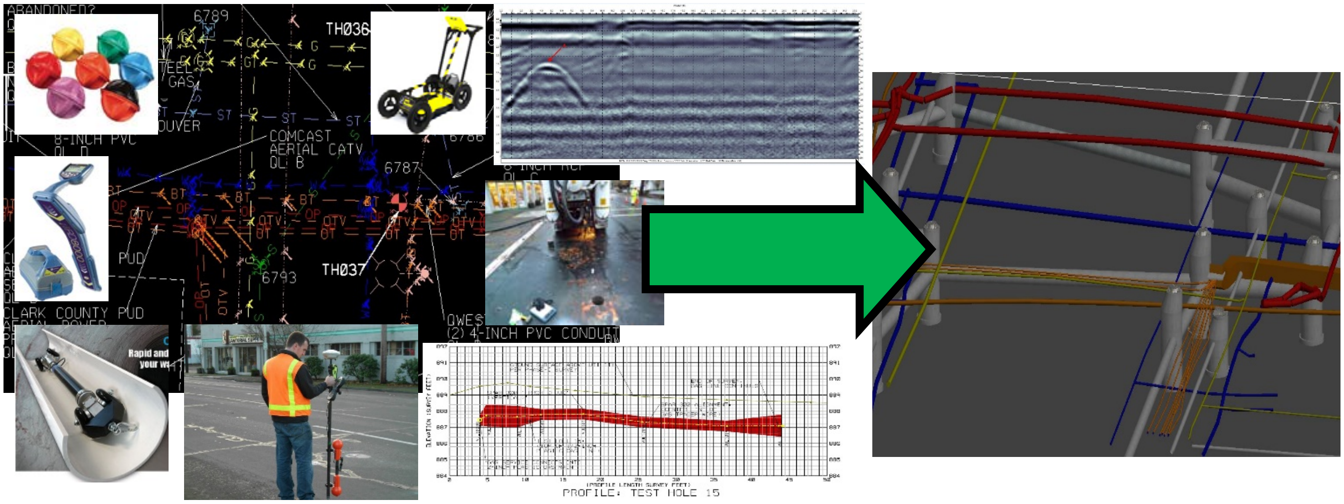

3-D Utility Survey Practices Executive Summary

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Executive Summary

A 3-D Utility Initiative was started by the Wisconsin Department of Transportation (WisDOT) to:

1. Determine best practical mapping technologies for acquiring 3-D utility alignments; and
2. Incorporate associated standards and best practices.

The goal is to establish WisDOT guidelines for systematic and efficient acquisition of 3-D utility data for use with current and evolving virtual design and construction (VDC) and related digital project delivery technologies and utility engineering best practices that improve safety, mitigate risks and reduce costs.

A primary focus was the field trialing of a new inductive electromagnetic (EM) detection and mapping instrument, the Optimal Ranging "Spar 300", which can acquire both horizontal and vertical alignment coordinates along with associated observation accuracy metrics. For comparison purposes, single frequency pulse ground penetrating radar (GPR) was included in the field trials for acquiring 3-D utility data. To evaluate performance and effectiveness on different existing utility installation scenarios, a variety of GPR and Spar 300 data were compared against: 1) ground truth (e.g., vacuum excavated test holes); and, 2) as available, utility “as-built” information of known quality. The effort described within this report includes acquisition and analysis of data from five WisDOT pilot projects (one completed in each region) and two supplemental projects.

The investigation included review of practices, guidelines and standards including:

1. Subsurface Utility Engineering (SUE,) standard practices, including current WisDOT policies;
2. Construction Institute of the American Society of Civil Engineers *Standard Guidelines for Collecting and Depicting Existing Subsurface Utility Data* (CI/ASCE 38-02);
3. CI/ASCE XX-XX standard for the *Collection, Administration, and Exchange of Utility Infrastructure Data* (a.k.a. utility “as-built” data) for documenting new infrastructure installations; and
4. Standard mandates regarding traceability of utilities.

Questionnaires were sent to forty five (45) state transportation departments to investigate existing 3-D utility data policies, and evaluate content and performance. States were also queried for policies which: 1) stipulate utility traceability requirements; and 2) address control and liability for data on utilities within public right of way. To gain a diversity of perspectives on visions and implications regarding 3-D mapping, questionnaires were also sent to stakeholders involved in the WisDOT 3-D Utility Initiative including: WisDOT upper and mid-level managers; regional utility coordinators involved with the pilot projects; Wisconsin Transportation Builders Association (WTBA) representatives and contractors; owners of utility infrastructure facilities; and a consultant firm hired to acquire data for several of the pilot projects.

The detailed analysis of acquired Spar 300 data indicated nearly 90% of observed 3-D coordinates derived from vacuum excavated test holes and “as-built” data (of known quality) fell within the Spar manufacturer's predefined accuracy bounds. The observed accuracies for the pilot project data, when using the manufacturer's recommended accuracy ranges, exceeded the manufacture’s specifications which state 68.2% (or, in statistical terms, one-sigma (1-σ)) of observations should fall within the stated accuracy range for actual depths. Recommended visual and analytical inspection practices provided within this study will effectively remove apparent erroneous observations and further improve observed statistical reliability; however, these pilot projects were specifically developed to review Spar 300 data without professional intervention for outlier removal, so all data, including obvious poor observations, were included in the analysis. The results of the comparative analysis indicate utilizing a tool such as the Spar 300 early in the design process will notably enhance project development by providing useful and characterized 3-D coordinate data on buried infrastructure, enabling:

1. Improved analytics for identifying clash issues and avoiding utility relocations;
2. Preparation of plans, specifications and 3-D digital models that facilitate VDC technologies, and;
3. Expedite project delivery with fewer risks of unanticipated utility related delays and damage.

Two pilot projects included GPR operations, but clay content within soils at one project location prevented acquisition of useful information. However, where GPR was effective there was very good correlation with both test hole depths and Spar observations. For that reason the study supports systematic acquisition of overlapping of GPR profiles with Spar observations to: 1) confirm depth observations and bolster confidence in derived 3-D alignments; and 2) identify and resolve discrepant observations.

A review of commercial products available specifically for 3-D mapping of buried utility infrastructure indicates the Optimal Ranging Spar 300 is on the cutting edge of technology for mapping: 1) non-pressurized non-metal pipes which can be accessed with an EM sonde, or energized rodder or fish tape; and 2) conductive cables and metal pipes. Other inductive EM pipe and cable instruments are capable of providing depth data, but appear to be designed in particular for rapid 2-D detection and not systematic 3-D mapping with appropriate metadata. A caveat is the Spar 300 is extremely sensitive to EM distortion; accordingly, operation in utility congested corridors requires a higher level of care and experience to effectively derive useful 3-D data. Optimal Ranging, Inc. is reportedly working to improve algorithms to remove distortion caused by adjacent buried infrastructure and reduce observation error.

A survey was sent to forty five (45) state transportation departments, of which nineteen (19) provided responses which indicated that none of the states have any policies, practices or specifications regarding acquisition and usage of 3-D utility data. Nine (9) states indicated they have statues or standards which require utilities installed within public right of way to be traceable. From these applicable regulations a policy can be adapted that is suitable for Wisconsin.

Questionnaires were also sent to fourteen (14) total individuals who are stakeholders in the WisDOT 3-D survey initiative. Twelve (12) of the fourteen (14) representatives responded with completed questionnaires which were reviewed and gleaned for content to be included within the development of this report. Comments ranged from positive to negative, but all were helpful for gaining insight and helped mold recommendations provided throughout the report.

Mandated usage of qualified professional subsurface utility engineering practitioners for acquiring, managing, analyzing and resolving issues, and overseeing usage of 3-D data on buried infrastructure throughout project development and delivery is essential for a successful implementation of practices utilizing 3-D utility data. In addition, careful adherence to CI/ASCE 38-02 standard guidelines, now considered in legal courtrooms as an industry standard for collecting and depicting subsurface utility data, is indispensable for safeguarding WisDOT from risk and liability resulting from errors and omissions. This study indicates technology and practices for mapping 3-D utility alignments are established and available and will improve safety, reduce costs and mitigate risks associated with utilities for most if not all WisDOT projects.

Five independent studies conducted over the past 25 years indicate a formal SUE process executed by a qualified professional engineer which includes project scoping, appropriate qualified data acquired in accordance with CI/ASCE 38-02 standard guidelines, utility conflict identification, risk assessment, and resolution engineering, and effective utility coordination throughout project development and delivery, provides an excellent ROI, ranging from a low of $3.41 to a high of $22.21. These studies were performed without use of current remote sensing 3-D QL B mapping technologies, such as the Spar 300, which should further improve the average ROI, which is generally considered to be around $4.52. The Pulaski project included within this WisDOT research effort appears to support this theory as the realized ROI for utilizing the Spar 300 was estimated to be $15.90.

Recommendations are provided throughout the main report and an executive summary of recommendations is provided below. In addition a section of the main report is dedicated to short term applications and long term goals for implementing guidelines, technologies, and processes for acquiring and utilizing 3-D utility data and SUE practices for the benefit of all stakeholders including WisDOT, utility owners, project contractors, and the public.

Executive Summary of Recommendations

Key recommendations provided throughout the entire main report are summarized below. For additional information refer to the main report for: 1) individual sections for basis supporting recommendations; and 2) Appendix F for complete listing of all recommendations. (Note: "QL B" observations inherently imply use of geophysical remote sensing technologies such as EM and GPR in accordance with CI/ASCE 38-02 standard guidelines.)

Utility Engineering Work Scope Criteria

- Utility engineering work scope development, including data acquisition, soft and hard conflict and risk analytics, resolution engineering, coordination, and agreement preparation, should: 1) be performed by a qualified professional; and 2) include identification of areas where 3-D data will be required or most useful.

- Use an iterative, multi-phased approach for SUE operations, knowing that all work beyond Phase I is more or less guesswork until Phase I data, consisting of 2-D QL D, QL C, QL B 2-D and 3-D QL B depictions, can be evaluated. After conflict and risk analytics have been performed, re-estimate and authorize Phase II operations to specifically acquire additional 2-D and 3-D QL B and discrete 3-D QL A data as is required based on Phase I results to complete designs, coordination, and construction planning.

- Within the work scope, a professional utility engineer, in accordance with a statutory mandate to hold paramount the interests of the public from a holistic stance, must evaluate project risks while also considering implications to utility infrastructure owners. For example, utilities may have improvements in planning which could be affected by a new surfacing that generates a moratorium on pavement cuts. Coordination and agreements activities therefore need to be performed to recognize and protect the interests of all parties.

- Use experienced SUE professionals to acquire, analyze and develop qualified 3-D utility base maps utilizing CI/ASCE 38-02 in the early stages of project development for identifying and resolving conflicts with design and construction. Further leverage this information by making it available to contractors and field engineers for reducing risk of damage and improving worker safety and construction efficiency.

- 3-D QL B alignment data obtained using geophysical methods is typically more cost effective and provides more comprehensive coverage and information than discrete vacuum excavation (QL A test hole) methods. This does not suggest test holes are not necessary; however, this strategy can be cost effective by providing more useful (i.e., entire alignments verses discrete observations) information earlier and enable engineers to better refine where test holes are necessary.

- Consultants providing utility designating, utility locating, engineering survey, and submittal preparation in accordance with CI/ASCE 38-02 standard guidelines must have the required equipment, experience and capability to perform utility field investigations independent of the Digger's Hotline (Dial 811) One-Call services.

- A critical pre-requisite to any 3-D field operation is developing a 2-D QL B base map in accordance with CI/ASCE 38-02. The 2-D mapping enables assessment of needs, strategy, limitations, and expense for acquiring 3-D utility information.

- Utilities may not need to be profiled using 3-D QL B methods for the entire project, but only where useful for completing designs, coordination, and construction planning. 3-D QL B utility mapping campaigns should be defined prior to authorization to help reduce cost and increase processing efficiency; however, if areas cannot be predefined, it can perhaps be more cost effective to comprehensively perform 3-D data acquisition during Phase I SUE utility designating operations and subsequently develop specific profiles where needed.

- Establish standard pre-qualifications for firms providing vacuum excavation test hole services to ensure facility integrity is protected, site restoration is appropriate, appropriate observation and verification data recorded, and work conducted under direct charge of a professional engineer per CI/ASCE 38-02.

- All utility mapping campaign data submittals, especially 3-D surveys, must include a certified engineering report to document the effort and responsible professional party, report findings, and highlight data acquisition issues.

<u>3-D Utility Data Observation and Visualization Criteria</u>

3-D QL B Acquisition

- A suggested standard observation interval for 3-D QL B alignments is between 10 and 20 feet with attempts to avoid areas of known distortion. The standard should permit professional judgment override when prudent.

- 3-D observations must include derived accuracy / error (e.g., the 95% confidence intervals for the horizontal and vertical positional solution), especially if plans are to be provided to contractors.

- Surface point ground elevation associated with 2-D and 3-D QL B data should be recorded with each observation.

- Utilize GPR in tandem with Spar 300 3-D mapping operations to reduce costs by providing independent validation Spar 300 data and further reduce test holes required.

- Effective GPR use includes multiple systematic sweeps in which copious quantities of data are recorded with accurate geo-referencing.

- Recorded GPR survey data should enable precise replication of the imaged subgrade and accurate geo-referencing of observed anomalies in 3-D space. Data analysis should include post-survey processing and review by specialists.

3-D QL A Acquisition

- To streamline vacuum excavations and facilitate confirmation that targeted utilities were indeed exposed and recorded properly (as opposed to some other geospatially coincident facility), data must be sequentially and systematically developed from QL D to QL B, to the extent practical. Otherwise, test hole results should not be interpreted as QL A data.

- Test hole submittals should include location data, failed attempts, and apparent discrepancies with record data. Plan sheet depictions should include referenced test hole information and clarify the measurement representations (i.e., top, bottom or center of utility, conduit type and construction, etc.).

3-D Data Visualization

- All CADD existing utility reference files should depict underground utilities with designated quality levels in accordance with CI/ASCE 38-02 standard guidelines.

- 3-D QL B data must be well annotated and depicted to enable the engineer to readily identify the confidence and reliability of the visualized 3-D alignments, and avoid the tendency to be lulled into assuming depictions are completely accurate when in fact depicted 3-D alignments will be comprised of a wide range of data reliability. This human tendency cannot be ignored and must be highlighted. Successful leveraging of 3-D QL B data can be achieved by keeping the providers of the data engaged to monitor data usage and/or provide interpretation and analytical services.

- Professional judgment (by qualified and experienced professionals) is required when synthesizing 2-D and 3-D QL B information and interpreting results.

<u>WisDOT Policies and Standards</u>

- Implement standardized tracer wire installations and verification procedures for facilitating subsequent detection using “direct connect” EM methods and derivation of 3-D alignments, or Implement a policy to make utilities readily detectable (“locatable”) in the field with conventional pipe and cable or RFID locating equipment.

- For installations found to have non-functional or improperly installed tracer wire, require contractor to re-install the wire, or excavate QL A test holes for location confirmation and install radio frequency identification (RFID) marker balls per established specifications used by Virginia DOT.

- WisDOT CADD standards do not address 3-D utility depiction and data annotation. Horizontal (2-D) alignments depicted in accordance with CI/ASCE 38-02 will be confused with overlaid Spar 300 3-D utility alignments; therefore, line styles should be modified to clearly distinguish Spar 300 derived 3-D alignments and facilitate interpretation efforts.

- Modify WisDOT CADD standard bore hole symbol for depicting QL A test holes (potholes) with more accurate 2-D and 3-D visual representation of the observed 3-D position for the target utility (e.g., cross hairs or a center point).

- Standardize depiction of the error envelope for derived 3-D QL B utility alignments.

- Enforce Chapter 13 of the WisDOT Guide to Utility Coordination entitled "PS&E Plan Requirements" to ensure compliance with the CI/ASCE 38-02 standard.

- Educate contractors and utility companies on 3-D utility data acquisition, usage and limitations to avoid misinterpretation and promote optimal usage to derive maximum value from the data.

<u>WisDOT Project Development and Delivery Practices</u>

- Begin posturing WisDOT for implementing "Digital Project Delivery" methods including qualified 3-D utility information to facilitate contractor bidding, planning, scheduling and construction including utilizing machine control.

- Implement 3-D CADD design which incorporates 3-D utility information to mitigate conflicts, reduce costs, and proactively control risk.

- Implement usage of utility conflict matrices in accordance with SHRP 2 REPORT S2-R15B-RW-1 *Identification of Utility Conflicts and Solutions* to promote systematic treatment of utilities on projects and enhance communication and cooperation between WisDOT and the utilities.

- Standardized process for conflict assessment, resolution development, and agreement preparation which promotes stakeholder collaboration, proactive planning, value engineering, and innovative contracting practices.

<u>WisDOT Management of Utility Installation Data</u>

- Implement a digital web based permit system and utility infrastructure database to ensure all activities within public right of way are tracked and asset management information are systematically updated with properly acquired as-built data.

- Require accurate and standardized digital "as-built" data records for all new installations based on the new CI/ASCE standard for the "Collection, Administration, and Exchange of Utility Infrastructure Data" currently in development.

- Preserve for future use the investment on project based utility mapping campaigns. Facility attribute, position and quality level information for utilities rediscovered in accordance with CI/ASCE 38 standards should be documented and stored digitally in accordance in a standardized manner.