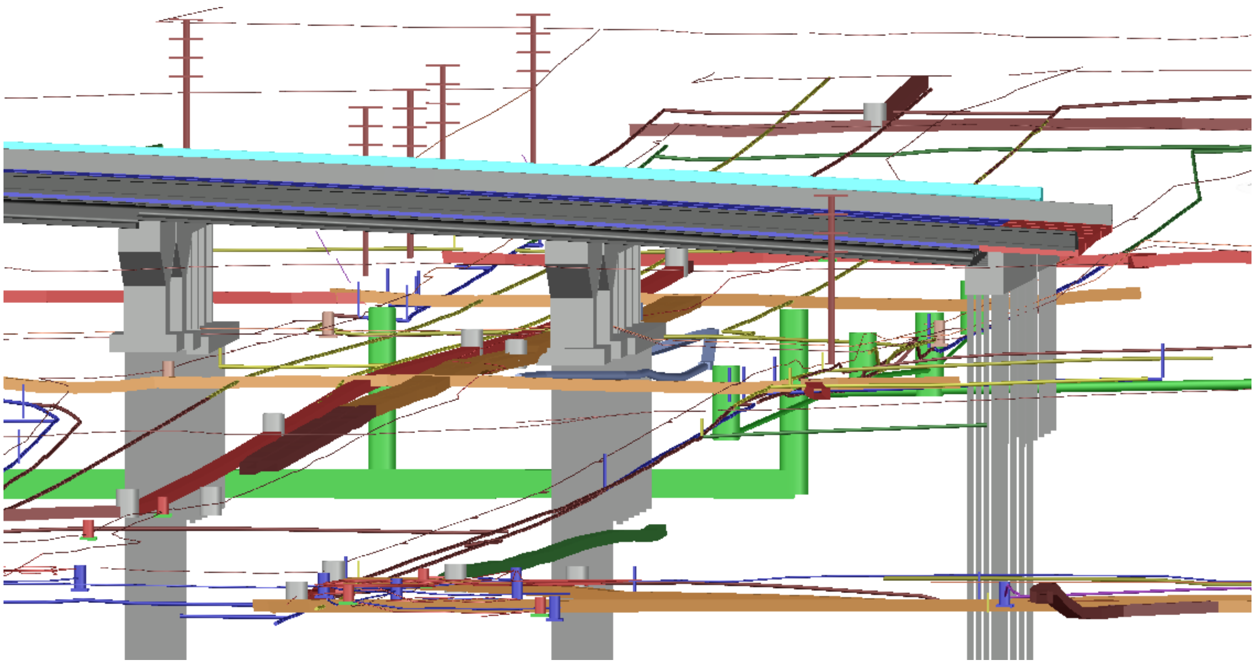

3D UTILITY SURVEY DATA EXECUTIVE SUMMARY

Wisconsin Department of Transportation

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This summary contains a high-level overview of the recommendations resulting from utility survey data research done between June of 2019 and January of 2022 which are detailed in the summary report. There are four main topics that will be addressed: Civil 3D related recommendations, collection, transfer and cost estimating recommendations, permit process recommendations, and clash detection recommendations.

1. Civil 3D Related Recommendations

A. CAD/BIM Platform Evaluation

First, there were six software evaluated for use within Civil 3D to incorporate 2D and 3D utility survey data: Navisworks, BIM 360, Forge Viewer, ArcGIS, Infraworks, and ReCap. Each of them is compatible with Civil 3D and have varying and overlapping functionalities. There are two main functionalities that Civil 3D does not have or is not well suited for: clash detection and state-wide utility modeling/storage. For clash detection, Naviswork is the recommended software for its in-depth and comprehensive functionality as well as its ability to access all the attributes/metadata within native Civil 3D models. For state-wide utility modeling, ArcGIS is the recommended software. While it is currently not within the scope of the department's utility program to develop a system-wide utility database, due to Autodesk and Esri partnering to enable data interoperability between ArcGIS and Civil 3D it is an ideal candidate if that becomes part of their program. There is significant value recognized in maintaining such a system-wide utility database as seen by such states as MDOT, CDOT, TxDOT, and Caltrans.

B. Utility Color Depiction

In general, WisDOT follows The American Public Works Association (APWA) guidelines for marking underground utilities as their color convention for depicting utilities in plans, which is a common drafting practice. 35 state DOT CAD workspaces were reviewed for their use of color to symbolize utilities (see Figure 1 in the summary report for more information) to determine what the consensus was. The consensus among the DOT standards aligns with the APWA guidelines. There was one exception where WisDOT CAD standards did not follow the consensus, and that is the color associated with the "E_UTL_TV_UG" layer, which is currently magenta or purple and not orange as other communications layers. It is recommended that this be changed to match the other communications, which is color number 31.

C. Utility Layer Standards

Regarding layers, all but one of the utility types within the scope of this report are accounted for within the WisDOT layer standards. A layer to represent underground steam pipelines is not within the current set. Following the WisDOT layer naming convention, it is recommended that a new layer named "E_UTL_STM_UG" be added to the standard set. Alternatively, the "E_UTL_G_PipeLine_UG" layer could be used, as its linetype displays "PIPL" designating a pipeline and its color is yellow, which is consistent with the APWA guidelines. However, in that steam is a critical utility, it may prove beneficial to differentiate it from a gas pipeline by placing it on its own layer and displaying its abbreviation of "STM".

D. Utility Linetype Depiction

Linetypes are the most common method and best practice for distinguish quality levels, and makes it significantly faster and easier for Civil 3D users to depict each utility line in this way. It is recommended that four additional linetypes be added to the WisDOT standard set to distinguish the four quality levels

A through D for each, using a text designator such as "E (QL B)" for electric of quality level B. Refer to "Appendix E: Utility Color and Line Type Standards of State DOTs" of the summary report for a tabulation of all of the state DOT utility standards that were reviewed. These 45 proposed linetypes are listed in the "Linetypes" section of the summary report.

E. Attributes

Regarding attributes, it is recommended to follow the ASCE38-02 guidelines and use a Civil 3D Property Set Definition to define the following attributes: Accuracy Level, Condition, Date of Depiction, Date of Installation, Date of Locate, Elevation, Encasement, End Point, Material, Number, Occupancy, Owner, Quality Level, Service Status, Size, and Type. Additional details about these attributes and the workflow to utilize them are outlined within the summary report.

F. Labeling

Labeling offers a way to automate the annotation of certain object types in Civil 3D, enabling the display of one or more attribute values as text in plans. While it is not the recommended way to depict quality level, as linetypes is, it can be useful to display other attribute data. It should be noted that only the following Civil 3D utility related object types support labeling: Lines and Curves (2D; i.e. all vertices have the same elevation), Feature Lines, Pipe Networks, Pressure Networks, and Points. 3D Polylines, which is a common way that 3D utility lines are depicted in Civil 3D, are not supported with labeling. One solution is to convert a 3D Polyline into a Feature Line, which is supported with labeling.

G. Variable Error Clouds

Variable error clouds refer to the horizontal and vertical estimate of the expected error in the position of the underground targeted utility. While this data can be used to depict a utility locate's upper and lower limits in profile view, there is no Civil 3D object type that natively supports depicting this type of data in 3D. The closest known method to depicting this in 3D is to manually create a series of adjacent cones whose base diameter reflects the vertical error of one point (i.e. back) and top diameter reflects the vertical error of another point (i.e. ahead). Due to the cost-benefit of depicting error clouds with this object type it is not recommended to maintain a 3D utility model with this information. However, when it comes to performing clash detection, an average or maximum (e.g. conservative) vertical variance could be represented by using a clearance clash type and setting the tolerance as such. See the section on "Clash Detection Workflow" in the summary report for more information.

H. Project Plan Sheets/Base Data

For depicting 2D and 3D utility survey data in plans there are three main ways that an Existing Utilities base data file (i.e. the Uti-Ex.dwg file) can be prepared: 2D, 3D Lines, and 3D Pipe/Pressure Networks. These three main ways can be combined in various combinations to depict data of varying sources and accuracies. Regardless of what object types compose the Existing Utilities base data file, they should all follow WisDOT plan production standards for layer, color, linetype, and weight when depicted in plan view. The use of Property Set Definitions applies to all objects, so attributes can be associated with any combination of object types used. Assuming an object contains 3D information (i.e. is a 3D object type), it's elevation can be queried at any location using the "ID" command. According to ASCE38-02 guidelines, it is recommended to "Place a note on the plans explaining the different utility "quality levels." An example of this note is outlined in the summary report.

I. Utility Survey Data Importing

For importing utility survey data, regardless of how it is collected the data is converted to an electronic format such as a CSV (comma separated value) or spreadsheet file (i.e. XLS or XLSX file) for submission. A common syntax is in the format of: Point Name, Northing, Easting, Elevation, Point Code. The Civil 3D "Import Survey Data" wizard enables the importing of data from field book files, point files, points in a drawing, and Survey LandXML data. The use of the appropriate point codes in the survey data is critical in correctly importing the data in accordance to WisDOT standards. A WisDOT standard "Figure Prefix Database" and "Linework Code Set" is already setup to support the proper importing of utility survey data. See the summary report for more information on the workflow to import this data.

J. 3D Modeling of Utility Survey Data

When generating a 3D model of utility survey data there are two primary ways to utilize native Civil 3D object types to depict 3D utilities: generating Pipe Networks or Pressure Networks from imported Survey Figures. For the majority of underground utilities Pressure Networks are the appropriate object type to use (i.e. gas, electric, communications, water). The exceptions to this would be gravity networks such as storm sewer and sanitary sewer. A Pipe/Pressure Network Catalog is an SQLite database file that contains all the part definitions such as pipes, elbows, and valves. For the purpose of depicting underground utility lines, it is recommended that a Pressure Network Catalog be setup with only the pipes of the appropriate sizes, which will eliminate the generation of unintended elbows between line segments. Additionally, styles can be setup to depict the Pressure Networks appropriately for plan view (i.e. plan sheets) and isometric view (i.e. models for clash detection).

2. Collection, Transfer and Cost Estimating Recommendations

The following is a list of equations for cost estimation of various survey collection and transfer tasks.

<u>Collecting Quality Level A Survey</u>

- $1,900 x "Number of Locates" ($5,000 minimum)

<u>Collecting Quality Level B Survey</u>

- *Depth < 10':* $8 x "Linear Feet" ($500 minimum)
- *10' ≤ Depth ≤ 50':* $16 x "Linear Feet" ($500 minimum)
- *[Alternately]* Quality Level A Cost x 10%

<u>Collecting Diggers Hotline Marking Survey</u>

- $750 x "Linear Miles"

<u>Transfer of Utility Survey into a Pressure Pipe Network (3D Model)</u>

- "Labor Rate ($/hr)"x ("Linear Feet"/5,000)

<u>Transfer/Association of Attributes onto a Pressure Pipe Network (Metadata)</u>

- "Labor Rate ($/hr)"x ("Linear Feet"/5,000)

Obtaining QL B data using SPAR is approximately 10% of what it would cost to get QL A data using potholing. SPAR also removes approximately 80% of the requirements for potholing.

To estimate costs to obtain quality level A data, according to local surveyors it costs between $1,600 and $2,200 per locate using potholing, with a minimum cost of $5,000 which includes mobilization. For estimating purposes, the following formula is proposed: the greater of $5,000 or $1,900 x “Number of Locates”.

To estimate costs to obtain quality level B data, first quantify the linear feet of all utilities to locate with depths less than 10’ and use the following proposed formula: the greater of $500 or $8 x “Linear Feet (less than 10’ deep)”. Second, quantify the linear feet of all utilities to locate with depths between 10’ and 50’ and use the following proposed formula: the greater of $500 or $16 x “Linear Feet (between 10’ and 50’ deep)”. The same equations would apply to only collecting horizontal locations (2D X,Y) as the operators effort to collect horizontal data is equivalent to that of collecting 3D data using a method such as SPAR.

When a 3D model is required, as in the case for performing clash detection, and 3D Pipe/Pressure Networks are to be created, this will involve extra manual processing time. There will be a one-time cost associated with the setup of an appropriate Pressure Pipe Catalog for use with all utility materials and sizes to be depicted. It is recommended that a focus be put on first setting up this catalog with only the various sizes required, as the extra time to also categorize them by material will not add value to the clash detection process. The initial setup of a utility-specific Pressure Pipe Catalog and appropriate Pipe Styles could take several weeks but would then be available for statewide use. A conservative estimate, depending upon the lengths of the individual utility lines imported, is for 5,000 linear feet of imported Survey Figures to be converted to Pipe Networks in one hour. For estimating the cost of transferring utility survey data into a 3D model using Pressure Pipe Networks, the following formula is proposed: “Labor Rate ($/hr)”x (“Linear Feet”/5,000).

According to ASCE 38-02, when discussing Ground Penetrating Radar it states, “However, for the moment, it is a utility-detection technique whose usefulness is limited to specific projects. Its costs are high, and probabilities of success, versus other methods, are low. It should never be the only utility imaging method in use.” This statement is supported by the findings of local surveyors (see the 2010 report titled “Subsurface Utility Mapping using the Spar 300 System by Optimal Ranging, Inc.”). The current state of the technology and practice has found that electromagnetic techniques such as those used in SPAR systems are far more accurate and effective in the majority of conditions than GPR. See Appendix B for SPAR Data Analysis in the summary report on the data collected across five WisDOT regions.

Contractors utilize multiple software platforms to consume and manipulate data, including Trimble Business Center, Autodesk software such as Civil 3D and AutoCAD, and Bentley software such as InRoads and MicroStation. Most contractors are able to leverage data in any source it’s provided, including the WisDOT standard platforms of Civil 3D for roadway design and MicroStation for bridges. Considering that contractors have access to all the same software platforms that their design counterparts have, it is the most ideal that any models or CAD files be provided to them in their native authoring formats to reduce data losses during translation (such as metadata/attributes that do not translate between platforms). There are no data standards when it comes to providing contractors utility survey data. It is therefore recommended that as much data, in their native format, be provided to contractors as early in the letting process as possible. The XYZ point data is the rawest, most base/important data, and contractors would prefer that this raw point data be transferred along with any other 3D data.

3. Permit Process Recommendations

Regarding permit specifications, there are two most ideal approaches to obtaining accurate 3D utility survey data for the purpose of clash detection and project coordination. The first, most ideal and accurate approach has been met with reluctance by the utility companies. This is to be provided with surveyed as-built data. There are two primary reasons that the utility companies are apprehensive to provide this source of data: 1) the Utility Accommodation Policy and Wis. Admin. Code Trans 220 do not require or specify providing as-built information and 2) some companies believe that providing an as-built places too high a risk on their facility. Other challenges that utility companies may experience are access to the proper equipment and additional costs associated with collecting 3D data. The reason that utility as-built data would be beneficial to obtain through the permitting process is because it would provide the highest level of accuracy of utility locations and therefore help to minimize the risk of utility conflicts. In order to accomplish the possibility of acquiring this data through the permitting process, it is recommended to address these concerns by updating the Utility Accommodation Policy and/or Trans 220 to state that 3D as-built data may be requested.

The second approach is to obtain proposed plans or electronic files with 3D location information in conjunction with survey of the field staking, which is a practice that has been used recently on select WisDOT projects. The following is the proposed permit language to use for this approach:

In order to facilitate the use of a 3D model for clash detection, WisDOT requires you to provide horizontal and vertical information (XYZ) for proposed underground utility relocation plans submitted for permit for the upcoming <project name> project. Please provide location and elevations at each bend or critical point (any location which significantly affects how the facility is depicted), preferably with ties to project stationing so that the location can be readily identified. Permit plans must be prepared using the Project datum [North American Vertical Datum of 1988, NAVD 88 (2007) adjusted; coordinates referenced to the Wisconsin Coordinate Reference Systems (WISCRS), <project county> County, NAD 1983 (2007)]. The Department will not accept "depth below grade". Any changes to the plan must be approved by WisDOT and amended into the permit. The location of the proposed facility must be field staked in the permitted location prior to construction.

It is not common or best practice to dictate means and methods (i.e. utility installation methods) to utility companies in permits, as they have both the incentive and expertise to determine this themselves. An exception to this may be in the case of crossing an active roadway where directional drilling may be specified for uninterrupted operation. Detailed information about several trenchless utility installation methods is contained within the summary report.

In addition to the information noted above, there are other forms of data that utility companies may be required to deliver according to permit specifications. These forms can be used in combination to produce a sufficient 3D depiction of their facility location. Regardless of the source of the data, it is recommended to specify that it references the project's horizontal coordinate system and vertical datum, annotating elevations and not depths. These sources, in order of least to greatest accuracy, are:

1) Proposed Plans (3D data; CAD files or plan sheets with adequate dimensioning to locate the facility in 3D)

2) Surveyed Stakeout (2D data; ground survey locates of the staking that utility companies perform of the proposed facility layout in advance of installation/relocation)
3) Horizontal Directional Drilling (HDD) Locating System (3D data; information from tracking the bore head during the drilling operation)
   - Accuracy: ± 1' vertically
4) As-Built Quality Level B Survey (3D data; subsurface survey of the as-built conditions, e.g. SPAR)
   - Accuracy: ± 0.8' vertically
5) As-Built Quality Level A Survey (3D data; subsurface survey of the as-built conditions, e.g. potholing)
   - Accuracy: ± 0.03' vertically (or per GPS receiver specifications)

Regardless of the data source, it's just as important to maintain an accurate record of the source of each depicted representation of utility locations (among other attributes that may have been captured). This record enables designers and contractors working on a project to determine the quality of the locates, informing decisions throughout the lifecycle of the project. To facilitate this, it is first recommended that distinct linetypes be used to depict utilities according to their appropriate quality levels. Second, it is recommended that a Property Set Definition (such as described in the "Attributes" section of the summary report) be used to associate all collected attributes to the objects depicting the data. These two methods will enable users to visually or by property query (i.e. "ID" the object) the utility depictions to make informed decisions; decisions which may be critical to the design in avoiding utility conflicts.

4. Clash Detection Recommendations

As noted within the previous Civil 3D Related Recommendations, Naviswork is the recommended software for its in-depth and comprehensive functionality as well as its ability to access all the attributes/metadata within native Civil 3D models. The recommended workflow is described in detail within Appendix C of the summary report.

One of the most important best practices of the clash detection review process is the practice of how the resolution is facilitated. This involves the preparation of both an NWF file which contains a navigable set of results for all detected clashes in each clash test (i.e. the Navisworks file where the clash tests have been prepared and processed), and individual clash result spreadsheets that tabulate the results and document who is responsible to check and respond to each clash. It is recommended that the role of BIM manager/coordinator be defined to oversee this process and coordinate with each discipline lead. It important to define and communicate the timeframe that these responses are required by so that each of the leads determine who will be responsible for updating the design models and plans. Subsequent rounds of clash detection can be processed to ensure the clashes have been resolved as dictated by the project schedule and available resources. The details of this resolution process are outlined further in the summary report.

Regarding cost estimates for performing clash detection reviews, the findings of a 2009 University of Florida study coincided with those of the Wisconsin Zoo Interchange Core 2 project. It is therefore recommended that 0.06% of the project cost be used to estimate the cost of one clash detection review. This can vary depending upon the complexity of the project but provides a good means of quantifying these costs during the scoping of a project. It should also be noted that there can be an expected savings of 1% to 10% of the contract value through clash detections.