STRATEGIC PLAN TO OPTIMIZE THE MANAGEMENT OF RIGHT-OF-WAY PARCEL AND UTILITY INFORMATION AT FDOT

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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

UNIT CONVERSIONS

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
AREA				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
FORCE and PRESSURE or STRESS				
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
FORCE and PRESSURE or STRESS				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
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16. Abstract

The Florida Department of Transportation (FDOT) manages a huge right-of-way asset. Examples of core processes related to this asset include determining right-of-way boundaries; inventorying roadside features; preparing right-of-way maps; acquiring, selling, and leasing assets; and regulating the accommodation of utilities within the right-of-way. Ready access to related information is a key requirement not just for streamlining project delivery but also throughout the life cycle of transportation infrastructure facilities. This report summarizes the results of research conducted to assist FDOT in developing a strategic implementation plan for the management of right-of-way parcel and utility data at the department. To support this effort, the research involved a review of current FDOT systems and practices and development of recommendations as to what vision and/or strategies to pursue. More specifically, the research included conducting meetings with key stakeholders, reviewing and analyzing existing documentation, developing data models, conducting a demonstration of a prototype application developed to test the data models, examining potential implications related to the Bentley Map® initiative, and preparing recommendations for implementation. Meetings with key stakeholders included meetings with officials from Central Office as well as Districts 5 and 6. The purpose of the meetings was to learn or confirm information about business processes, systems, and other items of interest in connection with the management of right-of-way parcel and utility data. Also of interest was to gather suitable sample project data. The research included a comprehensive review of MicroStation design libraries in use at the department and a determination on how to apply this information to the development of a data model and protocol for the extraction of parcel and utility data from MicroStation into a geographic information system (GIS) environment. The research team evaluated expanded and compact versions of the data model, which includes features, feature attributes, and linkages to other business processes within the department, including projects and documents. Recommendations include implementing a systematic use of existing survey and Bentley GEOPAK® data to generate parcel shapes in Bentley MicroStation® for later use in other applications including GIS as well as a systematic database approach for managing utility-related levels in MicroStation. Recommendations also include steps for integrating parcel and utility data into FDOT's enterprise GIS framework.

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EXECUTIVE SUMMARY

The Florida Department of Transportation (FDOT) is responsible for the safe operation and management of thousands of miles of highways. More than 12,000 centerline miles are on-system miles, of which roughly half are located in urban areas. This total includes 456 centerline miles that are part of the Florida Turnpike Enterprise. FDOT manages a huge right-of-way asset. Examples of core processes related to this asset include determining right-of-way boundaries; inventorying roadside features; preparing right-of-way maps; acquiring, selling, and leasing property interests; and regulating the accommodation of utilities within the right-of-way. Ready access to related information is a key requirement not just for streamlining project delivery but also throughout the life cycle of transportation infrastructure facilities.

The Texas A&M Transportation Institute (TTI) conducted research to assist FDOT in developing a strategic implementation plan for the management of right-of-way parcel and utility data at the department. To support this effort, the research involved a review of current FDOT systems and practices and development of recommendations as to what vision and/or strategies to pursue. To achieve this goal, the research team conducted meetings with key stakeholders, reviewed and analyzed existing documentation, developed data models, conducted a demonstration of a prototype application to test the extraction of parcel and utility data from Bentley® MicroStation® to Esri® ArcGIS®, examined potential implications related to the Bentley Map® initiative, and prepared recommendations for implementation.

Meetings with key stakeholders included meetings with officials from Central Office, Districts 5, and District 6. The purpose of the meetings was to learn or confirm information about business processes, systems, and other items of interest in connection with the management of right-of-way parcel and utility data. Also of interest was to gather suitable sample project data. The meetings and conference calls covered a wide range of topics, including as surveys and titles, right-of-way acquisition, utility coordination and production of utility plans, geographic information system (GIS) practices and initiatives, permits, and coordination with other aspects of the project development process.

The research included a comprehensive review of MicroStation design libraries in use at the department and a determination on how to apply this information to the development of a data model and protocol for the extraction of parcel and utility data from MicroStation into a GIS environment. FDOT uses a number of design libraries in MicroStation. Each design library includes levels and their corresponding descriptions and properties, as well as filters. The number of levels within each design library has evolved over the years. However, from year to year, levels have been added to some libraries, but, at the same time, other levels have been removed from some libraries. Most design libraries include graphical elements for plan views, cross-sections and profiles, and annotations. These libraries also provide separate levels to differentiate between existing features on the ground and features that are being proposed. In addition, there are a few specialized design libraries that store information about print styles and toolboxes used by the FDOT MicroStation workspace.

The FDOT design libraries for the 2012 FDOT MicroStation workspace include 1,647 levels, 117 of which include a name or description related to right-of-way map graphical elements.

These levels appear in five design libraries: fdot_common_levels.dgnlib (i.e., FDOT's standard common levels), fdot_v8_levels.dgnlib (standard roadway levels), rwlevels.dgnlib (standard right-of-way levels), strlevels.dgnlib (standard structure levels), and survey_levels.dgnlib (standard survey levels). Although the design libraries include graphical elements to depict parcels being acquired, mainly by using property lines and existing and proposed right-of-way lines, there is a not a polygon or shape parcel level in the MicroStation design libraries. As a result, parcel information in MicroStation design files is not stored as shapes or polygons.

For utility facilities, the 2012 design libraries include 184 levels that depict a wide range of utility installation graphical elements. These levels appear in three design libraries: fdot_v8_levels.dgnlib (standard roadway levels), strlevels.dgnlib (standard structure levels), and survey_levels.dgnlib (standard survey levels).

The research team considered several options to identify and merge parcel boundaries to create polygons, either before or after importing the data into ArcGIS, including generating parcel shapes in ArcGIS, generating parcel shapes in MicroStation using features from the right-of-way file, and generating parcel shapes in MicroStation using Bentley GEOPAK® data. A major advantage of using survey data already residing in GEOPAK files is that this information is already available and is based on field survey data. Because of the advantages of this approach, the research team explored it further to develop a generalized protocol to develop parcel shapes in MicroStation. This made it necessary to add a parcel level to the right-of-way design library. For completeness, the research team added five parcel levels to handle various kinds of parcels that the department deals with on a regular basis: fee parcels, easements, leases, licenses, and condominium units.

Given the way FDOT has structured its MicroStation design libraries and levels, it is possible to imagine a wide range of data modeling alternatives to manage right-of-way and utility-related information. The research team considered a wide spectrum of potential modeling alternatives, including expanded and compact modeling approaches for spatial and attribute (i.e., non-spatial) data. A potential implementation at FDOT would likely fall somewhere between these four extreme alternatives. In addition to basic spatial and attribute data, the research team also considered linkages to other business processes such as projects and documents through the use of many-to-many relationship tables.

For the purpose of demonstrating the process to import MicroStation features into a GIS environment, the research team developed and tested a compact data model assuming a point feature table for point features, a line feature table for linear features, and a polygon feature table for polygon features. However, the research team also considered other compact modeling approaches, e.g., one in which separate point, line, and polygon features are defined for different categories of features classes, e.g., oil and gas, water, communications, and so on. For attribute data, the research team used a compact approach that involved using a single master table containing a list of all the potential features in the database, a master list of attributes containing a list of all the potential attributes that could be associated with any feature class, and a third table containing actual attribute values for individual features. In addition to these groups of tables, the data model includes a table to handle a master list of projects and a table to handle a master list of documents. The data model also includes tables to handle the many-to-many

relationship between features and documents and the many-to-many relationship between projects and documents. For simplicity, this version of the model does not include a user table or many-to-many tables to handle the relationship between the user table and other tables in the data model.

The prototype application uses a common three-tier client-server architecture in which user interface, functional process logic, and data storage and access are logically separated. The modular architecture provides the benefit that any of the tiers can be upgraded or replaced independently if there is a change in FDOT requirements or technology. In the application architecture, the user interface is represented by a presentation tier, the functional process logic is represented by a business logic tier, and data storage and access are represented by a data tier. In ArcGIS, the elements of the presentation tier are displayed to a user as five tools on the graphical user interface, as follows: Import MS Features, Edit Attribute Values, Link Projects, Link Documents, and Delete Features.

The main objective of the prototype application was to demonstrate a testing environment for the data model that could enable users to import right-of-way parcels and utility features from MicroStation files into ArcGIS, including feature attribution provided by the MicroStation design library; link parcels and utility features to projects; link parcels and utility features to documents; enter attribute information for parcels or utility features; and delete parcels or utility features from the geodatabase.

The research team noted some issues that could affect the performance of the application. For example, MicroStation data such as parcel information in tables and annotation can be imported into ArcGIS, but that information is not automatically attached to features. Likewise, there are numerous data items in design files related to utility installations that are provided in the form of tables or other types of annotation. To address these issues, it would be necessary to consider strategies such as applying scripts to automate linking annotations to features, using a commercial platform such as Safe Software®'s Feature Manipulation Engine (FME®) to automate this process (provided the linework in MicroStation is sufficiently clean and contiguous, and annotation design, location and, content follow predictable rules), and using GPS data collectors equipped with data dictionaries to enable users to capture attribute data directly in the field.

In some instances, MicroStation attribute information was not imported when the research team imported a design file into ArcGIS. The issue occurred unpredictably after making certain additions or deletions to the sample MicroStation files. The research team found that this issue was related to an interface issue between ArcGIS and MicroStation, and could be resolved in most cases by compacting the design file upon exit from MicroStation.

Design elements in MicroStation, particularly in the case of utility lines, were often discontinuous, consisting of multiple, disconnected line elements. Breaks in the line elements in MicroStation are normally not an issue because these elements appear to be connected to the user. However, they can create a problem when converting MicroStation features to GIS features. This issue could be resolved by requiring designers to avoid "unnatural" line breaks for utility features by following a link/node model, e.g., by having line breaks at "logical" nodes

such as junction boxes, manholes or valves, therefore reducing the number of MicroStation elements depicting utility feature as much as possible.

The research also included recommendations to improve the management of right-of-way parcel and utility data at FDOT based on the results of the research. Recommendations for right-of-way parcel data management include the following:

- Include parcel levels in FDOT right-of-way design library,
- Use GEOPAK to visualize parcel information and create parcel shapes,
- Update GEOPAK database for use in Design and Computation Manager,
- Develop new standards for depicting parcels on FDOT MicroStation files, and
- Integrate application with the Electronic Document Management System (EDMS) and the Right-of-Way Management System (RWMS) using mapping component.

Recommendations for utility data management include the following:

- Complete attribution for utility features,
- Change business process to capture utility data after relocation, and
- Update computer aided design (CAD) standard to require continuous utility features in MicroStation.

General recommendations include the following:

- Facilitate electronic collaboration between FDOT and utility owners,
- Use geodatabase as permanent storage for right-of-way and utility data,
- Remove inconsistencies in the naming of standard MicroStation levels, and
- Implement Bentley Map on a trial basis.

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LIST OF ABBREVIATIONS AND ACRONYMS

AM/FM	Automated mapping/facility management
API	Application programming interface
ASCE	American Society of Civil Engineers
BLM	Bureau of Land Management
CAD	Computer-aided design
CADD	Computer-aided design and drafting
CI	Construction Institute
COGO	Coordinate Geometry
DISDI	Defense Installation Spatial Data Infrastructure
DOR	Department of Revenue
DTM	Digital terrain model
EDMS	Electronic Document Management System
EGF	Enterprise GIS Framework
EIP	Enterprise Information Portal
EOR	Engineer of record
ER	Entity relationship
FDOT	Florida Department of Transportation
FGDC	Federal Geographic Data Committee
FID	Feature ID
FME	Feature Manipulation Engine
GAMA	GIS Asset Management Application
GEV	GIS Enterprise View
GIS	Geographic information systems
IT	Information technology
ITS	Intelligent transportation systems
JPA	Joint project agreement
NAD	North American Datum
NAVD	North American Vertical Datum
NCHRP	National Cooperative Highway Research Program
NILS	National Integrated Land System
NGVD	National Geodetic Vertical Datum
NSDI	National Spatial Data Infrastructure
OT	Order of taking
PD&E	Project development and environment
PDF	Portable document format
PITS	Permit Information Tracking System
PLSS	Public Land Survey System
POL	Petroleum, oil, and lubricant
PSEE	Project Suite Enterprise Edition
QLA	Quality level A
QLB	Quality level B
RGB	Red, green, and brown
ROW	Right-of-way
RWMS	Right-of-Way Management System

SCADA	Supervisory control and data acquisition
SDSFIE	Spatial Data Standards for Facilities, Infrastructure, and Environment
SDMS	Survey Data Management System
SUE	Subsurface utility engineering
TGO	Trimble Geomatics Office
TIFF	Tagged image file format
TTI	Texas A&M Transportation Institute
UTM	Universal Transverse Mercator
VBA	Visual Basic for Applications
VVH	Verified vertical and horizontal
XFM	XML feature modeling
XML	Extensible Markup Language

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CHAPTER 1. INTRODUCTION

The Florida Department of Transportation (FDOT) is responsible for the safe operation and management of thousands of miles of highways. More than 12,000 centerline miles are on-system miles, of which roughly half are located in urban areas (i.e., areas with a population of at least 5,000) (*1*). This total includes 456 centerline miles that are part of the Florida Turnpike Enterprise.

By all accounts, FDOT manages a huge right-of-way (ROW) asset. Managing this asset involves considerable resources and linkages to numerous business processes. Examples of core processes related to the right-of-way asset itself include determining right-of-way boundaries; inventorying roadside features; preparing right-of-way maps; buying, selling, and leasing assets; regulating the accommodation of utilities within the right-of-way; and preparing reports documenting right-of-way assets. Ready access to related information, as is the case for other core data at FDOT, is a key requirement not just for streamlining project delivery but also throughout the life cycle of transportation infrastructure facilities.

Central to this effort is FDOT's enterprise geographic information system (GIS) initiative. While FDOT has used GIS for years, concerns about the lack of data integration and coordination resulting in redundant data storage and ineffective workflows prompted FDOT to develop an enterprise GIS framework to enable data and technology sharing between the FDOT Central Office and district offices. In 2008, FDOT completed a report that provided recommendations for that framework, which included the following definition of an enterprise GIS (*2*):

> *Enterprise GIS is an organization-wide framework for Department communication and collaboration of shared geospatial data and GIS resources that enhances existing business processes and provides an efficient way to plan, analyze, and manage transportation infrastructure and related elements.*

Of the four framework options studied in the 2008 report, the report recommended Option 3 (a distributed enterprise GIS with enterprise standards). The report included the results of an analysis of data flows within core functional areas, including planning, environmental management, design, construction, maintenance, operations, and materials. Right-of-way and utility data issues were not focal points of the analysis, although indirect references to those issues highlighted items such as the need to improve the digitalization of parcels and right-of-way maps and inefficiencies in the depiction and extraction of utility features.

FDOT would like to incorporate right-of-way parcel and utility data into its existing enterprise GIS system. Currently, FDOT has multiple portals that serve portable document format (PDF) files of right-of-way maps in the Central Office and District Offices (*3*). Figure 1 shows districts where online right-of-way maps are available, according to information gathered from the FDOT website (*3*). Figure 2 shows a sample index of FDOT right-of-way projects in Manatee County (District 1).
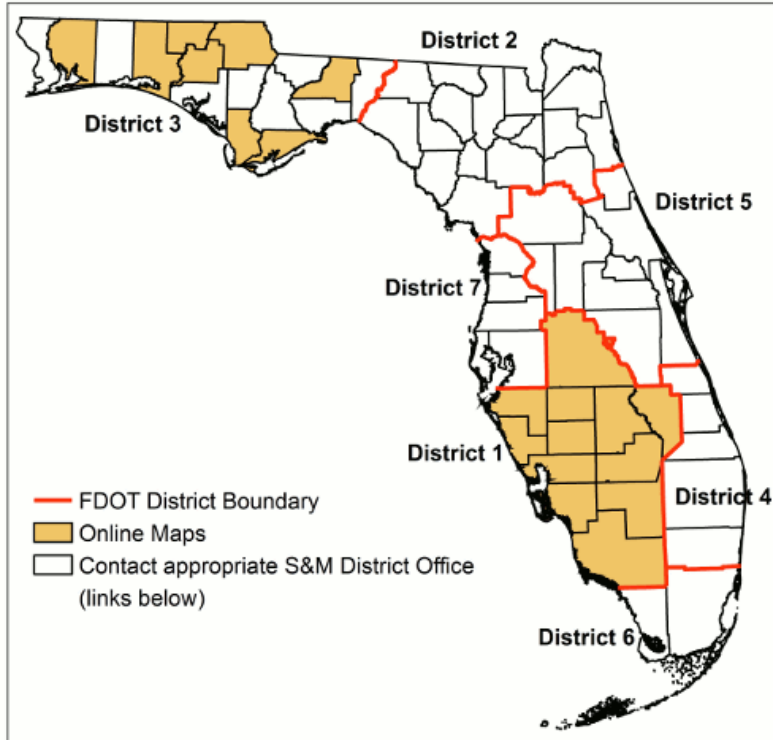
Figure 1. Available Online Right-of-Way Maps at FDOT (*3*).
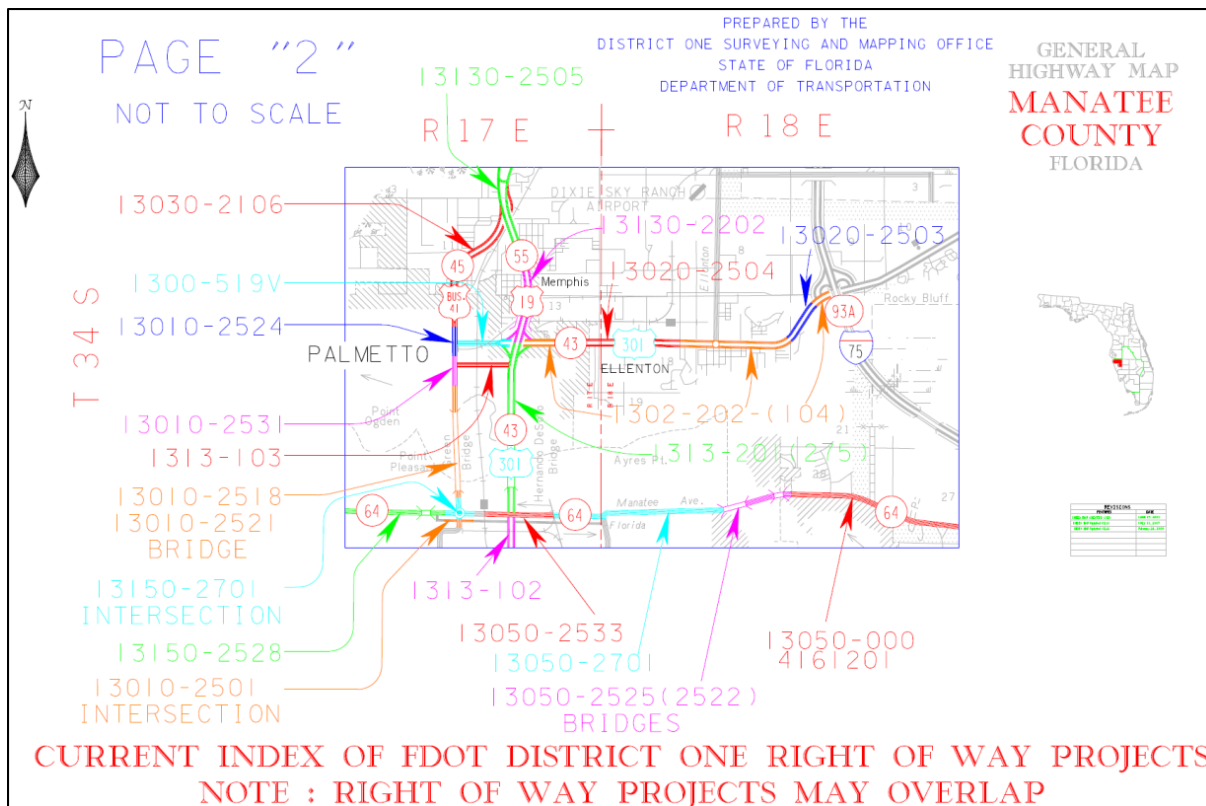
Figure 2. Sample Index of FDOT District 1 Right-of-Way Projects (*3*).

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FDOT also gathers a substantial amount of data and deliverables in connection with subsurface utility engineering (SUE) activities, not to mention other utility data collected during design, construction, and construction inspection activities. Following the FDOT *Utility Accommodation Manual* (*4*), when utility owners relocate their facilities as part of an FDOT project, those utility owners must submit as-built plans as required by their permit or relocation agreement. Similarly, when highway contractors relocate utilities as part of the highway contract, FDOT or the highway contractor must provide as-built plans.

FDOT's Electronic Document Management System (EDMS) is designed to store documents at the completion of a project but not as part of the workflow associated with project development. FDOT would like to keep track of key, relevant documents produced during project development. FDOT has an extensive aerial photography archive collection, which is the largest in the state and includes over 450,000 digital images that date back to 1951 as well as over 700,000 aerial photos that can date back to the 1940s. FDOT's website includes an application that enables users to identify what is available and order aerials for specific areas of interest (*5*).

RESEARCH OBJECTIVE

The purpose of the research was to assist FDOT in developing a strategic implementation plan for the management of right-of-way parcel and utility data at the department. To support this effort, the Texas A&M Transportation Institute (TTI) conducted research to review current FDOT systems and practices and develop recommendations as to what vision and/or strategies to pursue. Recommendations included a mock-up demonstration of selected strategies using FDOT's enterprise GIS framework. More specifically, the research involved conducting meetings with key stakeholders, reviewing and analyzing existing documentation, developing and testing data models, conducting a mock-up demonstration, and developing a set of recommendations for implementation.

This report is divided into chapters as follows:

- Chapter 1 is this introductory chapter.
- Chapter 2 describes a review and analysis of existing documentation.
- Chapter 3 describes an analysis of data modeling approaches.
- Chapter 4 summarizes the results of the data model testing.
- Chapter 5 summarizes conclusions and recommendations.

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CHAPTER 2. ANALYSIS OF EXISTING DOCUMENTATION

INTRODUCTION

This chapter summarizes the work completed to assess current business practices at FDOT related to the management of right-of-way parcel and utility information. It describes lessons learned from meetings with stakeholders at the Central Office, District 5, and District 6; an analysis of documentation received from these stakeholders, including sample project data; and an assessment of practices and potential for the extraction of parcel and utility features from Bentley® MicroStation® to Esri® ArcGIS®.

STAKEHOLDER MEETINGS

In coordination with FDOT, the research team scheduled a set of meetings and conference calls with key stakeholders at FDOT. The purpose of the meetings was to learn or confirm information about business processes, systems, and other items of interest in connection with the management of right-of-way parcel and utility data. Also of interest was to learn about and request suitable sample project data.

Meetings and conference calls at the Central Office in Tallahassee focused mainly on the following topics: Right-of-way acquisition, information technology (IT) plans and systems, utilities, construction, and demonstration of extraction of GIS features from MicroStation files. Part of this effort also included attending a Bentley Map® training class in December 2012 that focused on an introduction to Bentley Map Administrator. The training class provided an overview and hands-on exercises for extensible markup language (XML) feature modeling (XFM), including feature properties, feature annotation, and database properties.

In conjunction with FDOT officials, two districts (District 5 and District 6) were selected to conduct interviews about right-of-way and utility data processes and to gather sample project data. Meetings and conference calls with these two districts covered topics such as surveys and titles, right-of-way acquisition, utilities, GIS, permits, and design-build projects. District 5 officials in DeLand provided sample documents for the following two projects:

- Project No. 238429-3 (Lake County, State Road 50) (Table 1), and
- Project No. 239203-2 (Orange County, State Road 50) (Table 2).

District 6 officials in Miami provided sample documents for the following two projects:

- State Road 826 (Palmetto Expressway) and State Road 836 (Dolphin Expressway), including files for Project Section 5 provided by BCC Engineering Consultants (Table 3), and
- Krome Avenue from 8th Street to SW 88th Street (Table 4).

Districts also provided non-project related project templates both in Primavera format (P6 version 7) and PDF.

Table 1. Sample District 5 Files – Project No. 238429-3 (Lake County, State Road 50).

Category	Description/Comment
Survey files	Existing roadway topography (TOPORD01.dgn), vertical design files and final elevations, and two PDF files that contain horizontal design files and final coordinates.
GEOPAK files	One file project survey data, including information about right-of-way parcels and easements.
Utility plans	Existing utilities (UTEXRD01.dgn), including information about utility installations and utility investigations, one ESRI ArcGIS file showing an import of the utility data file into GIS, and one PDF file with planned utility adjustments.
Drainage plans	Existing drainage design file (DREXRD01.dgn).
Right-of-way maps	Design files including cover sheet and parcel tabulations (19 files).
Parcel and subordination	PDF files from Section 11070 that include warranty deeds, special warranty deeds, acknowledgements, affidavits, parcel descriptions, orders of taking, subordinations of utility interests, city resolutions, and other types of documents (38 files). Note: parcels that include subordination agreements are repeated in folder "Parcels with Utility Subordination." One PDF file that contains subordination documents for four parcels.
Utility permits	One Excel file containing a list of utility permits on SR 50 and SR 25, 11 PDF files of actual FDOT utility permits, 13 PDF files containing utility permits and one utility permit spreadsheet (folder "SR 25"), 15 PDF files of utility permits, and one utility permit spreadsheet (folder "SR 50").
Project scheduling	None
As-built plans	None

Table 2. Sample District 5 Files – Project No. 239203-2 (Orange County, State Road 50).

Category	Description/Comment
Survey files	Two files with existing roadway topography (TOPORD00.dgn and TOPORD01.dgn), vertical design files and final elevations, and two PDF files that contain horizontal design files and final coordinates.
GEOPAK files	One file project survey data, including information about right-of-way parcels and easements.
Utility plans	Three files with existing utilities (UTEXRD01.dgn, UTEXRD02.dgn, and UTEXRD03.dgn), including information about utility installations and utility investigations, two PDF files containing utility work schedules, one PDF file containing utility installation and adjustment special provision for highway contractor, and one PDF file showing design files with utility markups (red, brown, and green).
Drainage plans	Five design files containing existing structures and flood data.
Right-of-way maps	Design files including cover sheet and parcel tabulations (18 files), and PDF versions of the design files (20 files). Copies of the design sheets rwdetl02 and rwdetl03 were only provided in PDF.
Parcel and subordination	One PDF file from Section 75060 including warranty deeds, special warranty deeds, quitclaim deeds, acknowledgements, affidavits, parcel descriptions, orders of taking, subordinations of utility interests, city resolutions, and other types of documents; and one PDF file containing civil actions and law suits related to the project.
Utility permits	None
Project scheduling	Three PDF files of Primavera templates for design and monumentation.
As-built plans	One image of the title sheet of the project design files, and one image of the title sheet of the utility adjustments design files, both in tagged image file format (TIFF).

Table 3. Sample District 6 Files – State Road 826 (Palmetto Expressway) and State Road 836 (Dolphin Expressway).

Category	Description/Comment
Survey files	Existing roadway topography (TOPORD01.dgn), vertical design files and final elevations, and two PDF files that contain horizontal design files and final coordinates. Survey network control design files (10 files) and two digital terrain model files for early ITS deployment and construction stages, provided by the consultant.
GEOPAK files	One file project survey data, including information about right-of-way parcels and easements.
Utility plans	Existing utilities (UTEXRD02.dgn), including information about utility installations and utility investigations. One design file of existing utilities (UTEXRD01.dgn), including information about utility installations and utility investigations, provided by the consultant.
Design plans	Roadway design files (6 files) including cross-sections (3 files), typical sections (3 files) and one airport glide path file in AutoCAD .dwg format.
Drainage plans	Three design files containing existing and proposed drainage structures.
Right-of-way maps	Design files containing right-of-way maps, including cover sheet and tabulations (48 files), and one right-of-way design file from consultant.
Parcel and subordination	One Word document containing parcel description for parcel 836, and deed and other acquisition documents for several other parcels (25 documents).
Utility permits	None
Project scheduling	Design submittal schedule in Excel format, provided by consultant.
As-built plans	None
Other	Consultant also provided ITS design files (29 files); lighting design files (5 files); maintenance files for four zones and two phases (163 files); signing design files (3 files); structural design files of footings, foundations, and piers (18 files); mechanically stabilized earth wall design (22 files), and traffic operations for several stages, zones, and phases (206 files).

Table 4. Sample District 6 Files – Krome Avenue from 8th Street to SW 88th Street.

Category	Description/Comment
Survey files	Existing roadway topography (4 files).
GEOPAK files	None
Utility plans	Three files with existing utilities including information about utility installations and utility investigations.
Drainage plans	Existing drainage design file (DREXRD01.dgn).
Right-of-way maps	Design files containing right-of-way maps including cover sheet and tabulations (30 files).
Parcel and subordination	None
Utility permits	None
Project scheduling	None
As-built plans	None

BUSINESS PRACTICE FEEDBACK FROM STAKEHOLDERS

The research team consolidated and analyzed the feedback and documentation gathered during the various meetings and conference calls with Central Office, District 5, and District 6 officials, as well as the documentation received in connection with the two sample projects in District 5 and District 6.

Title Searches

District 5 conducts title searches for all properties to be acquired. This activity is normally conducted in-house. The district does not conduct title searches on existing right-of-way because this would be a complex, massive effort that would not be feasible. As a result, interests such as utility easements in the existing right-of-way are not discovered during this phase. Sometimes, what the district does is to use the results of the title searches on the property the department will acquire for clues where there might be easements on the right-of-way, e.g., if there is a utility easement on the property to be acquired and the utility alignment might point in the direction of the existing right-of-way.

A title search for new right-of-way shows property rights that utility owners have. If there are any known subordinate agreements, they are researched as well. Utility owners are asked for information about easements or other property rights once Phase 2 development plans are complete. This practice is intended as a backup in case no public records exist of the utility rights, and to proactively find potential non-public property rights.

At District 6, for properties to be acquired, the district conducts title searches in-house or through a title sub consultant to the roadway design consultant. The district conducts title searches on existing right-of-way in situations such as encroachments or when easements are thought to exist. District officials mentioned a situation at the Keys in Monroe County in which decades ago FDOT built a state road, but kept ownership of the old right-of-way (which happens to be adjacent to the existing road). Property owners abutting the old right-of-way have been encroaching on the old right-of-way, which forced district officials to do a title search to examine what kind of property interests might exist.

Title searches for new right-of-way typically occur around 60-percent design. Depending on the need, title searches can occur earlier and sometimes even during the project development and environmental (PD&E) phase, for example if a mitigation area is needed. However, even after title searches are complete, it is often not clear who owns what portion of the required right-of-way, and often a judge must be involved to make a decision based on available titles. FDOT also performs titles searches for their own property because of frequent encroachments.

District 6 officials indicated they pay special attention to situations in which the easement documentation suggests the easement applies to the entire property but in reality the intent was for the easement to apply only to a small section (e.g., a cell tower) or strip (e.g., a utility line). In these cases, district officials contact the property owner and work with the parties to make sure the easement documentation is amended to reflect what is actually supposed to happen on the ground.

Title searches at District 6 vary drastically between Miami-Dade County and Monroe County. At Miami-Dade County, all title searches are now done electronically. By comparison, at Monroe County, title searches are still done manually.

The district has some challenges with scanning and entering the title search documentation into EDMS. Due to the lack of staff resources and overwhelming amount of documents this is not done all the time. More recently, title searches use electronic documents in PDF, which makes it easier to enter them into the EDMS.

Survey and Ground Control

All projects use a single horizontal network and a single vertical network. For horizontal control, new projects use North American Datum (NAD) 1983, 2007 realization. Many active projects use older realization versions, e.g., NAD 1983, 1990 realization or 1996 realization. In general, once a project starts with a realization version (i.e., as soon as the initial survey starts), the project continues with this control through the end of the construction phase. For vertical control, projects typically use North American Vertical Datum (NAVD) 1988, including the sample data provided. Occasionally, FDOT uses National Geodetic Vertical Datum 29 (NGVD29) as the vertical datum. Information about the horizontal and vertical datum used is normally shown as a general note on right-of-way maps.

Right-of-way maps are usually prepared on 24x36-inch paper size. Some parcels might not be shown to scale, e.g., if there is a drainage easement some distance away from the highway right-of-way. District officials were not sure if the engineer-of-record (EOR) maintains georeferenced versions of all the parcels.

At District 6, preparing parcel sketches is more common that full-fledged right-of-way maps. The reason is that many projects only have a few parcels to acquire, which would make preparing right-of-way maps an unnecessary expense. Parcel sketches are usually prepared on 8.5x11-inch page size. The content should be the same as in the traditional right-of-way maps.

Over time, the use of control surveys has declined at the district. Many right-of-way lines are hand drafted and come from right-of-way surveys, not control surveys. District officials highlighted that right-of-way lines developed from right-of-way surveys are not as accurate as those from control surveys. A right-of-way survey uses an offset from a control survey or control line. Occasionally, there are significant errors that require a control survey in addition to the right-of-way survey. The deciding factor on whether to use right-of-way surveys or control surveys is the number of parcels involved. Right-of-way surveys are cheaper, but they need to be checked more closely to make sure that they are somewhat accurate.

Right-of-Way Management System (RWMS)

Around 2003, FDOT replaced the Right-of-Way Control System, which had been in operation for years, with a new system called the Right-of-Way Management System (RWMS). This

system includes data for active projects beginning in 2003 and only a very small percentage of projects prior to that year. FDOT uses RWMS to track and manage the acquisition of right-of-way parcels for transportation projects, as well as mitigation and relocation activities. District staff or consultants enter information into RWMS.

In RWMS, parcels are uniquely identified within a project, but multiple projects could have parcels that have the same parcel ID. Therefore, to uniquely identify parcels, it is necessary to use a combination of project ID and parcel ID. This is sufficient for most parcels since, typically, FDOT purchase parcels for specific projects. However, FDOT might also purchase a non-project-related "property of opportunity" if the corresponding requirements are met.

In RWMS, a parcel represents a property interest that FDOT acquires, which can be whole or partial (i.e., if FDOT only acquires a portion of the property). FDOT typically acquires property in fee simple. However, a substantial number of takings (particularly partial takings) are temporary easements or perpetual easements.

In general, parcel IDs represent individual property interests. However, it is possible for a property to be owned by multiple owners (in this case, each owner is listed with the corresponding ownership percentage) or for a single ownership to have multiple parcels. In this case, if there is commonality among those parcels, FDOT districts frequently create just one parcel record in RWMS and provide references to each subparcel using letters in a comment box. For example, a parcel could be No. 100 and each subparcel would be referred to as 100-A, 100-B, or 100-C. At District 5, if the subparcels are contiguous, the district assigns letters "–A" or "–B" to each parcel. However, if the parcels are apart, e.g., if one of the parcels is across the street, the parcels have different parcel numbers. Having different parcel numbers is useful if issues affect only one of the parcels, which allows FDOT to close on the parcels that do not have issues. If parcels are linked and one of them has an issue, FDOT cannot close on any of the parcels.

In general, FDOT uses the following standard for numbering parcels (*6*):

- 1 – 99 (reserved for contracts, suit information, utility contracts, and other agreements and contracts on the project),
- 100 – 699 (for all parcels acquired in fee),
- 700 – 799 (for all temporary easements),
- 800 – 899 (for all perpetual easements), and
- 900 – 999 (for all license agreements).

If the number of parcels on a project exceeds the allocated series, the series may be extended by adding 1000. For example, the first fee parcel after 699 would become parcel 1100 and the first temporary easement after parcel 799 would become parcel 1700.

All instruments relating to a parcel to be acquired are assigned sequential numerical suffixes, starting with the instruments for the primary interests, e.g., 100.1, 100.2, and 100.3. For example, the following convention for numbering documents in connection with subordination of utility rights would apply: 100.1 for a special warranty deed, and 100.2, 1003, and higher

would be used for the actual subordination agreements with the utility owner and a local public agency.

Subparcels could also involve multiple takings. Additional property takings could lead to a need for additional parcels, or they can be part of the same parcel. An example would be a maintenance-type parcel such as a water retention area. Often the property owner prefers to have the water retention area away from the highway in the back of the property, which then results in the need for an easement to access the water retention area from the road.

RWMS includes documents in PDF, but not all districts are currently online. Some districts are still in the process of scanning information. FDOT's preference would be to link documents from an online GIS environment, rather than having the actual right-of-way maps in the GIS.

Enterprise GIS Framework (EGF)

EGF is a configurable platform for the visualization of georeferenced data at the department. The system is based on ArcGIS Server® version 9.3, and uses Microsoft® Silverlight®, Esri ArcSDE®, and Oracle Spatial®. Available via FDOT's Enterprise Information Portal (EIP), the GIS Enterprise View (GEV) is built on top of EGF. GEV is the main GIS viewer used by Central Office for displaying base map layers (*2*). GEV can be embedded into other applications and is intended as a one-stop shop for GIS information for FDOT internal use. FDOT is currently planning to upgrade the system to ArcGIS Server version 10.

In the system, roads are divided into segments. A right-of-way map could encompass several segments. A highway project could also span several segments. The road network in the system is composed of centerlines that come from a number of sources, including Navteq (through a statewide license). For roads being planned or designed, FDOT uses approximate locations based on information included in the FDOT five-year work program.

Currently, RWMS does not interface with EGF. The only right-of-way data layer in EGF is outdoor advertising structures (based on latitude and longitude geographic coordinate data collected in the field).

FDOT's coordinate system is based on Universal Transverse Mercator (UTM) state plane coordinates. In the past, right-of-way maps used to be on arbitrary coordinate systems, for which there is little to no coordinate information. Most right-of-way maps nowadays are based on UTM. However, it is possible that individual districts still use an arbitrary coordinate system for individual MicroStation files.

Electronic Document Management System

FDOT's EDMS is built on OpenText® Connectivity Solutions® (which used to be called Hummingbird). The system is integrated across many FDOT business areas. The focus of the integration effort is to provide ties to existing systems. In EDMS, attributes provide keys to

systems for which sharing information is a requirement. The main elements are project number and contract number (as well as other important fields) that link several types of documents.

For parcel documents, the book and page number is the legal description of a recorded deed. Only appraisal documents are in EDMS (in PDF), including legal descriptions, photos, and other elements. In some districts, right-of-way maps are also stored in EDMS.

ProjectSuite Enterprise Edition (PSEE)

PSEE is a Web-based application that provides information about capital improvement projects, which uses a dashboard connected to a centralized repository of georeferenced information. The system is the result of integration of a wide range of systems. There was not a strategic plan for the development of the system, but rather a decision that integrating systems made the most business sense.

FDOT officials indicated that, for the most part, documents can be handled using current interfaces. As a result, FDOT does not see an immediate need to improve overall electronic document management practices. Depending on the type of data, the data may be accessed in a variety of ways. For example, PSEE provides links to FDOT's EDMS. PSEE also uses an embedded EGF mapping component. However, although the system provides access to a wide range of project-related business data, this information is not georeferenced, which means it is possible to retrieve documents at the project level, but it is not possible to query or find documents using data such as milepost ranges.

The system was written from a project management perspective, with a focus on pre-construction activities up to letting. Currently, the system does not show right-of-way lines. FDOT officials indicated this layer would be useful to support a variety of processes, e.g., to verify or monitor encroachments. To deal with encroachments, FDOT currently goes to the field to get an acknowledgement from property owners about the encroachments, or resolve it if it is a safety issue. FDOT would benefit greatly from having a representation of the actual right-of-way line, because it is not necessarily shown by monuments in the field.

Extraction of Features from MicroStation Files

FDOT has begun to experiment with prototype procedures to export MicroStation parcel data to a GIS environment, more specifically by extracting linear features from a couple of relevant levels in MicroStation, importing those linear features into the GIS, and generating polygon features in Esri shapefile format. The process has also included generating right-of-way sheet outlines. Although the process works, it is too cumbersome for a large scale operation. A critical issue that affects the feasibility of using this process is that linear features in MicroStation are not "closed," meaning a parcel outline consists of disconnected lines that may even be located on different MicroStation levels. Since the outline of a parcel consists of several lines and not a single polygon, all lines must be imported into the GIS and then manually reviewed by a technician to determine if they are useful or needed.

FDOT typically uses 2D data, but some data sources provide 3D information. For example, existing digital terrain models (DTMs) are increasingly allowing highway contractors to use machine control in the field. 3D data for utility facilities is limited to vertical locations provided by test holes. Additional 3D data for utility facilities would be desirable, but FDOT does not have a process to collect, store, or use these data.

Excess and Surplus Property

Mapping of excess property involves a determination by FDOT that the property is no longer needed. Once an excess property is declared to be surplus, it must be offered for sale to abutting property owners or the public, depending on the case. The process to dispose of surplus property can vary considerably from county to county. The Florida Department of Revenue (DOR) consolidates parcel data from all counties in the state. Practices vary widely, including how counties uniquely identify parcels. In some cases, counties keep a record of FDOT right-of-way parcels, but in many other cases, the counties do not track right-of-way parcels because these parcels are no longer taxable. In some counties, parcels can be mapped to a DOR ID. Overall, the DOR layer only provides a general reference to locations and is not always reliable.

FDOT might acquire a portion of a parcel through an order of taking (OT) and then the uneconomic remainder through a voluntary sale using a regular deed. If FDOT acquires property through an order of taking, the property cannot be sold by FDOT for 10 years, making it critical to know how the property was acquired.

Depending on the case, RWMS might contain a reference to just one parcel being acquired or two parcels being acquired (one parcel record for the required parcel and a second parcel record for the excess parcel). Frequently, the two parcels are handled separately if the acquisition process followed is different (e.g., a condemnation proceeding for the required parcel and deal for the excess parcel). Regardless of whether there are one or two different parcel records, district personnel would like to make sure that a GIS application shows both subparcels separately. This differentiation would make it easier for the district to manage the property asset more effectively, e.g., if the district decides to lease or sell the excess property.

To differentiate between required property and excess property, District 5 uses specific graphical elements on right-of-way maps. For required right-of-way, the district labels the line "R/W Line." For excess property, it labels the line "Taking Line." However, district officials indicated that there is a need for a different symbology on right-of-way maps to facilitate the distinction between taking lines and right-of-way lines so that the maps show clearly what property FDOT owns. There may also be a need to track whether a parcel is leased. Currently, RWMS shows only one parcel, but district staff would like to see more information, e.g., in situations where a contractor needs additional right-of-way during construction.

A surveying and mapping viewer shows outlines of parcels, which provide a link to the right-of-way map (in PDF). This document shows the FDOT project number. The parcel ID given in the system is typically the DOR ID.

District 6 developed a Web-based application called GIS Asset Management Application (GAMA). Currently, GAMA contains records of excess and surplus property interests within the right-of-way that might generate revenue for the department. Data for the application comes from RWMS, which is linked with the GIS application. Depending on the case, surplus property can be leased or sold. RWMS data reside locally and must be manually updated every day. County data are provided via a copy file and are also manually updated every day.

The district uses GAMA to identify parcels for leasing purposes. The interface enables users to view and select parcels to retrieve information about those parcels. Parcel information includes a link to the tax information on the county website. There are two types of parcels: inequitable and equitable. For inequitable parcels, FDOT must make an offer to the abutting owner. For equitable parcels, FDOT must offer the parcel for public bid. Parcel status can be temporarily surplus or surplus. Temporarily surplus means that the parcel can be leased, while surplus means that the parcel is for sale.

Examples of temporarily surplus parcels include parcels under freeways, which are leased to the city, as well as sidewalk space the city leases to individual businesses on behalf of FDOT. Officials described an example in the Miami area, where the city leases long stretches of right-of-way from FDOT, and then issues permits to business owners at $20 per square foot per year. FDOT receives 20-percent of this revenue. This business model required a change in law because typically FDOT only leases to abutting property owners, and in this case, café owners are typically not the property owners. The city provides a supplemental to the lease contract between FDOT and the city, which includes a sketch and area of the lease permit. No survey or parcel identification was conducted. The burden to measure anything in the field is the city's responsibility, not FDOT.

GAMA can assign one parcel ID to many GIS polygons. The application enables users to upload data or parcel documents for each parcel in PDF. Currently, there is a master parcel that has all the files that pertain to multiple parcels. The district is planning to provide functionality to link all documents to all parcels in the future. Other tools within the system include a property management calculator and a dashboard with lease information.

Within GAMA, individual parcels are traced by hand using the Web-based application. As a result, outlines are only used for general reference. The district never intended for this application to provide accurate parcel locations and, in fact, a disclaimer alerts system users about the limitations of the information provided. Other sources of data are georeferenced MicroStation files (for the right-of-way line) and TIFF files.

GAMA was developed using concepts and the framework identified during the development of EGF. The district based all GIS development on these initial requirements and recommendations of the GIS framework. District 6 officials adopted the conceptual framework, but completed the implementation using ArcGIS Server 10. GAMA uses a higher-level application programming interface (API) in which Silverlight provides an interface to create simple parcel outlines.

Utility Coordination

The utility coordination process at FDOT may vary from district to district. In general, the process starts when planning for a new road begins and the district liaison has local meetings with utility owners. For large projects, there might be a significant number of meetings. The relationship between FDOT and utility owners is fundamentally different from the relationship between FDOT and a highway contractor. Although there are rules that govern the accommodation of utility facilities in the state right-of-way, the rules are frequently difficult to enforce. In addition, FDOT deals with numerous small, local utility owners that have few resources and often lack the capability to follow all accommodation rules.

Utility coordination can be in-house or outsourced. District 6 prefers coordination consultants that report directly to FDOT. FDOT found that the final product was not as good if the utility coordinator reported to the main consultant.

FDOT's practice for utility investigations is to collect quality level B (QLB) and quality level (QLA) data in situations where there are drainage improvements and/or geometric improvements. In Florida, the northeast is generally hillier, which results in more subsurface utility issues. The south is flatter, which results in fewer issues. Soil and geological conditions are also different around the state. The FDOT *Plans Preparation Manual* provides guidance on the timing and use of utility investigations (*7*).

All utility information should be transferred to the topographic file that goes into design phase. However, this is not always the case. For major projects, the district uses professional services contracts to handle the design work. Typically, the main consulting firm uses sub consultants for specialized tasks. Surveying and mapping is one of those specialties (utility investigations are carried out under this category because of the requirement for a registered surveyor or mapper to certify the deliverables). FDOT can also hire surveying and mapping sub consultants separately. Typically, these separate contracts have two elements: utility surveys and utility coordination. Utility relocation can be included in the highway contract if requested by the utility owner.

Surveying aboveground utility facilities typically occurs between 0- and 30-percent design. FDOT's 30-percent plans include existing information about utility facilities, as known to the department. Typically this information is in a separate file. For most projects, FDOT sends these plans to utility owners in hard copy for markup and then incorporates the confirmed and/or corrected information into the 60-percent design file. Not all utility owners provide this information. The utility conflict matrix starts somewhere between 30- and 60-percent design and helps the district identify utility conflicts and the need for test holes.

FDOT sends a hard copy of the 60-percent plans (also known as initial plans or Phase 2 plans) to utility owners for further confirmation and utility relocation plans, and utility owners have to return them before the completion of the 90-percent plans. In some cases, FDOT provides plans in electronic format. The 60-percent plans include elements such as drainage and traffic signals, as well as the utility conflict matrix. Normally between 60- and 90-percent design, FDOT determines which utility facilities have to be relocated. If there is a need for more test holes at this point, FDOT orders this data collection as needed.

The 90-percent plans include proposed utility locations. FDOT uses red, green, and brown (RGBs) to indicate utility information, as follows: red means "remove," green means "existing lines," and brown means "proposed lines." These utility lines on the plans are only approximate. The EOR ultimately determines where utility lines should be displayed on the files. The EOR is also responsible for ensuring that there is sufficient right-of-way to accommodate utility facilities. The 90-percent plans are sent to utility owners to convey the plans for relocation. Once the RGBs are in the 90-percent plans, locations are fixed and utility owners have the plan controls. Typically, all utility facilities that must be relocated are moved by the time plans are complete. However, some large utility owners relocate their lines during the right-of-way acquisition phase that follows the completion of plans. For advance utility relocation in new right-of-way, FDOT stakes the right-of-way. Normal staking occurs typically at the end of right-of-way acquisition or during letting phase.

FDOT finishes record data collection and QLB data collection by 30-percent design, depending on the type of utility conflicts. QLA data collection should be complete at 60-percent design. A comment was that some of the QLB data collection could be conducted early, along with the development of DTMs. QLB and QLA deliverables are typically computer-aided design (CAD) files in state plane coordinates. QLA work is also referred to as verified vertical and horizontal (VVH). FDOT officials highlighted that the requirements for utility investigations in the Florida One Call legislation (Florida Statute Chapter 556) (8) are not the same as the provisions in the American Society of Civil Engineers/Construction Institute (ASCE/CI) 38-02 standard (9). The Florida statute requires the state to identify utility installations on certain projects by using a One Call service.

In District 6, district officials highlighted that soil conditions in South Florida (a combination of high water table and rocky soil) make it difficult to use test holes beyond 4–5 feet in depth. The alternative to test holes is the use of a back-hoe to excavate or trenching. Using surface-level geophysical methods for detecting underground utility installations does not work well in District 6, and the district hardly uses this technology.

The district usually makes a determination for test holes at around 60-percent design, but, theoretically, test holes can be ordered at any time until 100-percent design. As soon as the district has the basic design, it starts the requests for test holes because it may take some time to get approval. A good example of the use of test holes is a mast arm because of the huge foundation it needs. The district typically designs the mast arm and then requests test holes to identify all utility facilities that are in the immediate vicinity. The districts priority is to "design-out" conflicts as much as possible, which can be problematic if there are utility issues at 90-percent design.

Districts must provide a utility certification package at letting. At this point in the process, everything should be cleared with no cases pending. Sometimes, if a utility owner is not cooperative, FDOT has a legal process that provides a 30-day notice and enables FDOT to relocate the utility in conflict and send the bill to the utility owner.

All the paperwork and agreements with utility owners have to be in place prior to advertising the job. Relocation of utility facilities must be complete before construction starts. FDOT tries to

avoid a situation in which two competing contractors are in the field at the same time (utility contractor and roadway contractor) because that can easily result in chaos.

During the construction phase, the main problem is unknown utility facilities that are discovered once the construction starts. Typically, if a contractor knows about utility facilities, it makes it easier to schedule around those locations. Sometimes, there are design changes during the construction phase. However, if the change requires a supplemental agreement between the contractor and FDOT, the result can be costly to the department.

If the contractor finds that a utility facility is in the wrong place, the contractor will usually mark the construction drawing to show the correct location. FDOT scans all completed project plans, which means that some of those plans could contain information about the actual location of utility facilities on the right-of-way.

Utility relocations in the highway contract are popular because utility owners often get better prices than handling the relocation on their own. Officials mentioned that sometimes the roadway contractor is sufficiently familiar with utility relocation work and might propose a low utility relocation cost. The result would be a lower cost to the utility owner. Currently, some utility owners only do relocation work in the highway contract. If the utility relocation cost of the winning bid is too high, the utility owner can reject the bid, which may put a different bidder into the winning position. If the utility owner accepts the bid and the utility-related amount is higher than the original estimate, the utility owner has 14 days to come up with the difference.

Lump sum contracts are limited to $100,000 at the district. A lump sum contract does not involve a second set of plans.

Most utility relocations in the state are not reimbursable and do not involve QLB or QLA utility investigations. Each district has its own contract with SUE providers and can request service if their involvement is needed.

FDOTis responsible for identifying underground facilities owned by FDOT, including intelligent transportation system (ITS) installations; electrical lights, high mast lights, and underground feeders; and water and sewer lines at rest areas. ITS facilities and FDOT-owned facilities are not reported through the One Call system. For ITS installations, FDOT has a separate vendor that can be called, but this is not always known.

Subordination Agreements

Subordination agreements are legal documents that allow utility owners to maintain a reimbursable relocation status based on property rights predating FDOT's property acquisition. For example, if a utility owner has a private easement outside the FDOT right-of-way, and FDOT acquires the property including the easement, FDOT would execute a subordination agreement with the utility owner guaranteeing that FDOT will pay for the utility relocation if needed by a future highway project. A single, small parcel could have a dozen documents related to utility subordination agreements. FDOT needs to track subordination agreements to have a record of which facilities in the right-of-way are reimbursable. A problem is that after

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acquisition, all parcels become part of the right-of-way, and this information is lost or only exists in the agreement itself.

Subordination agreements depend to a large degree on the actual, specific rights of the property owner's easement. Not every easement that FDOT acquires is converted to a subordination agreement. Before FDOT gives subordination rights, it reviews the easement to see what exactly it provides. In some cases, FDOT allows a utility owner to maintain an easement in the public right-of-way if the utility facility and FDOT infrastructure can coexist, and the existing easement does not provide rights that can result in future problems for FDOT.

Utility Coordination in Design-Build Projects

Utility relocations in design-build projects can use a joint project agreement (JPA). This agreement entails separate plans for utility relocation, which might include upgrades. JPAs are some of the newer contractual tools that were not available to FDOT until just a few years ago.

The process for storing documents in design-build projects is the same as for traditional projects. For a recent megaproject, the computer system at FDOT was not capable enough to handle all the engineering files, and FDOT decided to use Bentley ProjectWise®. Design-build projects typically result in several submissions from the consultant to the FDOT project manager. For example, a submission might involve a 100-percent submission for a bridge, while other portions of the project are still at 30- or 60-percent design. If the contractor changes something in the field, there are plan revisions. The last revision basically becomes the as-built. For each version, there is a separate document that summarizes the changes made with each revision.

Most plans are in 2D, but for complex structures the consultant might use 3D plans. The 3D plans are mostly used for areas with heavy use of rebar or pre-tension, for example segmental bridges with pre-tension elements.

Right-of-way parcel records are in a file that is kept by the right-of-way section. The plans show the new right-of-way line, which is also included in the as-built file. Parcel information is not in the design files that are transferred to the design builder because FDOT believes they are really unnecessary information for the designer or the contractor.

For the most part, permanent records include utility relocations. Utility owners usually give FDOT a set of plans that become the utility as-builts, but they do not necessarily meet FDOT design standards. FDOT transfers the location of the utility lines to the design files, and the design-builder gets a copy of the as-builts. However, since the utility files do not follow FDOT standards, utility lines in the design files might not be necessarily be accurate. If there is a change to a proposed utility line in the field, the utility owner should record it on its as-builts, but that change is typically not transferred to the roadway design plans or roadway as-builts. Typically, it does not matter to the highway contractor where the utility line is actually located, for example, if the line was installed one foot deeper as planned.

For design-build projects, minor project changes are acceptable, but major changes require new documents. FDOT provides approval for each batch of documents, which can be at different

stages of project development. As-builts are typically provided at the end of a project. During the design-build phase, FDOT cannot purchase any additional right-of-way. Requests for permits within six months of construction are handed off to the Construction Division. If a utility facility needs to be relocated, there should be another permit for the new location.

For a recent megaproject, FDOT developed 100-percent design plans costing about $30 million of the $900 million contract. These plans, although signed and sealed, were provided to the design-builder for reference only. Although the plan is for the design-builder to develop its own setup plans, FDOT needed accurate design plans to identify and justify the right-of-way acquisition in court. FDOT could have decided to produce less than 100-percent plans for the design-build project, but that could have potentially led to problems in court. The plans are also "insurance" against requests from the design-builder for more right-of-way during the project development process. If the design-build team needs additional right-of-way based on their new design, the design-build team is responsible for the acquisition, or must pay FDOT for the acquisition. If the design requires more utility relocation, the design-build team is also responsible for the additional cost. Technically, the design-build team can acquire right-of-way. Therefore FDOT does not need to have all right-of-way acquired before the project is being built.

Utility Permits

Currently, permits for utility installations in the right-of-way require plans depicting milepost, offset (typically from the right-of-way line), and installation depth information. If there are changes during construction, the utility owner should provide as-builts of the actual installation. However, in most cases, FDOT does not receive as-builts from utility owners. FDOT is reviewing the permitting process and is evaluating the feasibility of requiring the submission of georeferenced as-built information. Although FDOT inspectors should verify all utility installations, this does not happen often due to a lack of staff resources. In the case of highway contracts, contractors do not have to provide as-builts for utility relocations in their contracts, unless there is a contract-specific provision. FDOT specifications indicate that a contractor must provide as-built plans in the case of jack-and-bore and horizontal drilling construction items.

The department uses the Permit Information Tracking System (PITS) to track permits statewide. The system, which has been in use since about 2000, issues permit numbers for all permits statewide. FDOT is in the process of developing a new online utility permitting system. One of the issues being discussed, which the utility industry has raised, is related to procedures to safeguard proprietary information. Utility permits in Florida are free, with a few exceptions.

The department issues three types of permits: driveway (or access) permits, utility permits, and drainage permits. Utility permits are usually handled at the field office level. The district maintenance office only learns about specific cases that require special attention. It is not clear how many utility permits districts handle. One issue with permits in the past was that field offices often attached special provisions to permits, which typically duplicated existing regulations with slight differences and thus caused confusion or conflicts. The *Utility Accommodation Manual* is the main source of information and regulation for utility owners (*4*).

ASSESSMENT OF AVAILABLE DOCUMENTATION

MicroStation Design Libraries

FDOT uses a number of design libraries in MicroStation. For example, the FDOT 2010 MicroStation workspace installation provides 15 design libraries. Each design library includes levels and their corresponding descriptions and properties, as well as filters. Table 5 provides a summary of the design libraries that were potentially relevant to the research. Also shown in Table 5 is the number of levels within each design library, which has evolved over the years. In reality, levels have been added to the libraries from year to year, but, at the same time, other levels have been removed from those libraries. For example, for right-of-way and survey levels:

- 97 right-of-way levels and 13 survey levels were removed in 2008 (Table 6),
- 76 right-of-way levels and 3 survey levels were added in 2008 (Table 7),
- No right-of-way or survey level changes took place in 2010, and
- Two survey levels were added in 2012 (Table 8).

Table 5. Number of Levels by Design Library and Year.

Design Library	Description	2004	2008	2010	2012
countymappinglevels	FDOT Standard County Mapping Levels	n/a	199	199	199
fdot_common_levels	FDOT Standard Common Levels	55	72	87	87
fdot_v8_levels	FDOT Standard Roadway Levels	662	723	753	753
photogrammetry	FDOT Standard Photogrammetric Levels	n/a	36	35	35
rwlevels	FDOT Standard Right-of-Way Levels	198	172	172	172
strlevels	FDOT Standard Structure Levels	203	210	211	211
survey_levels	FDOT Standard Survey Levels	197	187	187	190
Total		**1,315**	**1,599**	**1,644**	**1,647**
Grand Total					**6,205**

Table 6. Right-of-Way and Survey Levels *Removed* in 2008.

Design Library	Name	Description
rwlevels	AdhocPoint	Miscellaneous: Adhoc Points Placed by SheetInfo
rwlevels	BarScale	Cell:Miscellaneous:Map Sheet Bar Scale
rwlevels	EaseExistLeader	Annotation:Leader:Easement (Existing)
rwlevels	EaseExistLine	Easement:Existing Easement Line
rwlevels	EaseExistStaTie	Annotation:Station Tie:Easement (Existing)
rwlevels	EaseExistText	Annotation:Text:Easement Lines (Existing)
rwlevels	EaseExistWidthArrow	Annotation:Arrow:Easement Width (Existing)
rwlevels	EaseLic_pLeader	Annotation:Leader:License (Proposed)
rwlevels	EaseLic_pLine	Easement:License (Proposed)
rwlevels	EaseLic_pStaTie	Annotation:Station Tie:License (Proposed)
rwlevels	EaseLic_pText	Annotation:Text:Easement Lines, License (Proposed)
rwlevels	EaseLic_pWidthArrow	Annotation:Arrow:License Width (Proposed)
rwlevels	EasePerp_pLeader	Annotation:Leader:Easement Perpetual (Proposed)

Table 6. Right-of-Way and Survey Levels *Removed* in 2008 (Continued).

Design Library	Name	Description
rwlevels	EasePerp_pLine	Easement:Perpetual Easement Line (Proposed)
rwlevels	EasePerp_pStaTie	Annotation:Station Tie:Easement Perpetual (Proposed)
rwlevels	EasePerp_pText	Annotation:Text:Easement Lines, Perpetual (Proposed)
rwlevels	EasePerp_pWidthArrow	Annotation:Arrow:Easement Perpetual Width (Proposed)
rwlevels	EaseTemp_pLeader	Annotation:Leader:Easement Temporary (Proposed)
rwlevels	EaseTemp_pLine	Easement:Temporary Easement Line (Proposed)
rwlevels	EaseTemp_pStaTie	Annotation:Station Tie:Easement Temporary (Proposed)
rwlevels	EaseTemp_pText	Annotation:Text:Easement Lines, Temporary (Proposed)
rwlevels	EaseTemp_pWidthArrow	Annotation:Arrow:Easement Temporary Width (Proposed)
rwlevels	GovCityLimitHLine	Government:City Limit Line (Hash Only)
rwlevels	GovCityLimitLine	Government:City Limit Line
rwlevels	GovCountyLine	Government:County Line
rwlevels	GovGrantLine	Government:Grant Line
rwlevels	GovGreenLeaderWt0	Annotation:Leader:Government (color = green)(weight = 0)
rwlevels	GovGreenLeaderWt2	Annotation:Leader:Government (color = green)(weight = 2)
rwlevels	GovGreenStaTie	Annotation:Station Tie:Government (color = green)
rwlevels	GovGreenTextWt0	Annotation:Government Text Green Weight of 0
rwlevels	GovGreenTextWt2	Annotation:Government Text Green Weight of 2
rwlevels	GovLotLine	Government:Lot Line
rwlevels	GovMeanderLine	Government:Meander Line
rwlevels	GovParkHLine	Government:National or State Park or Forest Line (Hash Only)
rwlevels	GovParkLine	Government:National or State Park or Forest Line
rwlevels	GovQtrQtrLine	Government:Quarter / Quarter Section Line
rwlevels	GovQuarterLine	Government:Quarter Section Line
rwlevels	GovRedLeaderWt0	Annotation:Leader:Government (color = red)(weight = 0)
rwlevels	GovRedLeaderWt2	Annotation:Leader:Government (color = red)(weight = 2)
rwlevels	GovRedStaTie	Annotation:Station Tie:Government (color = red)
rwlevels	GovRedTextWt0	Annotation:Government Text Red Weight of 0
rwlevels	GovRedTextWt2	Annotation:Government Text Red Weight of 2
rwlevels	GovSectionLine	Government:Section Line
rwlevels	GovStateLine	Government:State Line
rwlevels	GovTwpRgeLine	Government:Township and Range Government Survey Line
rwlevels	LA_LineExist	Existing:Limited Access Line
rwlevels	LA_pLine	Proposed:Limited Access Line
rwlevels	LOCLeader	Annotation:Leader:Limits of Construction (Proposed)
rwlevels	LOCLine	Proposed:Limits of Construction Line
rwlevels	LOCStaTie	Annotation:Station Tie:Limits of Construction (Proposed)
rwlevels	LOCText	Annotation:Text: Limits of Construction (Proposed)
rwlevels	Maint_pLeader	Annotation:Leader:Maintenance
rwlevels	Maint_pLine	Proposed:Maintenance Line
rwlevels	Maint_pStaTie	Annotation:Station Tie:Maintenance
rwlevels	Maint_pText	Annotation:Text: Maintenance
rwlevels	Maint_pWidthArrow	Annotation:Arrow:Maintenance Width (Proposed)
rwlevels	NonVehcExistLeader	Annotation:Leader:Non Vehicular Access
rwlevels	NonVehcExistLine	Existing:Non-Vehicular Access Line
rwlevels	NonVehcExistStaTie	Annotation:Station Tie:Non Vehicular Access
rwlevels	NonVehcExistText	Annotation:Text:Non-Vehicular Access (Existing)
rwlevels	NorthArrow	Cell:Miscellaneous:North Arrow
rwlevels	PlotBorderSht	Cell:Sheet Element, Shape for Outside Sheet Border
rwlevels	PropertyLineExist	Existing:Property Line
rwlevels	PropertyLineHook	Cell:Miscellaneous:Property Line Hook

Table 6. Right-of-Way and Survey Levels *Removed* in 2008 (Continued).

Design Library	Name	Description
rwlevels	PropertyLineSymbol	Cell:Miscellaneous:Property Line Symbol
rwlevels	PropLineLeaderExist	Annotation:Leader:Property Line (Existing)
rwlevels	PropLineStaTieExist	Annotation:Station Tie:Property Line (Existing)
rwlevels	PropLineTextExist	Annotation:Text:Property Line (Existing)
rwlevels	RW_LineExist	Existing:RW Line
rwlevels	RW_pLine	Proposed:Right-of-way Line
rwlevels	RWandLA_eText	Annotation:Text:R/W & L/A Lines (Existing)
rwlevels	RWandLA_eWidthArrow	Annotation:Arrow:RW & LA Width (Existing)
rwlevels	RWandLA_pLeader	Annotation:Leader:R/W & L/A (Proposed)
rwlevels	RWandLA_pStaTie	Annotation:Station Tie:R/W & L/A Lines (Proposed)
rwlevels	RWandLA_pText	Annotation:Text:R/W & L/A Lines Taking Lines (Proposed)
rwlevels	RWandLA_pWidthArrow	Annotation:Arrow:RW & LA Width (Proposed)
rwlevels	ShtCoverTextWt0	Cell:Sheet Element, Cover Sheet Linear and Text Wt 0
rwlevels	ShtCoverTextWt1	Cell:Sheet Element, Cover Sheet Linear and Text Wt 1
rwlevels	ShtCoverTextWt2	Cell:Sheet Element, Cover Sheet Linear and Text Wt 2
rwlevels	ShtCoverTextWt3	Cell:Sheet Element, Cover Sheet Linear and Text Wt 3
rwlevels	ShtCoverTextWt4	Cell:Sheet Element, Cover Sheet Linear and Text Wt 4
rwlevels	ShtCoverTextWt5	Cell:Sheet Element, Cover Sheet Linear and Text Wt 5
rwlevels	ShtInsideBorder	Cell:Sheet Element, Inside Sheet Border
rwlevels	ShtLegendText	Cell:Sheet Element, Sheet Legend Data
rwlevels	ShtTitleBlkLineWt0	Cell:Sheet Element, Sheet Title Block Lines Wt 0
rwlevels	ShtTitleBlkLineWt1	Cell:Sheet Element, Sheet Title Block Lines Wt 1
rwlevels	ShtTitleBlkLineWt2	Cell:Sheet Element, Sheet Title Block Lines Wt 2
rwlevels	ShtTitleBlkSignature	Cell:Sheet Element, Sheet Title Block Signature Line Wt 0
rwlevels	ShtTitleBlkTextWt0	Cell:Sheet Element, Sheet Title Block Text Wt 0
rwlevels	ShtTitleBlkTextWt1	Cell:Sheet Element, Sheet Title Block Text Wt 1
rwlevels	ShtTitleBlkTextWt2	Cell:Sheet Element, Sheet Title Block Text Wt 2
rwlevels	ShtTitleBlkTextWt3	Cell:Sheet Element, Sheet Title Block Text Wt 3
rwlevels	Topo_eText	Annotation:Text:Miscellaneous: All Other Topograhic Element Lables (Reference Files)
rwlevels	EaseExistCenterline	Baseline:Centerline:Easement (Existing)
rwlevels	RWandLA_eLeader	Annotation:Leader:R/W & L/A (Existing)
rwlevels	RWandLA_eStaTie	Annotation:Station Tie:R/W & L/A Lines (Existing)
rwlevels	SubDivRW_eWidthArrow	Annotation:Arrow:Subdivision
survey_levels	CityLimitLine_ep	City Limit Line
survey_levels	CLPropConst_ep	Center Line Proposed Construction
survey_levels	CountyLine_ep	County Line
survey_levels	EasementPerp_ep	Easement Lines Perpetual (Existing)
survey_levels	EasementTemp_ep	Easements Temporary (Existing)
survey_levels	NorthArw_ep	North Arrows
survey_levels	PropLines_ep	Property Line / Lot Line
survey_levels	RailroadCL_ep	Railroad Center Line
survey_levels	SectCorner_ep	Section Corner, 1/4 Section Corner E or W, N or S
survey_levels	SectCornerQt_ep	Quarter Section Line
survey_levels	SectionLines_ep	Section Lines
survey_levels	Subdivision_ep	Subdivision Line
survey_levels	TownshipRange_ep	Township / Range Lines

Table 7. Right-of-Way and Survey Levels *Added* in 2008.

Design Library	Name	Description
rwlevels	ConstLimitsLeader	Annotation:Leader:Limits of Construction (Proposed)
rwlevels	ConstLimitsStaTie	Annotation:Station Tie:Limits of Construction (Proposed)
rwlevels	ConstLimitsText	Annotation:Text: Limits of Construction (Proposed)
rwlevels	EaseLine_ep	Easement:Easement Line (Existing)
rwlevels	EaseLineLeader_ep	Annotation:Leader:Easement (Existing)
rwlevels	EaseLineStaTie_ep	Annotation:Station Tie:Easement (Existing)
rwlevels	EaseLineText_ep	Annotation:Text:Easement Lines (Existing)
rwlevels	EaseLineWidthArrow_ep	Annotation:Arrow:Easement Width (Existing)
rwlevels	EaseLineCenterline_ep	Baseline:Centerline:Easement (Existing)
rwlevels	EaseLicLine	Easement:License (Proposed)
rwlevels	EaseLicLeader	Annotation:Leader:License (Proposed)
rwlevels	EaseLicStaTie	Annotation:Station Tie:License (Proposed)
rwlevels	EaseLicText	Annotation:Text:Easement Lines, License (Proposed)
rwlevels	EaseLicWidthArrow	Annotation:Arrow:License Width (Proposed)
rwlevels	EasePerpLine	Easement:Perpetual Easement Line (Proposed)
rwlevels	EasePerpLeader	Annotation:Leader:Easement Perpetual (Proposed)
rwlevels	EasePerpStaTie	Annotation:Station Tie:Easement Perpetual (Proposed)
rwlevels	EasePerpText	Annotation:Text:Easement Lines, Perpetual (Proposed)
rwlevels	EasePerpWidthArrow	Annotation:Arrow:Easement Perpetual Width (Proposed)
rwlevels	EaseTempLine	Easement:Temporary Easement Line (Proposed)
rwlevels	EaseTempLeader	Annotation:Leader:Easement Temporary (Proposed)
rwlevels	EaseTempStaTie	Annotation:Station Tie:Easement Temporary (Proposed)
rwlevels	EaseTempText	Annotation:Text:Easement Lines, Temporary (Proposed)
rwlevels	EaseTempWidthArrow	Annotation:Arrow:Easement Temporary Width (Proposed)
rwlevels	GovCityLimitHLine_ep	Government:City Limit Line (Hash Only)
rwlevels	GovCityLimitLine_ep	Government:City Limit Line
rwlevels	GovCountyLine_ep	Government:County Line
rwlevels	GovGrantLine_ep	Government:Grant Line
rwlevels	GovGreenLeaderWt0_ep	Annotation:Leader:Government (color = green)(weight = 0)
rwlevels	GovGreenLeaderWt2_ep	Annotation:Leader:Government (color = green)(weight = 2)
rwlevels	GovGreenStaTie_ep	Annotation:Station Tie:Government (color = green)
rwlevels	GovGreenTextWt0_ep	Annotation:Government Text Green Weight of 0
rwlevels	GovGreenTextWt2_ep	Annotation:Government Text Green Weight of 2
rwlevels	GovLotLine_ep	Government:Lot Line
rwlevels	GovMeanderLine_ep	Government:Meander Line
rwlevels	GovParkHLine_ep	Government:National or State Park or Forest Line (Hash Only)
rwlevels	GovParkLine_ep	Government:National or State Park or Forest Line
rwlevels	GovQtrQtrLine_ep	Government:Quarter / Quarter Section Line
rwlevels	GovQuarterLine_ep	Government:Quarter Section Line
rwlevels	GovRedLeaderWt0_ep	Annotation:Leader:Government (color = red)(weight = 0)
rwlevels	GovRedLeaderWt2_ep	Annotation:Leader:Government (color = red)(weight = 2)
rwlevels	GovRedStaTie_ep	Annotation:Station Tie:Government (color = red)
rwlevels	GovRedTextWt0_ep	Annotation:Government Text Red Weight of 0
rwlevels	GovRedTextWt2_ep	Annotation:Government Text Red Weight of 2
rwlevels	GovSectionLine_ep	Government:Section Line
rwlevels	GovStateLine_ep	Government:State Line
rwlevels	GovTwpRgeLine_ep	Government:Township and Range Government Survey Line
rwlevels	LARWLine	Proposed:Limited Access Right-of-way Line
rwlevels	LARWLine_ep	Existing:Limited Access Right-of-way Line
rwlevels	MaintLeader	Annotation:Leader:Maintenance

Table 7. Right-of-Way and Survey Levels *Added* in 2008 (Continued).

Design Library	Name	Description
rwlevels	MaintLine	Proposed:Maintenance Line
rwlevels	MaintStaTie	Annotation:Station Tie:Maintenance
rwlevels	MaintText	Annotation:Text: Maintenance
rwlevels	MaintWidthArrow	Annotation:Arrow:Maintenance Width (Proposed)
rwlevels	NonVehcLeader_ep	Annotation:Leader:Non Vehicular Access
rwlevels	NonVehcLine_ep	Existing:Non-Vehicular Access Line
rwlevels	NonVehcStaTie_ep	Annotation:Station Tie:Non Vehicular Access
rwlevels	NonVehcText_ep	Annotation:Text:Non-Vehicular Access (Existing)
rwlevels	PropertyLine_ep	Existing:Property Line
rwlevels	PropertyLineHook_ep	Cell:Miscellaneous:Property Line Hook
rwlevels	PropertyLineLeader_ep	Annotation:Leader:Property Line (Existing)
rwlevels	PropertyLineStaTie_ep	Annotation:Station Tie:Property Line (Existing)
rwlevels	PropertyLineSymbol_ep	Cell:Miscellaneous:Property Line Symbol
rwlevels	PropertyLineText_ep	Annotation:Text:Property Line (Existing)
rwlevels	RWLine	Proposed:Right-of-way Line
rwlevels	RWLine_ep	Existing:RW Line
rwlevels	RWandLA_Leader	Annotation:Leader:R/W & L/A (Proposed)
rwlevels	RWandLA_Leader_ep	Annotation:Leader:R/W & L/A (Existing)
rwlevels	RWandLA_StaTie	Annotation:Station Tie:R/W & L/A Lines (Proposed)
rwlevels	RWandLA_StaTie_ep	Annotation:Station Tie:R/W & L/A Lines (Existing)
rwlevels	RWandLA_Text	Annotation:Text:R/W & L/A Lines Taking Lines (Proposed)
rwlevels	RWandLA_Text_ep	Annotation:Text:R/W & L/A Lines (Existing)
rwlevels	RWandLA_WidthArrow	Annotation:Arrow:RW & LA Width (Proposed)
rwlevels	RWandLA_WidthArrow_ep	Annotation:Arrow:RW & LA Width (Existing)
rwlevels	SubDivRW_WidthArrow	Annotation:Arrow:Subdivision
rwlevels	TopoText_ep	Annotation:Text:Miscellaneous: All Other Topograhic Element Lables (Reference Files)
survey_levels	GuardrailDbl_ep	Guardrail Double Face
survey_levels	PavtMisc_ep	Pavement Parking Lot/Guardrail/Misc Pavement
survey_levels	CableBarrier_ep	Cable Barrier

Table 8. Right-of-Way and Survey Levels *Added* in 2012.

Design Library	Name	Description
survey_levels	ValveBFP_ep	Valve (Back Flow Preventer), Valve Box
survey_levels	Bollard_ep	Bollards

A review of the level structure revealed several critical characteristics that were relevant to the research because of their impact on the development of a database of right-of-way and utility feature classes. Relevant level structure characteristics include the following:

- The level number is a unique identifier only within a design library and may or may not be repeated in a different design library. For example, Level "0" (i.e., the default MicroStation level) appears in at least six design libraries. However, the level number can be used to identify level libraries and groups, based on FDOT's pre-defined range of levels (Table 9).

Table 9. FDOT's Assigned Ranges of Levels for Level Libraries.

Level Range	Level Library	Group
100-699	Common	
700-999	Photogrammetry	
1000-1499	Survey	
1500-1999	Right-of-way	
2000-3999	Structures	
5000-5499	Roadway	Plan View
5500-5749	Roadway	Traffic Control
5750-5999	Roadway	Geotech
6000-6499	Roadway	Cross-Sections
6500-6999	Roadway	Drainage
7000-7499	Roadway	Utilities
7500-7999	Roadway	Signing & Pavement
8000-8499	Roadway	Signals
8500-8999	Roadway	Lighting
9000-9499	Roadway	Landscape
9500-9999	Roadway	Drafting

- Although the groups in Table 9 were necessary, they were not sufficient. For example, in the case of utility installations, it was of interest to identify groups by type of utility (e.g., gas, sanitary sewer, gas, and so on). To facilitate this process, the research team imported the design library level data into Microsoft Access® and added feature class category and feature class type fields (and corresponding look up tables) to characterize each MicroStation level that involved right-of-way or utility elements. Table 10 shows the list of feature class categories, and Table 11 shows the list of feature class types. Notice that Table 11 includes a record for parcels to represent parcel polygons or shapes, which the research team developed as part of the project.

Table 10. Feature Class Categories.

Feature Class Category ID	Feature Class Category Name
1	Right-of-way
2	Utility
3	Null

Table 11. Feature Class Types.

Feature Class Type ID	Feature Class Type Name	Feature Class Category Name
1	Access	Right-of-way
2	Communication	Utility
3	Driveway	Right-of-way
4	Easement	Right-of-way
5	Electric	Utility
6	Fence	Right-of-way
7	Gas	Utility
8	License	Right-of-way
9	Monument	Right-of-way
10	Non-Potable Water	Utility
11	Petroleum	Utility
12	Property	Right-of-way
13	Right-of-way	Right-of-way
14	Sanitary Sewer	Utility
15	Sewer	Utility
16	Subdivision	Right-of-way
17	Undefined ROW	Right-of-way
18	Undefined Utility	Utility
19	Water	Utility
20	NULL	Null
21	Parcel	Right-of-way

- Different levels handle existing and proposed design features. However, not all proposed-feature levels have equivalent existing-feature levels, and not all existing-feature levels have equivalent proposed-feature levels. Something similar happens with the relationship between plan-view levels and cross-section levels. The lack of a comprehensive treatment for MicroStation levels introduces complexity in the analysis and modeling of existing and proposed features, including right-of-way and utility features.

- It was not possible to group certain utility levels into an appropriate utility type (e.g., water, sanitary sewer, and so on) because of the lack of sufficient descriptive information. Examples include "Vent," "Wood strain pole," and "Unknown valve box." For convenience, the research team created an "Undefined Utility Feature" feature class type in order to include these MicroStation level in the data model. Similarly, it was not possible to group certain right-of-way levels into an appropriate right-of-way type because of the lack of sufficient descriptive information. To include these levels in the data model, the research team created an "Undefined Right-of-way Feature" feature class type. During implementation, FDOT will need to formulate a plan to deal with these non-assigned MicroStation levels.

- There were unusual level names that could represent redundant design elements. For example, most water utility features start with the word "water," except for water valves, which start with the word "valves." There was also one case of a water utility feature that started with the word "utility." Similar cases were found for sanitary sewer levels. For the most part, these levels start with "sanitary," except for valves, which may or may not include the word "sanitary."

- There were several instances of MicroStation levels having the same (or a similar) name or description, both within the same or different design libraries. This could result in problems when comparing or running queries on levels across design libraries. For example, there are 27 duplicate levels (a total of 54 records) in the 2012 CAD standard. Of these, Table 12 shows 11 levels (a total of 22 records) where both level name and description were identical. Table 13 shows 16 duplicate feature classes (a total of 32 records) where the same level had different level descriptions. For example, "EaseLicLine" is described in the fdot_v8_levels design library as "License Agreement Line," and in the rwlevels design library as "Easement:License (Proposed)." Ideally, an element or object should belong to only one level across design libraries.

Table 12. Level Names with Identical Level Descriptions in 2012 Design Libraries.

ID	Level	Level Description	Design Library
209	AdhocPoint_dp	Adhoc Points Placed by SheetInfo	fdot_common_levels
1249	AdhocPoint_dp	Adhoc Points Placed by SheetInfo	strlevels
1490	CableBarrier_ep	Cable Barrier	survey_levels
1664	CableBarrier_ep	Cable Barrier	survey_levels
200	Default	Default MicroStation Level	fdot_common_levels
1106	Default	Default MicroStation Level	rwlevels
460	EaseLine_ep	Easement:Easement Line (Existing)	fdot_v8_levels
1113	EaseLine_ep	Easement:Easement Line (Existing)	rwlevels
552	GovCityLimitLine_ep	Government:City Limit Line	fdot_v8_levels
1132	GovCityLimitLine_ep	Government:City Limit Line	rwlevels
1133	GovCountyLine_ep	Government:County Line	rwlevels
553	GovCountyLine_ep	Government:County Line	fdot_v8_levels
554	GovQuarterLine_ep	Government:Quarter Section Line	fdot_v8_levels
1145	GovQuarterLine_ep	Government:Quarter Section Line	rwlevels
723	PayItem_dp	Pay Item Number Label Elements	fdot_v8_levels
1345	PayItem_dp	Pay Item Number Label Elements	strlevels
224	PlotBorder_dp	Plot Border	fdot_common_levels
1358	PlotBorder_dp	Plot Border	strlevels
821	RRBaseline	Baseline:Rail Road Centerline	fdot_v8_levels
1195	RRBaseline	Baseline:Rail Road Centerline	rwlevels
921	SubDivLine	Existing:Subdivision Line	fdot_v8_levels
1224	SubDivLine	Existing:Subdivision Line	rwlevels

Table 13. Level Names with Different Feature Class Descriptions in 2012 Design Libraries.

ID	Level	Level Description	Design Library
1096	ConstLimits	Proposed:Limits of Construction Line	rwlevels
374	ConstLimits	Construction Limits	fdot_v8_levels
1279	DrainMisc	Drain Miscellaneous Hardware	strlevels
439	DrainMisc	Miscellaneous Drainage Items	fdot_v8_levels
1109	EaseLicLine	Easement:License (Proposed)	rwlevels
459	EaseLicLine	License Agreement Line	fdot_v8_levels
1120	EasePerpLine	Easement:Perpetual Easement Line (Proposed)	rwlevels
461	EasePerpLine	Easement Lines Perpetual	fdot_v8_levels
463	EaseTempLine	Easement Lines Temporary	fdot_v8_levels
1125	EaseTempLine	Easement:Temporary Easement Line (Proposed)	rwlevels
1151	GovSectionLine_ep	Government:Section Line	rwlevels
555	GovSectionLine_ep	Section Lines	fdot_v8_levels
1153	GovTwpRgeLine_ep	Government:Township and Range Government Survey Line	rwlevels
556	GovTwpRgeLine_ep	Township / Range Lines	fdot_v8_levels
590	Guardrail	Guardrail	fdot_v8_levels
1306	Guardrail	Guardrail and Post, Thrie and W Beam	strlevels
655	LARWLine	Limited Access Right-of-way	fdot_v8_levels
1154	LARWLine	Proposed:Limited Access Right-of-way Line	rwlevels
656	LARWLine_ep	Limited Access Right-of-way (Existing)	fdot_v8_levels
1155	LARWLine_ep	Existing:Limited Access Right-of-way Line	rwlevels
798	PropertyLine_ep	Property Lines	fdot_v8_levels
1188	PropertyLine_ep	Existing:Property Line	rwlevels
1210	RWLine	Proposed:Right-of-Way Line	rwlevels
824	RWLine	Right-of-way Lines	fdot_v8_levels
825	RWLine_ep	Right-of-way Lines (Existing)	fdot_v8_levels
1211	RWLine_ep	Existing:RW Line	rwlevels
873	SignMisc	Miscellaneous Sign Symbols	fdot_v8_levels
1412	SignMisc	Sign Miscellaneous Plates and Hardware	strlevels
1445	TextNotes		strlevels
255	TextNotes	Text - Notes	fdot_common_levels
1458	Viewport	Viewport	strlevels
274	Viewport	Viewport (For AutoCAD Use)	fdot_common_levels

- The same level description may be used for different level names either in the same design library or in different design libraries. Table 14 shows 206 records where the same level description was used for two or more different levels in the 2012 design libraries. In most cases, the difference between two level names with the same description was the suffix "_ep" for a level in the survey_levels design library that appeared without the suffix in the fdot_v8_levels design library.

Table 14. Duplicate Level Descriptions in 2012 Design Libraries.

ID	Level	Level Description	Design Library
1594	Scratch1_dp	A scratch level for temporary or informational items	survey_levels
1595	Scratch2_dp	A scratch level for temporary or informational items	survey_levels
1390	Rebar9	Auxiliary Rebar	strlevels
1384	Rebar3	Auxiliary Rebar	strlevels
1383	Rebar2	Auxiliary Rebar	strlevels
1382	Rebar11	Auxiliary Rebar	strlevels
1381	Rebar10	Auxiliary Rebar	strlevels
1386	Rebar5	Auxiliary Rebar	strlevels
1385	Rebar4	Auxiliary Rebar	strlevels
1389	Rebar8	Auxiliary Rebar	strlevels
1388	Rebar7	Auxiliary Rebar	strlevels
1387	Rebar6	Auxiliary Rebar	strlevels
305	BarrierWall	Barrier Wall All Types	fdot_v8_levels
1480	BarrierWall_ep	Barrier Wall All Types	survey_levels
322	BoxCulvert	Box Culvert	fdot_v8_levels
1485	BoxCulvert_ep	Box Culvert	survey_levels
1486	Bridge_ep	Bridge	survey_levels
324	Bridge	Bridge	fdot_v8_levels
1295	FencePosts	Bridge Mounted Chain Link Fencing	strlevels
1296	Fencing	Bridge Mounted Chain Link Fencing	strlevels
327	Building	Buildings	fdot_v8_levels
1488	Building_ep	Buildings	survey_levels
1490	CableBarrier_ep	Cable Barrier	survey_levels
1664	CableBarrier_ep	Cable Barrier	survey_levels
330	CableBarrier	Cable Barrier	fdot_v8_levels
1494	CATVCond_ep	Cable TV Conduit System	survey_levels
342	CATVCond	Cable TV Conduit System	fdot_v8_levels
338	CATVAer	Cable TV Line (Aerial)	fdot_v8_levels
1492	CATV_ep	Cable TV Line (Aerial)	survey_levels
339	CATVBur	Cable TV Line (Buried)	fdot_v8_levels
1493	CATVBur_ep	Cable TV Line (Buried)	survey_levels
1091	ClipBorder	Cell:Miscellaneous:R/W Clip Border	rwlevels
1092	ClipBorderLine	Cell:Miscellaneous:R/W Clip Border	rwlevels
1093	ClipBorderOutside	Cell:Miscellaneous:R/W Clip Border	rwlevels
1500	ConcSlabs_ep	Concrete Slabs	survey_levels
357	ConcSlabs	Concrete Slabs	fdot_v8_levels
1020	XSShapeDep02_dp	Cross-Section Shape Dependent	fdot_v8_levels
1028	XSShapeDep10_dp	Cross-Section Shape Dependent	fdot_v8_levels
1027	XSShapeDep09_dp	Cross-Section Shape Dependent	fdot_v8_levels
1026	XSShapeDep08_dp	Cross-Section Shape Dependent	fdot_v8_levels
1025	XSShapeDep07_dp	Cross-Section Shape Dependent	fdot_v8_levels
1024	XSShapeDep06_dp	Cross-Section Shape Dependent	fdot_v8_levels
1023	XSShapeDep05_dp	Cross-Section Shape Dependent	fdot_v8_levels
1022	XSShapeDep04_dp	Cross-Section Shape Dependent	fdot_v8_levels
1021	XSShapeDep03_dp	Cross-Section Shape Dependent	fdot_v8_levels
1019	XSShapeDep01_dp	Cross-Section Shape Dependent	fdot_v8_levels
1030	XSShapeIndep02_dp	Cross-Section Shape Independent	fdot_v8_levels
1032	XSShapeIndep04_dp	Cross-Section Shape Independent	fdot_v8_levels

Table 14. Duplicate Level Descriptions in 2012 Design Libraries (Continued).

ID	Level	Level Description	Design Library
1029	XSShapeIndep01_dp	Cross-Section Shape Independent	fdot_v8_levels
1036	XSShapeIndep08_dp	Cross-Section Shape Independent	fdot_v8_levels
1033	XSShapeIndep05_dp	Cross-Section Shape Independent	fdot_v8_levels
1031	XSShapeIndep03_dp	Cross-Section Shape Independent	fdot_v8_levels
1034	XSShapeIndep06_dp	Cross-Section Shape Independent	fdot_v8_levels
1035	XSShapeIndep07_dp	Cross-Section Shape Independent	fdot_v8_levels
1038	XSShapeIndep10_dp	Cross-Section Shape Independent	fdot_v8_levels
1037	XSShapeIndep09_dp	Cross-Section Shape Independent	fdot_v8_levels
395	CurbRamp	Curb Cut Ramp	fdot_v8_levels
1504	CurbRamp_ep	Curb Cut Ramp	survey_levels
419	DrainDivides00	Drainage Divides	fdot_v8_levels
421	DrainDivides01	Drainage Divides	fdot_v8_levels
431	DrainDivides06	Drainage Divides	fdot_v8_levels
425	DrainDivides03	Drainage Divides	fdot_v8_levels
429	DrainDivides05	Drainage Divides	fdot_v8_levels
423	DrainDivides02	Drainage Divides	fdot_v8_levels
433	DrainDivides07	Drainage Divides	fdot_v8_levels
435	DrainDivides08	Drainage Divides	fdot_v8_levels
437	DrainDivides09	Drainage Divides	fdot_v8_levels
427	DrainDivides04	Drainage Divides	fdot_v8_levels
420	DrainDivides00_ep	Drainage Divides (Existing)	fdot_v8_levels
424	DrainDivides02_ep	Drainage Divides (Existing)	fdot_v8_levels
426	DrainDivides03_ep	Drainage Divides (Existing)	fdot_v8_levels
428	DrainDivides04_ep	Drainage Divides (Existing)	fdot_v8_levels
430	DrainDivides05_ep	Drainage Divides (Existing)	fdot_v8_levels
432	DrainDivides06_ep	Drainage Divides (Existing)	fdot_v8_levels
434	DrainDivides07_ep	Drainage Divides (Existing)	fdot_v8_levels
436	DrainDivides08_ep	Drainage Divides (Existing)	fdot_v8_levels
438	DrainDivides09_ep	Drainage Divides (Existing)	fdot_v8_levels
422	DrainDivides01_ep	Drainage Divides (Existing)	fdot_v8_levels
445	Driveway	Driveway (Drive, Lane, Turnouts)	fdot_v8_levels
1512	Driveway_ep	Driveway (Drive, Lane, Turnouts)	survey_levels
1574	Pond_ep	Edge of Water	survey_levels
1655	WaterEdge_ep	Edge of Water	survey_levels
470	ElectPSO	Electrical Outlet	fdot_v8_levels
1580	PowerElecOut_ep	Electrical Outlet	survey_levels
1516	FireHydrant_ep	Fire Hydrant	survey_levels
512	FireHydrant	Fire Hydrant	fdot_v8_levels
1524	Gauges_ep	Gauges	survey_levels
534	Gauges	Gauges	fdot_v8_levels
538	GeotechFillPatt1_px	Geotechnical Fill Pattern - (earth, wood, muck, concrete, rock, riprap) as defined in project	fdot_v8_levels
537	GeotechFillPatt1	Geotechnical Fill Pattern - (earth, wood, muck, concrete, rock, riprap) as defined in project	fdot_v8_levels
539	GeotechFillPatt2	Geotechnical Fill Pattern - clay, sand	fdot_v8_levels
540	GeotechFillPatt2_px	Geotechnical Fill Pattern - clay, sand	fdot_v8_levels
546	GeotechFillPatt5_px	Geotechnical Fill Pattern - coquina	fdot_v8_levels
545	GeotechFillPatt5	Geotechnical Fill Pattern - coquina	fdot_v8_levels
549	GeotechFillPatt7	Geotechnical Fill Pattern - gravel	fdot_v8_levels

Table 14. Duplicate Level Descriptions in 2012 Design Libraries (Continued).

ID	Level	Level Description	Design Library
550	GeotechFillPatt7_px	Geotechnical Fill Pattern - gravel	fdot_v8_levels
547	GeotechFillPatt6	Geotechnical Fill Pattern - limestone	fdot_v8_levels
548	GeotechFillPatt6_px	Geotechnical Fill Pattern - limestone	fdot_v8_levels
543	GeotechFillPatt4	Geotechnical Fill Pattern - sand	fdot_v8_levels
544	GeotechFillPatt4_px	Geotechnical Fill Pattern - sand	fdot_v8_levels
541	GeotechFillPatt3	Geotechnical Fill Pattern - shell	fdot_v8_levels
542	GeotechFillPatt3_px	Geotechnical Fill Pattern - shell	fdot_v8_levels
590	Guardrail	Guardrail	fdot_v8_levels
592	Guardrail_px	Guardrail	fdot_v8_levels
593	GuardrailDbl	Guardrail Double Face	fdot_v8_levels
1526	GuardrailDbl_ep	Guardrail Double Face	survey_levels
595	GuardrailLt	Guardrail Left	fdot_v8_levels
1527	GuardrailLt_ep	Guardrail Left	survey_levels
1528	GuardrailRt_ep	Guardrail Right	survey_levels
596	GuardrailRt	Guardrail Right	fdot_v8_levels
598	Handrail	Handrails	fdot_v8_levels
1530	Handrail_ep	Handrails	survey_levels
1628	Tower_ep	High Mast Light Poles or Towers, Transmission Tower, Antenna	survey_levels
946	Tower	High Mast Light Poles or Towers, Transmission Tower, Antenna	fdot_v8_levels
635	ITSDetail20	ITS Details	fdot_v8_levels
634	ITSDetail12	ITS Details	fdot_v8_levels
633	ITSDetail11	ITS Details	fdot_v8_levels
632	ITSDetail10	ITS Details	fdot_v8_levels
631	ITSDetail02	ITS Details	fdot_v8_levels
636	ITSDetail21	ITS Details	fdot_v8_levels
629	ITSDetail00	ITS Details	fdot_v8_levels
640	ITSDetail32	ITS Details	fdot_v8_levels
630	ITSDetail01	ITS Details	fdot_v8_levels
637	ITSDetail22	ITS Details	fdot_v8_levels
638	ITSDetail30	ITS Details	fdot_v8_levels
639	ITSDetail31	ITS Details	fdot_v8_levels
642	ITSEquip01	ITS Equipment Racks	fdot_v8_levels
643	ITSEquip02	ITS Equipment Racks	fdot_v8_levels
641	ITSEquip00	ITS Equipment Racks	fdot_v8_levels
1327	LightingArch	Lighting Architectural	strlevels
1328	LightingArch_h	Lighting Architectural	strlevels
674	ManholeElec	Manhole (Electric)	fdot_v8_levels
1544	ManholeElec_ep	Manhole (Electric)	survey_levels
1545	ManholeGas_ep	Manhole (Gas)	survey_levels
675	ManholeGas	Manhole (Gas)	fdot_v8_levels
1546	ManholeSS_ep	Manhole (Sanitary Sewer)	survey_levels
676	ManholeSS	Manhole (Sanitary Sewer)	fdot_v8_levels
677	ManholeSW	Manhole (Storm Water)	fdot_v8_levels
1547	ManholeSW_ep	Manhole (Storm Water)	survey_levels
1548	ManholeTel_ep	Manhole (Telephone)	survey_levels
678	ManholeTel	Manhole (Telephone)	fdot_v8_levels
1338	Metal Framing_h	Metal Framing	strlevels
1337	Metal Framing	Metal Framing	strlevels
1549	MeterElec_ep	Meter (Electric)	survey_levels

Table 14. Duplicate Level Descriptions in 2012 Design Libraries (Continued).

ID	Level	Level Description	Design Library
467	ElecMeter	Meter (Electric)	fdot_v8_levels
1551	MeterGas_ep	Meter (Gas)	survey_levels
532	GasMeter	Meter (Gas)	fdot_v8_levels
716	PatternLines3_dp	Pattern Lines for Cross-Sections alternate for side streets, critical xsections or drainage structures	fdot_v8_levels
715	PatternLines2_dp	Pattern Lines for Cross-Sections alternate for side streets, critical xsections or drainage structures	fdot_v8_levels
1365	PostTension	Post-Tensioning SteelStrands and Bars	strlevels
1367	PostTension2	Post-Tensioning SteelStrands and Bars	strlevels
1368	PostTension2_h	Post-Tensioning SteelStrands and Bars	strlevels
1369	PostTension3	Post-Tensioning SteelStrands and Bars	strlevels
1370	PostTension3_h	Post-Tensioning SteelStrands and Bars	strlevels
713	Overlay2_px	Proposed Overlay Layer for Cross-Sections	fdot_v8_levels
712	Overlay1_px	Proposed Overlay Layer for Cross-Sections	fdot_v8_levels
711	Overlay_px	Proposed Overlay Layer for Cross-Sections	fdot_v8_levels
800	PumpNonPet	Pump (Non Petroleum)	fdot_v8_levels
1584	PumpNonPet_ep	Pump (Non Petroleum)	survey_levels
275	Xreference_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
278	Xreference03_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
279	Xreference04_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
277	Xreference02_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
281	Xreference06_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
282	Xreference07_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
283	Xreference08_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
284	Xreference09_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
276	Xreference01_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
280	Xreference05_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
285	Xreference10_dp	Reference Files (For AutoCAD Use)	fdot_common_levels
824	RWLine	Right-of-way Lines	fdot_v8_levels
1397	RW_Line	Right-of-way lines	strlevels
1588	RipRap_ep	Rip Rap, Rubble	survey_levels
810	RipRap	Rip Rap, Rubble	fdot_v8_levels
236	SheetLinesMisc4_dp	Sheet Lines	fdot_common_levels
235	SheetLinesMisc3_dp	Sheet Lines	fdot_common_levels
234	SheetLinesMisc2_dp	Sheet Lines	fdot_common_levels
233	SheetLinesMisc1_dp	Sheet Lines	fdot_common_levels
232	SheetLines_dp	Sheet Lines	fdot_common_levels
909	Sprinkler	Sprinkler Head	fdot_v8_levels
1612	Sprinkler_ep	Sprinkler Head	survey_levels
933	TeleAer	Telephone Line (Aerial)	fdot_v8_levels
1621	Tele_ep	Telephone Line (aerial)	survey_levels
1573	PoleTel_ep	Telephone Pole	survey_levels
789	PoleTel	Telephone Pole	fdot_v8_levels
1623	TeleMisc_ep	Telephone Service Box, Booth or Pedestal	survey_levels
937	TeleMisc	Telephone Service Box, Booth or Pedestal	fdot_v8_levels
1265	CL_Major	Use as needed	strlevels
1266	CL_Minor	Use as needed	strlevels
981	ValveCvrEff	Valve Cover (Effluent)	fdot_v8_levels
1640	ValveCvrEff_ep	Valve Cover (Effluent)	survey_levels

ID	Level	Level Description	Design Library
1641	ValveCvrGas_ep	Valve Cover (Gas)	survey_levels
982	ValveCvrGas	Valve Cover (Gas)	fdot_v8_levels
983	ValveCvrSewer	Valve Cover (Sewer)	fdot_v8_levels
1642	ValveCvrSewer_ep	Valve Cover (Sewer)	survey_levels
984	ValveCvrWater	Valve Cover (Water)	fdot_v8_levels
1643	ValveCvrWater_ep	Valve Cover (Water)	survey_levels
990	Vaults	Vaults Above Grade and Below Grade	fdot_v8_levels
1649	Vault_ep	Vaults Above Grade and Below Grade	survey_levels
994	VentGas	Vent (Gas)	fdot_v8_levels
1651	VentGas_ep	Vent (Gas)	survey_levels
995	VentSewer	Vent (Sewer)	fdot_v8_levels
1652	VentSewer_ep	Vent (Sewer)	survey_levels
989	ValveWaterNP	Water Line Non Potable	fdot_v8_levels
985	ValveCvrWaterNP	Water Line Non Potable	fdot_v8_levels
1004	WaterNP	Water Line Non Potable	fdot_v8_levels

- The level name is not always sufficiently descriptive to identify the features contained in its class. An alternative is to use the level description for the purpose of modeling features in a database environment. However, there were difficulties with this approach because of issues such as the following:

  o Level descriptions that include special characters, e.g., &, :, /, (, and), which can be problematic for database modeling purposes.
  o Lack of consistency and redundant use of singular and plural level descriptions, e.g., "ROW Line" and "ROW Lines."
  o Inconsistent use of certain level name qualifiers, e.g., using "aerial" for some levels and "overhead" for other levels, or not using "aerial" or "overhead" for all above-ground installations. A similar situation occurs for buried or underground installations.
  o Spelling and capitalization inconsistencies. Examples are inconsistencies in the way abbreviations and descriptors are used, e.g., ROW versus RW or R/W, With versus w/, Misc. vs. Miscellaneous, (Existing) versus – Existing, Elec. versus electric or electrical, and Junct. versus junction.

- Inconsistent use of the term "Utility" to refer to utility installations.
- Absence of a specific level to handle parcel polygons or shapes.

FDOT MicroStation Rules

To check CAD file compliance with FDOT standards, FDOT has developed a mechanism that checks each MicroStation file for compliance with the standards. Whenever a project design file is opened or closed within the FDOT MicroStation workspace, a quality control script called QC Inspector checks the file's compliance with FDOT symbology standards and presents a compliance metric to the user. For each element in the design file, the script checks whether the level exists in the appropriate design library. The percentage compliance metric is the number of

elements in the design file that have a valid level name (as defined in the appropriate design library) divided by the total number of elements in the design file.

A higher standard applies for levels with design elements that will be shared across disciplines or that will be used for quantity calculations for pay items. In the rule files, these levels are marked as "critical" levels. If the design element is on a level that FDOT has marked as "critical," the script checks (in addition to the level name) whether the level's line color, line weight, and line style follow the FDOT symbology standard. All 172 levels in the right-of-way design library (rwlevels.dgnlib) are critical levels. For the FDOT 2012 MicroStation workspace installation, the parameters for QC checks are stored in 38 separate rule files (.rul), as shown in Table 15. In general, more than one rule file may apply for a design file that was created using a particular design library.

Table 15. FDOT Standard Rules.

Standard Rule	Rule Description
ALGNRD	Alignment Design
AUTOSP	AutoTURN
CLIPRD	Clip Border
DRDTRD	Drainage Detail
DREXRD	Existing Drainage
DRMPRD	Drainage Mapping
DRPRRD	Drainage Proposed
DRXSRD	Drainage Cross-Section
DSGNLD	Landscaping
DSGNLT	Lighting
DSGNRD	Roadway Design
DSGNSG	Signalization
DSGNSP	Signing & Pavement Marking
DTMRD	Digital Terrain
GEOTECH	Geotechnical
GSWKSP	GuidSIGN
IRRGLD	Irrigation
ITSSP	Intelligent Transportation System
KEYSHT	Key Sheets
MRARSP	Mast Arm Details
OPEN	All Levels and Symbology Accepted
PDXSRD	Pond Cross-Section
PLANRD	Roadway Plan Sheet
PLPRRD	Roadway Plan/Profile Sheet
QTDSRD	Quantity Computation
RDXSRD	Roadway Cross-Section
RDXSSP	Signing & Pavement Cross-Section
RWDTRD	Right-of-Way Detail for Roadway
RWENG10	Right-of-Way
SPST10	Structural
TCDSRD	Traffic Control
TOPORD	Existing Topography
TOPORW	Existing Topography
TYPDRD	Typical Section

Table 15. FDOT Standard Rules (Continued).

Standard Rule	Rule Description
TYPSRD	Typical Section
UTADRD	Utilities Adjustment
UTEXRD	Existing Utilities
UTPRRD	Utilities Proposed

In addition to the compliance metric, the quality control mechanism can provide a detailed listing of design elements that do not follow FDOT standards, along with a description of the error. Table 16 shows a few records from a report that was created for an FDOT right-of-way map that consisted of 3661 design elements (text, lines, points, and so on). Of these elements, 1439 did not follow the FDOT design standard, resulting in a compliance rate of 60 percent (calculated as (3661–1439)/3661). In addition to this metric, the QC report provided a detailed listing of the design element and the error associated with each of the 1439 highlighted errors.

In practice, these reports were interesting as a reference but were difficult to use. As a result, the research team developed a script to summarize the detailed QC report in one of two ways: a compact version and a compact expanded version. Table 17 shows a sample of the compact expanded report, which groups errors of the same type and provides a total count. For example, Table 16 shows several lines that were on an invalid level called "PropLineLeaderExist." Table 17 shows only one record with the invalid level name, and a count of design elements with that error. As a result, the report included only 51 records.

Table 16. Sample QC Inspector Report

Filename:	..\rwdetl04.dgn			
Compliance:	60% Critical File (1439 errors(s) out of 3661 elements checked)			
Rule:	rweng10			
Last Modified By:	sm559sj			
Last Modified Date:	7/21/2011 3:03:32 PM			
***** Errors				
Element Type (Level/Model)	**Invalid Level**	**Invalid Color**	**Invalid Weight**	**Invalid Line Style**
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (SubVacOrigLotStaTie / Default)				arrowtie
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (PropLineLeaderExist / Default)	PropLineLeaderExist			
LineString (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (PropertyLine_ep / Default)				2
Line (PropertyLine_ep / Default)				2
Line (PropertyLine_ep / Default)				2
LineString (PropLineLeaderExist / Default)	PropLineLeaderExist			
LineString (PropLineLeaderExist / Default)	PropLineLeaderExist			
Line (SubVacOrigLotStaTie / Default)				arrowtie
Line (BuildingStaTie / Default)				arrowtie
Line (BuildingStaTie / Default)				arrowtie
…				

Table 17. Sample Compact Expanded QC Inspector Report.

Filename:	..\rwdetl04.dgn				
Compliance:	60% Critical File (1439 errors(s) out of 3661 elements checked)				
Rule:	rweng10				
Last Modified By:	sm559sj				
Last Modified Date:	7/21/2011 3:03:32 PM				
*****Errors					
Element Type (Level/Model)	**Level Name**	**Invalid Level**	**Invalid Color**	**Invalid Weight**	**Invalid Line Style**
Line	PropLineLeaderExist	13			
Line	SubVacOrigLotStaTie				2
Line	PropertyLine_ep				5
Line	BuildingStaTie				4
Line	ScratchLevel3				3
Line	RWandLA_Leader				2
Line	EaseLineLeader_ep				3
Line	2	37			
Line	10	2			
Line	15	1			
Line	16	4			
Line	SubVacOrigLotLeader				7
Line	RW_pLine	4			
Line	RW_LineExist	2			
…					

The compact option of the report is shown in Table 18. This report lists the number of symbology errors (i.e., invalid level, invalid line color, invalid line weight, and invalid line style) by element type, e.g., text, line, arc, curve, or complex shape. This report reduces the number of records to 15, by further grouping the errors without showing the invalid level of the design element. For example, record (or line) four of the report shows that there were 63 line elements in the design file on invalid levels, which includes the 13 line elements on level "PropLineLeaderExist" mentioned above. Record (or line) five shows that, in addition, there were 26 line elements that were on levels with a correct name but with an invalid line style.

Table 18. Sample Compact QC Inspector Report.

Filename:	..\rwdetl04.dgn			
Compliance:	60% Critical File (1439 errors(s) out of 3661 elements checked)			
Rule:	rweng10			
Last Modified By:	sm559sj			
Last Modified Date:	7/21/2011 3:03:32 PM			
*****Errors				
Element Type (Level/Model)	**Invalid Level**	**Invalid Color**	**Invalid Weight**	**Invalid Line Style**
Text				63
LineString				94
LineString	1072			
Line	63			
Line				26
Arc				2
Curve	95			
BsplineCurve	2			
ComplexShape	1			
Ellipse	2			
Arc	5			
TextNode	8			
Text	5			
Text		1		
Text			1	

Information about Parcels in MicroStation

FDOT design sheets show information about property interests that FDOT is planning to acquire for a highway project. Parcels (also known as takings) are represented visually in MicroStation files using linear features, more specifically the existing right-of-way line, the proposed right-of-way line, and existing property lines (Figure 3, Figure 4). To avoid clutter, files typically do not show or highlight parcels using shaded areas. Although useful for the purpose of the design file, this practice can make it difficult to determine the boundaries of parcels on design files, especially for stakeholders who may not be familiar with FDOT design files or CAD standards. A shaded area (Figure 5) would be useful to address this problem.
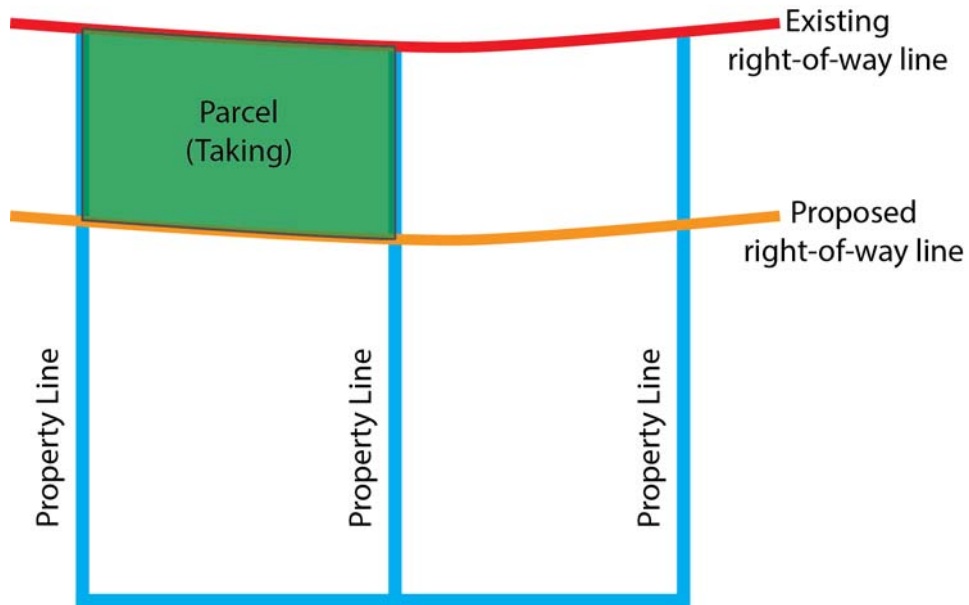
Figure 3. Conceptual Representation of a Right-of-Way Parcel.
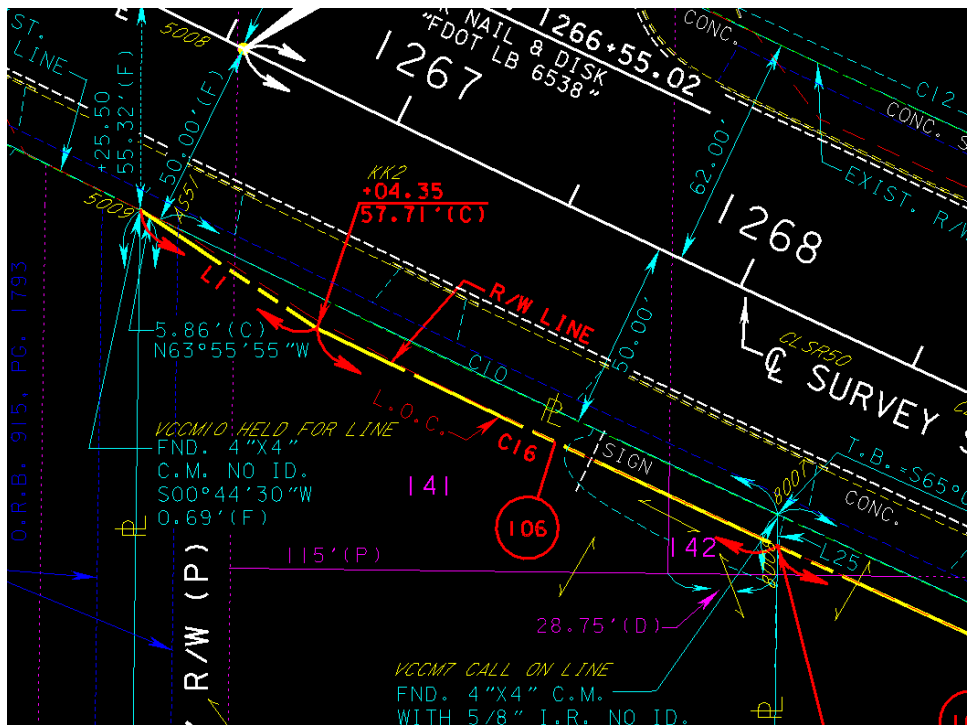
Figure 4. Sample FDOT Design Drawing with Property Parcels.
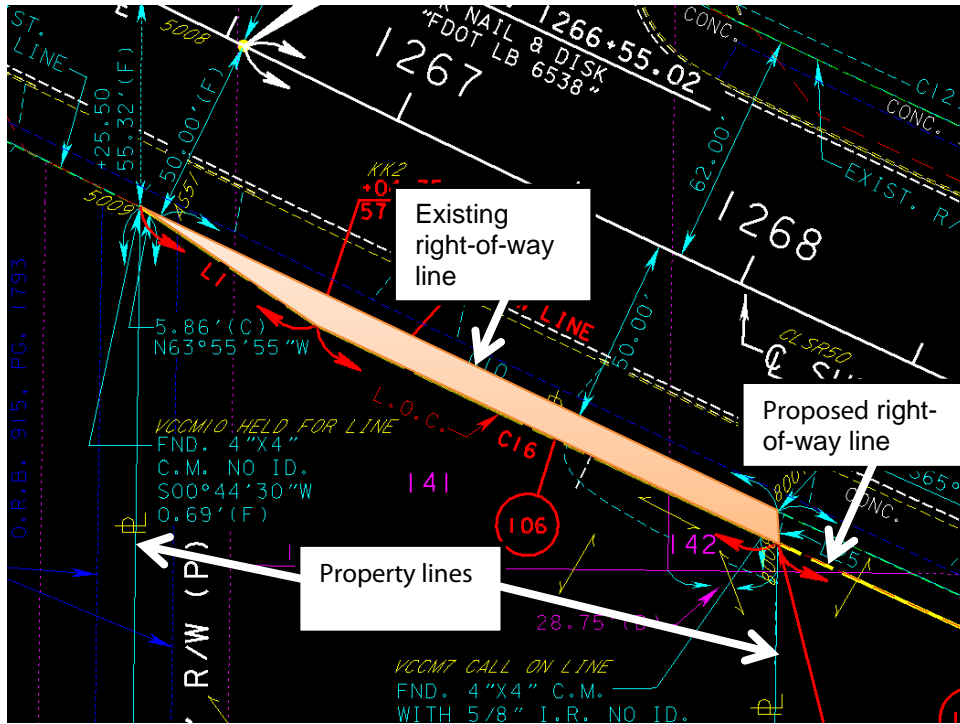
Figure 5. Boundary of Property Parcel 106 in FDOT Sample Design Drawing.

Because MicroStation design files do not use shapes or polygons to represent parcels, it is not straightforward to extract parcel information from MicroStation and display this information as polygons within a GIS. For example, Figure 6 provides a screenshot of the design file in Figure 4 after it was imported into ArcGIS. It shows that the parcel does not exist as a polygon. To assemble a polygon, it would be necessary to identify and merge the correct set of polylines that form the boundary of the parcel.
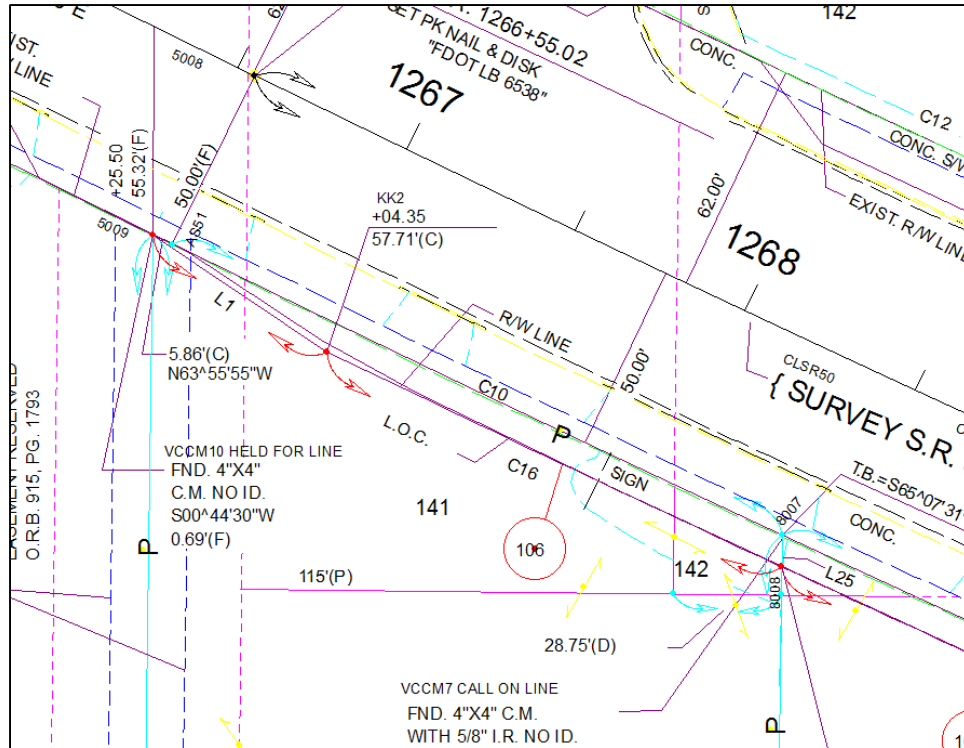
Figure 6. Sample FDOT Design Drawing with Property Parcels after Import to GIS.

ArcGIS stores design element information automatically in five default feature classes: Annotation, Point, Polyline, Polygon, and MultiPatch. ArcGIS can also read and store some of the attribute data for each design element. For example, Figure 7 shows the attributes of a property line highlighted in green. The property was stored as a Polyline element with a feature ID (FID) of 1306. Level, layer, color, line type, elevation, and line weight are imported attributes from the MicroStation file.
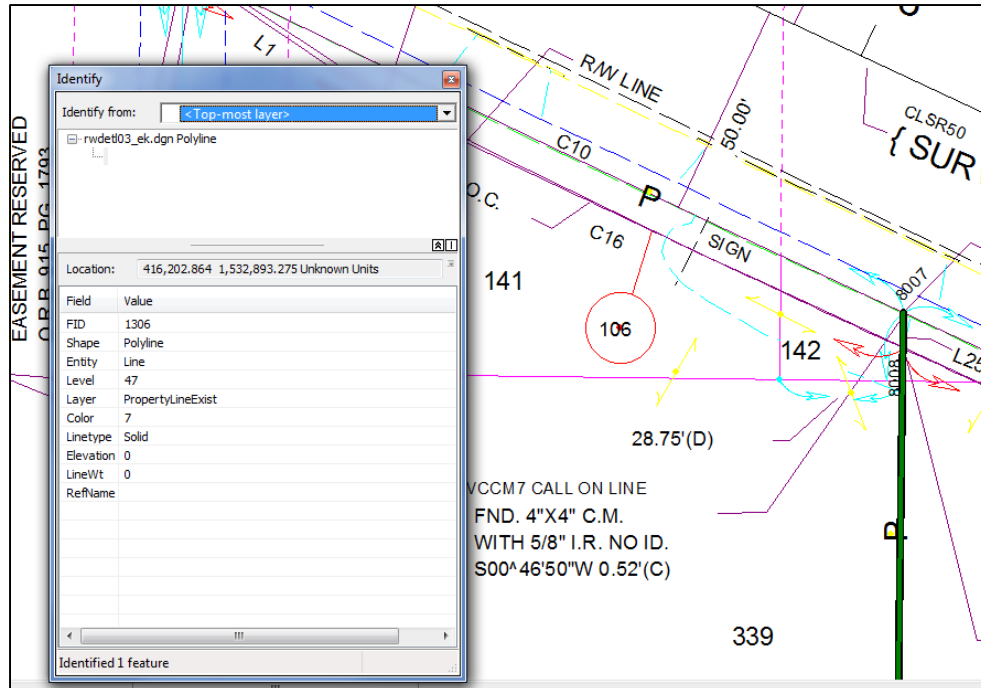
Figure 7. Imported Design Drawing Data in ArcGIS: Property Line (Highlighted).

Information about Utility Installations in MicroStation

Utility information is stored in MicroStation files in a format that makes it easier to import into ArcGIS than right-of-way parcels because different types of utility features tend to use different MicroStation levels. This simplifies the task to identify certain types of utility installations. Figure 8 provides a screenshot of an FDOT design file showing several utility installations. Figure 9 highlights the location of a buried fiber optic line in the same design file.

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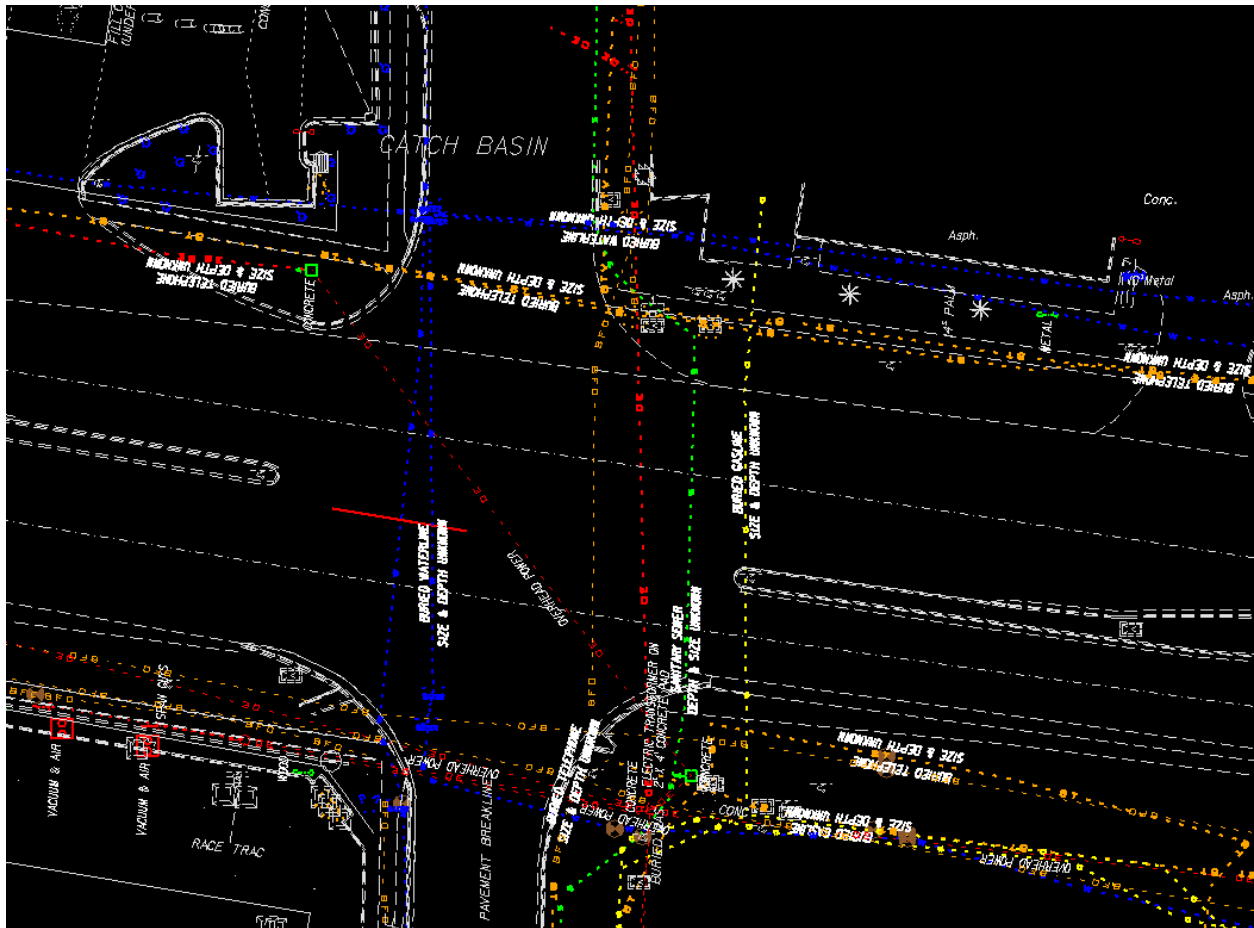
Figure 8. Sample Utility Installations in MicroStation File.
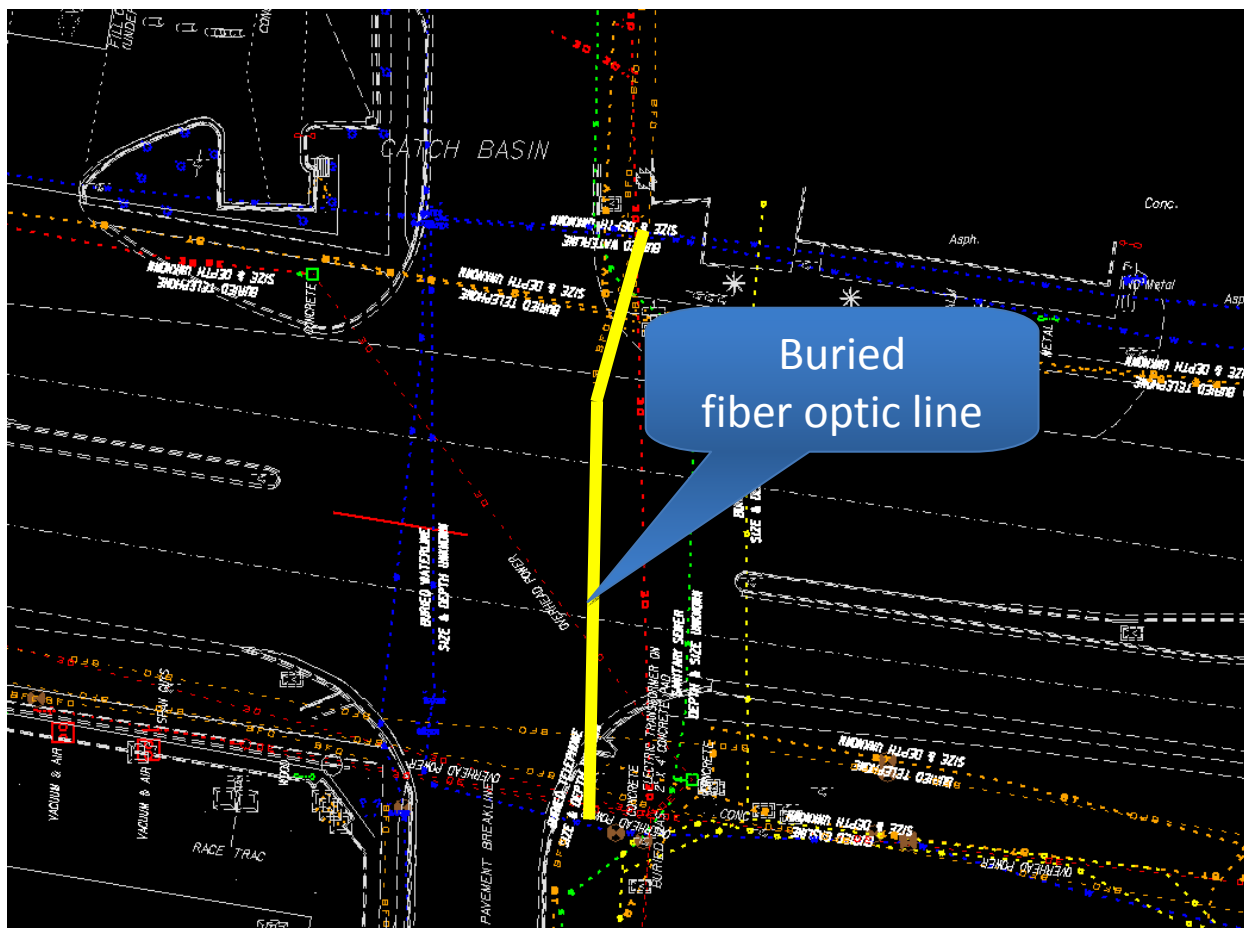
Figure 9. Sample Utility Installations in MicroStation File (Buried Fiber Optic Line Highlighted).

Figure 10 shows a screenshot of the design file after importing the file into ArcGIS. In general, loading a MicroStation file into ArcGIS generates features for all graphical elements, as long as these elements are physically stored in the MicroStation file. Reference files are not imported into ArcGIS. For example, the median shown in Figure 9 is not shown in Figure 10. The reason is that the median design elements in the MicroStation file are actually stored in a reference file.

At the same time, ArcGIS imports all features in the MicroStation file, including features that are not set to "visible" in MicroStation. A MicroStation file might *look* clean because undesired design elements are on levels that are not displayed. However, importing the file into ArcGIS brings in all design elements, regardless of visibility status.
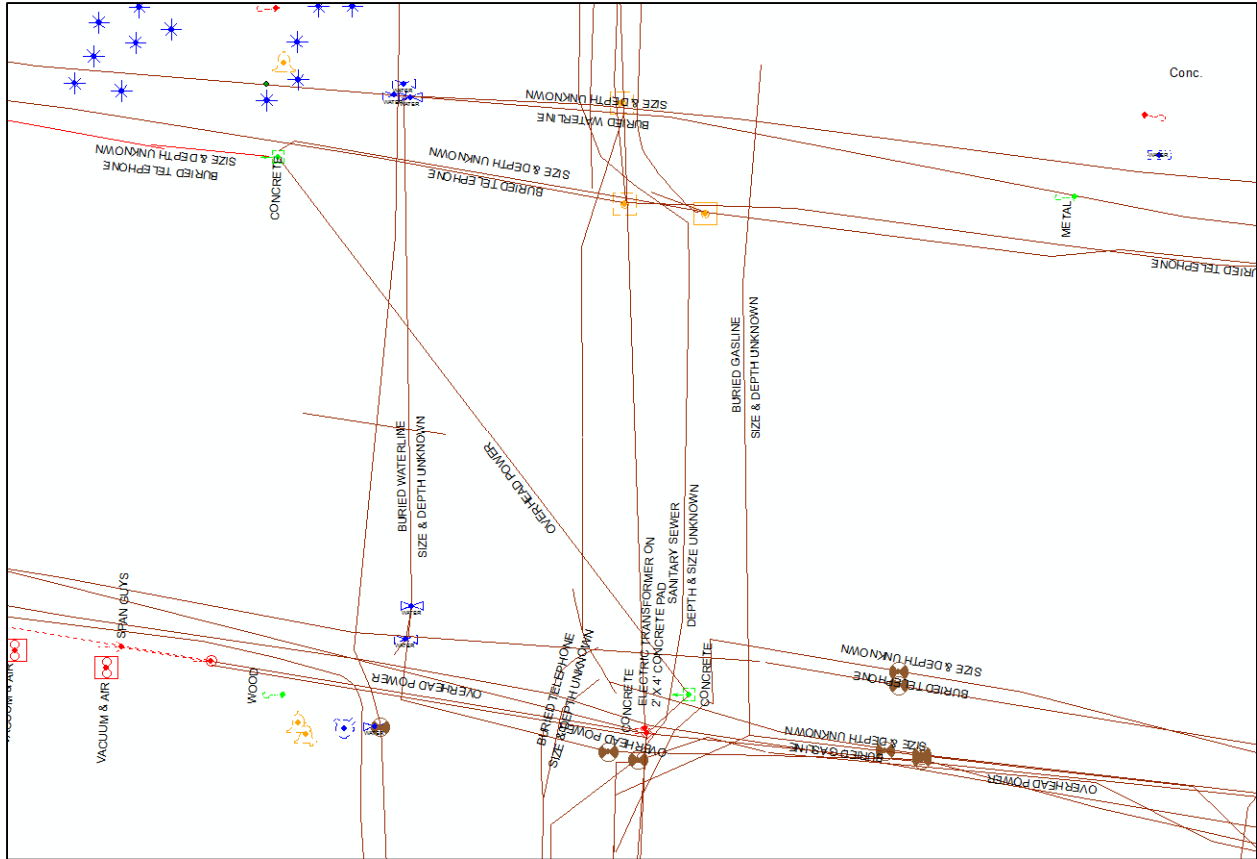
Figure 10. Sample Utility Design Elements after Importing to ArcGIS.

Importing utility design elements to ArcGIS also imports MicroStation attributes, as shown in Figure 11. The figure shows the attributes of the buried fiber optic line that was highlighted in Figure 9. Note that the fiber optic line is stored in ArcGIS as several polyline elements, one of which is highlighted in Figure 11. The element has a feature ID of 2520.
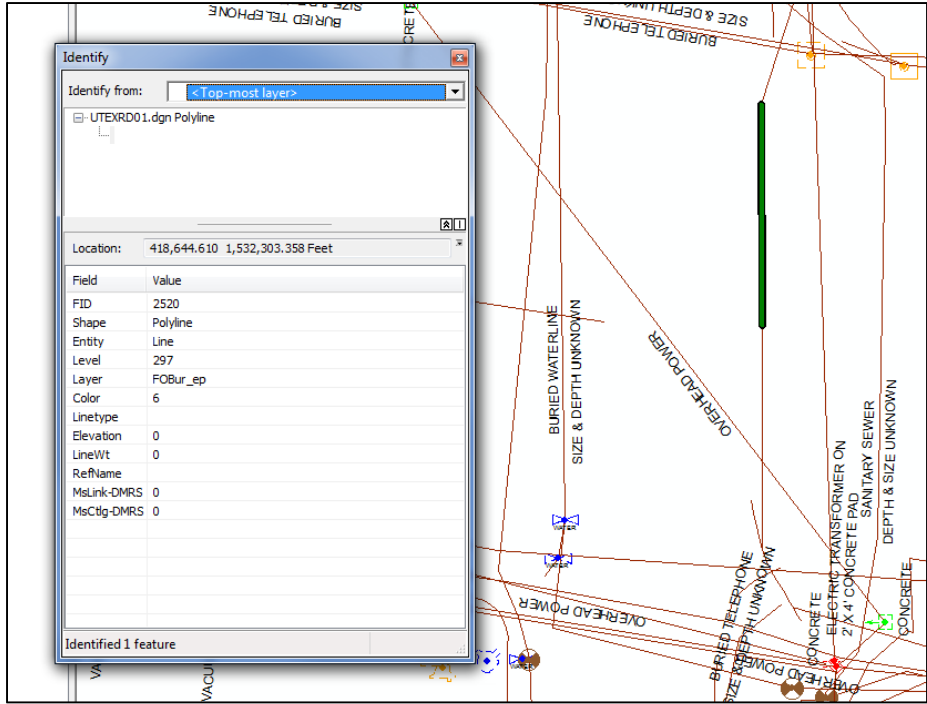
Figure 11. Sample Utility Design Element Data in ArcGIS.

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CHAPTER 3. DATA MODELING APPROACHES

INTRODUCTION

This chapter summarizes the work completed to assess potential data modeling approaches for right-of-way and utility data, with a focus on the extraction of MicroStation features into an ArcGIS environment. It also includes a description of the data modeling strategy the research team developed to extract sample parcel and utility features. Chapter 4 discusses the results of the data extraction tests conducted.

RIGHT-OF-WAY PARCEL DATA MODELING TRENDS

There is a wide range of right-of-way asset management practices at state DOTs around the country (*10*, *11*). Typically, agencies maintain right-of-way asset data using paper records, spreadsheets, various engineering software systems, desktop databases, and custom-built applications. In most cases, parcels are identified by using a unique parcel ID which may be unique within a project, but not necessarily across the enterprise. For visualization purposes, some state DOTs generate shaded areas or shapes within their CAD environment to highlight the location of the parcels they are acquiring. However, this is not a universal practice. In some cases, agencies maintain electronic copies of those shaded areas or shapes, but, in general, these elements are not included in as-built drawings or official engineering records. The official parcel record is still the deed and other supporting documents such as survey plats and property descriptions that an authoritative agency maintains.

In general, state DOTs are only beginning to explore the use of geospatial platforms to develop or maintain inventories of their right-of-way assets. However, there is not a generalized or universally accepted data model for the inventory of these assets. As part of a previously completed research project for TxDOT, the research team prepared a literature review of parcel and cadastral data modeling approaches (*12*). An update of relevant aspects of this literature review follows.

National Integrated Land System (NILS)

NILS is a Public Land Survey System (PLSS)-based land management system for the collection, management, and sharing of survey data, cadastral data, and land record data, which involves the Bureau of Land Management (BLM) and other stakeholders (*15*). NILS includes a PLSS data model and four software modules:

- **Survey Management**. This module supports the capture and processing of field data.

- **Measurement Management**. This module enables the combination of measurement data from a variety of sources into an integrated PLSS network.

- **Parcel Management**. This module provides GIS-based feature classes, tools, and procedures for editing land records.

- **GeoCommunicator**. This module is a Web portal for sharing information, which includes a Web-based mapping interface and a map service that enables users to overlay BLM-hosted data layers on client GIS applications.

Federal Geographic Data Committee (FGDC) Cadastral Data Standard

The FGDC Cadastral Data Content Standard provides semantic definitions of objects related to land surveying, land records, and landownership information (*16*). The model provides feature and attribute definitions for elements such as cadastral data, parcels, rights and interests, and restrictions. In the standard, a parcel is "a single cadastral unit, which is the spatial extent of the past, present, and future rights and interests in real property." Similarly, rights and interests are "the benefits or enjoyment in real property that can be conveyed, transferred, or otherwise allocated to another for economic remuneration." Restrictions capture "information related to administrative, judicial, or other limitations or permissions for the use and enjoyment of land by the land right holder." The model treats parcels as spatial data elements, whereas rights and interests as well as restrictions are non-spatial data elements that affect parcels.

The standard includes several logical-level entity-relationship (ER) diagrams that describe entity names and relationships among entities. As an illustration, Figure 12 shows the ER diagram for the parcel subject area. The model is generic in that it is not tied to any specific GIS architecture or database platform. The model provides basic attribution for parcel data, including parcel ID, actual and legal area, parcel transactions, restrictions, and rights and interests. The model includes the following interest and restriction subtypes: separated rights (e.g., mineral rights), encumbrances (e.g., easements, grazing rights, fishing rights, development rights, floodplains, liens, leases, or mortgages), and tribal interests.

A subset of the Cadastral Data Content Standard is the Cadastral National Spatial Data Infrastructure (NSDI), which includes a minimum set of attributes about land parcels to facilitate the distribution of cadastral information (*17*). The Cadastral NSDI has two components: cadastral reference and parcels. The cadastral reference provides elements that are necessary for querying, mapping, and navigation purposes, including information about the survey system used. Parcels contain information about a piece of property and its characteristics. Parcels may be polygons or points with enough attribute information to link the spatial component to attribute data produced externally. On federally managed public lands, parcels include information about grazing leases, mineral surveys, and use authorizations. On private lands, parcels are typically tax parcels, which may include additional information about restrictions such as easements.
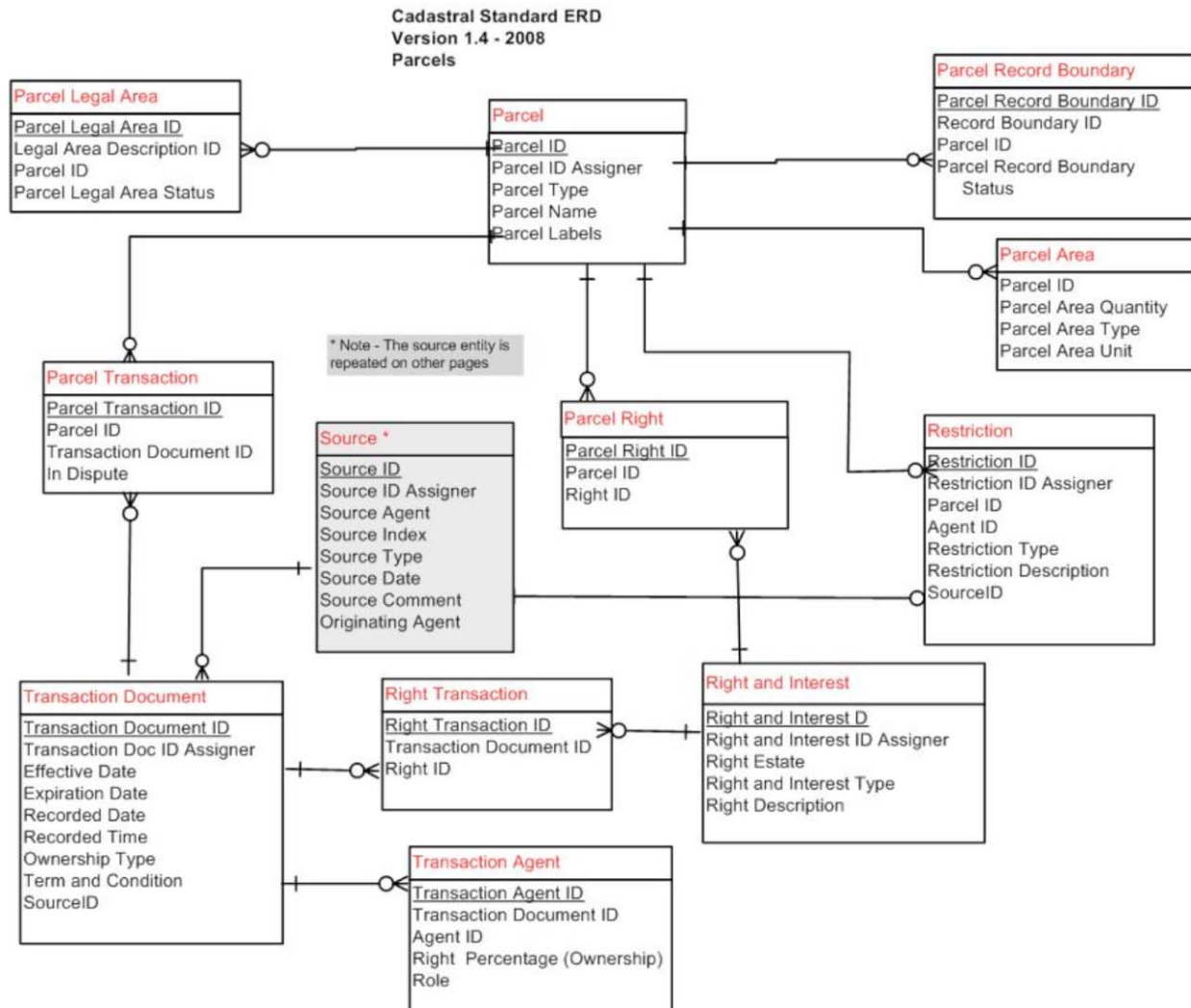
Figure 12. FGDC Cadastral Data Content Standard ER Diagram – Parcel Subject Area (*16*).

ArcGIS™ Local Government Information Model

The ArcGIS Local Government Information Model is a data model that enables the representation of a wide range of features and layers of interest to local jurisdictions (*18*). One of these areas is land records, which includes feature classes such as owner parcels, tax parcels, and encumbrances. Each of these spatial entities includes all the basic attributes needed to characterize the entities. The Local Government Information Model was introduced in ArcGIS 10.

NCHRP Projects 8-55 and 8-55A

National Cooperative Highway Research Program (NCHRP) projects 8-55 and 8-55A were undertaken to identify data elements to include in a spatial data model for a right-of-way information system (*11*). The modeling approach was to use a spatial entity to manage parcels (in the form of spatial cadastral data obtained from the tax assessor's office or equivalent) and a spatial entity to manage highway project alignments (obtained from project alignment and project end data). Non-spatial entities are linked to the parcel and project entities using one-to-many relationships to handle different aspects or activities of the right-of-way management process. For example, the initial parcel review activity includes project ID and parcel ID as the primary key as well as estimated value, complexity, and appraisal requirement as attributes. Likewise, the lease agreement activity includes project ID and parcel ID as the primary key as well as tenant ID, date of lease, term of lease, personal liability insurance, and lease agreement as attributes.

TxDOT Research Project 0-5788

The purpose of TxDOT Research Project 0-5788 (Right-of-Way Real Property Asset Management Architecture) was to develop a prototype data architecture to facilitate the inventory and management of TxDOT right-of-way assets (*12*). As part of the project, the researchers evaluated right-of-way data practices at TxDOT and other agencies, and developed and tested a prototype GIS-based right-of-way asset data model.

As Figure 13 shows, property rights in Texas are frequently separated from the parcel. In fact, for decades, TxDOT has not acquired mineral rights when acquiring right-of-way for transportation projects. Strictly speaking, it may be possible for some property rights to have a different spatial outline from that of the original parcel. At the highest level, managing right-of-way assets systematically involves managing four types of data: data about features on the ground (normally on the state right-of-way); data about right-of-way asset documents; data about projects; and data about users who may need to interact with features, documents, or projects. As Figure 14 shows, the relationships among features, projects, documents, and users are many to many. Figure 15 shows a view of the corresponding logical data model.

The researchers used a standalone database environment (Microsoft Access), a standalone GIS environment (ArcGIS), and a Web-based environment (Internet Explorer) to test the right-of-way asset data model database design. As an illustration, Figure 16 and Figure 17 show sample views of the Web-based environment, which enables the retrieval of feature- and project-related documents using tabular and/or map views. Figure 16 outlines sheet layouts (including project sheets and right-of-way map outlines) for a sample project in the San Antonio area. Figure 17 includes a zoomed-in view that shows parcels and a customized version of the ArcGIS Identify tool, which displays attribute data, linkages to documents, and metadata for any parcel selected.
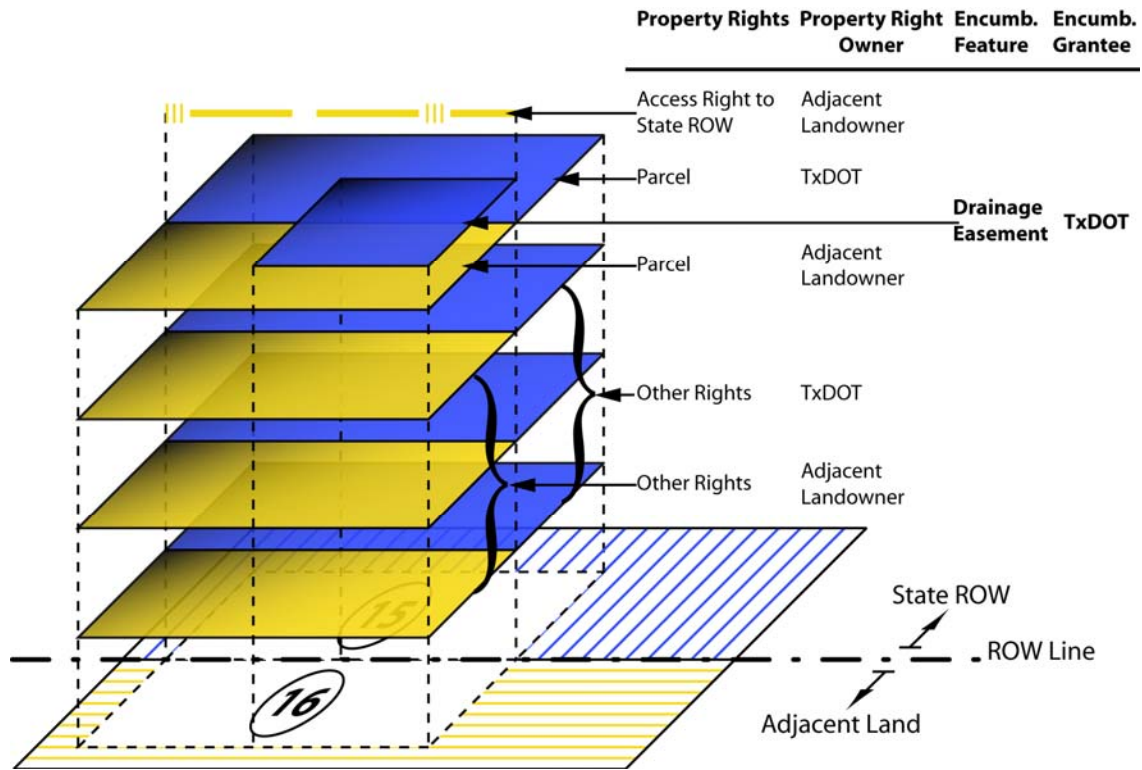
Note: Blue represents TxDOT ownership; yellow represents ownership by others.

Figure 13. Easement Encumbrance on Privately Owned Property Right Feature.
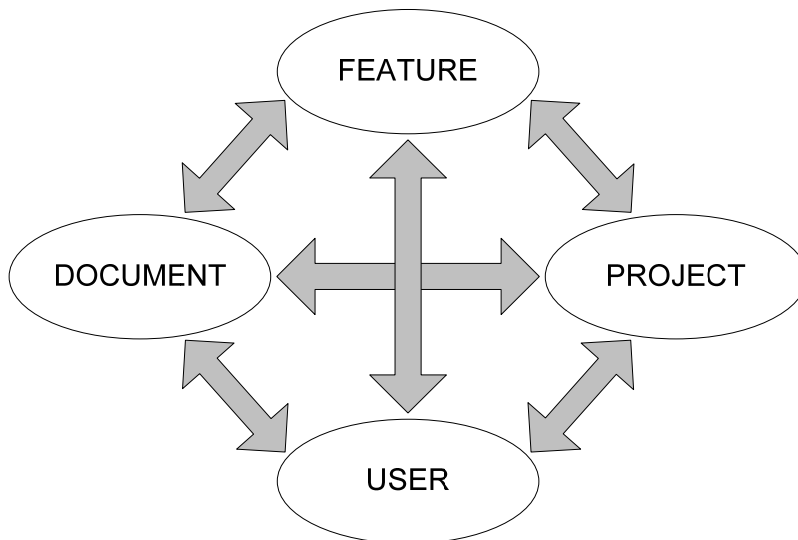
Figure 14. Right-of-Way Asset Data Model – Conceptual Design.
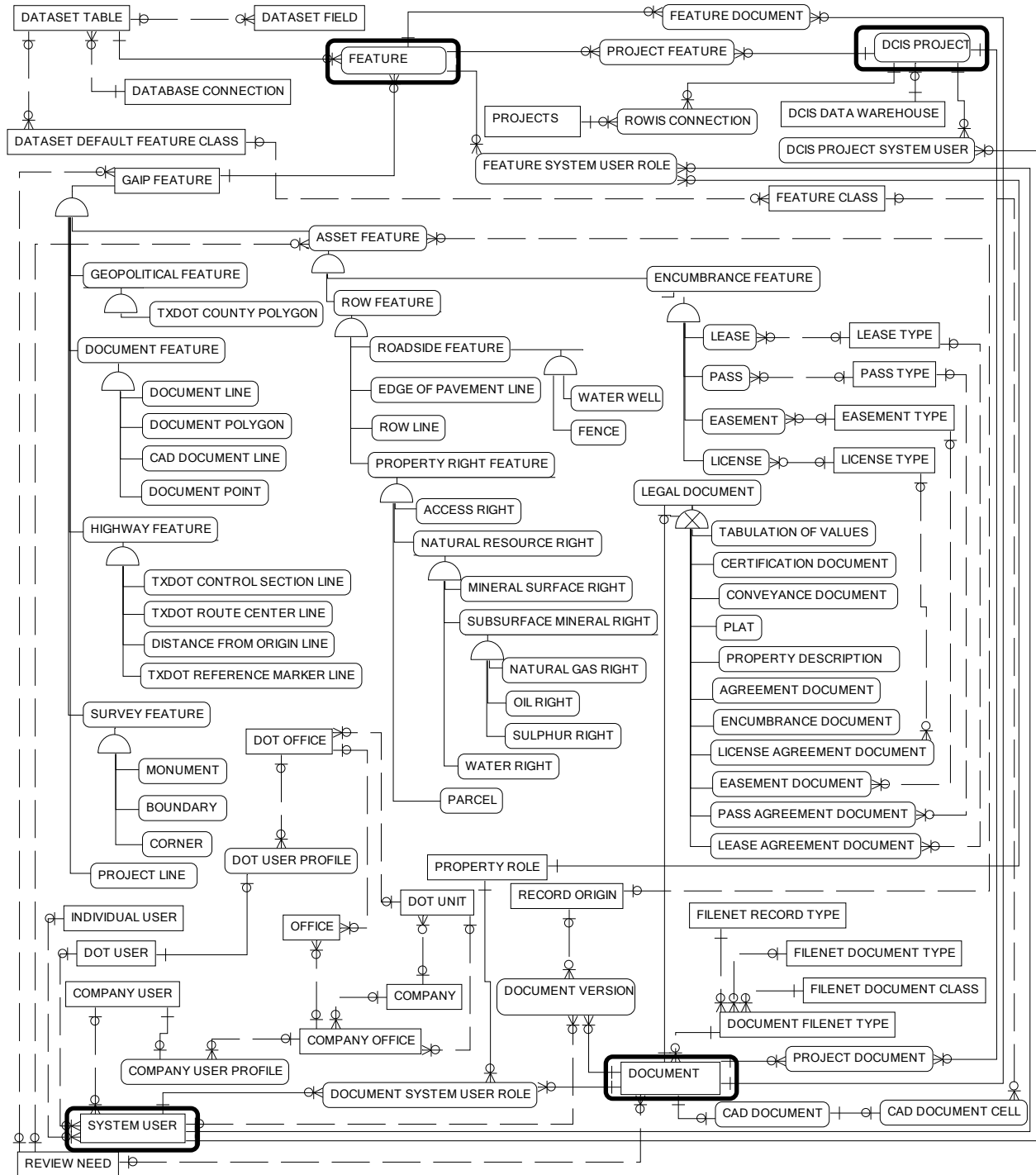
Figure 15. Right-of-Way Asset Data Model – Entity Overview.
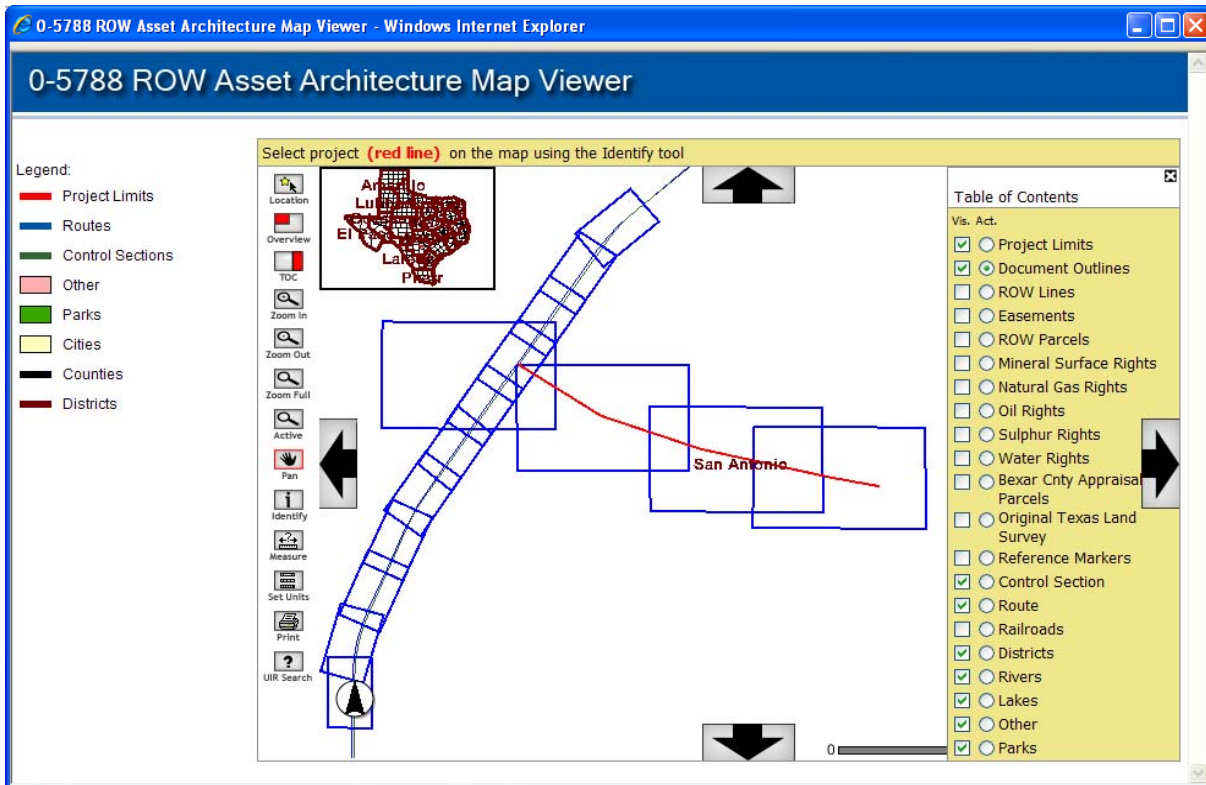
Figure 16. Interactive Map Viewer – Document Outline View.
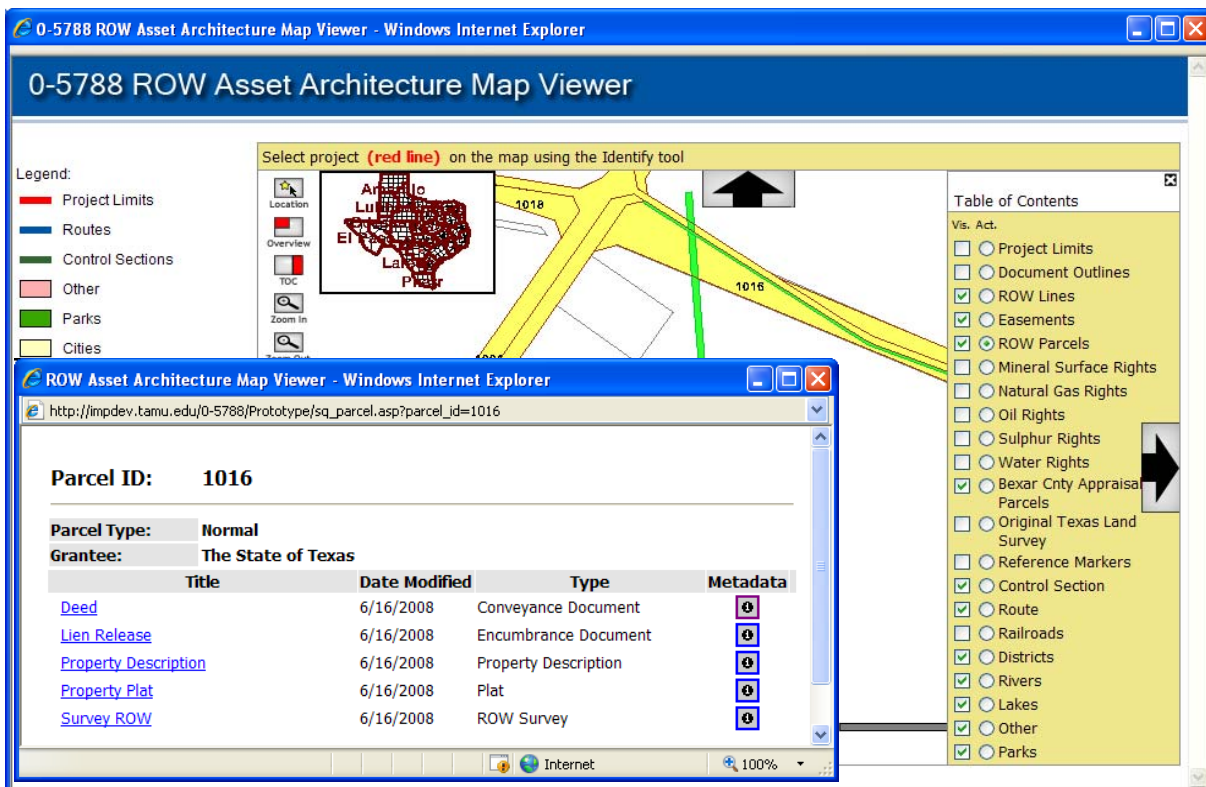
Figure 17. Interactive Map Viewer – Parcel Document View.

The research focused primarily on the data model and the GIS-based visualization component, but relatively little on the development of efficient mechanisms to extract parcel information from MicroStation files. In general, the approach involved using information that already existed in these files (primarily property boundaries and existing and proposed right-of-way lines) as well as property descriptions, importing linear features into the GIS, and generating polygon features. In cases where a file was not georeferenced (e.g., a right-of-way map that was available in TIFF or a MicroStation file that used an arbitrary coordinate system), the researchers manually georeferenced the file in the GIS and traced lines to develop polygon parcel features.

Subsequent efforts at TxDOT focused on the development of scripts to automate the extraction of parcel boundaries in MicroStation and the development of standalone or cloud-based parcel visualization tools with simple linkages to other pieces of information such as basic project data or documents (Figure 18, Figure 19). According to information provided by TxDOT officials, attempts at using Safe Software's Feature Manipulation Engine (FME®) were largely unsuccessful, noting that the FME approach worked efficiently when the MicroStation file used the proper survey level library, was referenced correctly, was placed in the correct coordinate system before processing, and contained line work that closed properly to form polygons. However, it resulted in a very slow process if the MicroStation file did not use a survey level library, was referenced incorrectly, was not placed in the correct coordinate system before processing, or contained line work that did not close properly to form polygons.

Because of these difficulties, officials concluded that a manual approach to generate parcel polygons was at least as efficient as using a script-based procedure, with the advantage that the operator could achieve more predictable results when processing parcels manually. Nonetheless, officials noted the following limitations of the manual approach: (a) difficulty to determine the shape of the line work elements that compose a parcel polygon; (b) need to manually import many components into the GIS to determine precise boundaries; and (c) additional processing time when dealing with curves. Note: As described in a subsequent section in more detail, the research team experienced similar difficulties while trying to generate parcel features using sample project data from Districts 5 and 6.

Figure 18. Standalone ArcGIS Tool to Visualize Parcel Acquisition Process (*13*).
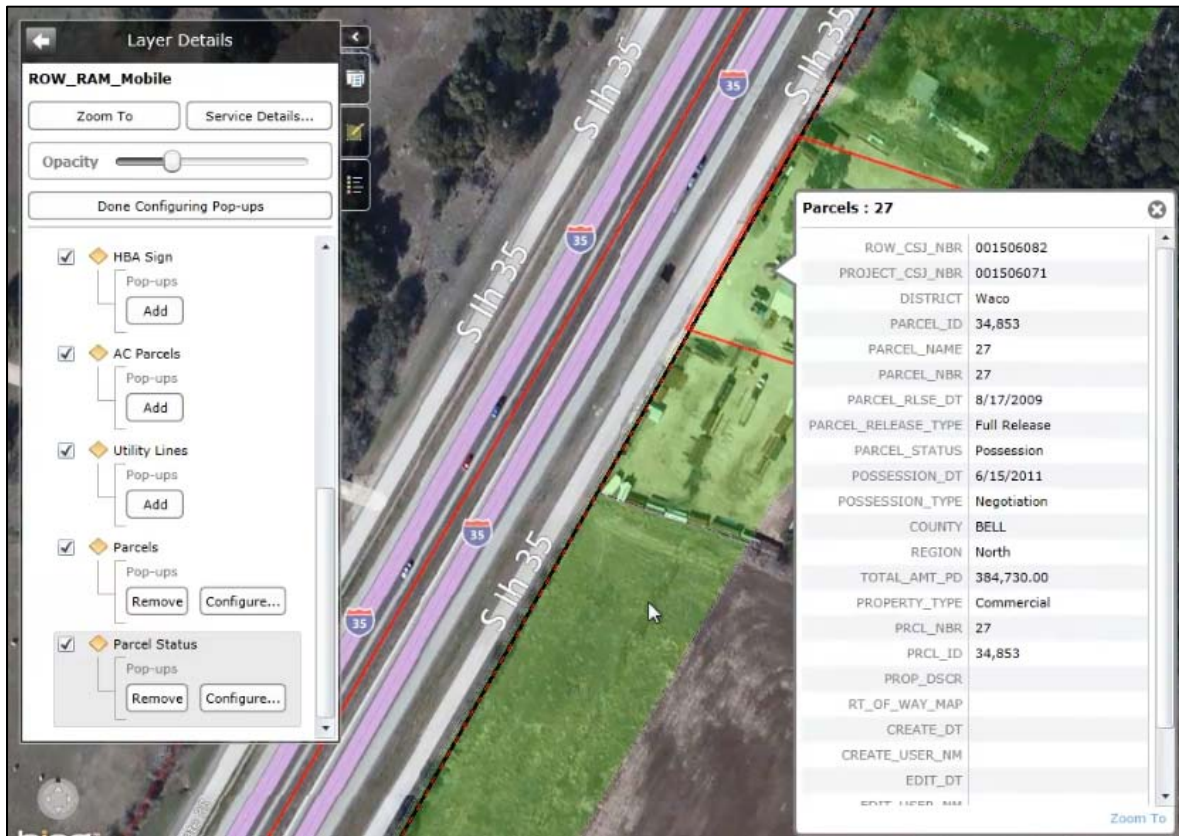
Figure 19. Online Tool to Visualize Parcel Acquisition Process (*14*).

UTILITY DATA MODELING TRENDS

Traditional automated mapping/facility management (AM/FM) systems are now becoming GIS-based. These systems provide industry-specific 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.

GIS vendors and user groups have developed data models and templates for specific utility industry sectors, e.g., electric, petroleum, gas, telecommunications, and water. A short sample of data models follows. Sector-specific data models facilitate vertical data integration within each utility sector. However, this application island approach makes horizontal data integration, i.e., data integration across industry sectors, more difficult. This is a challenge that transportation agencies must face because of their role as stewards of the right-of-way that utility installations occupy within transportation corridors. This challenge leads to difficulties at transportation agencies in applying utility industry data models to manage utility facilities within the right-of-way.

ArcGIS Data Models

Esri has published several data models for various utility industry sectors, including energy, petroleum, pipelines, telecommunications, and water. As an illustration, the telecommunications data model includes a variety of elements to handle overhead facilities, underground structures, cables, and devices (*19*). Figure 20 shows model components for overhead facilities, and Figure 21 shows model components for underground structures.

Bentley Utility Models

Bentley utility data models include XFM definitions, network model definitions, and industry-specific business rules. The XFM schema also includes domain lists, property-based symbology and annotation, placement commands, a user interface, and workspaces (*20*).

Feature

Telecom FeatureStructure

WorkOrderID <text, 20>
ProjectNumber <text, 20>
ProjectName <text, 20>
Owner <text, 20>
CLLI <text, 20>
AccountCode <text, 20>
Cost <double>
InstallationDate <date>
IPID <GUID>
Comments <text, 100>

AnchorGuy

GuyCount <long int>
LeadLength <short int>
WireMaterial (d) <long int>
WireSize (d) <long int>
WireStrength (d) <long int>
AnchorSize <long int>
AnchorType (d) <long int>
RodType (d) <long int>
AnchorGuyType (d) <long int>

Subtypes include: Back, Bridle, Sidewalk and Standard

Pole

Class (d) <long int>
Diameter <double>
FoundationType (d) <long int>
Grounded <text, 5>
Height (d) <long int>
Material (d) <long int>
Style (d) <text, 5>
TreatmentType (d) <long int>
YearManufactured <long int>
HasRiser (d) <text, 5>

PushBrace

PBClass (d) <long int>
Height (d) <long int>
PBMaterial (d) <long int>

Subtypes include: Wood, Non-wood, H-Frame and Tower

Riser

Height <long int>
RiserMaterial (d) <long int>
Diameter <double>

Attachment

Figure 20. ArcGIS Telecommunications Data Model – Overhead Facilities (*19*).

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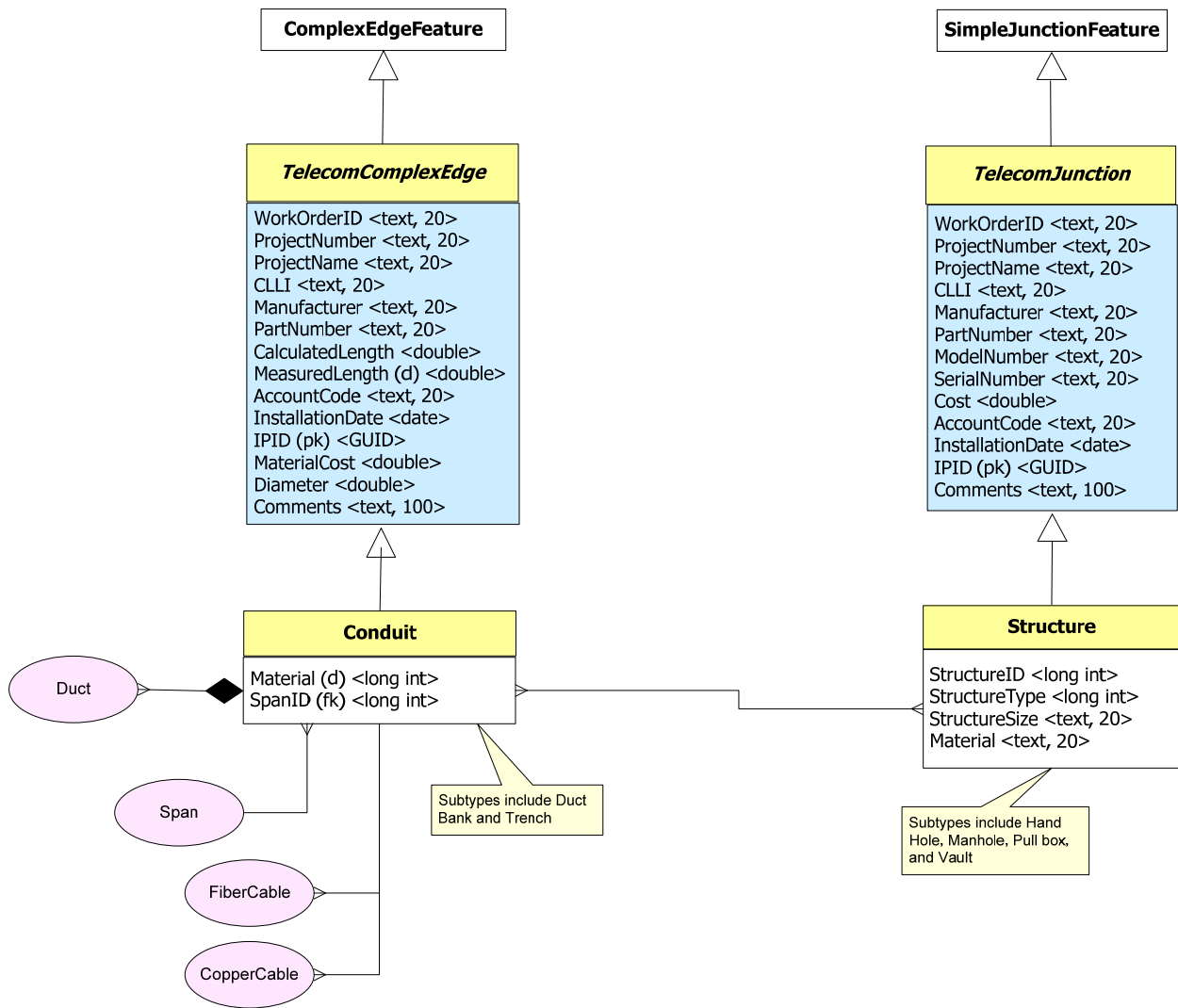
Figure 21. ArcGIS Telecommunications Data Model – Underground Structures (*19*).

U.S. Department of Defense Spatial Data Standards

The U.S. Department of Defense maintains the Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE) through the Defense Installation Spatial Data Infrastructure (DISDI) Group (*21*). The U.S. Army Corps of Engineers' CAD/GIS Technology Center maintained SDSFIE prior to DISDI. SDSFIE is a highly simplified data model of features with a specific focus on the need to minimize feature attributes. SDSFIE is intended to link spatial features with business databases that contain attribute data about those facilities, primarily at military bases and other federal installations. The model is vendor neutral.

Utility features in SDSFIE are grouped under the category of public works features (*21*). Table 19 lists the utility feature classes in this group, and Figure 22 shows typical attributes associated with these feature classes.

Table 19. Utility Features in the Public Works Group in SDSFIE (*21*).

Feature Class Name	Definition
AbstractUtilityClass	The root abstract class from which all public works features inherit.
CommUtilityNode	A subdivision of a communications network, particularly an asset that participates in the transmission of a signal but is not a cable (e.g., an amplifier, antenna, or splitter).
CommUtilitySegment	A subdivision of a communications network, particularly a cable for the transmission of a signal.
ElectricalUtilityNode	A subdivision of an electrical distribution network, particularly an asset that participates in the transmission of electricity but that is not a line (e.g., a transformer, fuse, generator, meter, or switch).
ElectricalUtilitySegment	A subdivision of an electrical distribution network, particularly a line for the transmission of electricity.
GasUtilityNode	A subdivision of a gas distribution network, particularly an asset that participates in the transmission of some heat or installation gas product but that is not a pipeline (e.g., a pump, valve, or fitting).
GasUtilitySegment	A subdivision of a gas distribution network, particularly a pipeline for the transmission of some heat or installation gas product.
POLUtilityNode	A subdivision of a petroleum, oil, and lubricant (POL) distribution network, particularly an asset that participates in the transmission of some POL product but that is not a pipeline (e.g., a pump, valve, or fitting).
POLUtilitySegment	A subdivision of a POL distribution network, particularly a pipeline for the transmission of some POL product.
ThermalUtilityNode	A subdivision of a thermal distribution network, particularly an asset that participates in the transmission of chilled water, refrigerant, hot water, or steam but that is not a pipeline (e.g., a pump, valve, or fitting).
ThermalUtilitySegment	A subdivision of a thermal distribution network, particularly a pipeline for the transmission of chilled water, refrigerant, hot water, or steam.
UtilityFeature	Any feature of importance to the utility that does not participate in the network itself. Examples include supervisory control and data acquisition (SCADA) sensors, cathodic protection devices, utility markers, and areas.
WastewaterUtilityNode	A subdivision of a wastewater network, particularly an asset that participates in the handling of storm water, sewage, or industrial wastewater, but that is not a pipeline (e.g., a pump, holding facility, or treatment facility).
WastewaterUtilitySegment	A subdivision of a wastewater network, particularly a pipeline for the transport of storm water, sewage, or industrial waste between the source, holding facilities, and/or treatment facilities.
WaterUtilityNode	A subdivision of a water distribution network, particularly an asset that participates in the transmission of water but that is not a pipeline (e.g., a pump, valve, or fitting).
WaterUtilitySegment	A subdivision of a water distribution network, particularly a distribution pipeline.
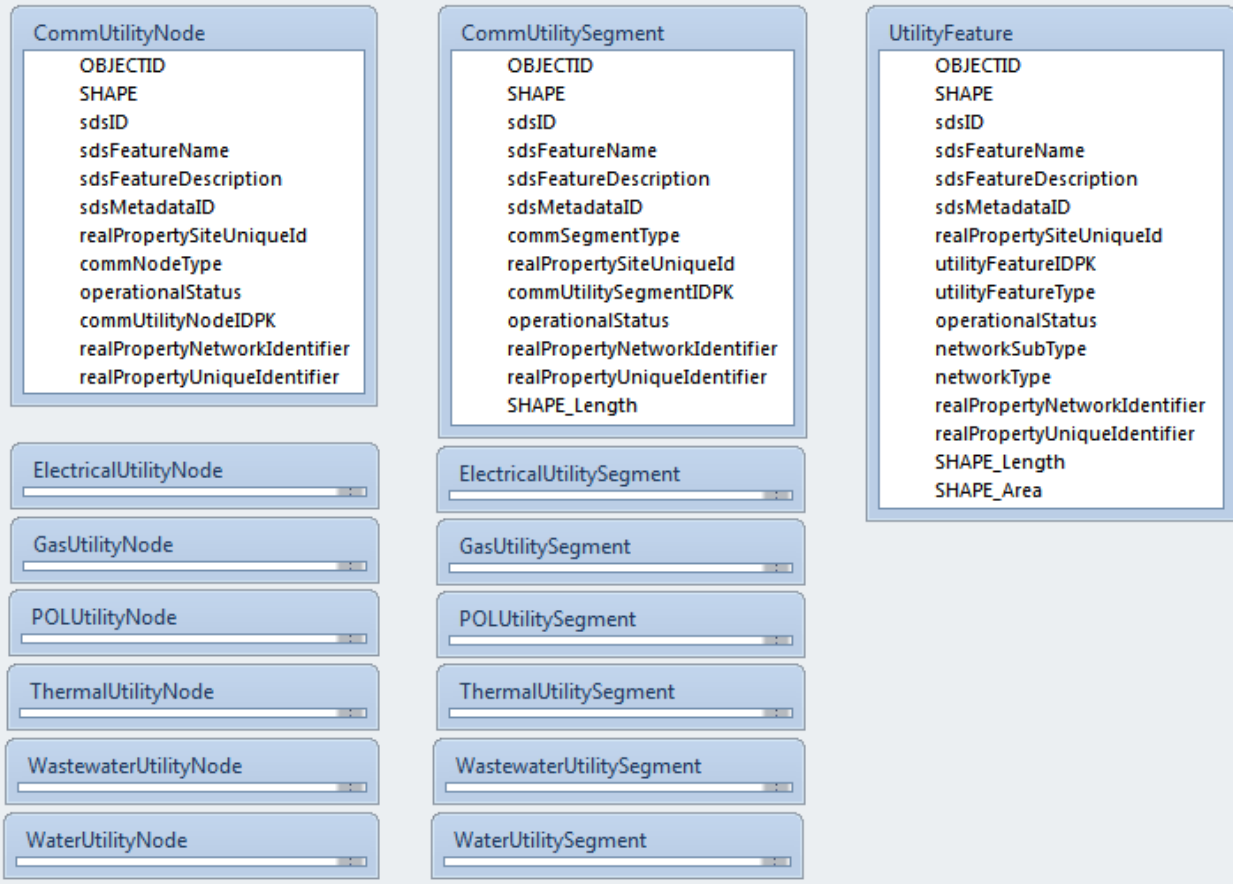
Notes:
All point (i.e., node) feature classes have essentially the same attributes as the communication utility node feature class.
All line (i.e., segment) feature classes have essentially the same attributes as the communication utility segment feature class.

Figure 22. Point, Polyline, and Polygon Utility Features in SDSFIE (*21*).

Differentiation among different types of facilities within a specific utility class is by attribute. For example, field CommNodeType in feature class CommUtilityNode enables the differentiation among communication point features such as access points, attenuators, and splices. Likewise, field CommSegmentType in feature class CommUtilitySegment enables the differentiation among segmented cables and service loops. In general, the model does not provide the capability to store data such as line capacities, dimensions, or material, based on the assumption that this information is already stored on some type of business database. It also does not provide the ability to store ownership information because the focus is primarily facilities owned by the U.S. government.

The current version of SDSFIE (3.0) is a significant departure from previous versions in the way features and feature attributes are modeled. While SDSFIE 3.0 includes a low number of feature classes and differentiation among facility types is possible mainly by attribute, previous versions of the model enabled an explicit representation of different types of facilities by using different feature classes. It is not clear from the SDSFIE 3.0 documentation why the decision was made to simplify the model in such a radical way. It is possible the cost to maintain the database could have been a strong motivation to simplify the model. It is also possible the database may have

had a large number of unpopulated fields, raising the question why it was necessary to maintain a large database when a simpler one would have produced similar results.

TxDOT Project 5-2110-01

In the early to mid-2000s, TTI researchers experimented with the development of a data model and data dictionary for the inventory of utility facilities using global positioning system (GPS) equipment (*22*). The researchers developed a utility feature code library for the Trimble Geomatics Office (TGO) environment that contained the same number of feature codes as the number of utility-related feature codes developed for the Survey Data Management System (SDMS) environment, which TxDOT was using at the moment (Figure 23). The data tags per feature in TGO were the same data tags used for the corresponding SDMS sequence files, except for a few tags that were not necessary in TGO because the survey controller software added location-related attributes automatically. In other words, the TGO feature code library only had to contain non-spatial attribute data tags. For each attribute, the researchers added a list of values to choose from during the data collection phase. As opposed to the SDMS file structure, a single TGO file contained both the list of feature codes and their corresponding attribute data tags, as shown in Figure 23. Figure 24 shows a sample of data points collected in the field, including the corresponding feature attribute values.
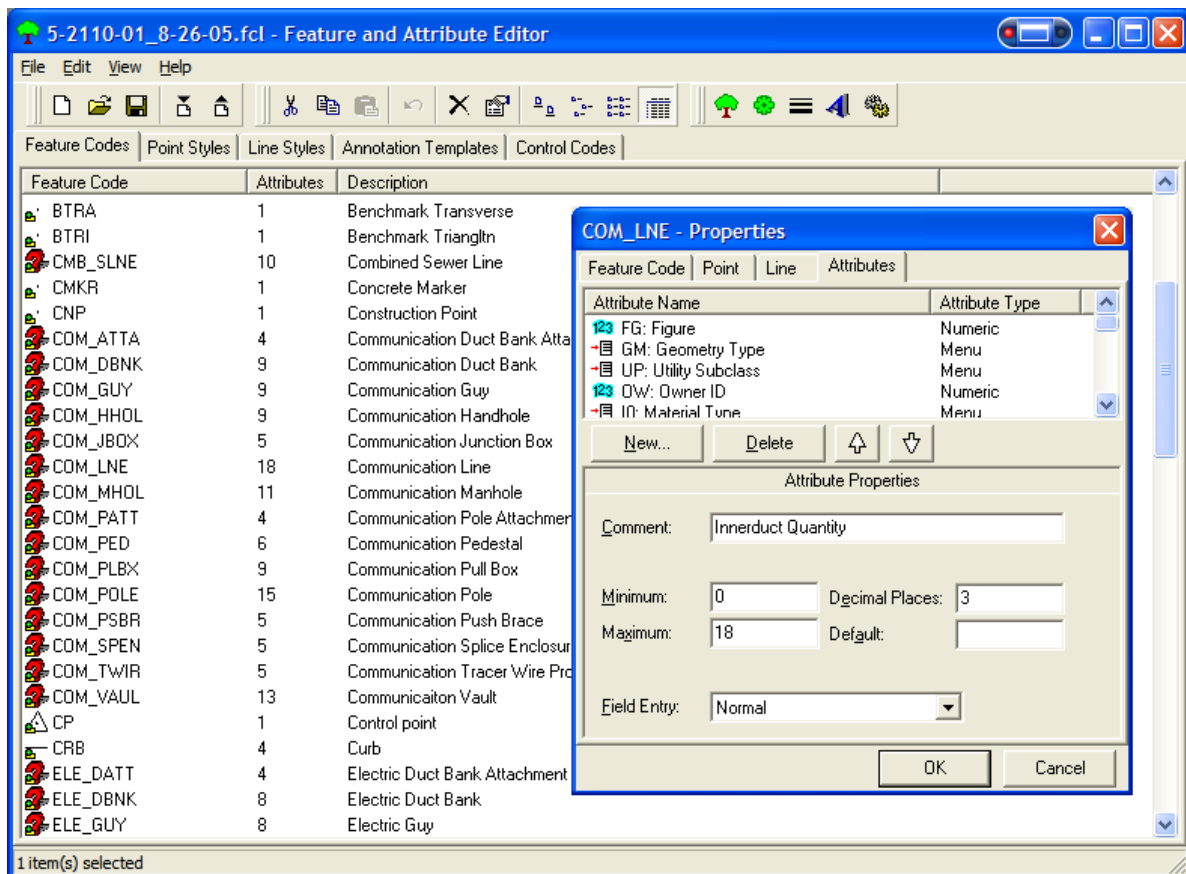
Figure 23. TGO Feature Code Library (*22*).
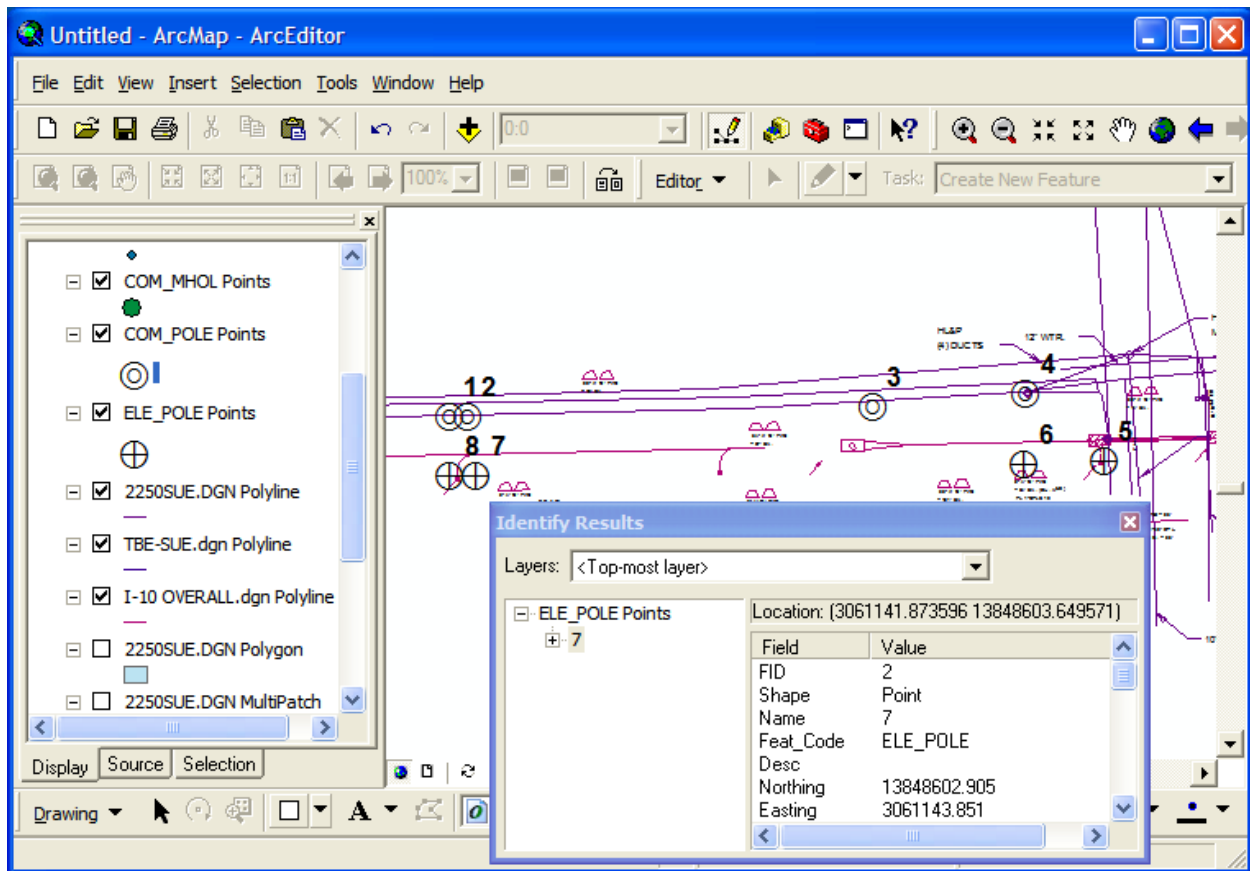
Figure 24. ArcGIS Project Screen after Adding Shape and MicroStation Files (*22*).

RIGHT-OF-WAY AND UTILITY DATA MODELING ALTERNATIVES

Given the way FDOT has structured its MicroStation design libraries and levels, it is possible to imagine a wide range of data modeling alternatives to manage right-of-way and utility-related information. In general, the spectrum of potential modeling alternatives includes expanded and compact modeling approaches for spatial and attribute (i.e., non-spatial) data, as Figure 25 shows. A potential implementation at FDOT would likely fall somewhere between these four extreme alternatives.

In addition to basic spatial and attribute data, it would be necessary to model other data elements such as project, document, or user information. As described previously (see, e.g., Figure 14 and Figure 15), managing right-of-way or utility feature information systematically involves managing four types of data: features on the ground (normally on the state right-of-way); right-of-way or utility feature documents; projects; and users who may need to interact with features, documents, or projects. Relationships among these four different types of data are many to many. For example, a feature can be associated with multiple projects, documents, and users. Likewise, a project can be associated with multiple features, documents, and users. The normal strategy to handle these relationships in database applications is by using many-to-many tables and customized user interfaces.
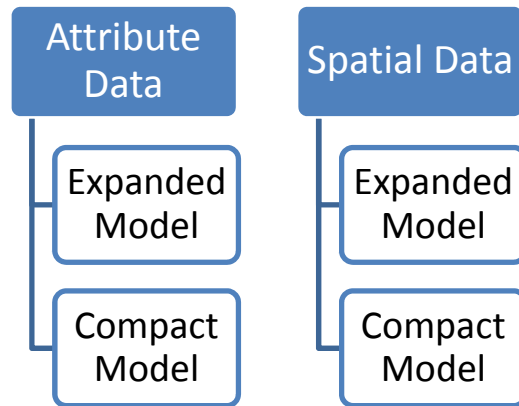
Figure 25. Spatial and Attribute Data Modeling Approaches.

Expanded Modeling Approach

For attribute data, the expanded modeling approach involves using individual tables to handle all the information associated with different right-of-way or utility features. Strictly speaking, there is no need for a master list of features (although enterprise applications would probably need this table anyway to handle "universal" feature IDs). This approach is conceptually simple and intuitive. However, it becomes increasingly difficult to manage as the number of right-of-way or utility feature types in the database increases. For example, in the 2004–2012 FDOT design libraries there are 208 different MicroStation levels that contain right-of-way elements and 235 different MicroStation levels with utility elements. A large portion of these levels correspond to features that either exist on the ground or are being proposed as part of a transportation project. With the expanded modeling approach, it would be necessary to create an attribute table in the database for each level, in addition to lookup tables and other required tables. A strategy to reduce this impact would be to select only a reduced set of MicroStation levels that are considered critical for inventorying and managing right-of-way and utility features on the ground.

For spatial data, the expanded modeling approach involves using individual feature classes in the database to represent separate types of features on the ground, e.g., a water line feature class in the database is used to map water lines in the field. Similarly, a water valve feature class is used to map water valves in the field. Depending on the implementation, it may be possible to store all attribute data within the corresponding spatial data tables. However, it is quite common to store spatial data and attribute data in different table spaces within the enterprise. As in the case of the expanded modeling approach for attribute data, having separate feature classes for individual right-of-way or utility feature types on the ground is conceptually simple and intuitive. However, it becomes increasingly difficult to manage as the number of feature types in the database increases. In general, this type of modeling approach can be compatible with either attribute data approach (i.e., an expanded modeling approach or a compact modeling approach).

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As an illustration of the expanded modeling approach, Figure 26 provides a high-level view of what the data model would look like, using as a foundation general feature descriptions from the existing FDOT MicroStation design libraries (and five additional levels developed during the research to handle different types of parcel features). Figure 27 provides a zoomed-in view that shows a small sample of right-of-way features. Figure 28 provides a zoomed-in view that shows a small sample of utility features. Figure 29 provides a zoomed-in view that shows a small sample of undefined right-of-way and undefined utility features. The entities shown in Figure 26 through Figure 29 could be used to handle spatial, attribute (i.e., non-spatial), or spatial and attribute data for each of the features shown.

In general, features are first grouped into categories (right-of-way related features and utility features) and then into types within each category (e.g., right-of-way, property, easement, and so on). The features in Figure 29 correspond to features that could not be immediately grouped into an appropriate type of feature.

Readers should note that the diagrams in Figure 26 through Figure 29 are intended to illustrate the various categories and types of features, but do not provide an exact 1:1 match to the list of levels in the FDOT design libraries. For readability reasons, feature names in Figure 26 through Figure 29 are clean, "sanitized" versions of MicroStation level descriptions. In addition, the diagrams do not provide an explicit differentiation between existing and proposed features. In reality, FDOT design libraries include different levels for existing and proposed features, e.g., "Fiber Optic Splice Box (Existing)" and "Fiber Optic Splice Box." For simplicity, the diagram only shows one feature ("Fiber Optic Splice Box"). The diagrams do not show attributes. As needed, attributes could be added to individual tables, including primary and foreign keys as well as relationships associated with each table.

In a physical implementation of this model, all groupings of features would disappear, including all supertype entities such as RIGHT OF WAY RELATED FEATURE, PROPERTY FEATURE, COMMUNICATION FEATURE, etc. Only subtypes at the lowest level (e.g., RIGHT OF WAY LINE, TELEPHONE POLE) would remain. This creates a structural issue when linking multiple features to multiple documents via a linking table (i.e., FEATURE DOCUMENT), because multiple parents would reference documents. To maintain the many-to-many relationship between features and documents, the model stores a master record of features in a table called features, e.g., using a Feature Class ID to identify the type of feature and a Feature ID to identify a feature within a class of features. The referential integrity between the master record of feature and records of features in the feature tables would need to be maintained through code.

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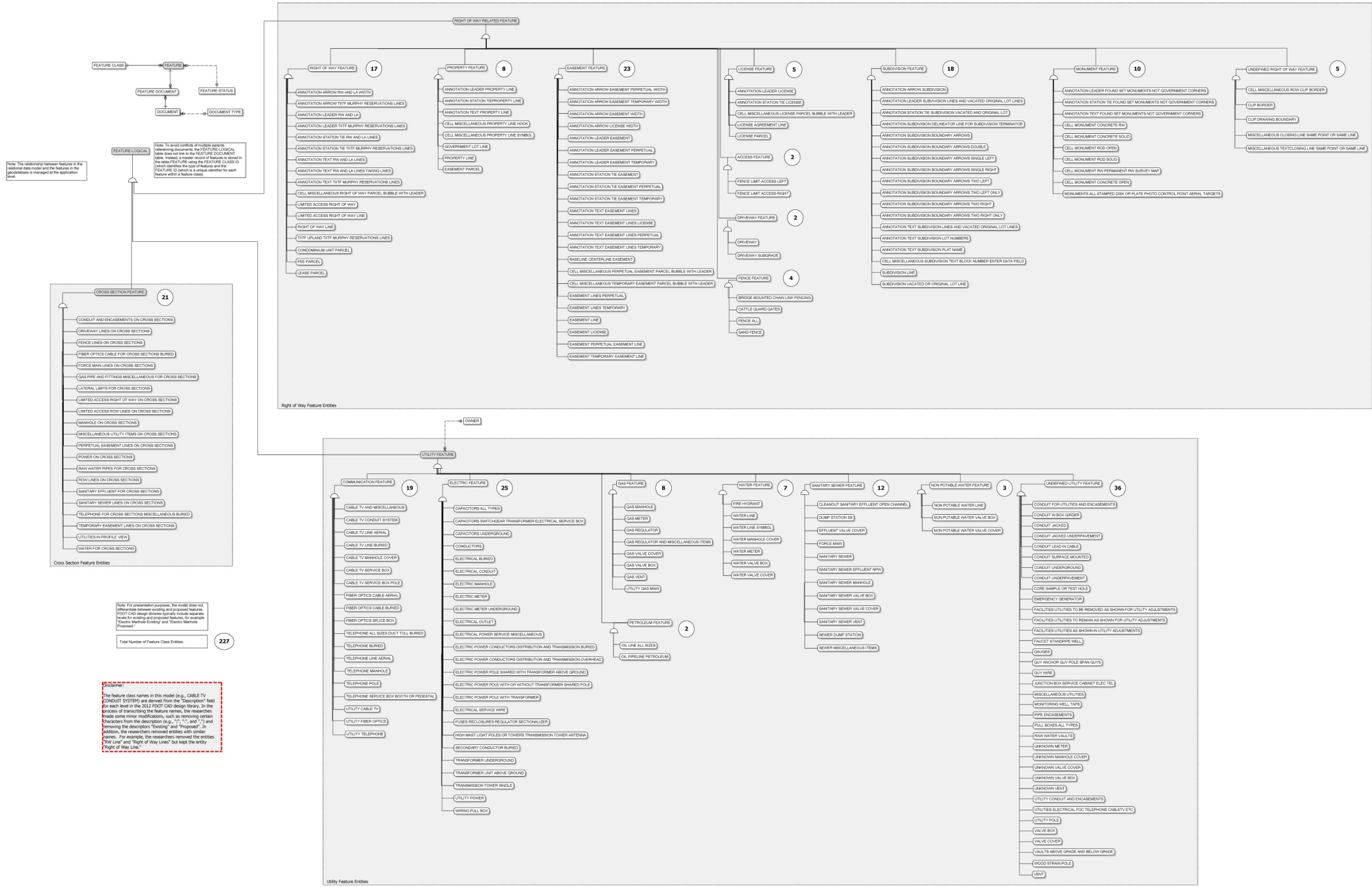
Figure 26. Expanded Data Model.
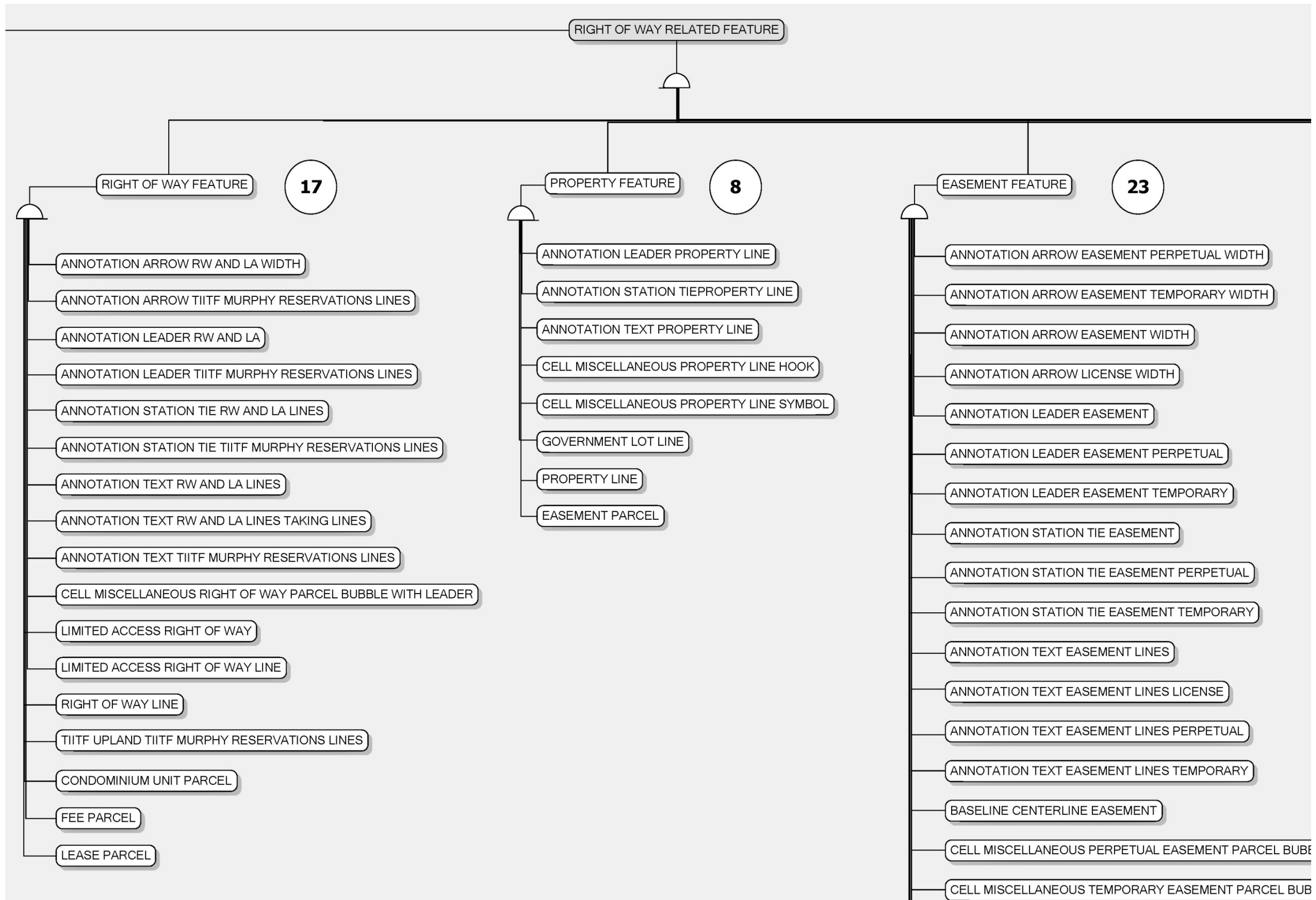
Figure 27. Expanded Data Model – Sample Right-of-Way Tables.
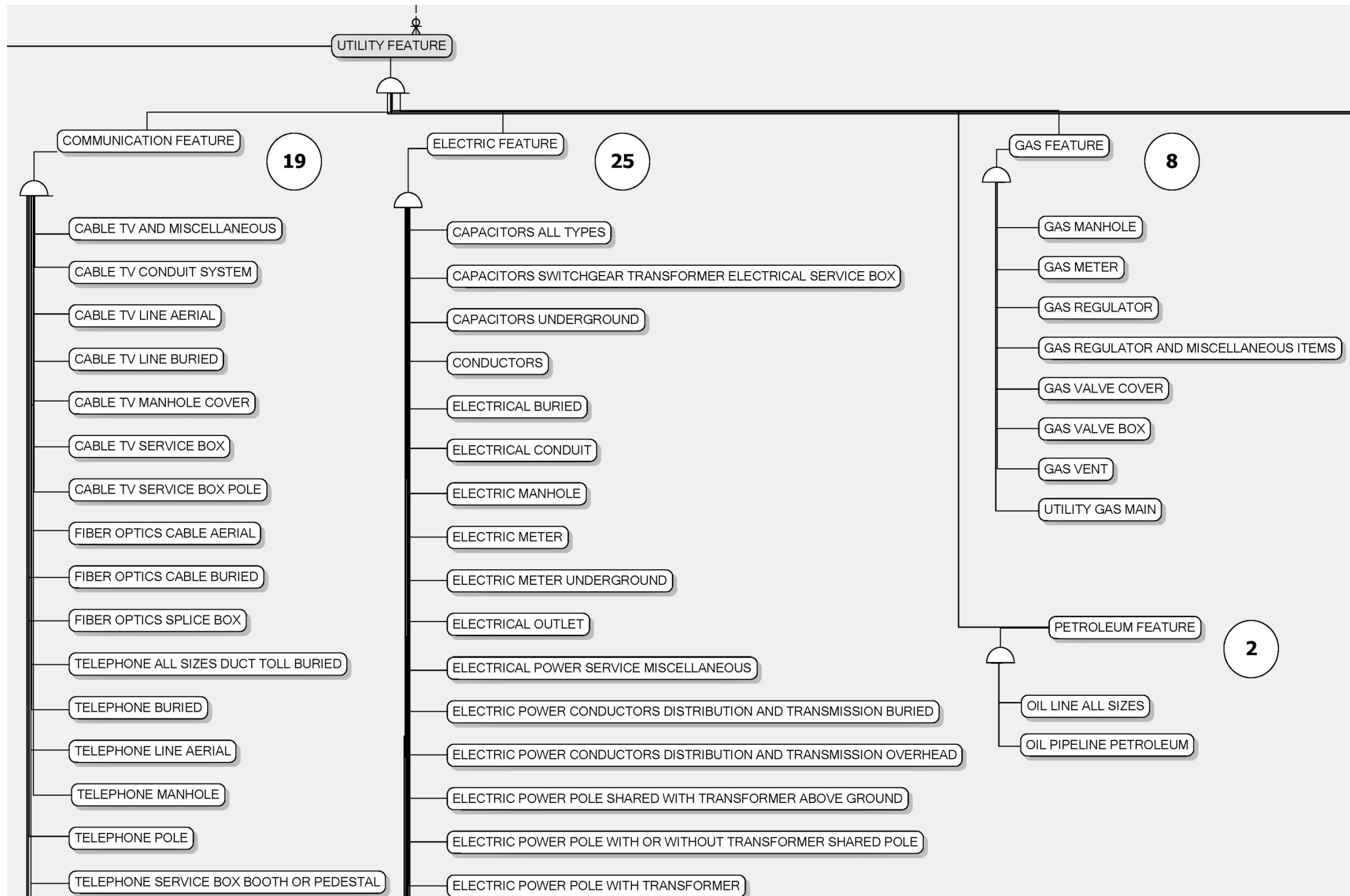
Figure 28. Expanded Data Model – Sample Utility Tables.
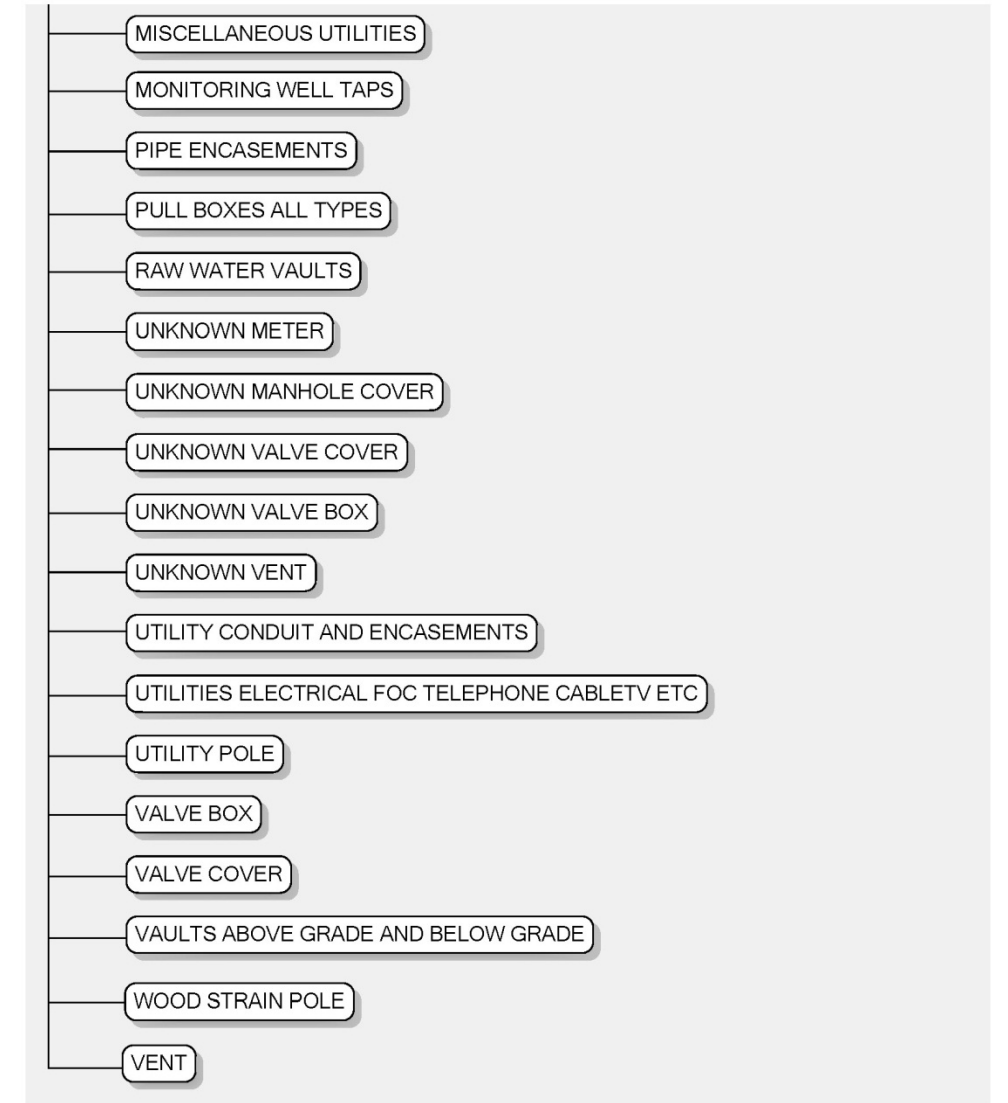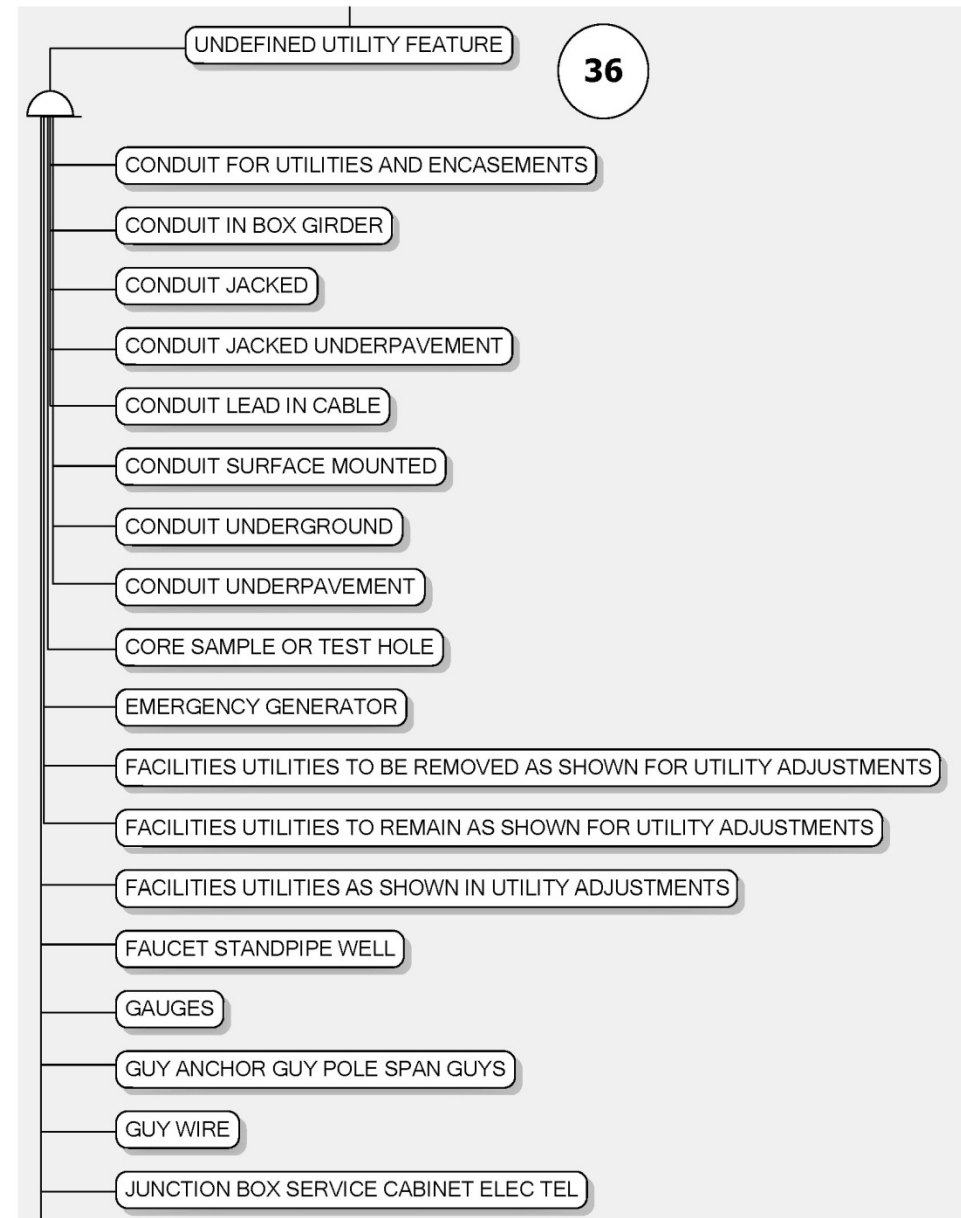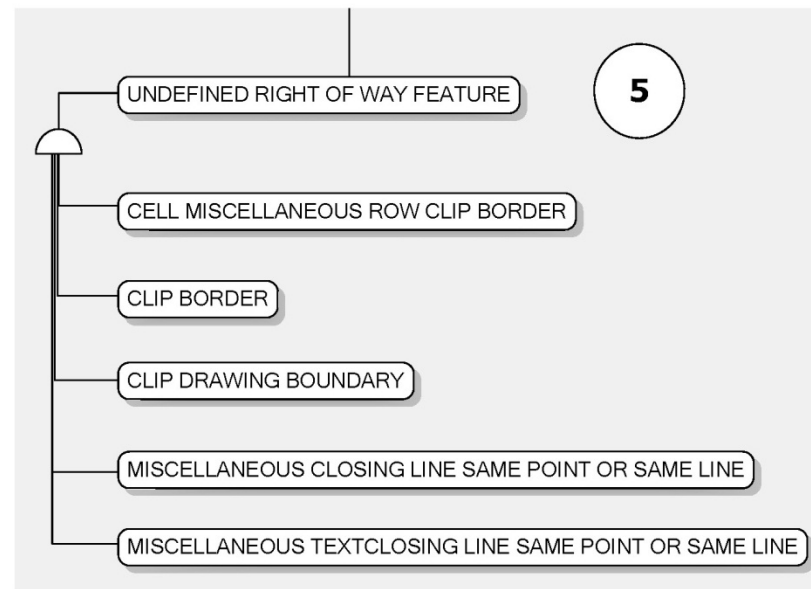
Figure 29. Expanded Data Model – Undefined Right-of-Way and Utility Features.

Compact Modeling Approach

A variety of scenarios may be possible for developing compact modeling approaches for attribute data. A highly flexible approach that retailers and other outfits use to handle widely diversified inventories involves using a single master table that contains a list of all the potential features in the database. In addition, a master list of attributes contains a list of all the potential attributes that could be associated with any feature class. A third table contains actual attribute values for individual features, essentially using one record per attribute value and as many records as needed to characterize the specific feature of interest. This approach is appropriate if there are large numbers of different types of objects, and the number of attributes associated with each object is markedly different. It is also compact from a database design perspective. For example, for the 443 different MicroStation levels in the FDOT design libraries that represent existing or planned right-of-way or utility features, it would be necessary to create only one master table of feature classes, one master table of features, one master table of attributes, and one table with actual attribute values for each feature in the database (not counting lookup tables and other required tables). However, the tradeoff is additional complexity in the design of user interfaces and data quality controls.

A variety of scenarios may be possible for developing compact modeling approaches for spatial data. An extremely compact modeling approach would involve using three feature tables to handle spatial information for different feature classes: a point feature table for point features, a line feature table for linear features, and a polygon feature table for polygon features. A (less extreme) variation of this modeling approach would involve identifying general categories of feature classes (e.g., oil and gas, water, communications, and so on) and then using a point feature table, a line feature table, and a polygon feature table within each category, in effect, following a similar approach to the SDSFIE model described previously (*21*). Regardless of modeling approach, a few more tables would be necessary to handle data elements such as text or annotations.

For the purpose of demonstrating the process to import MicroStation features into a GIS environment, the research team developed and tested a compact data model assuming a point feature table for point features, a line feature table for linear features, and a polygon feature table for polygon features. Figure 30 provides a view of the data model (logical data model level), including entities, primary keys, foreign keys, and relationships.

A brief description of each group of entities in Figure 30 follows:

- **Geodatabase Entities**. This version of the model shows three entities to represent three types of spatial features: point features, line features, and polygon features. In the model, the entities are called GIS POINT FEATURE, GIS LINE FEATURE, and GIS POLYGON FEATURE, respectively.

- **Feature Class Entities**. This group of entities enables the development of a master list of feature classes. The data source for this list could be the list of FDOT MicroStation levels. However, it could also be a generic list of features, which would be appropriate, for instance, if FDOT implements Bentley Map. The core entity in this group of entities

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is FEATURE CLASS. The rest of the entities are lookup tables. FEATURE CLASS TYPE enables grouping of feature classes by type, e.g., water, gas, driveway, easement, and so on. FEATURE CLASS CATEGORY enables further grouping of feature class types into the categories Utility and Right-of-Way.

- **Attribute Entities**. This group of entities enables the development of a master list of attributes that could potentially be associated with a feature class. The core entity in this group is ATTRIBUTE. The research team prepared a master list of attributes with feedback from FDOT officials (Table 20).

  FEATURE CLASS ATTRIBUTE is a linking entity between FEATURE CLASS and ATTRIBUTE, which enables the development of default lists of attributes that can be associated with individual feature classes. This table can be used to define the default attributes that are shown for a feature class. For example, the table could define that a telephone pole has owner, material, height, and diameter attributes. With the help of FDOT, the research team populated this table for a sample of 75 feature classes, for a total of 389 attribute definitions (or about five attributes per feature class). The appendix shows a comprehensive list of all attribute definitions for the sample of feature classes.

- **Feature Entities**. This group of entities enables the development of a comprehensive, enterprise-level list of features in the database, with each feature identified by a unique feature ID. The core entity in this group is FEATURE.

- **Attribute Lookup Entities**. This group of entities includes various lookup entities needed to populate feature attribute values.

- **Feature Attribute Value Entities**. This group of entities enables the population of feature attribute values for any feature that is managed in the database, i.e., a feature for which there is a record in FEATURE and a master list of feature attributes in FEATURE CLASS ATTRIBUTE. The core entity in this group is FEATURE ATTRIBUTE VALUE. Different type of values (string, real, integer, or Boolean) are being stored in separate fields, e.g., text values are stored in the STRING VALUE field, and integer values are stored in the INTEGER VALUE field. For documentation purposes, each record includes a timestamp. Each record also includes the option to associate a measurement unit with any attribute value.

Geodatabase Entities

GIS POINT FEATURE
FEATURE ID
FEATURE CLASS ID
OBJECT ID
SHAPE
LAYER

GIS LINE FEATURE
FEATURE ID
FEATURE CLASS ID
OBJECT ID
SHAPE
LAYER
SHAPE LENGTH

GIS POLYGON FEATURE
FEATURE ID
FEATURE CLASS ID
OBJECT ID
SHAPE
LAYER
SHAPE LENGTH
SHAPE AREA

Attribute Entities

ATTRIBUTE DOMAIN
ATTRIBUTE DOMAIN ID
ATTRIBUTE DOMAIN NAME
DATA TYPE NAME
ENUMERATION
MINIMUM VALUE
MAXIMUM VALUE

UNIT
UNIT ID
UNIT NAME
UNIT ABBREVIATION

ATTRIBUTE
ATTRIBUTE ID
ATTRIBUTE NAME
ATTRIBUTE LABEL
REFERENCE TABLE NAME
REFERENCE COLUMN NAME
COMMENT
ATTRIBUTE DOMAIN ID (FK)

ATTRIBUTE UNIT
ATTRIBUTE ID (FK)
UNIT ID (FK)

COMPANY
COMPANY ID
COMPANY NAME
COMPANY EMAIL ADDRESS
COMPANY PHYSICAL ADDRESS
COMPANY PHONE
COMPANY FAX
COMPANY WEB ADDRESS

EASEMENT DURATION TYPE
EASEMENT DURATION TYPE ID
EASEMENT DURATION TYPE NAME
EASEMENT DURATION TYPE DESCRIPTION

EASEMENT TYPE
EASEMENT TYPE ID
EASEMENT TYPE NAME
EASEMENT TYPE DESCRIPTION

FEATURE MATERIAL
FEATURE MATERIAL ID
FEATURE MATERIAL NAME
FEATURE MATERIAL DESCRIPTION

PARCEL TYPE
PARCEL TYPE ID
PARCEL TYPE NAME
PARCEL TYPE DESCRIPTION

PARCEL AQUISITION STATUS
PARCEL AQUISITION STATUS ID
PARCEL AQUISITION STATUS NAME
PARCEL AQUISITION STATUS DESCRIPTION

SUPPORT TYPE
SUPPORT TYPE ID
SUPPORT TYPE NAME
SUPPORT TYPE DESCRIPTION

FEATURE AUTHORIZATION
FEATURE AUTHORIZATION ID
FEATURE AUTHORIZATION NAME
FEATURE AUTHORIZATION DESCRIPTION

PARCEL AQUISITION TYPE
PARCEL AQUISITION TYPE ID
PARCEL AQUISITION TYPE NAME
PARCEL AQUISITION TYPE DESCRIPTION

QUALITY LEVEL
QUALITY LEVEL ID
QUALITY LEVEL NAME
QUALITY LEVEL DESCRIPTION

Attribute Lookup Entities

Feature Class Entities

FEATURE CLASS CATEGORY
FEATURE CLASS CATEGORY ID
FEATURE CLASS CATEGORY NAME

FEATURE CLASS TYPE
FEATURE CLASS TYPE ID
FEATURE CLASS TYPE NAME
FEATURE CLASS CATEGORY ID (FK)

FEATURE CLASS SHAPE
FEATURE CLASS SHAPE ID
FEATURE CLASS SHAPE NAME

DESIGN LIBRARY
DESIGN LIBRARY ID
DESIGN LIBRARY NAME
DESIGN LIBRARY YEAR

LINE WEIGHT
LINE WEIGHT ID
THICKNESS

LINE COLOR
LINE COLOR ID
RED VALUE
GREEN VALUE
BLUE VALUE
CUSTOMIZED COLOR FLAG

LINE STYLE
LINE STYLE ID
LINE STYLE NAME
DISCIPLINE NAME
LINE STYLE DESCRIPTION
RESOURCE FILE NAME
STANDARD LINE STYLE FLAG

FEATURE CLASS
FEATURE CLASS ID
FEATURE CLASS NAME
FEATURE CLASS NUMBER
FEATURE CLASS DESCRIPTION
CRITICAL LEVEL FLAG
DESIGN LIBRARY ID (FK)
FEATURE CLASS TYPE ID (FK)
LINE STYLE ID (FK)
LINE WEIGHT ID (FK)
LINE COLOR ID (FK)
FEATURE CLASS SHAPE ID (FK)

FEATURE CLASS ATTRIBUTE
FEATURE CLASS ID (FK)
ATTRIBUTE ID (FK)
REQUIRED ATTRIBUTE FLAG
DISPLAY ORDER NUMBER

Feature Entities

FEATURE SHAPE
FEATURE SHAPE ID
FEATURE SHAPE NAME

FEATURE
FEATURE ID
RECORD CREATION TIMESTAMP
FEATURE CLASS ID (FK)
FEATURE STATUS ID (FK)
FEATURE SHAPE ID (FK)

FEATURE STATUS
FEATURE STATUS ID
FEATURE STATUS NAME
COMMENT

OLD FEATURE
OLD FEATURE ID
FEATURE ID
RECORD CREATION TIMESTAMP
OLD FEATURE TIMESTAMP
FEATURE CLASS ID (FK)
FEATURE STATUS ID (FK)

PROJECT FEATURE
PROJECT ID (FK)
FEATURE ID (FK)

PROJECT
PROJECT ID
PROJECT ID TEXT
PROJECT FINANCIAL PLANNING NUMBER
PROJECT NAME
PROJECT FOLDER PATH

FEATURE DOCUMENT
FEATURE ID (FK)
DOCUMENT ID (FK)
FEATURE DOCUMENT NUMBER

DOCUMENT
DOCUMENT ID
DOCUMENT NAME
DOCUMENT FILE PATH
DOCUMENT DESCRIPTION
COMMENT

PROJECT DOCUMENT
PROJECT ID (FK)
DOCUMENT ID (FK)
PROJECT DOCUMENT NUMBER

Feature Attribute Value Entities

FEATURE ATTRIBUTE VALUE
FEATURE CLASS ID (FK)
ATTRIBUTE ID (FK)
FEATURE ID (FK)
STRING VALUE
REAL VALUE
INTEGER VALUE
BOOLEAN VALUE
RECORD CREATION TIMESTAMP
UNIT ID (FK)

OLD FEATURE ATTRIBUTE VALUE
OLD FEATURE ATTRIBUTE VALUE ID
FEATURE ID
ATTRIBUTE ID
RECORD CREATION TIMESTAMP
STRING VALUE
REAL VALUE
INTEGER VALUE
BOOLEAN VALUE
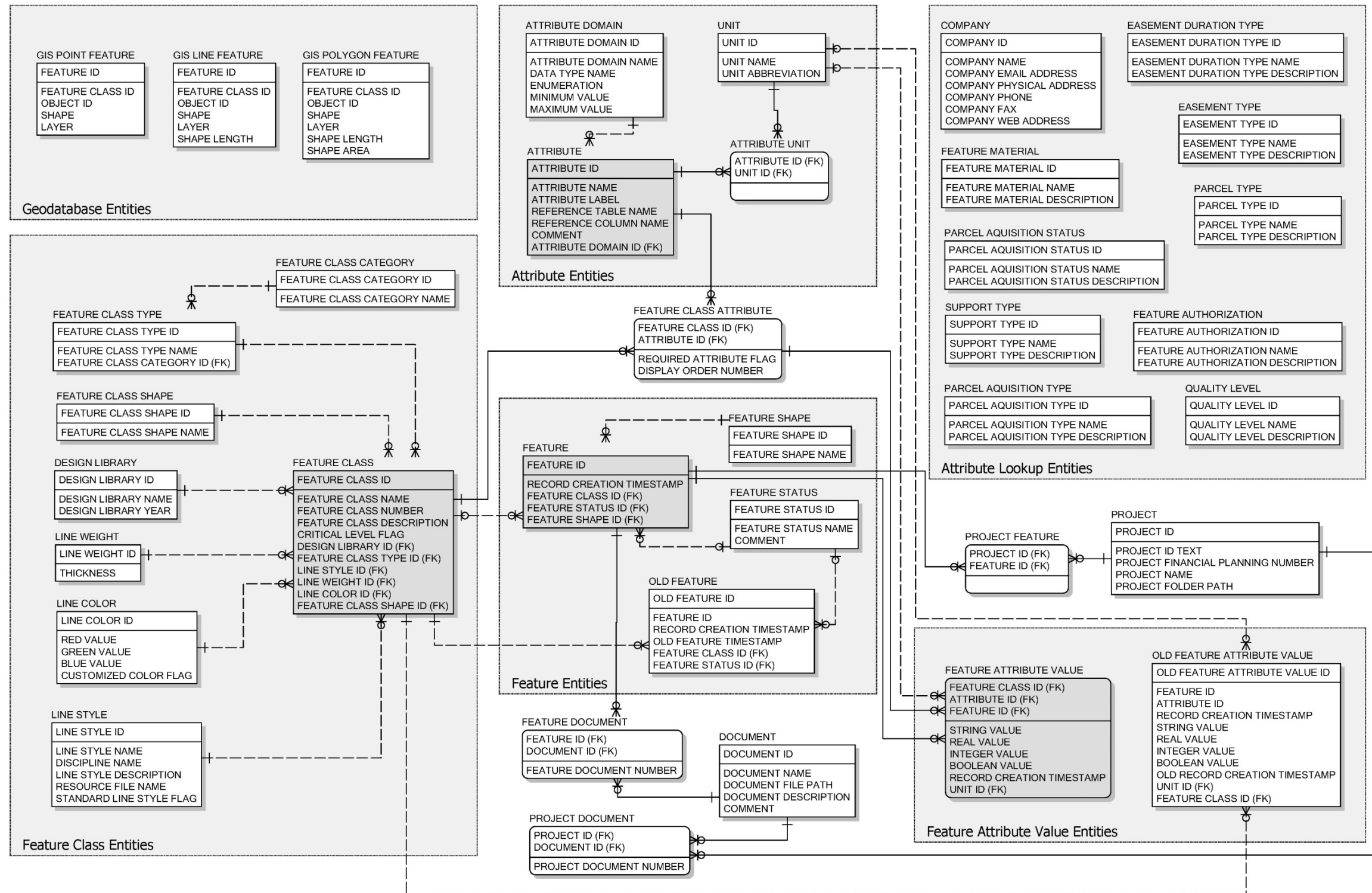OLD RECORD CREATION TIMESTAMP
UNIT ID (FK)
FEATURE CLASS ID (FK)

Figure 30. Compact Data Model.

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Table 20. Master List of Attributes.

Attribute	Comment	Reference Table
Owner	Owner is the company that owns the utility.	CMPNY
Quantity	Quantity describes a whole count of objects.	
Duct Quantity	Duct quantity describes a whole count of ducts within a duct bank.	
Height	Height is a measurement of an object.	
Width	Width is a measurement of an object.	
Length	Length is a measurement of an object.	
Depth	Depth is a measurement of an object.	
Diameter	Diameter is a measurement of an object.	
Size	Size describes a common industry measurement for an object.	
Duct Size	Duct size describes a common industry measurement for a duct.	
Material	Material describes the substance an object is made of.	FEAT_MTRL
Duct Material	Duct material describes the substance that the encasement of an object is made of.	FEAT_MTRL
Encasement Material	Encasement material describes the substance that the encasement of an object is made of.	FEAT_MTRL
Tracer Wire	Tracer wire indicates whether an object has a tracer wire.	
Warning Tape	Warning tape indicates whether an object has a warning tape.	
Foundation Depth	Foundation depth is a measurement of an object.	
Capacity	Capacity describes the nominal voltage of an object.	
Rated Voltage	Rated voltage describes the nominal rated voltage on an object.	
Placement	Placement describes the location of an object.	
Support Type	Support type describes how an object is supported.	SUPT_TYPE
Barrel Diameter	Barrel diameter is a measurement of an object.	
Barrel Height	Barrel height is a measurement of an object.	
Innerduct Quantity	Innerduct quantity describes a whole count of innerducts within an object.	
Box Length	Box Length is a measurement of an object.	
Box Width	Box Width is a measurement of an object.	
Box Height	Box Height is a measurement of an object.	
Parcel ID	Parcel ID is a unique ID for a parcel within an FDOT project.	
Project ID	Project ID is a unique identifier for an FDOT project.	PROJ
DOR Parcel ID	DOR ID is an ID for a parcel provided by the Florida Department of Revenue	
Parcel Type	Identifies the type of parcel.	PRCL_TYPE
Easement Type	Identifies the type of easement.	EASEMENT_TYPE
Easement Duration	Determines whether the easement is temporary or perpetual.	EASEMENT_DUR_TYPE
Authorization	Indicates the legal instrument by which a feature occupies the right-of-way.	FEAT_AUTH
Quality Level	Indicates the horizontal and vertical accuracy of utility data.	QLTY_LEVEL
Parcel Acquisition Status	Indicates the current status of a parcel in the acquisition process.	PRCL_AQUISITION_STAT
Parcel Acquisition Type	Indicates whether a parcel is acquired through negotiation or condemnation.	PRCL_AQUISITION_TYPE

In addition to these groups of entities, the data model includes an entity to handle a master list of projects and an entity to handle a master list of documents (entities PROJECT and DOCUMENT, respectively). The data model also includes entities FEATURE DOCUMENT to handle the many-to-many relationship between entities FEATURE and DOCUMENT, as well as PROJECT DOCUMENT to handle the many-to-many relationship between PROJECT and DOCUMENT. For simplicity, this version of the model does not include a USER entity or many-to-many entities to handle the relationship between USER and other entities in the data model.

GENERATING FEATURES IN ARCGIS

General Options

Two general options to generate ArcGIS features from MicroStation files include the following:

- Use an appropriate file export option in MicroStation. If Bentley Map has been installed and is active in MicroStation, users can select the Esri shapefile format (.shp) as one of the GIS file export options. Using this option results in three files for each level in the MicroStation file (.shp, .dbf, and .shx extensions, respectively). For example, if a MicroStation file includes 90 levels, using the Esri shapefile format option produces 270 files: 90 .shp files, 90 .dbf files, and 90 .shx files. The shapefiles can then be imported into ArcGIS by using the "Add Data" tool. Unfortunately, a major disadvantage of this approach (other than the large number of files generated from each MicroStation file) is that relevant MicroStation attribute data are not maintained. Typically, the only fields that are imported in ArcGIS are FID, Shape, and Geometry_L (Figure 31).

	FID	Shape	Geometry_L
	0	Polyline	2.855124
	1	Polyline	2.02884
	2	Polyline	8.017697
	3	Polyline	7.717105
	4	Polyline	37.736855
	5	Polyline	37.728923

Figure 31. Sample Attribute Data of MicroStation Feature Imported as Shapefile.

- Use the "Add Data" function in ArcGIS to load the MicroStation file directly. Using this procedure creates a temporary feature class in ArcGIS that has the same name as the MicroStation file and has five default feature classes to handle a variety of graphical elements in the MicroStation file: Annotation, Point, Polyline, Polygon, and MultiPatch. An advantage of this approach is that ArcGIS maintains critical MicroStation level information in the form of feature attributes, including level number and layer (which lists the MicroStation level or feature class name), as well as basic level attributes such as color, line type, elevation, and line weight. As an illustration, Figure 32 shows MicroStation attributes associated with a sample of polylines created when file RWDETL03.dgn was loaded into ArcGIS.

Table

rwdetl03.dgn Polyline

FID	Shape	Entity	Level	Layer	Color	Linetype	Elevation	LineWt	RefName
1	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWLG
2	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWRG
3	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWLG
4	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWRG
5	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWRG
6	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWRG
7	Polyline	Line	12	SubSingleArrow	5		0	1	
8	Polyline	Cell	15	MonConcSolid	4	Solid	0	1	MONSQS
9	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWLG
10	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWRG
11	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWLG
12	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWLG
13	Polyline	Cell	8	SubDivLineText	5	Solid	0	0	ARRWRG

I◄ ◄   1 ► ►I   (0 out of 2428 Selected)

rwdetl03.dgn Polyline

Figure 32. Sample GIS Attribute Information of Polyline Layer.

A disadvantage of this approach is that ArcGIS imports all the graphical elements associated with every MicroStation feature, which can result in a large number of unwanted features. For example, cells in MicroStation are typically point features that have a specific line or shape to visualize specific features in the file. In MicroStation, the point, line, and/or shape elements are integral components of the cell object. However, when that cell is imported into ArcGIS, the process separates those elements into separate features (which are stored in separate feature classes). Likewise, a shape in MicroStation is a polygon that includes a polyline to represent its perimeter. This polyline is an integral component of the shape. However, when the shape is imported into ArcGIS, the process separates the perimeter from the polygon and generates two different features (the perimeter in the polyline feature class and the polygon in the polygon feature class).

Extraction and Development of Parcel Features

As mentioned previously, FDOT does not have a business process to generate parcel features in MicroStation. While the current practice enables the determination of parcel boundaries and the

calculation of parcel areas, this practice does not extend to the generation of polygon features representing the parcels being acquired.

There are several options to identify and merge parcel boundaries to create polygons, either before or after importing the data into ArcGIS:

- **Generate Parcel Shapes in ArcGIS.** In this case, polygons would be generated in ArcGIS by merging polylines (more specifically, right-of-way and property line features) that have been imported from MicroStation. A major disadvantage of this approach is that it is very time consuming and difficult to identify the features that make up a parcel, then select these features, and finally run a script to join the features to form a polygon and then move the polygon to a permanent location. In addition, a user would need to manually add parcel attribute information at the end of the process.

- **Generate Parcel Shapes in MicroStation Using Features from the Right-of-Way File.** In this case, shapes would be generated in MicroStation by copying and merging right-of-way and property line features in MicroStation. A major disadvantage of this approach is that it is difficult and error-prone to identify and create parcels using right-of-way and property line intersections. Another approach would be to trace parcel shapes based on existing lines and curves. The research team quickly realized that this approach was not working well and only produced approximations of the actual parcel shape. For example, curved lines were very difficult to trace manually, e.g., in situations where graphical elements looked like straight lines on the screen but in reality represented curves. A better approach was to copy the relevant curves and lines to a separate level. However, it was still necessary to copy relevant lines and annotation, then trim and join lines to create parcel outlines, and finally create complex shapes or regions to define parcel polygons. Overall, the research team found this approach to be cumbersome and time consuming, probably making it unfeasible in practice. With the appropriate quality controls in place, this approach might be feasible if it becomes part of the designer's or consultant's business process because, during the design process, surveyors and designers are already familiar with the MicroStation elements that are used to represent parcels, making it easier to extract those linear elements to quickly generate parcel polygons or shapes.

- **Generate Parcel Shapes in MicroStation Using GEOPAK Data.** In this case, polygons would be generated in MicroStation by visualizing parcel elements in the GEOPAK file, and by creating parcel shapes directly by joining those elements. A major advantage of this approach is that it would use survey data (i.e., points, lines, and curves) already residing in GEOPAK files that are based on field survey data. As with the previous option, a disadvantage (which is easily fixable) is that the method requires the creation of at least one parcel level in the current MicroStation design libraries at FDOT to associate the shape features with the standard design libraries. It would also require knowledge about how parcel data are coded in the GEOPAK file, as well as a modification of the GEOPAK database for the Design and Computation Manager that would be used to visualize the parcels. A disadvantage of this approach is that not all FDOT parcel information is currently available in GEOPAK files.

Considering the advantages of the third approach, the research team explored it further to develop a generalized protocol to develop parcel shapes in MicroStation. This made it necessary to add a parcel level to the right-of-way design library. For completeness, the research team added not one but five parcel levels, as shown in Table 21 and Figure 33, to handle various kinds of parcels that the department deals with on a regular basis: fee parcels, easements, leases, licenses, and condominium units. The research team also added corresponding records in the FEATURE CLASS table.

Table 21. MicroStation Attributes of New Parcel Levels.

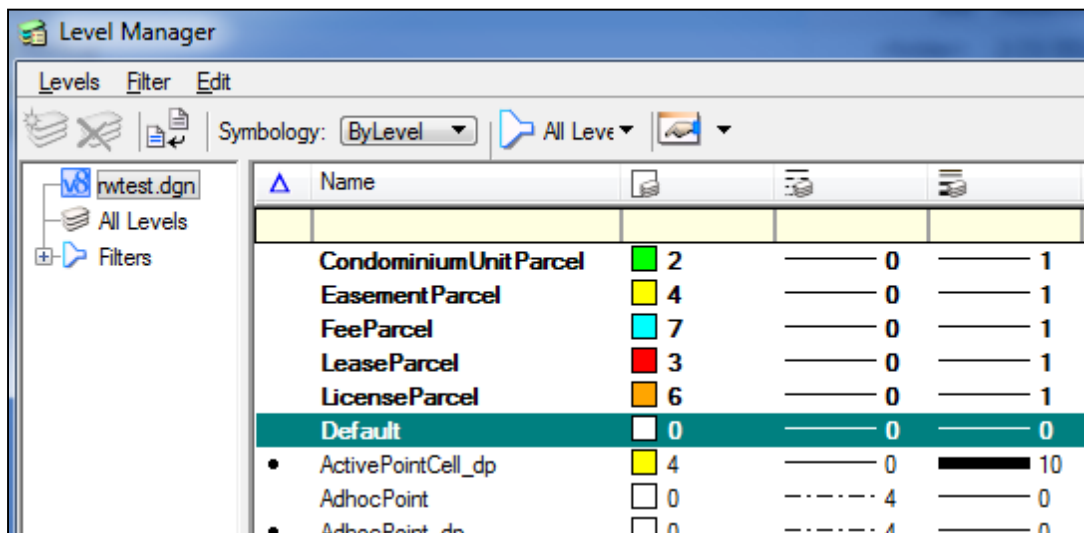| Name	No.	Description	Level Color	Level Style	Level Weight
FeeParcel	1672	In Fee (Simple Fee) Parcel	7	0	1
EasementParcel	1673	Easement Parcel	4	0	1
LeaseParcel	1674	Lease Parcel	3	0	1
LicenseParcel	1675	License Agreement Parcel	6	0	1
CondominiumUnitParcel	1676	Condominium Unit Parcel	2	0	1

Figure 33. Modified Design Library in MicroStation Level Manager.

The research team also added several attributes to the ATTRIBUTE table in the database to characterize each kind of parcel properly. Depending on the situation, a parcel may have one or more of the following attributes in the database:

- Feature ID,
- Parcel ID,
- Project ID,
- DOR Parcel ID,
- Parcel Type,

- Easement Type,
- Easement Duration,
- Authorization,
- Quality Level,
- Parcel Acquisition Status, and
- Parcel Acquisition Type.

To make the attribution of parcels easier for the user, the research team defined several lookup tables in the data model to store information related to parcel shapes. Figure 34 shows a summary of the data stored in the lookup tables.

Parcel Type	Easement Type	Easement Duration Type
• Parcel taking • Whole taking • Uneconomic remnant • Excess • Surplus	• Utility easement • Drainage easement • Conservation easement • Right-of-way easement • Access and maintenance easement	• Perpetual • Temporary

Feature Authorization	Parcel Acquisition Status	Parcel Acquisition Type
• Permit • Easement • Agreement • Unknown	• Appraised • In Negotiation • In Condemnation Proceedings • In Possession	• Negotiation • Condemnation

Figure 34. Characterization of Parcels in the Database.

Visualization of Parcels using GEOPAK

GEOPAK files contain survey data that can be accessed and reviewed using the GEOPAK Coordinate Geometry (COGO) Manager (Figure 35). There are several key-in commands that can be used to list parcels, parcel elements, and automatically provide parcel area calculations. If a GEOPAK parcel is coded with a parent tract area and a taking area, GEOPAK automatically calculates the area of the parent tract, the taking area, and the remaining area (see Figure 35). However, the research team found cases where parent tract and taking area of a parcel where coded as two separate parcels, e.g., parcels 801 and 801PARENT in Table 22. This table shows a list of 67 parcels from a sample GEOPAK file provided by District 5 for the SR 50 Lake County project.
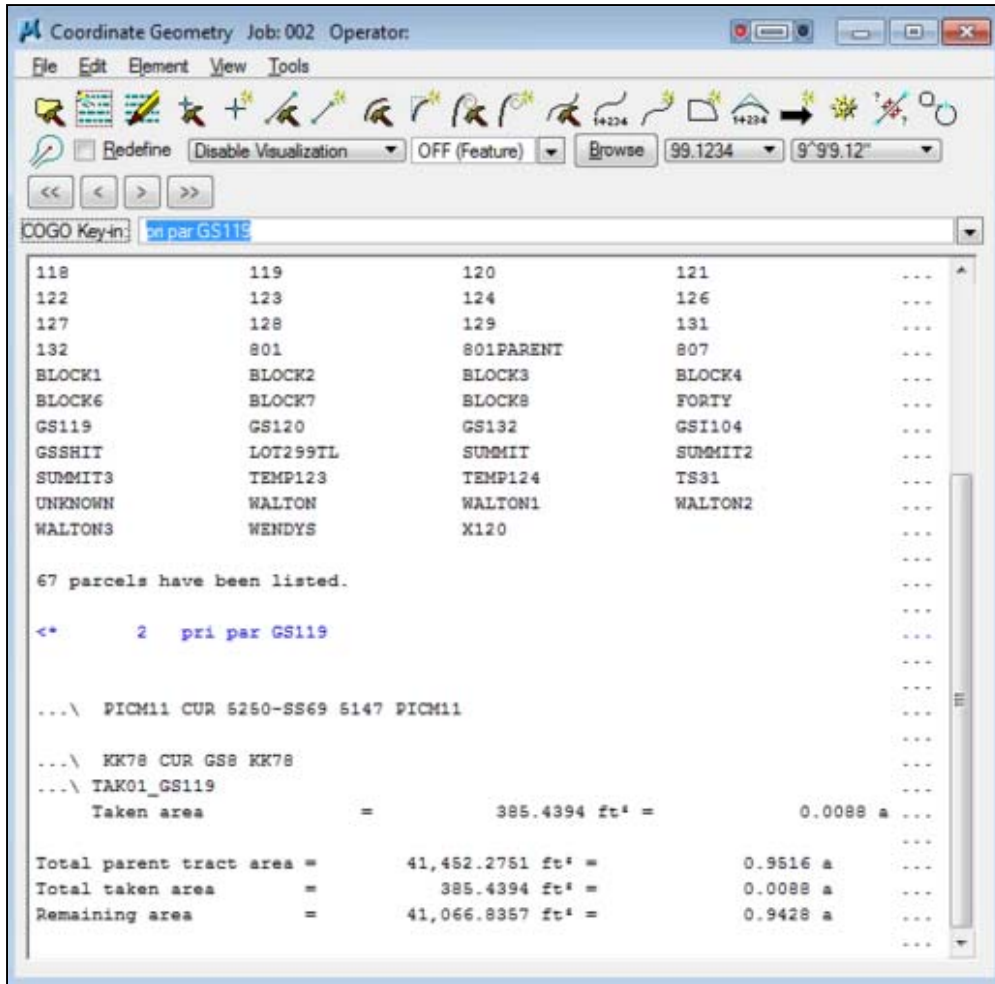
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Figure 35. Sample Output Using MicroStation GEOPAK Coordinate Geometry Manager.

The research team also found cases where the total parent tract area, the total taken area, and the remaining area as displayed by GEOPAK were of the same size. This would be expected if FDOT acquires the parcel as a whole, i.e., the area of the taking is the same of that of the parent tract. However, some parcels clearly had the shape of a typical taking area (slice), but still showed equal areas for taking area and parent tract. This can happen when the taking area and the parent tract are coded as *two separate* parcels in GEOPAK (with the same parcel ID), which makes GEOPAK's distinction between the three areas meaningless.

At the project level, this approach might work as long as the reviewer of the GEOPAK data is aware of the method that was used to code the GEOPAK parcels, and as long as the focus of the activity is to determine parcel areas. A person coding the taking area as a separate parcel would know that GEOPAK's size of the parent tract area would actually be the size of the taking area. However, this approach is not advisable from the standpoint of implementing a systematic approach for the visualization and management of parcels. An obvious reason is that if more than one user opens the GEOPAK file, those additional users might misinterpret the GEOPAK data. Another reason is that if parcels are coded as separate parcels for parent and taking area in GEOPAK, this also prevents the Design and Computation Manager from accurately visualizing

the corresponding lines. The research team also found cases of temporary and duplicate parcel data. For example, Table 22 shows two parcels that start with the word "Temp."

Table 22. Parcels Included in Sample GEOPAK File for SR 50 Lake County Project.

001	102	103	104A
104B	104C	104D	104E
104F	104G	104H	104I
106	107	108	109
110	111	112	113
114	115	116	117
118	119	120	121
122	123	124	126
127	128	129	131
132	801	801PARENT	807
BLOCK1	BLOCK2	BLOCK3	BLOCK4
BLOCK6	BLOCK7	BLOCK8	FORTY
GS119	GS120	GS132	GSI104
GSSHIT	LOT299TL	SUMMIT	SUMMIT2
SUMMIT3	TEMP123	TEMP124	TS31
UNKNOWN	WALTON	WALTON1	WALTON2
WALTON3	WENDYS	X120	

In the current FDOT business process, GEOPAK files are considered working documents that are mostly used to determine taking and remainder areas. The *CADD Production Criteria Handbook* (*23*) provides a guideline on the use of GEOPAK for the development of parcels and calculation of areas, but does not provide a standard for the production of a final deliverable GEOPAK file. As a result, most GEOPAK data contain numerous datasets, including temporary parcels and duplicate information, i.e., not necessarily a "clean" set of parcels. Because parcel data in GEOPAK files are not used beyond the calculation of parcel areas, standardizing the content of GEOPAK files to make these files part of the permanent repository of information would require a change in business practices.

Because the history of how the sample GEOPAK data were created was not available, the research team visualized all GEOPAK data and then deleted duplicates, other unwanted data, and data that appeared to be temporary. The research team visualized parcel information using the GEOPAK Design and Computational Manager using the FDOT 2010 workspace and GEOPAK database (Figure 36). The FDOT workspace provides a database that provides settings to automate the visualization process, such as selecting the level where the design element will be drawn, and which element of the parcel will be automatically drawn. Figure 36 provides a screenshot of the FDOT 2010 workspace Design and Computation Manager interface, and Figure 37 provides a screenshot of the related Draw Plan and Profile dialogue.
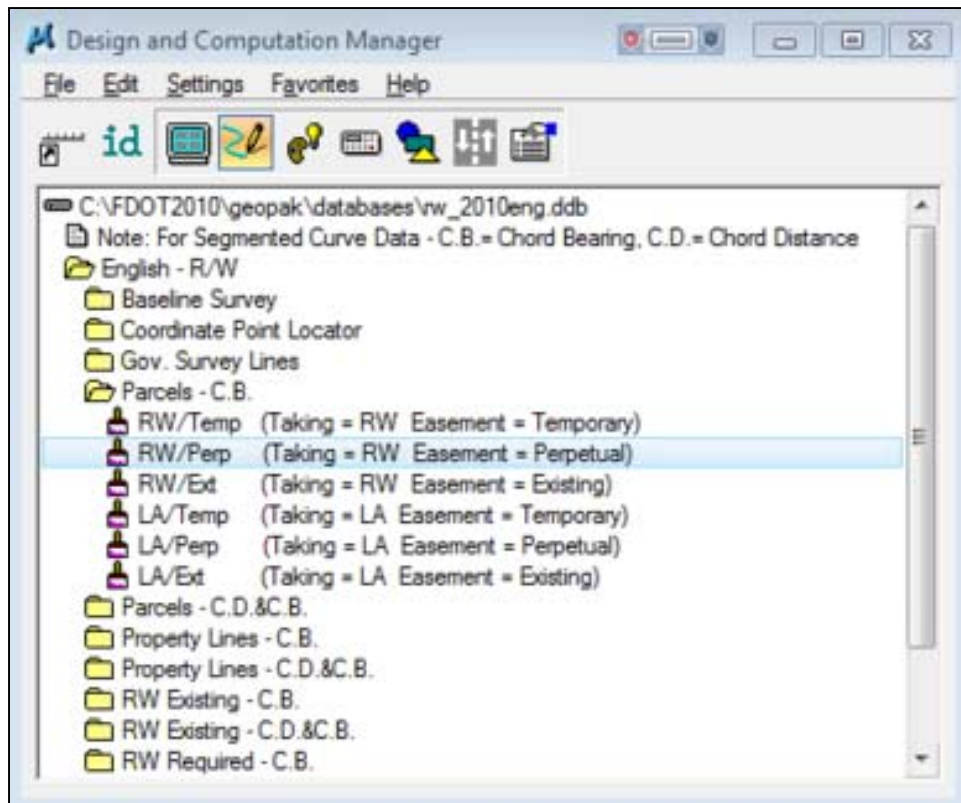
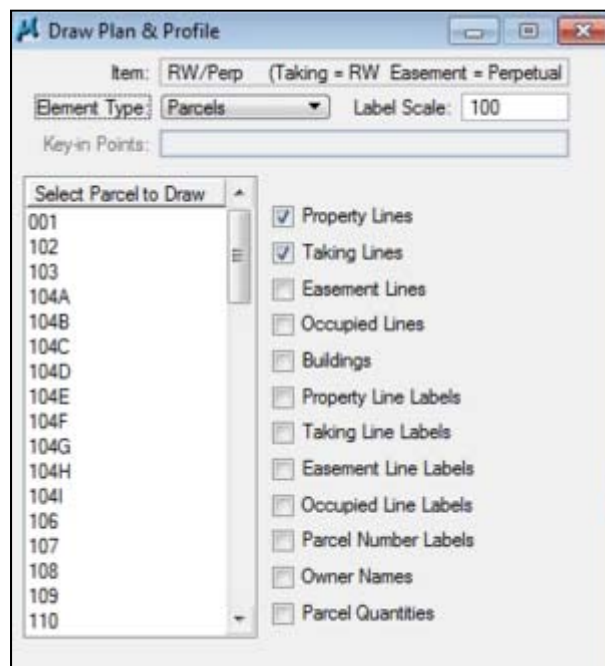**Figure 36. GEOPAK Design and Computation Manager – FDOT 2010 Workspace.**

Figure 37. GEOPAK Design and Computation Manager, Draw Plan & Profile Window – FDOT 2010 Workspace.

Figure 37 also shows the GEOPAK elements that can be selected to be included in the visualization if a user selects the element type "Parcels." These include elements such as property lines, taking lines, easement lines, occupied lines, buildings, property line labels, taking line labels, easement line labels, occupied line labels, parcel number labels, owner names, and parcel quantities. These elements are specific to the element type "Parcels." Other element types that can be selected at the top of the Draw Plan and Profile window include points, lines, curves, spirals, chains, stationing, and profiles.

However, because the current FDOT 2010 workspace does not include parcel levels, the levels cannot be selected by the Design and Computational Manager. To address this issue, the research team shared the modified design library that included the new parcel levels (Table 21) with members of the FDOT CADD team, who provided a modified GEOPAK database version that included settings to visualize GEOPAK data using the new, proposed parcel levels. Figure 38 shows a screenshot of the modified GEOPAK database. Notice that under "GIS Integration," the user has options to visualize parcels on one of five new parcel levels. Once the user chooses the appropriate elements to display, parcels in GEOPAK can be visualized by clicking on the parcel number under "Select Parcel to Draw" (Figure 37).
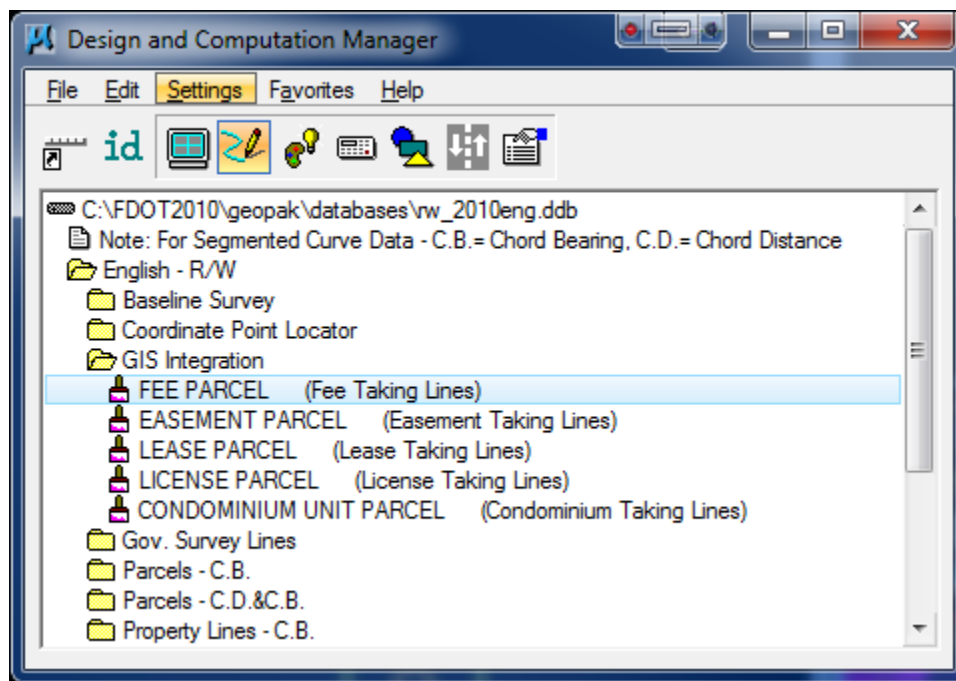

Figure 38. GEOPAK Design and Computation Manager Interface – Modified Version.

It is important to keep in mind that GEOPAK can only draw different types of lines correctly if the parcel was coded correctly within GEOPAK. If the GEOPAK database in the Design and Computation Manager is set up correctly, all lines are displayed on the correct and appropriate level. Since GEOPAK files are often working documents that include temporary data, this is not always the case. As mentioned previously, a parcel could be coded with a taking area that is a portion of a parent tract, or both areas could be coded as separate parcels. Since the author of the GEOPAK file was unknown, the research team selected all options in Figure 37 in an effort to

display all GEOPAK data in that file. The result of this visualization was a MicroStation file with property lines, easement lines, and annotation, as shown in Figure 39.
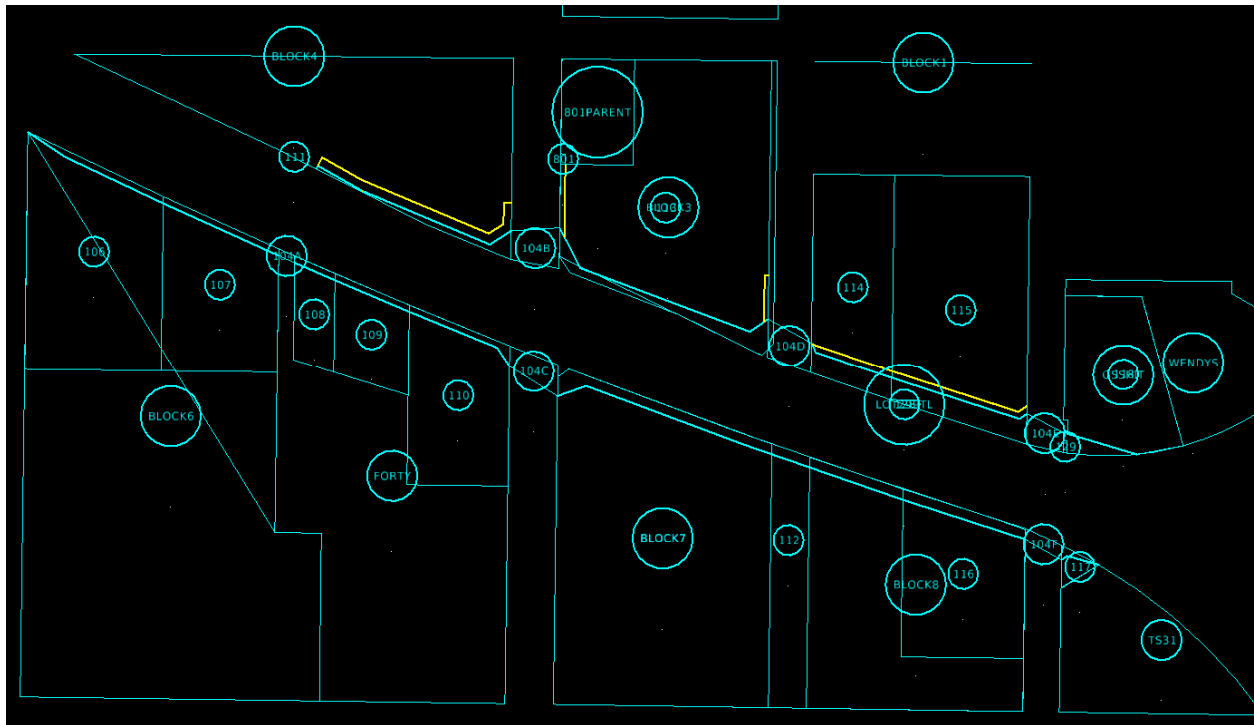

Figure 39. Partial View of GEOPAK Parcel Import from Sample District 5 Files – Project No. 238429-3 (Lake County, State Road 50).

Because the research team visualized all lines using the same visualization settings ("FEE PARCEL" in Figure 38), some of the property lines did not appear on the correct level, and parcel duplicates in the GEOPAK file were also visualized twice. Since the research team did not have any knowledge about the content of the file, it was preferable to display all GEOPAK data and then clean the data subsequently. Once GEOPAK visualized the parcel data, the research team cleaned the MicroStation file of duplicate lines, duplicate annotation, and any other unwanted data.

The final step to prepare the MicroStation file for import to ArcGIS was to identify and select parcel lines to form MicroStation shapes using the "Create Complex Shape" function, as shown in Figure 40. The research team generated polygon shapes in MicroStation by identifying the lines that make up a parcel (by clicking on each line one at a time) and then accepting the selection. After accepting the selection, the "Create Complex Shape" function merged the selected lines into one perimeter, or contiguous parcel line, and then converted that perimeter to a shape. The research team noted that there were multiple lines for adjacent parcels with shared boundaries, which made it easy to create parcels by using a separate line for each parcel.

Figure 40. MicroStation Create Complex Shape Tool Used to Create Parcels.

In practice, following this process to generate shapes is somewhat tedious because a user must create every parcel separately by clicking once on each parcel line. However, it is by far the easiest approach compared to any other process the research team tried because the GEOPAK file already contains information about the actual lines and curves that are used to create parcels and is not cluttered by other design file lines (which would make it difficult to identify parcel lines in typical design files). Once the research team was familiar with the process, cleaning and creating parcels for a right-of-way sheet only took a small amount of time. For example, a right-of-way sheet with 38 parcels took less than one hour to process in MicroStation. The research team expects that once the process is standardized, one to two minutes of processing time per parcel would be a reasonable estimate of the amount of time needed to prepare the MicroStation sheet for import to ArcGIS.

Once the research team created the parcel shapes, the next step was to save the file and use the "Add Data" function in ArcGIS to import the MicroStation file. Figure 41 shows the imported GEOPAK data, and Figure 42 shows the attribute data that were retained after importing the MicroStation design elements.

Figure 41. MicroStation GEOPAK Data after Importing Parcels to ArcGIS.

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	FID	Shape	Entity	Level	Layer	Color	Linetype	Elevation	LineWt	RefName
	85	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	86	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	87	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	88	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	89	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	90	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	91	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	92	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	93	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	94	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	
	95	Polygon	Complex Shape	1135	FeeParcel	7	Solid	0	1	

Figure 42. Sample GIS Attribute Data of MicroStation GEOPAK File.

Extraction and Development of Utility Features

The main source of utility data is utility features that are included in several standard FDOT design files. Following the standard FDOT file naming convention (AAAABB##.ext, where AAAA is the abbreviated file description, BB is the discipline, and ## is the sequence number), utility information can be found in files UTEXRD01.dgn and UTVHRD01.dgn, for existing and verified utility features, respectively. The verified utility file is typically a 3D version of the UTEXRD01.dgn file. Districts provided several examples of files with existing utilities, but no examples of files with verified utilities. Some utility features might also be included in the existing topography file (TOPORD01.dgn) of which FDOT provided several examples.

In general, utility information included in design files only provides information about existing utility installations prior to relocation. However, for long-term storage purposes, information about utility locations after relocation is much more useful. The research team reviewed a sample of project design files for evidence of information about utilities following a utility relocation. Whereas information about existing utilities is routinely included in FDOT design files, the research team could not find any examples of relocated utilities in the sample data that the research team reviewed. However, district officials indicated that files that are used during the utility relocation process (which are not part of the final MicroStation design files) do contain information about relocated utilities (or at least where the relocated utility installations would be located).

FDOT would realize the benefit of an inventory of utility installations in a GIS environment if the department could reassess its current business process and implement a protocol to store information about relocated utilities in MicroStation. This step would close the gap that currently exists between utility information that is available at some point during the design phase and the final MicroStation files that are used during the construction phase of a project. A potential strategy would be to require utility owners to collect as-built information of their relocated facilities and provide this information to FDOT at the conclusion of the relocation project. Information could be collected in the field using accepted survey protocols and

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delivered to TxDOT in MicroStation or GIS format. This new procedure would require a change to the current utility accommodation rules and considerable buy-in from the utility industry.

Utility features in MicroStation include point, linear, and polygon elements that are normally created using reserved MicroStation levels reserved. Because different types of utility features are already drawn on separate levels, it is relatively straightforward to generate utility features in ArcGIS. This process involves identifying the files that contain utility data and then selecting the desired levels with utility features. For the 2010 design libraries, there are 184 utility levels that depict a wide range of utility installation graphical elements that appear in three design libraries: fdot_v8_levels.dgnlib (standard roadway levels), strlevels.dgnlib (standard structure levels), and survey_levels.dgnlib (standard survey levels).

In general, the best option to generate utility features in ArcGIS involves loading a MicroStation file that contains utility features and annotation consisting of points, lines, and polygons directly into ArcGIS. A disadvantage of this approach is that ArcGIS does not support MicroStation referencing, which means that ArcGIS does not import design elements that are displayed in a MicroStation file via a referenced file. As a result, it is necessary to remove or hide all reference files in the MicroStation file that the user is preparing for import to ArcGIS in order to see which elements will be imported by ArcGIS. Another disadvantage is that—similar to the import of GEOPAK data mentioned previously—ArcGIS creates duplicate versions of MicroStation design elements using different ESRI feature classes. For example, a MicroStation shape is imported as one polygon feature and multiple line features. As a result, it is necessary to deal with several duplicate utility features after each import. Following the import, a user can review the attribute tables for feature classes and then edit the table to remove duplicates as necessary.

In addition to these issues, the research team came across some unusual results and unexpected behavior while attempting to create utility features using ArcGIS. In one case, the research team was unable to import any data from a MicroStation file into ArcGIS after modifying the MicroStation file provided by FDOT. If the original FDOT file was imported to ArcGIS, everything worked as expected. However, if the research team modified the file, ArcGIS displayed the elements but did not import any of the attribution.

The research team noted that design elements imported from MicroStation into ArcGIS were often discontinuous, consisting of numerous small features. This is a result of the way design elements are created in MicroStation. For example, depictions of utility lines in MicroStation often consist of multiple, disconnected line elements. These breaks in the line elements are not an issue for the reviewer of the plan because line elements often appear to be connected. Although these breaks are not visible to the reviewer, they create a problem when converting CAD features to GIS features. In a GIS environment, it is desirable to depict complete objects as much as possible to simplify the management of features. This issue could be resolved by implementing a requirement in the CAD standard to avoid unnatural line breaks for utility features as much as possible, essentially following a link/node approach.

In some cases, imported MicroStation files in ArcGIS did not display any attribution. After several rounds of troubleshooting the issue, the research team found that most of this unexpected behavior could be resolved in MicroStation by compacting the file and exiting MicroStation.

CHAPTER 4. DATA MODEL TESTING RESULTS

INTRODUCTION

This chapter summarizes the work completed to test the data model described in Chapter 3 through the use of a prototype application in ArcGIS. The chapter describes the prototype architecture, discusses the procedure to import MicroStation feature data into ArcGIS, and summarizes the results of the tests conducted using sample project data.

PROTOTYPE ARCHITECTURE

To test the data model described in the previous sections, the research team developed a prototype application in ArcGIS to facilitate data entry and querying. The prototype application is in Visual Basic for Applications (VBA) and is fully contained in an ArcGIS project .mxd file. The application architecture includes the ArcGIS application that links to a relational database and a geodatabase, as well as MicroStation files and other project documents. Figure 43 shows the general architecture of the prototype application.
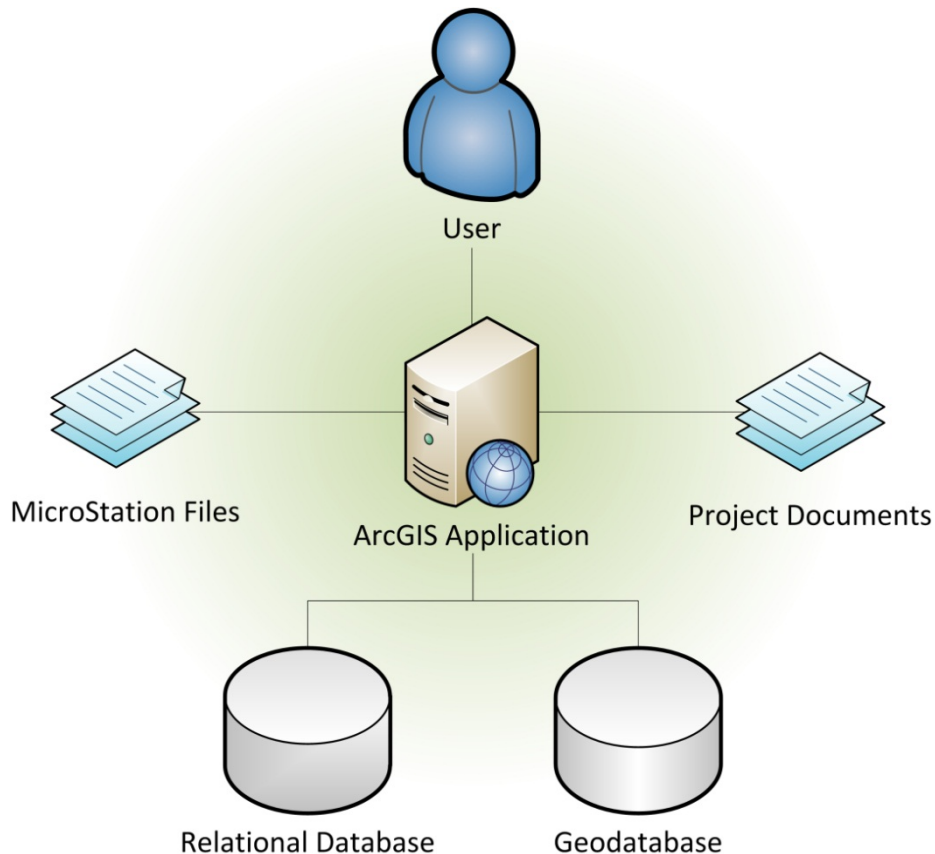

Figure 43. ArcGIS Prototype Architecture.

As mentioned previously, importing MicroStation features to ArcGIS can be accomplished by using the "Add Data" button in ArcGIS. This action stores all MicroStation on-the-fly in a group

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layer with the standard ArcGIS feature classes, which are annotation, point, polyline, polygon, and multipatch. As a result, ArcGIS adds a new group layer for each MicroStation file that a user adds to the map. This approach may be feasible for a small number of files or a single project, but it has severe limitations. For example, storing data in group layers makes it difficult to query the data, makes it much more difficult to handle and display the data, and can slow down ArcGIS to a point where it becomes unusable. Further, the .mxd file does not provide a permanent storage but relies on a reference to the MicroStation files. As a result, if the MicroStation files are moved or renamed, the .mxd file becomes unusable.

The research team used a file geodatabase to store GIS features. The file geodatabase contains three feature classes, GIS POINT FEATURE, GIS LINE FEATURE, and GIS POLYGON FEATURE. In addition to the spatial data, there are numerous additional data items for each feature such as attributes and attribute values. These data items could have been stored in the file geodatabase. However, the research team decided to store these in a separate relational database in order to keep the spatial database as lean and compact as possible.

The prototype application uses a common three-tier client-server architecture in which user interface, functional process logic, and data storage and access are logically separated. The modular architecture provides the additional benefit that any of the tiers can be upgraded or replaced independently if there is a change in FDOT requirements or technology. Figure 44 shows a depiction of the application architecture in which the user interface is represented by a presentation tier, the functional process logic is represented by a business logic tier, and data storage and access are represented by a data tier.

GIS APPLICATION FEATURES

As shown in Figure 44, the presentation tier has five elements that represent five tools that appear on the ArcGIS graphical user interface (Figure 45):

- Tool to import MicroStation features,
- Tool to edit attribute values,
- Tool to associate projects with features,
- Tool to associate documents with features, and
- Tool to delete features.

The following sections provide a detailed description of the functionality of each tool.
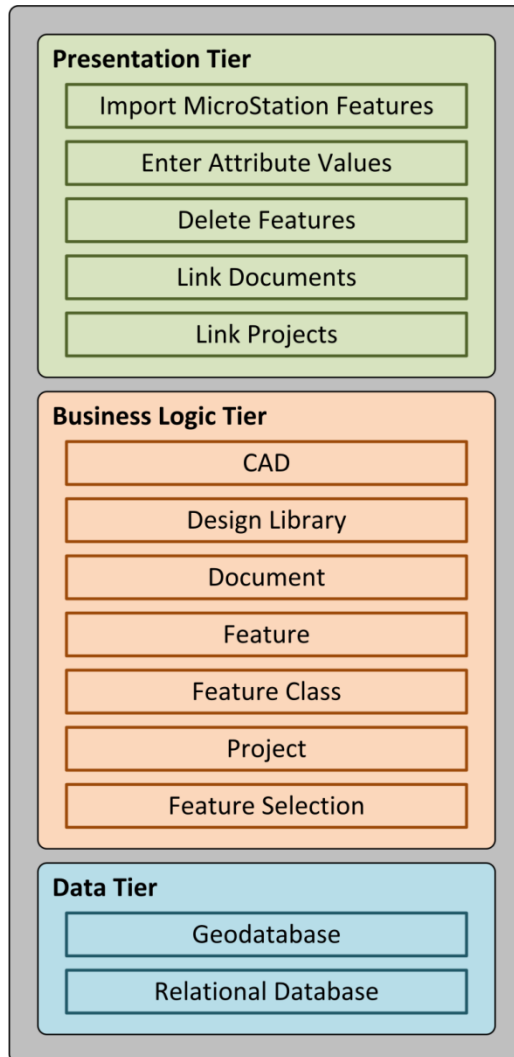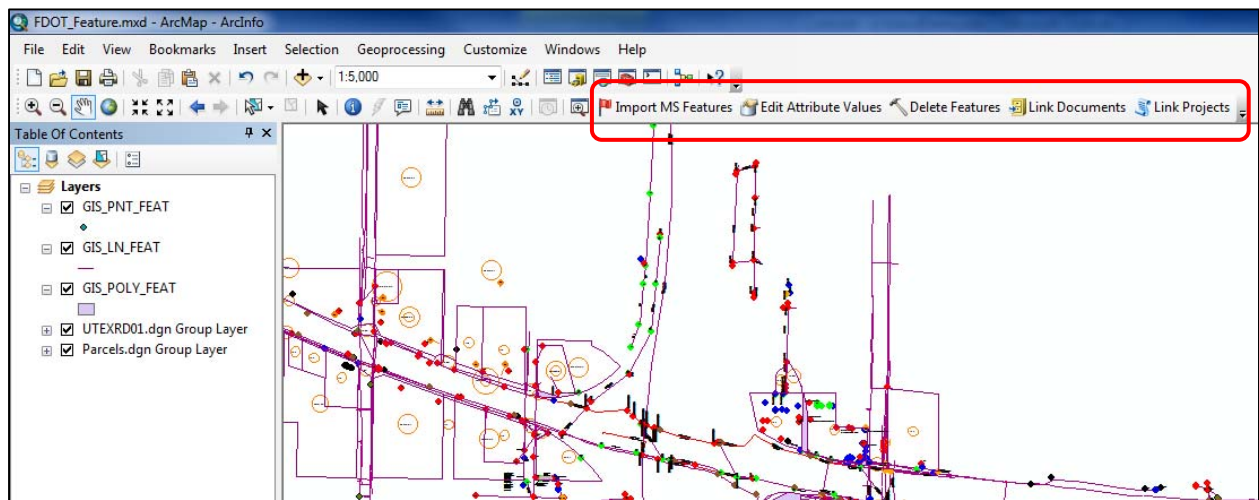
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Figure 44. ArcGIS Application Architecture.

Figure 45. ArcGIS Application: Five New Tools in ArcGIS.

Tool to Import MicroStation Features into ArcGIS

The purpose of this tool is to import features from the temporary ArcGIS feature classes to the permanent application geodatabase. The tool has four main areas: FDOT Design Libraries, MicroStation File, Import Features into Geodatabase, and Imported Features (Figure 46). Importantly, the FDOT Design Libraries section reads information from the relational database of the system, while the MicroStation File section reads information from the imported MicroStation file. The application thus allows comparing the imported features to the FDOT standard in order to make a selection of which features should be imported into the geodatabase.
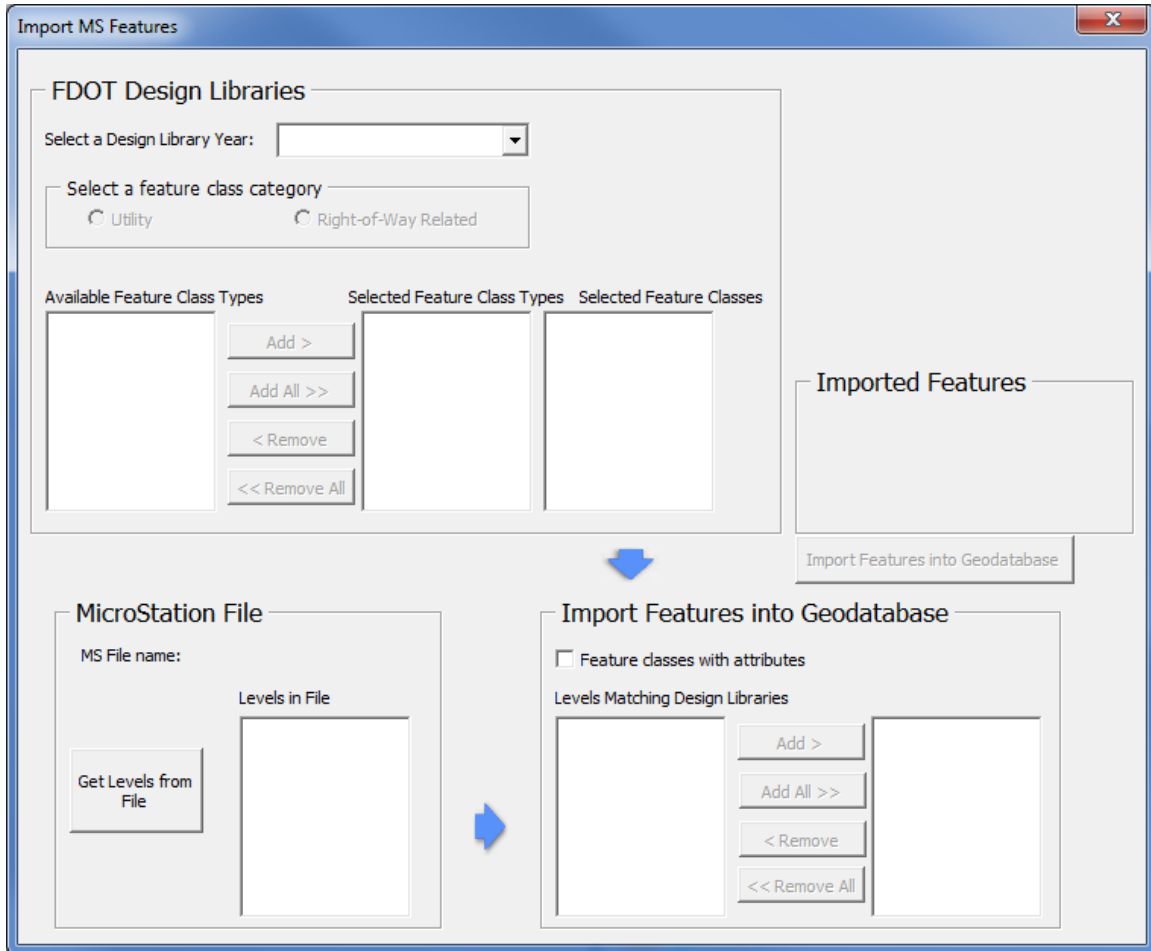
Figure 46. Tool to Extract MicroStation Features into ArcGIS.

To use this tool, a user must first select the design library year that applies to the imported MicroStation file. For example, a file that was created using the FDOT 2010 design standard should use the 2010 design library year (Figure 47.) In the next step, the user must select a feature class category, either Utility or Right-of-Way Related. Selecting Right-of-Way Related will display a list of all right-of-way feature class types for that year in the box "Available Feature Class Types" (Figure 48). At this point, a user can either select one or more feature class types to display a listing of feature classes of that type and click the "Add >" button to select it.

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Figure 49 shows the listing of Parcel feature classes after the user selected and added the Parcel feature class type.

Figure 47. Tool to Extract MicroStation Features into ArcGIS: Design Library Year Selection.

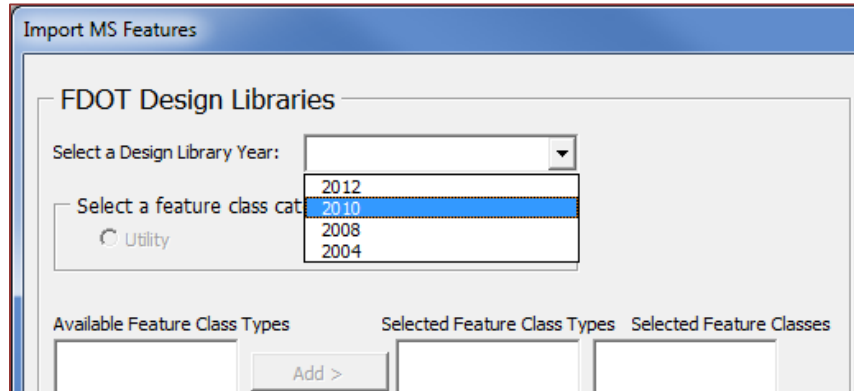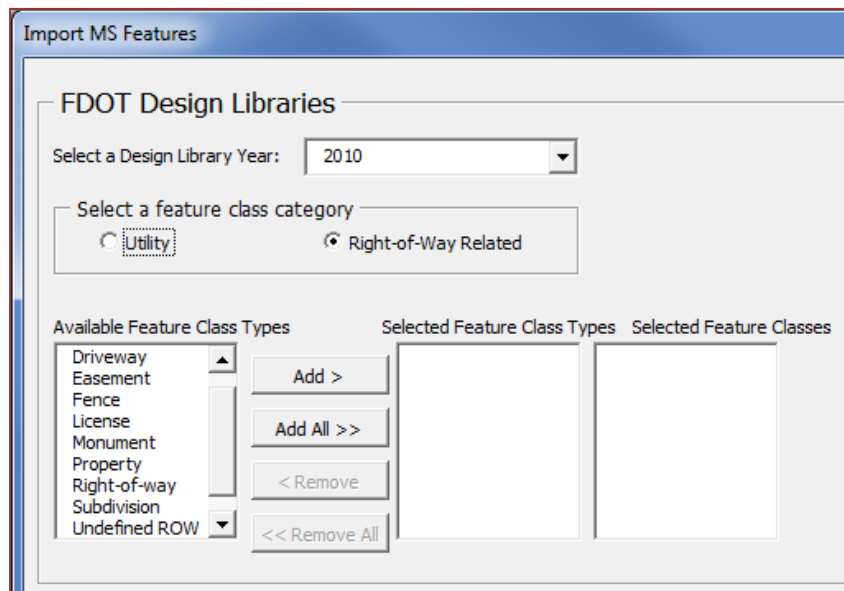**Figure 48. Tool to Extract MicroStation Features into ArcGIS: Right-of-Way Related Feature Class Category Selection.**
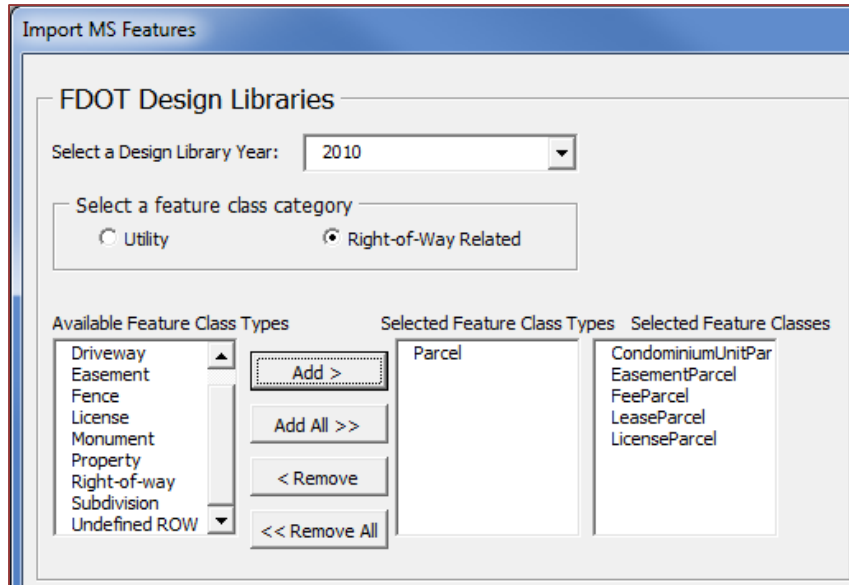
Figure 49. Tool to Extract MicroStation Features into ArcGIS: Select Right-of-Way Related Feature Classes.

In the next step, the application compares the level names that were provided by the MicroStation file with the selected feature classes. In order for this to work, a user must first load all level information from the MicroStation file into the application. A user can perform this task by clicking on the "Get Levels from File" button (Figure 50).
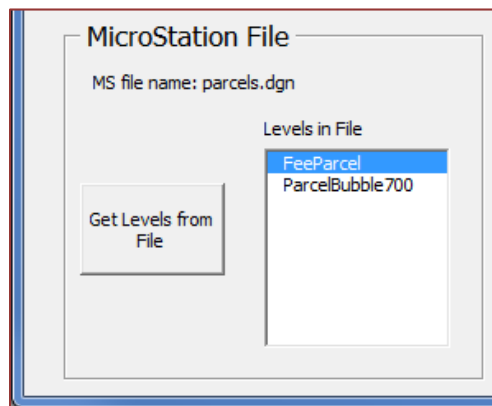
Figure 50. Tool to Extract MicroStation Features into ArcGIS: Get Levels From MicroStation File.

Pressing the button displays all level names from features that were added to ArcGIS. Simultaneously, the application compares this list of levels with the previously selected feature classes. If there are level names in the file that match feature classes, they are displayed in the box "Levels Matching Design Libraries." In this example, the application found the level "FeeParcel" to match a feature class "FeeParcel" of the 2010 design library (Figure 51).
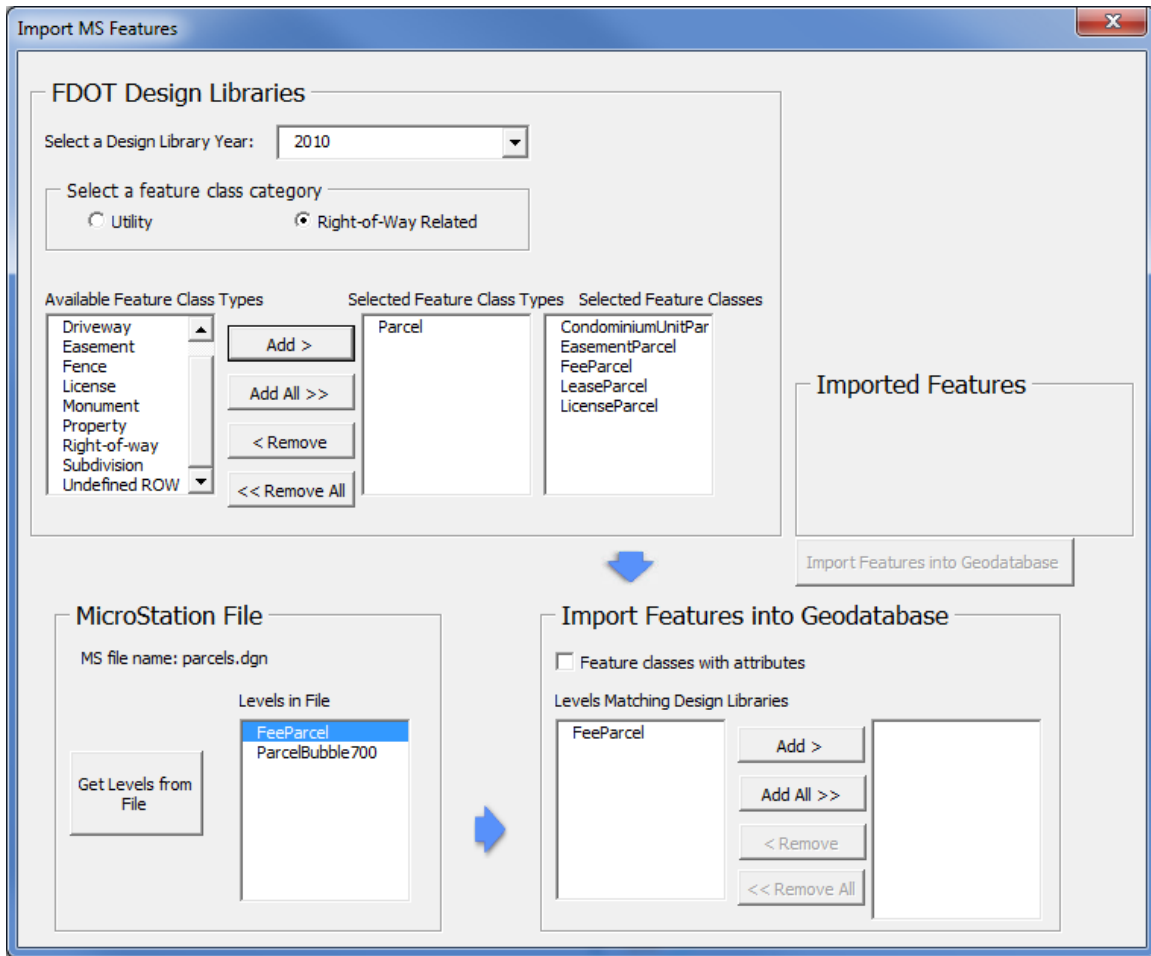
Figure 51. Tool to Extract MicroStation Features into ArcGIS: MicroStation Levels Matching Right-of-Way Related Levels in Design Libraries.

Features in the feature class "FeeParcel" are now ready to be imported. To do so, a user must select the level "FeeParcel" in the box "Levels Matching Design Libraries," click the "Add >" button, and finally click the "Import Features into Geodatabase" button. Once the process is complete, the application displays the number of points, lines, and polygons that were imported (Figure 52).
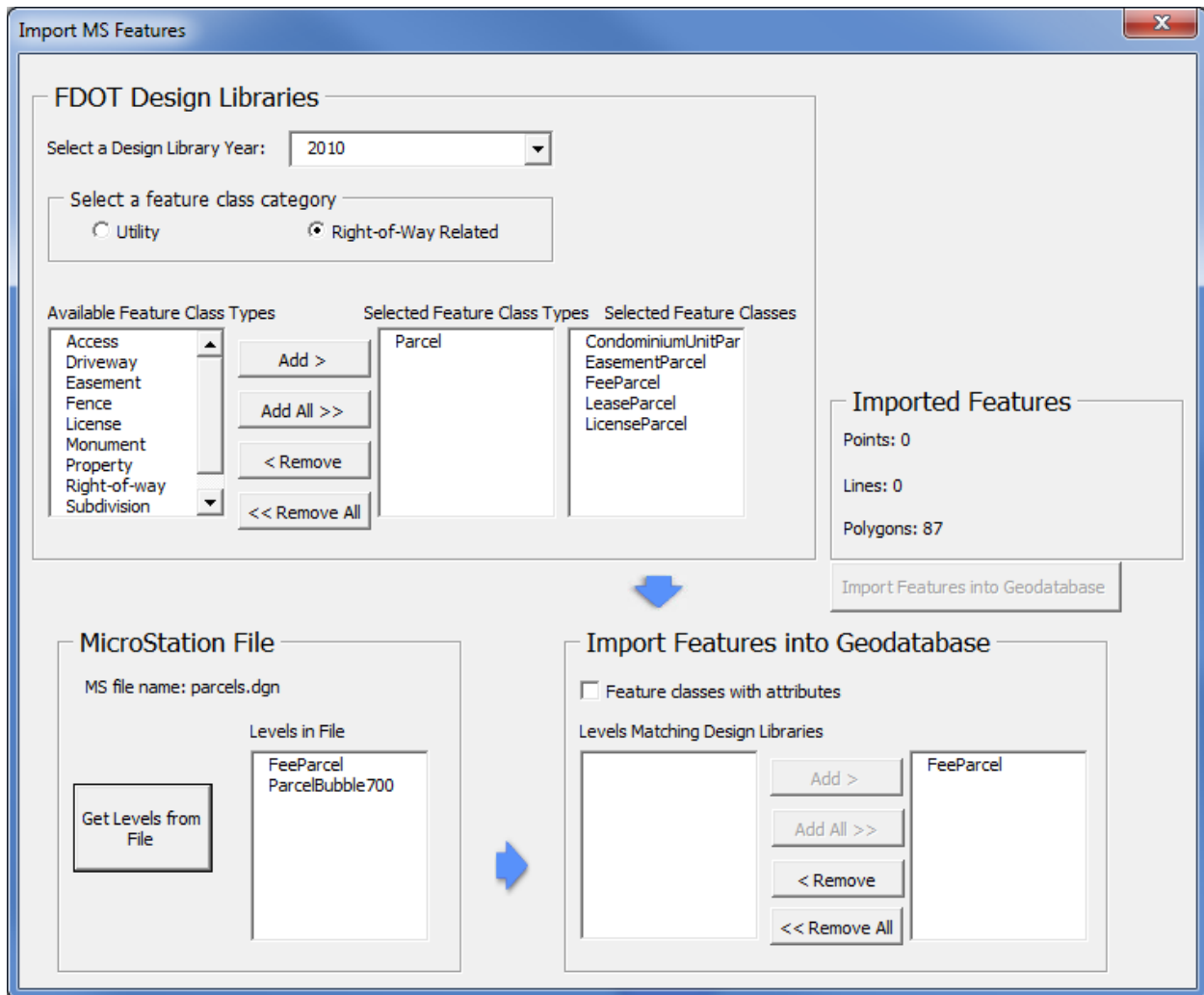
Figure 52. Tool to Extract MicroStation Features into ArcGIS: Import Right-of-Way Related MicroStation Features into Geodatabase.

Once the features are imported into the geodatabase, they can be displayed in ArcGIS by selecting GS_PNT_FEAT, GS_LN_FEAT, or GS_POLY_FEAT, as appropriate. Figure 53 provides a screenshot of the FeeParcel polygons imported in the previous example, located in the geospatial polygon feature class.
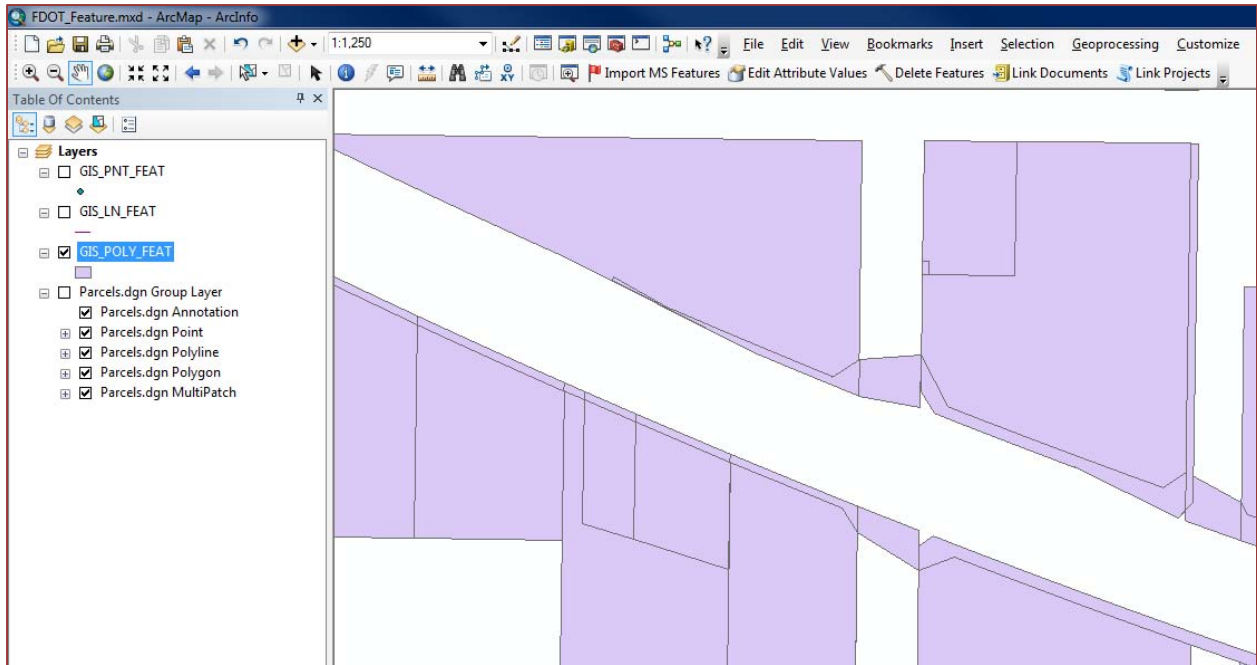
Figure 53. Tool to Extract MicroStation Features into ArcGIS: Imported FeeParcel Polygons in Geodatabase.

The procedure to import utility features is very similar to the procedure to import right-of-way related features, except that a user must select the "Utility" feature class category, then a utility feature class type, and finally a utility feature class. The user must then load levels from a MicroStation file with utility features and then import the features into the geodatabase as described above. Figure 54 provides a screenshot of the process to import buried fiber optic lines, which resulted in 956 additions to the geospatial line feature class.
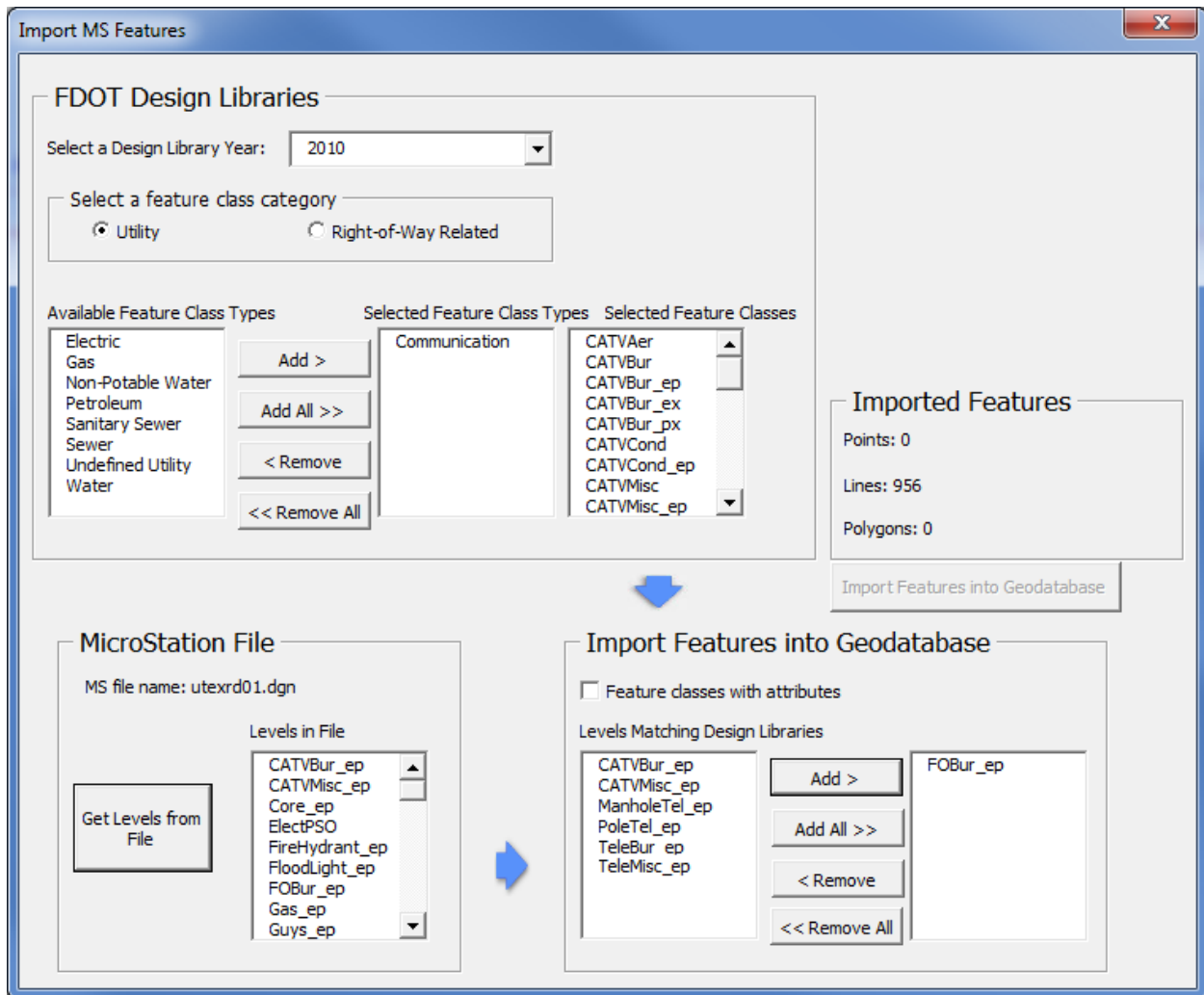
Figure 54. Tool to Extract MicroStation Features into ArcGIS: Import Utility MicroStation Features into Geodatabase.

Figure 55 provides a screenshot of the resulting line features representing buried fiber optic lines in the geodatabase.
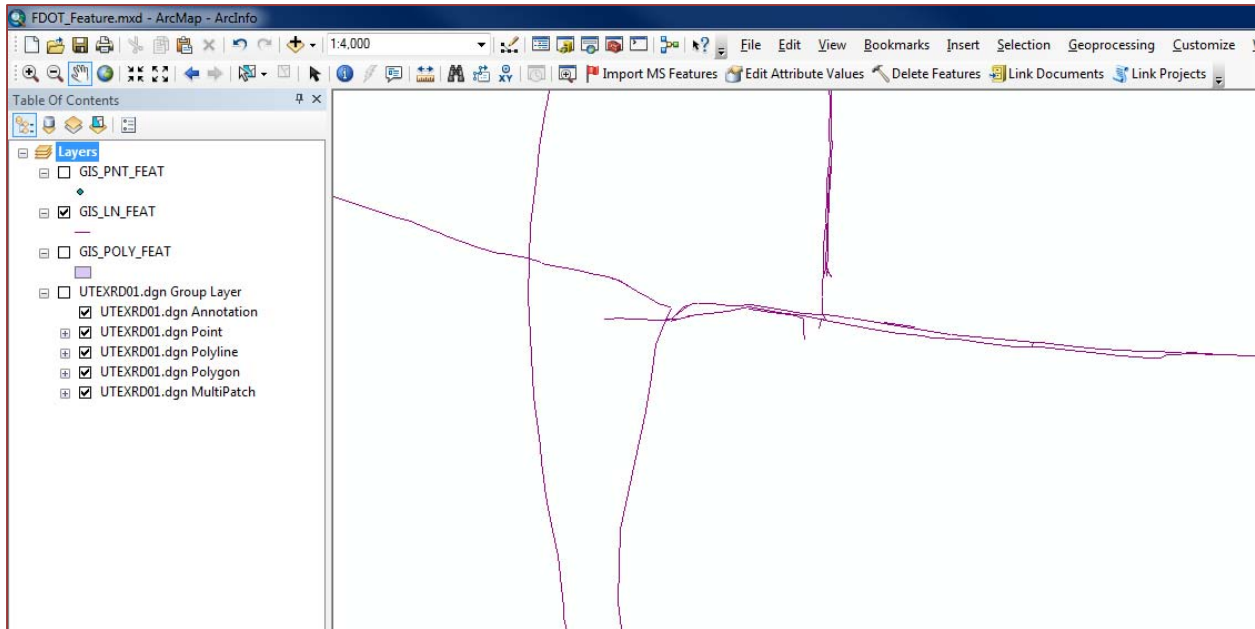
Figure 55. Tool to Extract MicroStation Features into ArcGIS: Imported FOBur_ep Lines in Geodatabase.

Tool to Edit Attribute Values

Once features are stored in the geodatabase, an interface can help populate the values for the feature's attributes. To help in this process, the research team developed a tool called "Edit Attribute Values." The first step in providing attribute values is to select the ArcGIS features from the geodatabase that need attribution. A user can do this by first making the data in the geodatabase visible and selectable, and then using one of the ArcGIS select features tools, for example "Select by Rectangle" to make a selection. The next step is to click the "Edit Attribute Values" icon to open the interface. In the top left corner, a drop-down menu shows the different types of feature classes that were selected by the user. Once the user selects a feature class, the box below will show all features of that feature class that were selected and are in the geodatabase. Figure 56 shows a screenshot of the tool where a user selected the feature class buried existing cable TV line, and the tool found 41 selected features of that feature class.
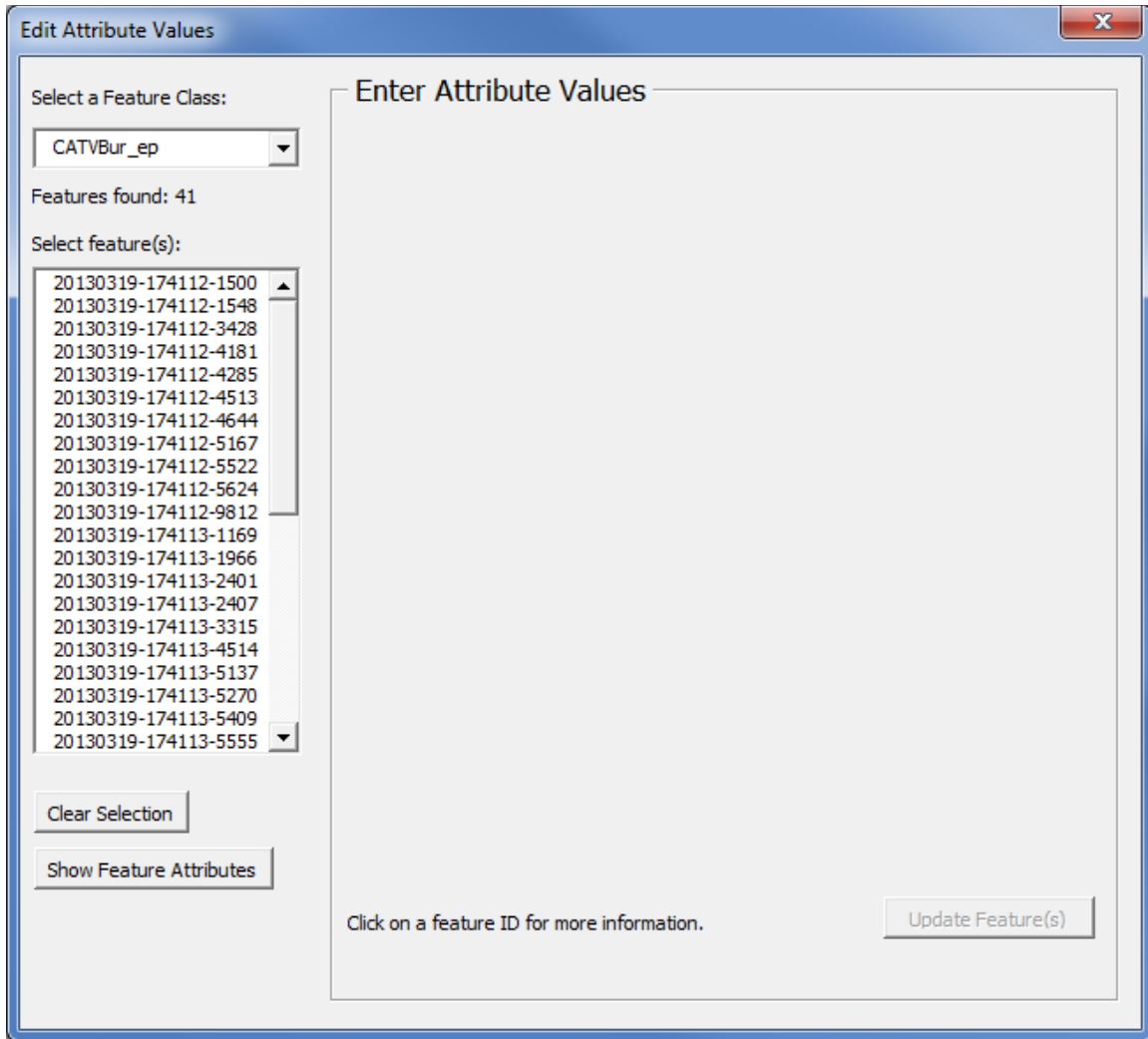
Figure 56. Tool to Edit Attribute Features: Select Features.

At this point a user can select one or more features to provide attribution. The multi-selection tool is useful if multiple utility features have the same attribute value, for example the same owner. In the example shown in Figure 57, a user selected a utility features and then clicked the "Show Feature Attributes" button to display attribute values. Note that if more than one feature is selected and one of the utility feature attributes already has a value, the application does not display that value even if the value is the same, because more than one feature is selected.

In this example, several attributes already have values. Readers should bear in mind that additional information about the utility installation might be available through the utility investigation process and could be added here at this point or at a later date. To edit attribute values, the user must click on the "Edit Feature(s)" button (which will turn into the "Update Feature(s)" button), make a change to an attribute, and then click the "Update Feature(s)" button. Most of the valid attribute values are provided by drop-down menus, which are defined in the relational database and can be easily modified by a system administrator.
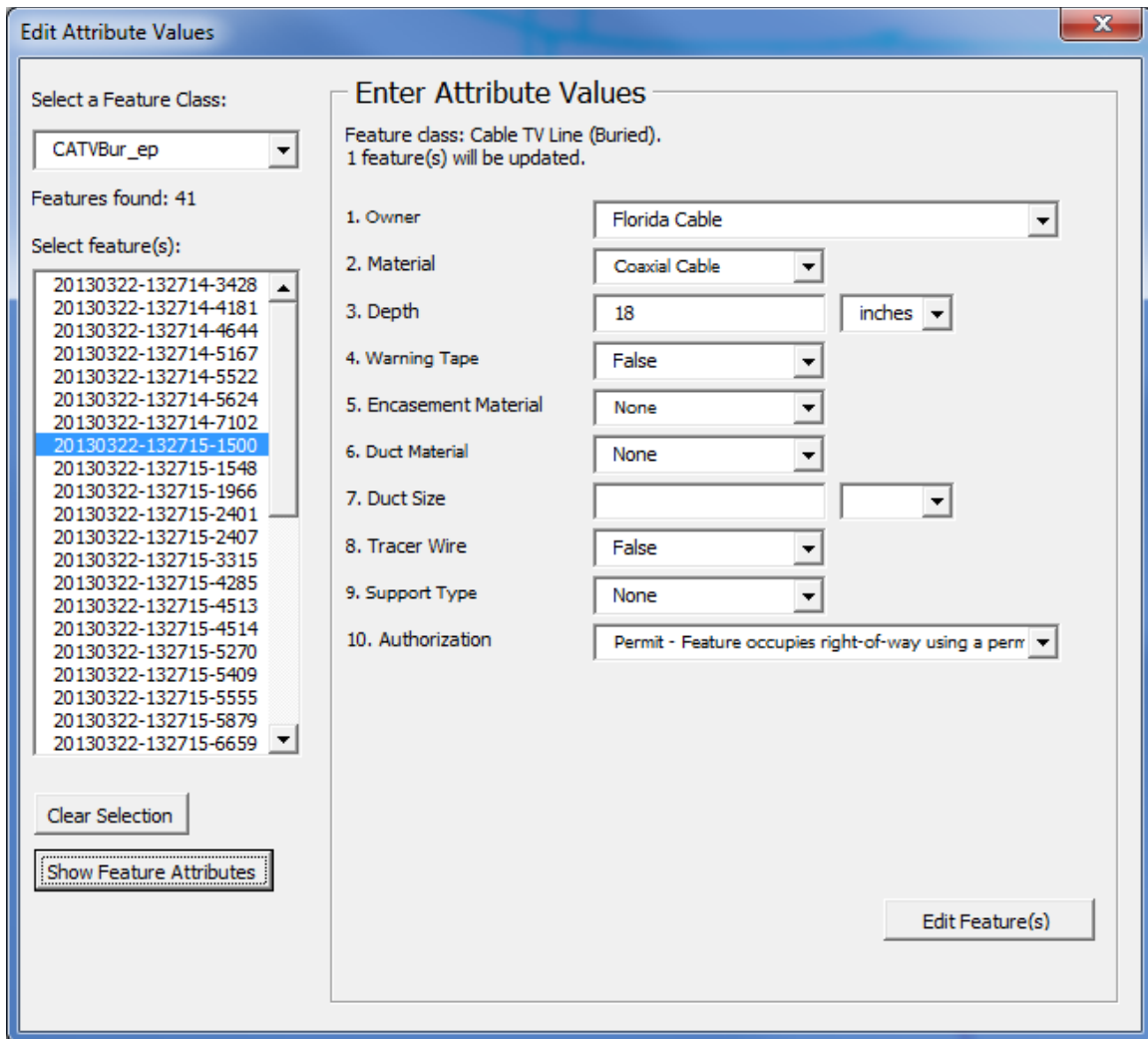
Figure 57. Tool to Edit Attribute Features: Show Feature Attributes of Buried Cable TV Line Feature.

The procedure to edit parcel information is very similar. First, a user must select a parcel feature class, then a parcel, and then show the parcel attributes. Figure 61 is an example of a parcel feature along with available attribute information.
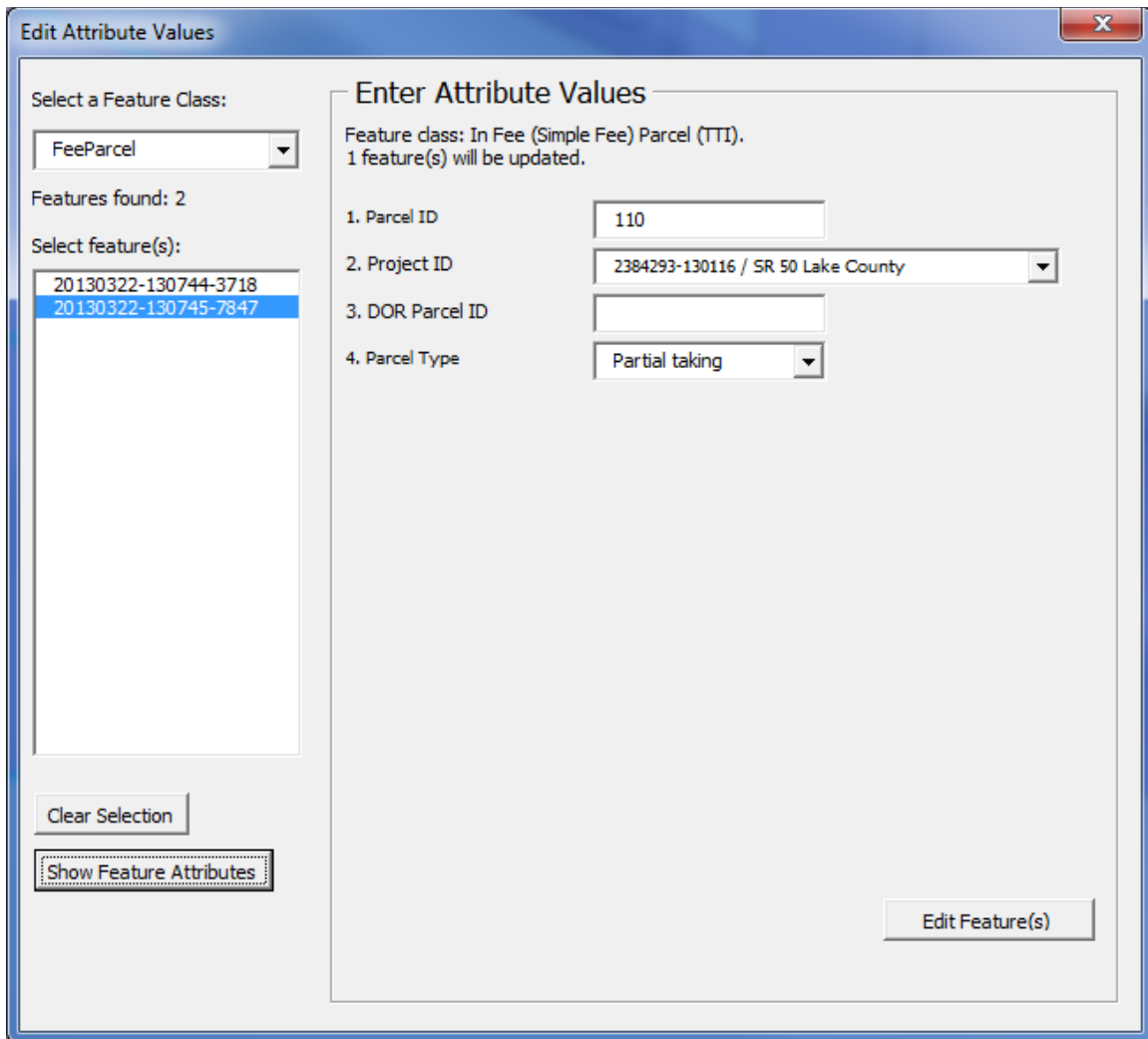
Figure 58. Tool to Edit Attribute Features: Show Feature Attributes of Parcel Feature.

The type of attributes shown for each feature class also depends on settings in the relational database and can easily be adjusted. The research team defined attributes for a selection of feature classes based on feedback provided by FDOT (see the appendix). For an implementation of the application, FDOT would need to complete the definition of attributes for all feature classes and add these definitions to the relational database.

Tool to Associate Projects with Features

The application provides a simple tool to provide links between features and projects. The purpose of this tool is to demonstrate this connectivity at the database level, but not necessarily to serve as a blueprint for implementation (because FDOT already has business processes and information systems that manage information about projects).

Any spatial feature in the geodatabase can be linked to any number of projects, and any project can be linked to any number of features. Once the user has selected one or more features in

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ArcGIS using the "Select Features" tool, the "Link Projects" tool allows a user to select a feature class, then a feature in that class, and a project. By clicking on the "Add Link" button, the application then links the feature to the selected project (Figure 59, Figure 60). Note that in order to be able to create a link, there must be a record of the project in the relational database. An asterisk next to one of the features indicates that the feature is already linked to a project, which can be displayed by clicking on the feature. If the link is no longer desired, a user can click on the displayed project link and click the "Delete Link" button to remove the link.
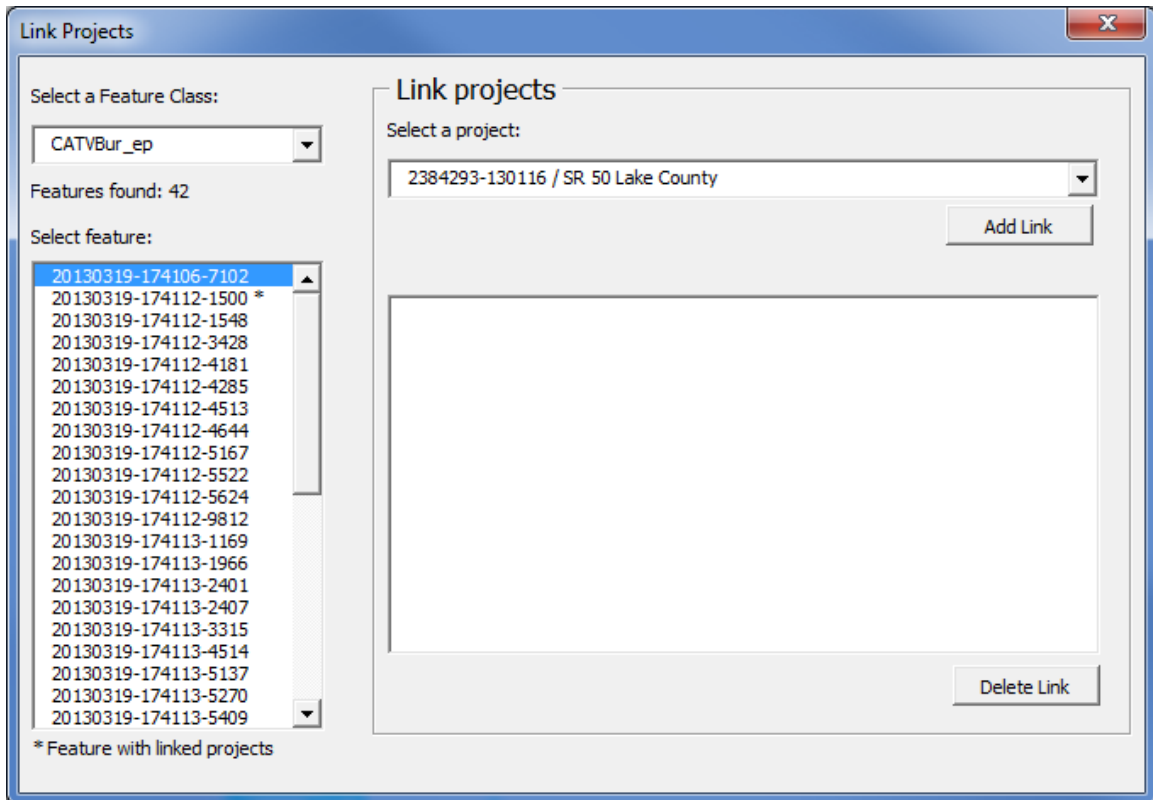
Figure 59. Tool to Associate Projects with Features: Create Link.
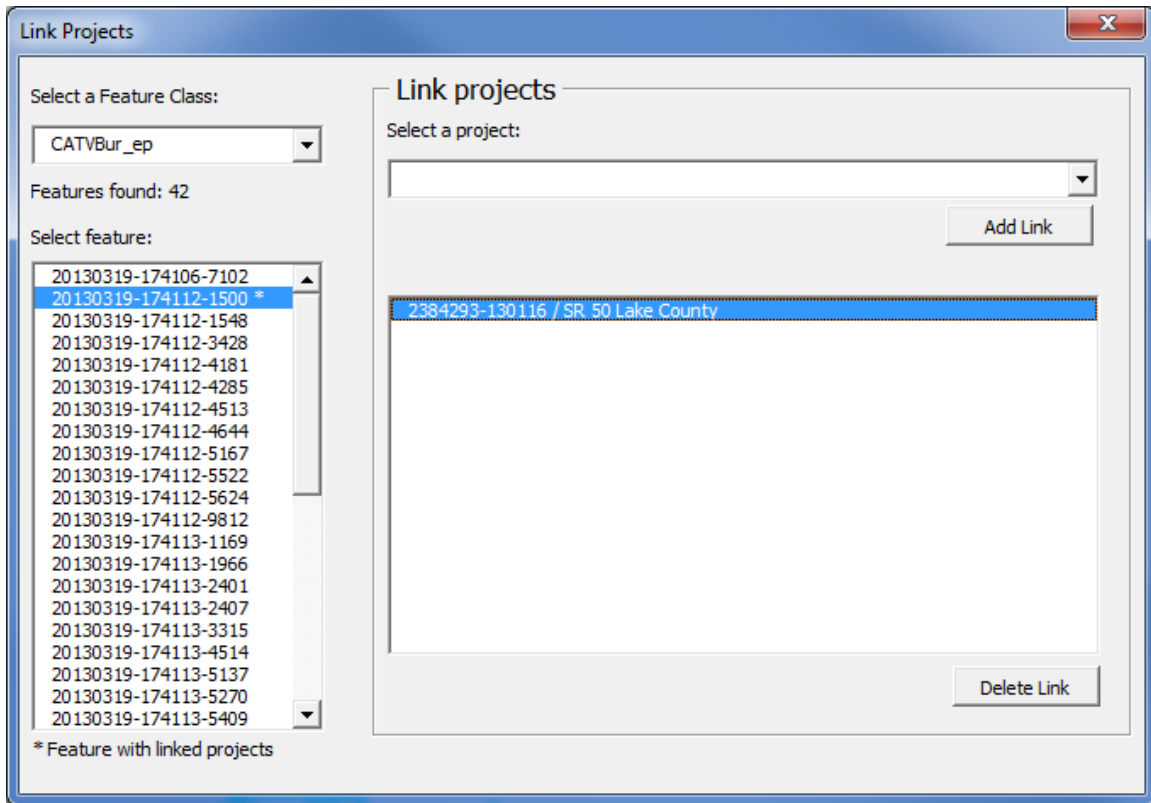
Figure 60. Tool to Associate Projects with Features: Delete Link.

Tool to Associate Documents with Features

The application also provides a tool to provide links between features and documents. The purpose of this tool is to demonstrate this connectivity at the database level, but not necessarily to serve as a blueprint for implementation (because FDOT already has or is implementing business processes and information systems that manage information about documents).

Any spatial feature in the geodatabase can be linked to any number of documents, and any document can be linked to any number of features. Once the user has selected one or more features in ArcGIS using the "Select Features" tool, the "Link Documents" tool allows a user to select a feature class, then a feature in that class, and a document. By clicking on the "Add Link" button, the application then links the feature to the selected document (see Figure 61). An asterisk next to one of the features indicates that the feature is already linked to a document, which can be displayed by clicking on the feature. If the link is no longer desired, a user can click on the displayed document link and click the "Delete Link" button to remove the link (see Figure 62). Note that in order to create a link, there must be a record of the document in the relational database (which currently must be created manually). In an implementation of the prototype, this manual effort would be replaced with a procedure that includes a function to upload documents, which automatically creates a record in the relational database.

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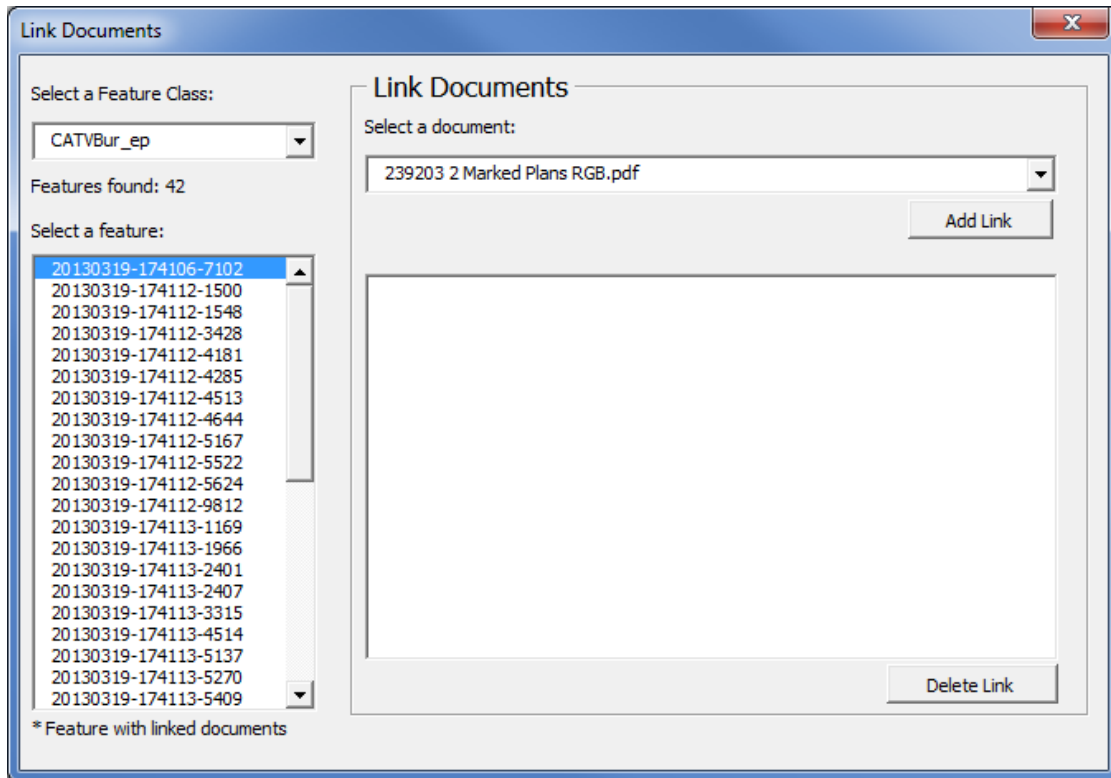
Figure 61. Tool to Associate Documents with Features: Create Link.
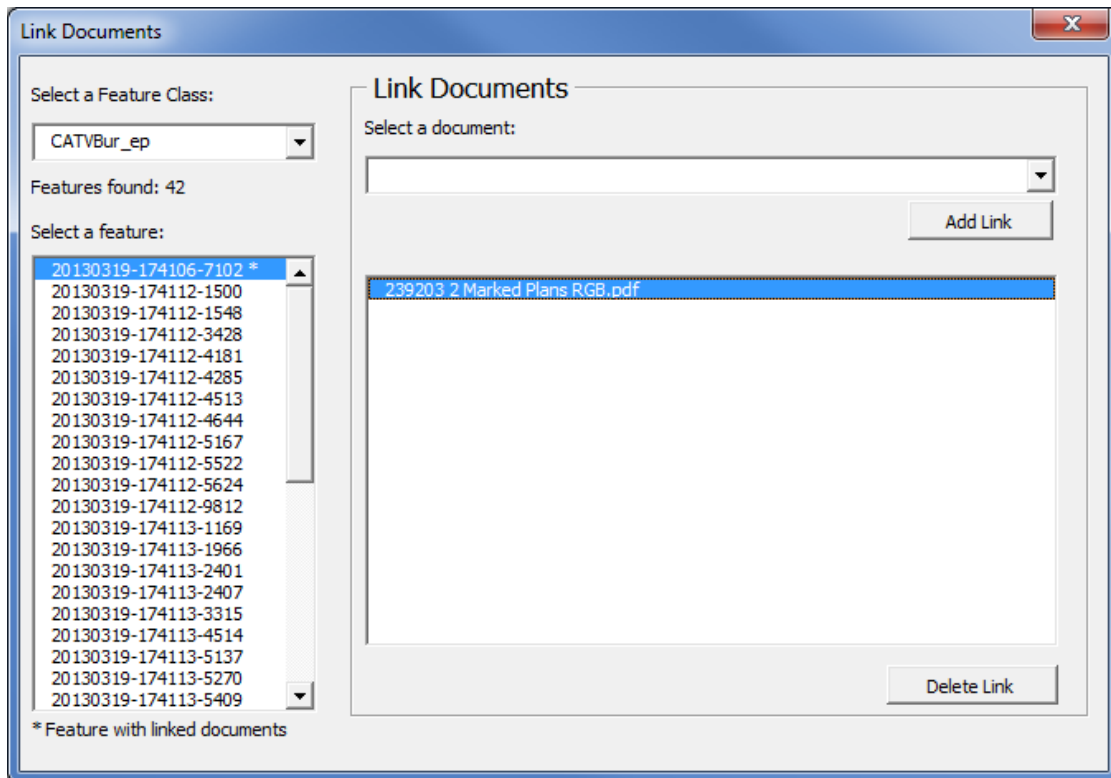
Figure 62. Tool to Associate Documents with Features: Delete Link.

Tool to Delete Features

The application provides a tool to delete features that are stored in the geodatabase, either at the feature level or at the feature class level (which deletes all features within a feature class). The tool only deletes features in the geodatabase that were imported using the "Import MS Features" tool, but not features in other layers such as the .dgn group layers. In order to delete features, the user must first select those features using the "Select Features" tool in ArcGIS. In order to delete all features within a feature class, the user must first select all the features in that feature class using the "Select Features" tool in ArcGIS. In other words, the application can only delete features that were selected by the user.

Once the user has selected one or more features, the user can select a feature class and then any number of features in that feature class (see Figure 63). Clicking the "Delete Selected Feature(s)" removes these features from the geodatabase. To delete all selected features within a feature class it is not necessary to select all features manually. Instead, a user would simply click the "Delete Selected Feature Class" button.
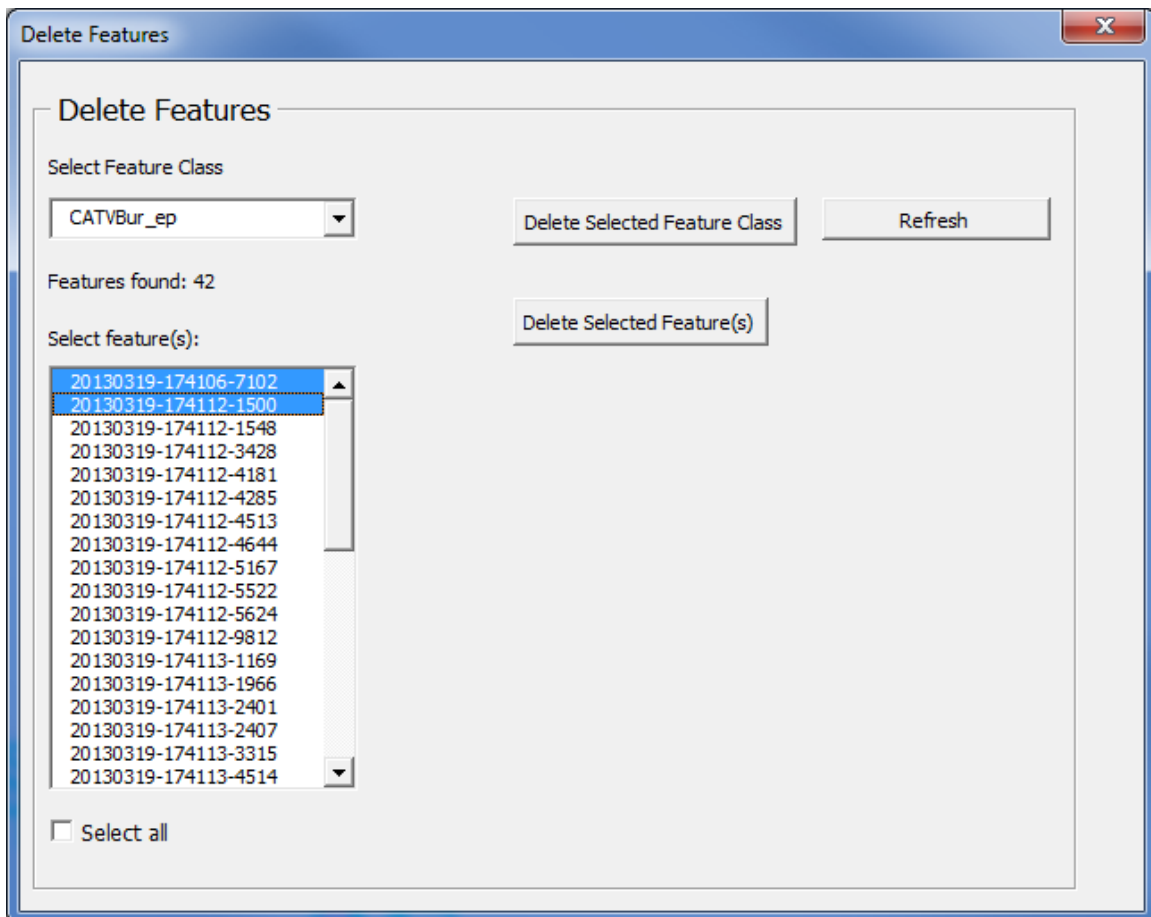
Figure 63. Tool to Delete Features.

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GENERAL COMMENTS ABOUT THE TESTING PROCESS

The main objective of the prototype application was to demonstrate a testing environment for the data model that could provide the following functionalities:

- Import right-of-way parcels and utility features from MicroStation files into ArcGIS, including feature attribution provided by the MicroStation design library,
- Link parcels and utility features to projects,
- Link parcels and utility features to documents,
- Enter attribute information for parcels or utility features, and
- Delete parcels or utility features from the geodatabase.

The prototype application was tested both at TTI and at FDOT.

As mentioned, using a modified FDOT design library and the GEOPAK Design and Computation database, the research team was able to visualize GEOPAK parcels in MicroStation files and then import the parcel shapes in these files into a geodatabase. Once a file was imported to ArcGIS, the research team was able to import right-of-way and utility features into a geodatabase, link features to project information and specific documents, and add or edit feature attribute information. Finally, the research team was able to delete features from the geodatabase.

The research team noted some issues that could affect the performance of the application. One of those issues is that MicroStation data such as parcel information in tables and annotation can be imported into ArcGIS, but that information is not automatically attached to features. For example, the parcel ID is an annotation that would need to be manually added as an attribute value to the parcel feature in ArcGIS. Scripts could be developed to automate this process in ArcGIS by detecting annotation styles and text, but there is no certainty at this point that the effectiveness of using such as script would be better than transcribing the parcel ID. A more effective strategy would be to develop a script in GEOPAK or MicroStation to automatically assign the parcel ID as an attribute to the shape that is created during the GEOPAK visualization process. However, this strategy would need to be tested to establish its feasibility.

In most cases, the research team did not have major issues importing design files into ArcGIS. However, in some instances, attribute information was not imported when the research team imported a design file with utility data into ArcGIS. In this case, it was not possible to identify the utility features and, therefore, importing utility features into the geodatabase did not succeed. The issue occurred unpredictably when the research team made certain additions or deletions to sample MicroStation files that districts provided to the research team. The research team found that this issue was related to an interface issue between the ArcGIS and MicroStation applications, and could be resolved in most cases by compacting the design file upon exit from MicroStation.

MicroStation files must be reviewed in MicroStation prior to importing features into ArcGIS to ensure that the proper content will import correctly. For example, a MicroStation file might

display design elements from a reference file, which can only be determined by reviewing the reference file manager. Data elements residing in reference files are not imported by ArcGIS.

There are also numerous data items in design files related to utility installations that are provided in the form of tables or other types of annotation. Although ArcGIS can import this information, it must be manually transcribed for each feature by selecting a feature, opening the edit attribute tool, and then manually entering the data. Most likely, this procedure would be too time-consuming and not feasible for large datasets. Using a commercial platform such as FME to automate this process might be possible provided the linework in MicroStation is sufficiently clean and contiguous, and annotation design, location, and content follow predictable rules).

Another strategy to address this issue, which is increasingly used in practice and the research team has experimented with in the past (*22*), involves using GPS data collectors equipped with data dictionaries that enable users to capture attribute data in the field while conducting regular survey activities or utility investigations. This type of protocol could also be used after utility installations are relocated. Once attribute data are captured in the field, the data could be imported into a geodatabase back in the office (or uploaded wirelessly from the field while data collection is taking place).

The research team noted that design elements in MicroStation, more specifically utility lines and to a lesser extent, right-of-way and parcel lines, were often discontinuous, consisting of multiple, disconnected line elements. This is a result of the way design elements are frequently created in MicroStation. Breaks in the line elements in MicroStation are normally not an issue for a designer or reviewer of the files because these elements appear to be connected. However, although these breaks are not visible to the reviewer, they can create a problem when converting MicroStation features to GIS features. In a GIS environment, it is normally desirable to depict complete objects as much as possible in order to simplify and optimize the management of features in the database. This issue could be resolved by implementing a requirement in the CAD standards, effectively requiring consultants to avoid "unnatural" line breaks for utility features by following a link/node model, e.g., by having line breaks at "logical" nodes such as junction boxes, manholes or valves, therefore reducing the number of CAD elements depicting utility feature as much as possible.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

FDOT is responsible for the safe operation and management of thousands of miles of highways. More than 12,000 centerline miles are on-system miles, of which roughly half are located in urban areas. This total includes 456 centerline miles that are part of the Florida Turnpike Enterprise. FDOT manages a huge right-of-way asset. Examples of core processes related to this asset include determining right-of-way boundaries; inventorying roadside features; preparing right-of-way maps; acquiring, selling, and leasing property interests; and regulating the accommodation of utilities within the right-of-way. Ready access to related information is a key requirement not just for streamlining project delivery but also throughout the life cycle of transportation infrastructure facilities.

This report summarizes the results of research conducted to assist FDOT in developing a strategic implementation plan for the management of right-of-way parcel and utility data at the department. To support this effort, the research involved a review of current FDOT systems and practices and development of recommendations as to what vision and/or strategies to pursue. To achieve this goal, the research team conducted meetings with key stakeholders, reviewed and analyzed existing documentation, developed data models, conducted a demonstration of a prototype application to test the extraction of parcel and utility data from MicroStation to ArcGIS, examined potential implications related to the Bentley Map initiative, and prepared recommendations for implementation.

Meetings with key stakeholders included meetings with officials from Central Office, Districts 5, and District 6. The purpose of the meetings was to learn or confirm information about business processes, systems, and other items of interest in connection with the management of right-of-way parcel and utility data. Also of interest was to gather suitable sample project data. The meetings and conference calls covered a wide range of topics, including as surveys and titles, right-of-way acquisition, utility coordination and production of utility plans, GIS practices and initiatives, permits, and coordination with other aspects of the project development process.

The research included a comprehensive review of MicroStation design libraries in use at the department and a determination on how to apply this information to the development of a data model and protocol for the extraction of parcel and utility data from MicroStation into a GIS environment. FDOT uses several design libraries in MicroStation. Each design library includes levels and their corresponding descriptions and properties, as well as filters. The number of levels within each design library has evolved over the years. From year to year, levels have been added to the library, but, at the same time, other levels have been removed from the library. The design libraries provide levels for graphical design elements on plan views and cross-sections and profiles, and levels for annotations and cells. The libraries also provide distinct levels for features that exist on the ground and features that are being proposed. In some cases, such as easement line annotation, the design libraries provide distinct levels for perpetual and temporary features.

For the 2012 workspace distribution, the FDOT design libraries include some 1,647 unique levels that can be used to depict a wide range of design elements. The research team identified

117 elements that were right-of-way map graphical elements and 184 levels that can be used to depict a wide range of utility installation graphical elements. Although the design libraries include graphical elements to depict parcels being acquired, mainly by using property lines and existing and proposed right-of-way lines, there is a not a polygon or shape parcel level in the MicroStation design libraries. As a result, parcel information in MicroStation design files is not stored as shapes or polygons.

The research team considered several options to identify and merge parcel boundaries to create polygons, either before or after importing the data into ArcGIS, including generating parcel shapes in ArcGIS, generating parcel shapes in MicroStation using design elements from the right-of-way file, and generating parcel shapes in MicroStation using GEOPAK data. A major advantage of using survey data already residing in GEOPAK files is that this information is readily available and is based on field survey data. Because of the advantages of this approach, the research team explored it further to develop a generalized protocol to develop parcel shapes in MicroStation. This made it necessary to add a parcel level to the right-of-way design library. For completeness, the research team added five parcel levels to handle various kinds of parcels that the department deals with on a regular basis: in fee (simple fee) parcels, easements, leases, licenses, and condominium units. Although the procedure using GEOPAK data worked better than any other procedure, it is important to note that GEOPAK is not used for all projects, e.g., in situations where parcel sketches are prepared. FDOT would need to encourage the use of GEOPAK for all projects, or develop an alternative procedure for projects that do not use GEOPAK to add georeferenced parcel shapes to parcel levels.

Given the way FDOT has structured its MicroStation design libraries and levels, it is possible to imagine a wide range of data modeling alternatives to manage right-of-way and utility-related information. The research team considered a wide spectrum of potential modeling alternatives, including expanded and compact modeling approaches for spatial and attribute (i.e., non-spatial) data. A potential implementation at FDOT would likely fall somewhere between these four extreme alternatives. In addition to basic spatial and attribute data, the research team also considered linkages to other business processes such as projects and documents through the use of many-to-many relationship tables.

For the purpose of demonstrating the process to import MicroStation features into a GIS environment, the research team developed and tested a compact data model including three spatial data tables: a point feature table for point features, a line feature table for linear features, and a polygon feature table for polygon features. However, the research team also considered other compact modeling approaches, e.g., one in which separate point, line, and polygon features are defined for different categories of features classes, e.g., oil and gas, water, communications, and so on. For attribute data, the research team used a compact approach that involved using a single master table containing a list of all the potential features in the database, a master list of attributes containing a list of all the potential attributes that could be associated with any feature class, and a third table containing actual attribute values for individual features. In addition to these groups of tables, the data model includes a table to handle a master list of projects and a table to handle a master list of documents. The data model also includes tables to handle the many-to-many relationship between features and documents and the many-to-many relationship between projects and documents. For simplicity, this version of the model did not include a user

table or many-to-many tables to handle the relationship between the user table and other tables in the data model.

Based on the compact data model, the research team developed a prototype application in ArcGIS to facilitate data entry and querying. The prototype application is in Visual Basic for Applications and is fully contained in an ArcGIS project .mxd file. The application architecture includes the ArcGIS application that links to a relational database and a geodatabase, as well as MicroStation files and other project documents.

The prototype application uses a common three-tier client-server architecture in which user interface, functional process logic, and data storage and access are logically separated. The modular architecture provides the benefit that any of the tiers can be upgraded or replaced independently if there is a change in FDOT requirements or technology. In the application architecture, the user interface is represented by a presentation tier, the functional process logic by a business logic tier, and data storage and access by a data tier. In ArcGIS, the elements of the presentation tier are displayed to a user as five tools on the graphical user interface, as follows: Import MS Features, Edit Attribute Values, Link Projects, Link Documents, and Delete Features.

The main objective of the prototype application was to demonstrate a testing environment for the data model that could provide the following functionalities:

- Import right-of-way parcels and utility features from MicroStation files into ArcGIS, including feature attribution provided by the MicroStation design library,
- Link parcels and utility features to projects,
- Link parcels and utility features to documents,
- Enter attribute information for parcels or utility features, and
- Delete parcels or utility features from the geodatabase.

The prototype application was tested both at TTI and at FDOT.

The research team noted some issues that could affect the performance of the application. For example, MicroStation data such as parcel information in tables and annotation can be imported into ArcGIS, but that information is not automatically attached to features. The parcel ID is an annotation that would need to be manually added as an attribute value to the parcel feature in ArcGIS. Scripts could be developed to automate this process in ArcGIS by detecting annotation styles and text, but there is no certainty at this point that the effectiveness of using such as script would be better than transcribing the parcel ID. A more effective strategy would be to develop a script in GEOPAK or MicroStation to automatically assign the parcel ID as an attribute to the shape that is created during the GEOPAK visualization process. However, this strategy would need to be tested to establish its feasibility.

Likewise, there are numerous data items in design files related to utility installations that are provided in the form of tables or other types of annotation. Although ArcGIS can import this information, it must be manually transcribed for each feature by selecting a feature, opening the edit attribute tool, and then manually entering the data. Using a commercial platform such as

FME to automate this process might be possible provided the linework in MicroStation is sufficiently clean and contiguous, and annotation design, location, and content follow predictable rules). Another strategy to address this issue, which is increasingly used in practice and the research team has experimented with in the past, involves using GPS data collectors equipped with data dictionaries that enable users to capture attribute data in the field while conducting regular survey activities or utility investigations. This type of protocol could also be used after utility installations are relocated. Once attribute data are captured in the field, the data could be imported into a geodatabase back in the office (or uploaded wirelessly from the field while data collection is taking place).

In most cases, the research team did not have major issues importing design files into ArcGIS. However, in some instances, MicroStation attribute information was not imported when the research team imported a design file with utility data into ArcGIS. The issue occurred unpredictably when the research team made certain additions or deletions to sample MicroStation files that districts provided to the research team. The research team found that this issue was related to an interface issue between ArcGIS and MicroStation, and could be resolved in most cases by compacting the design file upon exit from MicroStation.

MicroStation files must be reviewed in MicroStation prior to importing features into ArcGIS to ensure that the proper content will import correctly. For example, a MicroStation file might display design elements from a reference file, which can only be determined by reviewing the reference file manager. Data elements residing in reference files are not imported by ArcGIS.

Design elements in MicroStation, particularly in the case of utility lines, were often discontinuous, consisting of multiple, disconnected line elements. Breaks in the line elements in MicroStation are normally not an issue because these elements appear to be connected to the user. However, they can create a problem when converting MicroStation features to GIS features because in a GIS environment, it is normally desirable to depict complete objects as much as possible in order to simplify and optimize the management of features in the database. This issue could be resolved by requiring designers to avoid "unnatural" line breaks for utility features by following a link/node model, e.g., by having line breaks at "logical" nodes such as junction boxes, manholes, or valves, therefore reducing the number of CAD elements depicting utility feature as much as possible.

RECOMMENDATIONS

This section provides a summary of recommendations for the management of right-of-way parcel and utility data at FDOT based on the results of the research. Recommendations for right-of-way parcel data management include the following:

- Include parcel levels in FDOT right-of-way design library,
- Use GEOPAK to visualize parcel information and create parcel shapes,
- Update GEOPAK database for use in Design and Computation Manager,
- Develop new standards for depicting parcels on FDOT MicroStation files, and
- Integrate application with EDMS and RWMS using mapping component.

Recommendations for utility data management include the following:

- Complete attribution for utility features,
- Change business process to capture utility data after relocation, and
- Update CAD standard to require continuous utility features in MicroStation.

General recommendations include the following:

- Facilitate electronic collaboration between FDOT and utility owners,
- Use geodatabase as permanent storage for right-of-way and utility data,
- Remove inconsistencies in the naming of standard MicroStation levels, and
- Implement Bentley Map on a Trial Basis.

Include Parcel Levels in FDOT Right-of-Way Design Library

This research resulted in five new parcel levels (see Table 21), which correspond to common kinds of parcels that the department deals with on a regular basis: fee parcels, easements, leases, licenses, and condominium units. The research team recommends formalizing the inclusion of these new levels in the next release of the right-of-way design library. FDOT should also update its CAD standards to include a requirement that the new parcel levels should not be used for any other purpose (e.g., to delineate property lines or right-of-way lines since existing MicroStation levels can already be used for those purposes).

Additional parcel levels might be necessary (e.g., to manage the spatial component associated with utility subordination agreements), although the feasibility of these levels would need to be established since a limited number of parcel levels might be sufficient to track right-of-way information effectively. Spatial information for utility subordination was not included in any sample GEOPAK files that the research team reviewed. In order to store this information in a GIS as a parcel outline, this information would need to be created, either in MicroStation or ArcGIS. An easier way to deal with this issue might be to manage subordination as an attribute that could be associated with utility facilities. This attribute would enable officials to mark utility facilities affected by subordination and refer details of the subordination to linked documents.

Use GEOPAK to Visualize Parcel Information and Create Parcel Shapes

The research team evaluated several methods to create parcel shapes and import these into a geodatabase. The best method to create parcel shapes from existing design files involved using GEOPAK. Tracing parcel outlines in MicroStation or identifying parcel outlines an merging polygons in ArcGIS were too time consuming and cumbersome. Using GEOPAK survey data to visualize and create parcel shapes is less time consuming, but has several requirements. First, the project must have parcel data stored in GEOPAK. Second, the design library attached to the file must have at least one parcel level. Consequently, when creating an inventory of historical information using past project files, FDOT would need to modify the design libraries of previous

FDOT workspace editions, e.g., years 2004, 2008, 2010, and 2012, depending on which workspace version was used when the design files were created.

Update GEOPAK Database for Use in Design and Computation Manager

The research team recommends updating the GEOPAK database used for the GEOPAK Design and Computation Manager to facilitate the creation of parcel shapes. The process that the research team used to visualize parcel data used the most current version of the FDOT Design and Computation Manager database, which did not include the new parcel levels. To address this issue, FDOT made a modification to the current GEOPAK database to account for the new parcel levels. Using the modified GEOPAK database facilitated the production of parcel features during the research because parcels could be automatically saved to the correct level. This modified GEOPAK database would need to be included in the next FDOT workspace setup file.

Develop New Standards for Depicting Parcels on FDOT MicroStation Files

The research team recommends developing new standards for the depiction of parcels on FDOT MicroStation files. The outcome of the standard update should be that consultants are required to deliver design files with information about parcels on the new parcel levels, regardless of what survey software is used in the process. The standard could be worded in such a way that in the future, GEOPAK files would be considered authoritative data, as compared to temporary data. As such, GEOPAK file deliverables should not include duplicate data or temporary lines, parcels, or points. Further, FDOT should include in the standard a definition of how consultants should code parcels in GEOPAK. Specifically, it could state that a parcel should define the parent tract and the taking area, as compared to defining these areas as two separate parcels. The standard could also encourage including the parcel description in the GEOPAK legal description editor.

Parcel sketches are still used. Although they serve a purpose, the research team recommends using GEOPAK (or an alternative procedure that produces georeferenced parcel shapes) for all parcels that the department acquires. Some district personnel indicated that using GEOPAK in all cases is too cumbersome, which might point to the need for additional training on the use and configuration of GEOPAK.

As an additional benefit, having parcel data on a separate parcel level would provide a significant benefit to stakeholders outside of FDOT. These stakeholders, including property owners, often find it difficult to visualize the parcel(s) that FDOT is planning to acquire. Having parcel information on a separate level would make it straightforward to highlight, shade, or color parcels as needed for interacting with stakeholders, and then hide that information when it is not needed for that purpose.

Integrate Application with EDMS and RWMS Using Mapping Component

In its current format, RWMS can provide information about parcels such as area and ownership, and linkages to associated documents. However, RWMS cannot display parcel locations, either in the form of a reference point or actual parcel outlines. The GIS framework developed as part of the research could be used to provide this information.

Conceptually, RWMS could be modified to provide a link to parcel shapes and locations, or, alternatively, the GIS application could be modified to provide linkages to parcel documents and other information in EDMS and RWMS following the general approach that was demonstrated during the research. If FDOT modifies RWMS, parcel data in RWMS could be expanded to provide a hyperlink or map icon that would open a map interface with the location and shape of the parcel. The GIS application would be implemented as part of EGF, which would require a link between EGF and RWMS to uniquely identify parcels. This link could be the feature ID or a combination of project ID and parcel ID. Either way, records would need to added in both systems to provide the linkage.

Complete Attribution for Utility Features

One of the outcomes of the research is a list of potential attributes for utility feature classes, which involved several iterations between the research and FDOT officials. Where feasible, the research team used lookup tables to simplify the task of providing the attributes for individual features. The research team transcribed this information to an Excel table that contained a listing of all utility features included in the 2010 FDOT design libraries. The research team was able to expand attribution for several utility features that were similar to the utility features for which FDOT provided attribution. For example, the research team assumed the attributes for "Telephone (Buried)" to be the same as those for "Telephone (all sizes Buried), Duct, Toll" and "Telephone for Cross-Sections (Buried - Miscellaneous - Existing)." FDOT also provided a list of utility feature classes that are often seen along transportation corridors in Florida, but are currently not included in the FDOT standard. The research team also provided attribution for these feature classes. During implementation of the list of attributes, FDOT should review and complete the list of attributes and make changes to the relational database accordingly.

FDOT was also interested in providing a mechanism to enable users to track the property right status of utility installations that are located within the right-of-way (e.g., by easement, permit, or other type of property right). To address this need, the research team provided a look-up table in the database that can be linked to any type of utility feature class as needed. FDOT could either assign this attribute to all utility features, or select key or critical utility facilities that warrant tracking of property right status.

Change Business Process to Capture Utility Data after Relocation

For long-term asset management purposes, it will be critical to identify and manage utility locations, particularly after utility installations are relocated. However, design files only provide information about facilities before they are relocated or adjusted. The research team reviewed

sample project design files for evidence of information about utility installations following a utility relocation. The sample data that the research team reviewed did not include any such data. FDOT would benefit the most from utility features in a GIS if it could reassess its current business process and determine a procedure to store information about relocated utilities in MicroStation. This step would close the gap that currently remains between utility information that is available during the design phase and utility information that is available during the construction phase of a project.

A strategy to address this issue involves using GPS data collectors equipped with data dictionaries that enable users to capture attribute data in the field while conducting regular survey activities or utility investigations. This type of protocol could also be used after utility installations are relocated. Once attribute data are captured in the field, the data could be imported into a geodatabase back in the office (or uploaded wirelessly from the field while data collection is taking place).

Update CAD Standard to Require Continuous Utility Features in MicroStation

Depictions of utility lines in MicroStation often consist of multiple, disconnected line elements. These breaks in the line elements are not an issue for the reviewer of the MicroStation file (or resulting printouts) because line elements often appear to be connected. However, in a GIS environment, it is desirable to depict complete objects as much as possible. The updated CAD standard should include a requirement to avoid "unnatural" line breaks for utility features, effectively reducing the number of CAD elements depicting utility features as much as possible by following a link/node approach.

Facilitate Electronic Information Exchange between FDOT and Utility Owners

FDOT should pursue strategies that facilitate electronic information exchange with utility owners. The prototype developed during the research is one such mechanism. However, electronic information exchange could also involve the electronic review and markup of design files because of the potential for a significant reduction in the number of iterations between the department and utility owners. Ideally, the system would display utility information based on information provided by utility owners, with the appropriate safeguards to ensure data confidentiality. In practice, implementing such a system would involve a paradigm shift and willingness by the utility industry to adopt common data exchange standards with the department and other stakeholders.

Use Geodatabase as Permanent Storage for Right-of-Way and Utility Data

FDOT assembles a wealth of data about utility installations and right-of-way parcels during the project development and delivery process. Although this information is not necessarily discarded, it is scattered across a multitude of MicroStation files that are difficult to access and next to impossible to query. Implementing a system based on the prototype application tested during the research would give FDOT the ability to access utility and parcel data, as well as

integrate these data with current CAD and GIS frameworks. Data in the application could be used to facilitate the process of leasing unused right-of-way, identifying surplus right-of-way, and improving access to this information by the public.

Remove Inconsistencies in the Naming of Standard MicroStation Levels

FDOT should address issues with the current naming of MicroStation levels, including the following:

- Different levels handle existing and proposed design features. However, not all proposed-feature levels have equivalent existing-feature levels, and not all existing-feature levels have equivalent proposed-feature levels. Something similar happens with the relationship between plan-view levels and cross-section levels. The lack of a comprehensive treatment for MicroStation levels introduces complexity in the analysis and modeling of existing and proposed features, including right-of-way and utility features.

- Several utility levels lack sufficient descriptive information to identify the appropriate utility type. Examples include "Vent," "Wood strain pole," and "Unknown valve box." For convenience, the research team created an "Undefined Utility Feature" feature class type in order to include these MicroStation level in the expanded data model. Similarly, a number of right-of-way levels lack sufficient descriptive information in order to identify the appropriate right-of-way type. To include these levels in the data model, the research team created an "Undefined Right-of-way Feature" feature class type.

- There were unusual level names that could represent redundant design elements. For example, most water utility features start with the word "water," except for water valves, which start with the word "valves." There was also one case of a water utility feature that started with the word "utility." Similar cases were found for sanitary sewer levels. For the most part, these levels start with "sanitary," except for valves, which may or may not include the word "sanitary."

- There were several instances of MicroStation levels having the same (or a similar) name or description, both within the same or different design libraries. This could result in problems when comparing or running queries on levels across design libraries. Ideally, an element or object should belong to only one level across design libraries. Conversely, the research team found cases where the same level description was used for levels with different level names, both in the same design library or in different design libraries. In most cases, the difference between two level names with the same description was the suffix "_ep" for a level in the survey_levels design library that appeared without the suffix in the fdot_v8_levels design library.

- Because level names are not always sufficiently descriptive, an alternative is to use level descriptions when modeling features in a database environment. However, level descriptions in the current design libraries have issues such as the following:

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- o Level descriptions including special characters, e.g., &, :, /, (, and), which can be problematic for database modeling purposes.
- o Lack of consistency and redundant use of singular and plural level descriptions, e.g., "ROW Line" and "ROW Lines."
- o Inconsistent use of certain level name qualifiers, e.g., using "aerial" for some levels and "overhead" for other levels, or not using "aerial" or "overhead" for all above ground installations. A similar situation occurs for buried or underground installations.
- o Spelling and capitalization inconsistencies, such as the way abbreviations and descriptors are used, e.g., ROW versus RW or R/W, With versus w/, Misc. vs. Miscellaneous, (Existing) versus – Existing, Elec. versus electric or electrical, and Junct. versus junction.

Implement Bentley Map on a Trial Basis

Bentley Map provides several benefits to the current FDOT business process. For example, design elements in MicroStation would be treated as features, which means that every point, line, and polygon in a file would be defined as an instance of a feature class with a set of defined attributes. This approach is paradigm shift from the current graphics-based approach that FDOT uses to manage and organize design elements in MicroStation. The current quality control procedure at FDOT involves checking for compliance with FDOT CAD standards by comparing level names in the design files with level names in the standard. For critical levels, the procedure also checks line style, line weight, and line color. However, there is no way to detect if a line on a particular level is an actual representation of a feature that should reside on that level. For example, a consultant might accidentally place water lines on a gas line level. In Bentley Map, features can be identified directly using the feature ID or name, and do not need to be identified indirectly via level name. Using Bentley Map would also change the way design features could be imported into a geodatabase. Most likely, Bentley Map would significantly simplify this process. The research team recommends implementing Bentley Map on a trial basis, beginning with a prototype implementation for one or two trial projects.

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APPENDIX. ATTRIBUTES OF SELECTED FEATURE CLASSES

Table 23. Feature Class Attributes.

Feature Class Name	Feature Class Description	Attribute Name
CATVBur	Cable TV Line (Buried)	Authorization
CATVBur	Cable TV Line (Buried)	Depth
CATVBur	Cable TV Line (Buried)	Duct Material
CATVBur	Cable TV Line (Buried)	Duct Size
CATVBur	Cable TV Line (Buried)	Encasement Material
CATVBur	Cable TV Line (Buried)	Material
CATVBur	Cable TV Line (Buried)	Owner
CATVBur	Cable TV Line (Buried)	Support Type
CATVBur	Cable TV Line (Buried)	Tracer Wire
CATVBur	Cable TV Line (Buried)	Warning Tape
CATVBur_ep	Cable TV Line (Buried)	Authorization
CATVBur_ep	Cable TV Line (Buried)	Depth
CATVBur_ep	Cable TV Line (Buried)	Duct Material
CATVBur_ep	Cable TV Line (Buried)	Duct Size
CATVBur_ep	Cable TV Line (Buried)	Encasement Material
CATVBur_ep	Cable TV Line (Buried)	Material
CATVBur_ep	Cable TV Line (Buried)	Owner
CATVBur_ep	Cable TV Line (Buried)	Support Type
CATVBur_ep	Cable TV Line (Buried)	Tracer Wire
CATVBur_ep	Cable TV Line (Buried)	Warning Tape
CondominiumUnitParcel	Condominium Unit Parcel (TTI)	DOR Parcel ID
CondominiumUnitParcel	Condominium Unit Parcel (TTI)	Parcel ID
CondominiumUnitParcel	Condominium Unit Parcel (TTI)	Parcel Type
CondominiumUnitParcel	Condominium Unit Parcel (TTI)	Project ID
EasementParcel	Easement Parcel (TTI)	Easement Type
EasementParcel	Easement Parcel (TTI)	Parcel ID
EasementParcel	Easement Parcel (TTI)	Parcel Type
EasementParcel	Easement Parcel (TTI)	Project ID
ElectPSB	Electrical (Buried)	Authorization
ElectPSB	Electrical (Buried)	Authorization
ElectPSB	Electrical (Buried)	Capacity
ElectPSB	Electrical (Buried)	Capacity
ElectPSB	Electrical (Buried)	Depth
ElectPSB	Electrical (Buried)	Depth
ElectPSB	Electrical (Buried)	Duct Material
ElectPSB	Electrical (Buried)	Duct Material
ElectPSB	Electrical (Buried)	Duct Size
ElectPSB	Electrical (Buried)	Duct Size
ElectPSB	Electrical (Buried)	Encasement Material
ElectPSB	Electrical (Buried)	Encasement Material
ElectPSB	Electrical (Buried)	Innerduct Quantity
ElectPSB	Electrical (Buried)	Innerduct Quantity
ElectPSB	Electrical (Buried)	Owner
ElectPSB	Electrical (Buried)	Owner
ElectPSB	Electrical (Buried)	Warning Tape

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
ElectPSB	Electrical (Buried)	Warning Tape
FeeParcel	In Fee (Simple Fee) Parcel (TTI)	DOR Parcel ID
FeeParcel	In Fee (Simple Fee) Parcel (TTI)	Parcel ID
FeeParcel	In Fee (Simple Fee) Parcel (TTI)	Parcel Type
FeeParcel	In Fee (Simple Fee) Parcel (TTI)	Project ID
FireHydrant	Fire Hydrant	Authorization
FireHydrant	Fire Hydrant	Authorization
FireHydrant	Fire Hydrant	Owner
FireHydrant	Fire Hydrant	Owner
FireHydrant_ep	Fire Hydrant	Authorization
FireHydrant_ep	Fire Hydrant	Owner
FOBur_ep	Fiber Optics Cable (Underground)	Authorization
FOBur_ep	Fiber Optics Cable (Underground)	Depth
FOBur_ep	Fiber Optics Cable (Underground)	Diameter
FOBur_ep	Fiber Optics Cable (Underground)	Duct Material
FOBur_ep	Fiber Optics Cable (Underground)	Duct Quantity
FOBur_ep	Fiber Optics Cable (Underground)	Duct Size
FOBur_ep	Fiber Optics Cable (Underground)	Height
FOBur_ep	Fiber Optics Cable (Underground)	Length
FOBur_ep	Fiber Optics Cable (Underground)	Owner
FOBur_ep	Fiber Optics Cable (Underground)	Quantity
FOBur_ep	Fiber Optics Cable (Underground)	Tracer Wire
FOBur_ep	Fiber Optics Cable (Underground)	Warning Tape
FOBur_ep	Fiber Optics Cable (Underground)	Width
Gas_ep	Gas Line (all sizes)	Authorization
Gas_ep	Gas Line (all sizes)	Authorization
Gas_ep	Gas Line (all sizes)	Depth
Gas_ep	Gas Line (all sizes)	Diameter
Gas_ep	Gas Line (all sizes)	Diameter
Gas_ep	Gas Line (all sizes)	Encasement Material
Gas_ep	Gas Line (all sizes)	Encasement Material
Gas_ep	Gas Line (all sizes)	Material
Gas_ep	Gas Line (all sizes)	Material
Gas_ep	Gas Line (all sizes)	Owner
Gas_ep	Gas Line (all sizes)	Owner
Gas_ep	Gas Line (all sizes)	Warning Tape
Gas_ep	Gas Line (all sizes)	Warning Tape
Guys_ep	Guy Anchor, Guy pole, Span Guys	Authorization
Guys_ep	Guy Anchor, Guy pole, Span Guys	Authorization
Guys_ep	Guy Anchor, Guy pole, Span Guys	Height
Guys_ep	Guy Anchor, Guy pole, Span Guys	Material
Guys_ep	Guy Anchor, Guy pole, Span Guys	Owner
Guys_ep	Guy Anchor, Guy pole, Span Guys	Owner
Guys_ep	Guy Anchor, Guy pole, Span Guys	Placement
Guys_ep	Guy Anchor, Guy pole, Span Guys	Quantity
Guys_ep	Guy Anchor, Guy pole, Span Guys	Quantity
JunctBox	Junction Boxes, Service Cabinet (Elec/Tel)	Authorization
JunctBox	Junction Boxes, Service Cabinet (Elec/Tel)	Owner

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
LeaseParcel	Lease Parcel (TTI)	DOR Parcel ID
LeaseParcel	Lease Parcel (TTI)	Parcel ID
LeaseParcel	Lease Parcel (TTI)	Project ID
LicenseParcel	License Agreement Parcel (TTI)	DOR Parcel ID
LicenseParcel	License Agreement Parcel (TTI)	Parcel ID
LicenseParcel	License Agreement Parcel (TTI)	Project ID
ManholeElec	Manhole (Electric)	Authorization
ManholeElec	Manhole (Electric)	Authorization
ManholeElec	Manhole (Electric)	Barrel Diameter
ManholeElec	Manhole (Electric)	Barrel Diameter
ManholeElec	Manhole (Electric)	Barrel Height
ManholeElec	Manhole (Electric)	Barrel Height
ManholeElec	Manhole (Electric)	Box Height
ManholeElec	Manhole (Electric)	Box Height
ManholeElec	Manhole (Electric)	Box Length
ManholeElec	Manhole (Electric)	Box Length
ManholeElec	Manhole (Electric)	Box Width
ManholeElec	Manhole (Electric)	Box Width
ManholeElec	Manhole (Electric)	Material
ManholeElec	Manhole (Electric)	Material
ManholeElec	Manhole (Electric)	Owner
ManholeElec	Manhole (Electric)	Owner
ManholeElec_ep	Manhole (Electric)	Authorization
ManholeElec_ep	Manhole (Electric)	Barrel Diameter
ManholeElec_ep	Manhole (Electric)	Barrel Height
ManholeElec_ep	Manhole (Electric)	Box Height
ManholeElec_ep	Manhole (Electric)	Box Length
ManholeElec_ep	Manhole (Electric)	Box Width
ManholeElec_ep	Manhole (Electric)	Material
ManholeElec_ep	Manhole (Electric)	Owner
ManholeSS	Manhole (Sanitary Sewer)	Authorization
ManholeSS	Manhole (Sanitary Sewer)	Authorization
ManholeSS	Manhole (Sanitary Sewer)	Barrel Diameter
ManholeSS	Manhole (Sanitary Sewer)	Barrel Diameter
ManholeSS	Manhole (Sanitary Sewer)	Barrel Height
ManholeSS	Manhole (Sanitary Sewer)	Barrel Height
ManholeSS	Manhole (Sanitary Sewer)	Box Height
ManholeSS	Manhole (Sanitary Sewer)	Box Height
ManholeSS	Manhole (Sanitary Sewer)	Box Length
ManholeSS	Manhole (Sanitary Sewer)	Box Length
ManholeSS	Manhole (Sanitary Sewer)	Box Width
ManholeSS	Manhole (Sanitary Sewer)	Box Width
ManholeSS	Manhole (Sanitary Sewer)	Owner
ManholeSS	Manhole (Sanitary Sewer)	Owner
ManholeSS_ep	Manhole (Sanitary Sewer)	Authorization
ManholeSS_ep	Manhole (Sanitary Sewer)	Barrel Diameter
ManholeSS_ep	Manhole (Sanitary Sewer)	Barrel Height
ManholeSS_ep	Manhole (Sanitary Sewer)	Box Height

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
ManholeSS_ep	Manhole (Sanitary Sewer)	Box Length
ManholeSS_ep	Manhole (Sanitary Sewer)	Box Width
ManholeSS_ep	Manhole (Sanitary Sewer)	Owner
ManholeTel	Manhole (Telephone)	Authorization
ManholeTel	Manhole (Telephone)	Barrel Diameter
ManholeTel	Manhole (Telephone)	Barrel Height
ManholeTel	Manhole (Telephone)	Box Height
ManholeTel	Manhole (Telephone)	Owner
ManholeTel_ep	Manhole (Telephone)	Authorization
ManholeTel_ep	Manhole (Telephone)	Authorization
ManholeTel_ep	Manhole (Telephone)	Barrel Diameter
ManholeTel_ep	Manhole (Telephone)	Barrel Diameter
ManholeTel_ep	Manhole (Telephone)	Barrel Height
ManholeTel_ep	Manhole (Telephone)	Barrel Height
ManholeTel_ep	Manhole (Telephone)	Box Height
ManholeTel_ep	Manhole (Telephone)	Box Height
ManholeTel_ep	Manhole (Telephone)	Owner
ManholeTel_ep	Manhole (Telephone)	Owner
MeterWater_ep	Meter (Water)	Authorization
MeterWater_ep	Meter (Water)	Diameter
MeterWater_ep	Meter (Water)	Foundation Depth
MeterWater_ep	Meter (Water)	Height
MeterWater_ep	Meter (Water)	Material
MeterWater_ep	Meter (Water)	Owner
MeterWater_ep	Meter (Water)	Size
Oil	Oil Pipeline, Petroleum	Authorization
Oil	Oil Pipeline, Petroleum	Depth
Oil	Oil Pipeline, Petroleum	Diameter
Oil	Oil Pipeline, Petroleum	Encasement Material
Oil	Oil Pipeline, Petroleum	Material
Oil	Oil Pipeline, Petroleum	Owner
Oil	Oil Pipeline, Petroleum	Warning Tape
Oil_ep	Oil Line (all sizes)	Authorization
Oil_ep	Oil Line (all sizes)	Authorization
Oil_ep	Oil Line (all sizes)	Depth
Oil_ep	Oil Line (all sizes)	Depth
Oil_ep	Oil Line (all sizes)	Diameter
Oil_ep	Oil Line (all sizes)	Diameter
Oil_ep	Oil Line (all sizes)	Encasement Material
Oil_ep	Oil Line (all sizes)	Encasement Material
Oil_ep	Oil Line (all sizes)	Material
Oil_ep	Oil Line (all sizes)	Material
Oil_ep	Oil Line (all sizes)	Owner
Oil_ep	Oil Line (all sizes)	Owner
Oil_ep	Oil Line (all sizes)	Warning Tape
Oil_ep	Oil Line (all sizes)	Warning Tape
ParcelBubble800	Cell:Miscellaneous:Perpetual Easement Parcel Bubble with Leader	Authorization

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
ParcelBubble800	Cell:Miscellaneous:Perpetual Easement Parcel Bubble with Leader	DOR Parcel ID
ParcelBubble800	Cell:Miscellaneous:Perpetual Easement Parcel Bubble with Leader	Parcel ID
ParcelBubble800	Cell:Miscellaneous:Perpetual Easement Parcel Bubble with Leader	Parcel Type
ParcelBubble800	Cell:Miscellaneous:Perpetual Easement Parcel Bubble with Leader	Project ID
ParcelBubble900	Cell:Miscellaneous:License Parcel Bubble with Leader	Authorization
ParcelBubble900	Cell:Miscellaneous:License Parcel Bubble with Leader	Parcel ID
ParcelBubble900	Cell:Miscellaneous:License Parcel Bubble with Leader	Parcel Type
ParcelBubble900	Cell:Miscellaneous:License Parcel Bubble with Leader	Project ID
PolePower_ep	Power Pole with or without Transformer, shared pole	Authorization
PolePower_ep	Power Pole with or without Transformer, shared pole	Authorization
PolePower_ep	Power Pole with or without Transformer, shared pole	Diameter
PolePower_ep	Power Pole with or without Transformer, shared pole	Diameter
PolePower_ep	Power Pole with or without Transformer, shared pole	Foundation Depth
PolePower_ep	Power Pole with or without Transformer, shared pole	Foundation Depth
PolePower_ep	Power Pole with or without Transformer, shared pole	Height
PolePower_ep	Power Pole with or without Transformer, shared pole	Height
PolePower_ep	Power Pole with or without Transformer, shared pole	Material
PolePower_ep	Power Pole with or without Transformer, shared pole	Material
PolePower_ep	Power Pole with or without Transformer, shared pole	Owner
PolePower_ep	Power Pole with or without Transformer, shared pole	Owner
PoleTel	Telephone Pole	Authorization
PoleTel	Telephone Pole	Authorization
PoleTel	Telephone Pole	Diameter
PoleTel	Telephone Pole	Diameter
PoleTel	Telephone Pole	Foundation Depth
PoleTel	Telephone Pole	Foundation Depth
PoleTel	Telephone Pole	Height
PoleTel	Telephone Pole	Height
PoleTel	Telephone Pole	Material
PoleTel	Telephone Pole	Material
PoleTel	Telephone Pole	Owner
PoleTel	Telephone Pole	Owner
PoleTel_ep	Telephone Pole	Authorization
PoleTel_ep	Telephone Pole	Diameter
PoleTel_ep	Telephone Pole	Foundation Depth
PoleTel_ep	Telephone Pole	Height
PoleTel_ep	Telephone Pole	Material
PoleTel_ep	Telephone Pole	Owner
PullBox	Pull Boxes (All Types)	Authorization
PullBox	Pull Boxes (All Types)	Authorization
PullBox	Pull Boxes (All Types)	Height
PullBox	Pull Boxes (All Types)	Height
PullBox	Pull Boxes (All Types)	Length
PullBox	Pull Boxes (All Types)	Length
PullBox	Pull Boxes (All Types)	Owner

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
PullBox	Pull Boxes (All Types)	Owner
PullBox	Pull Boxes (All Types)	Width
PullBox	Pull Boxes (All Types)	Width
PullBox_ep	Wiring Pull Box	Authorization
PullBox_ep	Wiring Pull Box	Height
PullBox_ep	Wiring Pull Box	Length
PullBox_ep	Wiring Pull Box	Owner
PullBox_ep	Wiring Pull Box	Width
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Authorization
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Authorization
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Depth
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Diameter
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Encasement Material
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Material
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Owner
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Owner
SanitaryMisc_ep	Cleanout, Sanitary Effluent (Open channel)	Warning Tape
SanitarySewer	Sanitary Sewer	Authorization
SanitarySewer	Sanitary Sewer	Depth
SanitarySewer	Sanitary Sewer	Diameter
SanitarySewer	Sanitary Sewer	Encasement Material
SanitarySewer	Sanitary Sewer	Material
SanitarySewer	Sanitary Sewer	Owner
SanitarySewer	Sanitary Sewer	Warning Tape
SpliceBox	Fiber Optic Splice Box	Authorization
SpliceBox	Fiber Optic Splice Box	Authorization
SpliceBox	Fiber Optic Splice Box	Owner
SpliceBox	Fiber Optic Splice Box	Owner
SpliceBox_ep	Fiber Optic Splice Box (Existing)	Authorization
SpliceBox_ep	Fiber Optic Splice Box (Existing)	Owner
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Authorization
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Authorization
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Depth
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Depth
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Diameter
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Duct Material
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Duct Quantity
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Duct Quantity
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Duct Size
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Height
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Height
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Length
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Material
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Owner
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Owner
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Quantity
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Quantity
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Tracer Wire

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Warning Tape
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Width
TeleBur_ep	Telephone (all sizes Buried), Duct, Toll	Width
TeleMisc	Telephone Service Box, Booth or Pedestal	Authorization
TeleMisc	Telephone Service Box, Booth or Pedestal	Authorization
TeleMisc	Telephone Service Box, Booth or Pedestal	Height
TeleMisc	Telephone Service Box, Booth or Pedestal	Height
TeleMisc	Telephone Service Box, Booth or Pedestal	Owner
TeleMisc	Telephone Service Box, Booth or Pedestal	Owner
TeleMisc_ep	Telephone Service Box, Booth or Pedestal	Authorization
TeleMisc_ep	Telephone Service Box, Booth or Pedestal	Height
TeleMisc_ep	Telephone Service Box, Booth or Pedestal	Owner
TransformerAer	Transformer Unit (Above Ground)	Authorization
TransformerAer	Transformer Unit (Above Ground)	Authorization
TransformerAer	Transformer Unit (Above Ground)	Owner
TransformerAer	Transformer Unit (Above Ground)	Owner
TransformerAer	Transformer Unit (Above Ground)	Placement
TransformerAer	Transformer Unit (Above Ground)	Placement
TransformerAer	Transformer Unit (Above Ground)	Quantity
TransformerAer	Transformer Unit (Above Ground)	Quantity
TransformerAer	Transformer Unit (Above Ground)	Rated Voltage
TransformerAer	Transformer Unit (Above Ground)	Rated Voltage
UtilMisc_ep	Miscellaneous Utilities	Authorization
UtilMisc_ep	Miscellaneous Utilities	Authorization
UtilMisc_ep	Miscellaneous Utilities	Material
UtilMisc_ep	Miscellaneous Utilities	Material
UtilMisc_ep	Miscellaneous Utilities	Owner
UtilMisc_ep	Miscellaneous Utilities	Owner
UtilMisc_ep	Miscellaneous Utilities	Size
UtilMisc_ep	Miscellaneous Utilities	Size
Valve	Valve, Valve Box (Unknown) PROPOSED UNKNOW VALVE	Authorization
Valve	Valve, Valve Box (Unknown) PROPOSED UNKNOW VALVE	Owner
Valve_ep	Valve, Valve Box	Authorization
Valve_ep	Valve, Valve Box	Authorization
Valve_ep	Valve, Valve Box	Owner
Valve_ep	Valve, Valve Box	Owner
ValveCvrWater_ep	Valve Cover (Water)	Authorization
ValveCvrWater_ep	Valve Cover (Water)	Diameter
ValveCvrWater_ep	Valve Cover (Water)	Material
ValveCvrWater_ep	Valve Cover (Water)	Owner
ValveCvrWater_ep	Valve Cover (Water)	Size
ValveCvrWater_ep	Valve Cover (Water)	Width
ValveGas	Valve, Valve Box (Gas)	Authorization
ValveGas	Valve, Valve Box (Gas)	Authorization
ValveGas	Valve, Valve Box (Gas)	Owner
ValveGas	Valve, Valve Box (Gas)	Owner
ValveGas_ep	Valve (Gas), Valve Box	Authorization

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
ValveGas_ep	Valve (Gas), Valve Box	Owner
ValveWater	Valve, Valve Box (Water)	Authorization
ValveWater	Valve, Valve Box (Water)	Authorization
ValveWater	Valve, Valve Box (Water)	Depth
ValveWater	Valve, Valve Box (Water)	Depth
ValveWater	Valve, Valve Box (Water)	Diameter
ValveWater	Valve, Valve Box (Water)	Diameter
ValveWater	Valve, Valve Box (Water)	Owner
ValveWater	Valve, Valve Box (Water)	Owner
ValveWater_ep	Valve (Water), Valve Box	Authorization
ValveWater_ep	Valve (Water), Valve Box	Depth
ValveWater_ep	Valve (Water), Valve Box	Diameter
ValveWater_ep	Valve (Water), Valve Box	Owner
Vault_ep	Vaults Above Grade and Below Grade	Authorization
Vault_ep	Vaults Above Grade and Below Grade	Barrel Diameter
Vault_ep	Vaults Above Grade and Below Grade	Barrel Height
Vault_ep	Vaults Above Grade and Below Grade	Height
Vault_ep	Vaults Above Grade and Below Grade	Length
Vault_ep	Vaults Above Grade and Below Grade	Owner
Vault_ep	Vaults Above Grade and Below Grade	Width
Vaults	Vaults Above Grade and Below Grade	Authorization
Vaults	Vaults Above Grade and Below Grade	Authorization
Vaults	Vaults Above Grade and Below Grade	Barrel Diameter
Vaults	Vaults Above Grade and Below Grade	Barrel Diameter
Vaults	Vaults Above Grade and Below Grade	Barrel Height
Vaults	Vaults Above Grade and Below Grade	Barrel Height
Vaults	Vaults Above Grade and Below Grade	Height
Vaults	Vaults Above Grade and Below Grade	Height
Vaults	Vaults Above Grade and Below Grade	Length
Vaults	Vaults Above Grade and Below Grade	Length
Vaults	Vaults Above Grade and Below Grade	Owner
Vaults	Vaults Above Grade and Below Grade	Owner
Vaults	Vaults Above Grade and Below Grade	Width
Vaults	Vaults Above Grade and Below Grade	Width
VentGas	Vent (Gas)	Authorization
VentGas	Vent (Gas)	Authorization
VentGas	Vent (Gas)	Owner
VentGas	Vent (Gas)	Owner
VentGas_ep	Vent (Gas)	Authorization
VentGas_ep	Vent (Gas)	Owner
Water	Water Line	Authorization
Water	Water Line	Authorization
Water	Water Line	Depth
Water	Water Line	Depth
Water	Water Line	Diameter
Water	Water Line	Diameter
Water	Water Line	Encasement Material
Water	Water Line	Encasement Material

Table 23. Feature Class Attributes (Continued).

Feature Class Name	Feature Class Description	Attribute Name
Water	Water Line	Material
Water	Water Line	Material
Water	Water Line	Owner
Water	Water Line	Owner
Water	Water Line	Warning Tape
Water	Water Line	Warning Tape
Water_ep	Water Line (all sizes)	Authorization
Water_ep	Water Line (all sizes)	Depth
Water_ep	Water Line (all sizes)	Diameter
Water_ep	Water Line (all sizes)	Encasement Material
Water_ep	Water Line (all sizes)	Material
Water_ep	Water Line (all sizes)	Owner
Water_ep	Water Line (all sizes)	Warning Tape

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