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16. Abstract

Each year, thousands of utilities are installed within the Texas Department of Transportation (TxDOT) right-of-way (ROW). This proliferation of utilities makes it increasingly difficult for TxDOT to manage its own transportation system effectively and allow for more utilities. Research Project 0-2110 developed a prototype geographic information system (GIS)-based platform for the inventory of utilities located within the TxDOT ROW. As part of the project, the researchers compiled and reviewed existing sources of utility data at TxDOT, developed a prototype GIS-based utility inventory model, developed a prototype Internet-based data entry procedure to capture notice of proposed installation (NOPI) data, and provided recommendations for implementing and expanding the prototypes.

Implementation Projects 5-2110-01 and 5-2210-03 are the result of TxDOT's decision to implement the findings of research Project 0-2110. Project 5-2110-01 focuses on the implementation of the GIS-based utility inventory model, whereas Project 5-2110-03 focuses on the implementation of the Internet-based utility installation notice review process (also known as utility permitting process). This report is the first-year report for Project 5-2110-03. It summarizes the system analysis, design, and development phases and outlines the activities to be conducted during the second year.

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UTILITY INSTALLATION REVIEW SYSTEM—PROGRESS REPORT

by

Cesar Quiroga, P.E.
Associate Research Engineer
Texas Transportation Institute

Robert Pina
Programmer/Analyst I
Texas Transportation Institute

Doyle Dennis
Student Worker
Texas Transportation Institute

and

Sangita Sunkari
Programmer/Analyst II
Texas Transportation Institute

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

DISCLAIMER

The contents of this document reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This document does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge of the project was Cesar Quiroga, P.E. (Texas Registration #84274).

NOTICE

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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LIST OF ACRONYMS, ABBREVIATIONS, AND TERMS

ArcIMS	Arc Internet Map Server
ArcSDE	Arc Spatial Data Engine
ASP	Active server page
CAD	Computer-aided design
CD	Compact disk
CDO	Collaboration data object
CPS	City Public Service
DBMS	Database management system
DVD	Digital video disk
ESRI	Environmental Systems Research Institute
FSO	File system object
FHWA	Federal Highway Administration
GIS	Geographic information system
HTML	Hypertext mark-up language
IIS	Internet Information Server
ISD	(TxDOT's) Information Systems Division
IT	Information technology
NOPI	Notice of proposed installation
ODBC	Open database connection
PDF	Portable document format
ROW	Right-of-way
SAWS	San Antonio Water System

SMTP	Simple mail transfer protocol
SQL	Structured query language
SSL	Secure Socket Layer
TLMS	Texas Linear Measurement System
TNRIS	Texas Natural Resources Information System
TxDOT	Texas Department of Transportation
UIR	Utility installation review
XML	Extensible mark-up language

INTRODUCTION

Each year, there are thousands of new utility installations within the Texas Department of Transportation (TxDOT) right-of-way (ROW). This proliferation of utilities makes it increasingly difficult for TxDOT to manage its own transportation system effectively and allow for more utilities. Research Project 0-2110 developed a prototype geographic information system (GIS)-based platform for the inventory of utilities located within the TxDOT ROW (*1*). As part of the project, the researchers

- compiled and reviewed existing sources of utility data at TxDOT;
- developed a prototype GIS-based utility inventory model;
- developed a prototype Internet-based data entry procedure to capture notice of proposed installation (NOPI) data; and
- provided recommendations for implementing and expanding the prototypes.

Implementation Projects 5-2110-01 and 5-2210-03 are the result of TxDOT's decision to implement the findings of research Project 0-2110. Project 5-2110-01 focuses on the implementation of the GIS-based utility inventory model, whereas Project 5-2110-03 focuses on the implementation of the Internet-based utility installation notice review process (also known as utility permitting process). This report is the first-year report for Project 5-2110-03. A separate report is the first-year report for Project 5-2110-01 (*2*).

UTILITY INSTALLATION REVIEW (UIR) SYSTEM DEVELOPMENT

PROTOTYPE WORKFLOW

As part of research Project 0-2110, the researchers conducted a statewide survey as well as follow-up personal interviews with a reduced sample of districts to develop an understanding of the utility installation notice review process at TxDOT. Based on the responses provided, the researchers developed a conceptual model to represent the typical workflow associated with the submission, review, and approval of utility installation notices at TxDOT. The researchers also developed a prototype Internet-based installation notice review system (Figure 1) that took into consideration that workflow, while, at the same time, addressing two main limitations of the traditional, paper-based process:

- variability in procedures, data formats, documentation requirements, and quality of the spatial information provided by utility companies; and
- repetitive, labor intensive nature of the installation notice review process.

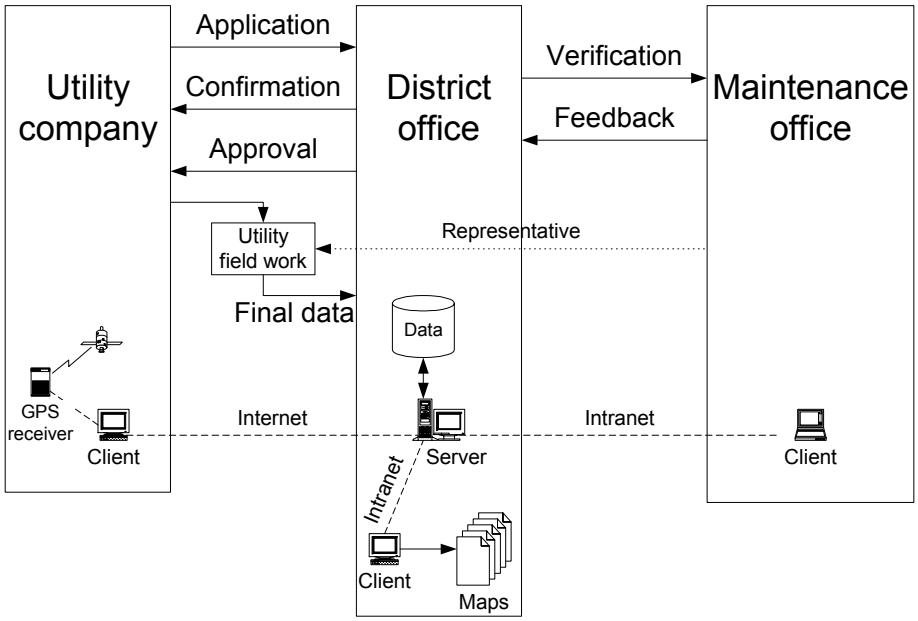

Figure 1. Prototype Data Flow for Conducting Online Installation Notice Reviews.

The following sections describe the work conducted during the first year of the implementation phase of the online utility installation review (UIR) system.

SYSTEM ANALYSIS

The researchers conducted a series of detailed interview sessions with TxDOT officials to determine system architecture (hardware, software, and system compatibility) requirements and system application (user) requirements.

Architecture Requirements

The researchers consulted with TxDOT Information Systems Division (ISD) officials to develop a set of system architecture requirements and specifications to ensure portability to the TxDOT architecture. A summary of architecture requirements follows.

Hardware Specifications (TxDOT Server)

A typical TxDOT web server that will host the UIR system will likely have the following characteristics:

- processor: quad gigahertz processors;
- memory: several gigabytes of memory;
- secondary storage: 20–25 gigabytes of hard drive space to be allocated to the UIR system; and
- tertiary storage: tape drive.

Software Requirements

The UIR system requires a number of software components that are part of TxDOT's information technology (IT) architecture. A summary of required software components follows:

- server operating system: Microsoft Server 2000;
- Internet server: Microsoft Internet Information Server (IIS) 5;
- database management system (DBMS): Oracle 9i;
- spatial data component: Environmental Systems Research Institute (ESRI) Arc Spatial Data Engine (ArcSDE) 8.3;
- map server: ESRI Arc Internet Map Server (ArcIMS);
- upload file component: SoftArtisans SAFileUp;
- e-mail component: simple mail transfer protocol (SMTP); and
- security component: Baltimore Secure Socket Layer (SSL) Certificate.

TxDOT ISD servers currently use 64-bit encryption with "on the fly" upgradeable 128-bit encryption for browsers that support 128-bit encryption.

Database Modeling Requirements

The UIR system must comply with TxDOT's data architecture requirements (*3*). The data modeling requirements include normalization of naming conventions and the development of the following models in Computer Associates' ERwin 4.1.4 format:

- Logical Model: This model identifies all the data entities and their relationships.
- Physical Model: This model represents the implementation of the logical model in a specific relational DBMS.
- Data Dictionary: This dictionary lists all data class words in a tabular format including their abbreviation, definition, an example, and format.

Application Installation and Updates

UIR system submittal to ISD (initial installation and subsequent updates) must be on a physical electronic medium such as compact disk (CD) or digital video disk (DVD). Delivery will also include an installation and update manual.

Application Requirements

The researchers conducted a series of meetings with the project panel and San Antonio District officials to develop an understanding of their vision and expectations concerning the implementation of the UIR system. This exercise resulted in the definition of a series of user requirements that helped drive the system design:

- Support dynamic permit processes: UIR should support a district-independent dynamic permit process to accommodate differences among districts without requiring major system modifications.
- Accommodate large and small utility companies: UIR must be flexible enough to support a wide range of utility company data submittal capabilities. The required data and submittal process must be flexible enough that small utility companies are able to submit notices while not restricting the performance and resources typically associated with larger utility companies.
- Cross-platform file support: UIR should enable users to upload and view files in a variety of file formats.
- Application output: UIR should produce at a minimum the following types of outputs:
    - online map displaying the location of existing and proposed utility installations,
    - printer-friendly version of the NOPI form, and
    - printer-friendly version of the approval form.
- User help: UIR should provide user help integrated into the system.

SYSTEM DESIGN

Following the identification of the architecture and application requirements, the researchers completed a formal system design phase that included developing three main components: system architecture, data workflow diagram, and database models.

System Architecture

As Figure 2 shows, UIR has two groups of components: client-side components and server-side components. On the client side, a hypertext mark-up language (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. 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. Minimum client requirements include either a Mosaic-based browser (e.g., Internet Explorer) or a Mozilla-based browser (e.g., Netscape Navigator) and Adobe Acrobat Reader. Both utility company users and TxDOT users can act as clients, but their interfaces are different and require different

access levels—for security, ISD will include the TxDOT user interface within the TxDOT Intranet where it cannot be accessed by utility company users.

On the server side, UIR includes a number of components, including the following:

- servers: web server (IIS), e-mail server, database server (Oracle), map server (ArcIMS), portable document format (PDF) server (AdLib eXpress Server);
- database: Oracle 9i;
- objects and components: file system object (FSO), file upload (SAFileUp); and
- connectors: open database connection (ODBC), spatial data engine (ArcSDE).

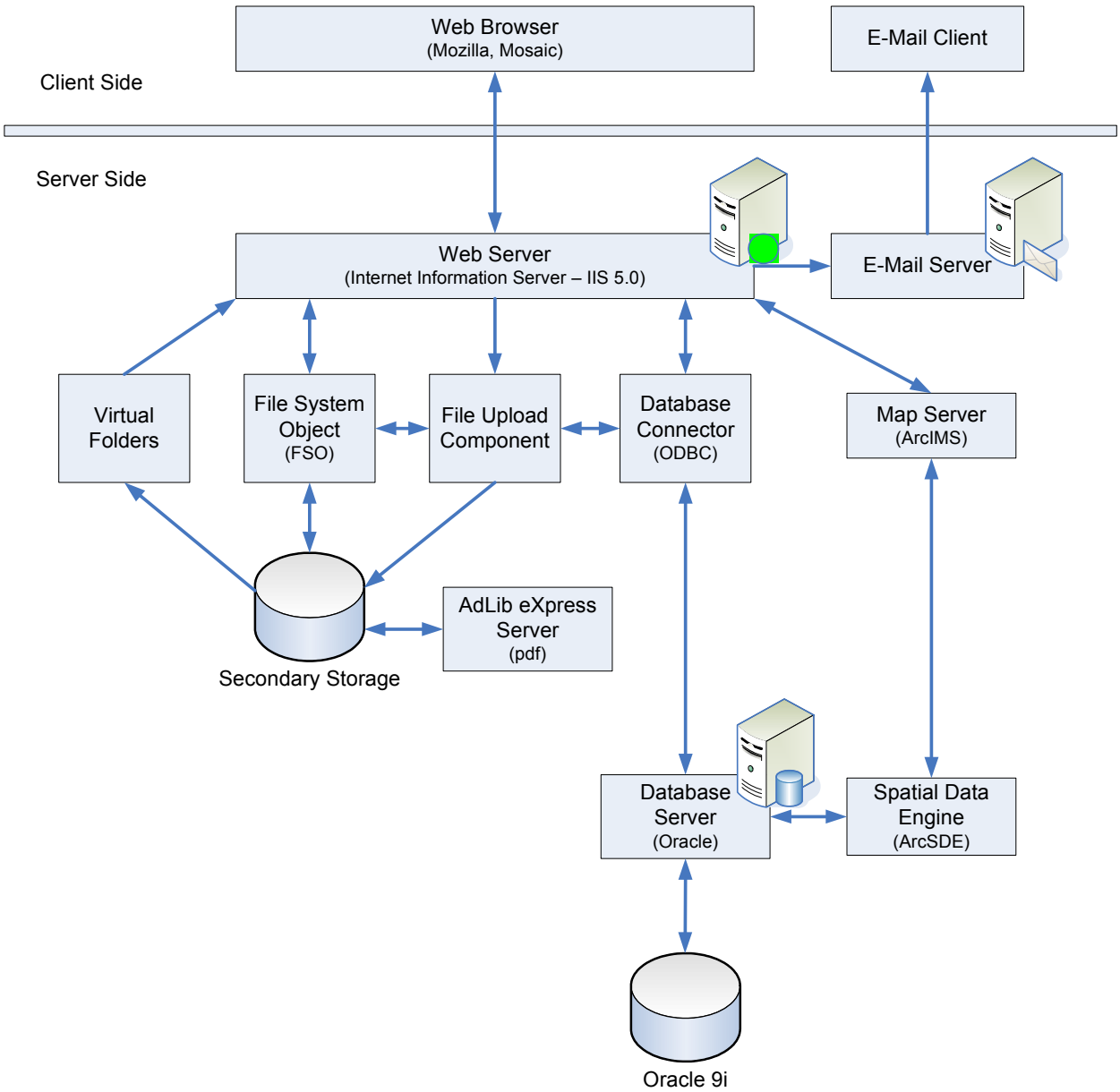

Figure 2. System Architecture.

Workflow Diagram

The workflow diagram outlines the steps that different offices go through during the utility installation data and review process, as well as the subsequent follow up during and after construction. The researchers gathered workflow data through a series of meetings with San Antonio District officials (district office, area office, and maintenance office levels) and representatives from three utility companies the district invited to participate: San Antonio Water System (SAWS), City Public Service (CPS), and SBC Communications.

At the meetings with San Antonio District officials, it became clear the utility installation review process was much more complex than the workflow originally established during the research phase. Rather than the straightforward linear workflow outlined in Figure 1, the actual workflow included many possible paths involving a rather large number of offices and individuals. It also became clear that different districts could be handling the review process in many different ways. For this reason, and considering the application requirement that the system should support differences in review practices throughout the state, the researchers developed a workflow diagram configuration—and subsequent database implementation—that relied on a dynamic relationship between office type responsibilities, events needed, events completed, and application status levels. This configuration enables individual districts to generate and manage their own workflow diagrams and corresponding tabular versions without having to make changes to the code.

Figure 3 shows the current version of the workflow diagram for the San Antonio District. Table 1 shows the corresponding tabular representation of the diagram. Notice in Figure 3 the workflow diagram involves five phases as follows:

- Review. This is the phase where district officials review the feasibility of allowing a new utility installation within the ROW. Depending on the specific path, the review could involve one or more area offices and maintenance offices, as well as interaction with utility companies to provide clarification or additional documentation. The outcome of this phase is either application approval or application rejection.
- Pre-construction. This is the phase where utility companies notify TxDOT at least 48 hours prior to construction or, if necessary, request an extension to start construction at a later date. The outcome of this phase is the notification.
- Construction. This is the phase where utility companies proceed with the installation in the field and TxDOT officials are conducting field inspections. This is also the phase where TxDOT field inspectors can stop construction and require utility companies to submit revised plans to address unexpected situations encountered during construction.
- Post-construction. This is the phase where TxDOT field inspectors notify the district utility permit office that construction has ended and utility companies submit as-built drawings to TxDOT. In this phase, district personnel can interact with utility companies as needed until the submission of as-builts reaches a satisfactory status.
- Utility inventory update. This is the phase where district personnel update the utility inventory based on as-built documentation provided by the utility companies.

Database Model

As mentioned previously, the data modeling requirements included normalization of naming conventions and the development of the following models:

- Logical Model: This model identifies all the data entities and their relationships.
- Physical Model: This model represents the implementation of the logical model in a specific relational DBMS (Oracle 9i).
- Data Dictionary: This dictionary lists all data class words in a tabular format including their abbreviation, definition, an example, and format.

Figure 4 shows the logical model and Figure 5 shows the physical model for Oracle.

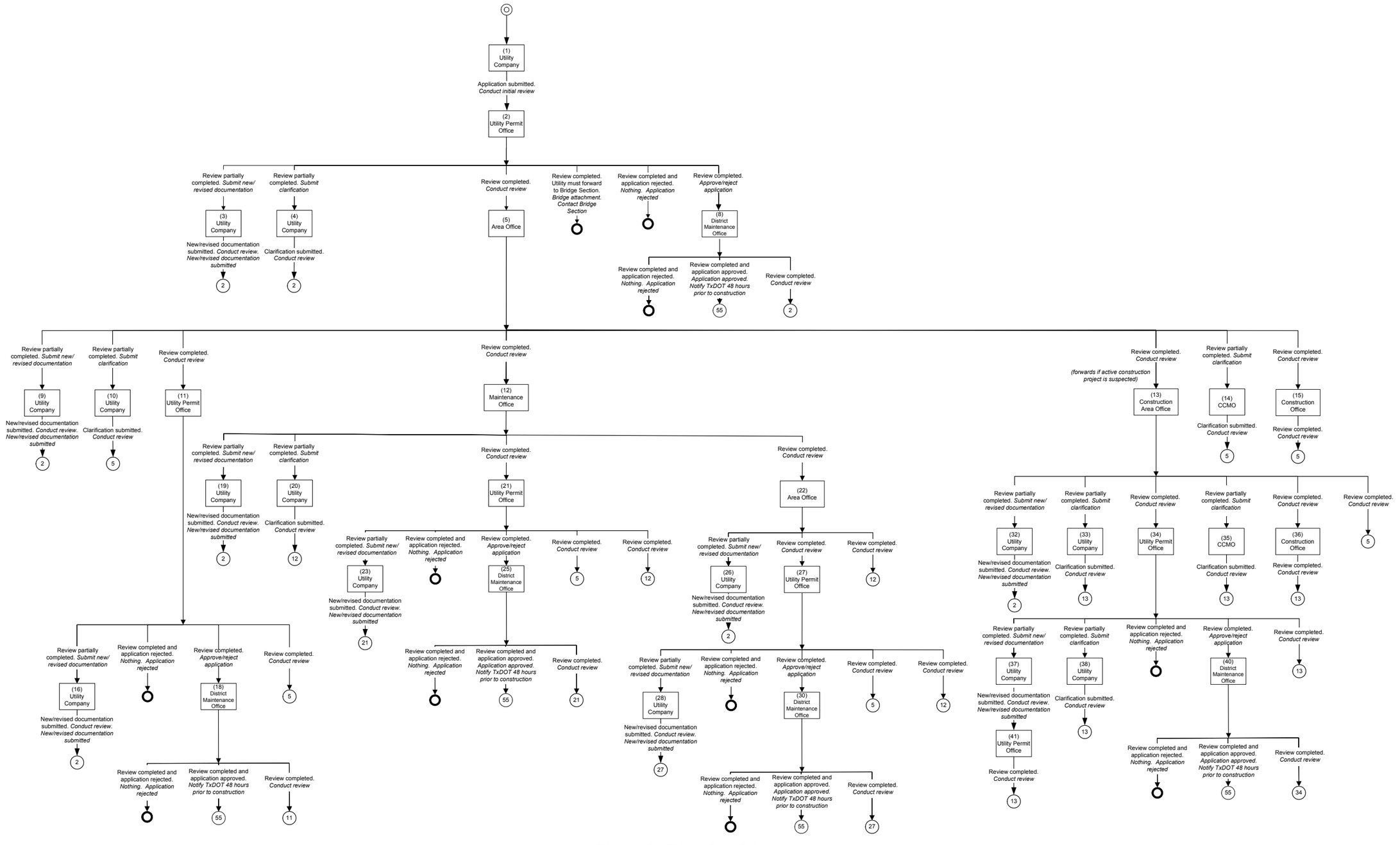

Figure 3. Workflow Diagram.

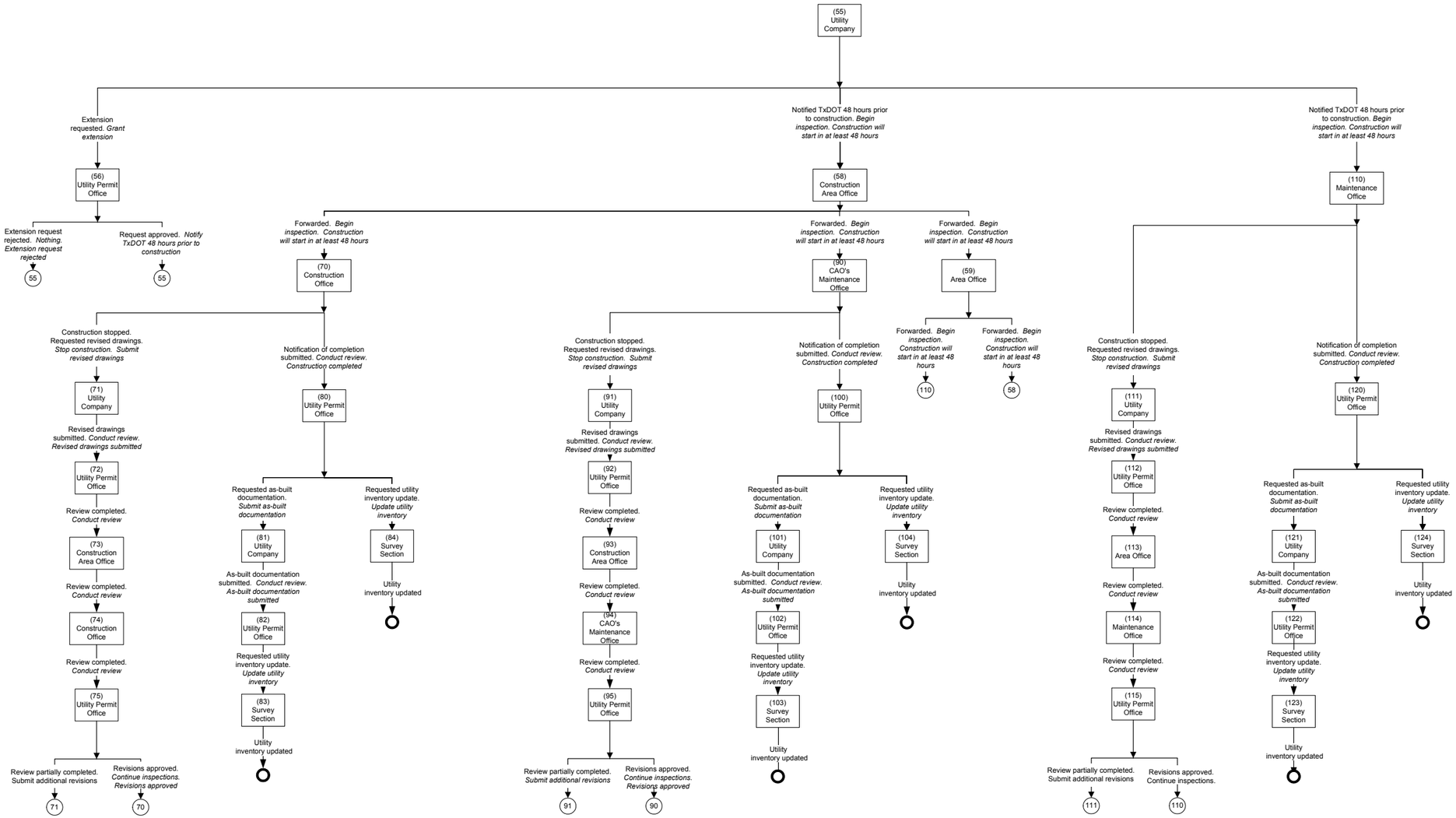

Figure 3. Workflow Diagram (Continued).

Table 1. Tabular Representation of the Workflow Diagram.

Loc	Next Loc	Office	Status	Event Completed	Event Needed
-99	-99	Utility Company	Rejected	Review completed and application rejected	Nothing. Application rejected
1	2	Utility Company	Submitted	Application submitted	Conduct initial review
2	-99	Utility Permit Office	Rejected	Review completed and application rejected	Nothing. Application rejected
2	-99	Utility Permit Office	Rejected	Review completed. Utility must forward to Bridge Section	Bridge attachment. Contact Bridge Section
2	3	Utility Permit Office	Under Review	Review partially completed	Submit new/revised documentation
2	4	Utility Permit Office	Under Review	Review partially completed	Submit clarification
2	5	Utility Permit Office	Under Review	Review completed	Conduct review
2	8	Utility Permit Office	Under Review	Review completed	Approve/reject application
3	2	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
4	2	Utility Company	Under Review	Clarification submitted	Conduct review
5	9	Area Office	Under Review	Review partially completed	Submit new/revised documentation
5	10	Area Office	Under Review	Review partially completed	Submit clarification
5	11	Area Office	Under Review	Review completed	Conduct review
5	12	Area Office	Under Review	Review completed	Conduct review
5	13	Area Office	Under Review	Review completed	Conduct review
5	14	Area Office	Under Review	Review partially completed	Submit clarification
5	15	Area Office	Under Review	Review completed	Conduct review
8	-99	District Maintenance Office	Rejected	Review completed and application rejected	Nothing. Application rejected
8	2	District Maintenance Office	Under Review	Review completed	Conduct review
8	55	District Maintenance Office	Approved	Review completed and application approved	Application approved. Notify TxDOT 48 hours prior to construction
9	2	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
10	5	Utility Company	Under Review	Clarification submitted	Conduct review
11	5	Utility Permit Office	Under Review	Review completed	Conduct review
11	16	Utility Permit Office	Under Review	Review partially completed	Submit new/revised documentation
11	-99	Utility Permit Office	Rejected	Review completed and application rejected	Nothing. Application rejected
11	18	Utility Permit Office	Under Review	Review completed	Approve/reject application
12	19	Maintenance Office	Under Review	Review partially completed	Submit new/revised documentation
12	20	Maintenance Office	Under Review	Review partially completed	Submit clarification
12	21	Maintenance Office	Under Review	Review completed	Conduct review
12	22	Maintenance Office	Under Review	Review completed	Conduct review
13	5	Area Office	Under Review	Review completed	Conduct review
13	32	Area Office	Under Review	Review partially completed	Submit new/revised documentation
13	33	Area Office	Under Review	Review partially completed	Submit clarification
13	34	Area Office	Under Review	Review completed	Conduct review
13	35	Area Office	Under Review	Review partially completed	Submit clarification
13	36	Area Office	Under Review	Review completed	Conduct review
14	5	CCMO	Under Review	Clarification submitted	Conduct review
15	5	Construction Office	Under Review	Review completed	Conduct review
16	2	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
18	-99	District Maintenance Office	Rejected	Review completed and application rejected	Nothing. Application rejected
18	11	District Maintenance Office	Under Review	Review completed	Conduct review
18	55	District Maintenance Office	Approved	Review completed and application approved	Application approved. Notify TxDOT 48 hours prior to construction
19	2	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
20	12	Utility Company	Under Review	Clarification submitted	Conduct review
21	5	Utility Permit Office	Under Review	Review completed	Conduct review
21	12	Utility Permit Office	Under Review	Review completed	Conduct review
21	23	Utility Permit Office	Under Review	Review partially completed	Submit new/revised documentation
21	-99	Utility Permit Office	Rejected	Review completed and application rejected	Nothing. Application rejected

Table 1. Tabular Representation of the Workflow Diagram (Continued).

Loc	Next Loc	Office	Status	Event Completed	Event Needed
21	25	Utility Permit Office	Under Review	Review completed	Approve/reject application
22	12	Area Office	Under Review	Review completed	Conduct review
22	26	Area Office	Under Review	Review partially completed	Submit new/revised documentation
22	27	Area Office	Under Review	Review completed	Conduct review
23	21	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
25	-99	District Maintenance Office	Rejected	Review completed and application rejected	Nothing. Application rejected
25	21	District Maintenance Office	Under Review	Clarification submitted	Conduct review
25	55	District Maintenance Office	Under Review	Review completed and application approved	Application approved. Notify TxDOT 48 hours prior to construction
26	2	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
27	5	Utility Permit Office	Under Review	Review completed	Conduct review
27	12	Utility Permit Office	Under Review	Review completed	Conduct review
27	28	Utility Permit Office	Under Review	Review partially completed	Submit new/revised documentation
27	-99	Utility Permit Office	Rejected	Review completed and application rejected	Nothing. Application rejected
27	30	Utility Permit Office	Under Review	Review completed	Approve/reject application
28	27	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
30	-99	District Maintenance Office	Rejected	Review completed and application rejected	Nothing. Application rejected
30	27	District Maintenance Office	Under Review	Review completed	Conduct review
30	55	District Maintenance Office	Approved	Review completed and application approved	Application approved. Notify TxDOT 48 hours prior to construction
32	2	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
33	13	Utility Company	Under Review	Clarification submitted	Conduct review
34	-99	Utility Permit Office	Rejected	Review completed and application rejected	Nothing. Application rejected
34	13	Utility Permit Office	Under Review	Review completed	Conduct review
34	37	Utility Permit Office	Under Review	Review partially completed	Submit new/revised documentation
34	38	Utility Permit Office	Under Review	Review partially completed	Submit clarification
34	40	Utility Permit Office	Under Review	Review completed	Approve/reject application
35	13	CCMO	Under Review	Clarification submitted	Conduct review
36	13	Construction Office	Under Review	Review completed	Conduct review
37	41	Utility Company	Under Review	New/revised documentation submitted	Conduct review. New/revised documentation submitted
38	13	Utility Company	Under Review	Clarification submitted	Conduct review
40	-99	District Maintenance Office	Rejected	Review completed and application rejected	Nothing. Application rejected
40	34	District Maintenance Office	Under Review	Review completed	Conduct review
40	55	District Maintenance Office	Approved	Review completed and application approved	Application approved. Notify TxDOT 48 hours prior to construction
41	13	Utility Permit Office	Under Review	Review completed	Conduct review
55	56	Utility Company	Approved	Extension requested	Grant extension
55	58	Utility Company	Construction	Notified TxDOT 48 hours prior to construction	Begin inspection. Construction will start in at least 48 hours
55	110	Utility Company	Construction	Notified TxDOT 48 hours prior to construction	Begin inspection. Construction will start in at least 48 hours
56	55	Utility Permit Office	Approved	Extension request rejected	Nothing. Extension request rejected
56	55	Utility Permit Office	Approved	Request approved	Request approved. Notify TxDOT 48 hours prior to construction
58	59	Area Office	Construction	Forwarded	Begin inspection. Construction will start in at least 48 hours
58	70	Area Office	Construction	Forwarded	Begin inspection. Construction will start in at least 48 hours
58	90	Maintenance Office	Construction	Forwarded	Begin inspection. Construction will start in at least 48 hours
59	58	Area Office	Construction	Forwarded	Begin inspection. Construction will start in at least 48 hours

Table 1. Tabular Representation of the Workflow Diagram (Continued).

Loc	Next Loc	Office	Status	Event Completed	Event Needed
59	110	Area Office	Construction	Forwarded	Begin inspection. Construction will start in at least 48 hours
70	71	Construction Office	Construction stopped. Under review	Construction stopped. Requested revised drawings	Stop construction. Submit revised drawings
70	80	Construction Office	Construction	Notification of completion submitted	Conduct review. Construction completed
71	72	Utility Company	Construction stopped. Under review	Revised drawings submitted	Conduct review. Revised drawings submitted
72	73	Utility Permit Office	Construction stopped. Under review	Review completed	Conduct review
73	74	Area Office	Construction stopped. Under review	Review completed	Conduct review
74	75	Construction Office	Construction stopped. Under review	Review completed	Conduct review
75	70	Utility Permit Office	Construction	Revisions approved	Continue inspections. Revisions approved
75	71	Utility Permit Office	Construction stopped. Under review	Review partially completed	Submit additional revisions
80	81	Utility Permit Office	Post Construction	Requested as-built documentation	Submit as-built documentation
80	84	Utility Permit Office	Post Construction	Requested utility inventory update	Update utility inventory
81	82	Utility Company	Post Construction	As-built documentation submitted	Conduct review. As-built documentation submitted
82	83	Utility Permit Office	Post Construction	Requested utility inventory update	Update utility inventory
83	-99	Survey Section	Completed	Utility inventory updated	Exit system
84	-99	Survey Section	Completed	Utility inventory updated	Exit system
90	91	Maintenance Office	Construction stopped. Under review	Construction stopped. Requested revised drawings	Stop construction. Submit revised drawings
90	100	Maintenance Office	Construction	Notification of completion submitted	Conduct review. Construction completed
91	92	Utility Company	Construction stopped. Under review	Revised drawings submitted	Conduct review. Revised drawings submitted
92	93	Utility Permit Office	Construction stopped. Under review	Review completed	Conduct review
93	94	Area Office	Construction stopped. Under review	Review completed	Conduct review
94	95	Maintenance Office	Construction stopped. Under review	Review completed	Conduct review
95	90	Utility Permit Office	Construction	Revisions approved	Continue inspections. Revisions approved
95	91	Utility Permit Office	Construction stopped. Under review	Review partially completed	Submit additional revisions
100	101	Utility Permit Office	Post Construction	Requested as-built documentation	Submit as-built documentation
100	104	Utility Permit Office	Post Construction	Requested utility inventory update	Update utility inventory
101	102	Utility Company	Post Construction	As-built documentation submitted	Conduct review. As-built documentation submitted
102	103	Utility Permit Office	Post Construction	Requested utility inventory update	Update utility inventory
103	-99	Survey Section	Completed	Utility inventory updated	Exit system
104	-99	Survey Section	Completed	Utility inventory updated	Exit system

Table 1. Tabular Representation of the Workflow Diagram (Continued).

Loc	Next Loc	Office	Status	Event Completed	Event Needed
110	111	Maintenance Office	Construction stopped. Under review	Construction stopped. Requested revised drawings	Stop construction. Submit revised drawings
110	120	Maintenance Office	Construction	Notification of completion submitted	Conduct review. Construction completed
111	112	Utility Company	Construction stopped. Under review	Revised drawings submitted	Conduct review. Revised drawings submitted
112	113	Utility Permit Office	Construction stopped. Under review	Review completed	Conduct review
113	114	Area Office	Construction stopped. Under review	Review completed	Conduct review
114	115	Maintenance Office	Construction stopped. Under review	Review completed	Conduct review
115	110	Utility Permit Office	Construction	Revisions approved	Continue inspections. Revisions approved
115	111	Utility Permit Office	Construction stopped. Under review	Review partially completed	Submit additional revisions
120	121	Utility Permit Office	Post Construction	Requested as-built documentation	Submit as-built documentation
120	124	Utility Permit Office	Post Construction	Requested utility inventory update	Update utility inventory
121	122	Utility Company	Post Construction	As-built documentation submitted	Conduct review. As-built documentation submitted
122	123	Utility Permit Office	Post Construction	Requested utility inventory update	Update utility inventory
123	-99	Survey Section	Completed	Utility inventory updated	Exit system
124	-99	Survey Section	Completed	Utility inventory updated	Exit system

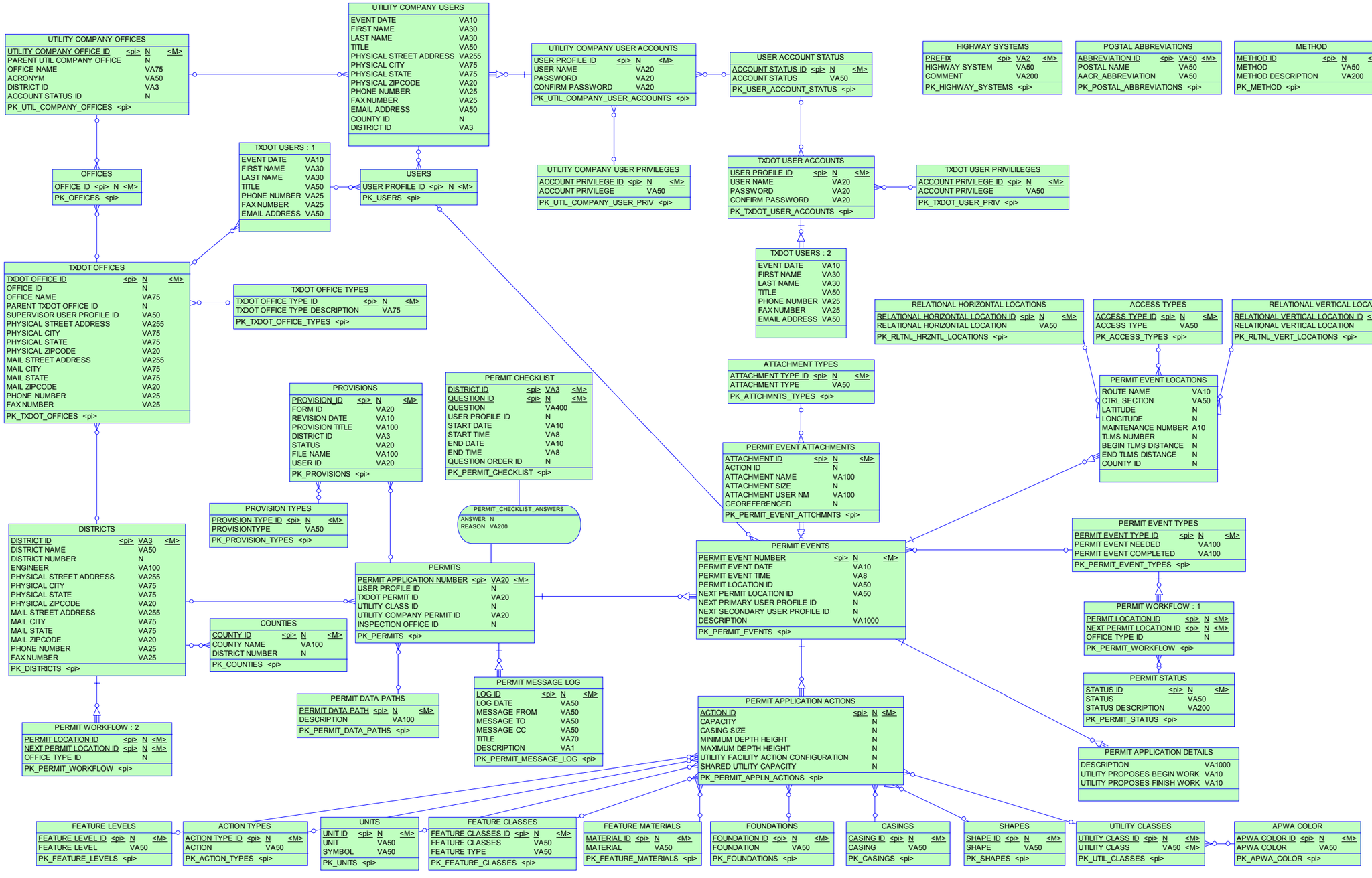

Figure 4. Logical Model.

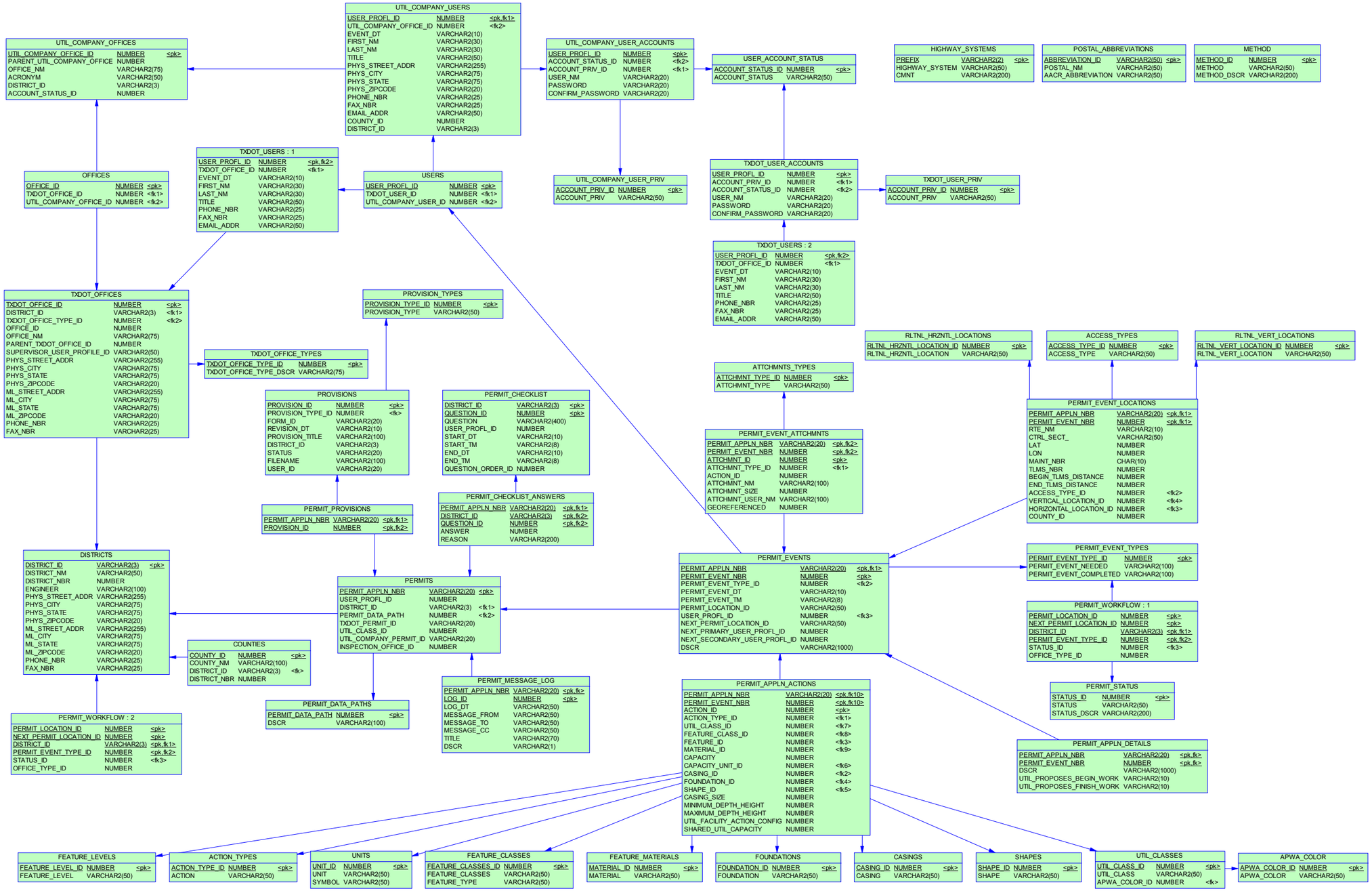

Figure 5. Physical Model.

SYSTEM DEVELOPMENT

System Architecture

Implementation of the system design involved developing interactions among several computers: one or more client computers, a web server, an Oracle server, and an e-mail server. The interaction begins with a client computer, which, as mentioned previously, has minimal technical requirements, mainly in the form of an Internet browser and e-mail software that supports the SMTP protocol (e.g., Microsoft Outlook, Novell GroupWise). This client computer interacts with a web server that serves the online application to the client computer over the Internet using IIS. The web server also stores all files uploaded by the client user in a designated folder that AdLib eXpress uses to generate PDF versions of those files. When the system generates a database request, the system sends the request to the Oracle server, which, in turn, completes the request and returns with a response. The Oracle server also houses ArcSDE, which handles spatial data requests. The final computer involved is the e-mail server, which sends application-driven e-mails to client users in response to requests made by the system through the web server.

Database

The researchers exported the ERwin database design in script format and then ran the script in Oracle to generate the database. After generating the database, the researchers populated the database with a "seed" data set that included records in tables PERMIT_WORKFLOW, PERMIT_EVENT_TYPES, and PERMIT_STATUS. These tables directly reflect the workflow gathered in the system design phase and control the flow of the online application. As mentioned previously, the design is dynamic so that if the online application flow needs changes, only the database entries will require modifications.

Code

The system is actually the integration of two subsystems: a data management subsystem and a web mapping subsystem. This modular architecture facilitated the development process.

Data Management Subsystem

The data management subsystem includes web pages and procedures that enable users on client computers to log into the system, enter data, upload files, review pending applications, and print forms. The subsystem generates web pages dynamically using active server pages (ASP) and then serves those pages to client computers. In addition, server-side scripts perform a variety of tasks such as connecting to the database, transforming and parsing data, and uploading files. ASP files also contain client-side scripts that make calls to client components, e.g., to check the client browser configuration.

The Oracle database stores all data entered by users, except files such as computer-aided design (CAD) drawings and other attachments, which are stored on the web server's hard drive. To interact with the Oracle database, the application uses structured query language (SQL) queries through an ODBC object. To upload files from client computers, the application uses SAFileUp, which is a server-side component that enables file uploading through client browser interfaces.

After uploading files to the server, the system makes those files available to view and download. At the same time, AdLib eXpress generates a PDF version of the uploaded files, which the system also makes available to view and download. As individual applications undergo processing, the data management subsystem automatically sends e-mails to designated officials or back to utility company users. ASP uses objects in the collaboration data object (CDO) library to pass SMTP requests to the e-mail server.

Web Mapping Subsystem

The web mapping subsystem includes web pages and procedures that enable users on client computers to view maps, query features, and select and view installation notice application locations. As Figure 2 shows, the system handles map requests through an ArcIMS map server, which includes an application server, a spatial server, and a map service. Every time the client sends a request, e.g., to zoom in, zoom out, or pan, the map service produces and delivers a snapshot of the map in image format back to the client through the spatial server. The application server directs incoming spatial requests to the appropriate spatial server.

To ensure integration with the data management subsystem, the researchers developed new ASP and ArcXML (ESRI's version of extensible mark-up language [XML]) code, JavaScript functions, and HTML pages, and customized native ArcIMS JavaScript functions and HTML pages to accommodate those new pages:

- ASP and ArcXML code. Using an ODBC link, ASP code queries 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 points along routes where utility company users click to define proposed utility installation locations. In this case, the spatial server response is a map image of installation notice 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.
- JavaScript functions. JavaScript functions create, manage, and delete the "acetate" layers used to dynamically display utility installation locations selected by the user. JavaScript functions generate ArcXML tags for the spatial server request based on the data retrieved by the ASP pages. 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 generate and alter HTML pages viewed by clients.
- HTML code. HTML code provides interaction with client computers through a series of frames, each of which has a specific function. HTML pages are the front end of the application and the only means of interaction between users 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.

To facilitate the utility installation application and review process, the researchers configured the web mapping subsystem to support the display and query of the following map layers:

- Routes: This layer is part of TxDOT's roadway inventory. It contains routes for the entire state. The UIR system queries the layer to determine the route number associated with the location of proposed utility installations.
- Control sections: This layer is part of TxDOT's roadway inventory. It contains control sections for the entire state. The UIR system queries the layer to determine the control section associated with the location of proposed utility installations.
- Streets: This layer is part of TxDOT's roadway inventory. It contains roadway centerlines TxDOT used to develop its Texas Linear Measurement System (TLMS).
- Counties: The researchers generated this layer using several online data sources, including data layers available through the Texas Natural Resources Information System (TNRIS) (*4*) and the Texas General Land Office (*5*).
- Maintenance office map: The researchers generated this layer using hard copy printouts provided by San Antonio District officials. The UIR system queries the layer to determine the maintenance office that, by jurisdiction, would be responsible for conducting the field inspection for new utility installations.
- Area office map: The researchers generated this layer using the maintenance office layer and hard copy printouts provided by San Antonio District officials.
- Districts: The researchers generated this layer based on the county layer and information available at the TxDOT web site.
- Utility inventory: This layer shows utility locations collected during the research phase.

It may be worth noting the map server can support the display and query of many other layers of information. Currently, the researchers are evaluating the feasibility of including ½-ft year 2003 aerial photography to support the identification of ROW and edge of pavement locations in Bexar County. Based on a preliminary analysis, the researchers believe using recent, geo-referenced fine-resolution aerial photography can support the online utility installation review process more effectively than the scanned ROW maps currently available through the TxDOT web site (*6*).

Utility Company User Interface

The utility company user interface supports the needs and responsibilities of utility companies during the installation notice review process. They include submitting new applications, viewing pending applications, viewing TxDOT special provisions, and managing user profile data. Figure 6 shows a collage of sample web pages included in the interface.

Administrative Interface

The administrative interface supports the needs and responsibilities of TxDOT officials during the 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 7 shows a collage of sample web pages included in the interface.

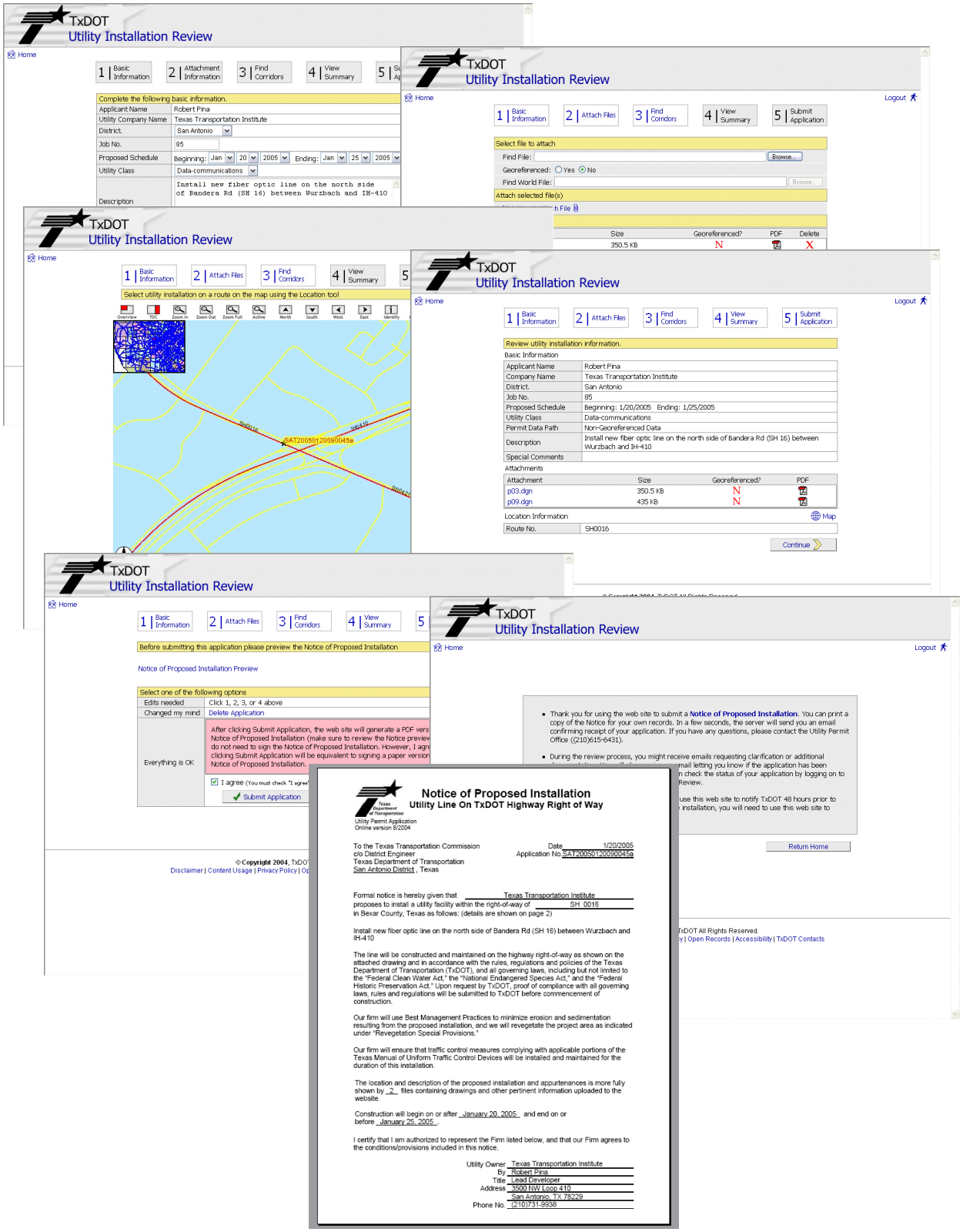

Figure 6. Sample Utility Company User Interface Web Pages.

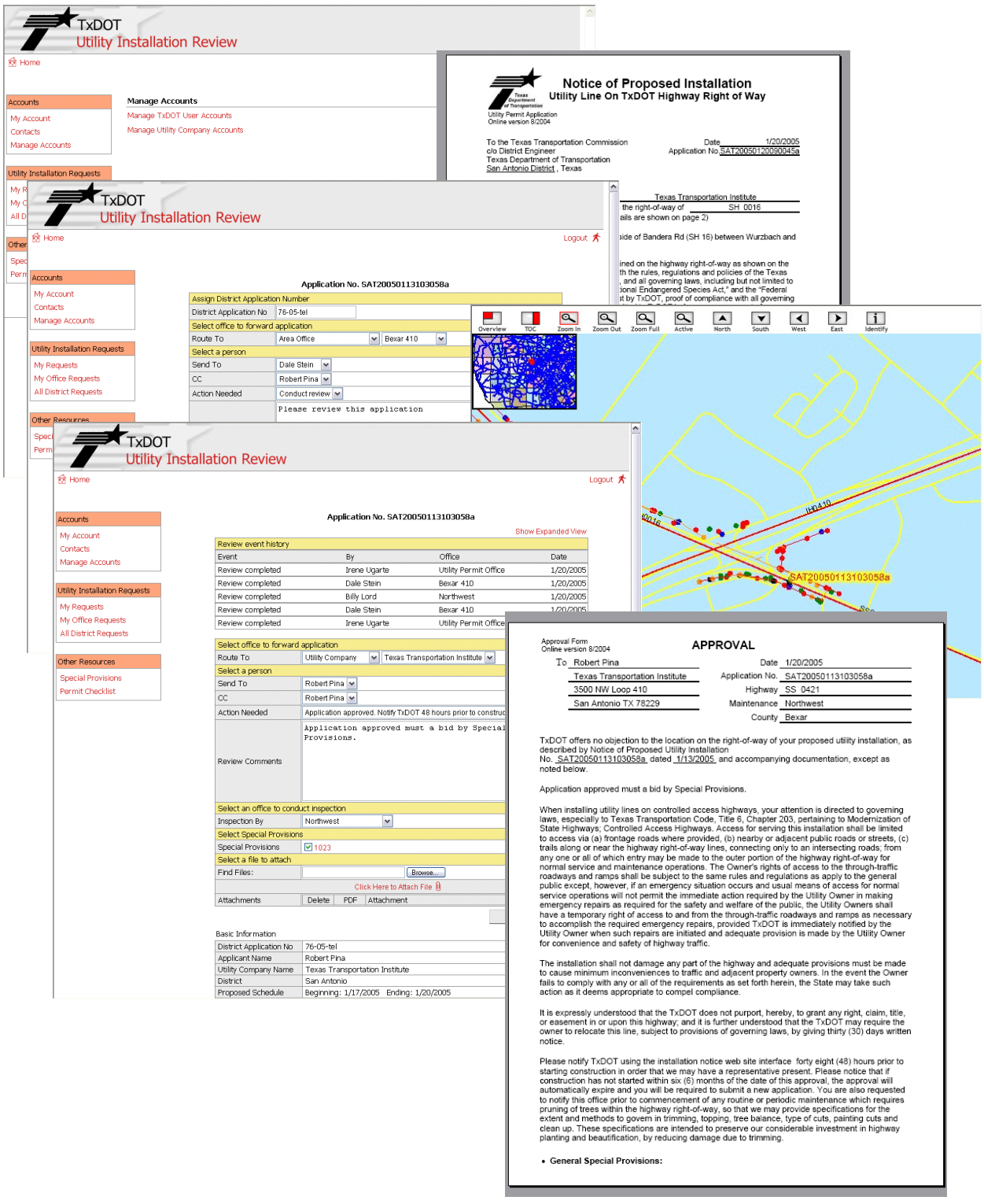

Figure 7. Sample Administrative Interface Web Pages.

SYSTEM TESTING AND DELIVERY

At the conclusion of fiscal year 2004, the development of the UIR system has achieved a beta level. As such, the system is functional from beginning to end, but it is not yet a finished product. In fiscal year 2005, the researchers will undertake a series of activities to test UIR, fine tune it, and deliver the system to TxDOT. Some of the activities will include the following:

- add capability to display fine-resolution aerial photography;
- test the system in conjunction with volunteer utility companies (as of this writing, SAWS and CPS have agreed to participate, with SBC declining the invitation to do so);
- provide training and technical assistance to both TxDOT and utility company users;
- fine tune the system to address feedback provided by TxDOT and utility company users;
- prepare documentation; and
- submit deliverables to TxDOT.

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