

# 3D Utility Survey and Modeling

*Resolving the Utility Conundrum*

3 D Design and Modeling for Highway Structures

Iowa State Center Scheman Bldg, Ames, Iowa

April 14 – 15, 2015

Utility Mapping Services, Inc.

Philip J. Meis, M.S., P.E. - Principal Engineer





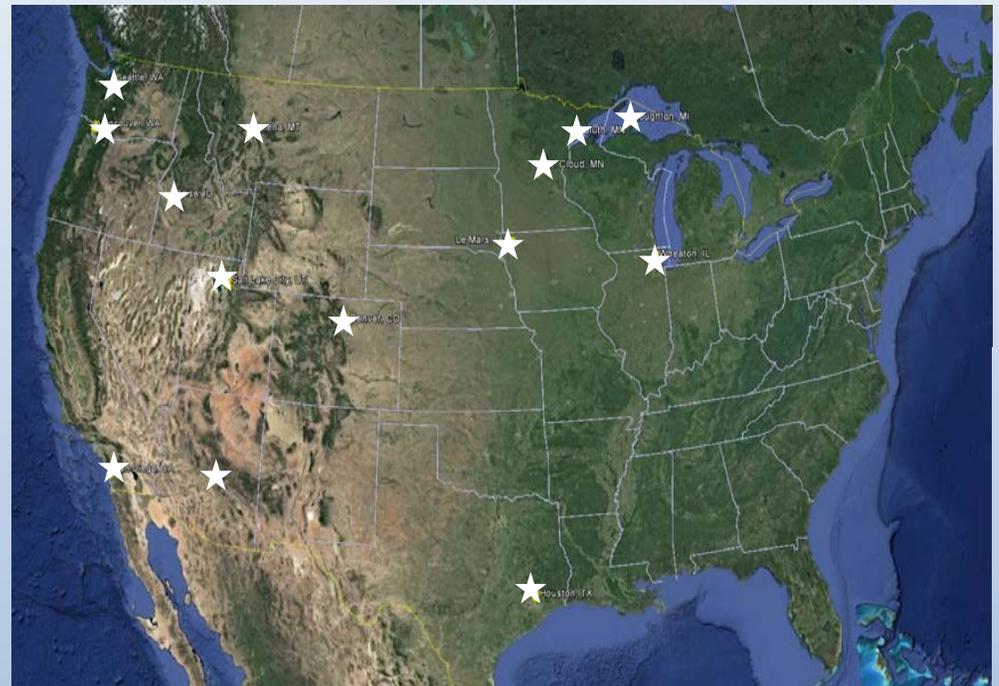
# Company Background

## Utility Mapping Services, Inc.

Highly specialized, small business specifically focused on Subsurface Utility Engineering (SUE).

Established in 2002 and staffed by engineers, geophysicists, surveyors, and geospatial data experts who are advancing state of the art SUE practices, UMS is recognized as a leader with unparalleled expertise at minimizing issues with existing infrastructure.

Approaches SUE as a rigorous, innovative, strategic, and technologically advanced professional engineering service.



Active in ASCE, AASHTO, TRB, SHRP2 R01A, R15B

Committee Lead for CI/ASCE Standard for the  
“Collection, Administration, and Exchange of  
Utility Infrastructure Data”

# Recent Research Participation

The Second  
STRATEGIC HIGHWAY RESEARCH PROGRAM

 SHRP 2 REPORT S2-R15B-RW-1

## Identification of Utility Conflicts and Solutions

CESAR QUIROGA AND EDGAR KRAUS  
Texas A&M Transportation Institute, Texas A&M University System

PAUL SCOTT  
Cardno TBE

TOM SWAFFORD AND PHILIP MEIS  
Utility Mapping Services

GARY MONDAY  
Ash Engineering

# Leading New Standard Development

## *Consensus Activity for the Collection, Administration, and Exchange of Utility Infrastructure Data*

*American Society of Civil Engineers*

*Construction Institute*



Utility Engineering and Program  
Management



# Recent UMS Research Efforts

**RESEARCH**

Report No. UT-11.07

**RECOMMENDED  
PROTOCOL AND  
STANDARDS FOR UTILITY  
DATA SUBMITTALS**

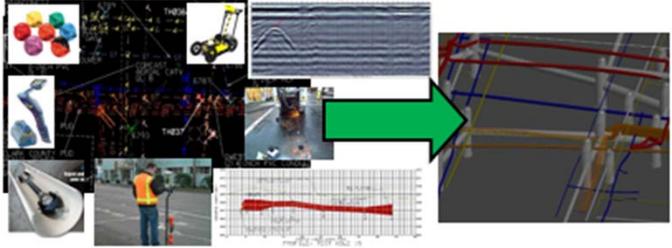
Prepared For:  
Utah Department of Transportation  
Research Division

Submitted By:  
Utility Mapping Services, Inc.

Authored By:  
Philip J. Meis, P.E.

Final Report  
February 2012

**UDOT**  
Utah Department of Transportation - Research Division  
4201 South 2700 West - P.O. Box 148410 - SLC, UT 84114-8410  
udot.utah.gov



**3-D Utility Survey Practices**

*August 13, 2014*

PROJECT ID 0656-23-09

Submitted to:  
Wisconsin Department of Transportation  
4802 Sheboygan Ave., Room 451  
Madison, WI 53707  
p. 608.266.0319



Submitted by:  
Utility Mapping Services, Inc.  
3947 East Calvary Road, Suite 103  
Duluth, MN 55803  
p. 218.728.8087  
www.umsi.us



Authored By:  
Philip J. Meis, P.E., Rodney Kent, Thomas Swafford, Donald Haines, Nathan Greer

Revised August 2014

# WisDOT 3D Initiative

3-D Utility Initiative was started by WisDOT to:

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

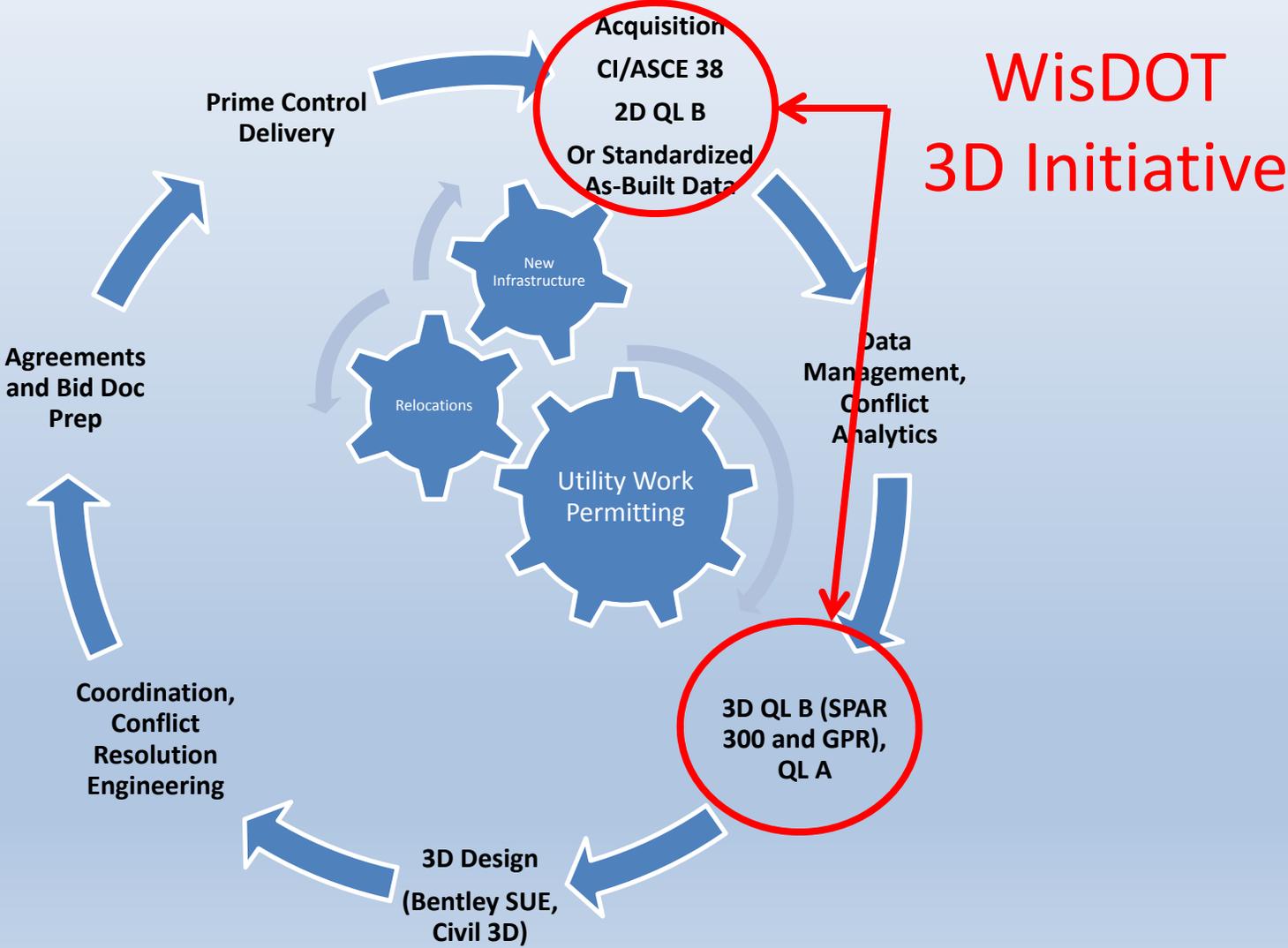
The goal is to establish WisDOT guidelines for systematic and efficient acquisition of 3-D utility data for use with current and evolving virtual design and construction (VDC) and related digital project delivery technologies and utility engineering best practices that improve safety, mitigate risks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

# WisDOT 3D Utility Survey Findings

- Evolving 2D Utility Survey Methods to 3D
- Geophysical Tools (sorry, no X-ray vision)
- Applicable Standards – Existing Infrastructure and New Infrastructure
  - CI/ASCE 38-02 – Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
  - CI/ASCE XX – Standard for the Collection, Administration, and Exchange of Utility Infrastructure Data (aka “As-Builts”)
- Data Management and Design Technologies (Utility Data is a Different Animal)
  - 3-D Model – Depicting an Interpretation and Risk (SHRP2 R01A)
  - Conflict Analytics, Resolutions, Agreements (SHRP2 R15B/C)
  - Digital Project Delivery / E-Delivery
  - As-Built / Life Cycle Data Management
- Professional Credentials for Utility Engineering

# Utility Management Strategy

## Digital Project Development and Delivery



# Strategic Utility Program for Project Development and Delivery

## Rediscovery of Existing Utilities

- Standardize Utility Surveying (CI/ASCE 38-02)
- 3-D Utility Data Modeling for Design
- Utilize Cross Disciplined “Utility Engineers”
- Engage Utility Owners as Full Partners
- Design With and Around Utility Infrastructure
- Integrate Utility Work with Mainline Work
- Collect Standardized Utility “As-Built” Data

## Digital Documenting of Newly Installed Utilities

# Pain Points with Utility Management



# Implications of Utilities on Bid



**Contractor Contingencies for handling Utility issues can equal 10% of Contract Cost**

**Contingencies for **UNKNOWN** / **RISK** = Higher Bids**

**Handwork = Higher Bids**

**Coordination with Independent Contractors = Higher Bids**

**Loss of Control & Changed Conditions = Change Orders**

With Digital Project Delivery the Project Schedule Critical Path is significantly shortened; however, archaic utility management practices wreak havoc on Digital Project Delivery time and cost saving strategies!

# Call Before You Dig 811 is the Utility's Last Line of Defense



## Non-Standard Data Source

One call markings are made for contractor to avoid facilities, not to accurately map them.

True gas main location  
CI/ASCE 38-02 QL A

811 Mark

# Recommend Four Phase Approach

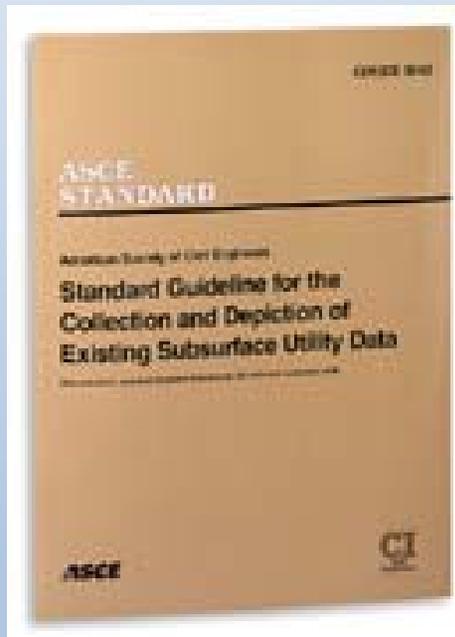
- Phase I – **2D** Mapping Effort, Conflict Identification & Matrix Development
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- Phase IV – Construction Management & Oversight

# Now an Industry Standard

## CI/ASCE 38-02 (The Standard)

<http://www.fhwa.dot.gov/programadmin/sueindex.cfm> )

## SUE (The Engineering Process)



**SUBSURFACE UTILITY ENGINEERING**  
Over the decades, highway designers have had a difficult time obtaining reliable subsurface utility information. Now, this information is available through the use of an engineering process called Subsurface Utility Engineering.

**MAJOR SUE ACTIVITIES:**

- Scope of Work** – The process of developing a written project-specific work plan package that consists of scope of work, levels of service vs. risk allocation, project schedule and desired project delivery method. The SUE work plan package is agreed upon by the SUE provider and the client, describing the SUE work to be performed.
- Designating** – The process of using a surface geophysical method or methods to interpret the presence of a subsurface utility and mark its horizontal position on the ground surface or on above-ground surface markers.
- Locating** – The process of exposing and recording the precise vertical and horizontal location and providing utility size and configuration of a utility.
- Data Management** – The process of surveying, designating, and locating information to project control and transferring it into the client's CADD system, GIS files, or project plans.
- Conflict Analysis** – The engineering process of using a conflict matrix to evaluate and compare depicted designating information with proposed plans (highway, bridge, drainage, and other) in order to inform all stakeholders of potential conflicts, potential resolutions and costs to cure.

**Project Application**

**STANDARD OF CARE**

The American Society of Civil Engineers (ASCE) has developed an important standard of care guideline, *Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data*, CI/ASCE 38-02.

This standard guideline describes four quality levels of utility depiction:

- Quality Level D** – Information derived from existing records or oral recollections.
- Quality Level C** – Information obtained by surveying and plotting visible above-ground utility features and by using professional judgment in correlating this information to Quality Level D.
- Quality Level B** – Information obtained through the application of appropriate surface geophysical methods to determine the existence and approximate horizontal position of subsurface utilities.
- Quality Level A** – Precise horizontal and vertical location of utilities obtained by the actual exposure and subsequent measurement of subsurface utilities, usually at a specific point.

To order a copy of ASCE Standard 38-02, please go to the ASCE Bookstore: <http://www.nubis.asce.org> or call 1-800-548-2723.

**SUE EXPERTISE**

- Competence.** SUE providers should be able to demonstrate a thorough knowledge and understanding of the major SUE activities and should be able to provide these services to the extent desired by the contracting agency.
- Experience.** Individuals assigned by the SUE provider to carry out the work should be well-trained, experienced, and capable. Those in responsible charge of the work and responsible for certifying deliverables should be engineers, geologists, and land surveyors employed by the SUE provider in accordance with state professional registration requirements.
- Equipment.** A wide range of equipment is necessary to detect the variety of subsurface utilities that may be present. Equipment available for utilization by the provider should include, but not be limited to, state-of-the-art designating equipment; vacuum excavation or comparable non-destructive locating equipment; state-of-the-art surveying and data recording equipment; and software systems compatible with those of the contracting agency.
- Timeliness.** Resources of the provider should be adequate to carry out the SUE work in a timely manner, considering other possible commitments of work and the contracting agency's anticipated needs.
- Financial Capacity.** SUE providers should have the financial capacity to provide the required services.
- Insurance.** SUE providers should have adequate insurance covering all aspects of work. Minimum amounts should be in accordance with the contracting agency's requirements.

## Adopted as a BEST PRACTICE



# Utility Mapping Equipment Examples

- Electromagnetic (EM) Locate & GPS Survey
- SPAR 300
- Ground Penetrating Radar (GPR) Noggin Sensors & Software Smartcart
- Acoustic Detection
- Vacuum Excavation

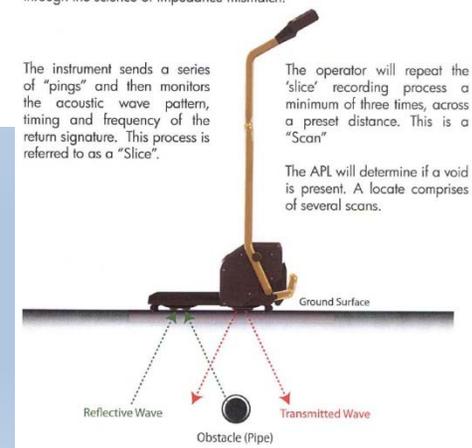


**ULTRA-TRAC® APL** locates the voids in the ground created by a pipe through the science of impedance mismatch.

The instrument sends a series of "pings" and then monitors the acoustic wave pattern, timing and frequency of the return signature. This process is referred to as a "Slice".

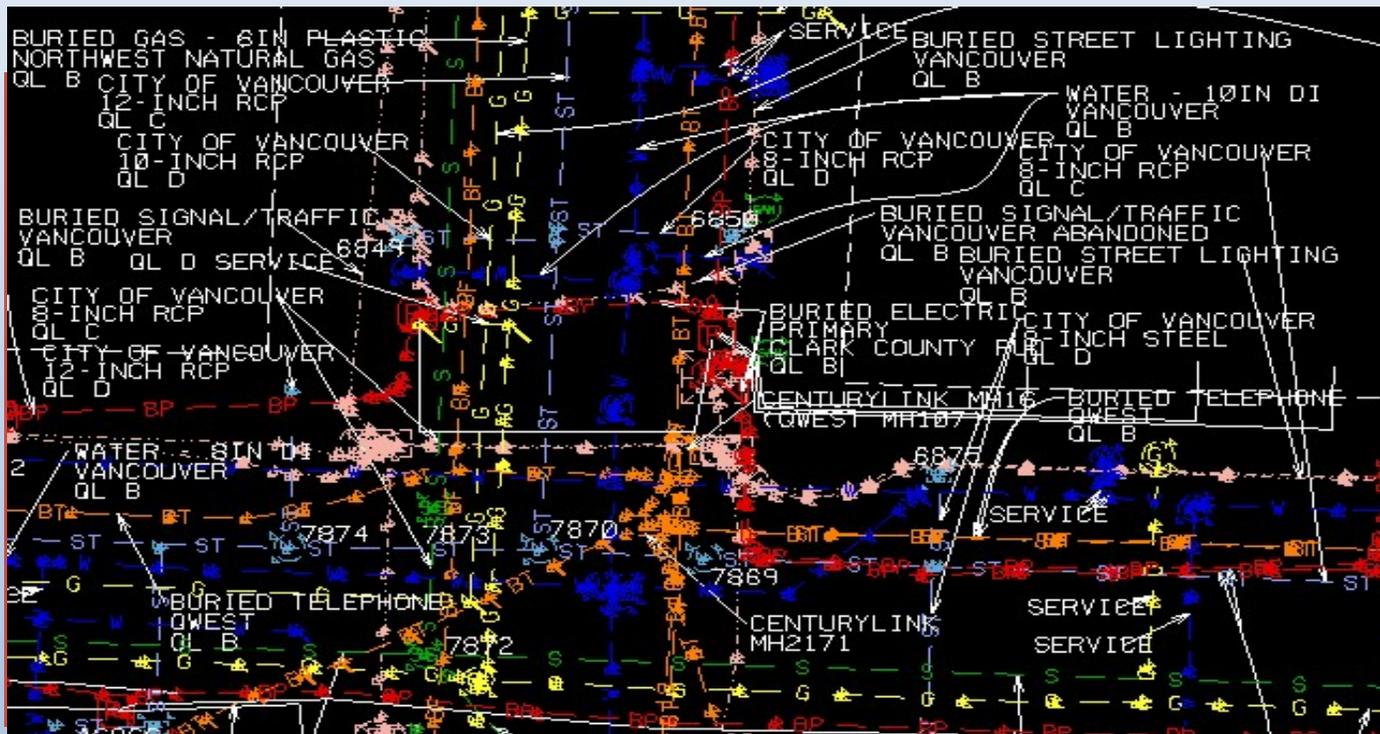
The operator will repeat the 'slice' recording process a minimum of three times, across a preset distance. This is a "Scan".

The APL will determine if a void is present. A locate comprises of several scans.



# Importance of a 2-D Base Map

*American Society of Civil Engineers (ASCE) Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data, CI/ASCE 38-02*

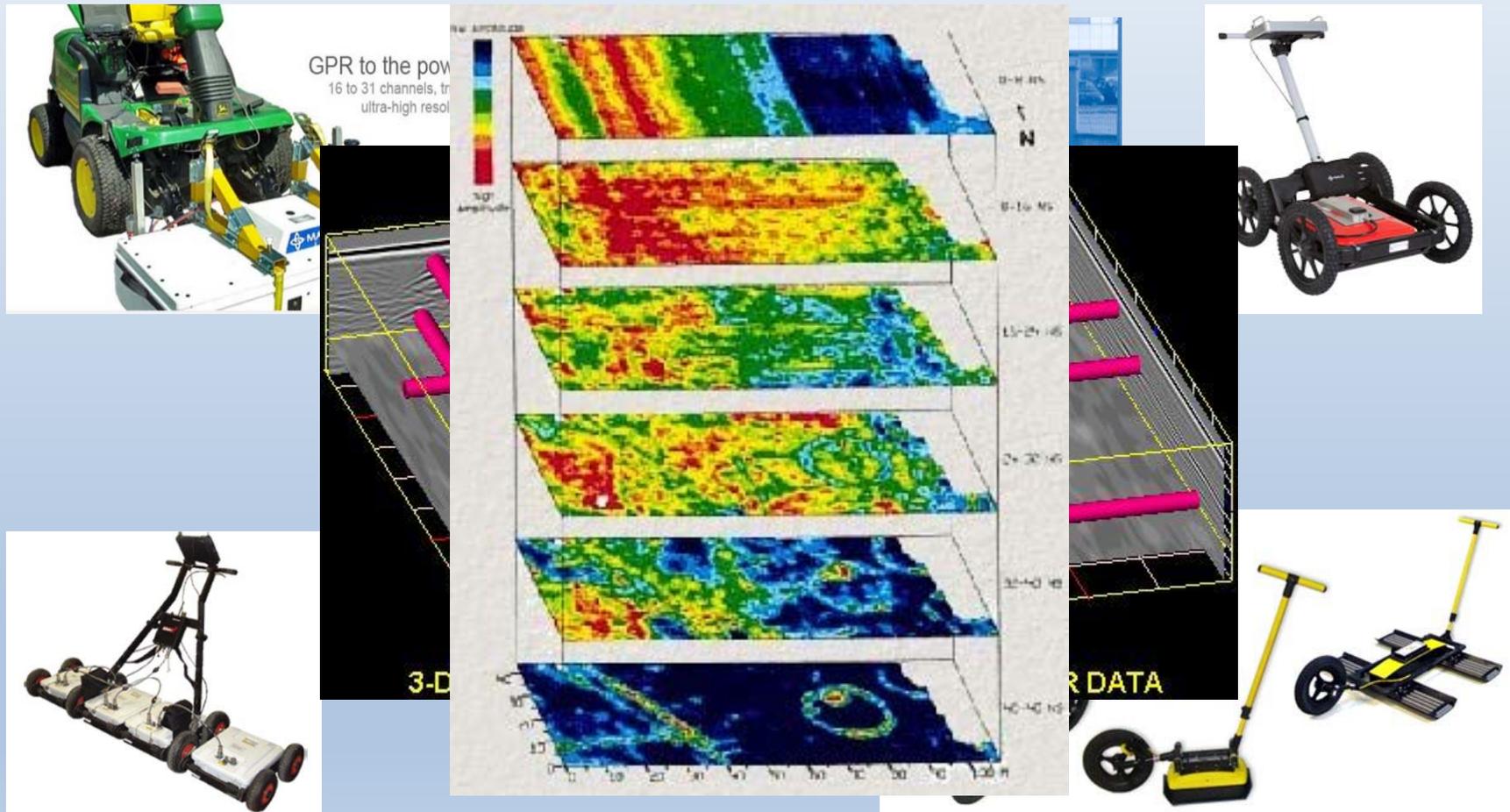


Standardized Data = More Data  
Requires Better Data Management Methods

# Recommend Four Phase Approach

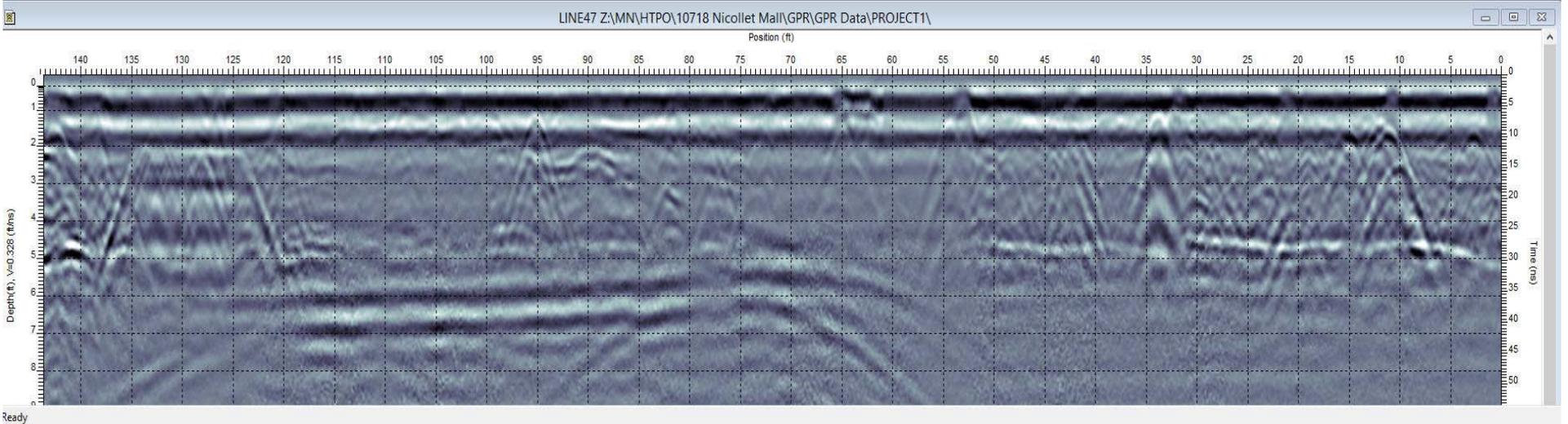
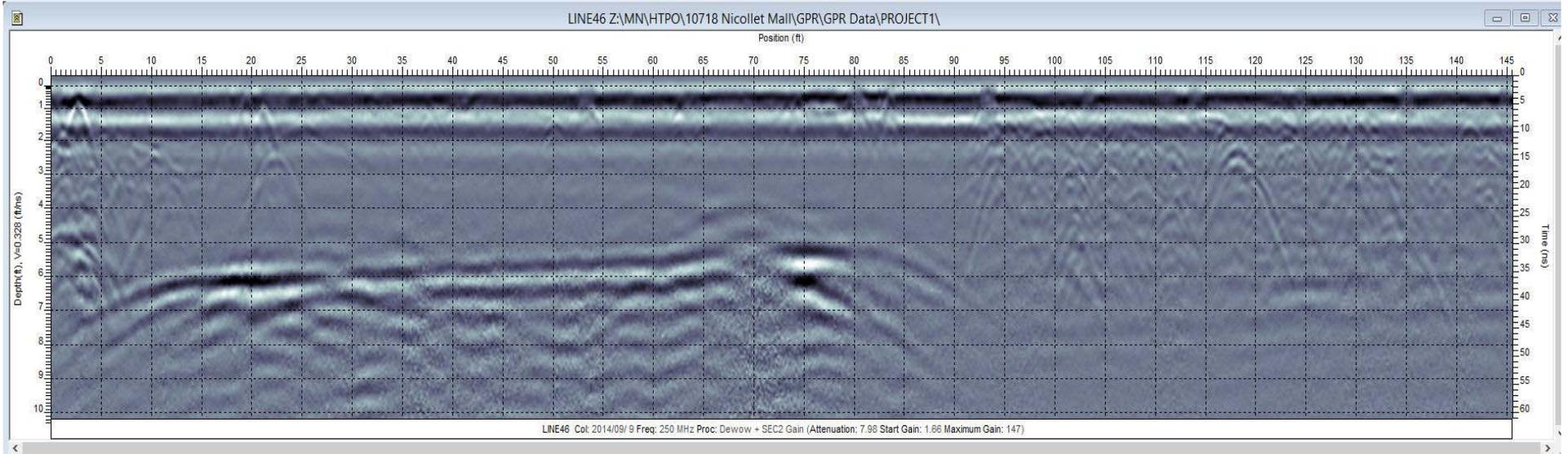
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# GPR 3-D QL B (Ideal vs Reality)

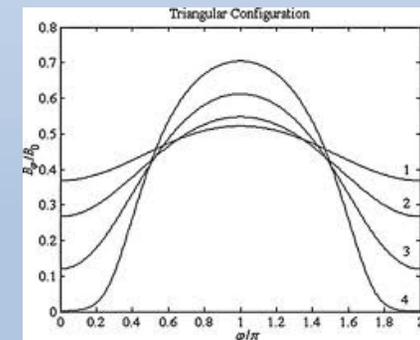
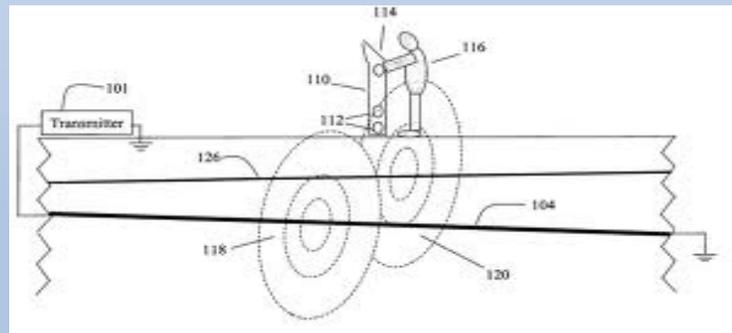
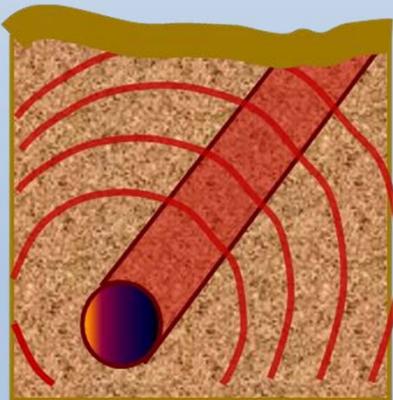
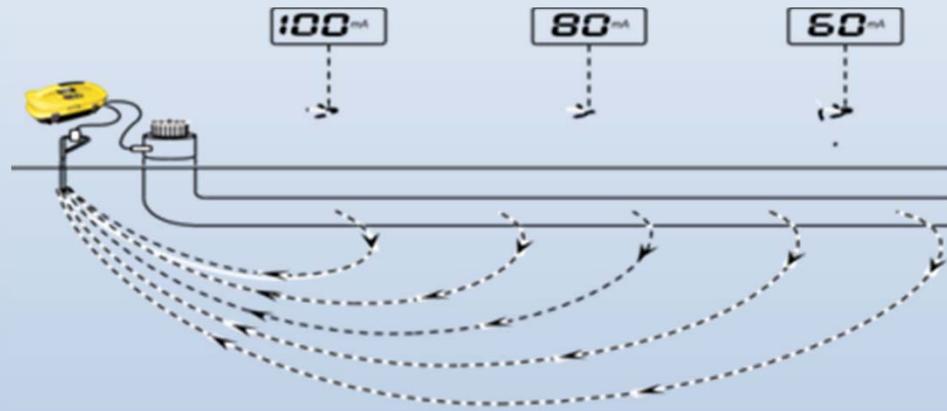
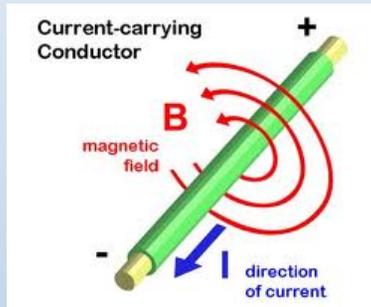


4/20/2015

# 2D QL B Map Required to Interpret GPR

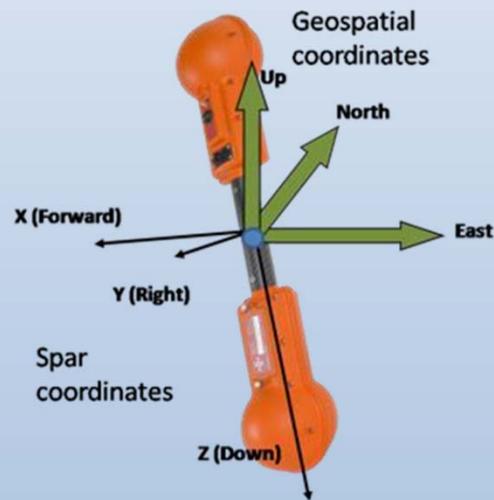


# Fundamental Electromagnetic (EM) Detection Principles



21

# SPAR 300 – 3D QL B EM Tool



- Two 3-d magnetic loop antennas
- 20 Hz – 10 kHz frequency
- 3-axis digital compass
- 3-axis accelerometer
- RTK-GNSS (optional)
- Bluetooth or USB host interface
- Zigbee (wireless sensor networking)
- Model-based optimization processor
- Quick-change 8-hr Li-Ion battery
- 5 hour with internal RTK

22

# SPAR 300 Data Monitoring and Management

**FieldSens View: peak**

57.9 dB  
9.50  
4.21  
45.3 m

1.5 ft UK7

RTK:Fixed H:0.024 ft V

Hide Signal 8440 Hz

Description	Category	Code
Line Util Vert 1: 10cm	Utility Survey	VA
Line Util Vert 2: 20cm	Utility Survey	VB
Line Util Vert 3: 50cm	Utility Survey	VC
Line Util Vert 4: 100cm	Utility Survey	VD
Line Util Vert 5: 200cm	Utility Survey	VE

Fixed  
(do not  
change)

User Choice  
(m, cm, in, sft)

User Choice  
(normal  
restrictions)

2.43 ft

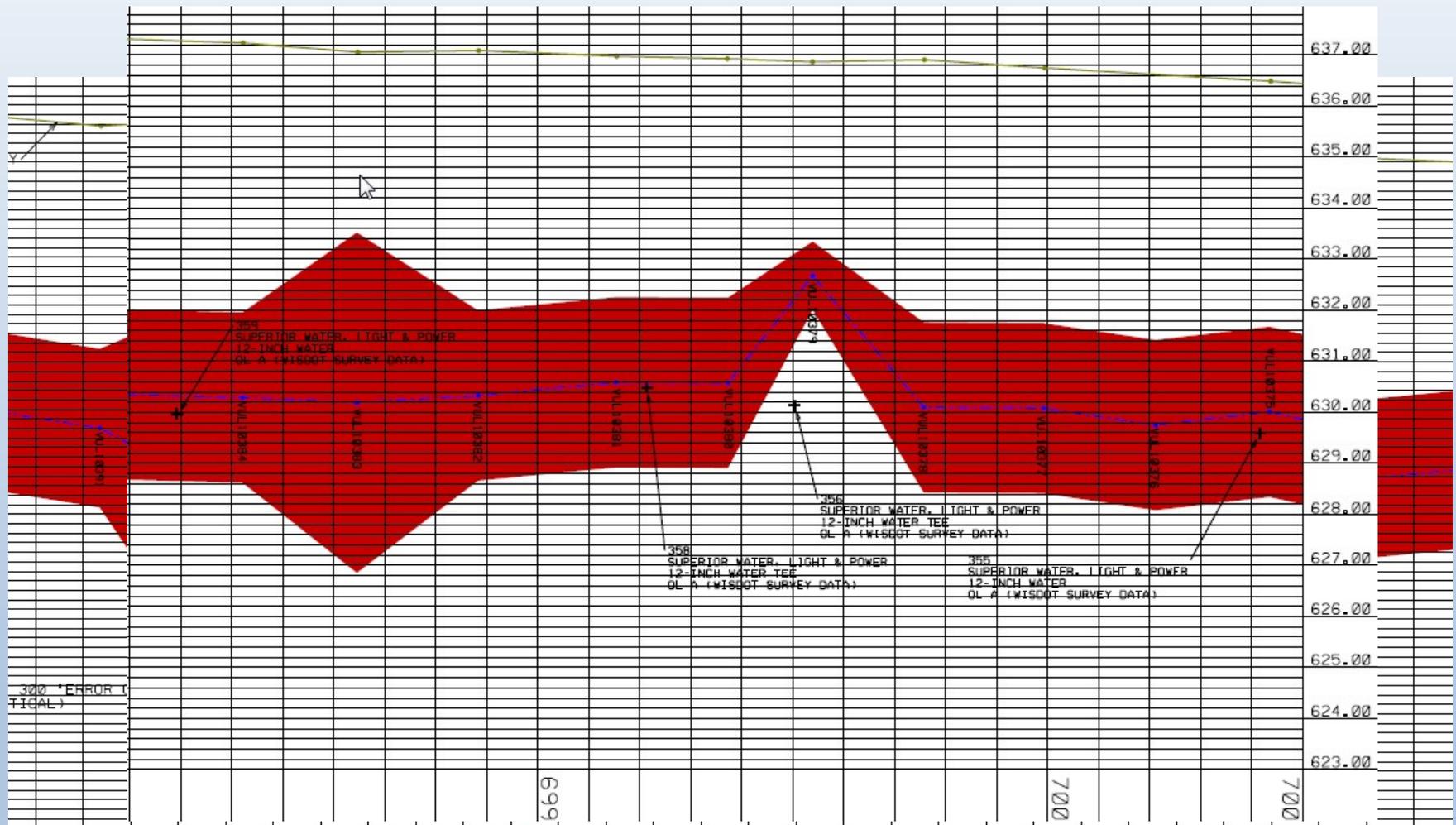
0.375 ft

039 ft RMS:014

Peak

Possible to determine when observations are good or suspect; record and quantify result accuracy.

# SPAR 300 Data Management



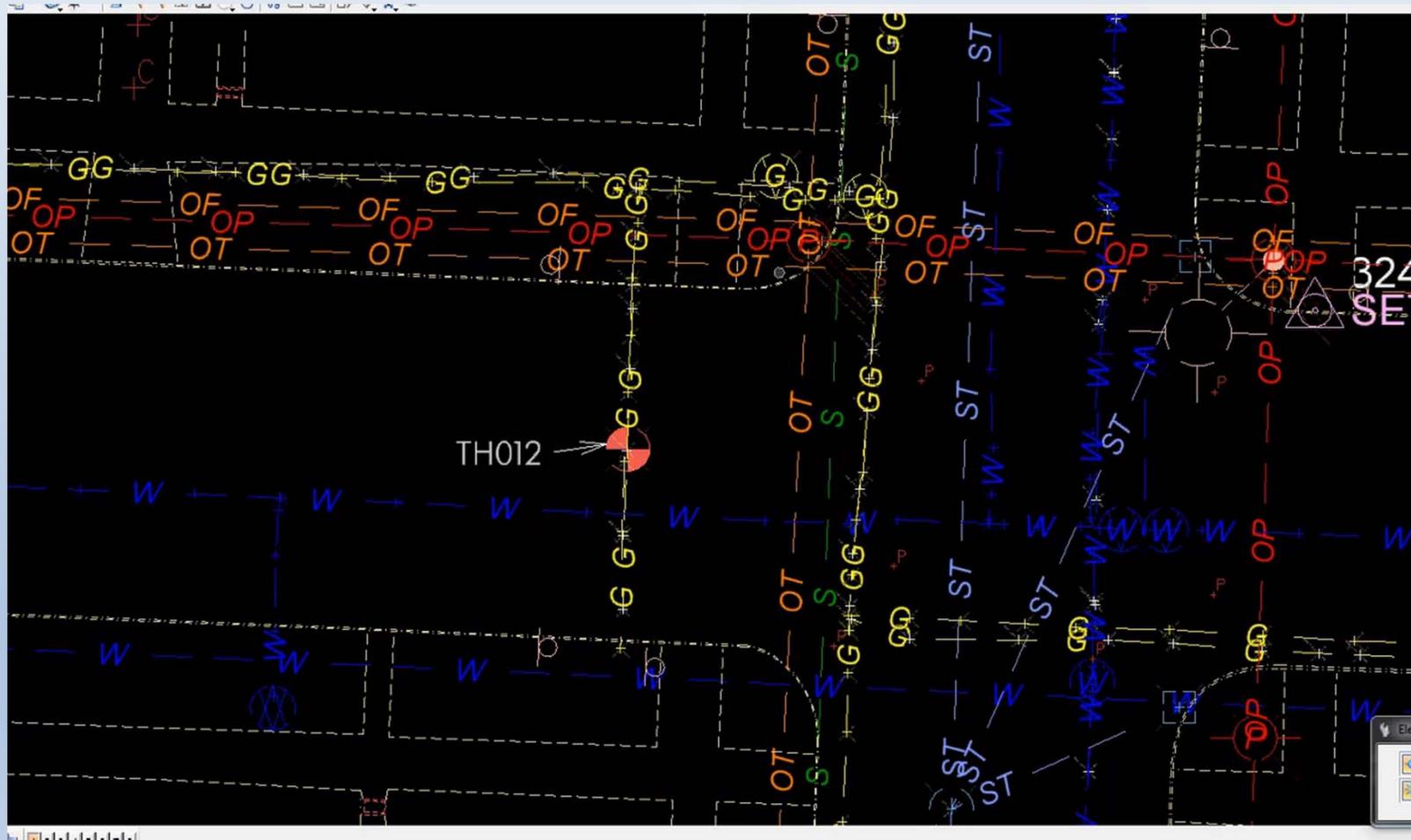
## Much Data to Manage and Interpret



Utility Engineering and Infrastructure  
Management



# 3D Cross Section Superior to Single Test Hole for Design





# Recommend Four Phase Approach

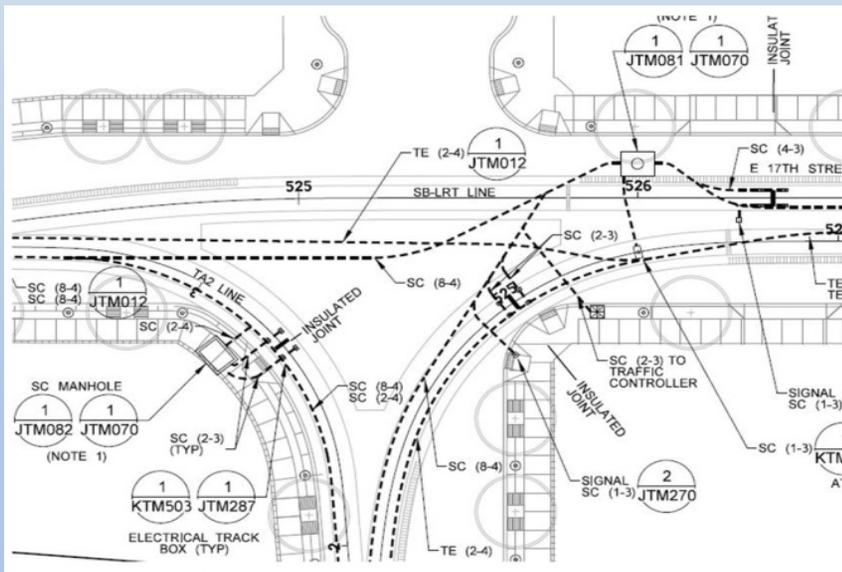
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# Importance of Data Management for Utility Conflicts and Solutions

- Manage the **complexity of utility infrastructure** data (spatial, attribute, metadata) in a structured, secure, readily accessible offsite (cloud) repository
- Itemize, manage and coordinate **clash detection and conflict analyses** results with project design and utility teams for efficient design coordination and value engineering
- Facilitate **utility coordination process** and **engagement** of utility **owners**
- **Integrate** utility betterments, new installations, relocations, protect-in-place alternatives into mainline schedule
- Facilitate **utility agreement development**
- **Facilitate digital project delivery (planning, bidding, and construction)**
- Facilitate field acquisition and management of utility **as-built data**

# UIM Application

Secure, robust web based utility infrastructure management (UIM) application is key to managing conflicts and resolutions within dynamic conditions (e.g., schedule, designs, segment limits) typically associated with large projects.



**LIGHT RAIL ALIGNMENT  
w/ SYSTEM DUCT BANKS**



**LIGHT RAIL ALIGNMENT  
w/ SYSTEM DUCT BANKS  
& EXISTING UTILITY CONFLICTS**

# Ex. – Proposed Curb and Gutter and Existing Gas Pipe

The screenshot shows the GEOdaisia web interface. At the top, there is a navigation bar with the GEOdaisia logo, the tagline "Referencing Fixed Points On The Earth's Crust", and user information for "dhaines@umsi.us". A search bar is also present. Below the navigation bar, the breadcrumb trail reads: "Dell Rapids, SD / Segment 1 - PCN 03RT / E1001". The main content area displays a conflict titled "E1001: PCG1 | UNGAS100 Conflict". There are several tabs: "Details", "0 Pictures", "1 Message", "0 Governance", "1 Resolution Set", and "Features' 16 Conflicts". The "Details" tab is active, showing a table of features involved in the conflict:

Feature	Additional Names	Owner	Feature Set/Type
PCG1		SDDOT (South Dakota Department of Transportation)	Roadway and Safety: Shoulder
UNGAS100		MidAmerican Energy	Gas Utilities: Buried Pipe

Below the table, there are sections for "UNGAS100 's Stationing" (From 137+66.70 L 41.85 to +00.00 0.00), "PCG1 Conflict Chain" (with a "Create Conflict Chain" button), and "UNGAS100 Conflict Chain" (with a "Create Conflict Chain" button). Other details include "Resolve By Date", "High Priority" (False), "Description" (BURIED GAS LINE CROSSING PROPOSED CURB & GUTTER), "Alignment" (474TH/475TH AVENUE (HIGHWAY 115)), "Spatial Orientation" (Parallel), "Adverse Impact" (Geospatially Coincident), "Adverse Impact Comment" (GAS LINE), and "Created by" (ngreer@umsi.us on 2/19/2014 11:52 AM).

At the bottom of the page, there is a footer with copyright information "© 2010-2014 - GEOdaisia" and links for "Terms and Conditions", "Privacy Policy", "Change Log", and "Tell us what you think or make a request".

# Conflict Resolution

Existing Conditions   Conflict Analysis   Resolution

Existing Conditions   Conflict Analysis   Resolution

## Conflict Analysis

The depth of the proposed cut at the McLoughlin under-crossing will require that this Gas Main be lowered/replaced (Ref. Transit 30% Plans, K159-K164) The Gas Valve at the Intersection of McLoughlin and G Street should also be relocated at that time to avoid a conflict with the proposed Storm Design along G Street. 3D QL-B data and Test Hole data has been obtained.

### Conflicts

0 Conflict Pictures

Conflict Number	Resolve By Date	Conflict Zone	Alignment	Features in Conflict		Description
<a href="#">51339</a>		CRC Project (Portland - Vancouver Bridge): Segment 5	G Street	GST   WSDOT (Washington Department of Transportation)   Roadway and Safety: Pavement Section	GVLVNW_16042   Northwest Natural   Gas Utilities: Valve	Conflict imported without a description.
<a href="#">40915</a>		CRC Project (Portland - Vancouver Bridge): Segment 4	McLoughlin Blvd	PSD562   WSDOT (Washington Department of Transportation)   Storm Drainage: Gravity Pipe	GASNW705   Northwest Natural   Gas Utilities: Buried Pipe	Line crosses proposed storm drainage
<a href="#">40005</a>		CRC Project (Portland - Vancouver Bridge): Segment 4	SB-LRT Light Rail Transit South Bound	DUCT BANK45   C-Tran   Rail: Duct Bank	GASNW705   Northwest Natural   Gas Utilities: Buried Pipe	Conflict imported without a description.
<a href="#">40907</a>		CRC Project (Portland - Vancouver Bridge): Segment 4	McLoughlin Blvd	PSD562   WSDOT (Washington Department of Transportation)   Storm Drainage: Gravity Pipe	GASNW705   Northwest Natural   Gas Utilities: Buried Pipe	Line crosses proposed storm drainage. Due to the amount of excavation (cut) to have the Light Rail undercrossing it appears that this gas line will need to be lowered or relocated.
<a href="#">40908</a>		CRC Project (Portland - Vancouver Bridge): Segment 4	McLoughlin Blvd	PSD444   WSDOT (Washington Department of Transportation)   Storm Drainage: Gravity Pipe	GASNW705   Northwest Natural   Gas Utilities: Buried Pipe	Line crosses proposed storm drainage. Due to the amount of excavation (cut) to have the Light Rail undercrossing it appears that this gas line will need to be lowered or relocated.

# Utility Conflict Resolution Activities for Project Development and Delivery

1. Utility 2D and 3D Field Data Acquisition
2. Hard & Soft Clash Detection, Populate UIM, Analysis
3. Utility Betterment and Constraint Identification
4. Conflict Resolution(s) & Alternative Design
5. **Value Engineer utility work, Integrate w/ mainline**
6. Utility Coordination, Negotiations, Agreements
7. Utility Construction Management Support, Verification and As-builts

# Terra Move™

*Cost effective and time sensitive alternatives to utility relocation needs.*



# Terra Shield™

*The industry's new standard for utility support and protect projects*



# Terra Cap™

*High Performance Protection for New or Existing Underground Utilities*



# Resolution Report for Agreements



Report generated utilizing Task, Cost along with other governing information managed in UIM; reports are used to support and supplement Utility Agreements

Columbia River CROSSING Resolution Information Report

CRC Project (Portland - Vancouver Bridge)  
CRC Project  
Resolution 9 - NWNWA (Proposed)

MS INC

<b>Primary Responsible Organization</b> Northwest Natural	<b>Conflict Numbers</b> 40005 , 40054 , 40771 , 40907 , 40908 , 40909 , 40911 , 40912 , 40913 , 40915 , 51338 , 51339
<b>Primary Responsible Party</b> Washington	

Created by ngreen@umsus on 4/18/2013 1:55 PM

**Existing Conditions**  
**Location Description**  
Gas Main extending East/West in the McLoughlin Blvd. roadway through the McLoughlin under-crossing of I-5 to McLoughlin and G Street.

**Feature Types**  
3 Storm Drainage Gravity Pipes  
2 Gas Utilities Valves  
2 Roadway and Safety Pavement Sections  
2 Survey and Photogrammetry Test Holes  
1 Gas Utilities Buried Pipe  
1 Rail Duct Bank  
1 Water Utilities Buried Pipe

**Survey Points**  
8 QL-A , 117 QL-B , 1 QL-D

**Owners**  
City of Vancouver: Public  
C-Trans: Public  
Northwest Natural: Private  
Unknown: Public  
WSDOT (Washington Department of Transportation): Public

**Existing Conditions Description**  
4-1/2" Steel Gas Main from the Gas Valve at the intersection of McLoughlin and G Street, approximately 20 feet Right of Station 0+86 (McLoughlin Blvd.), to approximately Station 550+20 (NB-LRT).

**Conflict Analysis**  
**Connected Features with Survey Points**  
From Test Hole 10 measure down -4.11 feet to Top External of GASNW705 | Elevation: 128.141000000 From Test Hole 15 measure down -5.03 feet to Top External of GASNW705 | Elevation: 135.097000000 From Test Hole 16 measure down -4.75 feet to Top External of GASNW705 | Elevation: 135.349000000 From Test Hole 25 measure down -4.21 feet to Top External of GASNW705 | Elevation: 121.876000000 From Test Hole 10 measure down -4.11 feet to Top External of WTRCV242 | Elevation: 128.141000000 From Test Hole 15 measure down -5.03 feet to Top External of WTRCV242 | Elevation: 135.097000000 From Test Hole 16 measure down -4.75 feet to Top External of WTRCV242 | Elevation: 135.349000000 From Test Hole 25 measure down -4.21 feet to Top External of WTRCV242 | Elevation: 121.876000000

**Conflict Analysis Description**  
The depth of the proposed cut at the McLoughlin under-crossing will require that this Gas Main be lowered/replaced (Ref. Transit 30% Plans, K159-K164) The Gas Valve at the Intersection of McLoughlin and G Street should also be relocated at that time to avoid a conflict with the proposed Storm Design along G Street. 3D QL-B data and Test Hole data has been obtained.

**Resolution**  
**Resolution Description**  
The depth of the proposed cut at the McLoughlin under-crossing will require that this Gas Main be lowered/replaced (Ref. Transit 30% Plans, K159-K164) The Gas Valve at the Intersection of McLoughlin and G Street should also be relocated at that time to avoid a conflict with the proposed Storm Design along G Street. 3D QL-B data and Test Hole data has been obtained.

**Tasks**  
**RELOCATE - Install or Bore New Gas Main**  
To maintain a Gas Main along this roadway a new Gas Line could be installed to the depth required by the proposed transit and roadway design from  
Page 1 of 3

**Construction Tasks**  
Page 2 of 3

**Tasks**  
**RELOCATE - Install or Bore New Gas Main**  
To maintain a Gas Main along this roadway a new Gas Line could be installed to the depth required by the proposed transit and roadway design from  
Page 1 of 3

4/20/2015

GEO works

36

# Recommend Four Phase Approach

- Phase I – **2D** Mapping Effort, Conflict Identification & Matrix Development
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# Construction Management

Utilize UIM to:

- Populate utility work within project scheduling software.
- Systematically evaluate technical approach and manage QA of utility work to ensure compliance with all identified governances and constraints.
- Automate creation of utility related agreements, submittals, permits, notifications etc.
- Monitor planned and approve completed work.
- Facilitate real-time as-built documentation of utilities in accordance with project requirements.
- Provide work verification information for payment.

# Strategy Return on Investment (ROI)

- CI/ASCE 38-02(SUE) vs Non-Standard Method
  - 5 Independent Studies - \$3.41-\$22.21/\$ invested
  - 10 States Utilize CI/ASCE 38-02 on all Projects (UT, MN, TX, VA, MT, PA, FL, SD, NC & GA) \* More State Utilize on some Projects
  - FHWA Mandated for Reimbursement
  - NEPA Process
  - Mitigate Contractor's Risk
  - Reduce Delay Impacts
- 3D QL B Geophysical Mapping vs Test Holes (Pot Holes)
  - 30%-60% Reduction in Test Holes
  - Complete Alignment for Design Purposes
  - Necessary for 3D Virtual Design and Construction Methods

# Strategy ROI and Merits

- Transfers responsibilities to prime contractor, reduce utility related claims resulting from third party failures to perform
- Project schedule optimized
- Utility work is optimized - mainline effort, competitively bid
- Contractor can quickly work deals with utilities by offering betterment opportunities, joint construction work, etc. (Laws may prevent public agencies from making such deals.)

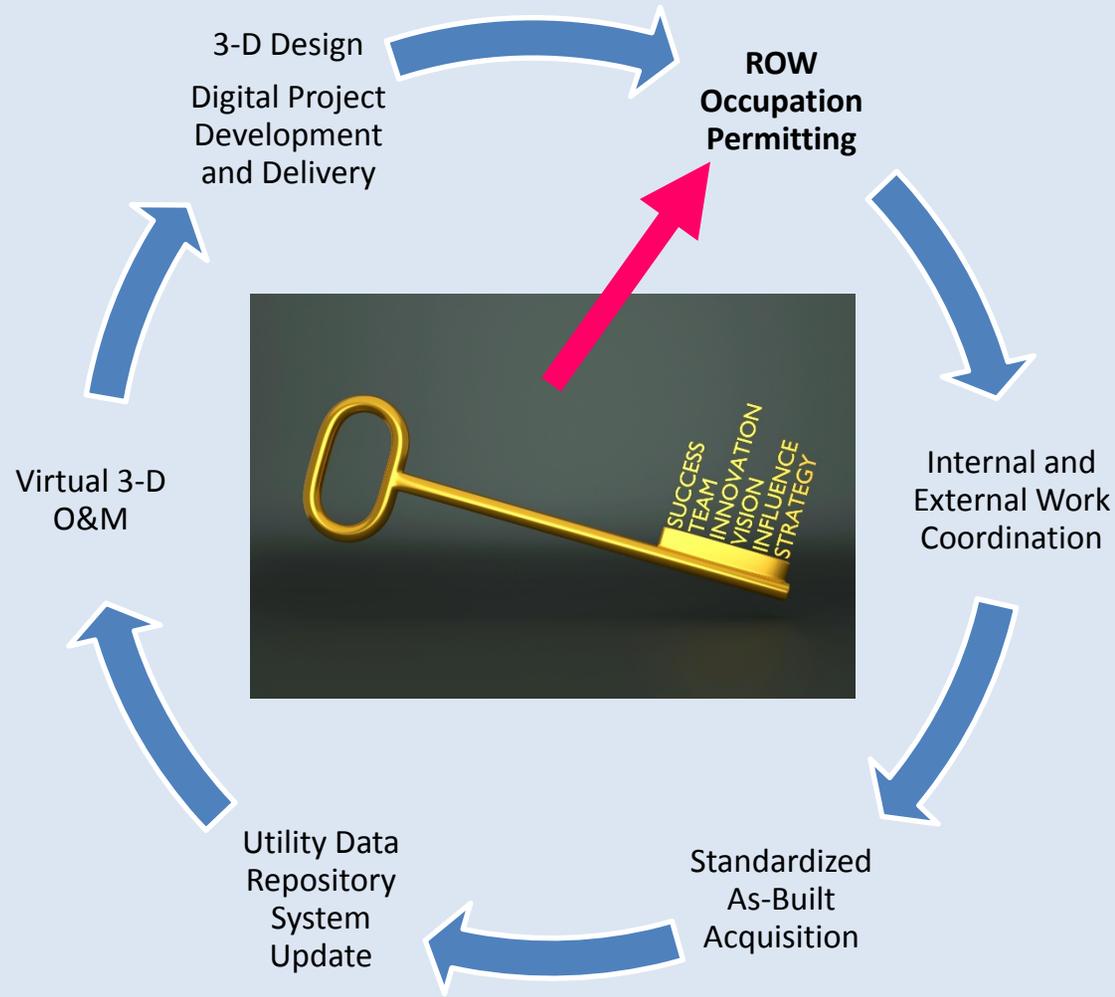
# Strategy ROI and Merits

For an additional project development cost of roughly 1% of the project, the contract bid can be reduced by 10% by eliminating utility related contingency costs. This is a 9% cost savings to the project owners!

# Long Term Strategies to Address Right of Way (ROW) Management

- Capture Standardized Documentation and Data on New Infrastructure Installations
- Robust Utility Infrastructure Data Repository
- WebGIS ROW Occupation Permit Application
- Coordinating / Monitoring External and Internal Construction Operations

# Utility Life Cycle Management Strategy



# Utility Engineer Qualifications

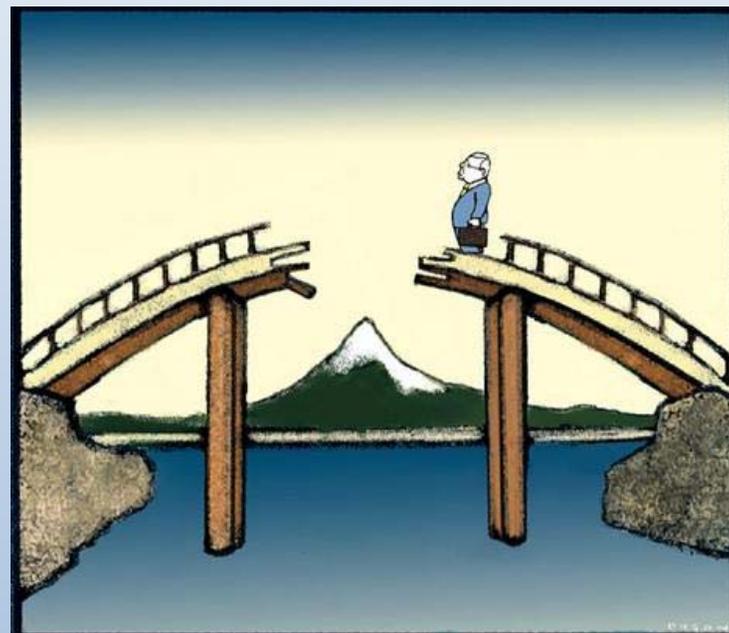
- Must Understand BOTH Agency and Utility Needs
- Be Knowledgeable in BOTH Agency and Utility Company Policies, Procedures, & Requirements
- Have "Cross Discipline" Design and Construction Experience in BOTH Transportation & Utilities
- Experienced in Identifying, Prioritizing, & Mitigating Risks for BOTH Transportation & Utilities



Need To Bridge the Gap  
*Utility Technical Discipline void*

# Utility Engineer Qualifications

- Ability to Establish Relationships, based on Mutual Understanding & Trust
- Ability to Recognize Time & Cost Innovative Utility Solutions



*Address the Utility  
Technical Discipline void....*



# Your Time is Appreciated

Philip J. Meis, P.E.

Vice President / Principal Engineer

c. 801.209.2032 d. 406.553.0883

[pjmeis@umsi.us](mailto:pjmeis@umsi.us)

[www.umsi.us](http://www.umsi.us) & [www.geo.works](http://www.geo.works)

