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GPR applied to detection and localization of utilities in urban areas

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Contents

- Utility detection - Components and roles
- Hardware and operating principles
- Data acquisition and field setup
- GPR processing and interpretation
- Localization – georeferencing the data
- Deliverables
- Types of projects and utilities

Components and roles

- **GPR scanning technology: 3 main components**
  - **1st – Pulsed GPR: generate EM waves and record reflections**
    - Main component: Antenna's central frequency: f=100 – 2600MHz,
    - Usually, **underground utility detection**: f=200 – 900MHz
    - Pulse duration: W=5 – 1.1ns
    - Main characteristics of GPR device:
      - Maximum scanning depth – **PENETRATION DEPTH**
      - Underground object detection resolution – **RADIAL RESOLUTION**
    - Main acquisition parameters of GPR device:
      - Horizontal scanning resolution – [scan/m], distance mode
      - Horizontal scanning resolution – [scan/sec], time mode
      - Vertical scanning resolution A/D – [samples/scan], all modes
      - Vertical scanning resolution A/D – [bits/sample], all modes
      - Antenna transmit rate – [kHz]

Components and roles

- **GPR scanning technology: 3 main components**
  - **2nd – Soil: shape & propagation velocity change of EM waves**
    - Main role: soil behavior as Low Pass (LP) filter, cause convolution of transmitted waveform
    - Parameter1: **Soil type** - soil dielectric permittivity: ε_R=1 – 81
      - Role: Definition of EM wave propagation velocity: v=3 – 30 [cm/ns], real part of dielectric permittivity.
      - Propagation velocity decreases with increasing relative permittivity
    - Parameter2 – **Soil moisture** – θ [m^3/m^3]
      - Role: Attenuation of EM wave and complex part of dielectric permittivity
    - Parameter3: **Soil porosity and compaction** (soil homogeneity)
      - Role: Influence on wave propagation mechanisms and dielectric permittivity
    - Parameter4: Soil surface condition…

Components and roles

- **GPR scanning technology: 3 main components**
  - **3rd – Underground utility: affect on EM wave's reflection form**
    - Parameter1 – **Shape, size and disposition**: cylindrical, rectangular, elliptical, complex geometry profile, horizontal/vertical array of utilities; small/medium/big diameter; parallel, intersected, one or more utilities…
      - Role: Definition of reflection geometry (reflection shape)
    - Parameter2 – **Man-made material**: metal, plastic, concrete, ceramic…
      - Role: Change of reflection amplitude and phase
    - Other object parameters: age, position, number…

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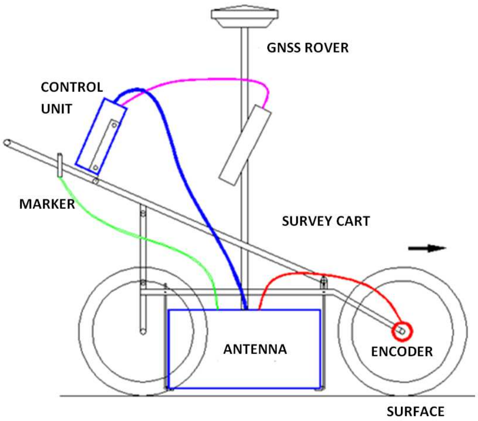
Basic hardware setup & tasks



Ristic, 2005

- **GPR scanning technology**
- high resolution, non-invasive scanning and precise detection of any kind of underground utility
- **GPR** consists of:
  - transmitter and receiver antenna
  - control unit
    + signal generation,
    + data storage and visualization,
    + data acquisition
  - connecting cables
  - battery supply
  - survey cart with incremental encoder
  - hardware marker
  - data bridge: synchronized work
  - **GNSS** rover

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Operating principles 1

1. When the **survey cart** moves on the **site surface** the **transmitting antenna** sends polarised, high frequency electromagnetic (EM) waves into the ground
2. Part of the EM waves is **reflected** from the dielectric boundary and the other part is **refracted** (Snell's law) and goes to the deeper layers
3. Two other mechanisms of EM wave propagation: **diffraction** and **reverberation**
4. This process is repeated until the EM waves become too weak
5. Time necessary for the propagation of EM waves from **transmitter antenna** to the boundary surface and it's reflection back to the **receiver antenna** is defined as a **two way travel t_R [ns] time**
6. The GPR measures **t_R**, and calculates the **relative depth z [cm]** of the underground object

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Operating principles 2

1. Theoretical background of GPR is based on Maxwell's equations. Practical use of Maxwell's equations for the determination of EM field properties during GPR scanning is difficult.
2. In real conditions, EM propagation velocity **v_r [cm/ns]** has spatial distribution in heterogeneous medium. Relative depth **z [cm]** was measured with **averaged** EM propagation velocity **v_r**. This equation is used for low-loss and non-magnetic soils.

$$z = v_r \cdot \frac{t_R}{2} = \frac{c \cdot t_R}{2\sqrt{\varepsilon_R}} \qquad v_r = \frac{c}{\sqrt{\varepsilon_R}}$$

3. For survey purposes, hardly simplified solution was used. EM propagation velocity **v_r** was used as **averaged** value for all layers from the site surface to the top of the target object.
4. The wavelength **λ_m [cm]** within soil decreases as velocity of propagation **v_r** slows in accordance: $\lambda_m = v_r/f$
5. Accuracy of simplified solution is good enough for utility detection and mapping.

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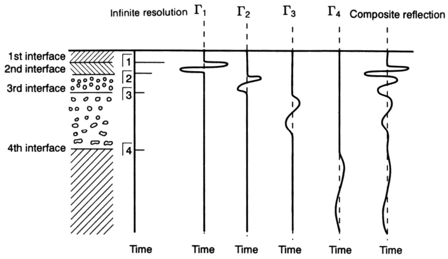
Composite reflection – A scan

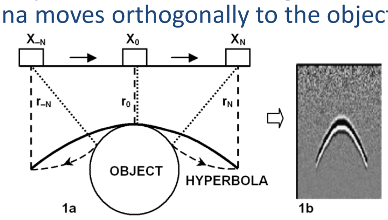
1. When transmit antenna sends time-domain EM energy into the ground with particular velocity and amplitude, receive antenna records a time-history of the pulse traveling through the subsurface layers.
2. Where interfaces spaced more closely than $\lambda_m/2$ the reflected signal from one interface will become combined with that from the other. That means **convolution** of multiple interface reflections – **composite reflection**.
3. Some form of **deconvolution processing** would be required in order to recognise the responses from the individual interfaces and to enable them to characterized and traced.



D. J. Daniels, 2004

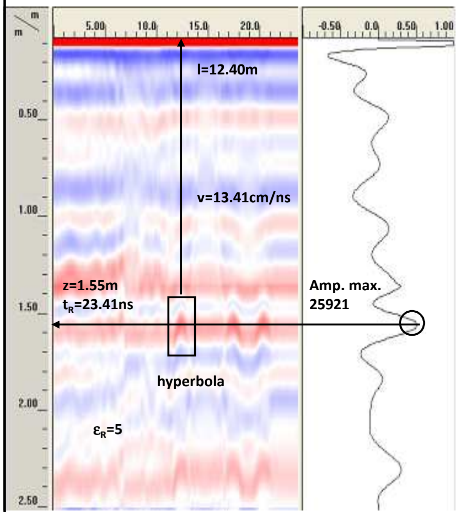
Radargram formation – B scan

1. **An array of consecutive recorded A scans make the radargram (B scan)**. A regular hyperbolic reflection originates when the antenna's trajectory is orthogonal to the **cylindrical object** axis.
2. The distance between the antenna and the object changes as the antenna moves. Changes in the distances of points x_{-N}, ..., x_0, ..., x_N are marked with lines r_{-N}, ..., r_0, ..., r_N (Fig. 1a). If these lines are orthogonal to the antenna's trajectory (Normal Move Out - NMO), connecting the successive end points of the lines produces the geometric shape of a hyperbola (Fig. 1a). The shortest line r_0, related to the hyperbola apex, represents the relative depth of the object.
3. Considering that the antenna's EM beam has an angle between 35° and 45°, it is possible to detect a cylindrical object even if it is not directly beneath the antenna. Fig. 1b represents an ideal radargram of an object in homogeneous soil while the antenna moves orthogonally to the object's axis.



Ristic, 2009

Radargram in real conditions



- Radargram with detected utility in real conditions has a number of clutter.
- Radargram can be color coded, with different colors (gray scales) assigned to amplitudes, and the result displayed as a cross section
- All points on the radargram include reflected wave amplitude data. Points on top of the segments have peak amplitude value. The peak on the shortest segment r_0 (antenna center is on the pipe axis) is highest (positive or negative)
- This value is criteria for scan searching and determination of location and depth of underground utility.
- Change in hyperbola shape as a function of: **propagation velocity**, **utility diameter** and **utility depth**.

Ristic, 2004

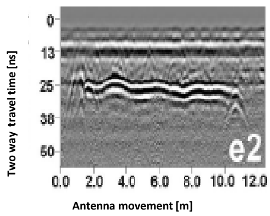
Radargram - utility detection

- **Utility detection depends on geometrical disposition of GPR and utility**

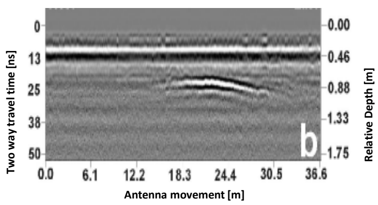
1. **Transversal scan**: hyperbolic reflection, relative utility depth, utility radius, EM wave propagation velocity, soil moisture content…
2. **Longitudinal scan**: hyperbolic reflection collapsed into a straight line, utility length, pipe inclination, changes of pipe diameter…
3. **Sharp angle scan**: distorted hyperbolic reflection, spatial orientation of utility route, relative utility depth...

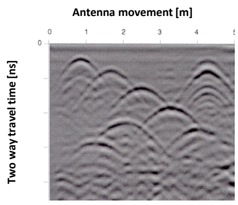
Dielectric permittivity, soil conductivity, soil structure, soil moisture content and utility congestion have impact on radargram quality.

3. Longitudinal scan α=0°



2. Sharp angle scan 0°<α<90°





1. Transversal scan α=90°

GPR - resolution

- **Wavelength λ and radial resolution δ**

$$\lambda = \frac{v}{f}[m] \qquad \delta = \frac{\lambda}{4} = \frac{Wv}{4}[m]$$

- **Wavelength calculation – example for soil with v=10cm/ns, ε_r=9**
  a) 200MHz, W=5ns, v=10cm/ns: **λ=0.1*10^9[m/s] / 0.2*10^9[Hz]=0.500m**
  b) 400MHz, W=2.5ns, v=10cm/ns: **λ=0.1*10^9[m/s] / 0.4*10^9[Hz]=0.250m**
  c) 900MHz, W=1.1ns, v=10cm/ns: **λ=0.1*10^9[m/s] / 0.9*10^9[Hz]=0.111m**

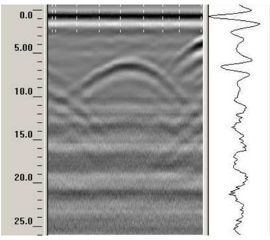
- **Radial resolution calculation - example for soil with v=10cm/ns, ε_r=9**
  a) 200MHz, **δ ≥ 12.5cm**
  b) 400MHz, **δ ≥ 6.25cm**
  c) 900MHz, **δ ≥ 2.77cm**

GPR – penetration depth

- **Penetration depth z_{max}**

$$z_{MAX} = v \cdot \frac{t_{MAX}}{2} \, [cm]$$

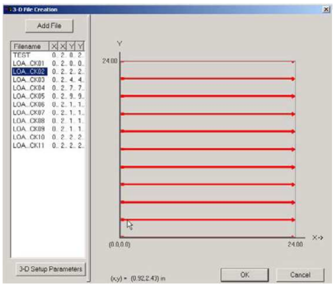
- **Penetration depth calculation - example for soil with v=10cm/ns, ε_r=9**
  a) 200MHz, v=10cm/ns, 512 samples: **z_{max}=10 [cm/s] * 150ns/2=750cm**
  b) 400MHz, v=10cm/ns, 512 samples: **z_{max}=10 [cm/s] * 50ns/2=250cm**
  c) 900MHz, v=10cm/ns, 512 samples: **z_{max}=10 [cm/s] * 15ns/2=75cm**

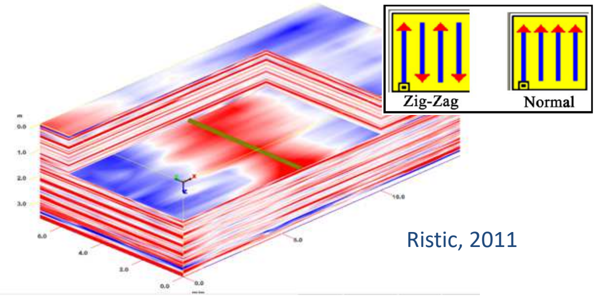


3D model – utility detection 1

▪ **3D model: definition, data acquisition, types**

- Array of paralel radargrams collected with **same system settings** and with **same offset** in structured **GRID** were used to form 3D model – spatial representation of subsurface data on survey location to certain depth
- Software use **interpolation** techniques to generate interspace data between the radargrams
- Data acquisition can be done **manually** or in **automated procedure**
- Data acquisition types: **Uni-Directional** (one baseline), **Zig-Zag** (two baselines)



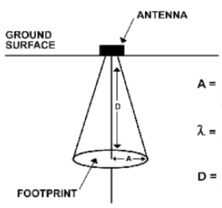


Ristic, 2011

3D model – utility detection 2

▪ **3D model: settings, manual management, exeptions**

- **GRID offset**: determined by the **antenna footprint with certain overlapping** on the minimal depth of interest
  1. Combining data from two perpendicular baselines
  2. Appending two separate files in one (in case of obstacle on surface)
  3. Varying density of radargrams (changeable offset)
  4. Non-regularly spaced radargrams (inserted radargrams)
  5. Radargrams collected at angles relative to the X and Y axes
  6. Non-regular line starting and ending points



$$A = \frac{\lambda}{4} + \frac{D}{\sqrt{K+1}}$$

A = approximate long dimension radius of footprint

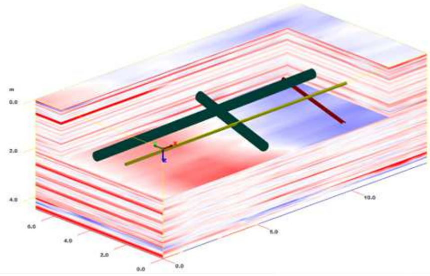
λ = center frequency wavelength of radar energy

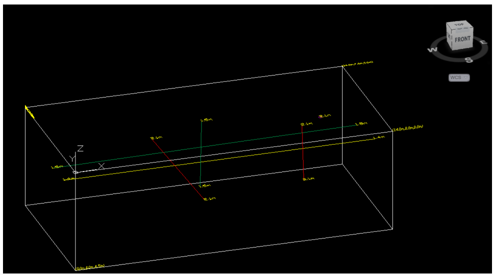
D = depth from ground surface to reflection surface

K = average relative dielectric permittivity (RDP) of material from ground surface to depth (D)

3D model – utility detection 3

- **3D model: data export, data georeferencing**
  - Export of points and lines into *.dxf or *.shp file, georeferenced data (relative to base or absolutely (GNSS or total station)), editable attributes
  - 3D slice export as *.csv
  - Export layer data in Google Earth (*.kml file)
  - Super 3D file (more than one 3D model) for complex surfaces – regions





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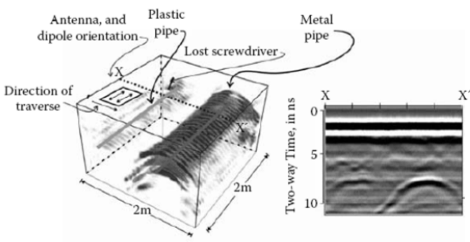
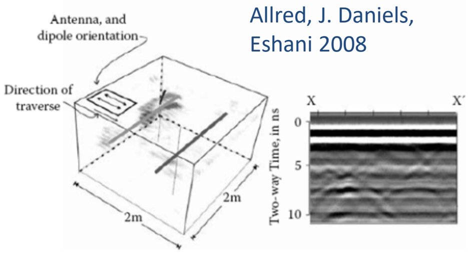
Polarization effects



(a) Antennas parallel to the axis of the pipe

Allred, J. Daniels, Eshani 2008



(b) Antennas perpendicular to the axis of the pipe

- As the EM wave propagates, the orientation and magnitude of vectors change as a function of time.
- Polarization describes the magnitude and direction of the EM field as a function of time and space.
- Linearly polarized signal has an electric field component in only one direction, then any linear metallic object oriented perpendicular to the direction of polarization will not scatter the signal, and the object will not be detected.
- Figures show 3D cube and cross sections over PVC (dielectric) and Cu (conductor) cylinders when the antennas are (a) parallel to the long axis and (b) perpendicular to the long axis of the cylinder.

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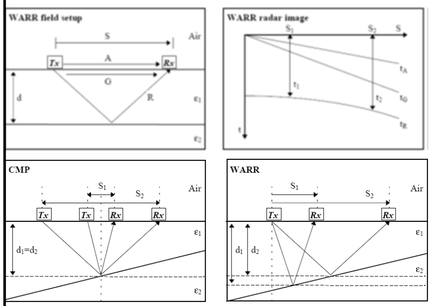
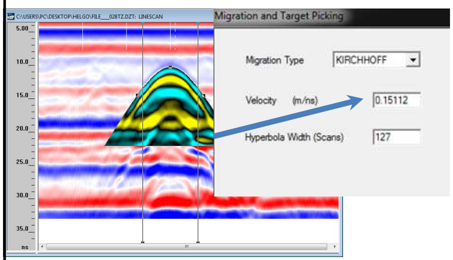
Propagation velocity assessment





- EM propagation velocity **v_r** has spatial distribution in heterogeneous soil.
- Relative depth **z** was measured with **averaged** EM propagation velocity

1. **Table data** - soil suitability map for GPR scanning (soil map)
2. **Ground truth** - recalibration on field
3. **Interactive** velocity interpretation
4. Velocity **measurement**, with bi-static shielded antenna
   a) WARR (Wide Angle Reflection and Refraction) method
   b) CMP (Common Mid Point) method
5. Software **estimation** of **v_r**

Modes of data acquisition

- **Scanning modes**
  - **Time mode:** scans were made in uniform time intervals, acquisition depends on movement speed, scans are stretched, additional post-processing
  - **Distance mode:** scans were made on equal distances defined by encoder's impulses
  - **Point mode:** rough surface scanning, only one scan per each scanning point
- **GPR/GNSS technology (distance mode)**
  - **Independent survey** - GPR scanning and GNSS survey are separated. It can be used for definition of route direction in case of unknown underground utilities' route detection
  - **Synchronized survey** - GNSS rover can measure just start and end coordinates, or more points on the scanned trajectory
    - GNSS measuring on equal distances, defined with software marker (software marker grid) in scan
    - GNSS measuring on arbitrary locations in scan defined with hardware marker

Field setup

- What are the objectives of the survey (metallic, non-metallic etc…)?
- What is the nature of the subsurface environment?
- What are the electrical properties of the materials at the site?
- How large is the survey area?
- What is the nature of the site access?
- What is the maximum depth of penetration?
- What are the line and trace spacing (horizontal resolution)?
- What is the vertical resolution needed to achieve the goals of a survey?

- **Fact:** Interpretation is the **intellectual process** of identifying anomalies on the GPR data and determining the nature (size, shape, and physical properties) of the object in the subsurface that is causing each anomaly. A good interpretation is the result of the **skill** of the interpreter (or sophistication of the pattern recognition algorithms), **the quality** of the data recorded in the field, and **the clarity** of the processed display used for interpretation (Allred, J. Daniels, Eshani 2008).

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GPR processing and interpretation

1. Onsite data processing

- Main goal is to remove interference and smooth noise.
- Processing of raw data using functions implemented in GPR control units software.
- The final outcome of GPR scanning are **marked locations of utilities**.
- Common functions are filters, whether FIR or IIR, which can be vertical (High Pass and Low Pass frequency filters) and horizontal (for example background removal and stacking) as well as scan gain normalization by Automatic Gain Correction.
- Functions for basic editing and data display are also implemented.
- Optional: automated formation of 3D model.

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GPR processing and interpretation

2. Post-processing (Office data processing)

- The most important prerequisite: high quality of raw data.
- The main goal: eliminate the influence of technology constrains and improve data display in order to better interpretation of results.
- Basic classification of processing functions
  - **Data editing:** cut, copy and append files, horizontal and vertical scale adjustment (rubber-banding, time-zero correction).
  - **Basic processing:** dewow, horizontal and vertical 1D and 2D filtering, 3D model processing, topographic corrections (vertical scale adjustment), data geo-referencing.
  - **Advanced processing:** deconvolution, migration, time varying gain, velocity analysis and depth conversion, Hilbert transform, spatial filter (2D Frequency Wave number (F-K) filter).
  - **Visualization and interpretation:** data display for 2D and 3D view, 2D and 3D interactive interpretation, data extraction, data export

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List of utility parameters

3. Parameters of utilities which can be acquired by GPR:

- depth (cable, pipe)
- trace directions in the horizontal and vertical planes
- lengths of straight utility segments
- pipe inclination
- changes of pipe diameter
- fluid/void ratio
- pipe material
- detection of pipe leakage

- Data transfer to Microsoft Access, AutoCAD (*.dxf, *.shp) and other specific file formats
- Spatial coordinates of the projection of the pipeline trace on the site surface are measured by GNSS rover
- All data integrated in CAD/GIS project: measured points on pipeline trace with attributes and georeferenced map

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Data localization - georeferencing

- Should be done in some of standard coordinate systems.
- Usual accuracy classes using GNSS technologies are:
  - Standard (few meters) – one GNSS rover
  - Increased (from 0.5 to 1m) – one GNSS rover with DGNSS correction
  - High (from 0.01m to 0.5m) – GNSS rover with correction from GNSS network of permanent base station.

1. **GPR antenna (sensor) position determination - vertical projection of utility trace on soil surface.**

   1.1 Direct positioning of sensor - Integrated system GPR + GNSS/TS

   - Measuring procedures
     - GNSS/TS measuring on equal distances, defined with software marker in GPR profile (distance mode)
     - GNSS/TS measuring on arbitrary locations in scan defined with hardware marker (distance mode)
     - GNSS/TS on equal time intervals (GPR time mode).

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Data localization - georeferencing

1. **GPR antenna (sensor) position determination**

   1.1 Direct positioning of sensor - Integrated system GPR + GNSS/TS

   - Horizontal offset between vertical axis of GNSS antenna/TS prism and axis of GPR antenna.
   - Vertical offset - vertical distance between the center of GNSS antenna/TS prism and soil surface or between the center of GNSS antenna/TS prism and center of GPR antenna.

   1.2 Indirect positioning of sensor – Non-integrated system. Characteristic position of sensor is marked with stake or paint and later measured using GNSS, TS or other survey techniques.

   1.3 Sensor position data processing

   - Real-time (e.g. GNSS Real Time Kinematic (RTK), Total Station survey, near real-time acquisition)
   - Post-processing (e.g. GNSS Post-Processing Kinematic (PPK), later acquisition)

2. **Determination of relative depth to the top of utility**

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Deliverables – good practice in Serbia

- **Utility detection results representation**
  - Detection and marking out the utility in the field and/or survey report. There are two types of the report:
    - Template Report in the form defined by the client
    - Template Report in the form according to the standards for utility cadastre - **mandatory in some countries** (France, Germany, Serbia, Estonia, Croatia, Slovenia...)
  - **The classes of underground utility objects** should be interpreted:
    - EU INSPIRE directive – Data specification on Utility and Government Services
    - Law country regulation
    - Specific owner's requests
  - For each object should be defined (GIS oriented solution):
    - Object Geometry (geo-referenced trace)
    - Topology
    - Attributes

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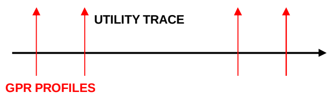
Project types 1

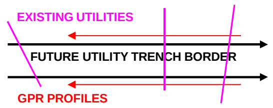
1. **Detection and mapping traces of existing uderground utilities** (subsequent project and/or check of utility condition, part of utility trace or complete network, unique utility)
   - Transversal and/or longitudinal radargrams
   - Changeable scanning depth
   - Start – trial scanning in several directions: detection of utility and determination of trace direction
   - Characteristic point scanning:
     - Relative depth and trace direction changes
     - Crossing with other underground utilities and roads
     - Paralel traces with other utilities
     - Changes of pipe diameter and pipe branch
     - Pipe inclination



Project types 2

2. Future utility trace analysis (all kinds of utilities in arbitrary disposition and depth to the projected future utility trench border)

- Line search scanning on two border lines of future route or for reconstruction needs
- Start – trial scanning in several directions: detection of utility and determination of trace direction in at least two points on the border!
- Characteristic point scanning:
  - Specified scanning depth (depth of projected trench depth)
  - Check "known" utilities from utility cadastre database
  - Check "unknown" utilities which aren't in utility cadastre database
  - Much more complicated project type



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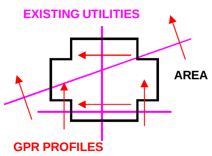
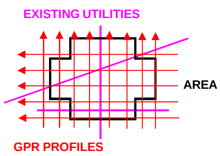
Project types 3

3. Area scanning with complete underground infrastructure analysis (2D and/or 3D scanning techniques)

- Complete factory yard, crossroad or square scanning
- Can be done in two ways
  - Advanced 2D scanning: Area edge analysis and control of certain directions – skilled operator, time consuming survey
  - 3D model (slides 17, 18, 19): time consuming survey and data processing





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Accuracy and Confidence level

1. **Accuracy will depend on**
   - Accuracy and offset of grid lines (3D model)
   - Accuracy of the base mapping
   - Resolution of instrumentation
   - Calibration of equipment
   - The skill of operator
   - Accuracy of georeferencing
   - The accuracy of the CAD / GIS draughting
2. **Confidence ratings**
   A. Horizontal and vertical position of utility confirmed by excavation or from viewing within a manhole or chamber.
   B. Utility position detected by two or more remote techniques, but not excavated (e.g. GPR + EML)
   C. Utility position detected by only one remote technique (e.g. only GPR or only EML)
   D. Utility position detected by EML induction
   E. Position of utility only known from the record drawings

Simplified Key for Line Types in Drawings

KEY

LINETYPES, ABBREVIATIONS, DEPTHS AND CONFIDENCE LEVELS (DEPTHS AND CONFIDENCE LEVELS ARE EXAMPLES ONLY)			EXPLANATION OF DEPTH AND CONFIDENCE: DEPTH	CONFIDENCE LEVEL
BT	(0.4 B)	TELECOMMUNICATIONS (BT)	0.40m	B
CATV	(0.2 A)	TELECOMMUNICATIONS (CATV)	0.20m	A
TELE	(0.6 C)	TELECOMMUNICATIONS (OTHER)	0.60m	C
G	(1.2 E)	GAS	1.20m	E
TCSU	(0.6 A)	TRAFFIC CONTROL SENSOR UNIT	0.60m	A
SL	(1.2 E)	STREET LIGHTING	1.20m	E
LV	(0.6 A)	LOW VOLTAGE	0.60m	A
HV	(0.9 D)	HIGH VOLTAGE	0.90m	D
W	(1.5 B)	WATER	1.50m	B
FWD	(0.4 B)	FOUL WATER DRAINAGE	0.40m	B
SWD	(1.4 A)	SURFACE WATER DRAINAGE	1.40m	A
FWRM	(0.9 A)	FOUL WATER RISING MAIN	0.90m	A
CS	(0.4 D)	COMBINED SEWER	0.40m	D
OF	(0.6 C)	OIL / FUEL	0.60m	C
U(GPR)	(0.1 E)	UNKNOWN UTILITY (non-metallic)	0.10m	E
U(EML)	(0.3 E)	UNKNOWN UTILITY (metallic)	0.30m	E

Utilities – main features 1

1. **Protecting utility network from external influences**
   – Prevention of fluid freezing (sewage, vater supply, gasline)
   – Air streaming in cable duct with high voltage cables
   – **Main types** of utilities:
      - **Gasline**
      - **Vater supply**
      - **Sewage**
      - **Heating pipes**
      - **High voltage cables (voltage > 1kV, separate or in cable duct)**
      - **Low voltage cables (voltage < 1kV)**
      - **Telecommunication cables**
      - **Optic fibre**
      - **Drainage**
      - **...**

Utilities – main features 2

2. **Protecting surrounding from utility network influence**
   – Preventing damage of surrounding utility
   – Building safety
   – Safe usage and maitenance
   – General rules of safe installation:
      - If possible, all utilities should be installed separately
      - Gasline should be at least 1m away from other utilities
      - High voltage cables should be at least 1m away from other utilities
      - Pipes and cables should not be in same trench
      - Vater supply is above sewage, high voltage cable is beneath low voltage cable...

3. **Technical requirements for utility instalation**
   – Optimal trace: minimum distance, change of direction and crossings
   – Soil structure and compactness should be appropriate
   – Utility access: Instalation of several utilities in one trench should be avoided

Utility disposition – street profile

- **General disposition of utilities in street profile (towards the street axis)**
  - Telecommunication cables, user connections
  - Low voltage cables, user connections
  - Gasline, low pressure network and user connections
  - Water supply, mid pressure network and user connections
  - Heating pipes, user connections
  - Drainage

  - Heating pipes, mainline
  - Water supply, mainline
  - High voltage cables
  - Telecommunication cables, mainline
  - Gasline, mid pressure

  - Main sewage and storm collectors and canals

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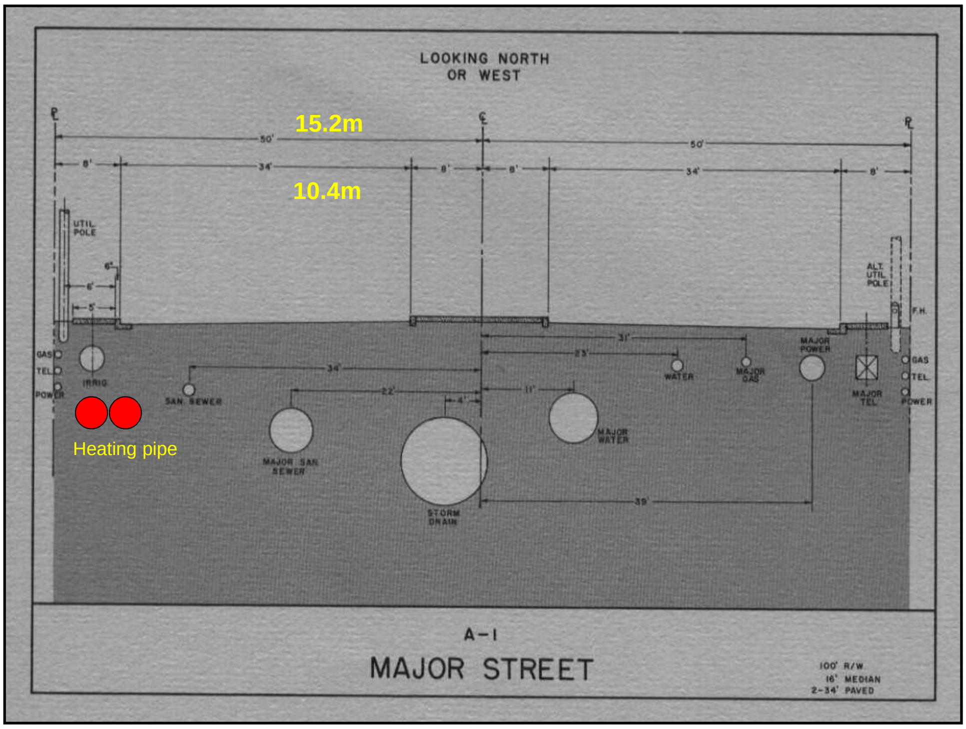
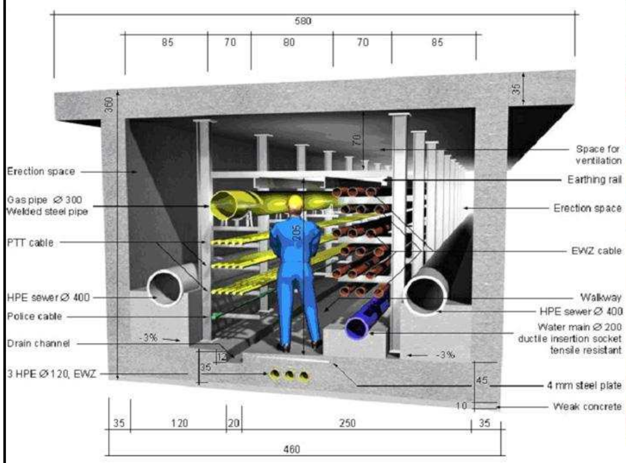


Utility tunnel



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Gasline

- Relative depth and diameter:
    - Low pressure, from 0.5m to 0.8m, (3/4”- 2”)
    - Mid pressure, from 0.8m to 1.5m, (6/4” - 20”)
    - High pressure, from 1.0m to 1.5m, (8 5/8” - 30”)
- Pipe material (important for identification!)
    - High pressure: steel
    - Mid and low pressure: plastic - PE (or steel)
- Gasline accessories
    - Pressure regulating stations
    - Valves and shafts (locked)
    - Outlets
    - Chatode protection (CPS)
    - Warning tables, markers
- Instalation characteristics
    - Pipes are installed with slope (0.2 – 0.5%), clay protection
    - Protection pipe is used on crossings
    - Pipes are installed deeper under the road crossings
    - Network structure: star- or ring-shaped

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Water supply

- Relative depth and diameter:
  - User connections, from 0.6m to 1.2m, (3/4”- 3”)
  - Mid pressure, from 1.2m to 1.8m, (V100 – V250)
  - High pressure, from 1.6m to 3.3m, (V300 – V700 and more)
- Pipe material (important for identification!)
  - High pressure: Cast iron, steel
  - Mid and low pressure: PE, PVC, steel, zync plated steel...
  - Concrete canals for technical usage
- Water supply accessories
  - Hydrants (underground and over ground, between 50 and 150m)
  - Valves (many types), latches and shafts (locked)
  - Faucets
  - Tanks, wells
  - Pump stations
- Instalation characteristics
  - Types of water supply: technical, process, hydrant, drinking water
  - Protection pipe is used on crossings
  - Pipes are installed deeper under the road crossings
  - Network structure: star- or ring-shaped

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Sewage

- Relative depth and diameter:
  - User connections, from 0.6m to 3.5m, (CS60 - CS200)
  - Street collectors, from 0.8m to 4.0m, (CS250 – CS600)
  - Major collectors, from 2.0m to 7.0m, (CS700 – CS1300 ...)
  - Collector canals, from 2.5m to 5.0m, (1.35x0.9m, 2.0x1.4m, 3.0x1.7m ...)
- Pipe and canal material (important for identification!)
  - Plastic: PVC mainly
  - Concrete: Concrete canals and AC pipes
  - Masonry: built sewage
  - Rare: ceramic, cast iron
- Sewage accessories
  - Pumping stations, purifiers (technical/process waste or sewage)
  - Shafts, with or without connections (between 30-100m, mainly 50m)
  - Drains, overflow and/or septic tanks
- Instalation characteristics
  - Types of sewage: separate (sanitary, storm, technical), combined CS
  - Wastewater facility: gravity, vacuum
  - User connections are installed with slope (1 – 2%), canals: several ‰
  - Network structure: radial, paralel, fan-shaped, branched

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Drainage

- Relative depth:
    - Shallow depth, perforated pipes, from 0.5m to 1.5m (2m)
- Pipe material (important for identification!)
  - Plastic: PVC, 50mm diameter and bigger, smooth and ribbed, slope 1%
  - Concrete: specific usage
  - Ceramic: 50mm diameter and bigger, slope 3%
- Drainage accessories
  - Pumping stations (if necessary)
  - Shafts, with or without connections
- Instalation characteristics
  - Types of drainage
    - Horizontal: standard drainage with one or more collectors
    - Vertical: borehole to aquifier
  - Network structure: grid pipes and partial grid – used in permeable soils, "mole" (without pipes) – used in hard impermeable soils usual 120mm diameter and bigger, slope 2-3%

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Heating pipes

- Relative depth and diameter:
    - User connections, from 0.5m to 0.8m, (25 - 125)
    - Major piping, from 0.8m to 4.0m, (150 – 600)
    - Two pipes in concrete canal, dillatation lyre, signal wire (leakage)
- Pipe and canal material (important for identification!)
  - Seamless steel pipes, preinsulated, newer
  - Seamless steel pipes, insulated, older
  - Concrete canals: from 0.75x0.5m to 2.5x1.5m
- Sewage accessories
  - Shafts and chambers with safety drain to sewage (locked)
  - Valves, air valves, fasteners, drains...
  - Heating plants
- Instalation characteristics
  - Heating mediums: steam (process industry), water (buildings), air (buildings)
  - Heating facilities: underground (water), overground (steam, air)
  - Temperature dillatation lyres: U, L and Z shape with sliders
  - Network structure: two/three pipes

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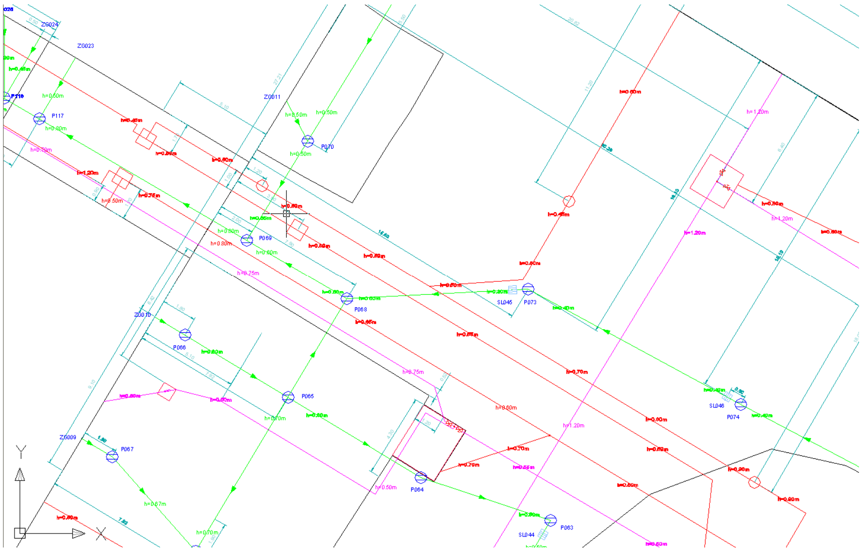
Power cables

- Relative depth and power:
  - High voltage cables, from 0.8m to 1.2m (1.4), (10kV, 20kV, 35kV)
  - Low voltage cables, from 0.6m to 0.8m, (220V – 380V)
  - Signal cables, control cables, CATV (0.5 – 0.8m)
- Cable structure and insulation
  - One, two, three, four or multiwired cables
  - High voltage cables: paper with cable oil, cotton yarn, tar and lead cover
  - Low voltage cables: plastic insulations
- Cable accessories
  - Shafts and chambers, arround 40m, masonry (locked)
  - Spare coils of cable
  - **Cable ducts**
- Instalation characteristics
  - Protection PVC pipe is used on crossings
  - One or more cables, concrete **cable ducts**, send and warning strip above
  - Distribution: underground, overground

Telecommunication cables

- Relative depth:
  - User connections, from 0.6m to 1.0m
  - Major distribution, from 1.0m to 1.6m, mostly in PVC protecting pipes
  - Single wires and bundle
- Cable structure and insulation
  - One, two or multiwired cables
  - PTT cables: plastic insulations
- Cable accessories
  - Shafts at 60 to 80m, crossings, direction changes (locked)
  - Markers, distribution lockers, cable gallery
  - Lead clumps on 5m with cable data
- Instalation characteristics
  - Telephone, telegraph and fibre optic networks
  - One or more cables, concrete cable ducts, PVC ducts
  - Distribution: underground/overground, wired/wireless

Utilities in factory yard - example



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GEOWEB - TRAINING COURSE ON MODERN GEODETIC TOPICS
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Thank you for your attention!

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