# Managing Gravity Pipelines in Philadelphia

Edward D Speer, P.E.[1] and George Collier[2]
[1]CDM, 1218 3rd Ave, Suite 1100, Seattle, WA 98101 email: speered@cdm.com
[2]Philadelphia Water Department, 1100 Market Street, 5th Floor, Philadelphia, PA 19107
email:george.coller@phila.gov

## Abstract

The Philadelphia (Pennsylvania) Water Department delivers drinking water and operates all storm and sanitary sewers within the city of Philadelphia. This 142-square-mile area contains 3,400 miles of publicly owned sanitary sewers, storm sewers, and a large area of combined sewers. As measurement technology has matured, the department has enhanced its systems for managing its infrastructure. In some areas, these changes have been dramatic. These include use of remote video equipment to inspect city sewers, online monitoring of levels and flows throughout the system, and geographic mapping tools that make it easier to locate specific pipes. Each of these programs requires large databases that require maintenance and application integration. To manage this information, the department has developed a comprehensive set of interfaces available throughout the citywide corporate network that address specific needs and provides for analysis that cuts across several systems.

## Background

The department manages collection, treatment, and discharge of municipal sewage within the city limits, as well as several outlying communities. Within the Collector Systems Division, operating units are divided into inlet cleaning, sewer maintenance, and flow control responsibilities. Work requirements include emergency response; periodic inspections and cleaning; regulatory reporting; support of capital projects; post-construction monitoring; data collection (monitoring) in support of system modeling; defective lateral detection and correction; and preventive maintenance of pumps, gates, and other appurtenances. The wide range of activities is supported by processes that provide information to help with tactical response and allocation of resources (both human resources and technical equipment).

## Asset references

A challenge in an old city like Philadelphia is having valid documentation on what pipes are in the ground: their size, material, and other descriptive attributes. Prior to digitization, traditional techniques for locating assets were used: primarily 1:200 scale catalogs of hand-maintained maps tiled across the city. For many years, these plat maps were the sole reference, other than street address, in locating features such as manholes. In the early 1990s, the department began to use a citywide planimetric geographic database. The features available (street centerlines, curbs, buildings, waterways) were used as reference in building an initial geographic information system (GIS) catalog of major department assets. Before the decade ended, the department had embarked upon an ambitious project to convert all of its paper drawings to electronic images, and to develop a geographic database of all underground assets. The conversion process was completed in 2005.

This asset database is implemented as a geodatabase managed through ESRI's Spatial Database Engine (ESRI, 2009). Two geometric networks (collections of topologically related features) are defined: one for the stormwater network and another for the wastewater network. All features that convey flow are included in these networks, including inlets, inlet pipes, manholes, outfalls, and pump stations (represented as points). The wastewater network contains all flow elements in the combined sewered areas, as well as the sanitary pipes within the city's separately sewered areas. General query and reporting of these assets are available through web-browser applications developed by the department. An example application screen is shown in Figure 1.

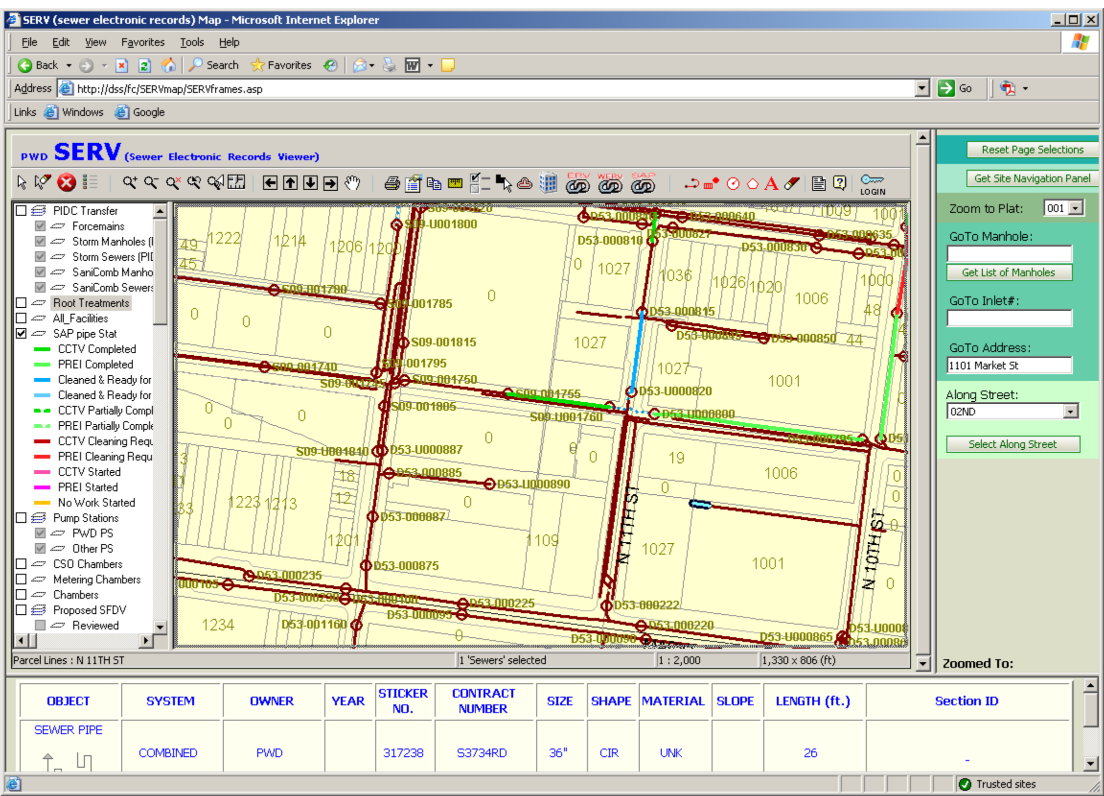

Figure 1. Sample output from geographic asset query tool

**Field Measurements**

As instrumentation technology matures and the cost of collecting good quality information decreases, all businesses are driven to gather and maintain data for asset management and service level assessment. For sewage and drainage, these measurements fall into two broad categories: static condition assessment and dynamic measurements of level and flow.

In 2001, the department began a Sewer Assessment Program that significantly expanded the amount of inspections undertaken in gravity pipelines. A certification program with training was developed to standardize all data to the Pipeline Assessment and Certification Program (PACP). A scoring technique was developed for structural, operational, and lateral issues. These scores help prioritize rehabilitation, spot repairs, and other work requests as a result of inspections.

In addition, several integration projects were begun with the objective of improving the field data being collected. Because the software provided with the remote camera equipment did not integrate with the city's GIS asset database, a process was developed to pre-populate relevant information for each inspection into the database record. For example, rather than relying on the camera operator to select the correct district, street name, and pipe size, this information is selected from a map interface during the initialization of the inspection. If pipe size or material is found to be incorrect in the asset data, the operator flags this information to be corrected by GIS asset maintenance staff.

Subsequent to the field inspection of gravity pipes, the database of observations, photographs, and video is transferred to a central server. A web-based application called SINSPECT can be utilized throughout the department to view the results of any inspection (including video and images). In addition, a work request interface has also been deployed to manage the requests for inspections that may be the result of design work, operational issues, capital planning, or customer service. This application allows users to make and track requests using a desktop browser. An integrated mapping interface eliminates confusion with regard to which pipes are requested—the requestor must indicate, based on the map, which pipelines are the subject of the request. Figure 2 illustrates the interface for the inspection request application. Figure 3 shows results of an inspection with the coded observation values.

Currently, the department is implementing a commercially based work order management system that will be used to request inspections and track all work orders, equipment, and staffing requirements.

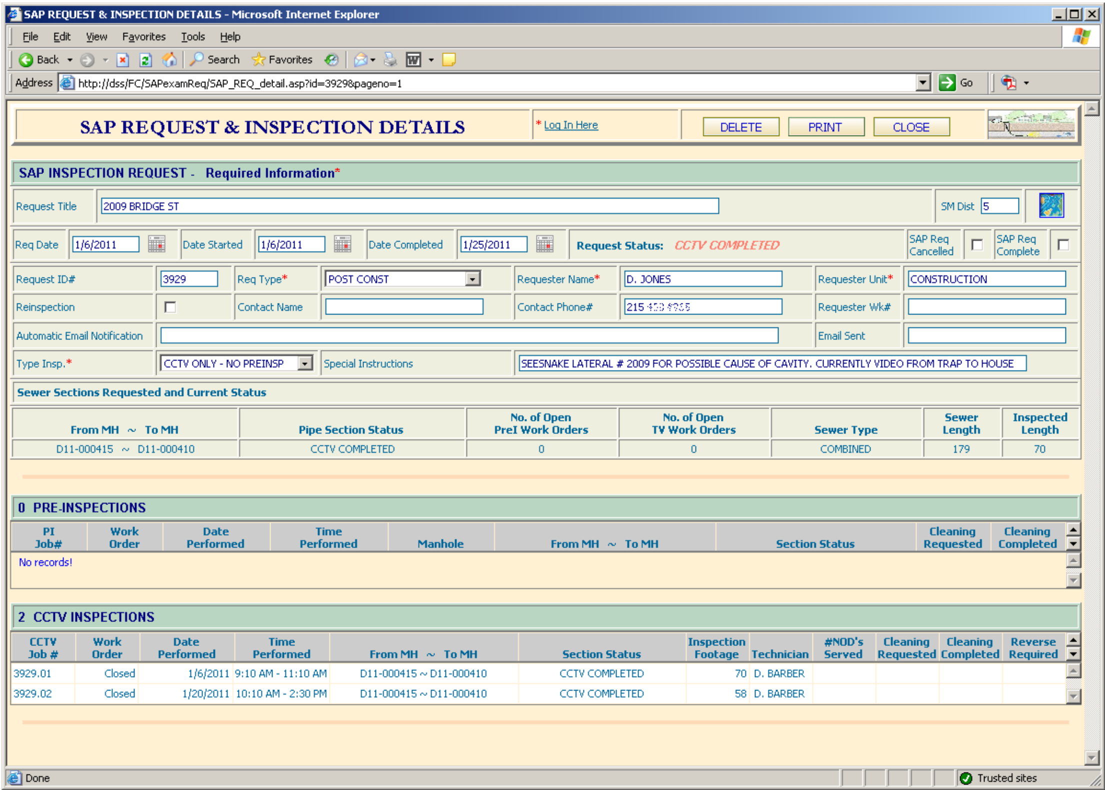


Figure 2. Sewer assessment request interface

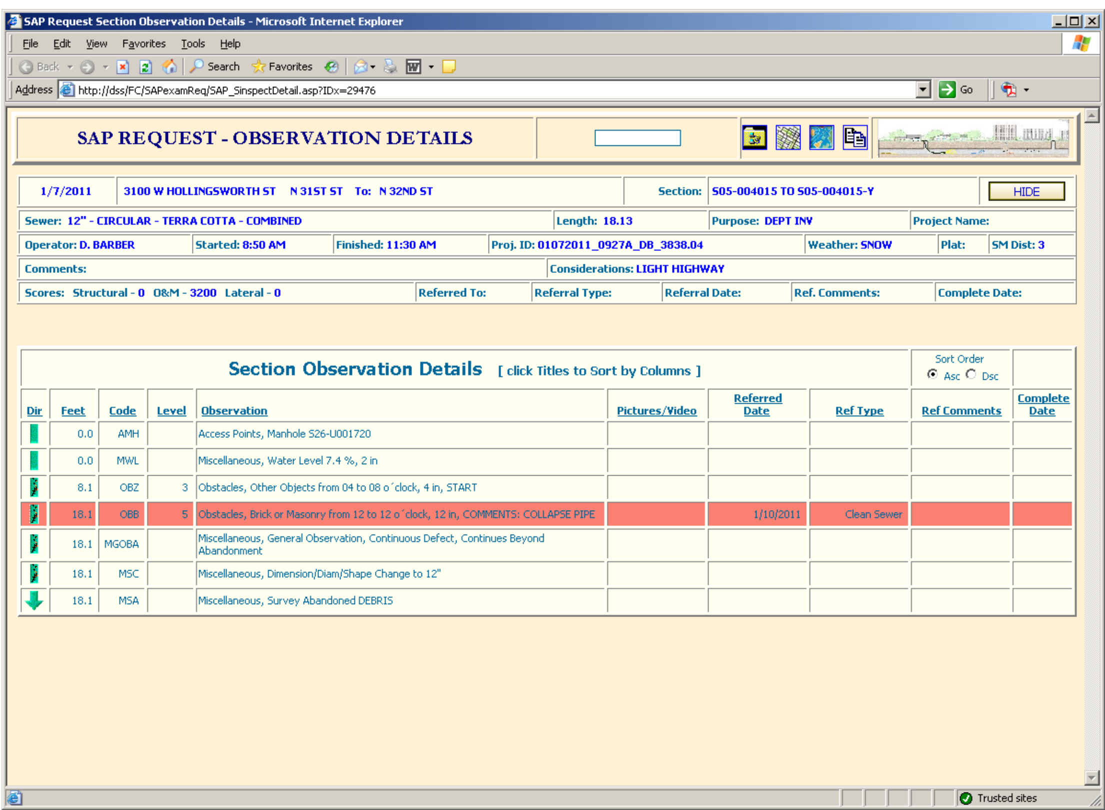


Figure 3. Sewer assessment reporting details

**Dynamic Measurement of Levels, Flows, and Rainfall**
The department contracted with a vendor in the mid-1990s to provide an enterprise system for monitoring outfalls in support of regulatory requirements for CSOs. This custom system relies primarily on pressure transducers to measure sewer levels in trunks and outfalls. Additional sensors measure flow rates and rainfall. Twice a day, a remote telemetry unit (RTU) at each remote site utilizes dial-up telephone lines to transmit the data to a central database server. Exception alarms cause the transmission to occur immediately.

Among the difficulties with this monitoring system are power and telephone requirements at CSO locations that are located in parks and ravines far from established commercial or residential service. Over the last two years, the monitoring network has been replaced with an off-the-shelf solution that utilizes cellular communication. In addition to a more modern and reliable storage mechanism, this system provides additional channels to capture discrete events, such as pump start and pump stop.

Flow meters are deployed at critical junctions and diversions within the collection system, and at 25 metering chambers where flows from adjoining jurisdictions enter the Philadelphia system. Because the department provides wastewater treatment for these communities, these data directly support billing contracts.

An application provided by the vendor (Figure 4) can be utilized to retrieve centrally stored monitoring data. A geographically integrated application has also been developed to retrieve and assess this information.

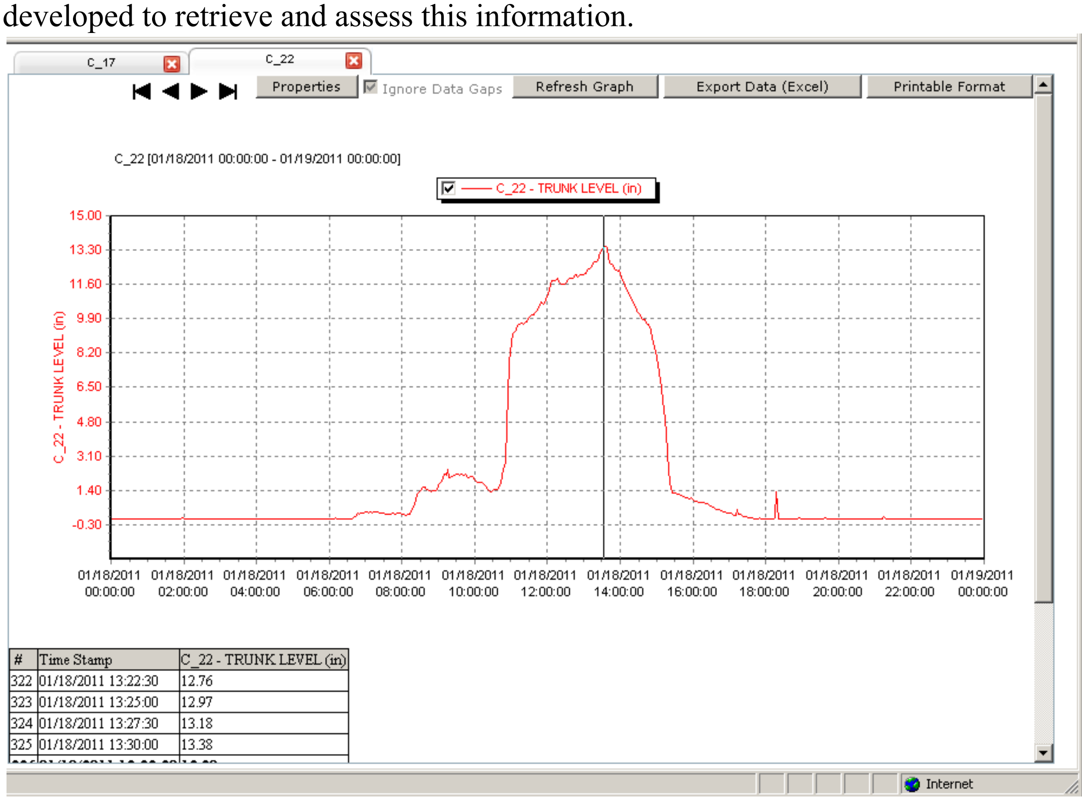

Figure 4. Data retrieval from dynamic level measurements

**Modeling, Real-Time Control, and Decision Support**
Regulatory requirements and rising capital costs have driven the department to expend significant effort to maximize utilization of its existing piping system. In a combined sewer system, operations must be based upon a sound understanding of the hydraulics and take advantage of capacity where it may occur, especially dynamically during the course of a rain event. In 1999, a study was undertaken to investigate the feasibility of real-time controls (RTC) for managing flows in the Southwest Drainage District. This study made use of an existing hydraulic model, implemented in the U.S. Environmental Protection Agency's (EPA's) Stormwater Management Model (Huber and Dickinson, 1988) that had been developed previously for hydraulic characterization. The illustrations from this study relied heavily on pipe profiles and maps that showed where overflows occurred and where capacity was present during the course of an event.

Subsequently, the department embarked on a project to build a Decision Support System (Mihocko, 2002), an operations-focused interface to bring a wide variety of operational information into a single platform for viewing by anyone on the city's wide-area network. This program was initially deployed in 2003. It continues to be updated and improved as new information becomes available and legacy applications are replaced with modern, data-compatible programs. Information on pump station equipment details, pump run-times, CSO inspections, problem locations, sodium hypochlorite dosages, rainfall totals, staff allocations, and more are available through this system. An example of such information is illustrated in the rainfall calendar application shown in Figure 5.

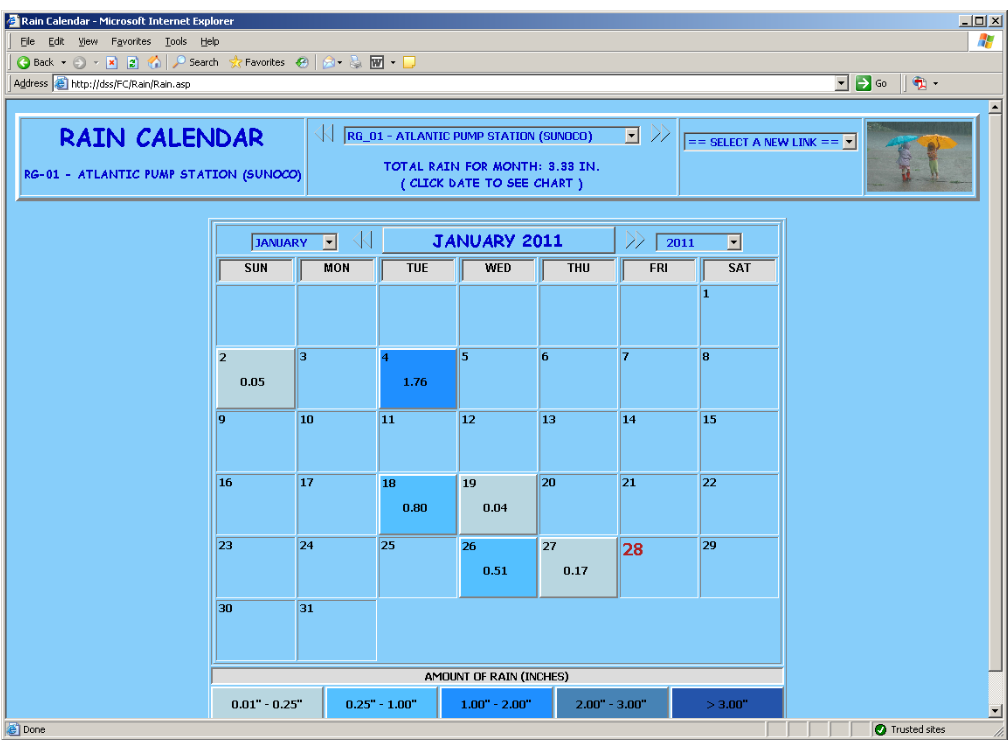

Figure 5. Rain calendar application

**Challenges**

Each data collection or display system must be configured to meet the specific needs of the organization. One specific requirement was display of the static asset data on planimetric displays. The department's standards for separated sewer systems call for single-trench construction within the right-of-way, whereby the sanitary sewer is located directly beneath the storm sewer. A "turnout" is placed every 300 to 500 feet where the storm sewer diverts slightly from the alignment to allow manholes to be connected directly to the lower sanitary pipe. This configuration is illustrated in plan view and elevation view in Figures 6a and 6b.

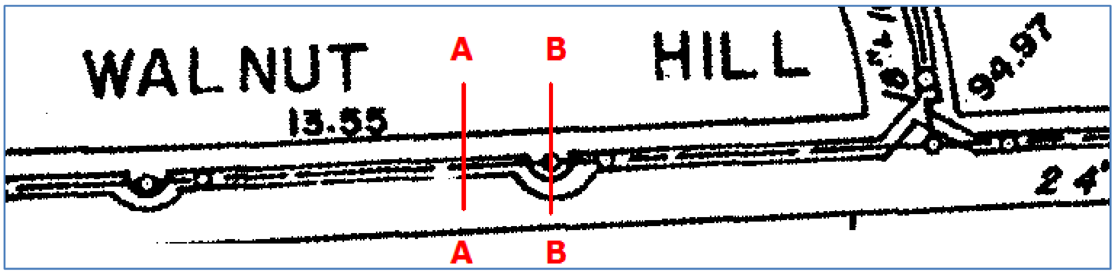


Figure 6a. Plan view of separated sewer segments in a single trench

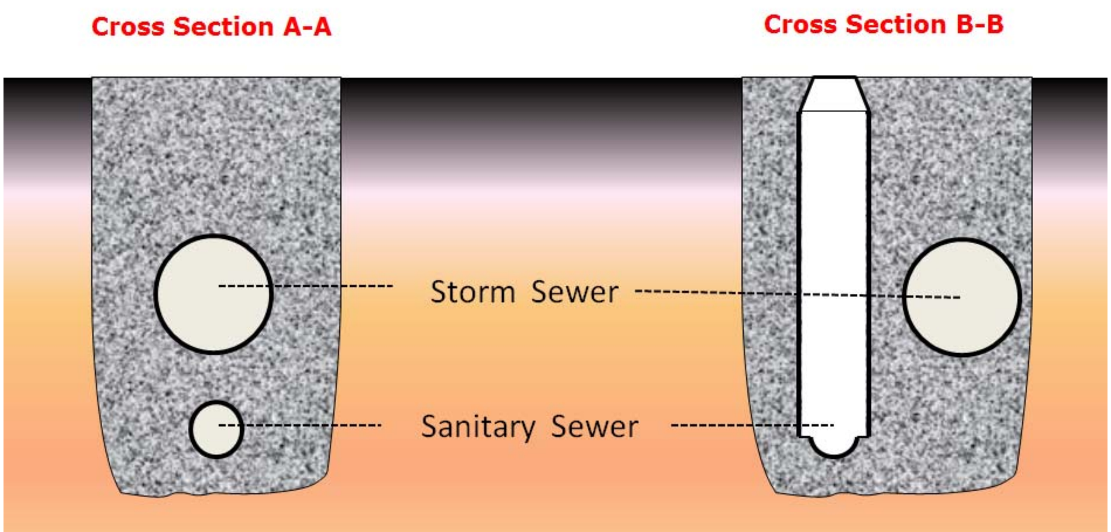


Figure 6b. Elevation view of separated sewer segments

This challenge in creating maps had been traditionally handled by symbology on hand-drawn plat maps similar to that shown in Figure 6a. However, many geographic editing and selection tools have difficulty when lines coincide in plan view. One response to this challenge was to separate the stormwater network from the wastewater network in the enterprise database. However, this separation is somewhat artificial, as structures such as combined sewer overflows and upper-end manholes are shared between the two networks. This separation precludes applications such as tracing from spanning across the two networks.

**Field Identification**

Prior to implementation of the geographic-based asset database, manholes were not individually tagged with an identifier. The standard method of identifying any feature in the field was to use the street network and utilize distances from intersections. One task of the Sewer Assessment Program was to develop a common field identifier for all manholes, junction chambers, and similar structures within the collection system. A complex set of rules was developed to embed geographic information into the identifier.

Curb inlets have a numeric identifier but are not embedded with location information. The geographic database was amended with a descriptor field based on rules that use street intersections, curb locations, and alternatively, parcel addresses. This information continues to be used in the field when mapping systems are unavailable or verbal communication is required.

## Conclusion

Asset management requires different kinds of information collected through various mechanisms and processes. Providing a central platform that can be used throughout the department has reduced efforts and time, while yielding a higher degree of data quality. Implementation of an integrated platform requires a common understanding of object definitions and workflow sequencing. Commercial products are often designed based on business assumptions that may not have the flexibility to adapt to each agency's situation. In these cases, the impact of modifying the workflow to match the management software should be weighed against the additional data manipulation that may be required. While the sources of information may be developed independently and use different commercial platforms or be programmed in-house, integration of this information provides tremendous value in support of the operation of Philadelphia's gravity pipe system.

## References

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