SHRP2 SOLUTIONS
TOOLS FOR THE ROAD AHEAD

# Caltrans R01A SHRP2 CASE STUDY

## Better Managing Utility Conflicts in California through the SHRP2 Solution: *3D Utility Location Data Repository (R01A)*


A challenge at transportation agencies nationwide is how to manage information about utility facilities that occupy the right of way in ways that facilitate data extraction and data analysis. The challenge is both during the process to deliver transportation projects and over the lifetime of both transportation and utility facilities. Transportation agencies are transitioning from 2D to 3D design and construction workflows. The challenges that agencies face with information managed in a 2D environment are compounded when information is managed in a 3D environment.

The R01A SHRP2 project, *3D Utility Location Data Repository*, tested a procedure to manage utility data during project delivery. As part of the second Strategic Highway Research Program (SHRP2) Implementation Assistance Program (IAP), 11 state departments of transportation (DOTs) received grants from the Federal Highway Administration (FHWA) to conduct a pilot utility data repository implementation. The goals and scope of the implementations varied widely depending on the needs of the individual state DOTs, but generally ranged from developing a 2D standalone geographic database of existing utilities within the right of way to developing an enterprise system architecture to manage utility facilities in a 3D environment. As part of the IAP, FHWA also provided one brainstorming training session to each state that requested it. The purpose of the brainstorming session was to discuss topics such as implementation goals, challenges, leadership buy-in, information technology (IT) involvement, and ideas for implementation scope and schedule.

The California Department of Transportation (Caltrans) grant focused on the development of a spatial database platform with a standardized set of data attributes using Oracle Spatial as the database platform and Bentley Map as the interface to visualize data stored in the Oracle database. The long-term goal of the implementation was to ensure the accurate identification of utility infrastructure during project planning and for conflict resolution during design and construction.

***Challenge Facing the Transportation Agency Using the Product***

Caltrans' District 11 (San Diego) already had a geographic information system (GIS) pilot application in Bentley Map. The application, originally developed in 2013, used a Bentley Map front end to access all utility data that resided in standalone MicroStation design files. The California Coordinate System of 1983 (CCS83) has six geographic zones and four North American Datum 1983 (NAD83) adjustments, which meant that separate standalone MicroStation files would be needed for each zone and NAD83 adjustment combination.

In 2016, it became clear that the data should not be stored in standalone MicroStation design files. Caltrans already used Oracle for other business applications, but was not familiar with Oracle Spatial. In addition to technical database design considerations, the agency wanted to address issues such as scalability and sustainability in order to determine the feasibility of using the Oracle Spatial platform as an enterprise repository of utility data. Specifically, Caltrans was interested in a spatial database platform that could fit into existing CAD and GIS business practices as much as possible without creating undue burden on planners, designers, utility engineering group (UEW) coordinators, and IT personnel.

***Caltrans Objectives***

Caltrans objectives as part of the pilot R01A implementation were to:

- Design the system in a development environment. This activity involved identifying system business requirements, developing system IT requirements, building the system, gathering sample project data, and populating the system.
- Migrate the system to a test environment.
- Train district UEW personnel.
- Migrate the system to a production environment.

***Approach Taken by the Agency to Implement the Product***

Initially, Caltrans installed Oracle 11g Spatial on Windows Server 2008 R2 and Bentley Map SS3 on top of MicroStation Select Series 3 (SS3). This version was a single database of utility tables. Oracle recommended Caltrans to install Oracle 12c because Oracle 11g was no longer supported and Caltrans wanted to include both 2D and 3D geometry along with a spatial reference identifier (SRID) in Oracle Spatial to manage coordinate system data. The move to Oracle 12c made it necessary for Caltrans to upgrade Bentley Map to SS4.

Based on the six CCS83 zones and NAD83 adjustments, Caltrans created 24 tablespaces in Oracle, each one with its own schema. Caltrans wanted to use the Oracle 12c multitenant architecture and create pluggable databases to separate the tablespaces. To this end, Caltrans developed structured query language (SQL) scripts to create database tables and required schema items, such as indexes, constraints, domains, and sequence generators. Caltrans then used Bentley Map Geospatial Administrator (GSA) to register the Oracle tables into 24 Bentley Map projects. The database schema has tables for point features, 2D and 3D linear features, and test holes locations (i.e., locations where was a positive confirmation of an underground utility facility) (Figure 1).

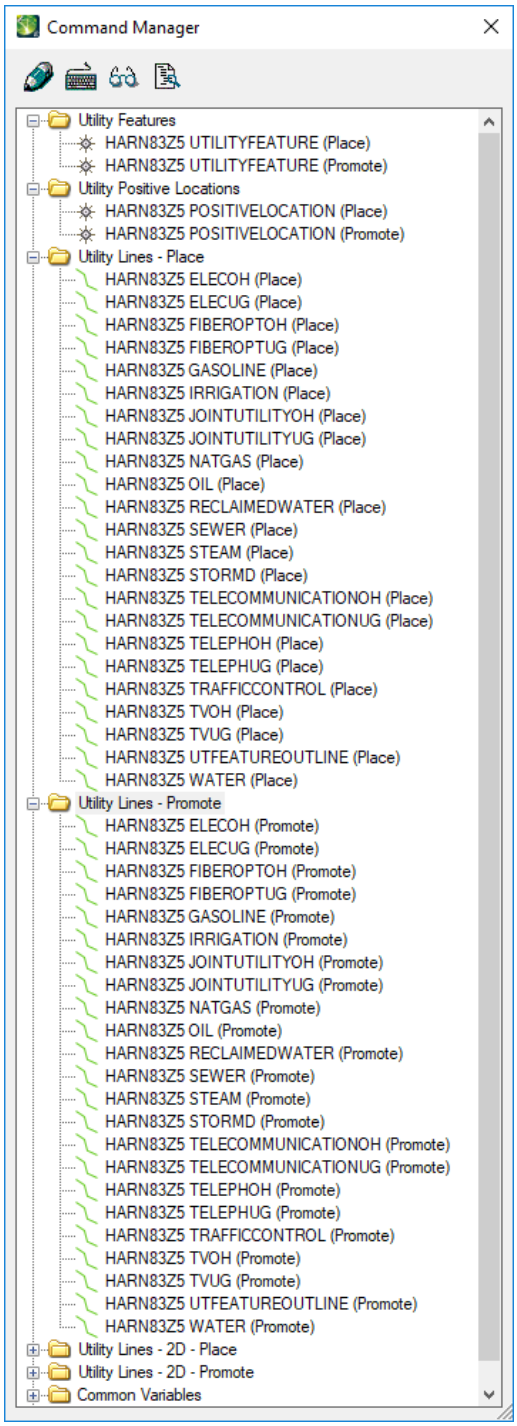


*Figure 1. Sample Place and Promote Tables.*

In the database architecture, SRID is an attribute at the individual utility feature level. Although Oracle 12c allows the 2D state plane SRID to be used with 3D queries, Bentley Map does not. Bentley Map does not support fenced areas or view queries if a 2D SRID is assigned to 3D features. To address this limitation, Caltrans created custom 3D coordinate systems in Oracle using the appropriate 2D CCS83 SRID and vertical SRID based on the North American Vertical Datum of 1988 (NAVD88) from the Oracle spatial tables.

Caltrans prepared a training manual and provided training to almost 50 officials at districts and headquarters. The training included UEW officials at all 12 districts. UEWs in each district consist of three-six officials. Caltrans conducted the training using a test database installed on a Windows Server 2008 R2 OS.

In November 2018, Caltrans installed Oracle Spatial 12c on a SPARC server running Solaris 11. As part of the process, Caltrans consolidated the 24 Oracle tablespaces into one database. A single database (instead of a container database consisting of multiple pluggable databases) became a better option for new hardware and backup processes. The Schema name is placed in front on each feature when the tables of the schema are registered from the Oracle database into the Bentley Map project.

The system includes tools for importing multiple utility features simultaneously. It also includes tools for post processing records, conducting database queries, and exporting features to MicroStation. The protocol for creating new records in the database includes steps for selecting utility features in MicroStation design files and promoting those utility features so they become database records with their corresponding attributes (Figure 2).

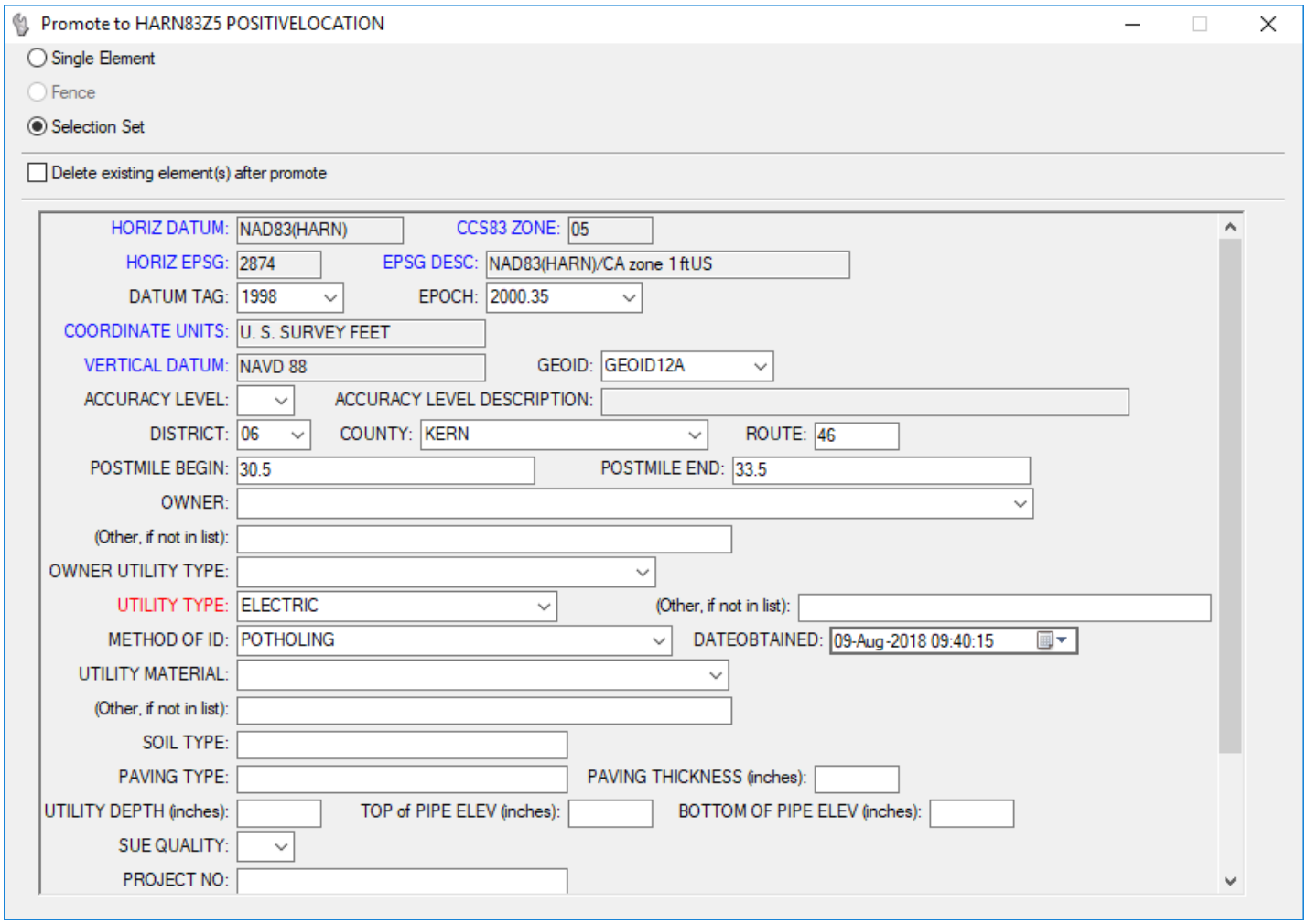

*Figure 2. Interface for populating utility attribute data.*

Currently, officials are developing FME templates and scripts to bring field data directly into Bentley Map projects and then post the information to the database.

***Utility Data Repository Benefits***

Caltrans identified the following benefits resulting from the pilot utility data repository implementation:

- Centralized data repository. Having a centralized, enterprise-level utility data repository offers significant advantages and potential compared to the standalone concept that existed prior to the R01A implementation. One of the reasons is that the Oracle database handles all 24 geographic zone/NAD 83 adjustment combinations in the California coordinate system in one coherent system, which will enable all 12 Caltrans districts to store, update, and share utility data across district boundaries. Caltrans had already identified long-term sustainability limitations of their standalone approach. One of the limitations was related to the way MicroStation files are set up, with geographic zones and NAD83 adjustments handled at the file level, not at the individual feature level. This limitation increases the risk of disassociation between utility features and their corresponding coordinate system information and makes spatial data operations and data exchange considerably more complex and unreliable.
- Limited number of steps to import data into the database. Although the database architecture and scripts involved a substantial amount of time and effort, the amount of work needed to extract features from MicroStation into Oracle Spatial users is anticipated to be relatively minor.

***Lessons Learned***

Lessons learned at Caltrans from the pilot utility data repository implementation include the following:

- Learning curve. No training was provided at the beginning on the use of Oracle and Oracle Spatial. Learning how to use this platform was challenging. Caltrans found it beneficial to start with simple SQL scripts to create tables with geometry and some attributes and then expand the scripts. This process was useful for learning Oracle SQL Developer.
- Surveying and software development experience. Involvement of personnel who had combined surveying and software development experience was critical for the development of the database architecture, scripts, and process.
- SRIDs for 2D and 3D features. Oracle Spatial includes SRIDs for the 2D California state plane systems. However, Caltrans had to create custom coordinate reference systems and SRIDs for 3D geometry.
- Software compatibility. Caltrans encountered several challenges because of a lack of compatibility between different software applications. Software vendors did not provide adequate documentation about compatibility issues. Although the agency found workarounds, there were delays.
- Interoperability with other CAD and GIS platforms. Caltrans began to explore interoperability opportunities with Autodesk Civil 3D 2016 and Esri ArcGIS 10.2. Results are not conclusive, but they point to software architecture characteristics that limit the potential for interoperability. For example, Autodesk Civil 3D 2016 limits the number of domain tables accessed at a time to the first 12 domain tables it encounters. The number of domain tables in the utility database is considerably larger than 12.

***Expectations for Integrating this Product into Normal Business Practices***

Caltrans' vision is to have a spatial database platform with a standardized set of data attributes to ensure the accurate identification of utility infrastructure during project planning and for conflict resolution during design and construction. Caltrans' implementation plan is based on CAD and GIS practices and procedures that are already largely in place at the agency.

***For more Information:***

To learn more about California's use of *Utility Location Data Repository* (R01A), contact Jesus Mora, Chief, Caltrans Office of CADD and Engineering GIS Support, at jesus.mora@dot.ca.gov.

To learn more about SHRP2 and the *Utility Location Data Repository* product, contact Julie Johnston, FHWA Utility & Value Engineering Program Manager, at Julie.Johnston@dot.gov.

**AASHTO SHRP2 Website:** http://shrp2.transportation.org/Pages/UtilityRelatedProducts.aspx
AASHTO's product page offers case studies, training modules, presentations, factsheets, guidance documents, and a list of other states implementing the SHRP2 utility products.