve these applications. Allowing users to identify pipes locations to proactively prevent line breaks during construction, as opposed to identifying shut off locations after a break has occurred, will increase the application's utility. The ability to check this information through a web-browser while out in the field at a construction site would be very beneficial to staff.

Importing high-accuracy CAD maps into the geodatabase would provide a level of precision greater than the existing data sets currently provide. The majority of the CAD data reviewed from the VA does not have spatial references and therefore require a complicated and timely import process. However, the new as-built drawings supplied by the contractors can be required to have a spatial reference, which makes it much easier to bring this information into GIS. This is beneficial because engineering-level and as-built construction drawings must reflect what is currently on the ground. This would allow for a more accurate placement of shut off and gate valve locations as they would be located directly on the pipelines themselves. The GIS datasets created for this project are digitized and therefore are showing relative locations of features, not precise locations. The spatial accuracy and use provisions for the project-created GIS data are specified in their respective metadata.

Future work could entail writing the correct language to be included in construction deliverable sections of new contracts for the VA. This language would specify that all CAD deliverable require spatial references, preferably into California Stat Plane, NAD 83, Zone III, feet. There is a tool within ArcMap, the Cad to Geodatabase Conversion tool, which creates new feature datasets into an existing geodatabase including annotation.

If no spatial reference exists in the CAD files, then a universal project file needs to be created. This can be difficult sometimes when trying to figure out the units used when creating the CAD file. The book, Lining Up Data in ArcGIS by Margaret Maher, provides techniques to identify data projections, and create the custom projections required to align CAD data (Maher 2013).

Lastly, training a staff member to update the GIS data and map services would reduce the dependency on one individual to make all of the changes required. As noted previously, the VA PAD campus does not currently employ another individual with GIS expertise, but that may change in the future.

6.4 Applying Geospatial Web Applications for other VA assets

One individual suggested including domestic water infrastructure information as well as irrigation infrastructure assets to the GIS database during the user presentation. This suggestion supports the project goal of illustrating the benefits of GIS technology and increasing GIS usage by the VA. Noting the locations of domestic water pipes as well as their entry points into buildings provides another valuable asset management tool for VA staff. Future work could include importing the spatially-referenced CAD drawings for domestic water pipelines. First the CAD file would need to be identified with the assistance of a project engineer. Then the information would be imported into ArcGIS as feature datasets. Determining naming conventions would be an important step, and would require input from the maintenance and project engineering staff as well. Maintaining consistency across disciplines allows for easier use of the information once it is available with a web application. Creating an enterprise-level geodatabase consisting of all the water-related assets would be an important step in providing tools to staff to increase productivity, saving the VA time and money.

Additional utility infrastructure, such as electricity, gas, and oxygen pipelines could also be incorporated into the GIS database and be available to users through web applications. This information would be particularly useful for field staff at construction sites to review before excavation or trenching activities occur.

At this time these applications are focused on external grounds assets, however another significant asset management potential is including internal building features: fire extinguishers, oxygen tanks, automated external defibrillators, and safety wash locations are but a few of the potential assets. Creating templates from the irrigation infrastructure web applications allows the technology to be applied to other assets located at the VA campus.

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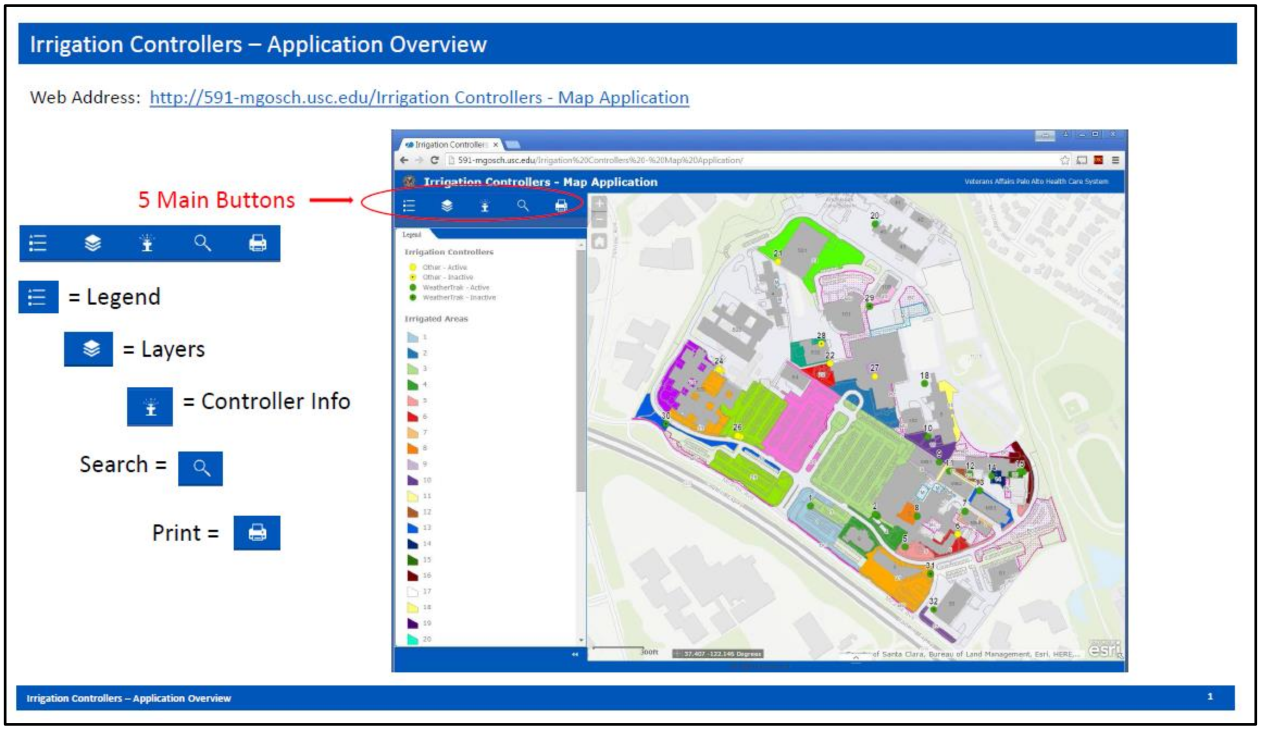
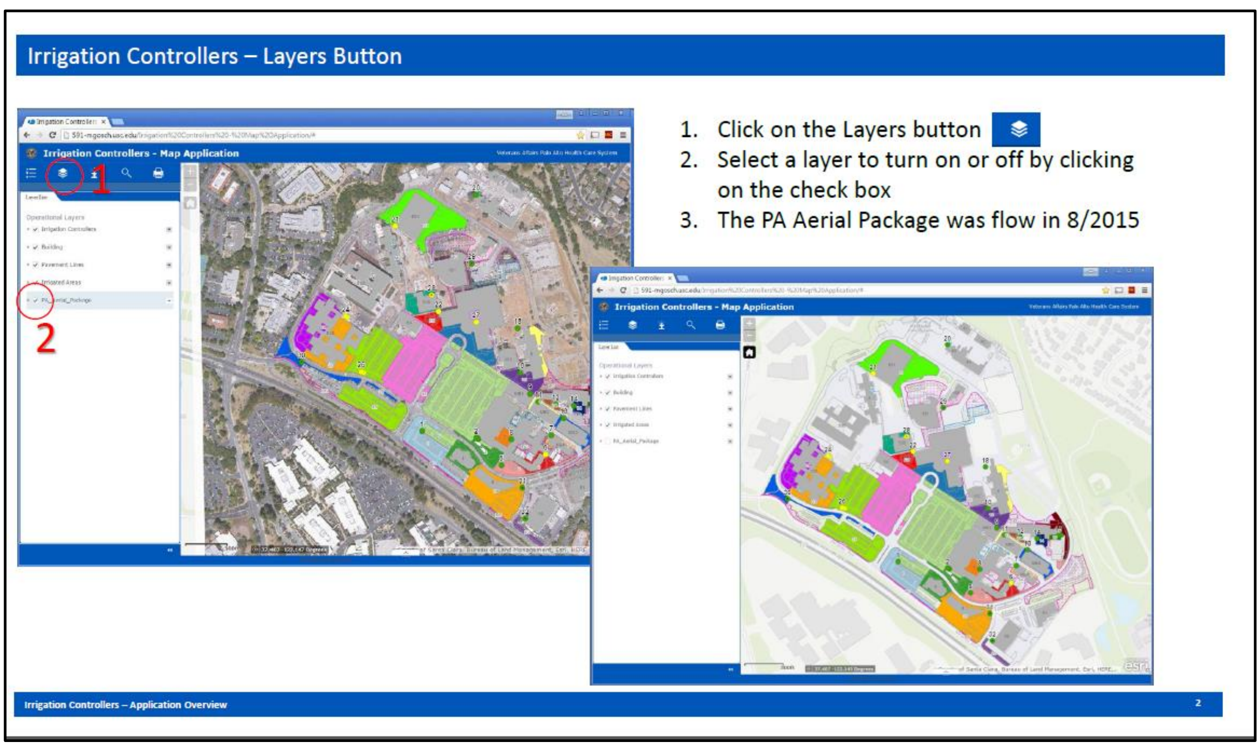
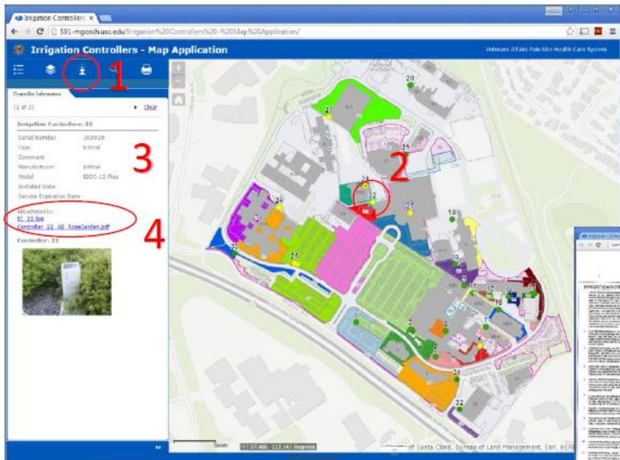
Appendix A: Irrigation Controllers – Map Application User Guide

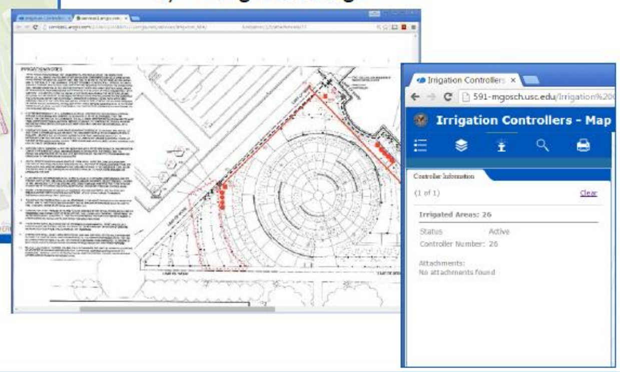




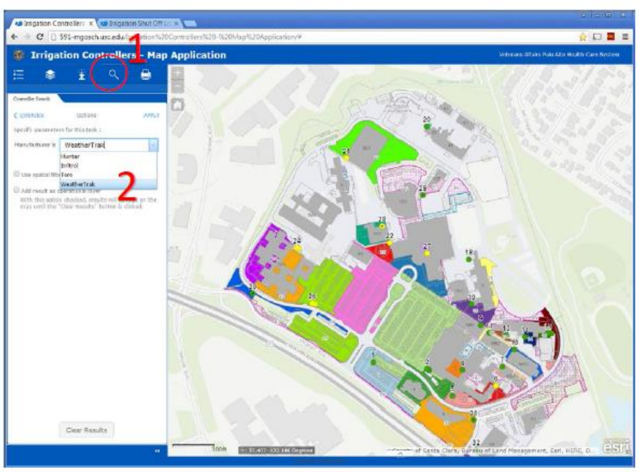
Irrigation Controllers – Controller Button



1. Click on the Controller button
2. Click on an irrigation controller or area
3. Its information pops up
4. Can also click on attachments
   a) Images
   b) As Builts
   c) Design Drawings

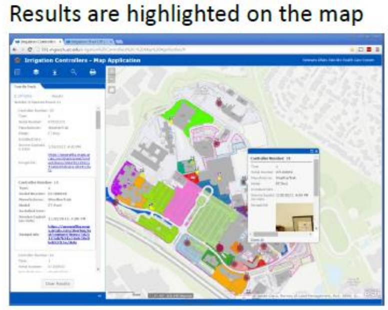


Irrigation Controllers – Search Button

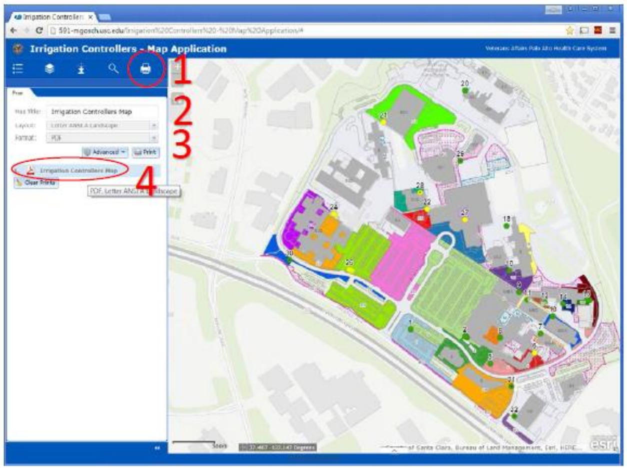


1. Click on the Search button
2. Click on controller manufacturer
3. Click on the drop-down menu and select a manufacturer
4. Click on Apply

5. Results are highlighted on the map



Irrigation Controllers – Print Button



1. Click on the Print button
2. Type in a map title
3. Click print
4. Click the newly created map link
5. You can download or print the map

Appendix B: Irrigation Controllers – Shut Off Locations User Guide

Irrigation Shut Off Locations – Application Overview

Web Address: http://591-mgosch.usc.edu/Irrigation Shut Off Locations - Map Application

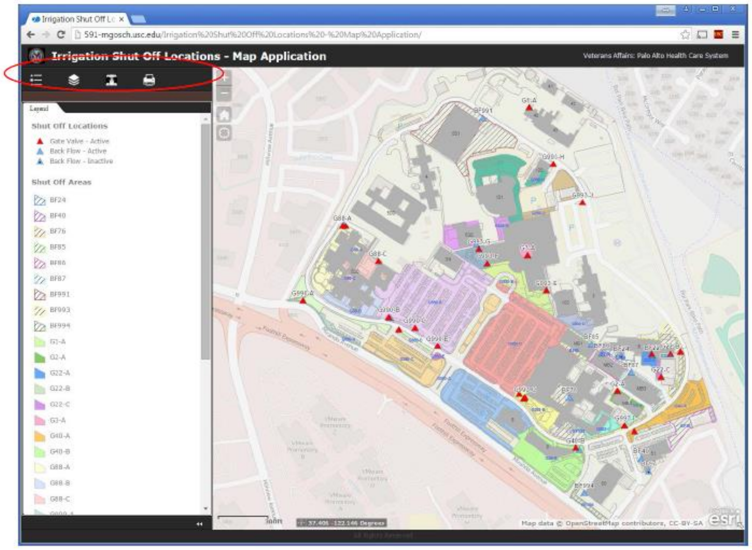
4 Main Buttons

= Legend

= Layers

= Shut Off Info

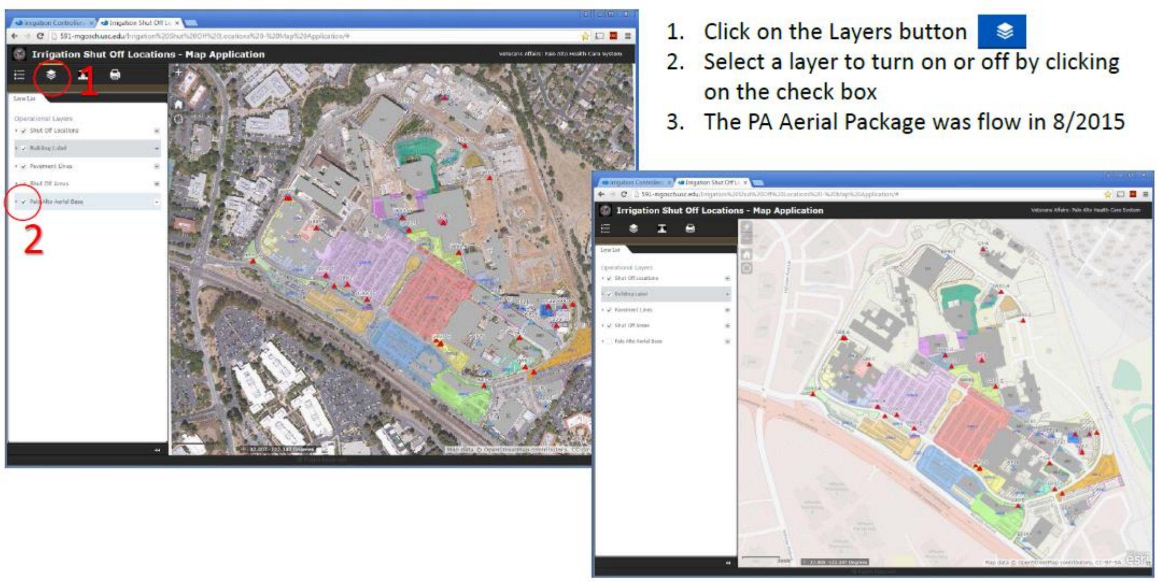
= Print



Irrigation Controllers – Application Overview 1

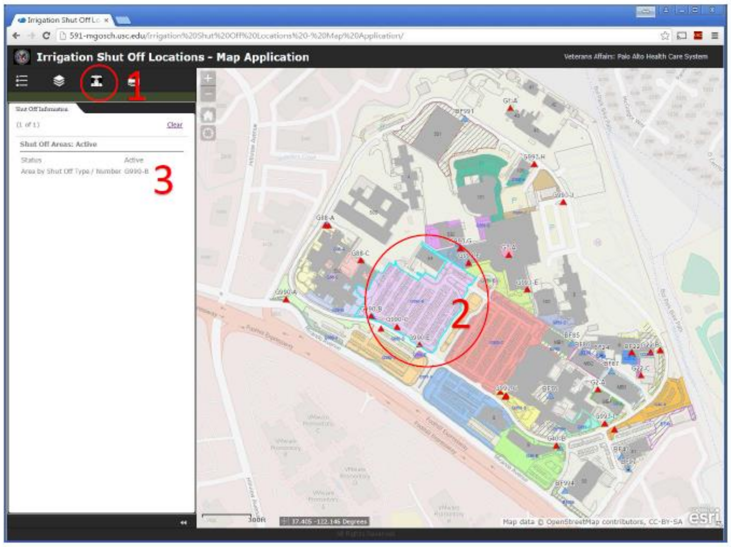
Irrigation Shut Off Locations – Layers Button

1. Click on the Layers button
2. Select a layer to turn on or off by clicking on the check box
3. The PA Aerial Package was flow in 8/2015



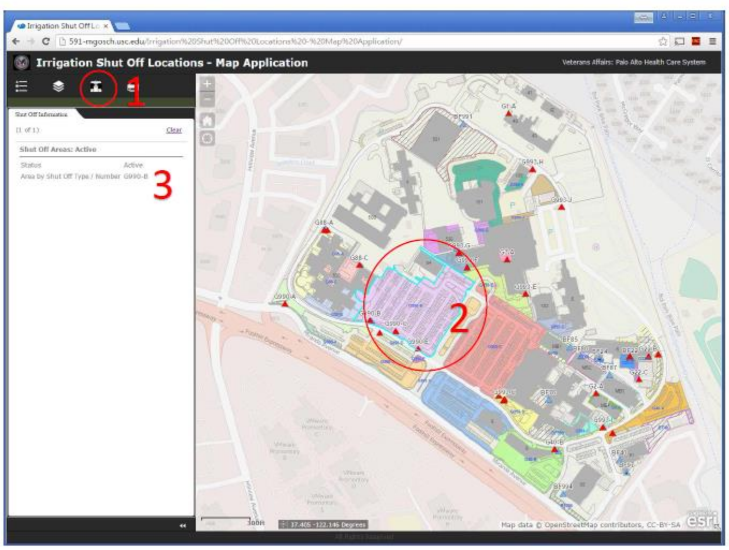
Irrigation Controllers – Application Overview 2

Irrigation Shut Off Locations – Shut Off Button



1. Click on the Shut Off button
2. Click on an shut off location or area
3. Its information pops up
   a) Identifies the back flow or gate valve number
4. Future enhancements – when you click on the shut off area, the gate valve or back flow location will be highlighted on the map

Irrigation Shut Off Locations – Shut Off Button



1. Click on the Shut Off button
2. Click on an shut off location or area
3. Its information pops up
   a) Identifies the back flow or gate valve number
4. Future enhancements – when you click on the shut off area, the gate valve or back flow location will be highlighted on the map

Irrigation Controllers – Application Overview 3

Appendix C: User Survey Form

Irrigation Map Applications - User Survey

Please select your name (all answers will be kept confidential):

1. How useful did you find these applications?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
They could help me be more effective	○	○	○	○	○
They could save me time when I use them	○	○	○	○	○
They meet my needs	○	○	○	○	○
They do everything I would expect them to	○	○	○	○	○
The Irrigation controller application is useful	○	○	○	○	○
The shut off locations application is useful	○	○	○	○	○

2. If you answered any question above with "disagree" or "strongly disagree" please let us know why you feel that way.

3. Is there more or different functionality you would like to use with either map application, please be specific.

4. How easily were you able to:

	Easily	Moderately easy	Not at all easy
Navigate around the application?	○	○	○
View information about a specific controller or shut off location?	○	○	○
Determine which point controlled a certain area?	○	○	○
Perform a search?	○	○	○

5. How satisfied are you with the applications?

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I am satisfied with it	○	○	○	○	○
I would recommend it to a coworker	○	○	○	○	○
It works the way I want it to work	○	○	○	○	○
I was able to find the information I was looking for	○	○	○	○	○

6. If you answered any question above with "disagree" or "strongly disagree" please let us know why you feel that way.

7. Can you think of any data or functions in your specific job that would benefit from this type of application? Please describe.

8. Do you have any other comments and/or suggestions?

Thank you for taking this survey! Please email this form to Megan.Gosch2@va.gov