Urban Modeling using OGC Standards

GISMO Membership Meeting, 15 June 2017

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CTO, Chief Engineer
Open Geospatial Consortium

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Urban Modeling using OGC Standards

• What is OGC and what standards have been approved recently
• 3D Data Integration
• Future City Pilot
• Underground Infrastructure Study
The Open Geospatial Consortium

Not-for-profit, international voluntary consensus standards organization; leading open innovation for geospatial data

• Founded in 1994
• 525+ member organizations
• 100 innovation initiatives
• 48 Open Standards
• 230 OGC certified products
• Thousands of implementations
• Enabling access to 100K+ datasets
Example OGC Commercial Members
What is a Standard?

• “An agreed way of doing something”
What is a Standard?

• “An agreed way of doing something”

• **Standards are distilled wisdom** of people with expertise in their subject matter and who know the needs of the organizations they represent – people such as manufacturers, sellers, buyers, customers, trade associations, users or regulators.

• **Standards are knowledge.** They are powerful tools that can help drive innovation and increase productivity. They can make organizations more successful and people’s everyday lives easier, safer and healthier.
Recent examples with research connections
2. 3D Tiles Community Standard (in process)
OGC’s Approach for Advancing Interoperability

- **Innovation Program** – a global, innovative, hands-on rapid prototyping and testing program designed to unite users and industry in accelerating interface development and validation, and the delivery of interoperability to the market.

- **Standards Program** – Consensus standards process similar to other Industry consortia (World Wide Web Consortium, OMA etc.).

- **Compliance Program** – allows organizations that implement an OGC standard to test their implementations with the mandatory elements of that standard.

- **Communications and Outreach Program** – education and training, encourage take up of OGC specifications, business development, communications programs.

OGC®
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abstract Specification Topic approved</td>
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<tr>
<td>11</td>
<td>Standards approved</td>
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<tr>
<td>2</td>
<td>new Community standard work items started</td>
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<td>1</td>
<td>Best Practice approved</td>
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<td>30+</td>
<td>Engineering Reports approved</td>
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<tr>
<td>2</td>
<td>Discussion or White Papers approved</td>
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<td>2</td>
<td>new Standards Working Groups (SWG)</td>
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<tr>
<td>2</td>
<td>new Domain Working Groups (DWGs)</td>
</tr>
<tr>
<td>1</td>
<td>new Subcommittee</td>
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</table>
OGC Standards approved in the past 6 months

• Discrete Global Grid Systems (DGGS) Core Standard

• InfraGML 1.0 Parts 0 through 6

• Coverage Implementation Schema (CIS) 1.1
  – CIS – ReferenceableGridCoverage Extension

• GeoAPI 3.0.1 Implementation Standard

• Moving Features Access
3D DATA INTEGRATION
Merging of spatial domains

- Geospatial, Civil Engineering & BIM come together in the Urban environment and are destined to work together
3D Data Integration

“3D integration may be the biggest challenge in 3D domain”

• how to integrate 3D data with different semantics
• how to integrate data above and below surface;
• how to integrate vector and voxel data;
• how to integrate bathymetry data with digital terrain data;
• how to integrate sensor data (temperature, wind air quality) with a 3D city model and
• how to integrate these with simulation software etc.

Towards sustainable and clean 3D Geoinformation
Jantien STOTER, Hugo LEDOUX, Sisi ZLATANOVA, Filip BILJECKI
3D GeolInformation, Department of Urbanism, Delft University of Technology

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3D City Modeling

Far more than the **3D visualization** of reality

- **geometry** and its **appearance** are only **one aspect** of an entity (not SMART)
- Key issue (to make things SMART): **Semantic modeling**
  - meaning / structure / relationships

- Enabling geospatial smart city services
- Need for standards to integrate data
Semantic 3D City Models - Berlin

>500,000 buildings;
- fully-automatically generated from 2D cadastre footprints & airborne laserscanning data.
- textures (automatically extracted from aerial images)
- semantic information (includes data from cadastre)
- 3D utility networks from the energy providers

modeled according to CityGML

Source: Nagel, Kolbe, 2010
Global use of CityGML City Models

- European-wide INSPIRE (Infrastructure for Spatial Information in Europe)
- Netherlands National 3D standard
- Germany: Berlin, Dresden, Stuttgart, Bonn, Cologne, Frankfurt/Main
- Austria: Vienna, Salzburg
- France: Paris
- Switzerland: Geneva
- Finland
- U.A.E. – Abu Dhabi
- Kingdom of Bahrain
- Malaysia
- China,
- Singapore

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New York City open data in CityGML

The 3D CityGML model is **Open Data!** Download: www.gis.bgu.tum.de/en/projects/new-york-city-3d/

- > 1,000,000 buildings
- > 866,000 land lots
- > 149,000 streets
- > 16,000 parks
- > 9,500 water bodies
- > DTM with 1m resolution
  - fully-automatically generated from the 2D geodata published in the NYC Open Data Portal
  - semantic and geometric transformations
  - all objects have 3D geometry
  - rich semantic information (5 - 75 attributes per object resulting from combining different NYC datasets)
  - integrated within 1 dataset!

Source: T. H. Kolbe, TUM
Challenges in Generating NYC 3D City Model

• only 2D and 2.5D data given → generation of 3D geometries
  – volumetric building and tree models
  – all other feature types mapped onto the terrain
  – special treatment of road geometries to include different height levels

• data heterogeneity
  – different coordinate reference systems
  – different exchange formats (Shapefiles, ESRI GeoDB, Excel etc.)
  – no standardized semantic data model / ontology (each department defines their own data structures)
  – 1:1, 1:n, and n:m mappings required

• huge data volume
  – large area with > 1 million buildings; big DTM;
  in total about 4 million objects
Multiple NYC CityGML Datasets

NYC 3-D Building Model

3D CityGML model from NYC Open Data

- > 1,000,000 buildings
- > 866,000 land lots
- > 149,000 streets
- > 16,000 parks
- > 9,500 water bodies
- DTM with 1m resolution

- fully-automatically generated from the 2D geodata published in the NYC Open Data Portal
- semantic and geometric transformations
- all objects have 3D geometry
- rich semantic information (5 - 75 attributes per object resulting from combining different NYC datasets)

http://www1.nyc.gov/site/doitt/initiatives/3d-building.page

Software supporting CityGML (as of Nov 2015)

- Oracle 11g / Tech. University of Berlin: Oracle schema/loader/updater citygml4j, open-source Java class library and API for the processing of 3D city models (free), can handle any ADE
  - VirtualCitySystems
  - Bentley: Bentley Map
  - Autodesk: LandXplorer CityGML Viewer (free) + studio (authoring/management)
  - Safe Software FME (reader & writer)
  - ESRI: ArcGIS10 (import)
  - University of Bonn: Aristoteles Viewer (free)
  - Snowflake software: Go Publisher WFS
  - Interactive Instruments: WFS
  - HST Stuttgart: QS-City 3D, a free online service for checking CityGML Data
  - CPA: SupportGIS3D
  - GTA: Tridicon CityDiscoverer
  - MetGeoinfo: CityGRID
  - Bitmanagement: BS Contact Geo 3D
  - Ptolemy3D: virtual globe CityGML plugin
  - RhinoTerrain: CityGML support in development
  - FH GK: CityGML-Toolchain, different tools incl. Sketch-Up plugin (free)
  - FZ Karlsruhe: FZKViewer, viewer for IFC and CityGML data (free)
  - Revisitor: WI-MAP

  LibCityGML: C++ Library ([http://code.google.com/p/libcitygml](http://code.google.com/p/libcitygml)), OpenSceneGraph
CityGML Quality Validation Domains

1. Schema conformity
   - Formal grammar (XML Schema)

2. Referential Integrity
   - Natural language specification, partly mapped to Schematron

3. Geometrie / Topologie
   - ISO 19107, Algebraic topology, computational geometry

4. Conformance Requirements
   - Natural language specification

5. Semantics
   - Natural language specification (if at all!)

6. Application-specific
   - Mostly project-specific, natural language specification, sometimes CityGML profiles (ISO 19109) or CityGML ADEs
CityGML QIE Validation Framework
Quality Check Example: Geometry

Ledoux: Three-dimensional primitives in the context of the CityGML QIE

Invalid Polygons

Valid Solid
Future City Pilot

• OGC Future City Pilot, Phase 1
  – Completed December 2016
  – Urban Planning, Urban Flooding, Health Alert, Dynamic Modeling
  – Cities: Greenwich, Rennes, Munich

• The Visionary Sponsors
  – Ordnance Survey Great Britain,
  – Sant Cugat del Vallès (Barcelona), Spain,
  – Institut National de l'Information Géographique et Forestière (IGN)
  – virtualcitySYSTEMS GmbH Berlin
FCP1 Scenario: Urban Planning

- Scenario: Model Update Validation
  - Static 3D models ‘easy’ to make
  - Maintaining a city model is harder
  - Validation of new components
  - Parts of a city planning tools

Graphics: IGN France
Transforming Traditional Approaches:
Example of Rennes, France: 1:100 year (mean depth)

Traditional transformation to a typical GIS layer

Traditional Map Display of Inundation
FCP1 Workflow of Inundation Modeling

2-D regular grid flood prediction models (e.g. LISFLOOD-FP)
2-D irregular mesh flood prediction models (e.g. Telemac-2D)

Digital Elevation Model of the floodplain
Urban/City building & infrastructure data
River data & hydrography data

Simulations

Output of 2-D flood prediction models

Classification & featurization of output (e.g. flood water depths)

CityGML format

Increasing interoperability
Increasing societal resilience
CityGML Encoding
FCP1 – Flood inundation model with other city infrastructure layers
Adding Dynamic Processes to Urban Models

Dynamizers

- Enhance properties of city objects by overriding static values
- Time-variant values from sensors, simulations, and external files
Dynamizer ADE for CityGML 2.0

Also allows representing Complex repetitive patterns

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FCP1 Scenario: Health Alerts

• Building Humidity and Heat during weather extremes
  – Dynamize: Override static CityGML properties with dynamic observations from SOS
  – Identify residents of senior living facility at risk

Visualization of and interaction with 3D building geometries

Real-time temperature, humidity accessed from SOS
FCP1 Scenario: Energy

- Provide better services to the citizens and the energy planners by making sophisticated solar potential analysis.
- Visualization of solar energy production for roofs and facades of building
Plans for Future City Pilot, Phase 2

• Run in 2017
• Also in the Geospatial, Civil Engineering & BIM
• Requirements are coming in
• Worldwide scope
• Include Indoor & Facility Management
  – VR, AR?

• Interested to sponsor or participate?
  – Let me know!
Underground Infrastructure

3D semantic modeling of utility networks, underground environment

• ROI for improving accuracy of geolocation of underground utilities
  – USDOT - ROI of $4.62 for $1.00 invested
    (Source: Between the Poles)

• Underground Infrastructure Mapping and Modeling Study
  – Sponsors: FCNY, SLA, OS
  – Workshop April 2017
  – Pilot to begin in 2017

Source: Singapore Land Authority

http://www.opengeospatial.org/projects/initiatives/undergroundcds
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OGC Concept Development Study (CDS)

- To assess emerging technologies & architectures in support of interoperability initiatives and open standards

- Process
  - 1. Request for Information (RFI)
    - Wide request for input on relevant technologies and open standards
    - RFI frames the questions to be addressed
  - 2. Workshop
    - Workshop to discuss and advance the concepts in the RFI
    - Presentations based on RFI Responses
  - 3. Report
    - Engineering Report of open standards and architecture views
    - Describe approach indicating feasibility and maturity

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# Responses to Underground RFI

<table>
<thead>
<tr>
<th>Accenture</th>
<th>Bentley</th>
<th>BGS</th>
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</thead>
<tbody>
<tr>
<td>Boston City</td>
<td>BRGM</td>
<td>Cesar Quiroga</td>
</tr>
<tr>
<td>CityGML Chair</td>
<td>Dassault Systemes</td>
<td>Delft University</td>
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<td>Dubai Elec/Water</td>
<td>EPRI</td>
<td>Erik Stubkjaer</td>
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<td>HERE</td>
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<td>Les Guest Assoc.</td>
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<td>Robin Danton</td>
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<td>Spacetime Technology</td>
<td>St Paul Minnesota</td>
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<tr>
<td>Swiss Water SJIB</td>
<td>Technics Group</td>
<td>Tech. Univ München</td>
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<tr>
<td></td>
<td>UMS Bernice</td>
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</table>
Underground CDS Workshop, April 2017

April 24th
1 – Opening, Introductions, Overview
2 – Cities with underground projects
3 – Underground information systems practices
4 – Data models for integration and data sharing

April 25th
5 – Underground Environment data model
6 – Data collection, curation, integration, analysis
7 – Breakout sessions
8 – Workshop summary; Planning Pilot phase
**Societal Benefits**: Quality of Life, ROI

**Use Cases for Interoperable Underground Infrastructure Data**
*Street Openings For Utility Work*
*Construction Design and Operations*
*Emergency Preparedness and Response*
*Smart Cities*

**Interoperable Environment**
*Secure, Safe*

- **Underground Environment**: Soils, bedrock, Water table
- **Foundation Layers**: Imagery, structures, roads, elevation

Source: Alan Leidner, NCNY
Data governance

UGI ownership not clearly defined

Data completeness & accuracy

Existing UGI:
1. Incomplete/hard to retrieve
2. Unreliable or inaccurate
3. Not georeferenced
4. Not digitised

Data sharing

No systematic sharing and some legal and confidentiality concerns

Data standards

No common UGI standards

Data platform

Yet to identify government-wide platform to support UGI use and sharing

Technology

Cost-effective and sustainable methods for UGI collection and management needs to be studied

Funding

Funding required by UGI owners in collection and management

Source: Ng Siau Yong, Singapore Land Authority
A common problem that costs:

- **Roadworks and congestion**: road works account for 38% of the most serious and severe traffic disruptions in London: total cost of £752M\(^1\).
- **Cable strikes**: Est 60,000 incidents per year (Cognisco 2015)
- **Excessive surveying and digging prior to new development**: Including abortive digging (unfound asset), or extended digging (crossing the whole road rather than a portion).
- **Physical ground constraints**: Late stage awareness of ground properties and physical constraints to planned development is costly.
  - Ground risks are one of main causes of project delay (50%), and of Insurance claims on completed projects.
  - Alignment of Crossrail was influenced by need to avoid over 200 existing obstructions
  - Crossrail2 re-routed via Balham due to geological concerns.
  - Access to a robust geological model estimated to deliver +£160M\(^3\) cost-savings to London construction projects.
- **Infiltration from the water supply network**: Infiltration of groundwater into underground assets is believed to costs the water industry £M annually.
  - In 2013/14, three water companies in the UK spent an additional £80 million responding to impacts of groundwater infiltration.
  - Leakage from the water supply network is significant due to aging infrastructure: for Thames Water’s = 641ML/d (about ~25% of daily supply).

Source: Andy Ryan, Ordnance Survey Great Britain
# Return on Investment

*Of Accurately Mapping the Underground Infrastructure*

<table>
<thead>
<tr>
<th>Project</th>
<th>ROI</th>
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<tbody>
<tr>
<td>PennDOT 2007</td>
<td>21X</td>
</tr>
<tr>
<td>Milan Expo 2015</td>
<td>16X</td>
</tr>
<tr>
<td>U.S. DOT 1999</td>
<td>4.6X</td>
</tr>
<tr>
<td>Toronto 2010</td>
<td>4.3X</td>
</tr>
<tr>
<td>Toronto 2004</td>
<td>3.4X</td>
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</tbody>
</table>

The rate of return for underground mapping projects ranges from 3.4X to 21X.

*Source: Eric Bergstrom, Accenture*
Use Case: Subsurface Utility Engineering (SUE)

- High potential for utility conflicts and relocations on projects
- Limited, narrow, and congested right-of-ways
- Increasingly tight project schedules
- Deeper utility installation using less detectible materials
- Multiple owner entities with inaccurate documentation
Use Case: Analytical Modeling

- GIS is typically the primary source of data for analytical models
  - Spatial Data
  - Physical Data
  - Geometric Network

- GIS is typically not built with analytical modeling as a primary use
  - Not all required data is in GIS
  - Data is not necessarily high-enough quality
  - Features are not necessarily at the right granularity

- GIS and Analytical Model diverge over time
  - Data changes in each need to be reconciled
  - Update / extend without overwriting corrected data
Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply
Use Case: Augmented Reality

- The potential of the virtual excavation for visualizing subsurface utility models, in an augmented reality context, for excavation work planning
- The appropriateness of the virtual excavation and of vertical pipe model projections to augment a changing terrain surface with subsurface utility models, to facilitate live excavation work
- The capacity of our augmentation techniques to facilitate planning on an actual excavation site
- The potential of using robotic total stations for providing high accuracy augmentations
The City of New York: Core data model

- To be used as a common model to exchange information

- What to be stored? Which schema?
- DEP?
- NYC applications
- Protocols?
- Web services, standards
- Files others
- DB others
- 3D viewers
- products

- Core data model (virtual)
The problem

- Different data models
  - Maintained by different organizations with a different purpose
  - Stored in different ways (systems, formats and schemas)
- Different representations of geometry and semantics
  - Lack of analytical capabilities (no network structure)
  - Lack of relationships (e.g. with above ground features of interest)
  - Interoperability issues
# City Infrastructure Lifecycle Management

## Interoperability: The Integration of Standards via the Platform

### How it's governed and represented

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>BOM</td>
<td>ISO/IEC 15288</td>
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<tr>
<td>KML</td>
<td>ISO 55000</td>
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<tr>
<td>OGC</td>
<td>ISO 16739</td>
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<td>ISO 10303 (STEP)</td>
<td>ISA 95</td>
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<td>CityGML</td>
<td>ISO TCS211</td>
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<td>CityGML 3.0</td>
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<tr>
<td>CI/ASCE 38-02</td>
<td></td>
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<td>ANSI/ASCE/EWRI 12-13, 1313, 14-13</td>
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<tr>
<td>ANSI/ASCE/EWRI 56-10, 57-10</td>
<td></td>
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<tr>
<td>ISO 15926 (Xmplant)</td>
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<tr>
<td>ASCE/EWRI 45-05, 46-05 &amp; 47-05</td>
<td></td>
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<tr>
<td>ASCE/EWRI 12-05, 13-05 &amp; 14-05</td>
<td></td>
</tr>
<tr>
<td>GML; GeoSciML; EarthResourceML; INSPIRE</td>
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</table>

### Information represented

- **Buildings**
- **Terrain & Land use**
- **Road & Traffic**
- **Rail**
- **Basements, Cellars**
- **Cable network**
- **Utilities**
- **Telecommunications**
- **Water**
- **Road Tunnels**
- **Subways**
- **Sewage**
- **Geology**
- **Geotech, RQD etc**
CityGML Utility Network ADE

The **CityGML Utility Network ADE** extends CityGML by the possibility to represent supply and disposal networks in 3D city models.
American Society of Civil Engineers (ASCE) Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data CI/ASCE 38-02

“Quality Levels” for Depicted Utility Infrastructure:

QL D - Verbal Account or Record
QL C - Records and Surface Features
QL B - Records and GP Detection (identify and work through discrepancies)
QL A - Exposed and Verified – Discrete

P.E. Affixes Seal to Product
ASCE / ANSI STANDARD
American Society of Civil Engineers

Standard for Recording and Exchanging Utility Infrastructure Data

This document uses both Système International (SI) units and customary units.
<table>
<thead>
<tr>
<th>Level</th>
<th>Positional Accuracy¹</th>
<th>Applies to</th>
<th>Comment</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>±15 mm (±0.1 feet) Vertical, ±50 mm (±0.2 feet) Horizontal</td>
<td>Z data</td>
<td>Coincides with requirements in ASCE 38-17 quality level A (QLA)</td>
</tr>
<tr>
<td>2</td>
<td>±50 mm (±0.2 feet)</td>
<td>X, Y, and Z data</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>±150 mm (±0.5 feet)</td>
<td>X, Y, and Z data</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>±300 mm (±1 foot)</td>
<td>X, Y, and Z data</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>±1000 mm (±3+ feet)</td>
<td>X, Y, and Z data</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>±1000 mm (±3+ feet)</td>
<td>X and Y data</td>
<td>Positional accuracy of the Z data is unreliable or not available</td>
</tr>
<tr>
<td>9</td>
<td>Indeterminate</td>
<td></td>
<td>Positional accuracy of the X, Y, and Z data is indeterminate.</td>
</tr>
</tbody>
</table>

¹ At the 95% confidence level, using the root-mean-square error (RMSE) in accordance with FGDC-STD-007.3-1998.

The positional accuracy levels defined in Table 2 match up loosely with the following concepts:

- Level 1 is designed specifically to match up with QLA as defined in ASCE 38-17.
- Level 2 is substantially identical to Level 1, but removes the close tolerance on vertical methods and thus can be generally achieved without the need for survey bench leveling.
- Level 3 is generally possible using GPS equipment and RTK methods.
- Level 4 is provided as an additional breakpoint between levels 3 and 5.
- Level 5 is generally achievable by post-processed mapping grade GPS equipment.
There is soil in between the various utilities, tunnels, foundations, etc.
Soil Heterogeneity in 2D.
Voxels for Underground Infrastructure - a vector-to-raster perspective

Ben Gorte, Sisi Zlatanova, Delft University of Technology

Integration of Underground Infrastructure Data
- pipes: water, sewer, gas, steam
- cable & fibre: electricity, telephone, cableTV, internet
- subway: tunnels, stations
- buildings: basements, foundations
- manholes, conduits, ducts

Not so much about what happens inside the pipes (etc.) ...

... but about what happens between the elements of different systems

- in relation to their surrounding: soil, salinity, water table
- in case of events

A technical or a political problem?

Certainly an organizational problem!
Multi-resolution Object Database

full res = 0.25m
Integrated modelling

- Underground water cycles are more complex in urban environments
- To understand these processes requires integration of data and process models from a range of scientific disciplines as well as public and private institutions

Manual transfer of surface and subsurface properties between 3D geological models (left) and coupled, grid based, process models (right). From Thames basin scale (kms) to abstraction borehole scale (cm) Watson et al., 2015.
Linked data: applied to groundwater monitoring

Legend:
- Features provided according to INSPIRE directive
- Observation(s) provided according to WaterML 2.0
Linked data: applied to groundwater monitoring

Legend:
- Features provided according to INSPIRE directive
- Observation(s) provided according to WaterML 2.0
Use of KLIP is enforced by law in Flanders

Source: Jef Daems, KLIP product owner
## Data Approach

<table>
<thead>
<tr>
<th>Users</th>
<th>Municipalities</th>
<th>Plan/Design Firms</th>
<th>Construction Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Utilities</td>
<td>Engineering Contractors</td>
<td>Emergency Responders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Security and Access Management</td>
<td></td>
</tr>
</tbody>
</table>

### Visualization/Applications

- **UIM Interface**
  - Visualize data on a map
  - Upload CAD data
  - Download data into CAD format

### Data Management

- **Common 3D Asset Database**
  - GIS & attribute data management
  - Data processing
  - Data organization
  - Cloud-based hosting & storage
  - Security

### Data Inputs

- CAD files: DWG, SHP, DGN formats

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Source: Eric Bergstrom, Accenture
GIS Data Storage Approach

**Standardized Data**
- CAD metadata submission standards
- Optional metadata fields
- Encourage electronic data exchange

**Integrate, Single Platform**
- Become a source of authoritative information
- Integrate data from multiple sources
- Remove inefficiencies associated with requesting information from multiple parties
- Interoperable with other geospatial systems

**Cloud-Based**
- View from a web-browser
- Scalable from individual field crew to enterprise-wide implementations

**Secure**
- Secure Microsoft Azure cloud platform
- Role-based access control
- Archive
- Store backup
- Track version history and changes

Source: Eric Bergstrom, Accenture
Underground Pilot

- 3D integration of underground critical infrastructure with secure online services for multiple applications
  - Routine SUE operations; Analytics, e.g. cascading failures
  - Foster coordination of data providers and consumers in secure message exchanges based on standards
Benefits of an Open Standards Approach

• **Reduce risk** by aligning projects on open standards, program development is based on proven practices

• **Improve choice in marketplace** by broaden choice of IT solutions through plug-and-play based on standards

• **Enable legacy systems to interoperate with new technologies** by adapting these systems to leverage standard interfaces and encodings.

• **Reduce overall system lifecycle costs** by reducing or eliminating custom integration through the use of open standards
For Details on OGC ...

OGC Standards
   – Freely available
   – www.opengeospatial.org/standards

OGC Innovation
   – http://www.opengeospatial.org/ogc/programs/ip

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