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16. Abstract

Each year, thousands of new utilities are installed within the Texas Department of Transportation (TxDOT) right-of-way (ROW). With the proliferation of utilities within its ROW, it is becoming increasingly difficult for TxDOT not only to allow more utilities but also to deliver and manage its own transportation system in a timely and efficient manner.

This research report describes a geographically referenced prototype model that allows TxDOT to tie the location of utility facilities to the state highway network and to associate the positional data with details of utility facility ownership, service or commodity type, infrastructure size, material, and other pertinent characteristics. The inventory model can accommodate a variety of utility-related processes within TxDOT including installation notices (also known as utility permits), joint use agreements, and deliverables from subsurface utility engineering (SUE) contracts.

This research report compiles and reviews existing sources of utility facility data at TxDOT, summarizes a geographic information system (GIS) model that represents the location of utility facilities located within the TxDOT ROW, describes a prototype Internet-based data entry procedure and accompanying data administrative procedure to capture utility installation notice data from utility companies, provides recommendations for implementing the prototype model, and provides recommendations for standards and minimum requirements for quality and content.

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A DATA PLATFORM FOR MANAGING UTILITIES ALONG HIGHWAY CORRIDORS

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NOTICE

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

ASCE	American Society of Civil Engineers
AM/FM	Automated mapping/facility management
APWA	American Public Works Association
ANSI	American National Standards Institute
ASP	Active server page
CAD	Computer aided design
CD	Compact disk
CDO	Collaboration data objects
CSJ	Control section job
DGPS	Differentially corrected global positioning system
DOQ	Digital orthoquadrangle
EPA	Environmental Protection Agency
ESRI	Environmental Systems Research Institute
FGDC	Federal Geographic Data Committee
FHWA	Federal Highway Administration
FTP	File transfer protocol
GASB	Governmental Accounting Standards Board
GIS	Geographic information system
GPS	Global positioning system
HTML	Hypertext mark-up language
IBWC	International Boundary and Water Commission
IIS	Internet Information Server

ISD	(TxDOT's) Information Systems Division
ITS	Intelligent transportation systems
LPA	Local participatory agency
MPRME	Mile Point to Reference Marker Equivalence
NCITS	National Committee for Information Technology Standards
NPDES	National Pollutant Discharge Elimination System
NSDI	National Spatial Data Infrastructure
OLE	Object linking and embedding
PDA	Personal digital assistant
PDF	Portable document format
QL	Quality level
ROW	Right-of-way
SDSFIE	Spatial Data Standard for Facilities, Infrastructures, and Environment
SDTS	Spatial Data Transfer Standard
SMTP	Simple mail transfer protocol
SQL	Structure query language
SUE	Subsurface utility engineering
TLMS	Texas Linear Measurement System
TNRCC	Texas Natural Resource Conservation Commission
TOC	Table of contents
TRICOM	Transportation Research Implementation Consortium for Operations and Management
TxDOT	Texas Department of Transportation
USGS	U.S. Geological Survey

UML	Unified modeling language
WGS 84	World Geodetic System of 1984
XML	Extensible mark-up language

CHAPTER 1. INTRODUCTION

RESEARCH NEED

Public utilities occupy the state ROW by statutory authority. Each year, thousands of new utilities are installed within the TxDOT ROW. With the proliferation of utilities within its ROW, it is becoming increasingly difficult for TxDOT not only to allow more utilities but also to deliver and manage its own transportation system in a timely and efficient manner.

Current practices for managing utility facility data within the TxDOT ROW are not comprehensive or appropriate. For example, TxDOT issues notices of installation (also known as utility permits) in perpetuity, i.e., without an expiration date, which provide only a rough description of the location of the utility within the ROW. In addition, TxDOT does not require utility owners to notify TxDOT of any changes affecting the utilities they operate. Furthermore, utility data storage and archival practices vary widely throughout the state. These practices, compounded by decades of utility facility installation and operation within the TxDOT ROW, have resulted in a lack of institutional memory that prevents TxDOT from knowing exactly what utilities are placed within its ROW, their status and location, and other operational characteristics.

Knowing the location and current operating status of the utilities located within the TxDOT ROW is crucial for managing the ROW and for planning and executing transportation improvements. Unfortunately, TxDOT has no system-wide capability to capture and inventory utility interests or medium to document and display them in reference to existing and proposed transportation improvements. This vacuum is particularly evident at the district level where engineers, planners, and construction and maintenance crews constantly have to struggle with the lack of appropriate documentation and tools to assist in the process of managing the ROW effectively.

There is a need to develop an appropriate utility data inventory model (and associated procedures) for TxDOT. This inventory model would need to be geographically referenced to allow TxDOT to tie the location of utility facilities to the state highway network and to associate the positional data with details of utility facility ownership, service or commodity type, infrastructure size, material, and other pertinent characteristics. The inventory model should be able to accommodate a variety of TxDOT business procedures including installation notices, joint use agreements, utility installations included in TxDOT construction contracts, and deliverables from subsurface utility engineering (SUE) contracts.

RESEARCH OBJECTIVES

The concept of using geographic information system (GIS) technology for managing spatial data is not new. However, research directed at how to implement that technology for managing utility facility data at TxDOT is needed. This report documents the development of a prototype GIS-based platform for the inventory of utility interests located within the TxDOT ROW. Specific objectives of the research include:

- compile and review existing sources of utility facility data at TxDOT;
- develop a GIS model to represent the location of utility facilities located within the TxDOT ROW and associated attribute data such as ownership, purpose, size, type, and other pertinent characteristics;
- develop a prototype Internet-based data entry procedure and accompanying administrative procedure to capture utility data from utility companies;
- provide recommendations for implementing the prototype GIS platform; and
- develop recommendations with respect to standards and minimum requirements concerning the quality and content of utility data.

This report is organized in chapters as follows:

- Chapter 1 is this introductory chapter.
- Chapter 2 documents an evaluation of existing data sources.
- Chapter 3 documents the utility data inventory model.
- Chapter 4 documents an Internet-based utility data capture prototype.
- Chapter 5 summarizes conclusions and recommendations.

CHAPTER 2. EVALUATION OF EXISTING DATA SOURCES

To determine the degree to which existing utility data sources could be used to build a GIS-based inventory of utilities, the researchers conducted a survey of utility coordinators at all 25 TxDOT districts, evaluated a variety of utility data samples, and assessed utility company data sources.

STATEWIDE SURVEY

Researchers distributed a generic survey to all 25 TxDOT districts. The objective of the survey was to assess trends and differences with respect to policies and procedures concerning the management of utility facility data throughout the state. Summarized results based on the 21 responses received by the researchers follow. Detailed results are shown in Appendix A.

Installation Notice Issues

- Roughly 60 percent of the districts process less than 500 proposed installation notices per year. Half of the remaining 40 percent process 1000-2000 installation notices per year. In total, TxDOT estimates it processes around 10,000 installation notices every year. Most districts keep installation notice records for a long time. However, a significant percentage of districts keep installation notice records for less than ten years.
- Most districts keep installation notice records in paper format, e.g., index cards, application forms, and file folders. Only a fraction of districts use electronic documentation techniques such as spreadsheets or databases.
- Roughly 40 percent of the districts have three or more officials who are responsible for capturing utility data from utility entities. Of the officials who deal with the installation notice process, 40 percent spend more than 50 percent of their time in that activity.
- The usual installation notice procedure is as follows (although there is considerable variation from district to district):
  - Utility company submits application to TxDOT district, area office, or maintenance office. Application includes Form 1023 (for non-controlled accessed highways) or Form 1082 (for controlled access highways), drawings, and descriptions. Designated TxDOT official date stamps application.
  - Designated TxDOT official conducts initial review and assigns application to area engineer or maintenance office.
  - Area engineer or maintenance office reviews utility map and site.
  - Designated official issues approval, attaches special provisions, and mails package to utility company. The official also sends copies, as appropriate, to appropriate levels within TxDOT (area engineer or maintenance office).
  - If needed, TxDOT schedules a preconstruction meeting.
  - Utility company begins work.
  - Area engineer or maintenance supervisor verifies installation in the field.
- Most districts conduct a visual inspection during the utility installation process. Only a few districts conduct a visual inspection after the utility installation process is completed.
- Preconstruction meetings are held only in the case of major utility installations. Most “routine” installations only require a maintenance supervisor to be present in the field when the utility work starts.

- Utility companies rarely notify TxDOT about changes in utility installation ownership status, geometric alignment, operational status, or other technical characteristics. Some utility companies notify TxDOT when they dismantle installations.
- TxDOT usually does not impose caps on the flow rate/volume/pressure/output of products/services that are carried on utility facilities located within the TxDOT ROW. In case of emergencies such as spills or blowouts, the clean-up job is usually the responsibility of the utility companies and/or the contractors in the field.

Data Collection/Data Management Issues

- Only 20 percent of districts use a map or graphical display to show the location of utilities within the ROW. Of the districts that use a map or graphical display, roughly half the districts show utility facility elevations in addition to horizontal alignment, overhead transmission lines, or leased utilities.
- Roughly 60 percent of the districts would prefer a district level or a county level as the appropriate level of administration for archiving utility data.
- The vast majority of districts would like to have engineering data and ROW data included in a utility facility database. Very few districts would like to have administration data, property accounting data, or state involvement data in the database.

EVALUATION OF UTILITY DATA SAMPLES

In coordination with the project director, the researchers selected two sample districts: an urban district (San Antonio) and a rural district (Lufkin). In both districts, the researchers interviewed TxDOT personnel who normally deal with utility data sources and examined available data forms and data processing, data archival, and data retrieval procedures. The researchers also evaluated a variety of utility data samples provided by TxDOT.

Installation Notice Data

The researchers evaluated installation notice data from three corridors that appeared to have a substantial amount of installation notice and construction activity in recent years. In San Antonio, two corridor sections were selected (Figure 2-1a): a 19.9-mi section on IH 410 from US 90 to the IH 410@IH 35 interchange and a 6.5-mi section on SH 16 (Bandera Road) from Loop 1604 to IH 410. In Lufkin, a 2.6-mi section on the US 69-BU 69J corridor from SL 287 to BU 59G was selected (Figure 2-1b). The researchers evaluated 227 proposed notices of installation: 80 on IH 410, 92 on SH 16, and 55 on US 69/BU 69J. In the case of the IH 410 installation notices, the average highway length affected was 0.34 mi, i.e., 1.7 percent of the total length considered (19.9 mi). In the case of the SH 16 installation notices, the average highway length affected was 0.41 mi, i.e., 6.3 percent of the total length considered (6.5 mi). In the case of the US 69/BU 69J installation notices, the average highway length affected was 0.30 mi, i.e., 11.6 percent of the total length considered (2.6 mi).

To analyze the spatial positional accuracy and completeness of the data, the researchers evaluated whether the data included a scaled map, reference marker data and/or control section mile point data, relative location with respect to the ROW line or highway centerline, and whether the utility data maps were available in digital format. Based on these criteria, the researchers rated the overall suitability of the utility data for inclusion in a GIS according to the scale given in Table 2-1. Table 2-2 shows a summary of the results. Notice the rating focused on spatial data quality as opposed to attribute, i.e., non-spatial, data quality. While attribute data were important and had to be evaluated, spatial data quality was more critical for determining whether existing utility data sources could be properly represented using a GIS-based system.

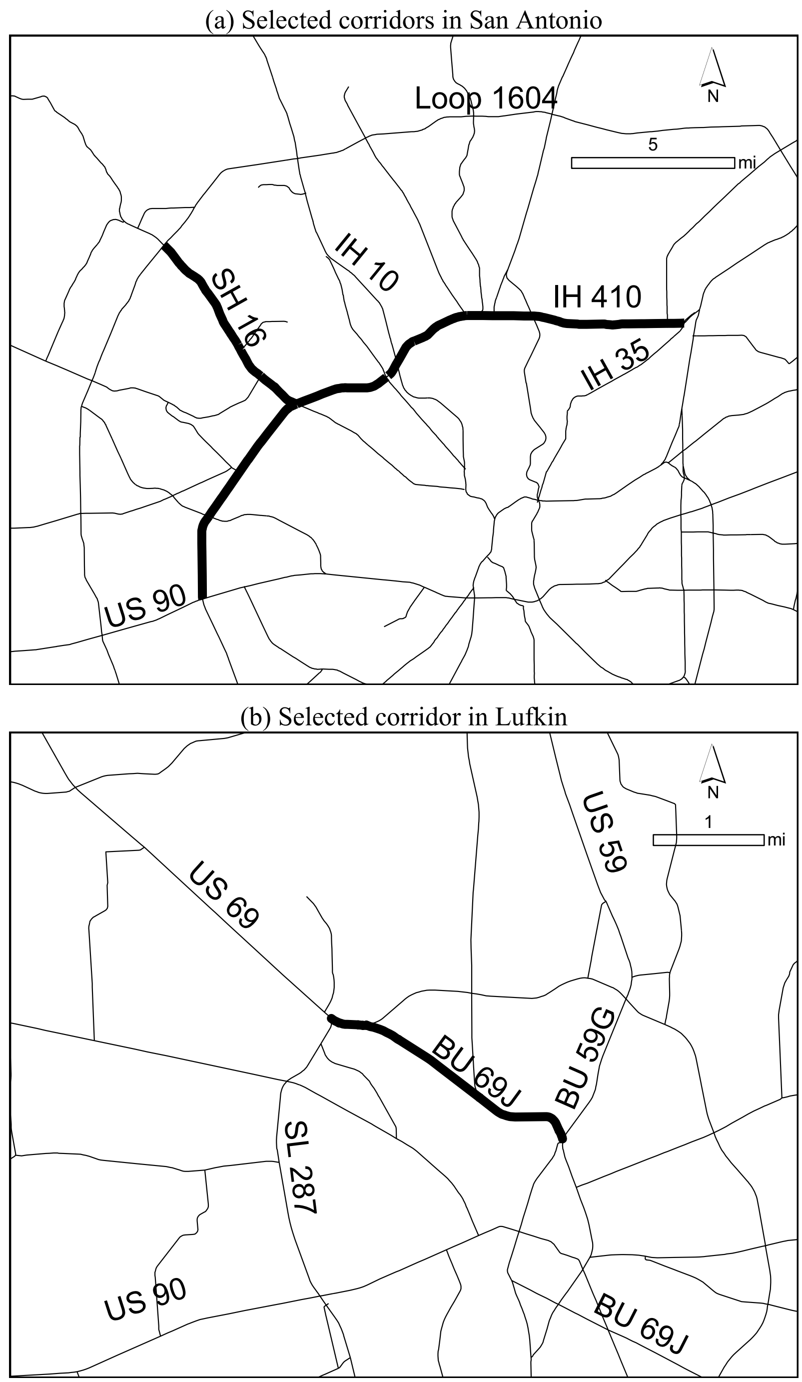


Figure 2-1. Selected Corridors in San Antonio and Lufkin.

Table 2-1. Utility Data GIS Suitability Rating.

Rating	Description
Very good	Utility data in digital format or a digital version would be easily available. Positional accuracy is good, and minor, if any, assumptions are required to import the utility data into a GIS.
Good	Positional accuracy is good and only a few assumptions are required to import the utility data into a GIS.
Weak	Positional accuracy is weak and several assumptions are required to import the utility data into a GIS.
Poor	Difficult to import utility data into a GIS. Major assumptions are required and substantial positional errors would be likely.
Very poor	Extremely difficult to import utility data into a GIS.

Table 2-2. Installation Notice Analysis.

Criteria	Percentage of notices
Map was included	79
Map included geometric scale	20
Reference marker data were included	5
Control section mile point data were included	10
Location with respect to the ROW line/highway centerline was included	21
Map was available in digital form	0

Rating	Percentage of notices
Very good	0
Good	2
Weak	25
Poor	40
Very poor	33

An analysis of the results shown in Table 2-2 indicates the following:

- Most installation notices included at least one drawing or map showing the approximate location of the proposed job. However, only about 20 percent of the drawings were scaled. An even lower percentage of drawings contained reference marker offsets or control section mile point data. Frequently, the drawings included crossing streets. However, because many drawings were not scaled or included only one crossing street, it was difficult to locate individual items along the highway centerline.
- In only about 20 percent of the cases, installation notices included a reference with respect to the ROW line. In some cases, the drawings showed the distance of the utility (mostly existing) with respect to the ROW line. In some other cases, the distance was included in the installation notice approval special provision sheet. The reliability of these distances, however, may be questionable because what the approval form shows is not necessarily what was finally installed in the field. Not surprisingly, drawings and other documentation received from some utility companies contained clearly visible warning labels to the effect that they could not guarantee the accuracy of the location of their utilities and that it was the user's responsibility to contact the utility locator to determine the present alignment of all underground facilities.
- All drawings evaluated were in paper format. Of the several utility companies contacted, only two agreed to provide copies of files in Microstation format. The digital data were

useful in cases where the paper drawings were confusing or insufficient. Unfortunately, the coordinate system data provided by the utility companies were incomplete and/or incorrect. As a result, it was not possible to properly overlay the electronic maps provided by the utility companies on the current TxDOT centerline map. The researchers attempted several coordinate transformation procedures, but a considerable offset between the TxDOT centerline map and the transformed utility maps still remained.

- There was considerable variability in the level of detail included in the drawings. Some drawings contained barely enough information to determine the location of existing and proposed installations. Other drawings were much more detailed; however, many details were difficult to read, without enough symbol legends, and contained information that TxDOT would probably consider irrelevant. This observation clearly highlights the need for the development of a simplified spatial data model for utility data. It also highlights the need for standards and specifications that could be required of utility companies when submitting installation notices.
- The spatial data quality of most notices was, at best, weak. For documentation purposes, however, the researchers made every effort to process as many utilities as possible, regardless of overall data quality. Because of the amount of time needed to understand and read the drawings, the number of individual assumptions, and the amount of manual distance computations needed, a student technician required from half an hour to an hour to process individual installation notices. For a district like San Antonio, that processes between 1000 and 2000 permits per year, that level of productivity would translate to the equivalent of one technician working half time to full time all year just processing new data. However, because of the poor data quality and low highway coverage levels, a GIS system based on that type of data would provide very little value.

Installation Notice Database

The researchers analyzed a copy of an Access database used by the San Antonio District to track the installation notice review process. This database is composed of several tables, queries, forms, and macros that provide the capability to issue and print approvals using a graphical interface. Figure 2-2 shows some of the screens available to users of the database.

The installation notice database uses the following tables:

- Utility Permits: This is the master table. It contains fields that summarize the installation notice review process including permit ID, control date fields, utility company name, address, control section, maintenance section, highway ID, and utility contractor.
- Addresses: This table contains mailing address data.
- Work Type Descriptions: This table includes a list of basic work types. Examples include overhead electric line, underground electric line, and aerial cable television.
- Maint Sect: This table contains basic information about maintenance offices, including name, supervisor's name, Area Engineer's name, and Area Office phone number.
- County Table: This table contains a list of county codes and county names.

The utility database has provided automation to the installation notice review process. However, the database is not relational and is not geo-referenced, i.e., it does not support linking installation notices to utility features in a GIS format. These two characteristics limit the potential of the database as the foundation for a statewide utility data management system.

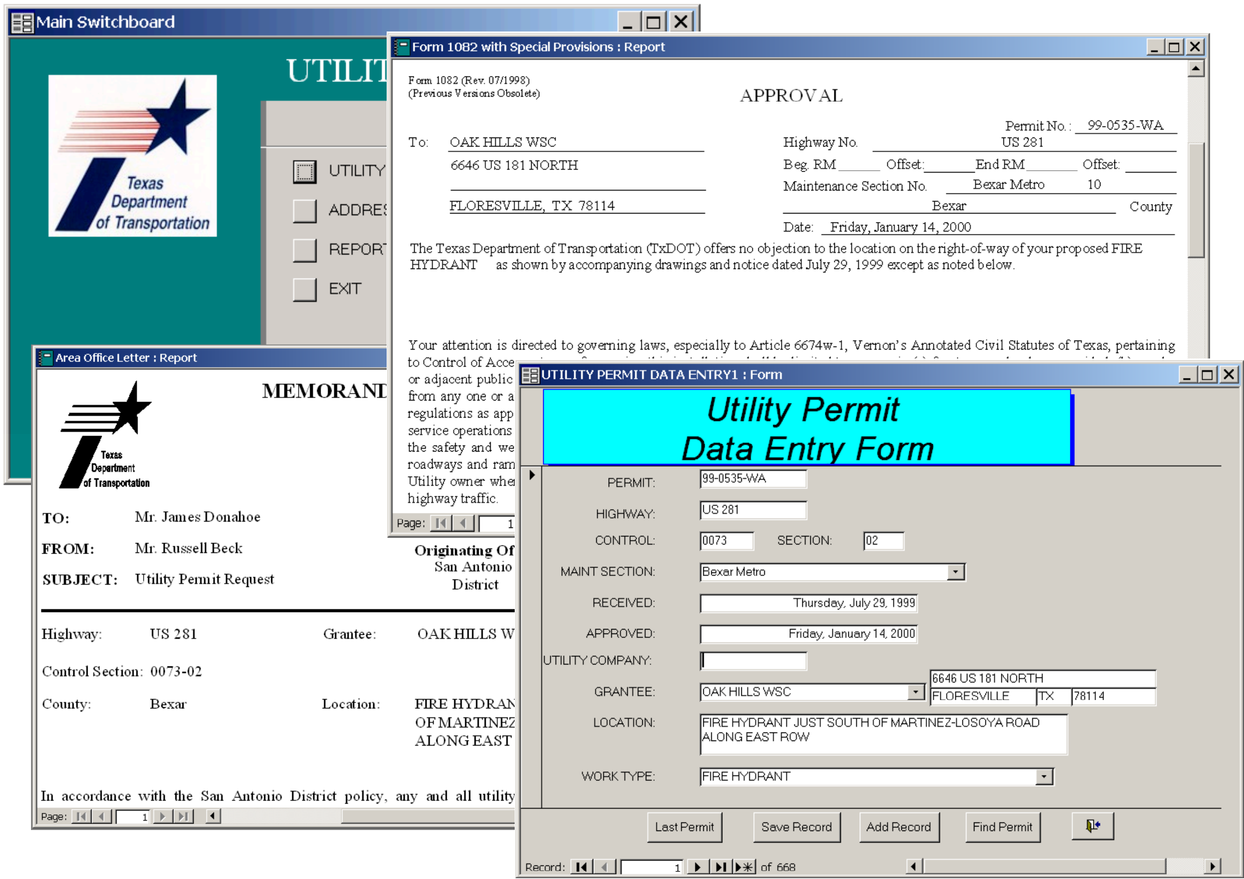


Figure 2-2. San Antonio District Installation Notice Database Interface.

Subsurface Utility Engineering Data

The researchers evaluated a sample SUE report that documented the alignment and type of utility facilities found along a section of US 59 in Nacogdoches County. The report included control section mile point data and project station location documentation. It did not include reference marker data. However, TxDOT maintains an equivalence lookup table to convert control section mile point data to reference marker data. The table is called Mile Point to Reference Marker Equivalence (MPRME) and is updated regularly. The report did not include vertical profiles of utility facilities. However, it did include cross sections documenting the elevation of underground installations at specific locations along US 59. The report did not document the positional accuracy of the data collected in the field.

TxDOT is increasingly using the SUE process to obtain information about the location of underground utility installations within the TxDOT ROW. Historically, there has been considerable variability in the way the SUE industry has defined and characterized SUE data collection methods, which has had an impact on the quality of the resulting data. For example, “designating” is now the preferred term for identifying the process of using a surface geophysical method to interpret the location of an underground utility. However, "locating" is sometimes used to identify the same process, even though "locating" is now the preferred term for identifying the process of exposing and determining horizontal and vertical coordinates of a utility facility. In an effort to standardize definitions, procedures, and quality expectations, the American Society of Civil Engineers (ASCE) sponsored the development of a consensus document that has recently become an ASCE standard (*1*). According to information provided to the researchers, there is a possibility the new standard might also become an American National Standards Institute (ANSI) standard. As Table 2-3 shows, the standard uses four quality level (QL) categories, each one implying a different set of conditions, therefore different data quality. For example, an inventory is QL "D" if it only uses information derived from existing records or oral recollections. In contrast, an inventory is QL "A" if it includes exposing existing underground installations and accurately surveying those locations. The classification scheme does not provide a horizontal positional accuracy numerical indicator to be associated with each QL. Only in the case of QL "A," the standard suggests the survey "should conform to applicable horizontal survey and mapping accuracy as defined or expected by the project owner" (*1*).

Table 2-3. Quality Levels (QLs) for Underground Utility Surveys –Adapted from (*1*).

Quality Level (QL)	Description
D	Information derived from existing records or oral recollections.
C	Information obtained by surveying and plotting visible above ground utility features and by using professional judgment in correlating this information to QL D information.
B	Information obtained through the application of appropriate surface geophysical methods to determine the existence and approximate horizontal position of subsurface utilities. QL B data should be reproducible at any point of their depiction using surface geophysical methods. This information is surveyed to applicable tolerances defined by the project and reduced onto plan documents.
A	Precise horizontal and vertical location of utilities obtained by the actual exposure (or verification of previously exposed and surveyed utilities) and subsequent measurement of subsurface utilities, usually at a specific point. Minimally intrusive excavation equipment is typically used to minimize the potential for utility damage. A precise horizontal and vertical location as well as other utility attributes are shown on plan documents. Accuracy is typically set at 15 mm vertical, and to applicable horizontal survey and mapping accuracy as defined or expected by the project owner.

As-Built Plans and Construction Plan Sheets

TxDOT provided samples of as-built plans and construction plan sheets. Similar to the SUE report described previously, the as-built plans and construction plan sheets included control section mile point data and project station locations. Using the MPRME table described before, it would be possible to convert the control section mile point data to highway ID and reference marker offsets. The plan sheets also included the location of the ROW lines and the horizontal alignment of utilities located within the ROW. Because the plan sheets include linear distances along corridors, and the linear distances can be converted to reference marker-based distances, it appears the plan sheets are sufficient for a first-phase conversion of utility data to a GIS format. Unfortunately, up-to-date plans, particularly those in electronic format, tend to cover relatively short distances. This reality limits the potential of using current as-built plans and construction plan sheets as the foundation for a utility data management system, at least in the short term.

Joint Use Agreements

The researchers analyzed a database used by the ROW Division at TxDOT to track the joint use agreement process. Figure 2-3 shows some of the screens available to users of the database.

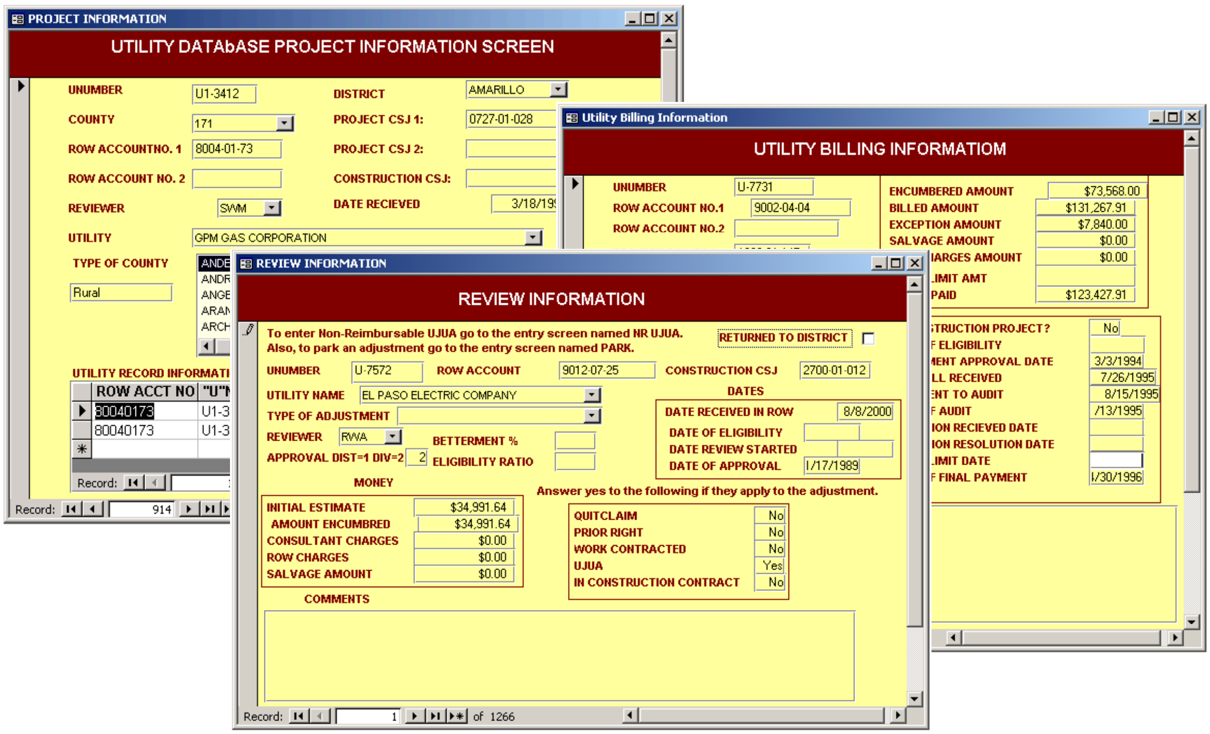


Figure 2-3. ROW Division Joint Use Agreement Database Interface.

Joint use agreements can be loosely defined as legal contracts between TxDOT and utility companies that define the role of each party, indicate which party is responsible for future changes, and which party owns the property interests. A joint use agreement is not necessary if an installation notice already exists and, therefore, the utility company receives no reimbursement for any relocation costs. A unique "U" number usually identifies joint use agreements. This number corresponds to a file folder that stores all the documentation associated with individual agreements. All reimbursable agreements have "U" numbers. However, there are cases where local participatory agencies (LPAs) handle ROW acquisitions. In these cases, TxDOT does not provide reimbursement for the cost of utility relocations, and, consequently, TxDOT does not assign a "U" number to the resulting joint use agreement. All joint use agreements, whether they have "U" numbers or not, are also tracked using a control section job (CSJ) number.

The database has provided some level of automation to the joint use agreement process. However, like the Access installation notice database application described previously, the joint use agreement database is not relational and is not geo-referenced. Further, the database lacks a unified identification mechanism for keeping track of all joint use agreements at TxDOT. These characteristics limit the scalability potential of the current database and the feasibility to integrate that database with other utility data sources at TxDOT.

UTILITY COMPANY DATA SOURCES

Most existing utility data sources at TxDOT do not provide a solid foundation for building a robust utility data management system. Installation notice documentation provides most of the available information. However, the quality (from the point of view of suitability for inclusion in a GIS) of this information is poor and the spatial coverage is sparse. Even assuming good spatial data quality, a sparse spatial coverage means that installation notice documentation alone would be insufficient for developing the utility data management system. It follows that the foundation of this system should be based on a more comprehensive data collection effort. Installation notice documentation would still play an important role, though, because it could be used to update specific utility features and attribute data on a regular basis. As opposed to installation notice documentation, SUE reports and highway improvement plan sheets typically provide enough level of detail and linear referencing information to build components of the utility data management system. Unfortunately, they represent only a fraction of the amount of utility data sources available at TxDOT.

One possible solution to address this limitation could be to use data already available at utility company databases. One of the benefits of this approach would be that a number of utility companies already have automated mapping/facility management (AM/FM) information systems in place to document their assets. However, a number of practical reasons could prevent TxDOT from tapping into this apparently vast data source:

- Utility data management practices vary widely among utility companies. Companies that have used AM/FM systems for years may be able to document spatial and attribute data characteristics associated with their assets quite effectively. However, other utility companies, particularly small, "mom-and-pop" type operations, tend to follow more informal approaches to asset management and, consequently, have a limited capability to document their assets effectively. Even in the case of major utility companies, geo-referencing standards and procedures vary widely. Regardless of how sophisticated the information system may be, however, utility companies are under no legal obligation to share their databases and digital maps with TxDOT and/or other agencies.
- The data needs of a transportation agency such as TxDOT are usually quite different from those of a typical utility company. Like most transportation agencies, TxDOT has an aggregated interest with respect to utility installations within the ROW and focus on location, basic data attribution, and physical interaction among all utility installations located within the ROW. In contrast, utility companies have a detailed interest in the safety and operational characteristics of their own installations. The AM/FM systems available in the market focus on providing vertical integration, i.e., they are tailored to satisfy the specific operational, maintenance, and dispatching needs of individual utility companies. This reality makes the process of exchanging and/or integrating data with other utility companies and transportation agencies difficult.
- Utility companies tend to be specialized. For example, electric utility companies do not normally operate water utilities and telephone companies do not normally operate gas utilities. In the field, however, there is considerable interaction among utilities. Still, utility data management systems tend to be utility-specific, with little room or flexibility to accommodate multiple users or changes in utility feature characteristics. Figure 2-4

illustrates this situation. A utility pole supports three installations, each one owned by a different utility company (Figure 2-4a): an electric line, a telephone line, and a data line. Each utility company uses a separate AM/FM system to document utility assets, which results in three different system representations for the same utility pole. The coordinates assigned to the pole, as indicated in the AM/FM systems, could be different. As a result, if one overlays sample files from the three AM/FM systems (Figure 2-4b), it might not be possible to determine whether the point features on the screen are representations of the same pole on the ground. Even if the point features match perfectly on the screen (Figure 2-4c), it might not be possible to know with absolute certainty whether the single point represents one pole or three poles that just happen to be very close to each other on the ground. The uncertainty of not knowing what is actually installed in the field could contribute to delays in the highway design or installation notice review process, not to mention potential liabilities in case there is any conflict among utility installations or between utility installations and highway structures.

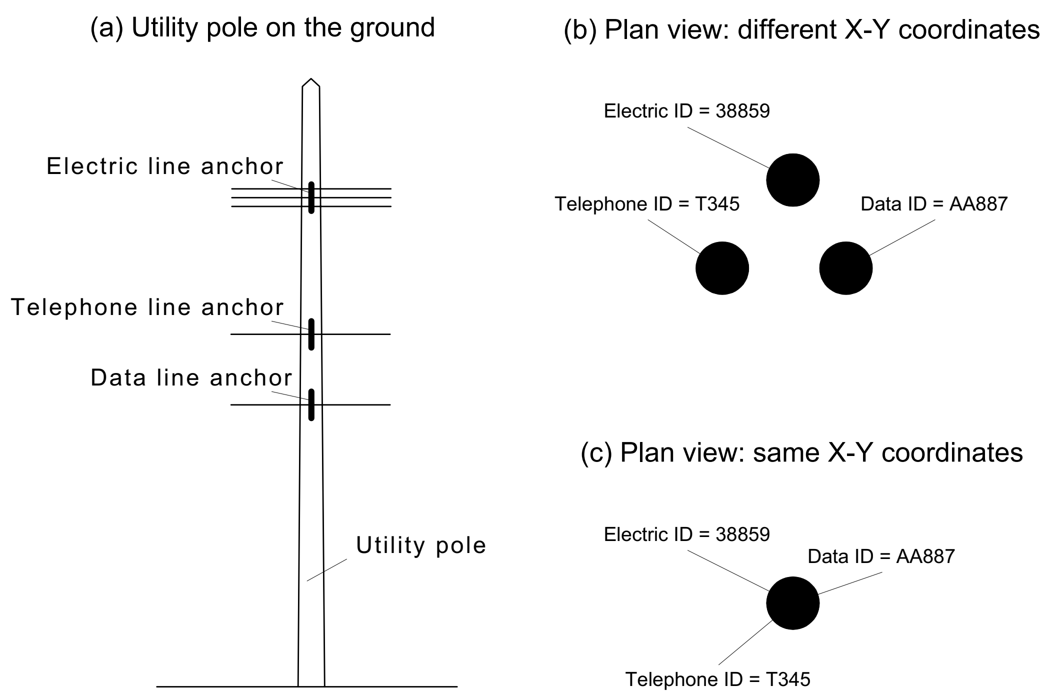


Figure 2-4. Sample Utility Pole Supporting Electric, Telephone, and Data Utilities.

Despite the challenges, data exchange and/or data integration between utility companies and government agencies such as TxDOT should be encouraged. Utility coordination councils or committees, which meet regularly to address utility issues at the local level, are a step in the right direction. However, more needs to be done. To facilitate data exchange and/or data integration among entities, it would be necessary to agree upon data exchange formats and standards. The inventory model and associated procedures developed as part of the research could be one of the founding mechanisms for that data exchange system. Subsequent chapters describe the model and associated procedures.

CHAPTER 3. UTILITY DATA INVENTORY MODEL

ROADWAY DATA MODEL FRAMEWORK

From the standpoint of a transportation agency like TxDOT, linearly referencing utility features, i.e., defining the parameters to completely characterize the relative position of utility features along highway networks, is important. TxDOT, for example, uses both a control section-distance approach and a reference marker-distance approach for linearly referencing objects or events along the state highway network. With the control section-distance approach, the state highway network is divided into controls and sections and objects/events are located by determining their relative distance with respect to the beginning of the specific section. Practically all construction projects in the state are tied to the control section-distance model, and many districts use this model to locate utilities within the ROW. With the reference marker-distance approach, the state highway network is divided into routes and objects/events are located by determining their relative distance from one or more reference markers that are physically located at strategic locations on all state highways. As mentioned in Chapter 2, TxDOT maintains an equivalence lookup table to convert control section mile point data to reference marker data MPRME. Figure 3-1 illustrates the conversion process and Table 3-1 shows a few sample records from the MPRME table.

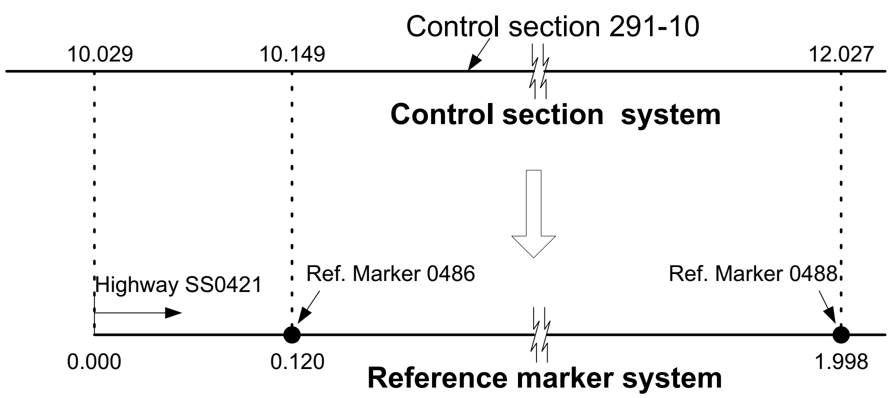


Figure 3-1. Control Section to Reference Marker Equivalence (Distances in Miles).

Table 3-1. Sample Records from the MPRME Table.

District ID	County ID	Control section	Begin MP	End MP	Length (mi)	HwyID	From RefMkr	From Dist	To RefMkr	To Dist	Date
15	15	029110	1	1.741	0.741	SH0016	0580	1.227	0582	0	Jan/2000
15	15	029110	1.741	3.699	1.958	SH0016	0582	0	0584	0	Jan/2000
15	15	029110	3.699	5.792	2.093	SH0016	0584	0	0586	0	Jan/2000
15	15	029110	5.792	7.759	1.967	SH0016	0586	0	0588	0	Jan/2000
15	15	029110	7.759	9.892	2.133	SH0016	0588	0	0590	0	Jan/2000
15	15	029110	9.892	10.029	0.137	SH0016	0590	0	0590	0.137	Jan/2000
15	15	029110	10.029	10.149	0.120	SS0421	0486	-0.120	0486	0	Jan/2000
15	15	029110	10.149	12.027	1.878	SS0421	0486	0	0488	0	Jan/2000
15	15	029110	12.027	13.882	1.855	SS0421	0488	0	0488	1.855	Jan/2000

As a base map, TxDOT uses a highway centerline map that was originally digitized using 1:24,000 U. S. Geological Survey (USGS) 7.5-min quadrangle maps. Using submeter positional accuracy level GPS data collected in San Antonio as a reference, the researchers have estimated the positional accuracy of the TxDOT centerline map as being 100-200 ft. The centerline map is "measured," meaning each vertex along linear features representing individual highways has a cumulative distance attribute. The first vertex has a distance attribute equal to zero, and the last vertex has a distance attribute equal to the length of the highway. The measure attribute can be used to locate point and/or linear features along the highway. For example, reference markers 0486 and 0488 in Figure 3-1 are located 0.120 miles and 1.998 miles, respectively, from the beginning of Spur Highway 421 in San Antonio. Using a GIS equipped with dynamic segmentation capabilities, it would be possible to locate the reference markers on a GIS screen just by specifying the relative distance of the point features from the beginning of their associated highways. As an illustration, Figure 3-2 shows the application of this process in the case of reference markers along state highways in San Antonio. Notice the location of reference markers 0486 and 0488 along SS 421.

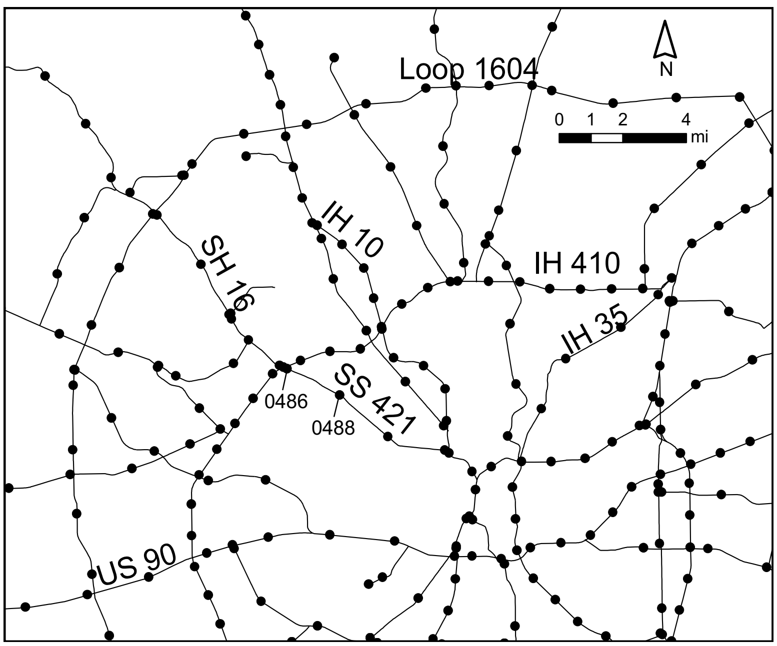


Figure 3-2. Reference Markers on State Highways in San Antonio.

Locating features on a GIS screen based on the alignment of an underlying highway map implies the positional accuracy of those features cannot be better than that of the underlying highway map. This would mean, for example, that the positional accuracy of reference markers 0486 and 0488 (Figure 3-2) could not be better than 100 ft in any direction (assuming of course the distances associated with these reference markers, 0.120 and 1.998 miles, respectively, do not have a larger implicit error). This would also mean, in the case of utility features, that if their location on the map depends on the alignment of the current TxDOT centerline map, their associated positional accuracy could not be better than 100 ft in any direction. In some cases where the actual highway alignment is complex, e.g., freeway interchanges and ramps, the positional error of the utility features could actually be much larger because the current TxDOT centerline map does not properly model complex highway geometries.

This observation has several implications for TxDOT. Perhaps the most critical one is the lack of compatibility of the mapped data with respect to other maps produced by TxDOT and other agencies. For example, TxDOT is currently developing a new roadbed centerline base map to address many of the limitations of the current centerline map. With the new base map, each roadbed, or direction of travel in the case of divided highways, will have its own directional centerline. This includes ramps and direct connectors. Each roadbed centerline will be divided into 6-14 mi long segments running between latitude- and longitude-fixed anchor points. The new roadbed centerline map will have a submeter positional accuracy level in any direction. This means the relative position of any utility point and/or linear feature located using the current TxDOT centerline map will likely "shift" when overlaid on the new roadbed centerline map.

The "shift," which in reality is an indication of a positional error, might prove to be quite substantial. For example, assume an installation notice shows a utility company has installed a utility pole on the north side of SH 16, 10 ft inside the ROW line, 227 ft from reference marker 0590 on SH 16 (Figure 3-3). Assume for simplicity the ROW width is 120 ft (i.e., 60 ft on either side of the centerline). Using the current TxDOT centerline map to locate the utility pole in the GIS, this feature would appear as being located on the north side of SH 16, 50 ft off the highway centerline (Figure 3-3a). Once the point feature has been generated in the GIS, a coordinate pair X_1, Y_1 is automatically assigned to the feature. Notice in Figure 3-3a the current TxDOT centerline map does not provide directional differentiation, and this includes entrance ramps, exit ramps, and turnaround lanes.

Now assume the point feature having X_1, Y_1 coordinates is overlaid on a submeter positional accuracy level directional centerline map that follows the new TxDOT roadbed centerline model (Figure 3-3b). Because of the differences in positional accuracy and resolution between the current and the new road base maps, the point feature in Figure 3-3b is displayed on the south side of the westbound roadbed centerline of SH-16. For the feature to be displayed on the north side of the westbound roadbed centerline, it would be necessary to modify its coordinates. This could be done by manually moving the point on the GIS screen. In practice, many more point and linear features would likely be affected and it would be necessary to move them as well. While there are several techniques available for accomplishing this task, including "rubber sheeting" and coordinate shifting, the process is not simple, requires considerable GIS expertise, and may result in additional positional errors. These errors must be added to the uncertainty associated with the original coordinates of the features being moved. As a result, while the need to move the features may be apparent to the analyst, the amount and direction of the required movement may be unknown, rendering the correction infeasible.

To ensure compatibility with the current and the new road base map (and any other map for that matter), it would be necessary to determine the location of utility features independently. For example, assume the utility pole in Figure 3-3 is surveyed in the field with a GPS receiver and a corresponding coordinate pair X_2, Y_2 is available. Assume for simplicity the positional accuracy level of the GPS receiver is at least submeter. When the resulting feature is displayed on the new submeter level roadbed centerline map, the point feature would correctly appear on the north side of the westbound roadbed centerline on SH 16 (Figure 3-3c). Using GIS linear referencing functions, it would be possible to determine linear referencing measures (cumulative distance and offset) for the point feature with respect to the westbound roadbed centerline on SH 16. Linear referencing measures would also be possible with respect to the current centerline map. These linear referencing measures would be different and most likely incorrect. However, at least the underlying X_2, Y_2 coordinates associated with the utility pole point feature would remain unchanged.

(a) Utility pole overlaying existing TxDOT centerline map (X_1, Y_1 coordinates are obtained from map)

(b) Utility pole overlaying new roadbed centerline map, using X_1, Y_1 coordinates from (a)

(c) Utility pole overlaying new roadbed centerline map, (X_2, Y_2 coordinates are obtained in the field)

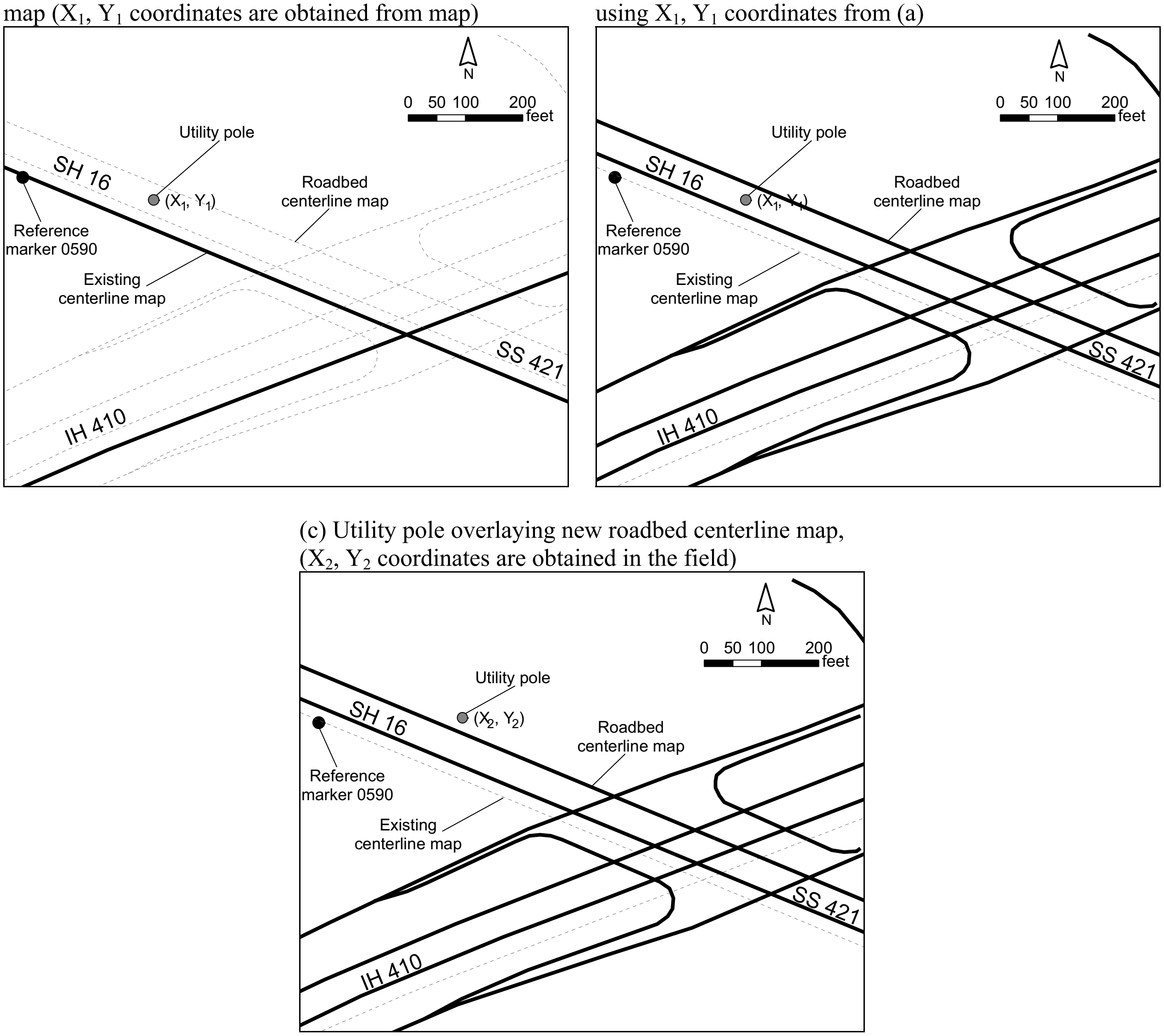


Figure 3-3. Utility Feature Overlaying Highway Centerline Maps.

Using a highway-independent GPS approach for the inventory of utilities has two additional advantages:

- An increasing number of TxDOT districts already have surveying-type or mapping-type GPS receivers in their inventory. The same is true of many utility companies. Small utility companies and location services might not necessarily have GPS receivers. However, access to GPS technology is becoming affordable. For example, a seven-day rental fee for a surveying-grade GPS receiver with data dictionary and attribute data recording capabilities is now around \$500. This makes a GPS-based approach for the inventory of utilities feasible.

- A highway-independent positioning system such as GPS could provide the foundation for a utility data exchange mechanism between utility companies and TxDOT. Practically all GPS receivers in the market output coordinate data in latitude-longitude pairs using the World Geodetic System of 1984 (WGS 84) datum. With this de facto standard, it should be relatively straightforward for utility companies to, for example, include an attachment with their notice installation containing the latitude-longitude coordinates of their proposed fieldwork. TxDOT could plot these coordinates, verify their location in the field, and provide comments tied to the latitude-longitude location of specific problem areas. When the utility work is completed, TxDOT could use the final latitude-longitude coordinates to update existing features or generate new features in the database. It should be noted that, even though GPS data are usually given in latitude-longitude pairs, these data can be easily projected in the GIS to other systems, e.g., to the State Plane Coordinate System normally used for TxDOT engineering applications.

UTILITY DATA MODEL

Recent Modeling Efforts

In general, for a utility data management system to respond to the needs of a transportation agency such as TxDOT, the system has to comply with a set of functional requirements including the following:

- geo-referenced inventory modeling that also allows utility locations to be associated with highway facility locations;
- flexibility to accept utility data from a variety of business procedures such as installation notices, SUE task orders, and joint use agreements;
- data standardization across procedures; and
- from an implementation perspective, support for automated data entry and data query procedures.

The use of GIS technology to manage utility data is increasing. As described in Chapter 2, however, commercially available AM/FM systems and applications have been driven by the inventory, operational, and maintenance needs of utility companies. Examples of AM/FM systems used by the utility industry include Azteca Systems' Cityworks (*2*), Miner & Miner's ArcFM (*3*), and Intergraph's Geofacilities Management System (*4*). These systems provide industry-specific comprehensive solutions for utility asset management—from design to construction to operations to maintenance—and include features such as asset management templates, service request and work order systems, graphical editing and design tools, wireless field data collection and/or editing, material inventory, and integrated engineering and network analysis tools. Some systems are also beginning to include reporting tools in response to asset valuation requirements such as GASB 34 (*5*).

Major GIS vendors are developing spatial data models for the utility industry. For example, ESRI is developing the following industry-specific data models with the goal to provide vertical integration within each industry and templates for the implementation of GIS projects (*6*): electric distribution, electric transmission, gas, petroleum, telecommunications, sewer storm water, and water distribution. Worth noting is that while the data models intend to provide integration within each industry, different groups of researchers and practitioners are in charge of different data models. One of the byproducts of this "application island" approach is that horizontal data integration, i.e., data integration across industries, becomes more difficult. As an illustration, ESRI is also developing a transportation data model to facilitate the management and display of transportation networks, facilitate data sharing, and provide a common ground for developers (*6*). The transportation data model includes an assets object type that is used to represent features located along the transportation network. Unfortunately, asset points and lines are subclasses. As such, they do not have a shape or extent and their existence is only implied by their relative location along the network. In other words, asset points and lines are not physical, independent features in the GIS. This modeling strategy is not only incompatible with the way utility features are handled in the other ESRI data models, but also, from the discussion at the beginning of this chapter, inadequate.

A number of efforts, mostly led by federal government agencies, are focusing on the development of open-architecture, non-proprietary spatial data models and standards. Worth noting is the Spatial Data Transfer Standard (SDTS) (*7*), which is mandatory for federal agencies, and the efforts by the Federal Geographic Data Committee (FGDC) to coordinate the development of the National Spatial Data Infrastructure (NSDI) (*8*). Also worth noting is the Spatial Data Standard for Facilities, Infrastructures, and Environment (SDSFIE), developed by the U.S. Army CADD/GIS Technology Center (*9*). This standard, which was approved by the National Committee for Information Technology Standards (NCITS) as NCITS 353 in 2001, provides a detailed catalog of features and database definitions for military facilities, civilian airports, and other public facilities. The standard includes a wide range of feature and database definitions for utility installations, including electric, gas, water, sewer, and communications facilities. The standard is designed to support the management of facilities and installations and provides a level of feature detail that is roughly comparable to that found in commercial AM/FM systems.

One of the limitations of current GIS technology in general is its inability to deal with the time dimension effectively. GIS software available today only provides static views of the world and compensates for this limitation by relying on map layers or attribute event tables to represent events. This approach has several drawbacks including redundant storage, lack of versioning continuity, and lack of temporal continuity. Some research has been devoted to develop data models that explicitly integrate time and geo-referenced data through space-time entities (*10*, *11*). However, this research effort has not yet resulted in commercial applications, leaving GIS administrators and developers with little option but to continue using the current "static view" technology they have used until now.

Spatial Data Model

Because a transportation agency such as TxDOT has an aggregated level of interest with respect to utility installations within the ROW, it makes sense to develop utility data models and systems that are consistent with TxDOT's mission and are compatible with other internal data management systems. From the review above, it appears that available systems and data models, while detailed and appropriate to assist in the process of managing the daily operation of utility installations, do not really address TxDOT's needs. For this reason, it was necessary to develop a customized, simplified prototype utility data inventory model. Figure 3-4 shows the prototype utility data inventory model. The model uses 2-D point and linear physical spaces (or features) that characterize the "footprint" on the ground occupied by one or more utility installations. Utility installations that share the same "footprint" are considered users of the physical space (or feature) they occupy. For example, each utility pole in Figure 3-4 represents a point feature with three users: each user is a utility anchor owned by a different utility company. Each user has a unique position ID within the feature. Similarly, the "footprint" created by the stacked lines between the utility poles represents a linear feature with three users; each user is a line owned by a different utility company. A duct bank would also represent a linear feature with as many potential users as the number of ducts. Each point or linear feature has a unique identifier that is used to keep track of events throughout the lifetime of the feature. In general, linear features begin and end at point features.

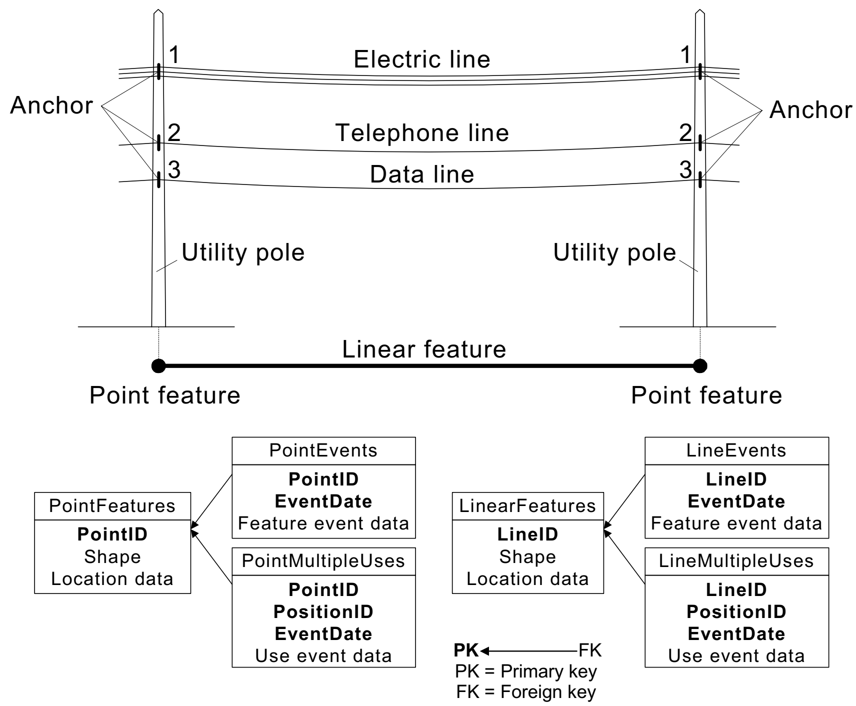


Figure 3-4. Aggregated Spatial and Database Model for Utility Features.

The spatial model assumes the location of point and linear features is independent of any highway base map. The highway base map still plays a significant role, though. As mentioned before, the highway map can provide linear referencing measures (both distance and offset measures) to utility features. Using functions now commonly available on many GIS software packages, the process to obtain linear referencing measures for utility features is relatively straightforward and does not have any effect on utility feature underlying coordinates.

X, Y coordinate pairs determine the location associated with the feature. Each feature has horizontal and vertical positional accuracy numerical indicators as well as a QL indicator that follows the ASCE standard described in Chapter 2. From a GIS management perspective, the spatial data model assumes that feature location updates, which would normally be associated with changes in QL, are handled using utility map versioning to avoid having two or more graphical features on the same map that actually represent the same feature on the ground. As the database schema section below describes, the feature event tables document changes in QL; however, because of current limitations in GIS technology, the actual change in coordinates must be handled using different versions of the utility inventory map.

Database Schema

Many things can happen throughout the lifetime of a feature. In general, there is a distinction between feature events and feature user events (Figure 3-4). Feature events refer to physical changes that affect the feature throughout its lifetime without affecting the location and/or characteristics of any of the users. For example, if a metal utility pole replaces a wooden one, a feature event would handle the change. Each feature event is time stamped. Feature user events refer to changes that affect any of the users associated with a feature. For example, if a new data line is attached to a series of existing utility poles, a feature user event would handle the change. Each feature user event is time stamped.

By default, every feature has one user, usually the first user, called the primary user. For example, it is reasonable to assume an electric line first occupies the linear physical space between two adjacent poles originally installed by an electric utility company. This would make the electric utility company the primary user of the linear feature connecting the two adjacent poles. By default, the feature owner is the primary user. Notice that ownership refers to the actual physical structure, e.g., a utility pole or a duct bank, not the ROW, which belongs to TxDOT. However, the feature owner is not necessarily also a feature user. For example, if TxDOT builds “utilidors” –tunnels that house several utility installations, TxDOT would own the linear feature but would lease the use of the “utilidor” to individual utility companies. In this case, TxDOT would own the linear feature but would not be a feature user.

As Figure 3-5 shows, the database uses a series of lookup tables to characterize individual features and feature users. Figure 3-6 shows actual entries included in the lookup tables. Table EventTypes describes the type of event that affects each feature or feature user (e.g., activation, change in properties, decommission, and change in quality level). Table UtilityClasses describes the overall group under which a utility facility can be classified (e.g., electric, telecommunications, chemical, water, sewer, and water-other). Table UtilitySubClasses describes a utility subclass used to further characterize the function of a specific utility feature (e.g., electric, data-communications, telephone, television, gas, storm water, sewage, and reclaimed water). Table FeatureClasses describes the relative importance of a utility feature (e.g., collector, distributor, main, and transmission). Table FeatureTypes contains names of linear or point features (e.g., cable, forced pipeline, gravity pipeline, anchor, box, dead end, guy, manhole, pole, pump, transformer, and valve). Table LocationTypes specifies whether the utility feature is underground, at ground level, or above ground. Table Units contains commonly used measurement units (e.g., feet, kilovolts, and pairs). Table MaterialTypes contains types of materials (e.g., aluminum, brick, cast iron, fiber optic, steel, and wood). Table CasingTypes contains types of encasing structures (e.g., conduit and concrete fill). Table UtilityCompanies contains a listing of registered utility companies. Table Method contains a listing of field data collection methods (e.g., Digitized DOQ –digital orthoquadrangle, DGPS—differential GPS—

beacon, and DGPS carrier-fixed). Table QualityLevels contains a listing of quality levels following the ASCE standard described in Chapter 2.

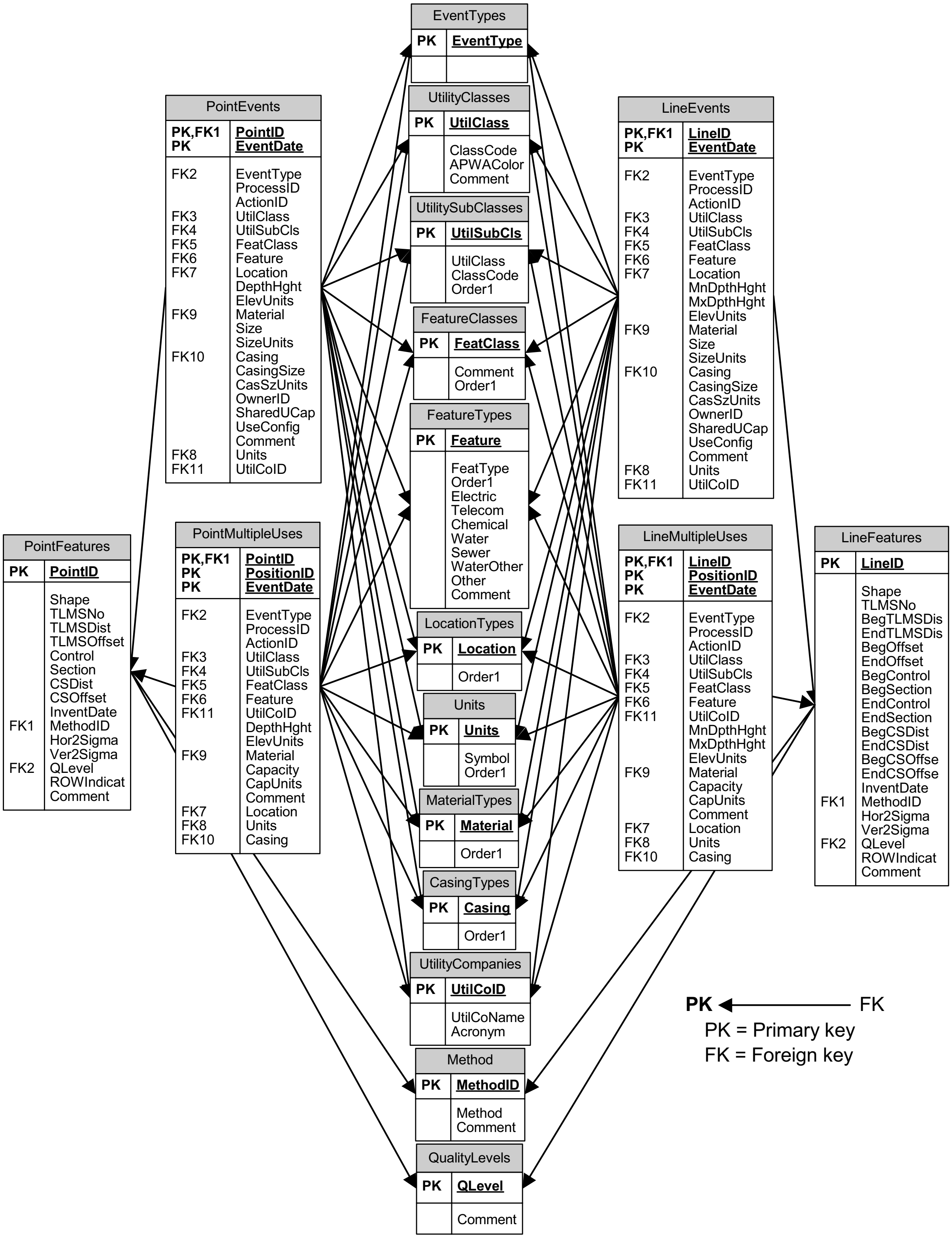


Figure 3-5. Utility Inventory Database Schema.

EventTypes
Activation
Change in properties
Change in quality level
Decomission
Initial inventory
Other

UtilityClasses	
Electric	(red) *
Telecommunications	(orange)
Chemical	(yellow)
Water	(blue)
Sewer	(green)
WaterOther	(purple)
Other	

* APWA color

UtilitySubClasses	
Electric	(electric) *
Data-communications	(orange)
Telephone	(orange)
Television	(orange)
Gas	(yellow)
Oil	(yellow)
Steam	(yellow)
Chemical-other	(yellow)
Water	(blue)
Sewage	(green)
Storm water	(green)
Irrigation	(purple)
Reclaimed water	(purple)
Slurry	(purple)
Other	

* APWA color

FeatureTypes	
Cable	(line)
Channel	(line)
Culvert	(line)
Ditch	(line)
Forced pipeline	(line)
Gravity pipeline	(line)
Other line	(line)
Tunnel	(line)
Anchor	(point)
Bore pit	(point)
Box	(point)
Dead end	(point)
Distributor	(point)
End cap	(point)
Fire hydrant	(point)
Guy	(point)
Inlet	(point)
Junction	(point)
Junction box	(point)
Manhole	(point)
Meter	(point)
Other	(point)
Pedestal	(point)
Platform	(point)
Pole	(point)
Pull box	(point)
Pump	(point)
Repeater	(point)
Riser	(point)
Splice enclosure	(point)
Street light	(point)
Tank	(point)
Tower	(point)
Transformer	(point)
Utility benchmark	(point)
Valve	(point)
Vent	(point)
Wye	(point)

FeatureClasses
Collector
Distribution
Main
Service
Transmission
Other

LocationTypes
Buried
Ground level
Above ground

Units
centimeters
feet
inches
kilovolts
meters
pairs
psi
volts
other

MaterialTypes
Aluminum
Brick
Cast iron
Concrete
Copper
Fiber optic
Galvanized iron
Plastic
Steel
Wood
Other

CasingTypes
None
Concrete fill
Conduit
Duct bank
Tunnel
Other

Method
Digitized - DOQ
Digitized - no DOQ
Digitized - CADD
Digitized - plans
GPS
DGPS - beacon
DGPS - code only
DGPS - floating baseline
DGPS - fixed baseline
Other

QualityLevels
A
B
C
D

Figure 3-6. Utility Database Lookup Table Entries.

The utility class and utility subclass characterizations in Figure 3-6 follow most of the color codes included in the American Public Works Association (APWA) Uniform Color Code Standard (*12*). This standard, which contractors widely use, provides a simple, yet effective mechanism for marking underground utilities on the ground based on a fixed set of colors easily identifiable in the field. For example, red identifies electric utility installations and blue identifies drinkable water utility installations. It may be worth noting the APWA classification system focuses on colors, not on labels. For example, telephone, cable television, and data communication utility installations are all marked in the field using orange paint, yet the group itself does not have an official name. For simplicity, the researchers used the term "Telecommunications" to group those utility installations. Likewise, gas, steam, oil, and other similar utility installations are all marked in the field using yellow paint, yet the group itself does not have an official name. For simplicity, the researchers used the term "Chemical" to group those utility installations. Notice that in the GIS it is not necessary to actually display utility installations using the APWA color codes. Many more colors, as well as a wide range of symbols and legends, are usually available to users depending on the specific need. However, for classification purposes, the APWA standard provides an effective utility grouping mechanism that is intuitive and easy to use.

The feature class and feature characterizations in Figure 3-6 were based on the researchers' perception of what could be relevant to TxDOT. The researchers tried to make the number of entry values as simplified and aggregated as possible, while at the same time providing flexibility to end users. In general, the idea was that if a feature had a "footprint" on the ground, there should be an entry for that feature in the database. Throughout the project, the researchers discussed available entry options with TxDOT officials, utility company representatives, and SUE contractors. In general, the feedback provided was that the list of options was adequate as a starting point; however, the researchers understand different groups have different perceptions of what should be considered important. For example, an electric utility company user might consider "splice enclosure" a critical entry value to have in the database because splice enclosures are important elements in the electric utility network. However, a TxDOT user might consider "splice enclosure" too detailed, particularly if the enclosures themselves are above ground, i.e., if they do not have a clearly defined "footprint" on the ground. The researchers believe feature class and feature characterization deserves some fine tuning work to make sure the database properly addresses TxDOT data needs without alienating utility companies and other potential users and/or data providers.

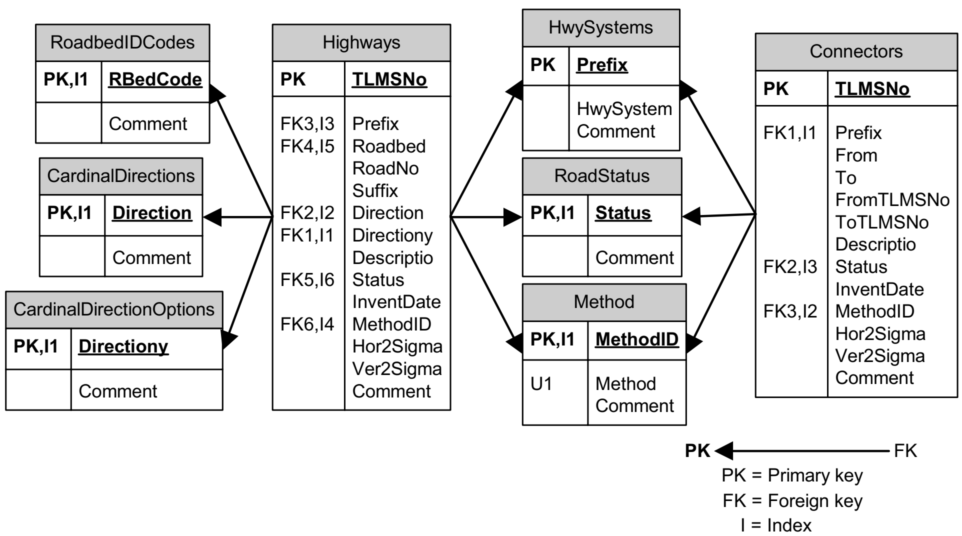
Tables PointFeatures and LineFeatures (Figure 3-5) contain fields that provide linear referencing measures (cumulative distances and offsets) to utility features. For simplicity, the tables only include two groups of fields: fields based on the new TxDOT roadbed centerline model and fields based on the control section-distance model. Because the database architecture is modular, however, the tables could easily have additional fields to provide linear referencing measures based on other models, e.g., the Texas reference marker model. For the new TxDOT roadbed centerline model, the researchers received a copy of the model architecture from the Information Systems Division (ISD) (*13*). For completeness, Figure 3-7 shows the database schema of that model, as implemented in the research project. Tables PointFeatures and LineFeatures in Figure 3-5 are related to tables Highways and Connectors in Figure 3-7 through field TLMSNo—Texas Linear Measurement System number—that uniquely identifies roadbed centerline features.

DATA COLLECTION

The researchers undertook a data collection effort along a 7-mi stretch of SH 16 between IH 410 and Loop 1604 in northwest San Antonio to test the feasibility of the utility data inventory model described in the previous sections. For the data collection, the researchers used a submeter-level Trimble Pro-XR GPS receiver equipped with attribute data logging capabilities through a standard data collector box (Figure 3-8). The data collection also included sample paper and/or electronic maps the researchers requested, and in some cases received, from utility companies. The data collection effort focused on ground-level and above-ground utility installations. However, the researchers also collected underground utility data in the immediate vicinity of the SH 16 and IH 410 interchange with the assistance of the One Call system in San Antonio. Location services contacted by the One Call system left color-coded markings on the ground to identify the location of underground utility installations. The researchers then surveyed the location of the color-coded markings with the GPS receiver. To the extent possible, the researchers completed the underground utility installation survey with data obtained from utility maps and installation notice applications.

Before going to the field, it was necessary to generate data dictionaries and upload those data dictionaries to the GPS receiver. The companion Prototype Utility Platform compact disk (CD) includes a copy of the data dictionaries. The procedure for loading and using the data dictionaries in the field is described in Report 2110-2: A Data Platform for Managing Utilities along Highway Corridors: User Manual. Data dictionaries are essentially drop-down lists with pre-specified entry values to speed up the data collection in the field. The researchers built two groups of data dictionaries: one group for surveying utility features, and the second group for surveying roadbed centerline features. The roadbed centerline data dictionary group was necessary because a roadbed centerline map following the new TxDOT roadbed centerline model was not available. With the submeter-level GPS receiver, it was possible to generate an accurate roadway inventory along SH 16 that was compatible with the new TxDOT roadbed centerline model, including both directions of travel, entrance ramps and exit ramps on IH 410 and Loop 1604, and intersecting streets.

(a) Database schema



(b) Database lookup table entries

HwySystems	
BF	Off Farm/Ranch Business Route
BI	Off Interstate Business Route
BS	Off State Business Route
BU	Off US Business Route
CN	Connector
CR	County Road (CRI Networks)
CS	City Street (City Networks)
FM	Farm to Market
FS	Farm to Market Spur
IH	Interstate Highway
PA	Principal Arterial Street System (PASS)
PR	Park Road
RE	Recreational Road
RL	Recreational Road Spur
RM	Ranch to Market
RP	Ramp
RR	Ranch Road
RS	Ranch to Market Spur
RU	Ranch Road Spur
SA	State Alternate
SH	State Highway
SL	State Loop
SS	State Spur
UA	US Alternate
UP	US Spur
US	US Highway

RoadbedIDCodes	
A	Main bed auxiliary road
F	Frontage road
G	Frontage supplemental
H	Frontage auxiliary
M	Main bed
S	Main bed supplemental
V	Segregated HOV lane
Y	Ferry
Z	Bi-directional HOV

RoadStatus	
A	Pre-construction alignment
C	Under construction
O	Open to traffic
R	Retired segment

Method
Digitized - DOQ
Digitized - no DOQ
Digitized - CADD
Digitized - plans
GPS
DGPS - beacon
DGPS - code only
DGPS - floating baseline
DGPS - fixed baseline
Other

CardinalDirections	
E	Posted East
N	Posted North
S	Posted South
W	Posted W

CardinalDirectionOptions	
A	Posted mornings, reverse during evenings
B	Bi-directional
P	Posted evenings, reverse during mornings
S	Simple
U	Unidirectional

Figure 3-7. New TxDOT Roadbed Centerline Model Database Architecture.

Figure 3-8. Data Collection Equipment.

GIS AND DATABASE DATA ENTRY

Converting the GPS spatial and attribute data collected in the field into GIS features was a three-step process: (a) downloading and preparing GPS data files; (b) generating GIS features; and (c) generating database records. A summarized description of each step follows. Complete details are included in the User Manual.

Downloading and Preparing GPS Data Files

Using Trimble's Pathfinder software, the researchers downloaded and prepared GPS data files. The GPS receiver had a beacon antenna that provided real-time differential correction capabilities through the U.S. Coast Guard differential correction signal network (*14*). However, the researchers determined post-differential correction considerably improved the positional accuracy of the GPS data. Post-differential correction was possible by using base files downloaded from the TxDOT file transfer protocol (ftp) site (*15*). The result was differentially corrected GPS (DGPS) data files that typically had a horizontal positional accuracy of about 2 ft (0.6 m), 2-sigma 95 percent confidence level. Readers should note different GPS receivers yield different positional accuracy levels. For example, a surveying-type GPS receiver—the receiver used was mapping-type—could yield centimeter-level horizontal positional accuracy levels.

Generating GIS Features

The next step in the data reduction process was generating utility data features in the GIS from the DGPS data files. The researchers accomplished this by generating export Pathfinder data files and merging each export file with a corresponding repository shape file in ArcView 3.2. Each repository shape file had an attribute table that mirrored the feature table (PointFeatures or LineFeatures) in the database schema shown in Figure 3-5. Unfortunately, due to Trimble hardware and software architecture limitations, the export GPS data files were not fully compatible with the database schema in Figure 3-5. As a result, it was necessary to manually populate some of the fields in the GIS attribute table, e.g., PointID, LineID, MethodID, InventDate, Hor2Sigma, and Vert2Sigma. It could have been possible to automate this process by developing a customized data entry interface in the GIS. However, TxDOT considered this strategy ineffective, given TxDOT's plan to migrate from ArcView 3.2 to ArcView 8.1 in the near future and the corresponding change from Avenue scripting to Visual Basic scripting.

With utility feature data in a GIS format, it was possible to generate a variety of maps. For example, Figure 3-9 shows utility features on a short 0.75-mi section of SH 16 overlaying the state highway centerline, city streets, and water features obtained from the TxDOT GIS urban file (*16*). Notice in Figure 3-9 the attribute table associated with utility point features and the grouping of point features by utility class (on the computer screen, the color codes follow the APWA Uniform Color standard). Although not shown in Figure 3-9, a variety of graphical symbols could be used to represent individual features. For example, a solid circle could represent a utility pole, a hollow circle could represent a manhole, and so on. Unfortunately, there is considerable overlap on the use of graphical symbols in the utility industry, which could lead to confusion in situations where all kinds of utility features need to be shown on the same map. Obviously, the number of graphical symbols used depends on the number of features that need to be included in the database. As mentioned previously, feature characterization needs some fine tuning work, and the most appropriate time to do this would be during the implementation phase of the research. Once the final list of features is assembled, it should be relatively straightforward to develop an appropriate graphical symbol library.

Figure 3-10 shows another view of utility features overlaying roadbed centerline features on a 0.25-mi section of SH 16. For completeness, Figure 3-10 also shows the current TxDOT centerline map (in dotted lines) and a table showing attribute data associated with the circled utility point feature. With the GIS it is also possible to do operations such as spatial queries (e.g., select all features within 150 ft of a utility pole), attribute table queries (e.g., select all sewer manholes), and distance measurements (e.g., calculate the distance from a utility pole to the westbound roadbed centerline on SH 16). By using linear referencing functions, it is also possible to determine the relative position of utility features along SH-16.

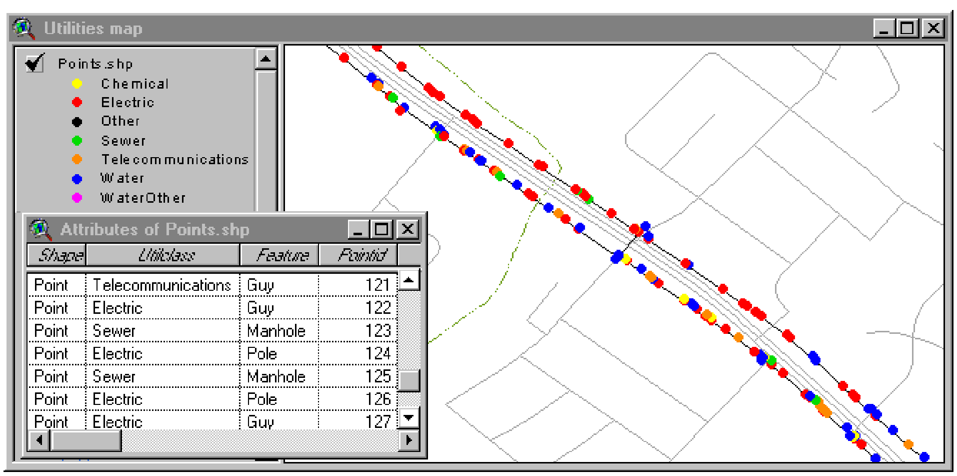


Figure 3-9. Utility Data Features Overlaying State Highway Centerlines, City Streets, and Water Features on SH 16.

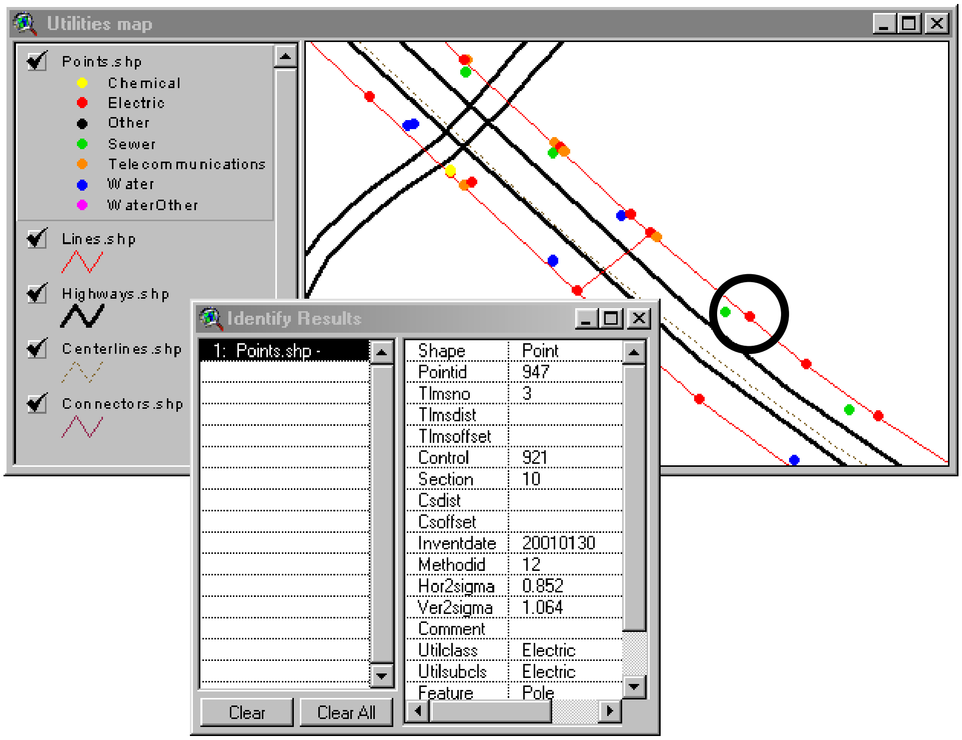


Figure 3-10. Utility Data Features Overlaying Roadbed Centerline Features on SH 16.

The data collection effort along the 7-mi stretch of SH 16 between IH 410 and Loop 1604 resulted in the following ArcView 3.2 format shape files, copies of which are included in the companion Prototype Utility Platform CD:

- points.shp: contains utility point features (1286 features inventoried);
- lines.shp: contains utility line features (478 features inventoried);
- highways.shp: contains roadbed centerline features (95 features inventoried); and
- connectors.shp: contains roadbed centerline connector features (28 features inventoried).

Generating Database Records

The last step in the data reduction process was generating database records in a relational database environment. ArcView 3.2 provided very limited support for relational database operations, and, as a result, a more robust development environment was necessary. For the prototype, the researchers used Access 2000, which is compatible with TxDOT's database architecture. The companion Prototype Utility Platform CD includes a copy of the resulting database file, which includes all attribute tables, lookup tables, and relationships shown in Figures 3-5, 3-6, and 3-7.

The researchers developed customized data entry forms for entering utility data into the database. Figure 3-11 shows the form for entering utility point data, and Figure 3-12 shows the form for entering utility line data. Both forms, which are similar in appearance, were designed to facilitate the entry of data associated with features, feature events, and feature user events.

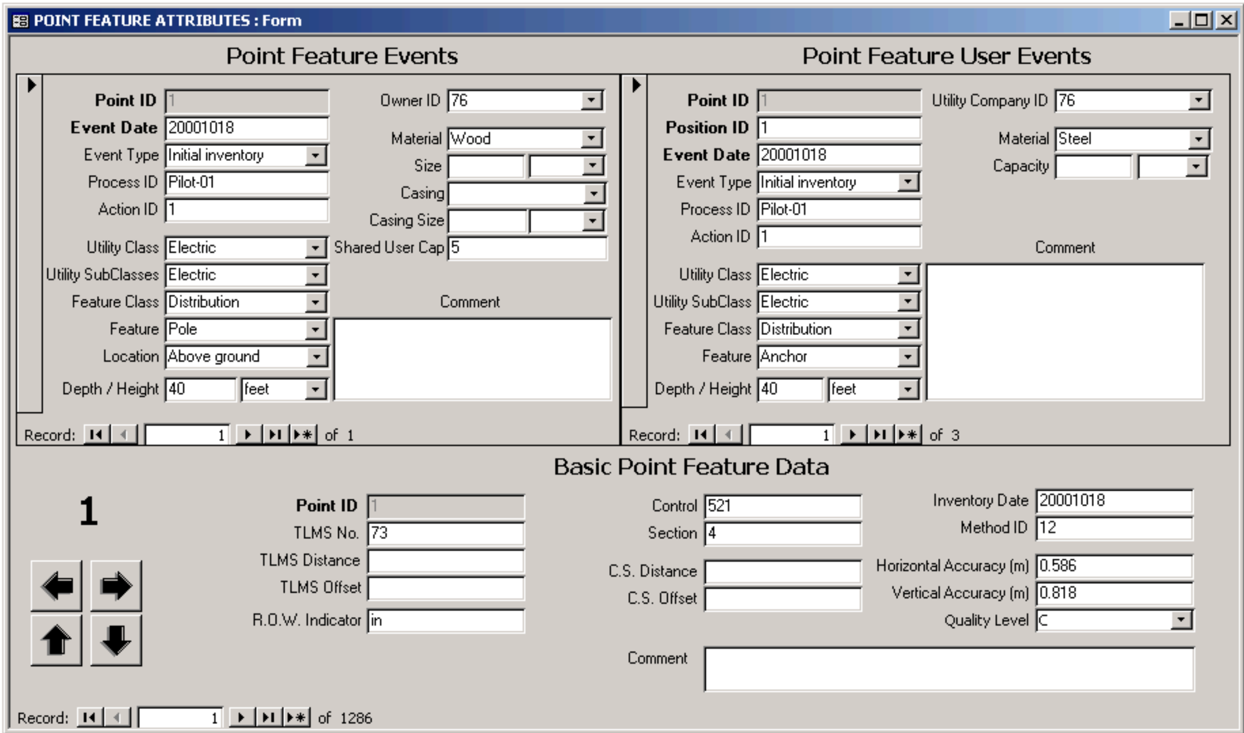


Figure 3-11. Data Entry Form for Utility Point Features.

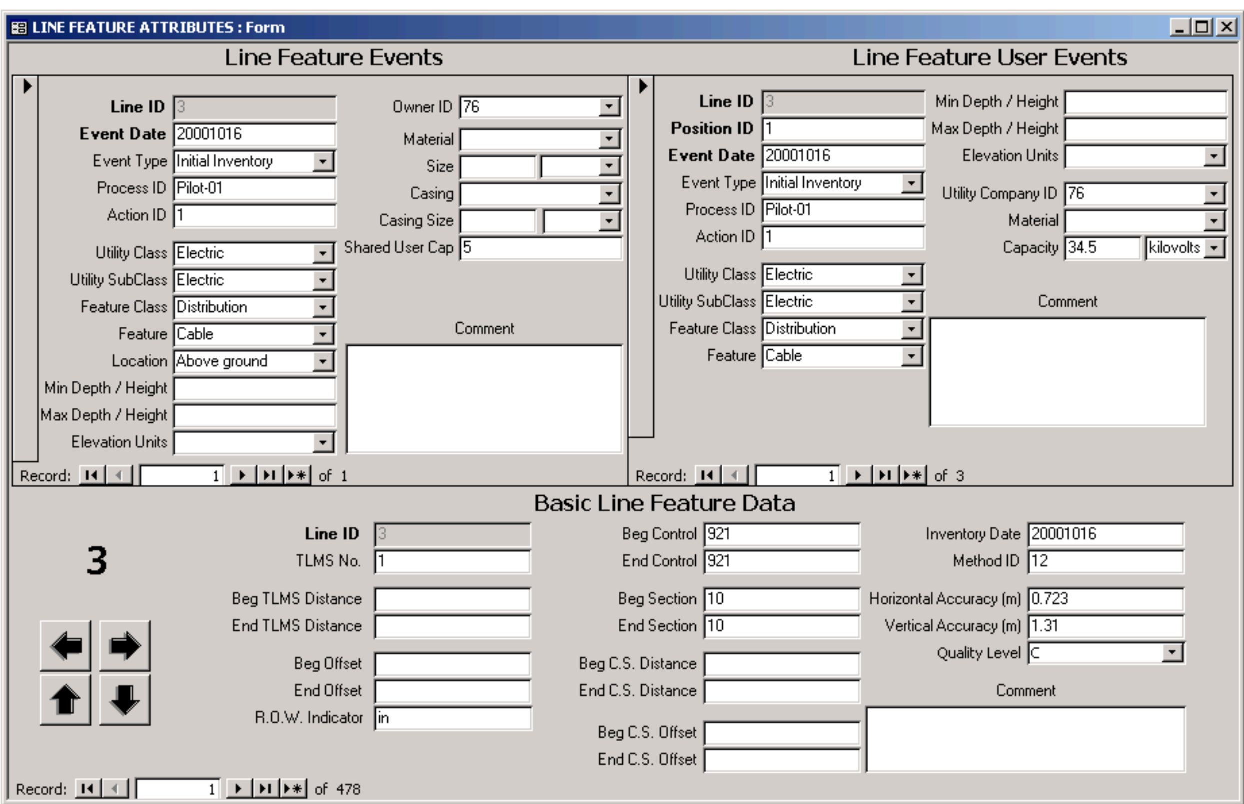


Figure 3-12. Data Entry Form for Utility Line Features.

Following the three-table database architecture shown in Figures 3-4 and 3-5, there has to be a record in the feature table (PointFeatures or LineFeatures) before being able to enter feature event data or feature user event data. Adding a record to the feature table is possible either by using the data entry form or by importing the ArcView attribute table into Access and using a query to append new records to the feature table. Once a feature record is in the database, it is possible to add as many feature event records and/or feature user event records as needed. For example, Figure 3-11 shows data associated with a point feature that was originally inventoried on October 18, 2000. The feature event section shows one feature event documenting the point feature initial inventory and describes the point feature as being a wooden utility pole owned by an electric utility company. If at any point in time a metal pole replaces the wooden pole without affecting any of the utility installations anchored to the pole, a new entry in the feature event section would record the change. The feature user event section shows there are three records associated with the point feature. Figure 3-11 shows one of the records, corresponding to a telephone line anchor. The other two records correspond to an electric line anchor and a data communications line anchor, respectively. Any change affecting any of these installations and/or a new installation that is anchored to the utility pole would be handled as a new record in the feature user event section.

The data entry forms in Figures 3-11 and 3-12 could also be useful for database query purposes, particularly in situations where the feature ID is already known, e.g., through the GIS interface, and it is of interest to retrieve all of the data associated with that particular feature. It may be worth noting the researchers also developed web-based database query tools in conjunction with a system designed to handle online installation notice applications. Chapter 4 describes the online system and corresponding database query tools. The researchers did not address other database query needs, which might arise during the implementation phase, as part of the research. Those database query needs may require the development of additional query forms.

In total, the data collection effort on SH 16 resulted in 7024 database records. As mentioned previously, the companion Prototype Utility Platform CD includes a copy of the database. The distribution of records was as follows:

- utility point features: 1286 feature records, 1286 feature event records, and 2143 feature user event records;
- utility line features: 478 feature records, 478 feature event records, and 1230 feature user event records; and
- highway features: 95 roadbed centerline features and 28 roadbed centerline connector features.

Whenever possible, the researchers used append queries to generate records in the database. Unfortunately, the data entry process was also labor intensive because of the lack of support of the Trimble data collection system for concatenated attribute data dictionaries, i.e., critical relational database structures needed for recording data associated with multiple user installations. This made it necessary to artificially add many fields to the data dictionary to keep track of all of the utility installations that had the same "footprint" on the ground and spend considerable time during the data reduction process to convert the raw data into a fully relational database. While the strategy worked, it was clear the data collection process and the corresponding database entry process were not efficient. For implementation, it would be advisable to develop/acquire a customized data collection tool. This tool would probably result from the combination of a GPS receiver and a personal digital assistant (PDA) device equipped with special-purpose software that supports both relational databases and GIS. For improved productivity, the device could include ports to connect sensors for locating underground installations and have communication capabilities with the database server. With a customized data collection tool, it would be possible to collect data in the field following the same data format as the GIS and database repository files. While surveyors would still need to conduct a data quality control back at the office, the data reduction process would be much faster, making the database population effort more efficient.

CHAPTER 4. NOTICE OF INSTALLATION (UTILITY PERMITTING) PROCESS

INTRODUCTION

Chapter 3 described a generic spatial and database model to inventory utility installations within the TxDOT ROW. Chapter 3 also documented the procedure used to collect utility data along a 7-mi stretch of SH 16 in San Antonio. Technically, using internal resources and/or through the SUE process, it should be possible to generate a comprehensive initial inventory of utilities within the TxDOT ROW. However, an inventory is only useful as long as it is current, which brings the issue of how to conduct inventory updates. There are several utility-related processes within TxDOT, and the challenge is to figure out ways to obtain data through those processes that could be used to maintain an up-to-date utility inventory.

By far, capturing data from the installation notice process is the most challenging. According to some TxDOT estimates, roughly 90% of all utility-related activities within TxDOT deal with the installation notice process. As mentioned in Chapter 2, TxDOT as a whole handles approximately 10,000 installation notices per year. Some large districts handle 1000-2000 installation notices per year. The entire process is time and labor intensive, and the amount of paperwork is quite substantial. In addition, procedures, data formats, documentation requirements, and quality of the spatial information provided by utility companies vary widely from district to district. For all these reasons, the research focused on developing a prototype database model and associated procedures to capture data from the installation notice process. It may be worth noting, however, that the lessons learned during the research do not just apply to the installation notice process. In fact, they could be used as leverage for the development of similar models and procedures for other utility-related processes at TxDOT.

This chapter describes a prototype Internet-based utility installation notice data collection and management system that supports both data transfer and map viewing capabilities. Three goals drove the development of the prototype: (1) to automate the installation notice data entry process, (2) to provide the capability to obtain data needed to maintain the utility inventory up-to-date; and (3) to substantially reduce turnaround times and paperwork. This chapter examines the current workflow and describes the architecture of the prototype system. Additional information about system installation and use can be found in Report 2110-2: A Data Platform for Managing Utilities along Highway Corridors: User Manual. Readers should note that, while the prototype relies on Internet-based techniques for the automated capture and management of installation notice data, the underlying database model is generic and could be easily adapted to develop reduced offline versions of the system. Those reduced systems would rely on traditional database queries and forms to capture and manage installation notice data at the district level. They would not be as automated as the Internet version. However, they could be useful in the short term if TxDOT foresees delays in the implementation of the Internet-based system. They could also benefit individual districts interested in starting the implementation of the database model quickly without having to wait for the Internet-based system to become operational.

EXAMINATION OF THE EXISTING PROCESS

The installation notice process at TxDOT begins when a utility company submits an installation notice document to the TxDOT district office having jurisdiction over the proposed installation site (Figure 4-1). As part of the application package, utility companies attach sketches or drawings documenting the location of the proposed installation. Upon receipt of the application form, a designated TxDOT official sends a memorandum to the appropriate maintenance supervisor or, in some cases, area engineer, for an on-site inspection of the proposed work. Depending on the results of the inspection, the field verifier makes a recommendation for/against approval. If the decision is to approve the proposed installation, a designated official signs and sends an approval notice to the utility company. The approval document also contains a list of special provisions and the name and phone number of a TxDOT official the utility company must notify 48 hours before proceeding with the proposed installation. There is currently no requirement for the submission of "as-built" documentation.

An evaluation of drawings, documents, and informal interviews with personnel in different districts revealed important workflow details. For example, examination of documents showed inconsistencies in data content, utility classification schemes, map symbology, and provision specifications, both within TxDOT and among utility companies. Procedures are not always followed, in particular field verifications. Further, there is apparently not a clear designation within the TxDOT classification system of the functions associated with the installation notice review process. Not surprisingly, discussions with affected personnel revealed the process was frequently considered secondary to the main responsibilities of the official. In other cases, officials felt they spent too much of their time doing repetitive work and manually processing applications. This finding is important because of the potential impact on the implementation of new systems and/or approaches. On the one hand, the need to improve the efficiency of the current process will likely result in faster system acceptability, leading to a smoother implementation process—especially if the installation notice processing job is made easier. On the other hand, there could be more resistance if system implementation increases procedural complexity, adds tasks, or takes more time to perform than do the existing procedures.

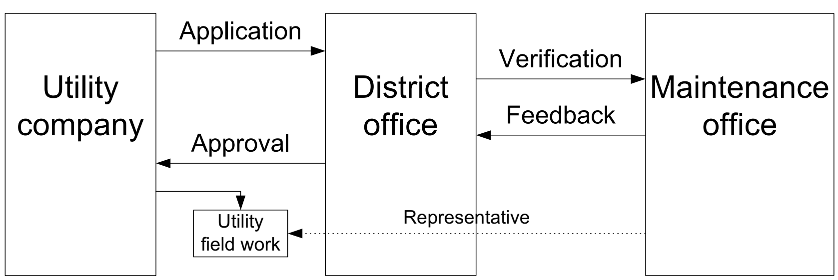


Figure 4-1. Existing Data Flow and Data Collection for Installation Notices.

JUSTIFICATION FOR AN INTERNET-BASED APPROACH

Most installation notice activities within TxDOT actually require very little face-to-face contact with utility companies. Furthermore, utility company field projects can occur anywhere at any given time, which means the installation notice process at TxDOT is necessarily spatially distributed and asynchronous. These characteristics make the installation notice process at

TxDOT an excellent candidate for the implementation of online, automated data collection and data processing strategies.

The Internet is rapidly transforming the way communities, governments, and businesses operate. Conducting transactions online has now become routine, and the number of sites that support electronic application filing and processing is increasing at a phenomenal rate. In the short term, that trend will likely continue, and perhaps accelerate even more, because of the increased perception of vulnerability of traditional mail-based delivery systems after the anthrax terrorist attacks in late 2001. An increasing number of government agencies are also realizing automated online transactions can result in improved productivity and lower costs. Many public agencies now operate websites that support the submission of permit applications online, including building permits, plumbing permits, parking permits, and dump permits. A few agencies have begun to use the Internet to support the utility permitting process. In general, however, those agencies limit their support to providing basic information about the permitting process (*17*, *18*, *19*) and/or including links to forms that utility companies have to download for subsequent offline processing and mailing (*20*, *21*, *22*, *23*, *24*, *25*, *26*, *27*, *28*). Usually, those forms are in formats such as Word or portable document format (PDF).

Internet-based mapping has made it considerably easier to share spatial data by providing online access to electronic maps and attribute data. Most GIS vendors have developed hypertext mark-up language (HTML)-based web mapping tools that only require users to have a browser such as Internet Explorer or Netscape installed on the client computers. A few vendors have experimented with special purpose viewer add-ons that need to be downloaded and installed on client computers before maps can be retrieved and viewed. One of the advantages of special purpose viewer add-ons as opposed to regular HTML viewers is that they allow users to download and view maps in vector format. In the process, they reduce the need for always having to communicate with the server for typical operations such as zoom-in, zoom-out, pan, and rotate. A few applications also provide red lining and annotation capabilities. Unfortunately, special purpose viewer add-ons tend to be much more demanding and sensitive to variations in client computer configurations than regular HTML viewers. This makes HTML-based applications more robust in situations where a wide range of users, most likely affiliated with different organizations, need to access and view the spatial data.

SYSTEM ARCHITECTURE

Prototype Workflow

To address the limitations of the current workflow, the researchers developed a prototype utility installation notice system that follows a web-based data entry approach. Figure 4-2 shows the data flow of the prototype system. Conceptually, the prototype system follows the existing workflow shown in Figure 4-1, with two exceptions. First, it assumes utility companies would be required to submit as-built documentation after they complete the utility installation in the field. Second, it assumes an installation notice application is active until GIS personnel in the district office have updated the utility base map using the as-built documentation provided by the utility companies.

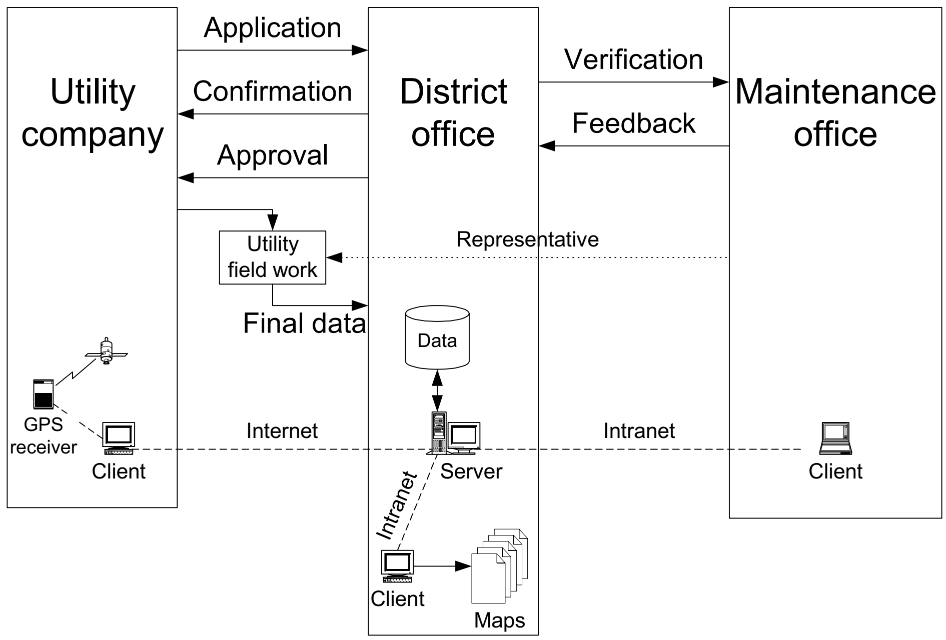


Figure 4-2. Prototype Data Flow and Data Collection for Installation Notices.

The prototype system attempts to reduce the internal and external communication workflow burden by using automated online documentation routing and e-mail notifications. Following the process in Figure 4-2, to submit an installation notice application, a utility company user logs into a website that contains several options for viewing and submitting notices of installation. The utility company user fills in basic data related to the installation notice application and attaches a file containing coordinate data for the proposed utility work. If needed for clarity, the user can include other attachments containing vector drawings and/or raster images. The database server converts the coordinate data file into temporary spatial features that can be displayed on a web GIS map and sends a confirmation to the utility company. An electronic copy of the application and a map of the area where the utility company proposes to do the fieldwork are available for viewing and printing at anytime through the interface. Upon submitting an application, the database server generates an entry for the installation notice in the database.

Based on the information received by the utility company, the system automatically sends an electronic communication to the appropriate district official responsible for initially reviewing the application (responsibility for the various levels of application processing in each district must be determined at the time of system implementation). The reviewer decides if field verification is necessary or if an immediate decision can be made regarding approval and sends an electronic notification accordingly. Comment lines are provided to support internal communication at each step along the process.

Having received notification by the initial reviewer and/or field verifier, a designated TxDOT administrator uses the system to approve or deny the application and sends an electronic notification to the utility company. The corresponding approval or rejection form is available for retrieval through the system interface. Assuming the decision was to approve the installation notice application, the utility company uses the interface to notify TxDOT 48 hours prior to beginning construction and conducts the necessary fieldwork. Upon completion, the utility company must upload as-built documentation including final coordinates and other characteristics. After a utility company has submitted as-built documentation and this documentation undergoes verification, the data become available for download by TxDOT personnel responsible for updating the utility base map at the district office. While an automated procedure could potentially enable the addition of new data to the base map, for purposes of quality control it is advisable to have TxDOT GIS personnel manually process the data. After the GIS personnel updates the utility base map, the installation notice records are ready for archival. In the prototype, installation notice records that are ready for archival are labeled "Archived," however, they are not automatically moved to an archival database. During implementation, a procedure should be in place to periodically review database records and move those records that are ready for archival.

The prototype uses a centralized data management architecture with distributed map and data access capabilities (Figure 4-3). This architecture does not result in any loss of data access to individual district offices. Rather, it enables greater access to utility data in the form of online queries and display from a web browser and data downloads to local computer systems. With appropriate server and database security measures in place, the system provides utility companies with access to maps and data documenting all utilities located within the TxDOT ROW, therefore facilitating the installation notice process. Notice in Figure 4-3 that the system architecture uses two separate interfaces—a utility company user interface and an administrative interface—to support the installation notice process. A centralized data management approach is also advantageous because it relieves local districts from the burden of having to provide personnel and expertise to maintain local web servers. This is particularly critical in the case of rural districts, where appropriate personnel and expertise may be difficult to find.

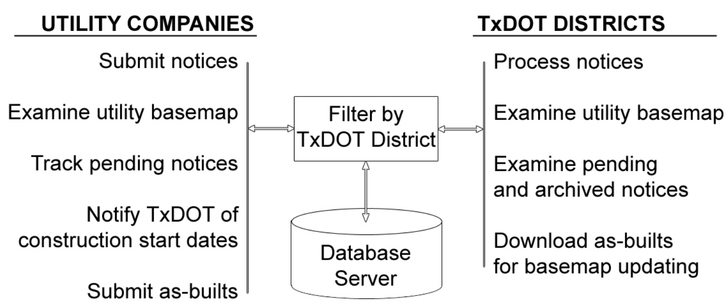


Figure 4-3. Functional Diagram of Prototype Installation Notice Application.

The prototype system adheres to a few simple design principles of human-computer interaction to reduce cognitive load and to increase the chances that users would adopt the system. To the extent possible, the interface design taps into the familiar existing workflow of the expected users to make the system easy to learn and use. Interface simplicity is an obvious requirement, but achieving a level of simplicity that is significantly "intuitive" requires numerous tests and redesigns. To comply with this requirement, the researchers used a formal usability analysis procedure called a cognitive walkthrough (*29*) to identify ambiguous task choices and to obtain feedback on potential redesign opportunities.

Database Schema

The researchers followed a relational database approach to manage all data associated with the installation notice process. As Figure 4-4 shows, the core table in the installation notice database schema is table Permits. This table contains basic data about installation notices, including a unique identifier that stays with the installation notice application, as well as date, time, and TxDOT user ID fields to keep track of the application throughout the review process. Table Permits also contains linear referencing data to associate installation notice locations with relative locations along the state highway network. Table UtilityCompanyUsers contains registered utility company user data including a user profile ID that is uniquely associated with installation notice records. Table TxDOTUsers contains registered TxDOT user data including toggle fields that describe the levels of responsibility assigned to each user. Table PermitLog contains notes and copies of e-mail messages generated during the review process. Table PermitApplDetails contains data associated with each of the actions that make up an installation notice application. Table PermitApplDetailsAsBuilt contains the same type of data as table PermitApplDetails, except the data represent as-built conditions. Table PermitApplAttachments contains all files uploaded by utility company users such as coordinate data files, computer aided design (CAD) drawings, and image files. Table PermitApplAttachmentsAsBuilt contains the same type of data as table PermitApplAttachments, except the data represent as-built conditions. Table PermitGeneralProvisions contains general special provisions that are "attached" to an installation notice application when the application is approved. Table PermitGeneralProvisionTypes contains a listing of all general special provisions at TxDOT, both statewide and district-specific. Table PermitRevegetationProvisions contains revegetation provisions that are "attached" to an installation notice application when the application is approved. Table PermitRevegetationProvisionTypes contains a listing of all revegetation provisions at TxDOT, both statewide and district-specific. Table PermitReviewAttachments contains all files uploaded by TxDOT personnel during the installation notice review process, e.g., digital pictures taken by maintenance supervisors in the field to document field verification activities.

The database schema contains a number of lookup tables, including PostalAbbreviations, UtilityCompanies, PermitStatus, Responsibilities, Districts, AreaOffices, MaintenanceOffices, PermitApplAttachTypes, FacilityActionConfigurations, and ActionTypes. Although not shown in Figure 4-4 for simplicity, the database schema also includes lookup tables that are shared with the inventory database schema (Figure 3-5). Readers should note that in the prototype system there is only one database file with one integrated database schema. For convenience in the presentation, Figure 3-5 shows only the tables that pertain directly to the utility inventory. Likewise, Figure 4-4 shows only the tables that pertain directly to the installation notice process.

It may be worth noting that, while the tables in the database use the term "permit" instead of "installation notice," the front end of all web pages, i.e., what system users see on their web browsers, use the term "installation notice" because the official name of the document at TxDOT is "Notice of Proposed Installation." If necessary, all internal changes to the system to ensure consistency with that official name could be made during implementation.

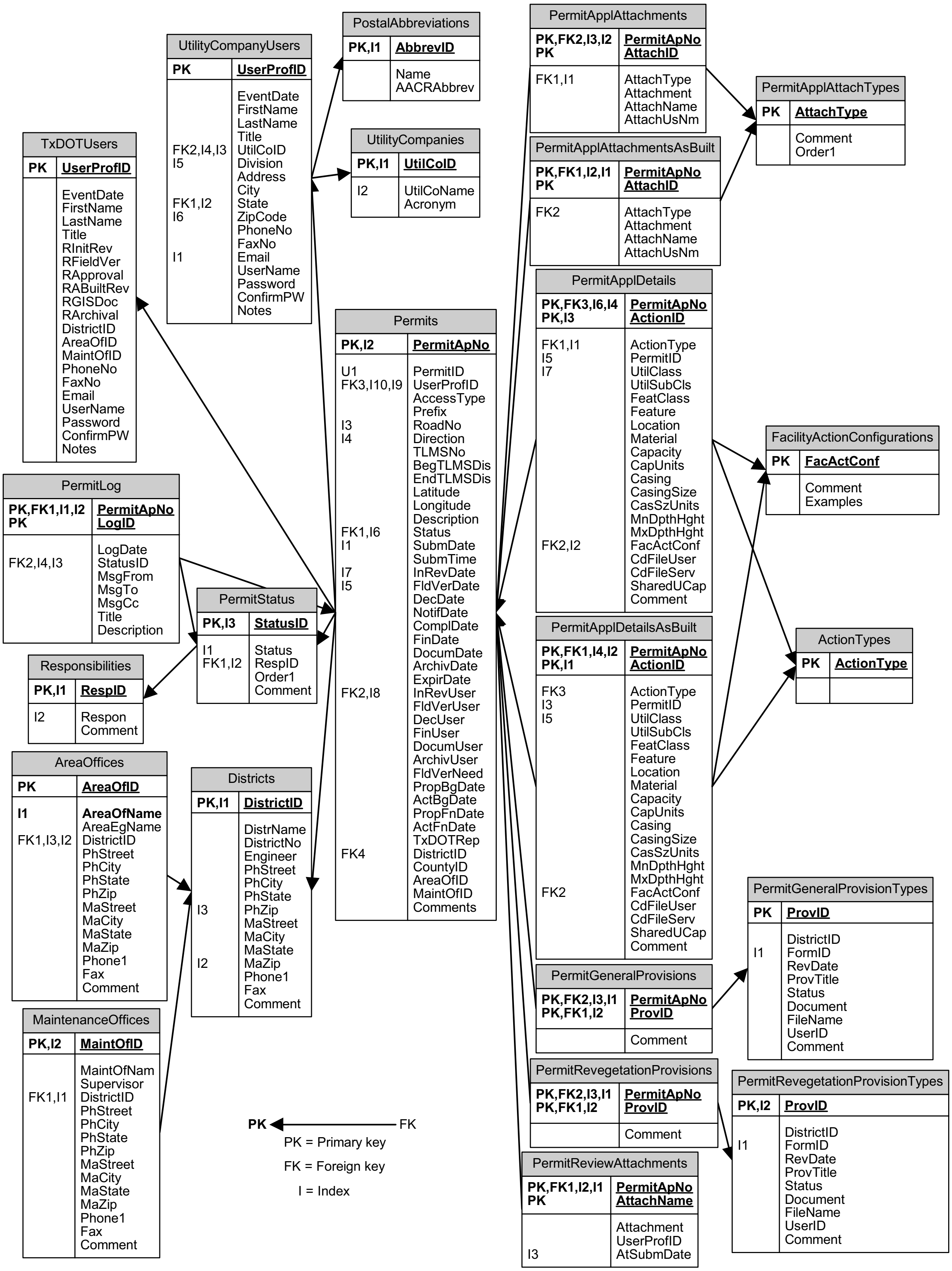


Figure 4-4. Installation Notice Database Schema.

Hardware and Software Architecture

Figure 4-5 shows the system architecture of the prototype installation notice system. As Figure 4-5 shows, the system has two groups of components: client-side components and server-side components. On the client side, an HTML viewer serves as a front-end interface that allows users on client computers to submit installation notice applications, select and view installation notice application data, review pending applications, and view and query utility maps. Minimum client requirements include Microsoft Internet Explorer 4.0 or Netscape Communicator 4.5 running on Windows 98 computers. Both utility company users and TxDOT users can act as clients. For security, the interface for TxDOT users, called administrative interface, is different from the utility company user interface to facilitate the integration of the administrative interface with the TxDOT Intranet where it cannot be accessed by utility company users. The client side also includes an e-mail client application to notify utility company users and/or TxDOT officials about the progress of the review process.

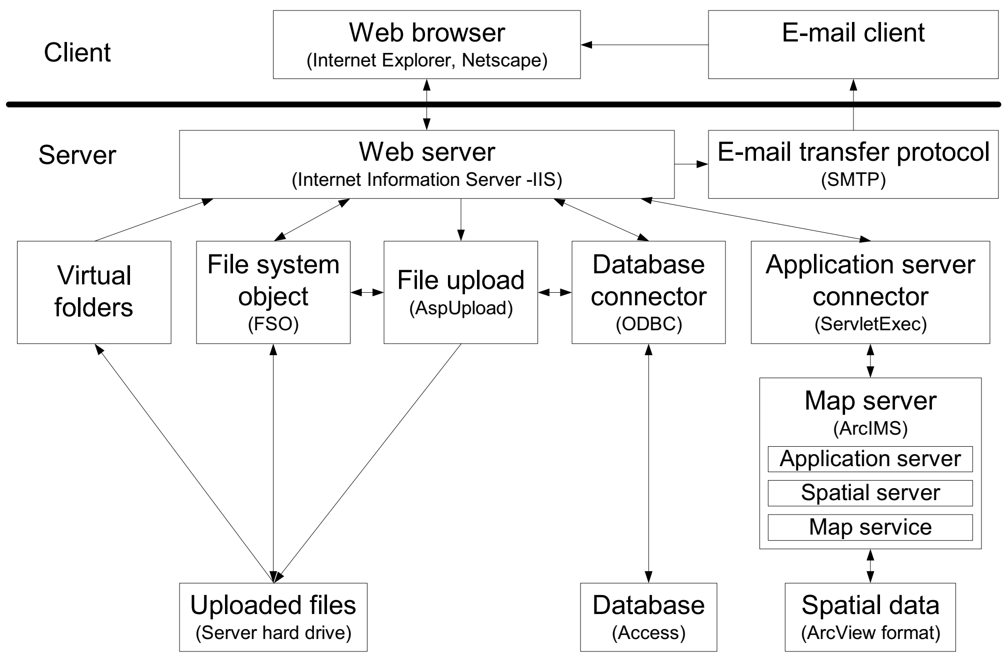


Figure 4-5. System Architecture.

On the server side, the prototype system includes several components that required installation and configuration, including a web server (Internet Information Server—IIS), a simple mail transfer protocol (SMTP), a file upload component for active server pages (AspUpload), a database file (Access), an application server connector (ServletExec), a map server (ArcIMS), and a web browser for ArcIMS Manager (Internet Explorer). Report 2110-2: A Data Platform for Managing Utilities along Highway Corridors: User Manual includes a complete listing of components, as well as installation procedures and hardware and software requirements.

The prototype server application is actually the combination of two subsystems that use different data flows and, consequently, different code structure: a notice data management subsystem and a web mapping subsystem. This modular architecture facilitated the development process and will likely result in considerable flexibility during implementation.

Notice Data Management Subsystem

The notice data management subsystem includes all web pages and procedures that allow users on client computers to log into the system, enter installation notice data, upload files, review pending applications, and print forms. The subsystem creates web pages dynamically using active server page (ASP) scripts and serves those pages to client computers in HTML format. In addition to server-side scripts, ASP files contain related client-side scripts and make calls to components that perform a variety of tasks such as connecting to the database, transforming and parsing data, and uploading files.

All data entered by users—including coordinate data files, CAD drawings, image files, and other attachments—are stored in the database. To interact with the Access database, the prototype uses structured query language (SQL) queries through an open database connectivity (ODBC) link. To upload files from client computers, the prototype uses AspUpload. AspUpload is a server-side component that enables the ASP application to accept, save, manipulate, and parse data from files uploaded with client browsers. The database stores uploaded files as object linking and embedding (OLE) objects, with the source of the object—or OLE server—being AspUpload. From a database integrity perspective, maintaining all uploaded files in the database is, of course, preferable. However, to facilitate access to those files from outside the prototype environment, e.g., if someone within TxDOT wanted to open an uploaded Microstation file directly in Microstation, the researchers decided to store a second, "unwrapped" copy of all uploaded files in a designated folder on the server hard drive. During implementation, TxDOT will need to decide whether it is necessary to maintain two copies of the uploaded files (in addition to regular backups which would need to be made anyway) or whether only one location is sufficient. If TxDOT decides to store only one copy and still provide external access to uploaded files, one possible solution could be to store the files outside the database in their native format, while maintaining a "linked" OLE object in the database that would point to the actual location of the uploaded file.

As installation notice applications undergo processing, the notice data management subsystem automatically sends e-mails to designated officials or back to utility company users. ASP uses collaboration data objects (CDOs) to pass requests to the SMTP for generating those e-mails.

Web Mapping Subsystem

The web mapping subsystem includes all web pages and procedures that allow users on client computers to view utility maps, query and retrieve map feature data, and select and view installation notice application locations and associated attribute data. As Figure 4-5 shows, the web server (IIS) and the application server connector (ServletExec) provide the connection between the client and the ArcIMS map server. The ArcIMS map server includes an application server, a spatial server, and a map service. The map service produces a snapshot of the map in image format. Every time the client sends a request, e.g., to zoom in or zoom out, the map service produces and delivers a new image file. With this information, the spatial server generates and delivers cartographic map image files to the client.

It was necessary to customize the ArcIMS server to integrate the web mapping subsystem with the notice data management subsystem. The customization of the ArcIMS server included (1) writing new ASP code, JavaScript functions, and HTML pages and (2) altering native ArcIMS JavaScript functions and HTML pages to accommodate the new pages. The customized pages integrate native ArcIMS utility-type functions and rely on ArcXML (ESRI's version of XML – extensible mark-up language) to pass requests to the spatial server and responses back to the client. A summary of the changes made follows.

ASP and ArcXML Code. Using an ODBC link, ASP code queries attribute and/or coordinate data from the database and packages the data for transfer to the JavaScript functions. ArcXML code passes requests to the spatial server, which, after processing by the map service, returns with responses packaged as ArcXML messages back to the client. For example, ArcXML generates requests to load "acetate" layers to display the location of coordinate data associated with installation notice applications. In this case, the spatial server response is a map image of installation notice coordinate data locations on the requested "acetate" layer. In general, to support map viewing and relational database querying capabilities, it was necessary to modify some default ArcIMS files. It was also necessary to develop a customized procedure to access utility attribute data and coordinate data residing on the server.

JavaScript Functions. JavaScript functions are the backbone of the web mapping subsystem. JavaScript functions create, manage, and delete the "acetate" layers used to dynamically display coordinate data. JavaScript functions generate the ArcXML tags for the spatial server request based on the utility data retrieved by the ASP pages. This happens when a user loads a map or when the user specifies a set of criteria for the display of multiple installation notice applications. JavaScript functions perform calculations such as conversion of screen coordinates to world coordinates. They also manage HTML page event handlers such as those used for clicking on the map, and even generate and alter HTML pages viewed by clients.

HTML Code. HTML code provides interaction with the client through the web browser. The HTML component is based on a series of window frames, each of which has a specific function (Figure 4-6). Frames are integrated, however, so that actions on any frame can result in updates being generated on other frames. For example, when the client uses the Text frame to select an installation notice application, the map frame highlights the location associated with that application and the table of contents (TOC) frame shows an index of all of the corresponding installation notice application actions. HTML pages are the front end of the application and the only means of interaction between the user and the JavaScript functions. The HTML component is the final product of the other two pieces of code, combining the map images created by the ArcXML and ASP code with the background and interactive work of the JavaScript functions.

Utility Company User Interface

The utility company user interface supports the needs and responsibilities of utility companies during the installation notice process. They include submitting new applications, viewing pending applications, viewing TxDOT special provisions, and managing user profile data. Figure 4-7 shows a functional diagram of the utility company interface, and Figure 4-8 shows a collage of sample web pages included in the interface. Report 2110-2: A Data Platform for Managing Utilities along Highway Corridors: User Manual includes full-size samples of all the utility company user interface pages included in the interface.

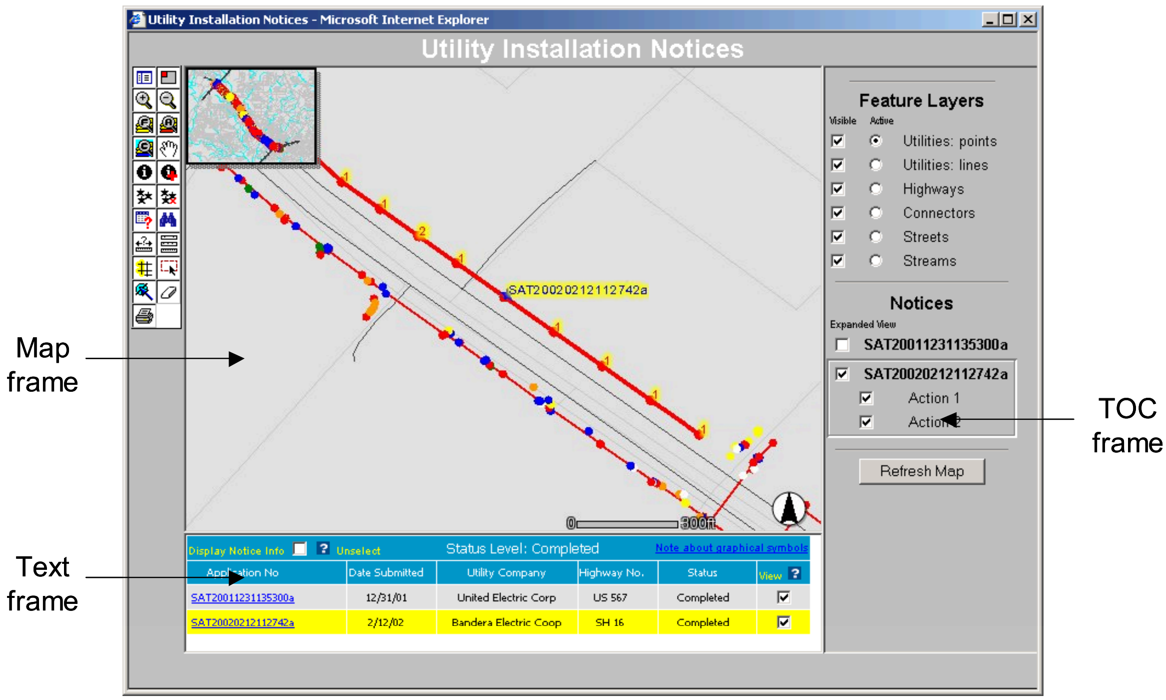


Figure 4-6. Web Mapping System Interface.

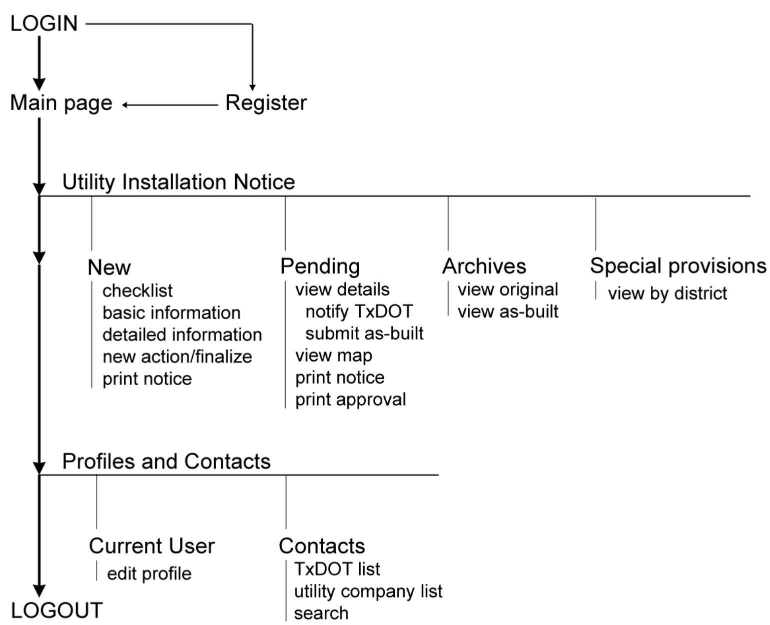


Figure 4-7. Functional Diagram of the Utility Company User Interface.

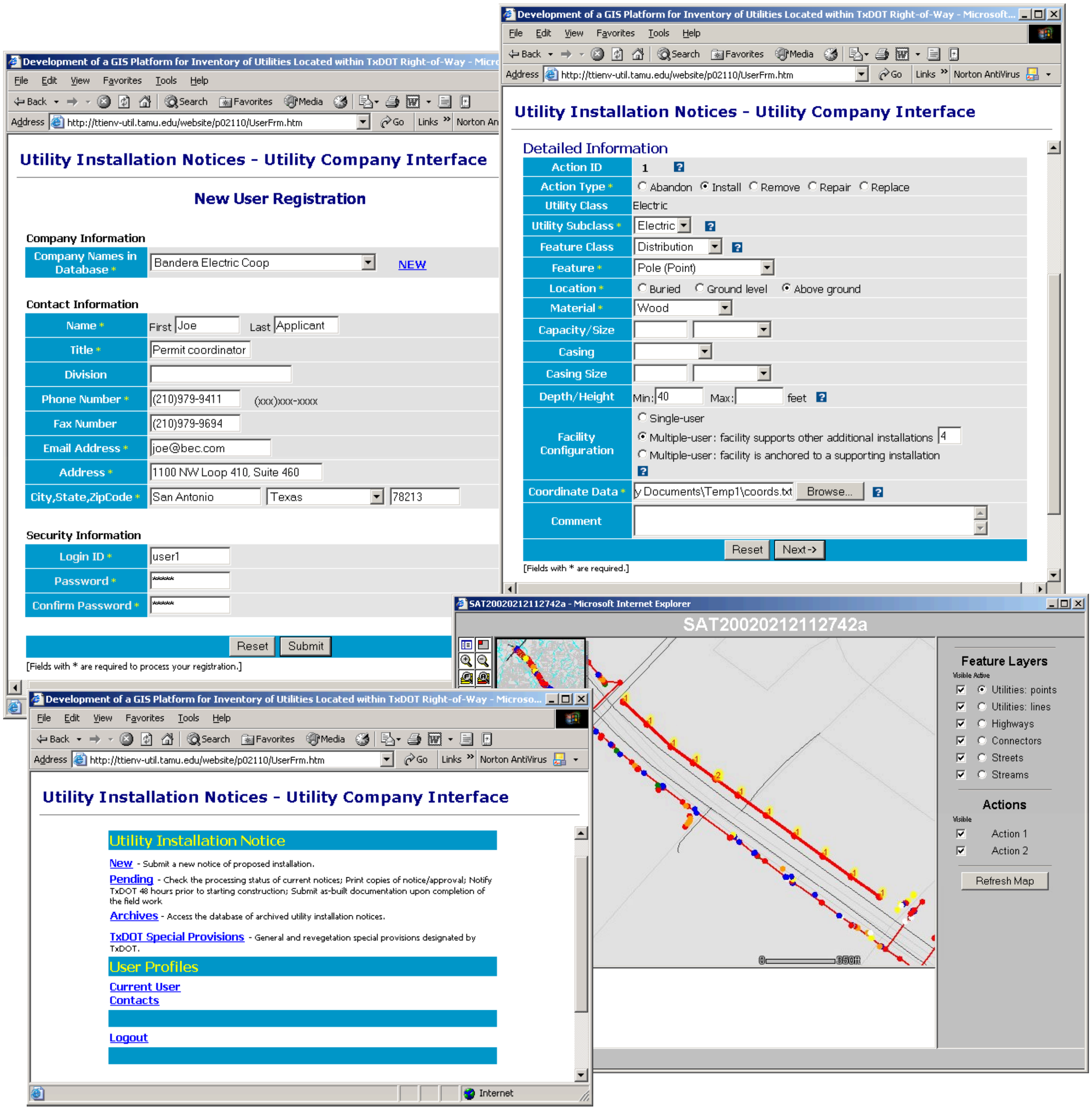


Figure 4-8. Sample Utility Company User Interface Web Pages.

Logging into the System

In order to submit notices of installation, users must first register with the system and create a user profile. The user profile contains contact data, company data, a user ID, and a password. Each profile has an internal ID number that allows the system to retrieve all pending and completed applications submitted by the user. User profile data are automatically inserted into all required forms to improve consistency and to reduce the work needed to complete the form. After logging into the system, users can enter new utility installation notice applications, review the status of pending applications, view TxDOT special provisions, and change profile data including UserID and password.

Submitting New Installation Notices

The process of entering new installation notices includes a short sequence of data input screens that allow editing and review before submitting a notice of installation to TxDOT. Where practical for purposes of database consistency, users choose field entries from a drop down list. In the event that an appropriate choice is not available, users may choose "other" and provide a written explanation of this choice. The interface follows a "shopping cart" design approach to allow users to document one or more actions associated with the current installation notice application. This is useful in the case of proposed utility work that involves more than one kind of action in the field, e.g., abandoning a section of pipeline and installing a replacement pipeline at a different location. Figure 4-9 shows a functional diagram of this process.

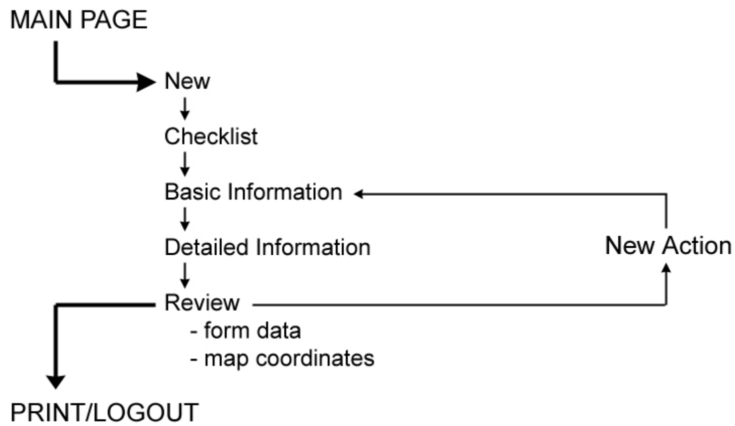


Figure 4-9. Functional Diagram of the Installation Notice Application Process.

It is important to note that users must upload coordinate data files indicating the location of the features to be installed. As Figure 4-6 shows, the system includes a web mapping tool that allows users on client computers to view those coordinates overlaying the base utility map, query utility features using the database architecture described previously, and select and view data associated with other concurrent installation notice applications on the same corridor.

During and after completing an application, the user is given the opportunity to make changes to the data provided. When the user is satisfied that the installation notice application data and coordinate files are correct, the user submits the form to complete the process. At this point, the database creates a permanent record for the application, and the application status becomes "Submitted." The user can then print the notice of installation and return to the Notice of Installation home page. The system sends an automated e-mail to the appropriate district representative indicating an application is now ready for processing.

Figure 4-10 shows a sample installation notice application form. Appendix B shows an expanded view of the application form template and, for completeness, the approval form template that would be accessible to utility company users after TxDOT approves the installation notice application. The form in Figure 4-10 and Appendix B loosely resembles existing TxDOT Forms 1023 and 1082. The actual layout and text included in the prototype form is an expanded version of a draft provided by TxDOT that intends to replace the current forms with a single unified form. The prototype form took the main elements included in the current TxDOT draft and added text elements that could be obtained directly from the online installation notice application. For convenience, the online application form has two sections. The first section, which can be printed on a single 8.5 inch x 11 inch sheet of paper, includes a summarized description of the proposed work, as well as text elements such as application ID, proposed construction beginning and ending dates, application date and time stamp, and utility company user data. The second section, which may take one or more sheets of paper depending on the number of actions included in the application, provides a more detailed description of each action. It also provides links to coordinate data files, attachments, and a map.

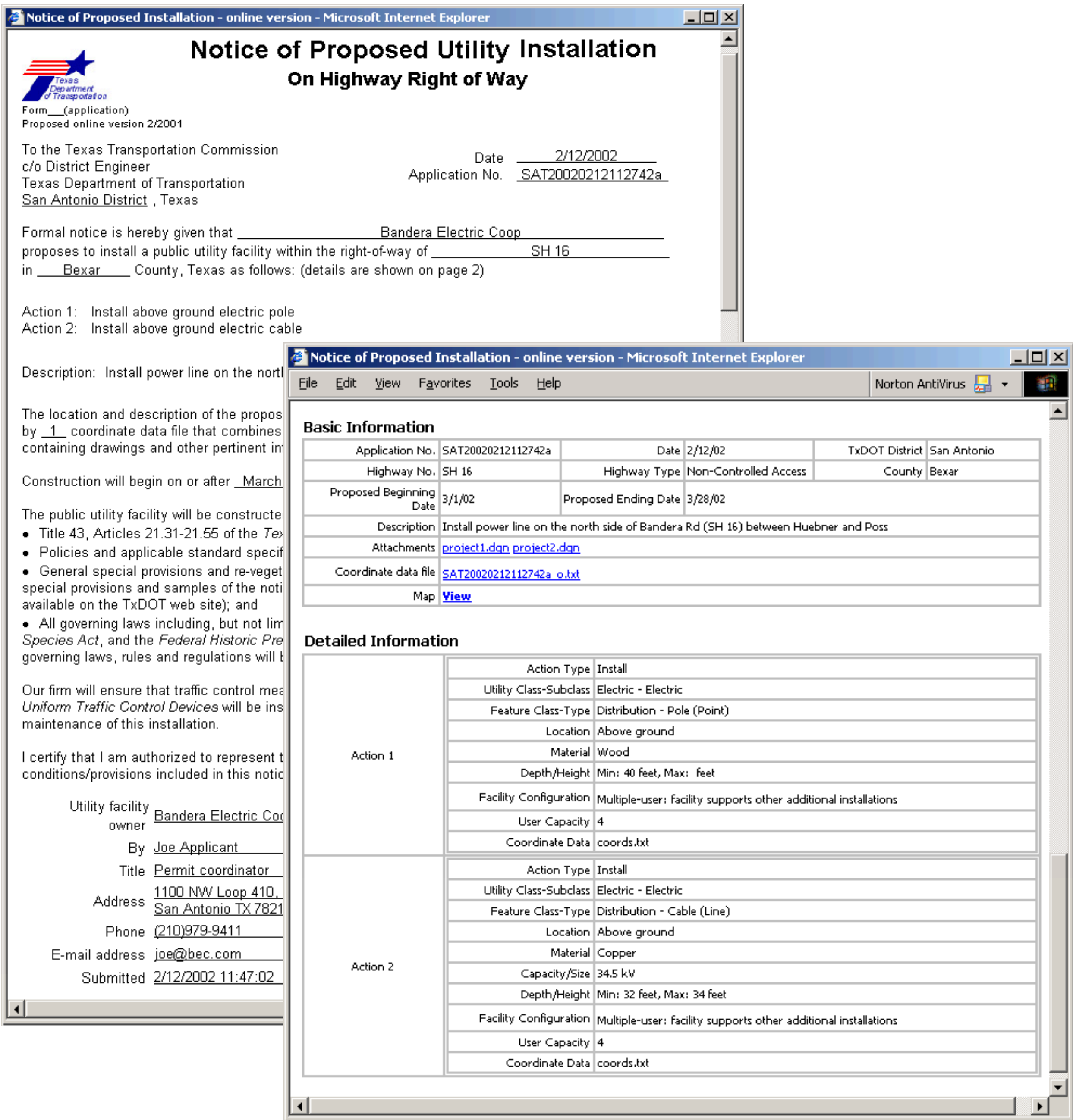


Figure 4-10. Notice of Proposed Utility Installation Prototype Form.

Reviewing Pending Applications

The system allows utility company users to view the status of individual applications as the application moves through the review process. If TxDOT grants approval, the utility company user receives an automated e-mail with instructions to use the interface for notifying TxDOT of the construction start date as well as submitting as-built documentation after finishing the field work. Figure 4-11 shows a functional diagram of the procedures for viewing pending records.

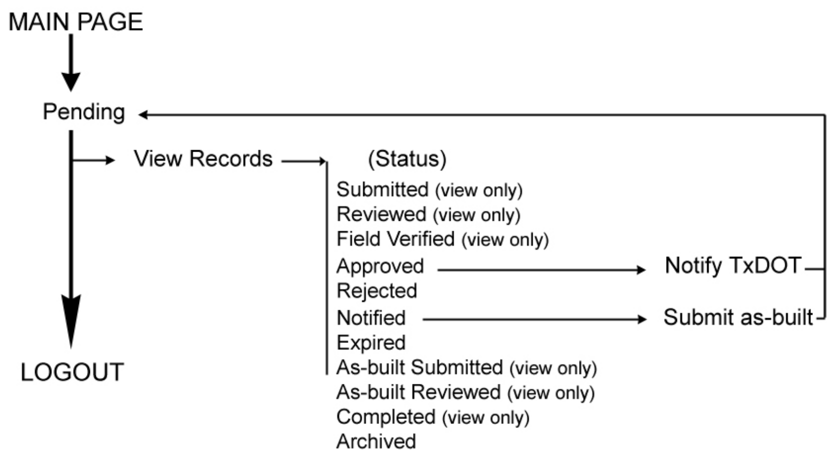


Figure 4-11. Functional Diagram of the Pending Application Process.

Administrative Interface

The administrative interface supports the needs and responsibilities of TxDOT officials during the installation notice review process. The system facilitates this process through automated e-mails that alert specified officials when an application has reached a status for which those officials are responsible. The specified official then logs into the system (a link is provided within the e-mail for convenience), clicks on the appropriate processing link in the navigation bar, and processes the application. Figure 4-12 shows a typical processing procedure, and Figure 4-13 shows a collage of sample web pages included in the interface. Report 2110-2: A Data Platform for Managing Utilities along Highway Corridors: User Manual includes full-size samples of all the administrative interface pages included in the interface.

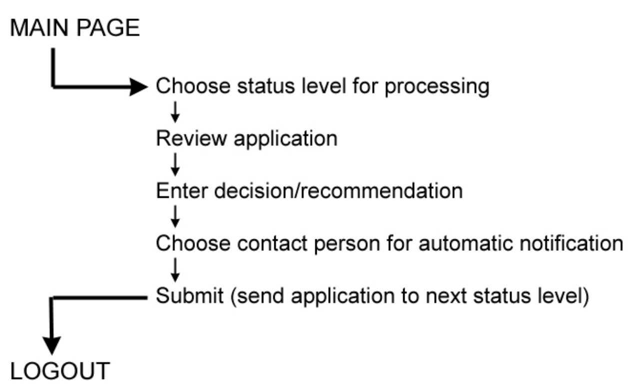


Figure 4-12. Functional Diagram of a Typical Installation Notice Review Process.

The prototype includes six levels of administrative responsibility to process installation notices. Table 4-1 provides a brief description of the activities associated with each level of responsibility. The prototype also includes 11 status options for installation notices. Table 4-2 provides a brief description of each status option and the corresponding relationship with the administrative responsibility levels. To encourage efficiency in the review process, the relationship between administrative responsibility levels and installation notice status is dynamic. Each time an application changes status, the system sends an automated e-mail to the individual responsible for the next required administrative task. An action by that individual in response to the automated e-mail triggers a change in application status, which, in turn, causes the system to send an e-mail to the next official. Depending on the status and/or action required, an automated e-mail may also be sent to the utility company user that submitted the application.

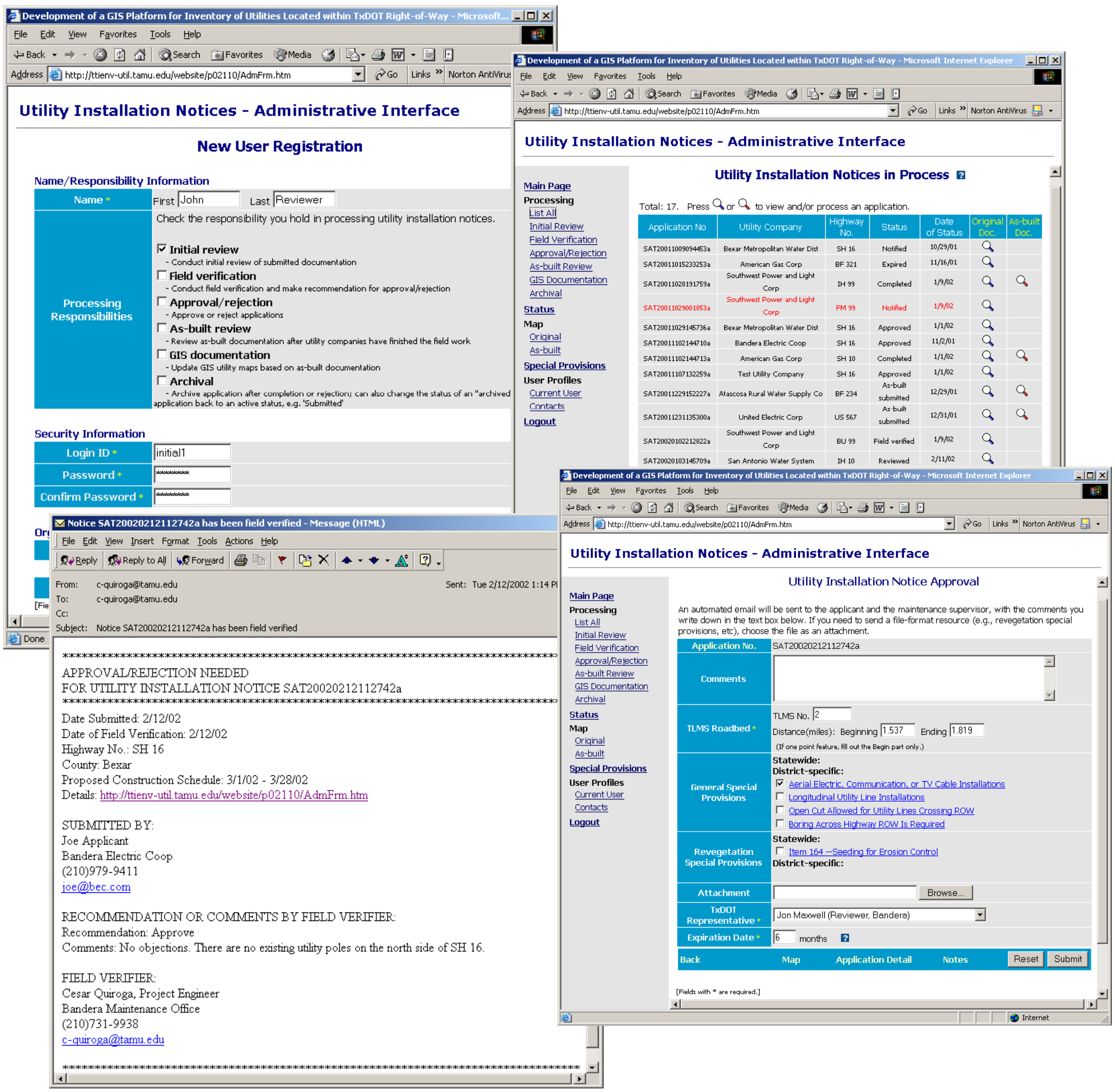


Figure 4-13. Sample Administrative Interface Web Pages.

Table 4-1. Administrative Responsibility Levels.

Response	Description
Initial review	Conduct initial review of submitted documentation
Field verification	Conduct field verification and make recommendation for approval/rejection
Approval/rejection	Approve or reject applications
As-built review	Review as-built documentation after utility companies have finished the field work
GIS documentation	Update GIS utility maps based on as-built documentation
Archival	Archive application after completion or rejection; can also change the status of an "Archived" application back to an active status

Table 4-2. Installation Notice Status Options.

Status	Is Reached After	Next Responsibility Level
Submitted	Electronic confirmation that an application has been received by the server has been sent to the utility company	Initial review
Reviewed	Application has been verified for completeness. Normally conducted by a utility coordinator at the district office	Field verification
Field verified	Maintenance Supervisor/Area Engineer recommends whether the proposed installation should be approved	Approval/rejection
Approved	Application has been approved and automated e-mail has been sent to the utility company	
Rejected	Application has been rejected and automated e-mail has been sent to the utility company	Archival
Notified	Utility company has given 48 hour notice to TxDOT prior to starting construction	
Expired	Utility company has not notified TxDOT of the construction start date prior to an expiration date set by the administrator responsible for approving the application	Archival
As-built submitted	Utility company has submitted a final set of coordinates indicating the location of the utilities installed	As-built review
As-built reviewed	TxDOT has reviewed and approved the as-built documentation submitted by the utility company	GIS documentation
Completed	GIS personnel at the district office have updated GIS utility map using as-built data provided by the utility company	Archival
Archived	All processing is complete	

SYSTEM PERFORMANCE

The prototype system has the potential to dramatically reduce paperwork and accelerate the submission and review of installation notice applications. Provided a utility company user already has the necessary supporting documentation ready, including coordinate data, the researchers estimate that filling in text boxes and uploading files for a typical installation notice application could take anywhere from five to fifteen minutes. After receiving the online application, the prototype system automatically generates a database record for the application and makes the data available to TxDOT officials. No paperwork is generated—everything is digital throughout the review process including the installation notice document and the corresponding approval form—which can translate into significant time and space savings for TxDOT. Utility companies would also benefit because they could follow the progress of the review process online at any time, making the process more efficient and expedient. They would also have access to the electronic installation notice application form and corresponding approval form and attachments.

For optimal performance, the prototype system assumes users are connected to the Internet using a high-speed connection, particularly for uploading files and/or displaying utility maps. For other operations such as reviewing the status of pending applications and printing forms, a slow dial-up connection is adequate. For displaying utility maps, because of the overhead caused by the rendering and transmission of map image files, it is best to use a high-speed Internet connection. For example, when a user loads the web mapping tool to request and display the full extent of the map shown in Figure 4-6 (11,700 features representing six feature layers: utility points, utility lines, highway directional centerlines, highway connectors, city streets, and streams), the spatial server generates image files that are roughly 50-80 kbytes in size. Using a high-speed connection operating at 530 kbps, loading the map for the first time takes about 20-25 seconds and subsequent map reloads take 2-4 seconds. In contrast, using a 56 kbps modem dial-up connection, loading the map for the first time takes 2-2.5 minutes and subsequent image reloads take 20-30 seconds. Notice that a high-speed Internet connection does not mean that the processor and/or operating system of a client computer would need to be high-end. The prototype online application performs well even on relatively slow computers because the prototype is HTML-based and the corresponding requirements in terms of client computer resources during execution are low.

TxDOT reviewed the system interface several times during development. The researchers noted the feedback offered during those reviews and made changes accordingly. Additional testing included "cognitive walkthroughs" to measure the degree to which new users could complete specific tasks without failure. A typical cognitive walkthrough would include a scenario ("you are a new utility company employee"), a task ("you are asked to submit an installation notice application"), and information needed to complete the task (contact information, basic and detailed installation information). The testing focused primarily on smaller task subsets to identify areas of ambiguity. The system has yet to be tested on actual utility company or TxDOT users.

During implementation, it may be necessary to modify some prototype components to optimize the operation and/or performance of the system. Some potential modifications include the following:

- The system uses a disaggregated "shopping cart" approach to document each action associated with an installation notice. While this approach may be necessary to support utility companies that do not have strong CAD or GIS capabilities, it might prove to be burdensome for utility companies that do have those capabilities in place. These companies might prefer a different procedure that would allow them to prepare all the files offline, make sure they comply with the spatial and database inventory model described in Chapter 3, and then use the interface to upload those files in a single operation. Indirectly, the prototype already supports that type of procedure by giving users the capability to upload attachments and other documentation. However, it would be necessary to modify the interface to better document that available option and to support the display of the uploaded files on the utility map.

- Currently, the web interface supports map viewing and querying, but not downloading. While the benefit of adding map downloading capabilities for TxDOT users is clear, TxDOT would need to evaluate the need to provide a similar capability to utility company users. Likewise, the web interface allows users to overlay coordinate data locations on the utility maps; however, it does not support overlaying uploaded CAD or GIS files. The prototype would need to be modified to support that functionality.
- The prototype system does not currently have the capability to recognize whether a professional engineer has signed and sealed drawings attached to installation notice applications. If TxDOT begins to require that all drawings must be signed and sealed by a registered professional engineer, it will be necessary to modify the prototype to accommodate that requirement. Related to this issue is the need to add data fields so that utility company users can document the horizontal accuracy, vertical accuracy, and QL of the data they upload. Accuracy and QL values could be different depending on whether the documentation reflects proposed or as-built conditions. For as-built documentation, it is reasonable for TxDOT to expect the data submitted to comply with a QL "A." In reality, this will translate into a requirement for utility companies to survey their facilities as the installation takes place in the field, which, for a number of utility companies, will probably involve a significant departure from current practice.
- After the review process has ended and the utility base map has been updated, installation notice records can be moved to an archival database. In the prototype, installation notice records that are ready for archival are labeled "Archived," however they are not automatically moved to an archival database. During implementation, it would be necessary to develop a procedure to periodically review database records and move those records that are ready for archival.
- The prototype was built using server components that were adequate for a small-scale experimental application. For implementation, TxDOT may have to modify some of the components to make the system more robust and reliable. For example, the prototype uses Access as the database platform. While TxDOT uses Access for a number of applications throughout the state, it would be advisable to migrate the prototype to a more robust database environment such as Oracle. Likewise, security in the prototype is limited to a simple user ID/password validation. For implementation, it would be necessary to apply a number of strategies such as using secure web pages for online transactions, encrypting passwords, storing data files on computers other than the web server, and using data warehouses to prevent direct outside access to the repository data on the TxDOT server. TxDOT could also optimize the code to make it more compatible with tools and techniques that have quickly become de facto standards. For example, except for most of the web mapping subsystem, the rest of the prototype does not support XML. XML has become a de facto standard for designing text formats that considerably simplifies the process of generating, reading, exchanging, and reporting data for online and offline applications alike. The prototype should be modified to comply with that standard.

Finally, as mentioned at the beginning of the chapter, it is important to note that the database model that gave origin to the prototype Internet system is generic and could be easily adapted to develop reduced offline versions of the system. Those offline versions would not be as automated as the Internet version. However, they could be useful in case TxDOT foresees delays in the implementation of the Internet-based system or if there are districts interested in starting the implementation of the database model quickly without having to wait for the Internet-based system to become operational.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Previous chapters document the development of a prototype GIS-based platform for the inventory of utility installations located within the TxDOT ROW. The need for the research was the increasing proliferation of utility facilities within the TxDOT ROW and the challenges TxDOT is facing not only to allow more utilities within the ROW but also to deliver and manage its transportation system in a timely and efficient manner.

This chapter summarizes the conclusions reached at the completion of the research and lists a series of recommendations. For convenience, the researchers grouped conclusions into existing utility data sources, prototype utility inventory model, and prototype installation notice system. They also grouped recommendations into general recommendations and recommendations for standards and minimum requirements for quality and content.

CONCLUSIONS

Existing Utility Data Sources

Most of the information about utility facilities located within the TxDOT ROW comes from the installation notice process. While the amount of documentation available could be quite sizable, the usability of the current records—from the point of view of developing a statewide GIS-based inventory of utilities—is limited. For example, many districts keep installation notice records for a long time, although a significant percentage of districts keep records for only a few years. TxDOT issues permits to occupy the ROW in perpetuity. Unfortunately, utility companies do not have to notify TxDOT about changes in utility installation ownership status, operational status, or other technical characteristics after completing the original installation in the field. As a result, it is not clear whether the information contained in existing installation notice records is still valid, particularly in the case of older records. In addition, installation notices cover relatively small areas, making the process of extrapolating that information to other locations along the highway network difficult.

Very few drawings attached to installation notices are scaled, include coordinate system data, or contain data such as reference marker offsets or control section mile point data. Some installation notices include a reference of relative location with respect to the ROW line. However, the reliability of that information is frequently questionable, particularly in the case of underground installations, because what the installation notice documentation shows is not necessarily what was finally installed in the field. There is considerable variability in the amount of data and level of detail contained in the drawings submitted with installation notices. Some drawings contain barely enough data to document the location of proposed and existing utilities. Other drawings contain much more data. Frequently, however, these are engineering drawings that are meaningful to utility company users but not necessarily to TxDOT users.

TxDOT is increasingly using the SUE process to obtain information about the location of underground utility installations within the TxDOT ROW. As opposed to utility company engineering drawings, SUE deliverables focus on information that is relevant to transportation agencies: utility location and brief utility feature attribution. Historically, there has been considerable variability in the way SUE data collection methods are defined and characterized. The adoption of a new ASCE standard (*1*), which formalizes definitions, procedures, and quality expectations, could result in more predictable, reliable deliverables. The new standard uses four QL categories; however, it does not provide a positional accuracy numerical indicator to be associated with each QL. Only in the case of QL "A" the standard suggests the survey "should conform to applicable horizontal survey and mapping accuracy as defined or expected by the project owner" (*1*). In practice, this means TxDOT should specify not only the quality level but also the horizontal positional accuracy and the vertical positional accuracy expected from the survey.

TxDOT manages a number of joint use agreements with utility companies. Those agreements usually have a unique "U" number that corresponds to a file folder that stores all the documentation associated with that particular agreement. All reimbursable agreements have "U" numbers. Non-reimbursable agreements, which result when local agencies handle ROW acquisitions, do not have "U" numbers. The ROW Division uses a database to keep track of the joint use agreement process. However, the database is not relational and is not geo-referenced. Further, the database lacks a unified identification mechanism for keeping track of all joint use agreements at TxDOT. These characteristics limit the scalability potential of the current database and the feasibility to integrate that database with other utility data sources at TxDOT.

A potential source of utility data could be utility company databases. Unfortunately, tapping into this apparently vast data source is quite challenging. For example, utility data management practices, geo-referencing standards, and procedures vary widely among utility companies. Many utility companies use AM/FM systems that give them the capability to document their assets effectively. However, this is not the norm, particularly in the case of small, "mom-and-pop" type operations. In addition, utility companies tend to be specialized, which usually drives the development of utility data management systems and models. Unfortunately, current data management systems and models do not properly handle the considerable level of physical interaction among utility installations in the field. Finally, utility companies tend to be very protective of their systems and data and do not easily share electronic data files with other agencies. When they do, they typically do not guarantee the accuracy of the locational information they provide and refer users to utility location services to determine the actual alignment of the utility installations.

In summary, TxDOT has access to a wide range of utility data sources such as installation notices, SUE deliverables, and joint use agreements. In theory, utility company databases could also be sources of utility data for TxDOT, although the likelihood that utility companies would agree to share that information with TxDOT on a statewide basis is probably quite low. Currently, TxDOT utility data sources are not compatible with each other and, as Chapter 2 documents, are not well suited for the development of a robust GIS-based inventory of utilities within TxDOT. Provided a GIS platform is in place, TxDOT utility data sources could be useful for populating and/or maintaining an inventory of utilities within the TxDOT ROW. However, it would be necessary to make substantial modifications to current data collection procedures.

Prototype Utility Inventory Model

TxDOT has started a process to replace its highway centerline map, and that process has a number of implications for the development of a platform for the inventory of utility installations within the TxDOT ROW. The current highway centerline map, which was originally digitized using 1:24,000 USGS 7.5-min quadrangle maps, has a positional accuracy of about 100-200 ft. TxDOT has used this map for a number of inventory applications, including highway features and pavement conditions. However, because inventory locations are tied to the alignment of the current centerline map, their positional accuracy is not better than that of the centerline map. The situation is worse in the case of complex highway geometries such as freeway interchanges and ramps because the current centerline map does not properly model those geometries. To address these limitations, TxDOT is developing a new roadbed centerline map, which will provide directional differentiation and will have a submeter positional accuracy.

Currently, TxDOT uses two linear referencing methods to locate features and events along the highway network: the control section-distance method and the reference marker-distance method. The two linear referencing methods are not compatible, forcing TxDOT to use a complex conversion table that needs to be updated on a regular basis. The new roadbed centerline map will support the inventory of highway features independently of the highway network alignment, in effect assuming that linear referencing measures will be derived measures. This process will facilitate inventory efforts along the state highway network using GPS and other technologies that are not inherently tied to any highway alignment.

A review of AM/FM GIS technology revealed that current systems, which are designed to address the daily operational and maintenance needs of utility companies, would not address TxDOT's needs. As part of the project, the researchers developed a simplified prototype utility data inventory model (Figure 5-1). This prototype model can be characterized as follows:

- The spatial model uses point and linear physical spaces that characterize the "footprint" on the ground occupied by one or more utility installations. Utility installations that share the same "footprint" are considered users of the physical space (or feature) they occupy. By default, every feature is assumed to have at least one user. Each point or linear feature has a unique identifier that remains with the feature throughout its lifetime.
- Point and linear features can be located independently of any highway base map, therefore providing compatibility with the new roadbed centerline map. X, Y coordinate pairs determine feature locations. However, the model is also compatible with the existing centerline map because it supports the calculation of distance and offset measures for individual features using GIS linear referencing functions.
- Each feature has horizontal and vertical positional accuracy indicators as well as a QL indicator that follows the new ASCE standard described in Chapter 2. The spatial data model assumes feature location updates are handled using utility map versioning. QL changes are also tracked using the feature event tables in the database.
- The database model uses a three-table architecture for both point and linear features to properly track feature events and feature user events.
- The database uses lookup tables to characterize individual features and feature users. Feature characterization is aggregated and corresponds to the researchers' perception of

what could be relevant to TxDOT. Feedback received from a number of potential stakeholders suggests that lookup table content is adequate as a starting point. During implementation, TxDOT will need to revisit feature characterization to make sure the number of entries in the database properly addresses TxDOT's needs.

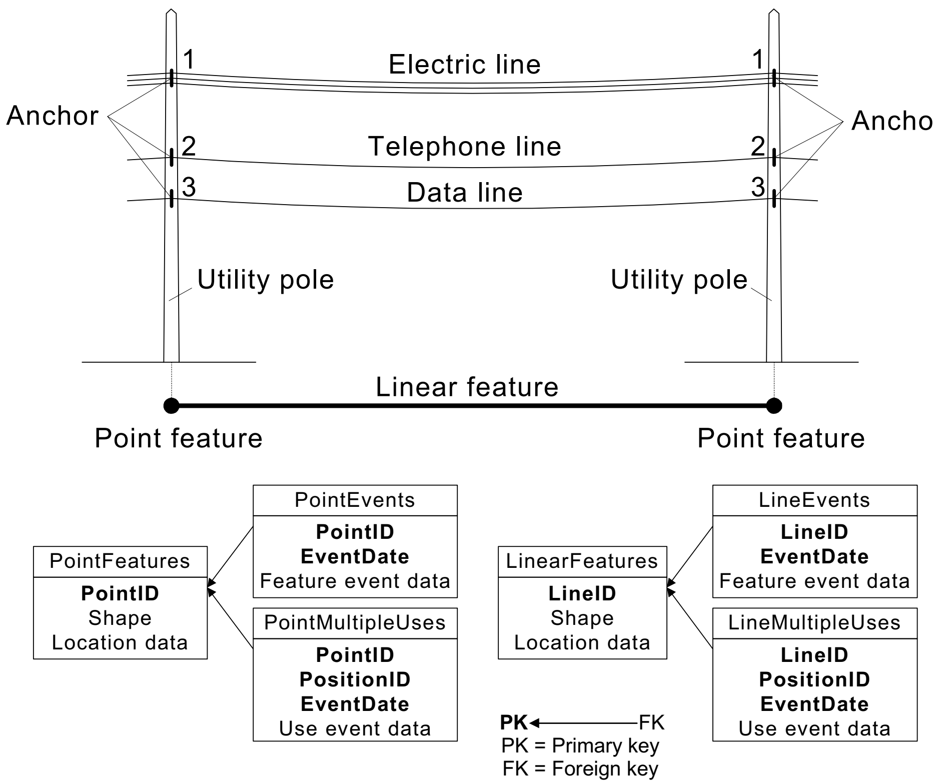


Figure 5-1. Prototype Utility Data Inventory Model.

The researchers tested the prototype utility inventory model using data collected along a 7-mi stretch of SH 16 between IH 410 and Loop 1604 in northwest San Antonio. The data collection included a survey of utility facilities using a submeter-level GPS receiver equipped with attribute data logging capabilities, a review of sample paper and/or electronic maps received from some utility companies, and, to the extent possible, existing installation notice documentation. A summary of the results from the data collection effort follows:

- The researchers generated ArcView 3.2 format GIS files—and corresponding Access database records—to document point and linear utility features along SH 16. There were additional files in ArcView 3.2 format to document roadbed centerline features along SH 16. With utility feature data in a GIS format, it was possible to generate a variety of maps and run spatial and non-spatial queries.
- The horizontal positional accuracy of the data collected in the field was submeter given the type of GPS receiver used (mapping). More accurate readings would be possible using a surveying-type receiver. Obviously, as the positional accuracy requirement increases, so does the cost of the data collection equipment.
- The process to convert GPS data into GIS features was fairly time consuming because the GPS equipment data collection box did not support relational database structures, and, as

a result, it could not record data associated with multiple user installations efficiently. For the data collection, it was necessary to artificially add fields to the GPS equipment data dictionary to keep track of all utility feature users and spend considerable time during the data reduction process to convert the raw data into relational database records. For implementation, it would be advisable to develop/acquire a customized data collection tool. This tool would probably result from the combination of a GPS receiver and a personal digital assistant (PDA) device equipped with special-purpose software that supports both relational databases and GIS.

- The research effort focused on the development of a prototype GIS platform and not on the development of GIS customization scripts. While customization scripts could considerably improve productivity by facilitating the production of special-purpose reports and maps, TxDOT considered this strategy ineffective, given TxDOT's plan to migrate from ArcView 3.2 to ArcView 8.1 in the near future and the corresponding change from Avenue scripting to Visual Basic scripting. It may be worth noting that ESRI introduced ArcGIS near the end of the research project, which prevented the researchers from the opportunity to develop prototype forms and reports using the new platform.

Prototype Installation Notice System

Inventories are only useful as long as they are current. There are several utility-related processes at TxDOT, and the challenge is how to use those processes to help maintain the utility inventory up-to-date. By far, obtaining data from the installation notice process is the most challenging because (1) most utility-related activities at TxDOT focus on processing installation notice applications; (2) the installation notice process is manual, labor intensive, and time consuming; and (3) procedures, data formats, documentation requirements, and quality of the spatial information provided by utility companies vary widely from district to district.

To address the limitations of the current installation notice process at TxDOT, the researchers developed a prototype system. The researchers chose a web-based data entry approach for the prototype because of three characteristics that make the installation notice process at TxDOT appropriate for the implementation of online, automated data collection and data processing strategies: little face-to-face contact with utility companies, spatial distribution, and asynchronous processing. Readers should note that, while the prototype relies on Internet-based techniques for capturing and managing installation notice data, the underlying database model is generic and could be easily adapted to develop reduced offline versions of the system. Those offline versions would not be as automated as the Internet version. However, they could be useful in case TxDOT foresees delays in the implementation of the Internet-based system or if there are districts interested in starting the implementation of the database model quickly without having to wait for the Internet-based system to become operational.

Figure 5-2 shows the data flow of the prototype system. The prototype system can be characterized as follows:

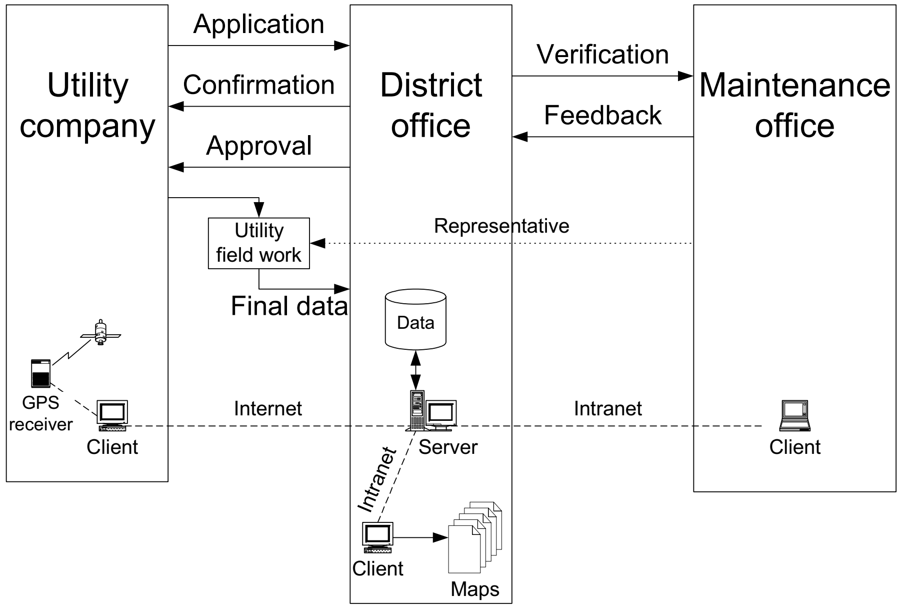


Figure 5-2. Prototype Data Flow and Data Collection for Installation Notices.

- Conceptually, the prototype system follows the existing workflow at TxDOT, with some exceptions. For example, it assumes utility companies upload coordinate data files to document the location of their proposed installation as well as-built documentation after they complete the utility installation in the field. The prototype also assigns an expiration date to the application and includes a number of control data elements to facilitate the review process by TxDOT officials.
- A relational database manages all data associated with the installation notice process. The database is structured around a core table that contains basic installation notice data, including a unique installation notice identifier, as well as date, time, and other fields to keep track of the application throughout the review process. The database supports file uploading and storage and contains a number of lookup tables, including tables that are shared with the utility inventory database schema.
- The prototype uses a centralized data management architecture with distributed map and data access capabilities. The centralized data management architecture relieves local districts from the burden of having to provide personnel and expertise to maintain local web servers. Distributed map and data access provides flexibility to districts because it enables access to utility data in the form of online queries and display from web browsers. The system also allows utility companies to access maps and data documenting existing and proposed installations located within the TxDOT ROW.
- The prototype system has client-side components and server-side components. The client-side components include an HTML viewer and an e-mail client application. The HTML viewer, e.g., Internet Explorer or Netscape, is used as a front-end interface to submit and review installation notice applications. The server-side components include two integrated subsystems: a notice data management subsystem and a web mapping subsystem. The notice data management subsystem allows users on client computers to log into the system and submit and review installation notice applications. The web mapping subsystem allows users on client computers to view utility maps, query and

retrieve map feature data, and select and view installation notice application locations and associated attribute data.

- The prototype system includes a utility company user interface and an administrative interface. The utility company user interface allows utility company users to submit and/or follow the progress of installation notice applications. The interface follows a “shopping cart” design approach to allow users to document each of the actions associated with an installation notice application. The administrative interface allows TxDOT administrators to review installation notice applications. The prototype includes six levels of administrative responsibility that are dynamically related to 11 installation notice status options. Each time an application changes status, the system sends an automated e-mail to the individual responsible for the next required administrative task. An action by that individual in response to the automated e-mail triggers a change in application status, which, in turn, results in an e-mail being sent to the next official. Depending on the status and/or action required, the system may also send an automated e-mail to the utility company user that submitted the installation notice application.
- The prototype system allows users to download and print copies of the application form, the approval form, and supporting documentation such as special provisions and coordinate data files. The printable installation notice form loosely resembles existing TxDOT Forms 1023 and 1082. The actual layout and text included in the prototype form is an expanded version of a draft provided by TxDOT that intends to replace the current forms with a single unified form. The prototype form took the main elements included in the current TxDOT draft and added text elements that could be obtained directly from the online installation notice application.

TxDOT reviewed the system interface several times during development. The researchers noted the feedback offered during those reviews and made changes accordingly. Additional testing included “cognitive walkthroughs” to measure the degree to which new users could complete specific tasks without failure. Results from the testing and additional feedback received by the researchers indicate the following:

- The prototype system has the potential to dramatically reduce paperwork and accelerate the submission and review of installation notice applications. Completing the online installation notice application, assuming all supporting documentation is ready, takes anywhere from five to fifteen minutes. Once submitted, there is a permanent database record for the application and the associated data are automatically available to TxDOT officials. The system does not generate paperwork—everything is digital throughout the review process, including the installation notice document and the corresponding approval form.
- For optimal performance, the prototype system assumes users are connected to the Internet using a high-speed connection, particularly for uploading files and/or displaying utility maps. For other operations such as reviewing the status of pending applications and printing forms, a slow dial-up connection is adequate. Notice that a high-speed Internet connection does not mean that the processor and/or operating system of a client computer would need to be high-end.
- Using the same database structure and procedures for all installation notices throughout the state has the advantage of standardizing the process, which can be of benefit to both

TxDOT and utility companies. Furthermore, the prototype includes a number of controls designed to improve TxDOT's ability to monitor the process better and to improve the accountability of utility companies.

- The system uses a disaggregated "shopping cart" approach to document each action associated with an installation notice. This approach may be necessary to support utility companies that do not have strong CAD or GIS capabilities, but it might prove to be burdensome for utility companies that do have those capabilities in place. These companies might prefer to prepare all files offline, making sure they comply with the utility inventory model described before, and then use the interface to upload those files in a single operation. It would be necessary to modify the prototype to support this process.
- The web interface supports map viewing and querying, but not downloading. While the benefit of adding map downloading capabilities for TxDOT users is clear, TxDOT would need to evaluate the need to provide a similar capability to utility company users. Likewise, the web interface allows users to overlay coordinate data locations on the utility maps, but it does not support overlaying uploaded CAD or GIS files. It would be necessary to modify the prototype to support that functionality.
- Currently, installation notice documentation does not need to have the seal of a registered professional engineer. If TxDOT implements this requirement in the future, it would be necessary to modify the prototype to accommodate that requirement. Related to this issue is the need to add data fields so that utility company users can document the horizontal accuracy, vertical accuracy, and QL of the data they upload.
- After the review process has ended and the utility base map has been updated, installation notice records can be moved to an archival database. In the prototype, installation notice records that are ready for archival are labeled "Archived," however they are not automatically moved to an archival database. During implementation, it would be necessary to develop a procedure to periodically review database records and move those records that are ready for archival.

RECOMMENDATIONS

General Recommendations

- Select a pilot district to conduct an inventory of utilities located within the TxDOT ROW using, as a foundation, the prototype inventory model developed in this research. Experience with the inventory of utilities at that district should provide valuable lessons when extending the inventory to the rest of the state. To the extent possible, TxDOT should carry out the inventory in coordination with utility companies, One Call centers, and other stakeholders. Despite the challenges, data exchange and/or data integration among agencies should be encouraged. Utility coordination councils and committees can play a significant role in this effort.
- Continue the development of the utility inventory model. Three areas in particular require attention:
    - Data elements: Add critical data elements that were not included in the original version of the prototype. Examples include feature footing characteristics, utility pole safety device data, and security data. Utility pole safety device data are

important because of the increasing awareness about the influence of utilities on roadside safety and the need to keep track of the location and status of safety devices such as crash cushions, concrete barriers, and guardrails (*30*). Security data are important because of the increasing awareness of vulnerabilities, particularly where major utility installations, e.g., transmission lines and gas pipelines, intersect major transportation facilities. Identifying those locations is critical in order to implement appropriate, proactive protection strategies.

  - GIS platform: Convert the prototype inventory model from ArcView 3.2 to ArcGIS following TxDOT's decision to adopt ArcGIS as part of the core GIS architecture. ArcGIS will offer the opportunity to better integrate data in a variety of formats, better document the data model using unified modeling language (UML) techniques, and develop customized data query and reporting procedures using industry standard database and development tools.
  - Data collection: Develop a customized data collection tool to increase the efficiency of the utility inventory process. In principle, the data collection tool would involve the connection of a GPS antenna to a personal digital assistant (PDA) device equipped with special-purpose software that supports relational database GIS functionalities. The data collection tool should be able to accommodate both utility inventory activities and installation notice field verification activities.
- Extend the inventory model to include private utilities and, in general, any type of "hidden" infrastructure located within the ROW. For example, with the increasing number of intelligent transportation system (ITS) devices installed on state highways such as roadside sensors, traffic controllers, and communication lines, it is becoming more difficult to manage that infrastructure effectively. Knowing the location of those installations is also critical in the planning, design, construction, and maintenance of transportation improvements. The spatial and database models described in this report could be used, perhaps with minor modifications, to address those additional types of inventory needs.
- Select a pilot district to test the Internet-based installation notice system using, as a foundation, the prototype developed in this research. The deployment of the pilot could be in phases. The first phase would focus on the introduction of utility companies and officials at the pilot TxDOT district to the system. In this phase, utility companies would still use the current paper-based procedure but would also use the prototype for testing purposes. The second phase would focus on the development of an updated version of the system using components that would be more appropriate for a robust, statewide implementation. The updated system would take into consideration feedback received from potential users as well as potential improvement ideas described previously in this report. At the same time, pilot demonstrations could start at other districts. Parallel to those developments, TxDOT would begin to assess possible changes to the current utility accommodation policy to make sure those changes support the increased levels of TxDOT monitoring and utility company accountability that are built into the installation notice system.
- Develop a database schema and associated data collection procedures for other utility-related processes within TxDOT, in particular, joint use agreements. The database and data entry interface development process would be very similar to the installation notice

system described in this research report; however, it would take into consideration aspects that uniquely pertain to the utility joint use agreement process. Like the installation notice system, the utility joint use agreement system would be compatible with the utility inventory model.

- Explore additional applications within TxDOT for Internet-based data capture and management techniques. These techniques are well suited for processes that require little face-to-face contact with customers and are spatially distributed and asynchronous. Examples of potential applications include driveway permits, drainage permits, sidewalk permits, and landscaping permits. Some of those processes could be enhanced considerably by the use of web mapping techniques similar to those described in this research report. Application of Internet-based procedures could result in reductions of paperwork and turnaround times and standardization of current processes.
- Develop and deliver application-specific GIS training modules to TxDOT users. In the past, GIS training has been generic and basic, however, this approach has failed to satisfy the needs of many end users. Experience shows that developing expertise is crucial to improve the quality of the work and increase the chances of successful implementation of the technology. Experience also suggests that general-purpose training materials developed by GIS vendors are normally not appropriate to address the needs of a transportation agency such as TxDOT. While there are ongoing efforts at the national level to develop instructional materials in the general area of application of GIS technologies to transportation, their focus is on generating awareness rather than the teaching of the technology. TxDOT should therefore take the lead in developing appropriate training materials that could satisfy the needs of TxDOT users. An implementation program similar to the Transportation Research Implementation Consortium for Operations and Management (TRICOM), which the Texas Transportation Institute is developing for TxDOT, would provide an excellent mechanism for the development and delivery of the GIS training materials.

Recommendations for Standards and Minimum Requirements for Quality and Content

- Require utility-related data submitted to TxDOT to comply with the TxDOT utility inventory model. The amount of data, positional accuracy, and quality level should depend on the purpose for which utility data are submitted (see below). To ensure users are familiarized with the spatial and database architecture of the utility inventory model, TxDOT should make a copy of the model, including data samples, available on the TxDOT website.
- Require all positional data associated with existing utility installations to include a horizontal positional accuracy indicator, a vertical positional accuracy indicator, and a QL indicator. Horizontal and vertical positional accuracy indicators should be consistent with current TxDOT specifications and apply at the individual feature level to clearly identify variations in accuracy and QL within the data submitted. Even though the new ASCE standard QL classification scheme was designed for underground installations, TxDOT could also use it for above-ground installations, provided a direct correlation between quality level and positional accuracy is established. For example, a 3-6 ft (1-2 m) horizontal positional accuracy (two sigma, 95 percent confidence level) could be associated with QL "C." Finer accuracy values could be associated with QL "B" and

"A." For as-built documentation, it is reasonable for TxDOT to expect the data submitted to comply with a QL "A." In reality, this will translate into a requirement for utility companies to survey their facilities as the utility installation takes place in the field, which, for a number of utility companies, will probably involve a significant departure from current practice.

- Require utility-related drawings and data submitted to TxDOT to be signed and sealed by a registered professional engineer. This requirement will probably have to be implemented in phases, particularly in the case of installation notices. In the short term, most SUE consultants and designers would probably be able to comply with the engineering seal requirement. Utility companies that interact with TxDOT in the utility joint use agreement process would probably be able to comply as well because of the close relationship between this process and the rest of the highway improvement design process. Imposing the engineering seal requirement on the installation notice process will be challenging and will probably require some combination of incentives and disincentives to encourage utility companies to comply.
- Require all positional data to be submitted in ArcGIS-compatible format and to include appropriate coordinate system and projection data. Either geographic coordinates, i.e., latitude-longitude (WGS 1984 datum), or projected coordinates would be acceptable, as long as the projection files are included. This requirement is critical so that "on-the-fly" coordinate transformations and overlay operations can be performed in the GIS. The requirement to include projection files would also have to apply to CAD drawings.

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APPENDIX A. STATEWIDE SURVEY

The researchers distributed a generic survey to all 25 TxDOT districts in the fall of 1999. The objective of the survey was to assess trends and differences with respect to policies and procedures concerning the management of utility facility data throughout the state. A summary of results follows, based on 21 responses received from the districts.

INSTALLATION NOTICE (UTILITY PERMITTING) PROCESS

On average, how many installation notices are issued by your District for the installation of public utility facilities within the TxDOT ROW per fiscal year?

Number of installation notices issued per year	Number of responses
<100	1
100-200	3
200-500	9
500-1,000	4
1,000-2,000	4
>2,000	0

How many years do you keep installation notice records?

Number of years utility records are kept	Number of responses
<5	0
5-10	3
>10	18

How do you keep records on installation notices? (select all that apply)

Record keeping method	Number of responses
Index cards	3
Application form	14
File folders	17
Electronic spreadsheet	4
Database	6
GIS	
Other:	
- Microfilm and microfiche	2
- Microfilm	1
- Log book	2

How many TxDOT officials capture utility data at the point of receipt from utility entities?

Number of TxDOT officials in charge of capturing utility data	Number of responses
1	7
2	6
3	5
4	2
5 or more	
N/A	1

How much time do TxDOT officials spend on processing installation notices?

Percentage of time spent on installation notices	Number of responses
<10%	6
10-25%	2
25-50%	5
50-75%	6
75-100%	2

Please summarize the installation notice approval process from beginning to end.

District	Installation notice approval process
Typical district (there is considerable variation from district to district)	Utility company submits application to TxDOT district, area office, or maintenance office. Application includes Form 1023 (for non-controlled accessed highways), Form 1082 (for controlled access highways), drawings and descriptions. Application is date stamped. Designated TxDOT official conducts initial review and assigns application to area engineer or maintenance office. Area engineer or maintenance office reviews utility map and site. Designated official issues approval and attaches special provisions, necessary maps, and comments. TxDOT mails copy of approval to utility company or contractor, as well as appropriate levels within TxDOT (district office, area engineer, or maintenance office). If needed, a preconstruction meeting is scheduled. Utility company begins work. Area engineer or maintenance supervisor verifies in the field that requirements are met.

If stream crossings are affected, who applies for any National Pollutant Discharge Elimination System (NPDES) permits?

NPDES permit responsibility	Number of responses
TxDOT	1
Utility owner	16
Other	
Nobody	4

Please list any additional requirements involving stream crossings.

District	Comment
Amarillo	Comply with Environmental Protection Agency (EPA) and Texas Natural Resource Conservation Commission (TNRCC) requirements
Bryan	Most utilities use directional boring to minimize adverse impacts at stream crossing
Corpus Christi	Possible boring, stream stabilization, and/or slope stabilization
Houston	Ask utility to be bored under stream
Laredo	Environmental clearance if requested by Area Engineer
Lufkin	Corps of Engineers
Pharr	Irrigation canals districts, International Boundary and Water Commission (IBWC) & Corps of Engineers
San Angelo	Permit requires utility owner to use best management practices to minimize erosion and sedimentation
San Antonio	Polluting control devices: silt fences, rock beams, etc.
Yoakum	For any major crossings, TxDOT requires boring

For which ROW width do you grant permit for installation of utilities within the ROW? (select all that apply)

ROW width for which permits are issued	Number of responses
<50 ft	11
50-100 ft	19
100-150 ft	18
150-200 ft	18
200-300 ft	18
>300 ft	18

How is utility installation monitored by TxDOT (select all that apply)?

Installation monitoring by TxDOT	Number of responses
Visual inspection during installation	20
Visual inspection after installation	13
Indirect methods	
No monitoring is done	
Other	
- By maintenance forces	1
- Little monitoring is done	1
- Vary in attention	1

Do you hold preconstruction conferences with the utility owners/operators?

Pre-construction conferences are held with utility companies	Number of responses
Always	1
Never	1
Depends on scope	19

After obtaining a utility permit, do utility owners notify TxDOT about changes in:

Frequency	Number of responses			
	Ownership status	Geometric alignment	Other technical characteristics	Operational status
Always		7	1	1
Sometimes/Rarely	16	13	18	14
Never	5	1	2	6

After the initial permit has been issued and serviced, does subsequent repair, modification, etc. require another permit?

Additional work requires another permit	Number of responses
Always	3
Never	6
In some cases *	12

* Relocation or extension in utility installation.
Changes in the line size (volts) or new poles.
Significant modification to the original submission.
Change of alignment.
If the proposed work affects the pavement area.
Not required if it is an emergency repair.

Are the installations dismantled by the owner at the termination of use?

Installations are dismantled at the termination of use	Number of responses
Always	4
Never	4
In some cases *	12
Do not know	1

* Some abandoned in place.
Overhead facilities only.
If utility facility is to be updated.

Does TxDOT impose caps on the flow rate/volume/pressure/output of products/services that are carried on utility facilities located within the TxDOT ROW?

Caps are imposed on product/service being carried	Number of responses
Always *	1
Never	16
In some cases *	4

* According to the Utility Accommodation Policy in the Right of Way Manual

Who is responsible for cleaning up spills/blowouts, etc. of hazardous materials? (select all that apply)

(a) During the permitting/construction process:

Entity	Number of responses
Utility owner	19
Utility operator	8
Contractor(s)	11
TxDOT	

(b) After the permitting/construction process:

Entity	Number of responses
Utility owner	19
Utility operator	9
Contractor(s)	5
TxDOT	2

DATA COLLECTION/DATA MANAGEMENT ISSUES

How do you map/display locations of utility facilities within the ROW? (select all that apply)

Method to display utility facilities	Number of responses
Installation notices	5
Paper map	4
Microstation file	
ArcView file	
As-built drawings	4
SUE deliverable	1
ROW maps	1
N/A	13

Do you use a map or graphical display to show the locations of utility facilities within the ROW?

Use map or graphical display to show utility locations	Number of responses
Yes	4
No	17

Does the map you currently use show utility facility depth in addition to horizontal alignment?

Map shows depth in addition to horizontal alignment	Number of responses
Yes	4
No	2
In some cases	1
N/A	14

Do you map overhead transmission lines?

Map shows overhead transmission lines	Number of responses
Yes	6
No	1
In some cases	1
N/A	13

Are owned and leased utilities recorded on the same map?

Owned and leased utilities are recorded on the same map	Number of responses
Yes	3
No	4
In some cases	
N/A	14

How frequently do you update your utility facility map?

Utility facility map update rate	Number of responses
Once a week	2
Once a month	1
Once every three months	
Once every six months	
Once every year	
Once every two years	
Rarely	1
Never	1
N/A	16

What would you see as the base utility data repository level?

Base utility data repository level	Number of responses
Route	4
County	7
Area	2
District	6
State	1
Other	1

Which data group(s) should be included in a utility facility database? (select all that apply)

Data groups that should be included in utility database	Number of responses
Administration data	7
Engineering data	16
Property accounting data	5
ROW data	19
State involvement data	4
Other:	
- Maintenance sections	2
- Utility type, size, depth, location	1
- Graphics data	1

ADDITIONAL COMMENTS FROM TXDOT OFFICIALS:

- Most of the rules and policies come from TxDOT's utility accommodation policy. There are some rules and policies that are directed by the utilities themselves.
- The functional utilization of any GIS platform for utilities will only be as reliable as the data input. Currently, most utilities do not know the location or depth of their facilities in the ROW with sufficient detail to place on a statewide inventory that would be of any use to field personnel. The location of these facilities would be a huge effort since most utilities, particularly in non-metropolitan areas, place their facilities by contract, do not have sufficient personnel to inspect these placements, and therefore do not exercise specific control over the location and depth. Likewise, most TxDOT districts do not have sufficient resources to inspect all utility installations. The need for the One Call legislation in the past two sessions is indicative of the lack of proper identification and control of the utility plant within public ROW and the resulting damage that can result from this non-control.
- The permit process is currently handled by too wide a variety of personnel in TxDOT. Every district has its own idea of what the process should be and who should implement it and this causes confusion to the utilities. The different implementations and degree of inspection result in haphazard placement within the state ROW. There currently is no manual for this function, no clear designation of who should implement or inspect the process, and, most importantly, no mention of this function or process in the classification system. A clear-cut guidance manual, standardization of personnel involved and recognition, in the classification system, for those who do this thankless job is urgently needed. Finally, the state should implement a fee process to recover handling, reproduction, and inspection costs.

APPENDIX B. PROTOTYPE INSTALLATION NOTICE AND APPROVAL FORMS

Texas Department of Transportation
Form ____ (application)
Proposed online version 2/2002

Notice of Proposed Utility Installation

On Highway Right of Way

To the Texas Transportation Commission
c/o District Engineer
Texas Department of Transportation
________________________, Texas

Date ______________________
Application No. ______________________

Formal notice is hereby given that ____
proposes to install a public utility facility within the right-of-way of ____________________________________
in ______________________________ County, Texas as follows: (details are shown on page 2)

Action <ActionID>:
:
:
:

Description:

The location and description of the proposed installation and appurtenances is more fully shown by ___1___ coordinate data file that combines coordinate data from _______ files originally uploaded and _______ files containing drawings and other pertinent information.

Construction will begin on or after <mmmmmmm dd, yyyy> and end on or before < mmmmmmm dd, yyyy > .

The public utility facility will be constructed and maintained on the highway right-of-way in accordance with:

- Title 43, Articles 21.31-21.55 of the *Texas Administrative Code*;
- Policies and applicable standard specifications of the Texas Department of Transportation (TxDOT);
- General special provisions and re-vegetation special provisions, as indicated on the Approval Form (typical special provisions and samples of the notice of the proposed public utility installation an approval form are available on the TxDOT web site); and
- All governing laws including, but not limited to, the *Federal Clean Water Act*, the *National Endangered Species Act*, and the *Federal Historic Preservation Act*. Upon request by TxDOT, proof of compliance with all governing laws, rules and regulations will be submitted to TxDOT before commencement of construction.

Our firm will ensure that traffic control measures complying with applicable portions of the *Texas Manual of Uniform Traffic Control Devices* will be installed and maintained for the duration of construction and/or maintenance of this installation.

I certify that I am authorized to represent the Firm listed below, and that our Firm agrees to the conditions/provisions included in this notice.

Utility facility owner ____________________________________ Company ID ____________________

By ____________________________________ User ID ____________________
Title ____________________________________

Address ____________________________________
____

Phone ____________________________________
E-mail address ____________________________________

Submitted <mmm/dd/yyyy hh:mm:ss am>

Texas Department of Transportation
Form ____ (approval)
Proposed online version 2/2002

APPROVAL

To: ______________________ Date ______________________
______________________ Application No. ______________________
______________________ Highway ______________________
______________________ TLMS No. ________ Begin ________ End ________
______________________ Maintenance Section ______________________
District ______________________

TxDOT offers no objection to the location on the right-of-way of your proposed public utility installation, as described on the Notice of Proposed Utility Installation No. ________________ dated ______________ and accompanying documentation, except as noted below.

In the case of utility installations on controlled access highways, your attention is directed to governing laws, especially to Texas Transportation Code, Title 6, Chapter 203, pertaining to Modernization of State Highways; Controlled Access Highways. Access for serving this installation shall be limited to access via (a) frontage roads where provided, (b) nearby or adjacent public roads or streets, (c) trails along or near the highway right-of-way lines, connecting only to an intersecting road; from any one or all of which entry may be made to the outer portion of the highway right-of-way for normal service and maintenance operations. The Owner's rights of access to the through traffic roadways and ramps shall be subject to the same rules and regulations as apply to the general public except, however, if an emergency situation occurs and usual means of access for normal service operations will not permit the immediate action required by the Utility Owner in making emergency repairs as required for the safety and welfare of the public, the Utility Owners shall have a temporary right of access to and from the through traffic roadways and ramps as necessary to accomplish the required emergency repairs, provided TxDOT is immediately notified by the Utility Owner when such repairs are initiated and adequate provision is made by the Utility Owner for convenience and safety of highway traffic.

The installation shall not damage any part of the highway and adequate provisions must be made to cause minimum inconveniences to traffic and adjacent property owners. In the event the Owner fails to comply with any or all of the requirements as set forth herein, the State may take such action as it deems appropriate to compel compliance.

It is expressly understood that the TxDOT does not purport, hereby, to grant any right, claim, title, or easement in or upon this highway; and it is further understood that the TxDOT may require the owner to relocate this line, subject to provisions of governing laws, by giving thirty (30) days written notice.

You are requested to notify ____ forty-eight (48) hours prior to starting construction in order that we may have a representative present. Please notice that if construction has not started within six (6) months of the date of this approval, the approval will automatically expire and you will be required to submit a new application. You are also requested to notify this office prior to commencement of any routine or periodic maintenance which requires pruning of trees within the highway right-of-way, so that we may provide specifications for the extent and methods to govern in trimming, topping, tree balance, type of cuts, painting cuts and clean up. These specifications are intended to preserve our considerable investment in highway planting and beautification, by reducing damage due to trimming.

- **General Special Provisions:**

☐ <Title of general special provision>
☐ <Title of general special provision>
☐ <Title of general special provision>
☐ :

- **Re-vegetation Special Provisions:** In order to minimize erosion and sedimentation resulting from the proposed installation, the project area will be re-vegetated in accordance with the following provision(s):

☐ <Title of re-vegetation special provision>
☐ <Title of re-vegetation special provision>

Approved by ______________________ Authorized by ______________________
District Engineer, ________________ District