WHICH WAY DOES IT FLOW? AN EFFORT TO MAP ROADSIDE DITCHES IN HOUSTON

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ABSTRACT

Open channels/ditches make up a critical component of the Houston storm drainage system. Because Houston is near sea level and relatively flat, survey grade GPS data collection with sub-inch accuracy was used to collect ditch profile transects and cross-street culvert information on over 2,300 miles of roadside ditches. A network of ditches and culverts was then generated and tied into the existing city GIS for a storm water network that will be used for hydrological modeling and assist in improving Houston's storm water assets.

KEYWORDS: storm water, GIS, GPS, RTK, survey, mapping

INTRODUCTION

In addition to being the fourth most populated city in the United States, the City of Houston (COH) has the second largest surface area (~650 square miles) in the US. The Bayou City’s boundaries also encompass over 1,800 miles of roads with roadside “open” storm water system features owned and/or maintained by the COH Public Works and Engineering Department (PWE). These features include channels, ditches, cross drain culverts, and berms; all of which combine to make a critical component of COH’s storm water drainage system. To keep these open drainage features functioning properly, which is necessary to transport storm water and mitigate flooding in the communities and surrounding areas, they must be inspected, cleaned, and maintained on a regularly scheduled basis and after major storm events (such as hurricanes and/or tropical storms). While significant data have been collected to inventory the closed-system storm water infrastructure throughout the city, open storm water drainage features were not previously surveyed, inventoried, or subjected to a condition assessment.

TLC Engineering, Inc., Parsons Water & Infrastructure Inc. (Parsons), and the JNE Green Team collaborated with PWE to implement a comprehensive approach for collecting geospatial data for the open storm water drainage features across the COH, and implemented the approach with great success.

The project approach involved using up to 11 two-person field teams over a five month period to capture the geographic locations and visible attributes of these storm water assets using survey grade Global Positioning Systems (GPS) and custom data entry forms. Up to 10 GIS analysts used these data to develop 3D cross sections and a complete linear network of the open drainage system with connections to the existing closed system network. The final product was a geodatabase that can be imported into the COH Geographic Information and Management System (GIMS) database and used by PWE to advance storm water asset management, mapping, modeling, analysis, operations and maintenance, and construction.

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REQUIREMENTS

Feature Data Requirements

The first step of the planning phase was to collaborate with the PWE to understand the specific needs of the users and intended uses for the data. This allowed the TLC team to understand the data requirements, strengthen the database design, and develop appropriate collection protocols and QA/QC methods. During this step, the team identified all feature types (road side ditches, culverts, discharges) to be collected as well as all specific attribution (material, condition, dimensions, etc.). The features that would be generated in the office (transect lines, ditch lines, culvert lines) by the GIS team were also identified. Table 1 lists the feature classes developed on the project.

Table 1 Features Collected or Digitized

Object Class Name	Description	Geometry	Source
dMiscPoint	GPS points or GIS generated points for documenting unique circumstances in the field that require review by office staff.	Point	Field/Office
dTransectLine	A 3D polyline generated in GIS which connects the points along a ditch transect	Polyline	Office
fCulvertPoint	GPS collected points for each end of street intersecting culverts	Point	Field
fQCPoint	GPS points used for checking and documenting equipment accuracy and calibration daily	Point	Field
fTransectPoint	GPS collected points along ditch transects. Transects typically have 11 transect points	Point	Field
dArtificialFlowLine	A 2D polyline used when necessary to maintain network connectivity or connectivity to the existing “closed system” storm water GIS network.	Polyline	Office
dCulvertLine	A 2D polyline generated in GIS which connects the culvert points. These features will contain the attributes collected in the field, and a link to the field photos	Polyline	Office
dDischargePoint	GPS point collected at the discharge location of a ditch (intersection with larger ditch, inlet, and headwall). Includes a link to the field photo.	Point	Field
dRoadSideDitch	A 2D polyline generated in GIS which connects ditch data points. These features contain the attributes collected in the field.	Polyline	Office

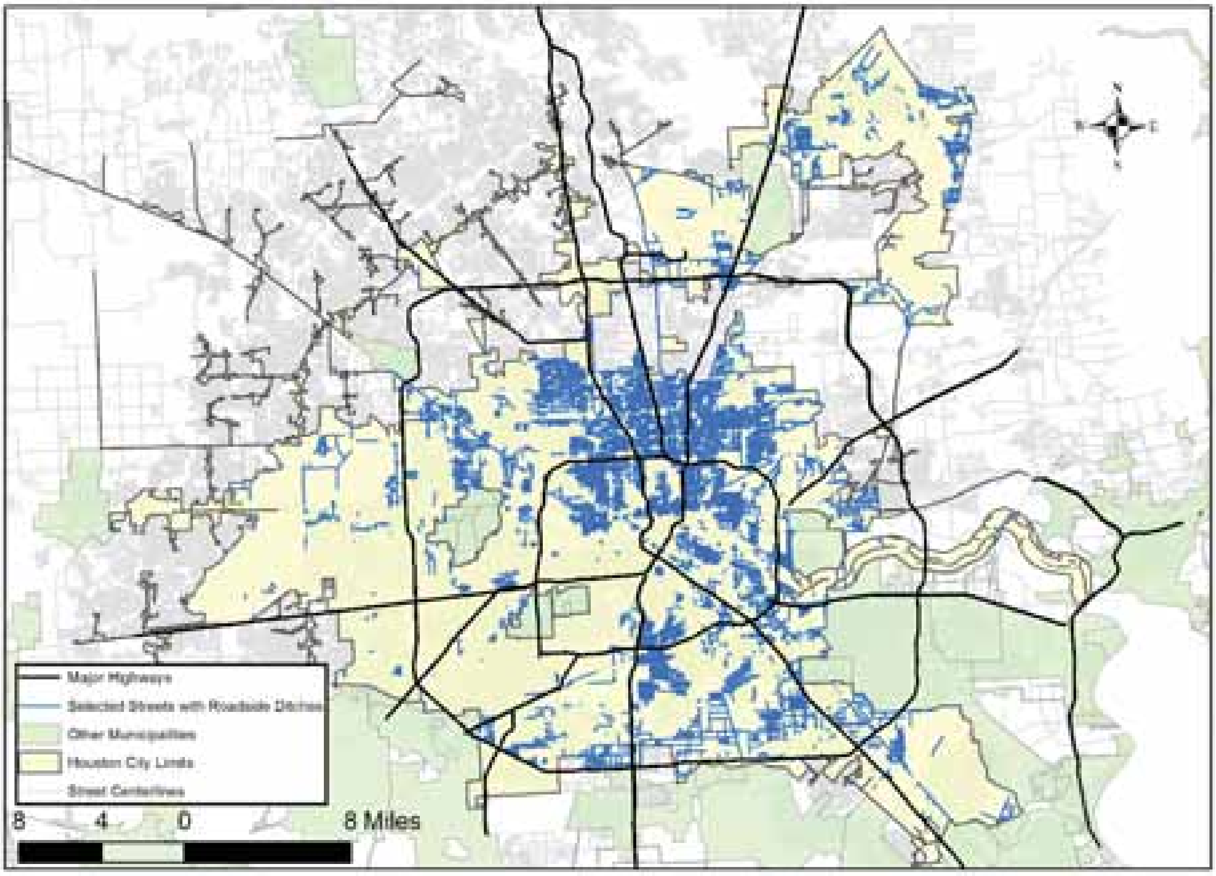
Accuracy Requirements

One of the main purposes of the project was to create a dataset that can be used for storm water and flood modeling to evaluate the adequacy of the open channel infrastructure. Because of the model sensitivities and the relatively flat topography of the project area, survey grade vertical accuracy (sub inch) was a requirement. In order to measure the up and downstream elevations, and general dimensions of the ditch segments, transects were collected at each end and at other key locations along the ditch segments. The Ditch Collection section discusses transect collection in more detail.

Project Area

The specific roads to be surveyed were selected prior to the start of the project and are shown in blue on Figure 1. These roads and their encompassing rights-of-way made up the project area.

Figure 1 Project Area Map



CHALLENGES

There were several challenges specific to this project that required creative and innovative solutions. Challenging factors included an aggressive schedule, a large project area, hazards from weather and proximity to roadways, and local subsidence that affects elevation accuracies, among others. One of the biggest challenges was developing methods for a large scale mapping project that achieved survey grade accuracy.

Survey grade collection equipment and software are made more for the surveying world and less for the GIS and mapping world. The “out of the box” setups in the survey grade GPS equipment have collection templates for work such as stake outs and general surveying with simple feature coding, which are typical when performing localized site surveys. The field collection software used on the data collectors, Trimble Access, was not as easily customizable as other mobile mapping software such as ESRI ArcMobile or Trimble TerraSync. To set up separate field data feature types and custom data entry forms with the specific attributes for each type, data dictionaries had to be created and imported into Trimble Business Center as feature code libraries. This enabled the use of domain tables for some attribute fields, which promoted efficiency and accuracy.

Another challenging factor with survey grade GPS is the need for a static base station in order to have real-time differential correction (RTK). This was made even more challenging by the large project area that was basically the entire City of Houston. With a large project area and aggressive schedule, setting up temporary base stations to broadcast correction signals was impractical. A relatively new option, the Virtual Reference Station (VRS) network was a logical solution for real-time differential correction. The VRS network is a subscription service that can be purchased from GPS equipment vendors and provides a correction factor from a network of static base stations via cellular connections between the rover units and a network server (Kislig, 2011). There are extensive base station networks near most metro areas of Texas and other places around the world.

METHODS

Establish Team Member Roles

Establishment of team member roles is an important step since it establishes the chain of command and specific responsibilities for each part of the project. Due to the aggressive schedule requirements, the project team was scaled up to include up to 11 two-person field teams, and up to 10 GIS Analysts. Table 2 lists the positions identified for the project and the primary roles for which each position was responsible.

Table 2. Team Member Roles

Position	Primary Roles
Project Manager	Responsible for all project deliverables. The Point of Contact (POC) for all subcontractor coordination, QA/QC coordination, and technical review of all deliverables. The primary POC regarding project GIS and field collection operations.
Field Manager	Develop mission plans, create field maps, coordinate data collection efforts, synchronize GPS units, and transfer all field data to the project repository site for download by GIS staff.
Field Technicians	Locate and collect positional data, attribute data, and photographic documentation for each surface feature. Two field technicians are on each field crew. Up to 11 crews at a time were used on the project
GIS Developer	Provide advanced GPS and GIS support to the project, oversee and perform in-office GIS updates, and manage any application development needs.
GIS Analysts	Develop the linear network. Up to 10 analysts at a time were used on the project
QA/QC Analyst	Review the field and office generated data. Perform independent QA/QC checks in the office and in the field.

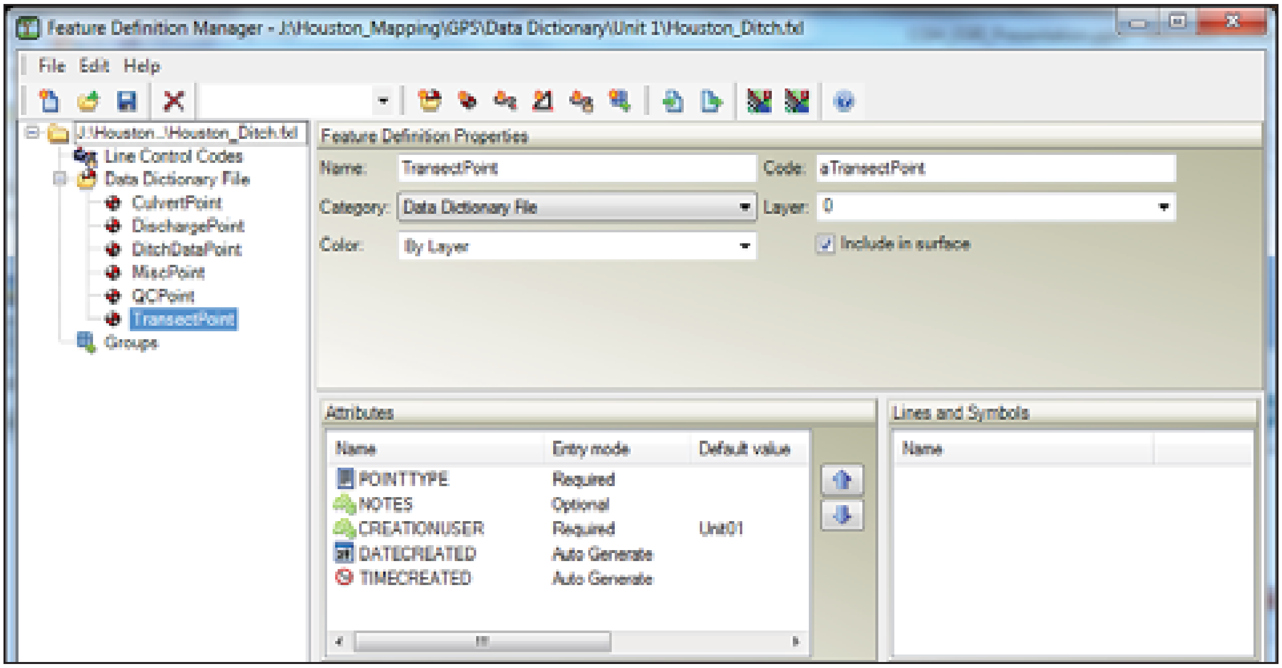
Database Design

The goal for this task was to develop a database design that would meet the identified inter-departmental needs, as well as promote efficiency and quality during field collection and in-office processing. The database design was based on a combination of the existing PWE storm water geodatabase and the specific needs for this project. The feature classes for roadside ditches and culverts were based on existing PWE feature classes for open channels and gravity mains and use existing PWE domain tables where possible. Additional fields were added to accommodate the specific attributes collected on this project. New feature classes were added for the field collected points (transect points, culvert points, discharge points, misc. points, and QC points) as well as for the 3D transect lines. Field photos were included in the geodatabase as attachments.

Customizations for Field Data Entry

Once the database design was completed, custom data entry forms were developed for collecting the specific feature attributes on the GPS data collection equipment. The data entry forms were developed in a way that promoted accuracy and efficiency in the field. Quality control checks were built into the data entry forms to prevent common data entry mistakes. The data entry fields were arranged in a manner that complements the most efficient work flows in the field. This was based on the team's experience with regard to the specific order in which the measurements and observations should be taken for speed, accuracy, and safety. Drop down menus were used whenever possible to minimize the number of keystrokes and potential entry errors on the data collection devices. The customized forms were developed by creating feature code libraries in the Trimble Business Center Feature Definition Manager. Each GPS unit had a unique feature code library file created to establish default values for GPS unit names that were stored as feature attributes and used in the photo naming convention. Figure 2 shows the Feature Definition Manager interface with the project feature code library.

**Figure 2	Project Feature Code Library in Trimble Business Center**



Name: TransectPoint
Code: aTransectPoint
Category: Data Dictionary File
Layer: 0
Color: By Layer
☑ Include in surface

Name	Entry mode	Default value
POINTTYPE	Required	
NOTES	Optional	
CREATIONUSER	Required	Unit01
DATECREATED	Auto Generate	
TIMECREATED	Auto Generate	

Prioritization for Data Collection Sequence

Prior to starting field data collection, field maps of the entire data collection area were developed and used to facilitate discussion that would geographically prioritize weekly deployment of the field crew. Variables that were considered when prioritizing maps were proximity to the field offices, any necessary traffic controls, data needs, jurisdictional and access issues, critical storm water management areas, and local events, including planned construction. It was beneficial to begin field work in the map areas closest to the field offices. This is because initially more trips back to the field office are required until the field crews get into a rhythm with the field procedures and equipment. Return trips to the field office are infrequent after the first week or two of collection. Major construction activities can also restrict access to areas, and can even alter the storm water infrastructure. When construction was planned or in progress for certain areas, those areas were considered exclusion zones until construction was completed.

Site Calibration

Localized subsidence around the Houston area causes measureable changes to ground surface elevations over time. Subsidence results from groundwater being pumped in certain areas of the greater Houston area (HGAC, 2014). Because the changes are not uniform across the city, it was important for this project to tie all the elevation data to a consistent vertical datum. A standard datum was developed during the Tropical Storm Allison Recovery Project and is referred to as the TSARP datum. All GPS data collected for this project was adjusted to the TSARP datum. To do this, a site calibration was created in Trimble Business Center. First, multiple monuments with published TSARP elevation values were collected all across the city. The monuments were collected with the same GPS equipment later used to collect the feature data on the project, but tripods and longer collection times were used to get the most accurate position possible. The collected position values along with the corresponding published TSARP values were entered into the site calibration model in Trimble Business Center so the feature data could be adjusted to the TSARP datum before exporting to GIS. More information about local subsidence and the TSARP can be found at the websites for the Harris Galveston Subsidence District http://www.hgsubsidence.org/, and the Harris County Flood Control District http://www.hcfcd.org/tsarp.asp.

Equipment

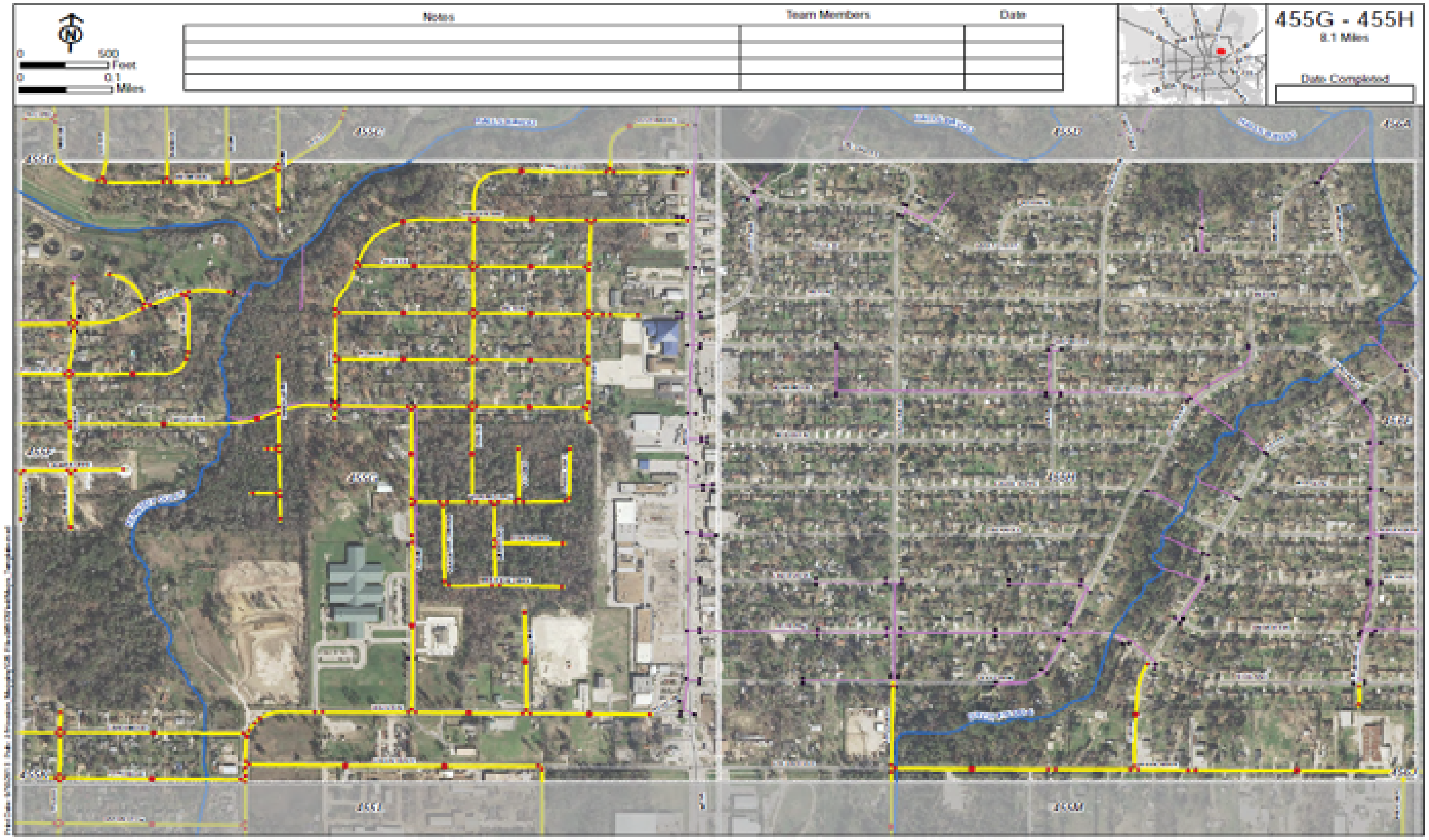
Prior to leaving the field office each morning, field crews reviewed the daily equipment check list to verify they had all essential tools. Field tools used for the project are listed below.

- GPS unit – Trimble R8, Trimble TSC3 data collector, and 2-meter survey rod;
- Extra GPS batteries;
- Metal ruler for measuring debris depth;
- Tape measure, used for culvert opening dimensions;
- Clip board with field maps, and project explanation letter; and
- Safety equipment: safety vests, snake guards, water, and first aid kit (kept in vehicle).

Health and Safety

Special attention was paid to Health and Safety due to the unique challenges of this project. The majority of the field work was conducted adjacent to or in the roadways, which presented a number of hazards, including interactions with vehicle traffic, and citizens in all parts of the city. Road side ditches presented several hazards, including steep grades and uneven ground; wet or submerged ground surfaces; heavy vegetation, including poison ivy; and and potentially dangerous wildlife and domestic animals. In addition, the area is known for its warm and humid climate. Heat stress was a concern, and drinking plenty of water was a requirement. Daily safety meetings were held before each day’s field work. All meetings were recorded on the daily health and safety log forms. Information included date, time, employees present, and topics covered. A health and safety plan was created for the project, and copies were kept in the vehicles during field work.

Figure 3 Example Field Map



Feature Location and Identification

Field technicians were familiar with how to identify various storm water infrastructure surface features, and were adept at locating them in the field. Identification of surface features to be collected required basic field mapping skills, knowledge of how a storm system works, and careful attention to detail. The first step in locating the features was to review field maps that had all available legacy data and roads and creeks printed on them. Field crews were only responsible for collecting drainage features along the road segments selected for this project. The selected segments were shown in bright yellow on the field maps. Small red dots were also shown on the field maps to indicate every location where transect collection was required. This included transects at segment ends and midstream transects when the segment was longer than 600 feet. An example field map is given in Figure 3. To ensure that features were not overlooked in the field, field technicians marked the maps to show areas that had been traversed.

GPS Data Collection

Trimble R8 survey grade GPS units and TSC3 data collectors with custom data entry forms were used to perform the field surveys. These units came with a subscription to the VRS networks, which enabled a cellular connection to static base stations across the city that provided real time differential corrections to the rover units. This VRS network connection made survey grade RTK collection a much more feasible solution on the project since setting up and taking down temporary base stations across the entire city would have been very time consuming and expensive. Prior to the VRS network, setting up temporary base stations would have been the only option for obtaining survey grade data. After capturing the spatial position information with the GPS equipment, the field crew members entered the appropriate field measurements and observations into the custom data entry forms in the Trimble Access application on the TSC3 data loggers. Digital photos of the features were also taken at this time and “attached” to the GPS points as a feature attribute. Photos were taken in a manner that best captures information about the feature (including feature condition), while also capturing the surrounding environmental context.

Prior to leaving the field office each morning, the GPS antennae and TSC3 data loggers were powered on. Once the TSC3 booted up, Trimble Access was launched and a new job file was created for the day. The job file naming follows the format of “T”, [Unit number], [date mmddyy]. After setting up the daily job files, every team collected a QC point in the field office parking lot on one of the established QC locations. Each crew would then verify that their unit was working properly and that the coordinates and elevation of the QC point matched the established values.

Ditch Collection

Ditches are linear conveyance paths where water flows and is directed to larger creeks, rivers, or a subsurface storm water network. A ditch is an open conduit or channel that may be made of several materials and take several shapes. A ditch segment is a portion of a ditch that has mostly consistent attributes and has defined start and end points (*e.g.,* culverts, ditch intersections, creek intersections, pond discharges, etc.). Other characteristics that partition segments are the point at which a ditch changes material, direction, slope, cross section shape, or size. To take advantage of the high accuracy of survey grade GPS, transects were collected as a linear set of points perpendicular to the ditches, including the flowline, tops of banks, pavement edge, road centerline (when safe), and right-of-way (ROW) edge. To collect segment end transects, the crews would start near a street intersection and begin collecting at one ROW location. The proper location to collect the ditch transect at a segment end was to be as close to the intersection as possible where the ditch still displayed the width, depth, and shape characteristics of the rest of the ditch. When choosing the location to collect a transect, the crews also avoided locations where they could not complete the transect on the other side of the road due to driveways, trees, or other obstructions. Once the transect location was chosen, the crew then collected 11 GPS positions at the points shown in Figure 4 while staying on a straight path perpendicular to the street. Once the second ROW point was collected on the other side of the street, the field crew then started on the transect for the adjacent roadway (see the diagram in Figure 5). Transects were collected at specific locations, including start and end points at street intersections, and midstream points whenever a ditch was longer than 600 feet. If the ditch changed direction or its physical properties changed within a block, a midstream transect was collected to indicate a change. Dimensional measurements of the ditches, such as length and width, were calculated in GIS software using automated tools. This method greatly increased field efficiency and accuracy by eliminating many manual field measurements and reducing the amount of data entry into the data collectors.

Figure 4 Locations of Transect GPS Points

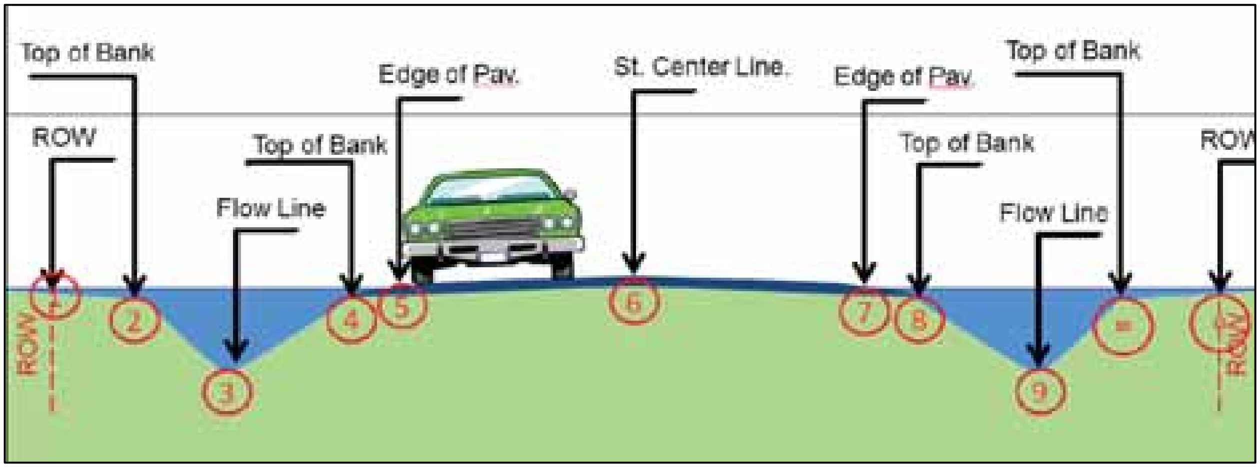
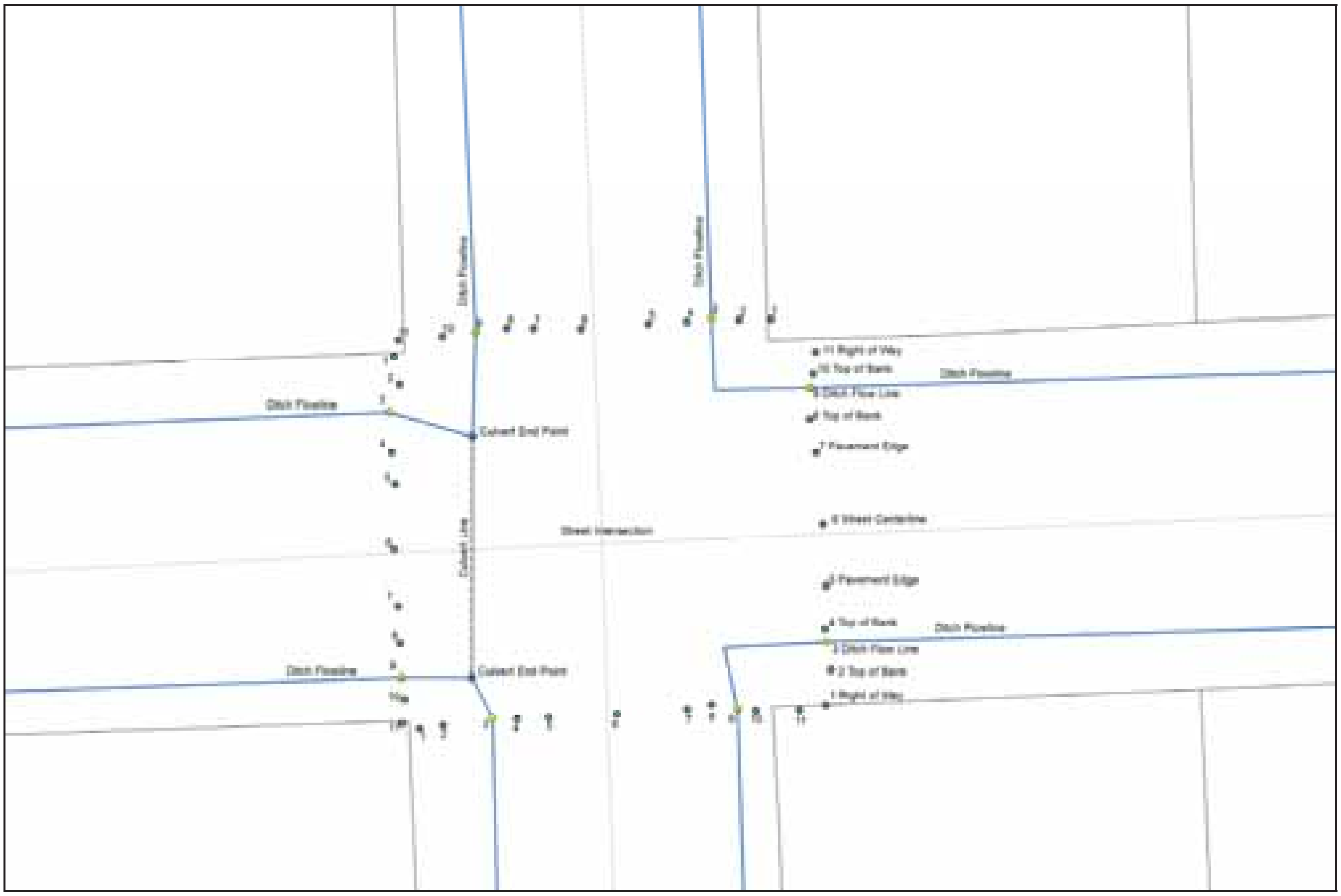


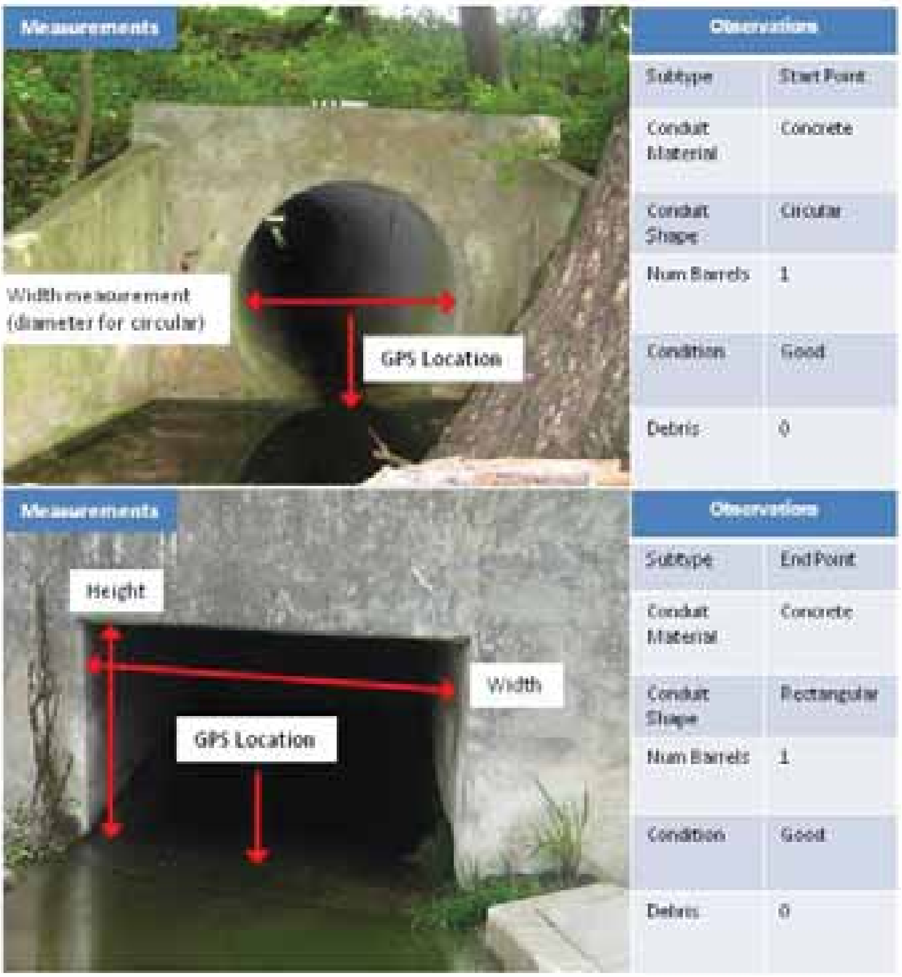
Figure 5 Example Intersection with Transect GPS Points and Culvert GPS Points



Culvert Collection

Culverts are linear features that temporarily divert surface flows underground to avoid obstacles. Culverts typically divert water under roadways, but they can also divert water under berms, railroad tracks, buildings, or other manmade features. Culverts were collected in the field as two end points. GPS points were collected by locating the tip of the survey rod on the bottom interior edge of the pipe where water enters or exits. When a cross street culvert was present, the culvert elevation was used for the connecting ditch end elevation. Along with the spatial locations of the end points, attributes were collected for each end point, including shape, material, diameter, number of barrels, and depth of debris. Field photos were also collected for each culvert endpoint and stored as a feature attribute. The linear culvert feature was created during the network generation phase. Only culverts under streets were collected; driveway culverts were excluded from this project.

Figure 6 Culvert Collection Examples



Observations	
Subtype	Start Point
Conduit Material	Concrete
Conduit Shape	Circular
Num Barrels	1
Condition	Good
Debris	0

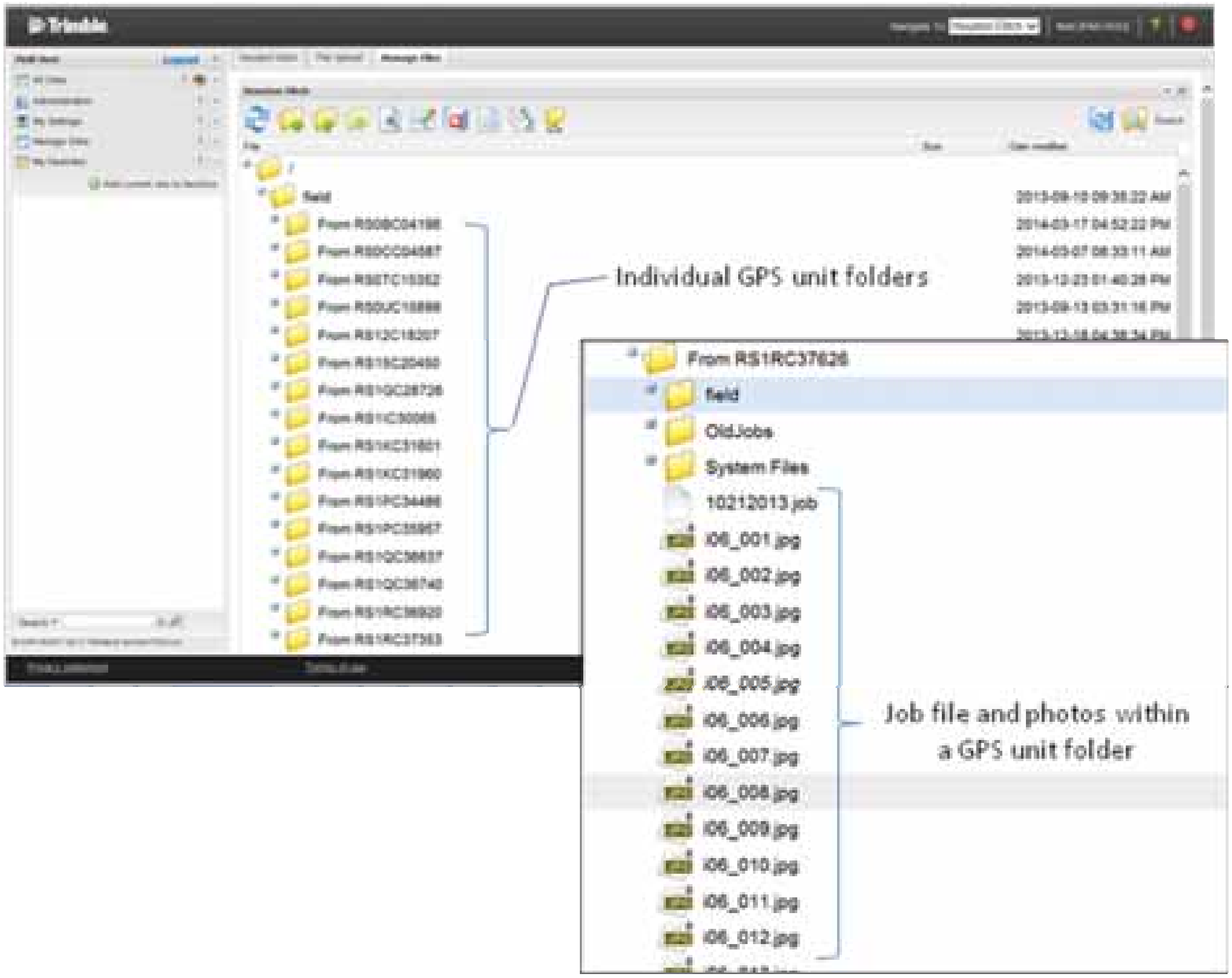
Observations	
Subtype	End Point
Conduit Material	Concrete
Conduit Shape	Rectangular
Num Barrels	1
Condition	Good
Debris	0

FIELD DATA PROCESSING

Trimble Access Service

Along with VRS services, Trimble’s cloud service via the Trimble Connected Community Explorer (TCCE) site was utilized as a means of transferring job files and photos from the field units to the main office. Files from the field were uploaded from the TSC3s to the cloud via an internet connection over a cellular network, or a WIFI network when available. A local backup of the photos and job files on the TSC3s were also maintained as a backup procedure. Using TCCE, files were synchronized with a local computer from the cloud. Figure 7 shows the TCCE web interface with a specific file folder for each Trimble unit’s files. Simple command line batch scripts were developed and used to transfer files to the main server organized by date then team, photos and job files. Job files were then brought into Trimble Business Center for processing, calibration, and exporting to a daily staging geodatabase.

Figure 7 TCCE interface for synchronizing field collected data with local network



ArcMap Models

Models were developed in ArcMap Model Builder to update standardized fields such as the project, types, and calculations for elevations based on measured heights for culverts. GPS QC information was also imported from TBC and added using model builder. This information included Positional Dilution of Precision (PDOP) values as well as calculated horizontal and vertical precisions in feet. Data were then transferred using models to an ArcSDE geodatabase where GIS analysts would then be able to finish QC and translate data. Figure 8 shows the ArcMap Model used for loading the data into the SDE geodatabase.

One step that facilitated the process of generating transect lines from points was a routine to “sort” and group the points for developing transects. Initially, XY pairings were used and analysts then reviewed and tagged a sort order to the points. The process of tagging was labor intensive; accordingly, an alternate method for sorting the points was created using SLQ server. The formula was predicated on time stamps and point types. Occasionally, if transect points were taken out of order, the sort order would get calculated incorrectly and created a cutback in the transect line when the “point to line” routine was run. These cutback errors were caught during the QC checks run using ESRI DataReviewer if not identified earlier by the GIS analysts. Implementing this method of tagging and sorting transect points was a huge increase in efficiency and allowed the GIS analysts to focus on other tasks.

ArcMap models were then developed to automate the transfer of road attributes to the ditch and transect segments as well as transfer point attributes to line features including centerline elevations. Figure 9 shows the model developed and used to transfer keymap IDs to different feature layers.

Models were specifically targeted where spatial joining and data transfer occurred. Models also assisted in the case of manipulation of data structure (adding and calculating standardized fields).

Models were also used to automate several tasks when delivering data to the client. This included creating the deliverable schema database and loading data that had been QC-reviewed. Figure 10 shows the model used to create the client deliverable database extract.

Figure 8 Data Loader Model

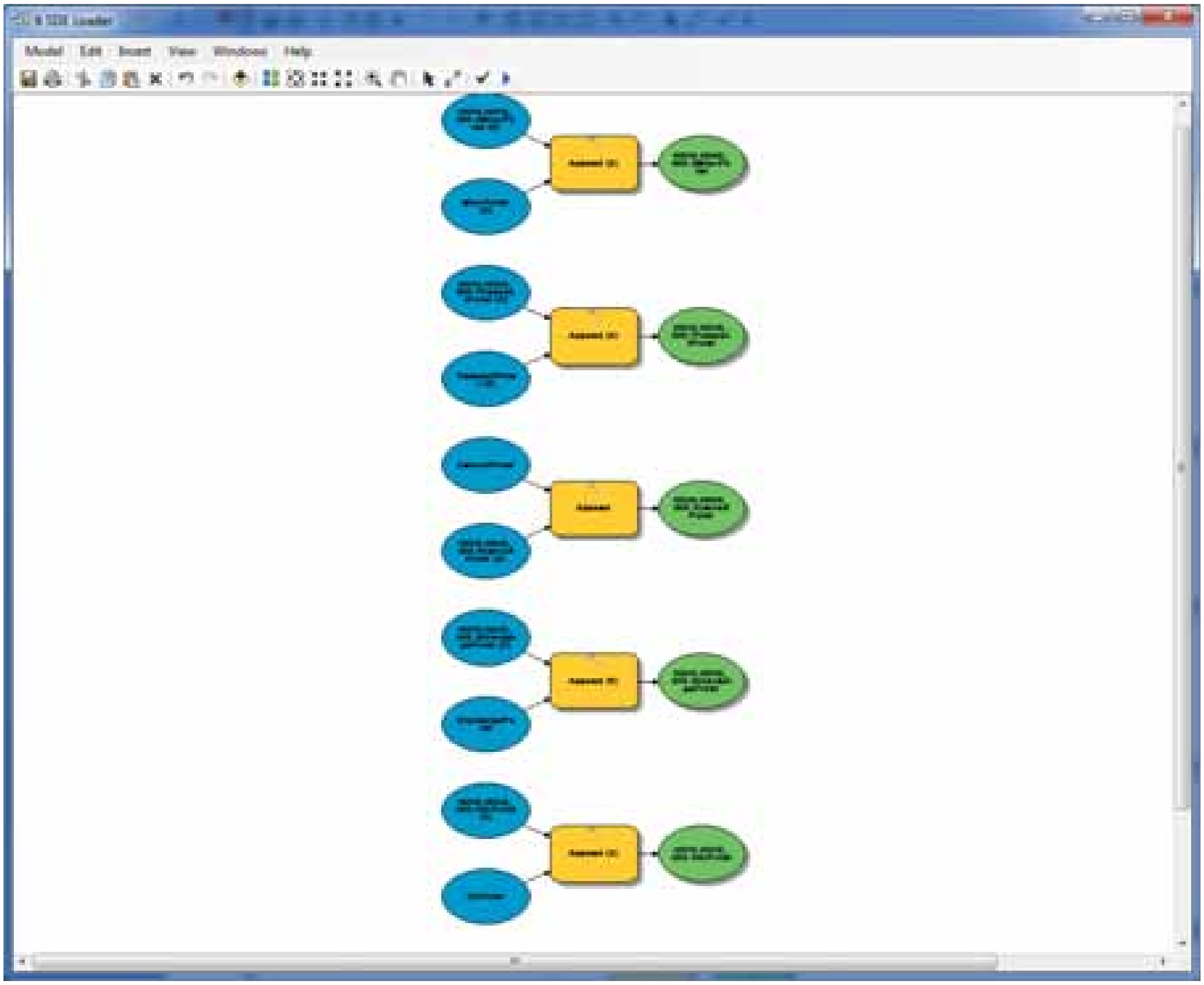


Figure 9 Keymap Model

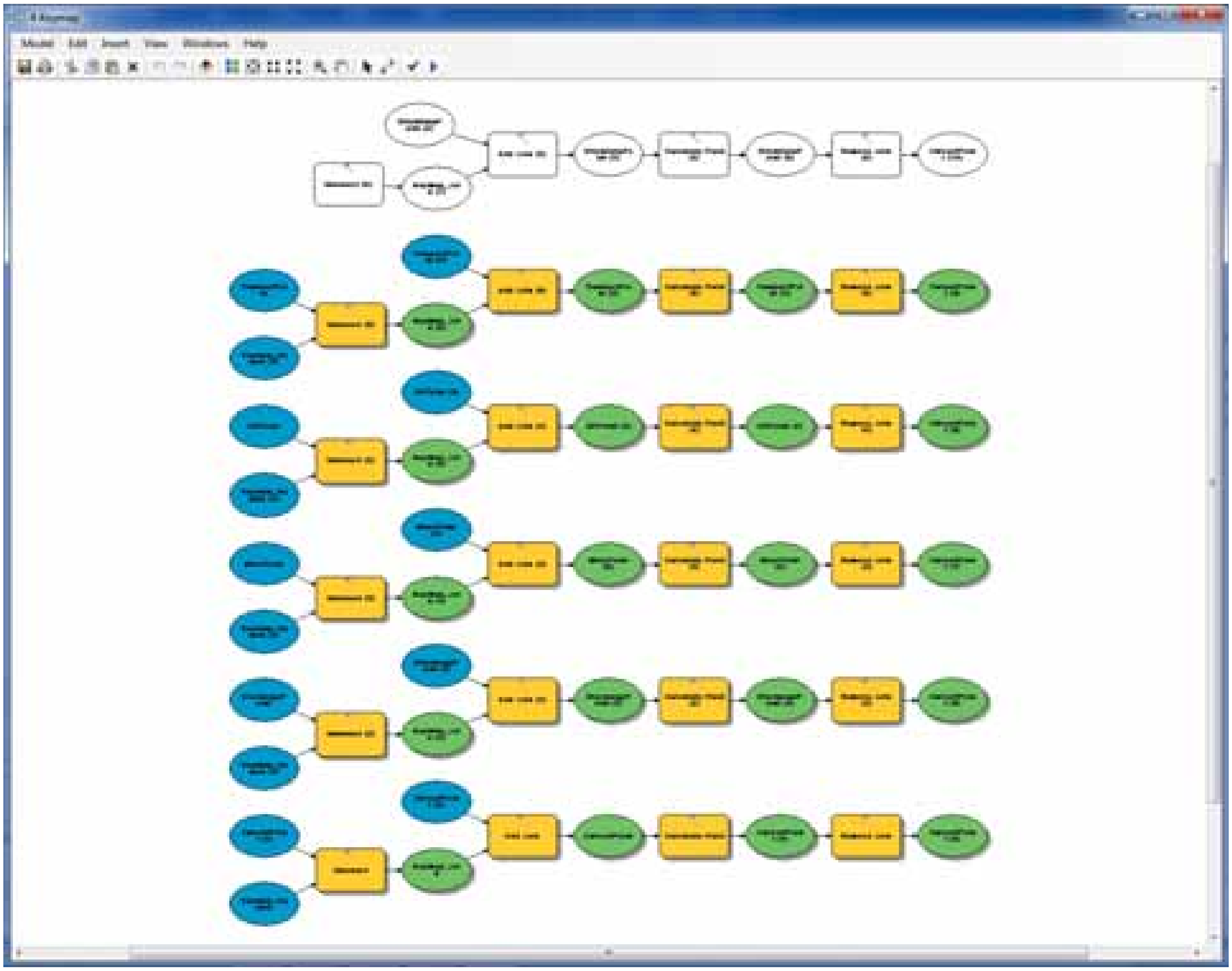
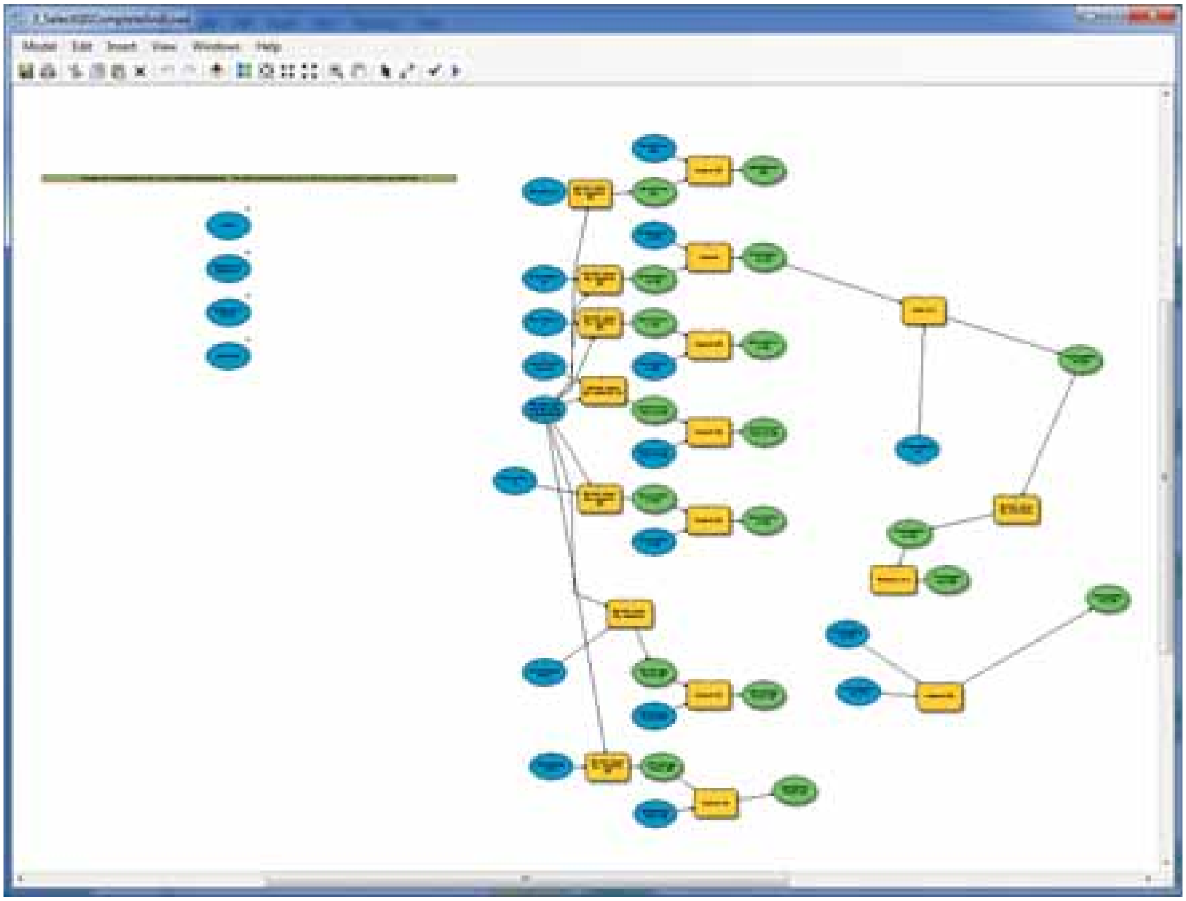


Figure 10 Loading Database Extract



THE SDE DATABASE

GIS analysts from throughout the company in different offices were able to work concurrently on the feature classes and did so in a non-versioned database. Since data were real-time, anyone could see what was already created and move on to an area that needed review. A versioned approach would have delayed and possibly lead to duplication of efforts. This was avoided in the approach taken. The only drawback was that the user had to save frequently since undo operations were not allowed. Critical to this approach, however, was the use of SQL Server Enterprise Studio Manager. The database was able to be monitored by user activity. In some cases, ESRI software would lock a table and not release the lock until a save was instituted. Thus, if a user had not recently saved, he or she could lock out another user, which slowed things down. By monitoring the database, the GIS Developer was able to send instant messages to the users to save edits so locks could be released. Without releasing the locks, users would experience processing delays without any warning.

Linear Network Development

As field-collected data were loaded into the SDE datasets, the GIS analysts began creating the linear network by digitizing polyline segments snapped to the GPS point features and/or existing GIS layers such as creeks and storm sewer inlets.

Roadside Ditches

Roadside ditch line segments were snapped between transect points that had their type classified as “flowline points.” When roadside ditch entered or exited a culvert end, the roadside ditch segment end would snap to that culvert point and the culvert elevation would become the elevation for that end of the ditch. Aerial imagery was also used to assist with digitizing roadside ditches along road segments that were not straight.

Culverts

Culvert lines were digitized by snapping between the GPS collected culvert endpoints. Culvert line attributes were transferred from the culvert points by running a model that automated the spatial join and attribute transfer. The GIS Analysts had to pay close attention to detail while digitizing culvert lines at intersections with multiple culverts. It could sometimes be hard to tell from just looking at the GPS points how the points should be connected. For example, four culvert end points (one at each corner) could be a pair of north/south culverts or a pair of east/west culverts. To digitize them properly, the GIS Analysts had to look at several pieces of information, including the size and material attributes of the points (which helps if they are different between culverts), the field photos (which can give surrounding context), aerial imagery, and Google Street View.

Artificial Flow lines

The artificial flow line feature class was developed to handle a couple different situations where it was difficult to create a completely connected network. One of these situations was when a roadside ditch needed to be snapped to an existing feature in the closed system GIS such as a storm water inlet. The existing GIS features were not mapped with survey grade accuracy and sometimes were out of position far enough that the project team needed to recollect them. These were collected as discharge points (this is the point at which the roadside ditch “discharges” into another feature). An artificial flowline would then be digitized between the discharge point and the corresponding feature in the existing GIS. Network connectivity was maintained and the PWE GIS Analysts can update their existing locations to the new survey grade location. Another situation where artificial flowlines were used was when more than one culvert endpoint was present on the same intersection corner. Typically, roadside ditches were snapped to culvert endpoints and the elevation of the culvert was used for the ditch elevation. When there were two culvert endpoints present, each crossing a different street, the ditches along each street were snapped to the culvert point with the lowest elevation. However, if there is enough water, flow could also go through the higher culvert, or water could be exiting from that culvert. To maintain a connected network, an artificial flowline was digitized from the higher culvert point and snapped directly to the roadside ditch line.

QA/QC

A detailed Quality Assurance Plan (QAP) was developed for the project. The QAP established the QA/QC team and responsibilities, the procedural quality assurance measures, the quality control checks, and the quality results documentation. Multiple procedural steps were put in to place to promote data quality in the field collection procedures and the GIS network development procedures. These included, but were not limited to, the use of domain tables in the customized field data entry forms, the collection and verification of QC calibration points, and the use of automated scripts to perform data loading and attribute updating. Field spot checks were also performed by recollecting a random selection of GPS collected features and verifying the attribute information for accuracy and completeness. After data were loaded into SDE and linear network features were developed, the ESRI DataReviewer tool was used to check the data for geometry errors, topological inconsistencies, as well as many attribute checks in the form of batch SQL queries. For example, queries were run to find culvert diameters less than 12 inches, ditch and culvert lines with null elevation values, or any features missing keymap IDs. DataReviewer was used to identify potential errors and then manage resolution of the identified issues. A custom built photo review tool (MS Access form) was also used to review all field photos and compare with the related feature attributes.

RESULTS AND CONCLUSIONS

After completion of the field GPS data collection, GPS data processing, and GIS data development, the TLC team was able to deliver a geodatabase that filled in a significant piece of the storm drainage infrastructure network: the roadside open channel and cross-street culvert network. In all, over 2,369 miles of roadside ditches were digitized. Over 5,840 individual culverts representing 208,815 linear feet were mapped. 3D transects numbering 31,800 were also developed by connecting over 345,000 survey-grade open channel transect positions. Figure 11 shows a map with an example of the data collected and created on the project.

DataReviewer checks indicated the data were generated with a greater than 99% accuracy based on all attribute batch query checks, geometry checks, and topology checks.

Successful completion of this project was the result of teamwork, careful coordination and planning, and implementation of innovative solutions based on the technology available. Although there were several unique challenges on this project: a large project area, aggressive schedule, and high accuracy requirements, the project team was able to provide a quality product by implementing the strategies below.

- Effective planning, including needs assessment, data model design;
- Well thought out customized field data entry forms and data collection procedures;
- Use of VRS network for real-time survey grade GPS across the city without the need for temporary base stations;
- Use of automated scripts and models to promote efficiency and quality; and
- Use of QA/QC tools, including ESRI Data Reviewer.

The roadside open channel network dataset created on this project will complete the PWE’s storm drainage network in its GIS and better enable them to manage their storm water assets. A solid inventory is a necessity to an effective asset management plan. The open channel network data will also enable the PWE to perform sophisticated analysis through modeling to evaluate the performance and adequacy of their infrastructure so that they can identify and prioritize improvement project and better serve the citizens of Houston by reducing the impact of flood events on property and lives.

Figure 11 Example Map of Project Data

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