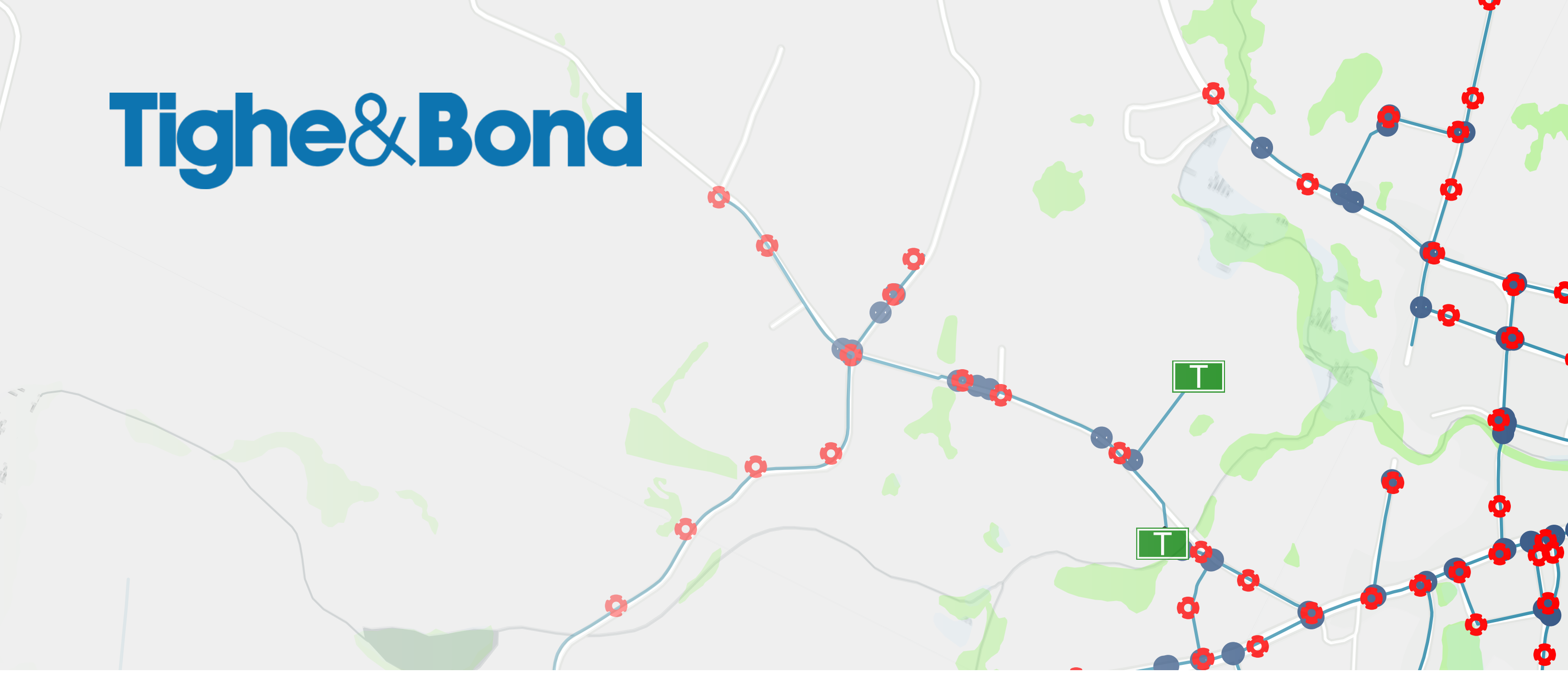

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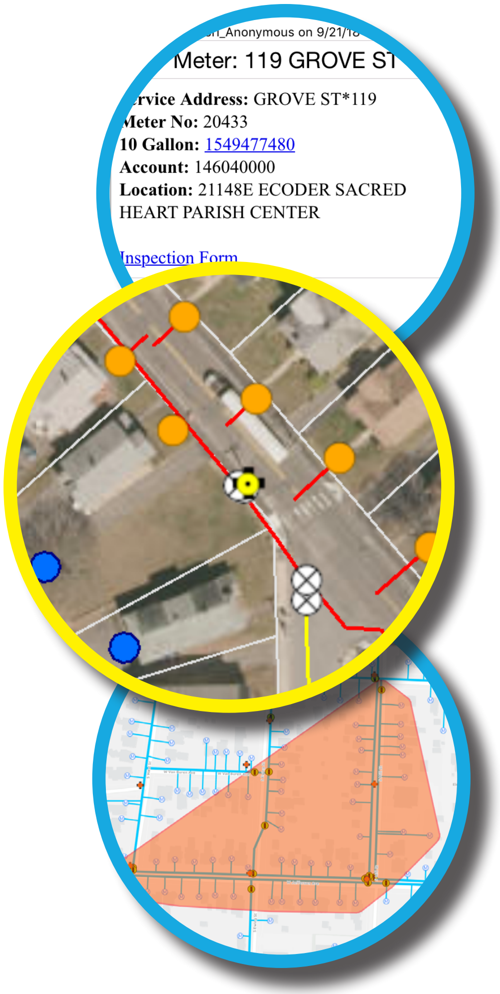
GIS Field Use Information Report



Prepared For:

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Definitions

Application: an interactive software program that is typically used on a mobile device (smart phone or tablet); commonly referred to as an "app"

Basemap: the background map that is used in a GIS map and displays a set of features (i.e. a topographical basemap shows the topography of the region); system attributes (assets) are shown on top of the basemap

Cloud: data storage that is accessed online and is saved in a remote server

Collection system: system of pipes that convey wastewater from sewer users to the centralized wastewater treatment facility

Community Water System (COM): a public water system which serves at least 15 service connections used by year round residents or regularly serves at least 25 year round residents

Distribution System: a system of conduits (laterals, distributors, pipes, mains, and their appurtenances, and in some cases includes interior plumbing) by which potable water is distributed to consumers. The Distribution System may include the source booster pumping stations, storage tanks and reservoirs.

Esri: GIS software company; acronym for Environmental Systems Research Institute

Geospatial:relating to or denoting data with locational information

GIS: geographic information system

PeopleGIS: New-England based GIS software company

Public Water System (PWS): a system for the provision to the public of water for human consumption, through pipes or other constructed conveyances, if such system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days of the year.

Publicly Owned Treatment Works (POTW): any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature which is owned by a public entity. A POTW includes any sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.

Sewer System: pipelines or conduits, pumping stations, force mains, and all other structures, devices, appurtenances, and facilities used for collecting and conveying wastes to a site or works for treatment or disposal.

Software platform: a major piece of software, as an operating system, an operating environment, or a database, under which various smaller application programs can be designed to run.

Utility Cloud: operations management software company

Section 1 Introduction

Geographic Information Systems (GIS) are an integral part of many water and wastewater systems' operations, offering mapping and database functionalities to meet utilities' many needs. From hydrant flushing and manhole inspections to emergency water main repair work, GIS allows users to store, map, and visualize geospatial data to help with both routine and emergency needs that arise at utilities. For drinking water systems, GIS data include locations of pipes, valves, hydrants, source(s), storage tank(s), pump stations, interconnections, and treatment facilities. Similarly for sewer systems, GIS data include locations of pipes, manholes, pump stations, and treatment facilities. GIS information includes physical features' locational information and descriptive attributes, such as pipe size, material, and age. GIS is a powerful tool that utilities are using to access digital data and to collect, store, and visualize asset data.

Users engage with GIS through software products, which are becoming more user friendly and affordable to reach a wider range of customers, including those without advanced knowledge of GIS. Mainstream GIS that water and sewer utilities can leverage is cloud-based and can be accessed using applications ("apps") on mobile devices, allowing multiple users within an organization to access and edit information both in the office and in the field. GIS can improve operational efficiency by streamlining paper-based planning, monitoring, and maintenance activities, using geospatial location tracking and digital forms to collect and store data in the cloud (AWWA, 2017; Woodall et al, 2017; Stern, 2015).

1.1 Background

Throughout the Commonwealth, maps are utilized by Publicly Owned Treatment Works (POTWs) and Public Water Systems (PWSs) (collectively, water utilities) for operational purposes and to meet federal and state regulatory requirements. Massachusetts Department of Environmental Protection (MassDEP) staff also use maps during emergency response efforts and for non-emergency scenarios, such as permitting, inspection and review of regulated facilities, troubleshooting utility issues, watershed protection, and resource planning. Mapping formats that are submitted to MassDEP by water utilities vary from hand drawings on road atlas maps and older blue-prints, to fully engineered GIS or Computer-Aided Design (CAD) maps.

Historically, MassDEP had no consistent method of tracking map availability or format on a statewide basis; however, in 2016, a collaborative effort between MassDEP's Water Utility Resilience Program (WURP) and GIS program resulted in the development of two map availability databases: one for community (COM) PWSs and one for municipal wastewater systems. These databases were designed to develop a uniform approach in tracking map availability and improve internal accessibility to water utility critical infrastructure information. The databases were populated with information found through internal MassDEP file review, available online information, and historical mapping efforts by various organizations, and allowed MassDEP to better understand and identify water utilities that may be in need of mapping assistance.

In 2017, MassDEP initiated the Enhancing Resiliency and Emergency Preparedness of Water Utilities through Improved Mapping Program and proceeded with a Request for

Quotes (RFQ) that sought bids from pre-qualified firms on the ITS53ProjServGIS statewide contract. In March 2017, MassDEP contracted to provide GIS mapping services free of charge for 32 communities, which were prioritized as 34 PWSs and 15 POTWs. This project also included verifying and mapping PWS interconnection throughout the state by requesting interconnection information from all COM PWSs in the state. A total of 1,195 interconnections were mapped through this effort, expanding MassDEP's previous interconnection inventory.

The data developed from the project mentioned above (referred to as the FY17 project) resulted in MassDEP and each PWS and/or POTW receiving a hard copy paper map of the respective drinking water distribution or sewer collection system, along with a thumb drive that contained a pdf image of the map, the GIS data, and a GIS metadata description report. Although most utilities maintain detailed records of their system assets, these data are not necessarily easily accessible or integrated. GIS data accurately represents the location and connection of all mapped assets, contains information about each asset (e.g., pipe size, material, date installed, flow direction for gravity systems), and brings these data together in a digital database that can be accessed anywhere. The FY17 project has assisted water utilities with enhancing their ability to better manage infrastructure assets, respond to emergencies, and meet regulatory mapping requirements as necessary. In addition, mapping initiated under this project will provide MassDEP with the tools necessary to evaluate, prioritize, and assist water utilities with critical infrastructure resilience planning and climate change adaptation, as well as improve MassDEP's ability to more efficiently respond to water utility emergencies.

In 2018, MassDEP contracted services again to:

1. Provide GIS mapping services for an additional 40 systems.
2. Validate and prepare water and sewer service area mapping for COM PWSs and POTWs across the Commonwealth.
3. Evaluate software platforms that can be implemented by small and large PWS and POTW's to effectively and efficiently leverage GIS data that has been developed through the MassDEP mapping program.

This report fulfills the third contract requirement of the 2018 Enhancing Resiliency and Emergency Preparedness of Water Utilities through Improved Mapping project.

MassDEP recognizes the value that GIS mapping can provide to the long-term planning and daily operations of PWS and POTW's, provided that appropriate field accessible technology hardware and software are implemented. The purpose of this report is to research and document field equipment and GIS technology that are being used successfully by water utilities. The information in this report will serve as a reference for Massachusetts water utilities that are receiving GIS mapping through their participation in the Enhancing Resiliency and Emergency Preparedness of Water Utilities through Improved Mapping project, as well as others in the water sector considering GIS technology. The information in this report will provide awareness that field use of GIS is common in the industry and will benefit any water utility.

1.2 Objectives

This report provides information that PWSs and POTWs can use to implement GIS in their office and field operations. GIS is a powerful tool, but utilities require appropriate software and equipment to leverage it in an uncomplicated manner. The primary objectives of this report are to:

1. Review how water and wastewater utilities can use their GIS data.
2. Summarize and compare existing GIS software commonly used by utilities throughout Massachusetts.

1.3 Approach

These objectives were accomplished by reviewing articles and presentations published in water and wastewater journals, and interviewing GIS software companies and utilities that are using GIS software.

Interviews were conducted with six utilities that currently use GIS as part of their daily operations, planning purposes, routine compliance reporting, and emergency response. The utilities interviewed serve communities across Massachusetts, ranging in size from 2,000 to 13,000 service connections.

Section 2
Uses of GIS

GIS can help water and wastewater utilities increase efficiency and improve accuracy (McKeon, 2015; Stern, 2015; Copeland, 2013; Hassy, 2010; Hassy, 2009; Mecham, 2003). This section reviews several ways in which water and wastewater utilities can utilize GIS in their routine and emergency operations. GIS provides a digital map of the system that can be accessed in the office or in the field, which can be more convenient than large paper plans or tie cards. The maps can then be used to spatially locate assets and to store data collected in the field, which can then be used for many utility operations, including asset management, compliance reporting, and regular maintenance. The utilities interviewed use GIS daily and have saved time and improved data organization since switching from paper-based to digital systems.

2.1 General Utility Applications

Many tasks common to both water and wastewater utilities can be streamlined using GIS, including:

- Mapping and visualizing the system
- Conducting inspections
- Managing data
- Performing asset management
- Managing work orders
- Engaging the public

The utilities interviewed use GIS for a range of operations. Some utilities use GIS only for general planning purposes while others use it throughout their operations for data collection and work implementation, both in the office and in the field. Additionally, multiple utilities interviewed commented on how GIS facilitated communication across departments within a community when the community used the same GIS platform across all departments.

FIGURE 2-1

GIS Data are Available on a Computer, Tablet, and Phone

2.1.1 System Mapping

GIS mapping provides utilities with a means to visualize their systems. GIS data typically contain multiple layers, each of which contains a different set of assets. Turning on and off layers allows users to visualize assets of interest on the map, making maps highly customizable. For example, a utility user can visualize water mains on a map by selecting the water main layer, and then add the fire hydrant layer to visualize the placement of fire hydrants relative to water mains throughout the system. This same visualization can be applied to other asset data layers such as valves, storage tanks, pump stations, manholes and treatment plants. Asset symbology, such as color or proportional sizing, can easily be changed, helping to differentiate among various assets, such as different sized water and sewer mains. Digital maps, unlike paper maps, also allow users to zoom in and out to provide a range of high level and detailed views of the system.

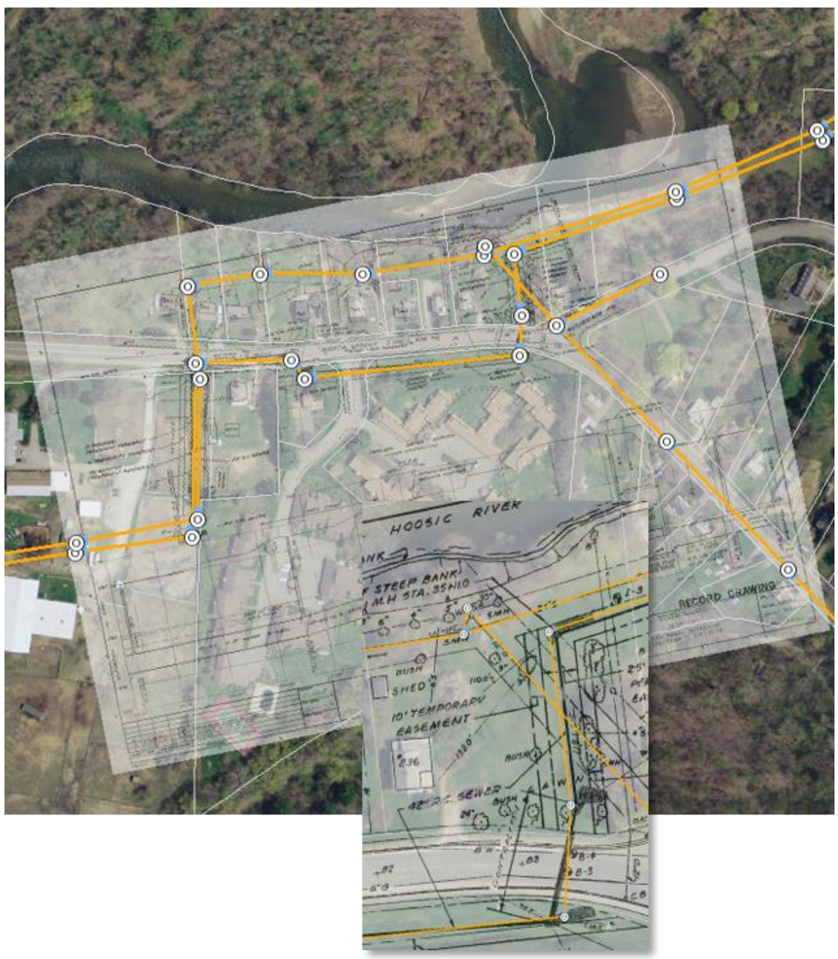


FIGURE 2-2

Pipe and Manhole Data and Plans Overlain on Satellite Image

Using different base maps, such as topography, imagery (similar to GoogleEarth) or streets, allows users to visualize assets with respect to different background attributes. For example, viewing the utility's water and sewer mains on a street map allows the users to see where the mains are in relation to homes and other buildings (Figure 2-2). A topographic map provides elevations and natural resources, which can be helpful for planning purposes. Changing the mapping layers shown, the asset symbology, and the background base map provides users a multitude of ways to visualize the system. Mapping for visualizing the distribution and/or collection system and for general planning was the most common way in which utilities use GIS, as indicated in the utility interviews.

2.1.2 System Database and Asset Management

GIS serves as a database for the utility. Many of the utilities interviewed found it helpful to have all system data saved in one program, with the ability to visualize the data spatially. Asset information, such as make, model, installation date, and inspection results, are linked to each asset and stored as attributes of each asset. Some utilities use the Check Up Program for Small Systems (CUPSS) provided by the United States Environmental Protection Agency (US EPA) to collect and manage asset data, which can be easily incorporated into their GIS. In addition, non-GIS data including scanned record plans, tie-cards, and pictures can be saved within GIS and linked to the specific asset (Figure 2-2). Once saved in the map, a user can easily access this scanned information by clicking on a specific asset. This feature saves time and allows utility personnel to access important system information remotely. The utilities interviewed also use the GIS platform to store data collected in the field, as well as electronic copies of paper records, including plans, tie cards, and inspection forms.

Asset management encompasses a large part of utility operations and can be significantly improved with the use of GIS (Cardoso et al, 2015; Copeland, 2013; Totman, 2016; Harris, 2017; Hassy, 2009; Hassy, 2010). The maps store locational data while the background database stores additional information about the assets' performance, history, and specifications. Displaying asset data on maps can help prioritize repairs – visualizing populations, resources, and other assets on the map can be used to identify high risk areas that might require more immediate attention (McKeon, 2015).

2.1.3 Inspections and Monitoring

Some of the interviewed utilities use GIS for mapping and data management, but they still rely on paper forms to track inspections and repairs. Many required inspections and routine tasks can be performed more efficiently using GIS. Typically, with a paper-based system (e.g. work orders, and daily logs) additional work is needed to store the hardcopy records or enter them into a computer-based data management program. Additionally, paper-based systems sometimes involve different people collecting and storing information, increasing the chances that data could be lost or copied incorrectly. GIS simplifies workflows and improves accuracy by providing digital communication and digital data entry. The utilities interviewed that use GIS to store data digitally in the field find the process to be more efficient than paper-based systems. Being able to enter the data digitally in the field has saved the utilities time and has made completing regulatory compliance reports easier.

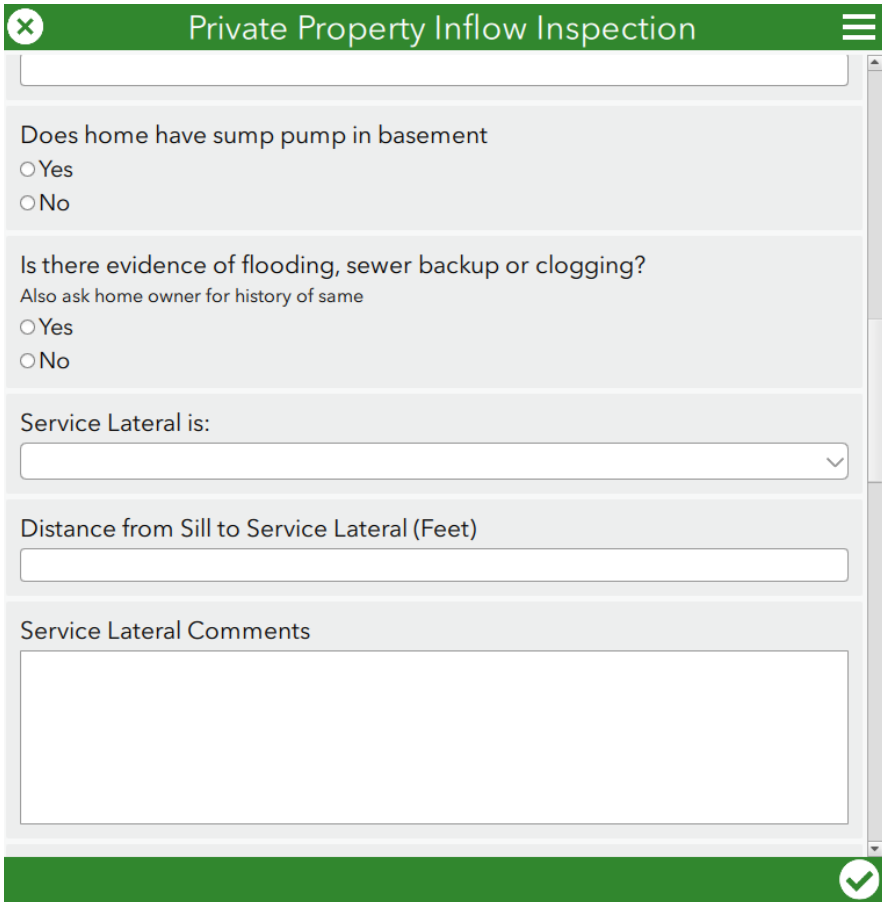


FIGURE 2-3

Example Inspection Form in GIS

Inspection forms can contain radio buttons, check boxes, drop down menus, comment boxes, and space for the user to draw a sketch or take a photograph. Figure 2-3 shows an example inspection form for an internal building inspection to identify private sewer inflow sources like sump pumps. Forms also can be used to guide crews through tasks that contain multiple steps, such as hydrant flushing, which supports correct and consistent work (McKeon, 2015).

Online access to maps outside the office can facilitate communication between office staff and field crews during inspections and monitoring activities. When field crews record data about an asset in the field, the information is saved in the mapping database and is then available to all users. Users can also browse inspection and reporting history for an asset to gain a better understanding of the asset’s performance and to adhere to the inspection schedule. Storing inspection and performance data in the GIS database also makes monitoring and preventative maintenance easier, which can save the utility costly emergency repairs. Real-time changes in asset symbology can be used to communicate the field crew’s progress through routine inspections, such as backflow preventer inspections and manhole inspections.

Digital data collection using GIS has largely been discussed for distribution and collection system operations (McKeon, 2015; Ekadis, 2016; Conant and Lewis, 2014; Stern, 2015;

Totman, 2016); however, GIS can significantly improve inspections and monitoring at water and wastewater treatment plants as well as at pump stations. Treatment plants and pump stations can be located in the system map as one or multiple assets in which data can be stored. Data collected during hourly, daily, weekly, and monthly rounds at water and wastewater treatment plants can be saved in the GIS database and be made available for compliance reporting. Furthermore, routine inspections of pump stations and pressure readings can be stored in pump station assets in the map.

2.1.4 Work Order Management

Work orders for preventative and corrective maintenance can be streamlined using cloud-based GIS platforms (McKeon, 2015; Stern, 2015; Pociask, 2015; Ekadis, 2016). Like inspection forms, work order management has traditionally been a time-consuming paper-based system. Paper-based work management systems require field crews to routinely travel to the office to pick up work orders and relevant site information (e.g., plans or tie cards), travel to the site and complete the work, and return to the office with completed work order forms. One of the utilities interviewed uses GIS to electronically manage work orders. A manager in the department creates an electronic work order in GIS and shares it with the field crew via a mobile device. Through GIS, the crew has access to the system map, including valve locations, and potentially scanned record plans and tie cards, depending on how developed their GIS database is. The work order and maintenance history are stored in the GIS platform and can be used to identify trends and prioritize capital improvements.

Digital, cloud-based work order management in GIS is especially helpful in emergency situations, when problems need to be addressed in a timely manner. During a water main break, field crew locations can be viewed in GIS enabling the superintendent to dispatch work to the nearest field crew. The field crew will have access to relevant system information in the field, without having to come back to the office. The GIS can contain valve locations, direction and number of turns to close, or information about inoperable valves. In addition, critical customers that will be impacted and hydrants that may be out of service can be identified immediately. Record plans and tie cards can be accessed from GIS to inform field crews of additional information from construction documents that will guide informed decision-making while in the field. Thus, GIS facilitates prompt response to emergency issues, which will minimize water loss and service interruptions. Over time, patterns of main breaks and other events may be solved through machine learning, which is a field of artificial intelligence (AI) that allows computers to learn from information and analyze large amounts of data to find patterns and hidden insights that will help better assess infrastructure replacement needs.

2.1.5 Public Engagement

Maps can be a great way to engage with the public, many of whom are the utility's customers. The utility can maintain a public version of their system map online, for example on the utility's website. The utility can publish combined sewer overflows, sanitary sewer overflows, water service outages, drinking water advisories, and upcoming capital improvements on their website to promote transparent operations and public engagement. GIS platforms can also be used to collect customer complaints or service information. Customers whose water and sewer providers enable GIS-based customer complaint collection can click on a location and complete a questionnaire describing their complaint, such as discolored water or low pressure. The utility can design the complaint form to request specific information that helps them troubleshoot the issue before responding. The utility can also design forms to gather specific information about service connections they may otherwise not be able to easily access, such as lead service lines. Collecting customer complaints or information in a spatial database allows the utility to collect information consistently, visualize problematic areas, and enhance their asset data within the distribution system to better prioritize improvements.

2.2 Water Applications

This section presents examples of routine, emergency, regulatory, and maintenance tasks that water utilities can perform more efficiently using GIS. These tasks include:

- Fire hydrant inspection and flushing
- Valve exercising
- Dig safe mark outs
- Valve isolation during a water main break
- Storage tank inspection
- Water meter replacement program
- Access to tie cards during routine and emergency repairs/replacement
- Water meter reading routing/tracking
- Water quality tracking

Water utilities that use GIS applications in their daily operations recognize many operational efficiencies.

Field crews that have GIS access to water service tie cards, record plans, and previous inspection data from a mobile device save time by having the information they need, when they need it, in the field. Traveling back to the office to make copies of paper records is no longer required. The information required to work on water customer service connections, marking out Dig Safe requests, or responding to a water main break, are always available through a mobile device. GIS tools accessed through a mobile device can provide valve isolation solutions instruction field crews the locations of valves to close to isolate a main break.

Recording the results of scheduled maintenance (hydrant flushing and valve exercising) and periodic inspections of hydrants, tanks, and pumps are documented at the time of inspections in the field. The resulting information is entered once eliminating the need for paper forms that require transcribing in the office. Information recorded in the field in GIS are available immediately to other field crews and office staff. Previous inspection data are also available to field crews at the time of inspection. The information recorded in GIS are well organized, in a shared location, and accessible as needed to simplify compliance reporting.

The use of GIS to schedule equipment repair and replacement (hydrants and water meters) provides efficiencies in scheduling by geography and recording results once in the field.

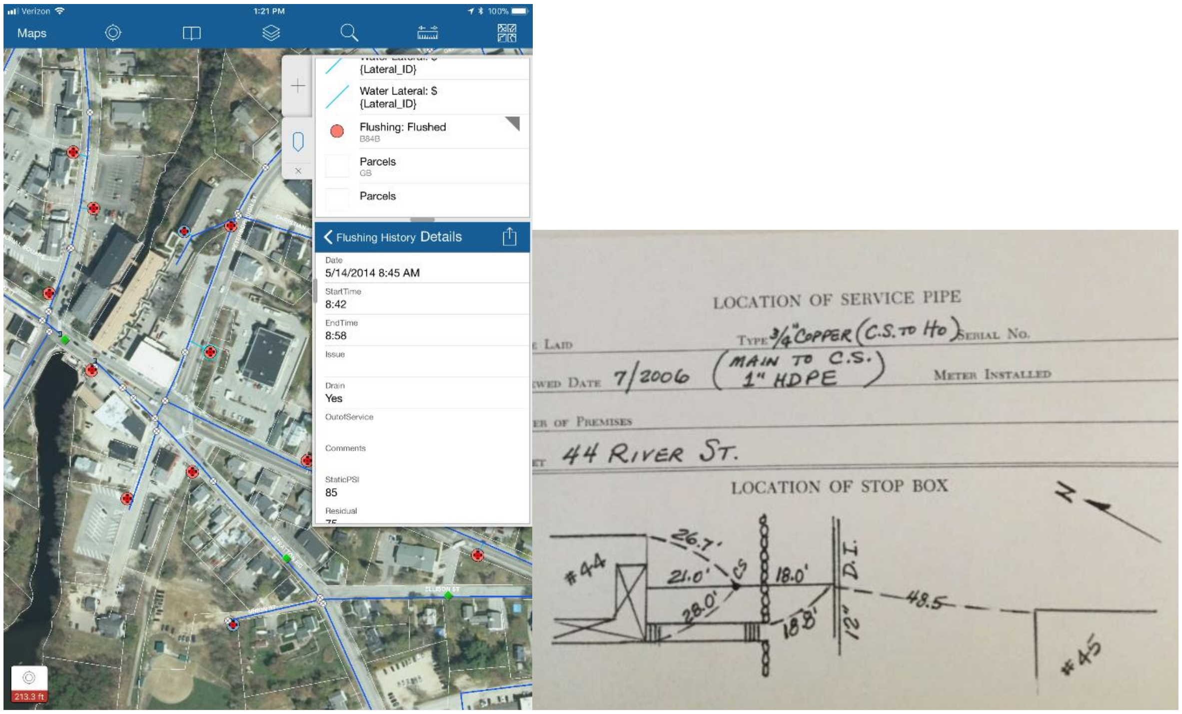


FIGURE 2-4
Valve Location and Stop Box Plans

Water system mapping in GIS also helps in visualizing challenges throughout the system and creating targeted solutions. Mapping dirty water complaints can be used to identify concentrations of customer reported issues and help water system operations address locations of their system that may require increased flushing frequency or alternatives such as ice-pigging

The utilities that were interviewed used GIS for a variety of utility operations, including hydrant flushing, water main relining projects, water meter installation projects, valve exercising, meter replacement and reading, backflow preventer inspections, daily rounds at the water treatment plant, and general planning purposes. One utility commented that GIS has been useful in responding to emergency situations, such as water main breaks, because it facilitates identifying nearby valves and providing field crews with more detailed directions so that valves can be shut off quickly to stop the flow of water.

2.3 Wastewater Applications

The same GIS capabilities that can enhance water system operations also can benefit wastewater utilities. GIS wastewater applications include:

- Pump station inspections
- Manhole inspections
- Access to sewer line CCTV inspection data
- Repair and replacement of wastewater system components
- Sanitary sewer overflow (SSO) documentation

- Fats, oil, and grease (FOG) inspections
- Infiltration and inflow programs, including building inspections

Wastewater utilities that use GIS applications in their daily operations recognize many operational efficiencies for many of the same reasons described for water utilities.

Field crews that have GIS access to sewer service tie cards, record plans, and previous inspection data from a mobile device save time by having the information they need, when they need it, in the field. Traveling back to the office to make copies of paper records is no longer required. The information required to work on sewer customer service connections and marking out Dig Safe requests are always available through a mobile device.

Recording the results of routine pump station, manhole, and FOG inspections, as well as SSO events are documented at the time of inspections in the field. The resulting information is entered once eliminating the need for paper forms that require transcribing in the office. Information recorded in the field in GIS are available immediately to other field crews and office staff. Previous inspection data are also available to field crews at the time of inspection. The information recorded in GIS are well organized, in a shared location, and accessible as needed to simplify compliance reporting.

Sewer system CCTV inspection information are typically provided on DVD. The CCTV video are large files and often remain on DVD and are not easily shared. These files can be uploaded to YouTube, each video linked to the corresponding sewer main in GIS and made accessible from a mobile device or office computer.

GIS is useful for infiltration and inflow (I/I) projects. Manhole and building inspections, including photos and sketches, can be documented using GIS software. Clusters of I/I-related issues can be identified by mapping the results of several types of inspections together. For example, flow isolation data can be mapped along with manhole inspection results to identify high infiltration areas that would benefit from sewer rehabilitation.

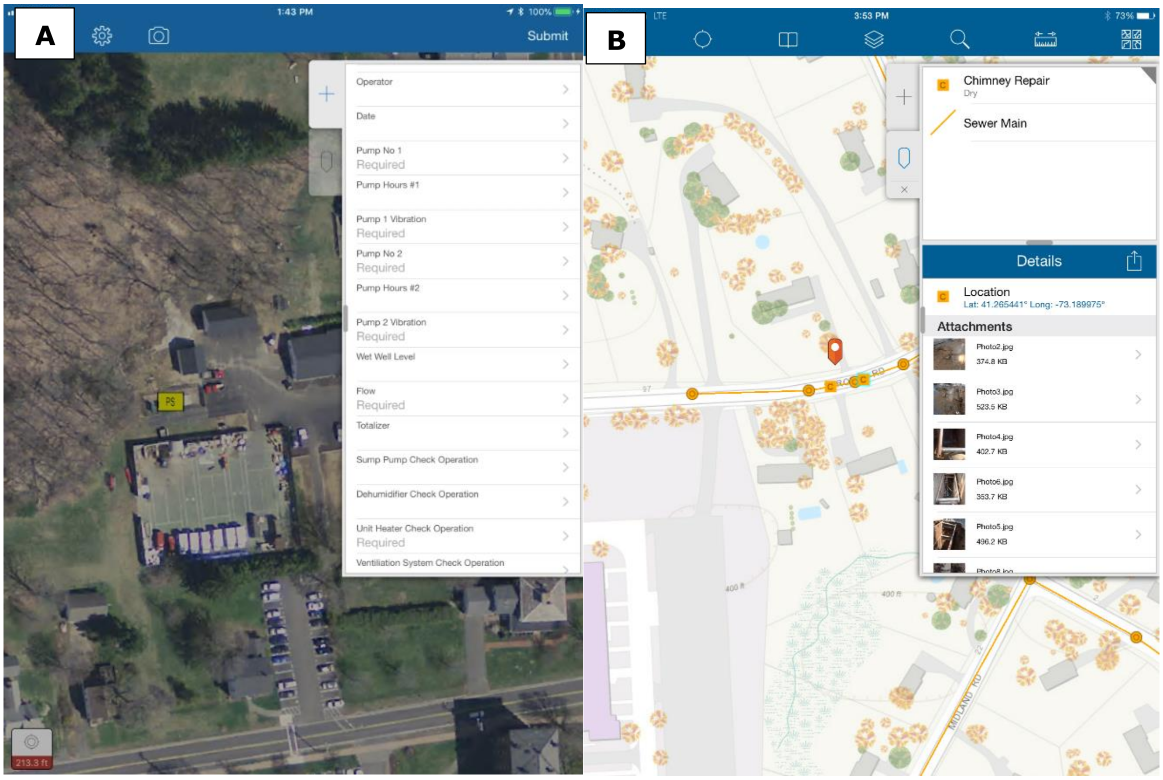


FIGURE 2-5

(A) Pump Station Inspection Data and (B) Sewer Chimney Repair Reports with Photographs

The utilities interviewed used GIS for several applications, including identifying which parcels have sewer service for planning purposes, creating electronic sewer permits, and conducting manhole inspections. Some of the utilities have found it useful to collaborate with other departments using GIS. For example, visualizing both water and sewer mains on digital maps helps with planning and can be shared with other departments when needed, such as the building department and board of health.

Section 3
GIS Software Programs

GIS platforms offer water and wastewater utilities a way to manage their asset and workflow data for easy visualization and more efficient operations. With online GIS platforms, data can be accessed and modified using a web browser on a desktop computer, or an application (app) on a mobile device (tablet or smartphone), eliminating the need for powerful hardware, and streamlining the data retrieval and entry process, while lowering the risk of data loss. Online GIS platforms also allow data to be shared across an organization in real time. Maintaining a digital database on the system helps utilities manage and track large amounts of data (Woodall, 2017). Environmental Systems Research Institute (Esri), PeopleGIS, and Utility Cloud are three platforms used by water and wastewater utilities in Massachusetts for storing, visualizing, collecting, and managing data. This section reviews the strengths, drawbacks, and cost structure of these platforms.

The three platforms provide similar tools for water and wastewater utilities, including maps with layering options to view assets throughout the system and forms to facilitate data collection and work management practices. They are all available on mobile devices, which allows utilities to use the software both in the office and in the field. The differences among the platforms pertain to their client focus, range of tools, and technical capabilities.

A utility must have their system data in a GIS format before using any of these platforms. Several utilities in Massachusetts have benefited from the MassDEP-funded program to digitize and map their system's assets, including the location and connectivity of mains, valves, pump stations, treatment facilities, etc.

Esri's ArcGIS is considered the industry standard GIS data format, and software platform. Esri GIS software Esri's ArcGIS is a GIS platform that offers a broad range of tools that are designed to be flexible to serve a wide range of users and industries. In contrast, PeopleGIS and Utility Cloud provide a subset of the tools offered by Esri that focus on work orders, permitting, and compliance reporting. While both offer mapping capabilities, PeopleGIS brands itself as a data management platform and Utility Cloud brands itself as an operations management platform. PeopleGIS and Utility Cloud aim to provide simple tools that can be used by utility clients without the help of a GIS expert or an outside consultant.

3.1 Esri

ArcGIS Online

Esri's ArcGIS (https://www.arcgis.com/index.html) is the industry standard, and as such, has become the most well-known and widely used GIS platform worldwide. ArcGIS is used by scientists, engineers, and analysts in a range of industries for geospatial mapping and analysis. ArcGIS is available as a desktop software program and through an online platform. The frequently updated online platform allows users access to the GIS maps online and provides users with many additional tools through the mobile apps.

3.1.1 Mapping

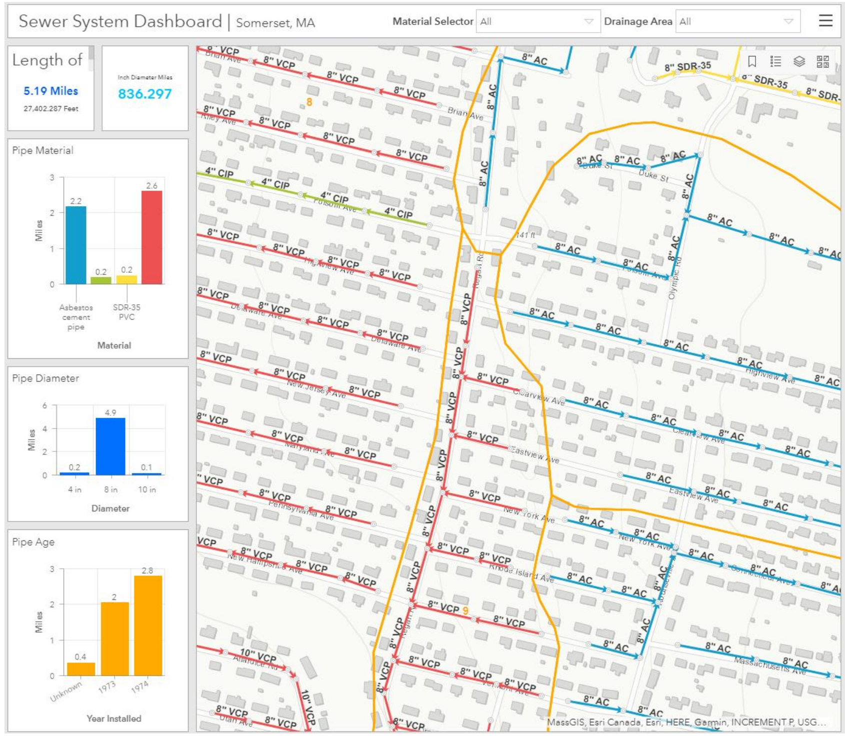
As with the other programs discussed in this report, end users interact with digital maps containing a choice of base maps, and layers with different assets. ArcGIS allows users to perform calculations on the data within database tables and present results on the map. Some utility users don't need to perform frequent geospatial calculations in GIS, but ArcGIS can perform spatial analyses when needed.

Examples include valve isolation tracing during a watermain break, network tracing to determine flow direction, buffering to determine customers within a distance of a treatment plant, or critical infrastructure within a floodplain or inundation zone

3.1.2 Form-Based Data Collection

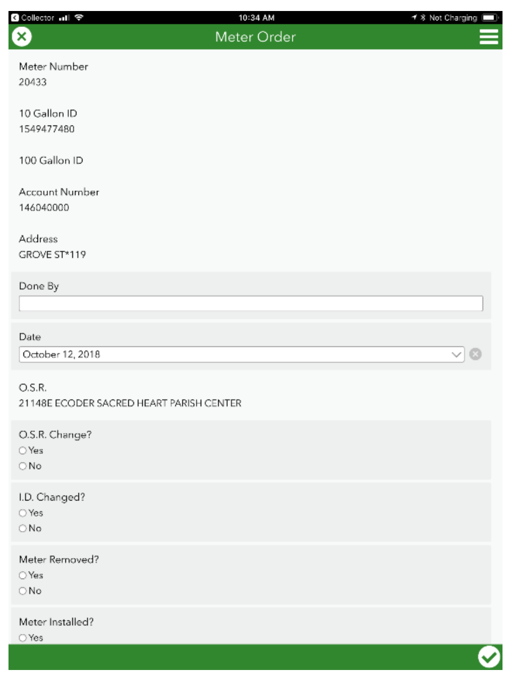
Esri's ArcGIS online platform contains several mobile apps that utilities can use to complete many routine and emergency tasks. The Collector and Survey123 apps are used to collect data in the field. Collector contains the map and shows the user's location. It can be used to add new assets and make edits to existing assets within the utility's existing GIS while in the field. Survey123 contains forms that are used to enter information about an asset, such as inspection results, in the field. Data entered in Collector and Survey123 get incorporated into the GIS database as asset-specific information. Once saved in the GIS database, users can click on the asset and see the update information that was collected in the field.

Esri also provides work order management apps: Workforce and Navigator. Workforce allows managers to assign work orders to staff currently in the field and receive status updates on the work, eliminating travel time to the office and paper forms. The app can be used for routine inspections but is especially useful for emergency operations, such as water main breaks, when issues need to be addressed as quickly as possible. Navigator provides optimal driving routes to staff members to navigate to various assets throughout the system. The Navigator app is also helpful for determining pre-planned routes, which many be useful for certain routine tasks such as water meter reading. The app directs the user through the pre-planned route to access assets of interest.



Within the office, **Operations Dashboard** is a useful tool for managing the various operations occurring throughout the system. Operation Dashboard is a data visualization app that allows the user to view maps of the existing system while simultaneously view new data being collected in real time.

Esri has many advantages over other GIS platforms, given that it is widely used, the industry standard, and frequently updated. It is a robust software with a wide range of tools and capabilities, and new functionality is released routinely. Esri offers numerous apps to help utilities address their many needs and the mapping software contains many tools to help users visualize any aspect of their data. One specific advantage for utility users is that Collector and Survey123 can be used offline. Therefore, field personnel can continue to view, collect, and save data when cellular data is unavailable. Synchronizing offline data is handled by Esri when the mobile device is connected to wi-fi.



Once established, the maps and apps are visually appealing and user friendly. Knowledge of GIS is required to create and organize data, create maps and configure forms. Utilities that do not have access to suitably trained GIS experts within their organization typically seek support through their municipality, or engineering consultants that are already engaged in providing consulting services to a utility. Esri is the industry standard, used by most municipalities and engineering consultants that use GIS, thus access to experienced GIS support are readily available.

3.1.3 Costs

Esri charges $500 per year for an individual ArcGIS online account. An ArcGIS online account provides access to the online GIS mapping software as well as a suite of applications, such as Survey123 and Collector which work together to build the organization's maps and database. The $500 annual fee includes service credits required to perform certain geoprocessing functions in ArcGIS, such as analytics and creating demographics maps, or for additional storage. Additional service credits can be purchased for a fee, depending on your user account type; however, water and wastewater utility clients do not typically require more service credits than those included in the ArcGIS online account.

3.2 PeopleGIS

PEOPLEGIS

PeopleGIS' SimpliCity (https://www.peoplegis.com/) is a web-based data management platform that includes GIS and other tools to help utilities track, manage, and automate operations. PeopleGIS began as a GIS platform, but has expanded into a data management platform to focus support of utilities. The company reportedly serves over 100 communities, mostly in New England. The SimpliCity online platform is made up of maps and forms that enable utilities to view and store spatial, asset, and operational data. These tools provide many of the same capabilities as ArcGIS that are useful for water and wastewater utilities. Users must purchase apps available in PeopleGIS separately, however, the company allows unlimited access, both in the number of users and the number of products created (i.e. maps or forms).

3.2.1 Mapping

System mapping is accomplished using MapsOnline, the app for mapping, which hosts the utility's system maps in the online platform. Utilities that purchase the MapsOnline app are required to participate in 1 to 2 days of on-site training provided by PeopleGIS. Like ArcGIS, maps can include multiple layers that can be turned on and off to show different sets of assets. MapsOnline allows the utility to specify what data is available to different users. For instance, the utility can limit the data displayed on publicly available maps and only display a subset of its data on maps that are shared with the public. MapsOnline supports the creation and hosting of an unlimited number of maps and can be used by an unlimited number of users. The unlimited access to the software is useful if there are many users within the utility or municipality and a wide variety of mapping needs.

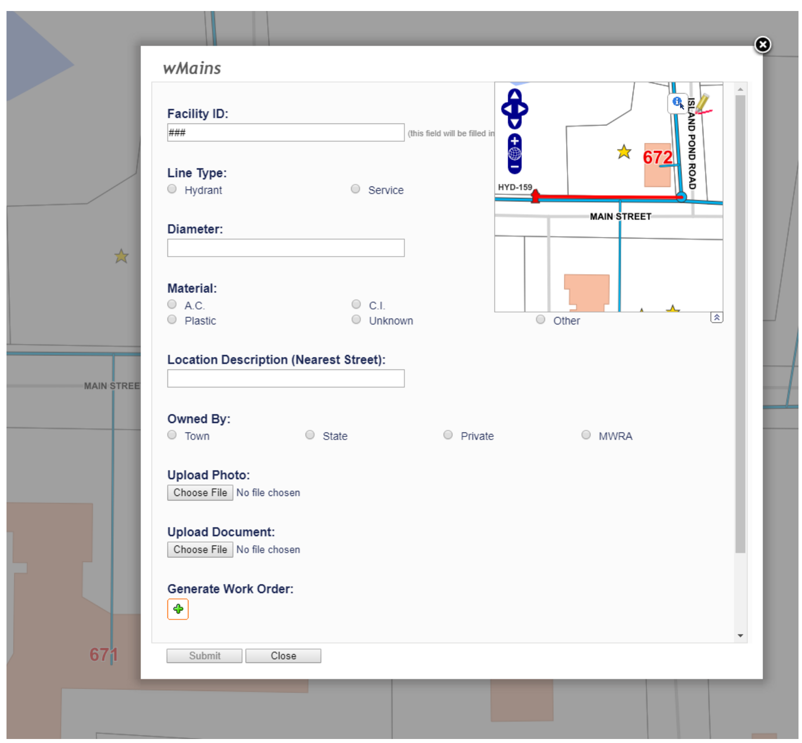
3.2.2 Form-Based Data Collection

Forms are used to collect information about the utility's assets and operations. They can be created by clients using the PeopleForms app or purchased as pre-made forms within a Professional Suite. The PeopleForms program allows users to create their own specific forms, and the process appears to be user-friendly. Utilities also have access to a Forms Library containing forms developed by other utilities. Utilities that purchase the PeopleForms app must participate in training, which teaches users how to create new forms. Like the MapsOnline training, the PeopleForms training typically includes one or two days of on-site training for an additional cost.

Clients also can purchase professional suites that contain pre-made forms that are designed to meet the utility's needs as well as a map for spatial visualization. Forms are divided into two categories: event forms and physical forms.

> *Event forms* are used to collect information about an event, such as an inspection or hydrant flushing, and store the data collected in the utility's database within SimpliCity.

> *Physical forms* are used to collect information about a physical asset, such as a fire hydrant or a valve, and link the data to the map through a street address so that the asset data can be displayed on a map.



Suites that are most commonly used by water and wastewater utilities include the Water Asset Management app, the Sewer Asset Management app, the Work Order Management app, the Permit app, and the Quick Assets app. The Quick Assets app is a simplified mapping app that is used to add new assets and modify existing assets in the field. Any edits made to maps in the field are marked as drafts, which can then be reviewed by office staff or any user with authorization to accept drafts. The authorized user can accept the drafts electronically within the app to finalize the edits so that the new information is saved within the map.

Advantages of PeopleGIS include its user-friendly interface, its pre-packaged sets of forms for utilities, and its unlimited licensing. The packages of forms simplify start-up for utilities because they are equipped with a number of forms that are developed specifically for utility operations. Unlimited licensing allows utilities to share the GIS maps and data with as many users as needed. One major drawback to using PeopleGIS is that currently there is no option to work offline. If no mobile wifi or data service is available, users cannot access PeopleGIS. Additionally, the utilities interviewed use Esri alongside PeopleGIS for handling geodatabases and performing complex geospatial calculations since PeopleGIS cannot perform such functions.

3.2.3 Costs

The cost to clients is based on the population served by the utility. Once a utility becomes a client, there is no limit to the number of users that can access the web-based platform. Similarly, if a client purchases PeopleForms or MapsOnline, there is no limit to the number of forms or maps that can be created. Upfront costs include set-up and training. App-specific training is required if the client is purchasing MapsOnline or PeopleForms. Clients are also charged an annual fee (based on community population) to have data hosted, receive customer service, and support continuous improvement of the platform.

A small utility using the Water Asset Management app, the Work Order Management app, and the Quick Assets app can expect to pay approximately $7,000 per year, plus an additional $3,000 to $4,000 for initial set up. A large utility can expect to pay approximately $12,000 per year for the same three apps. Additionally, PeopleGIS charges $1,500 per day for on-site training for utilities located in eastern Massachusetts. Additional fees may apply for on-site training if extensive and/or overnight travel is required.

3.3 Utility Cloud

utilitycloud

Utility Cloud (https://utilitycloud.us/) is a cloud-based operations management platform for utilities. It started as a water and wastewater regulatory compliance consultant and has since become an operations management platform that serves clients in over 100 countries. Their primary client base is international oil and gas industries, but they also serve water and sewer clients in New England. Utility Cloud is not a GIS platform and therefore cannot perform complex geospatial calculations. It works with GIS to store and manage data; a utility's asset data can be shared between Utility Cloud and a GIS platform, and the two platforms can automatically sync data from one to the other.

3.3.1 Mapping

Utility Cloud offers interactive, hierarchical maps to visualize the utility's assets. As a user focuses in on a particular asset, more of its data become visible. For example, zooming in on a pump station can show the pump station, pumps within it, and separate pump components (e.g., pump, motor, and flow meter). Maps can show data dynamically and update in real time, showing progression through regular maintenance programs or the locations of field crews.

3.3.2 Form-Based Data Collection

Asset and inspection data are saved in Utility Cloud by inputting data in forms or uploading data from SCADA (supervisory control and data acquisition) systems. The utility can create their own forms or use one previously developed by other utilities. Data entered into Utility Cloud can be exported to regulatory compliance reports.

Utility Cloud's platform is web-based, meaning that users access the platform via a web browser, as opposed to using a mobile app. Data saved by users in the field is available to all other users within the system, both in the field and in the office. Users can work offline, and data is synced to the cloud once connected to the internet.

3.3.3 Costs

The cost to clients is based on the number of users, the amount of cellular data used, and the implementation needs. Utility Cloud charges clients $85 per user per month ($1,020 per year) for the subscription and maintenance. User accounts are calculated at the end of the month as the average number of concurrent uses in a 24-hour period, after removing the two days with the highest usage. For example, weekday crews and weekend crews would share the same accounts. Cellular data costs $0.28 per GB per month, with a minimum requirement of 100 GB ($336 per year). Finally, additional costs are incurred for first-time implementation of Utility Cloud, depending on the specific needs of the client. First-time implementation needs may include data formatting, developing apps, and training.

3.4 GIS Software Summary

The software programs evaluated in this report are accessed through a web browser on desktop computers and web browsers or apps on mobile devices (smart phones and tablets), providing access to end users seamless regardless of the point of access; in the office or in the field.

GIS data storage is Cloud-based and managed by the software vendors, eliminating the utility need for managing servers, software installations, operating systems, and security.

The GIS software programs evaluating for this report will run on common computing platforms (Windows, iOS, and Android) and can be used to access GIS data through a web browser, or downloadable apps.

When used on mobile devices in the field, built-in GPS capabilities enable users to track their locations and identify nearby assets. To improve upon locational capabilities, users can pair a mobile device with Bluetooth enabled GPS devices if needed. Industry standard GPS hardware providers such as Trimble offer a mapping grade (+/- 1-meter accuracy) for approximately $2,500.

Section 4
Conclusions

GIS can significantly improve water and wastewater utility operations through digitizing mapping, data management, and data collection. Using GIS software can streamline many utility operations, such as mapping, planning, database management, asset management, routine inspections, emergency response, work order management, public engagement, and many more.

Esri, PeopleGIS, and Utility Cloud, three software platforms for engaging GIS data, have been used by water and wastewater utilities across Massachusetts. All three platforms allow users to visualize their assets in customizable maps and collect data at assets in the field using forms on mobile devices. They differ with respect to initial startup effort and support services, technical capabilities, licensing structure, and mobile features.

Multiple utilities that currently use one or more of the software platforms were interviewed to gauge the impact GIS has had on their system operations. The utilities interviewed experienced many benefits to using GIS, including time savings, paper reduction, improved communication, and easier data management.

We recommend that utilities consider the following questions as they look to implement GIS:

1. What tasks/operations is the utility looking to convert digitally?
2. How many GIS users will the utility have?
    a. Will any of the anticipated users primarily use GIS on a mobile device in the field?
3. Do other departments in the municipality use GIS?
4. Will the utility hire a GIS expert for in-house support, or rely on outside support from the software platform or consultant?

Answers to these questions will help the utility select the appropriate GIS software platform. All the utilities that were interviewed found that incorporating GIS into their operations saved time and increased the efficiency with which they complete tasks. Users of all three software platforms (Esri, PeopleGIS, and Utility Cloud) felt that the software they were using was user-friendly.

The cost to implement one of the three software platforms is mostly based on the size of the distribution/collection system but also depends on the initial startup effort, the number of tools, and how much ongoing support is required. Overall costs are similar for each of the software platforms. It is estimated that a small utility will pay $5,000 - $7,000 per year for GIS products and services, and that a large utility will pay $10,000 - $12,000 per year. Initial startup and training costs are estimated to be an additional $3,000 - $6,000. A small utility was assumed to have 3 GIS users (as defined in for each of the software platforms in Section 3) and a large utility was assumed to have 10 GIS users.

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