Ground penetrating radar (GPR)

Ground penetrating radar is a nondestructive geophysical method that produces a continuous cross-sectional profile or record of subsurface features, without drilling, probing, or digging. Ground penetrating radar (GPR) profiles are used for evaluating the location and depth of buried objects and to investigate the presence and continuity of natural subsurface conditions and features.

Ground penetrating radar operates by transmitting pulses of ultra high frequency radio waves (microwave electromagnetic energy) down into the ground through a transducer or antenna. The transmitted energy is reflected from various buried objects or distinct contacts between different earth materials. The antenna then receives the reflected waves and stores them in the digital control unit.

The ground penetrating radar antenna (transducer) is pulled along the ground by hand or behind a vehicle.

When the transmitted signal enters the ground, it contacts objects or subsurface strata with different electrical conductivities and dielectric constants. Part of the ground penetrating radar waves reflect off of the object or interface; while the rest of the waves pass through to the next interface.

The reflected signals return to the antenna, pass through the antenna, and are received by the digital control unit. The control unit registers the reflections against two-way travel time in nanoseconds and then amplifies the signals. The output signal voltage peaks are plotted on the ground penetrating radar profile as different color bands by the digital control unit.

For each reflected wave, the radar signal changes polarity twice. These polarity changes produce three bands on the radar profile for each interface contacted by the radar wave.

Ground penetrating radar waves can reach depths up to 100 feet (30 meters) in low conductivity materials such as dry sand or granite. Clays, shale, and other high conductivity materials, may attenuate or absorb GPR signals, greatly decreasing the depth of penetration to 3 feet (1 meter) or less.

The depth of penetration is also determined by the GPR antenna used. Antennas with low frequencies of from 25 to 200 MHz obtain subsurface reflections from deeper depths (about 30 to 100 feet or more), but have low resolution. These low frequency antennas are used for investigating the geology of a site, such as for locating sinkholes or fractures, and to locate large, deep buried objects.

Antennas with higher frequencies of from 300 to 1,000 MHz obtain reflections from shallow depths (0 to about 30 feet), and have high resolution. These high frequency antennas are used to investigate surface soils and to locate small or large, shallow buried objects and rebar in concrete.

GPR is a high-resolution technique of imaging shallow soil and ground structures using electro-magnetic (EM) waves in the frequency band of 10-1000 MHz.
Advantage of EM waves is that signals of relatively short wavelength can be generated and radiated into the ground to detect anomalous variations in dielectric properties of the geological material

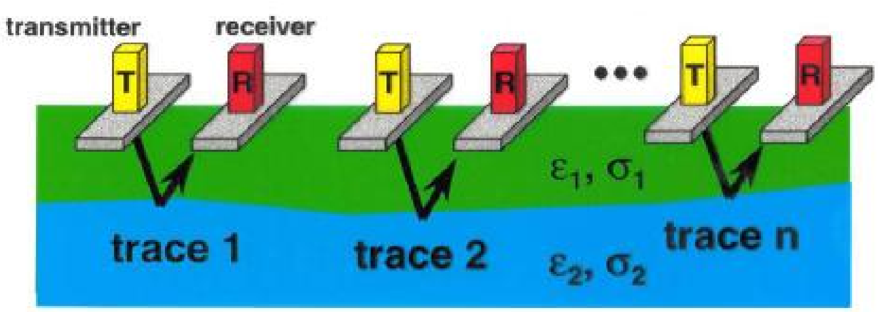
GPR – technical summary

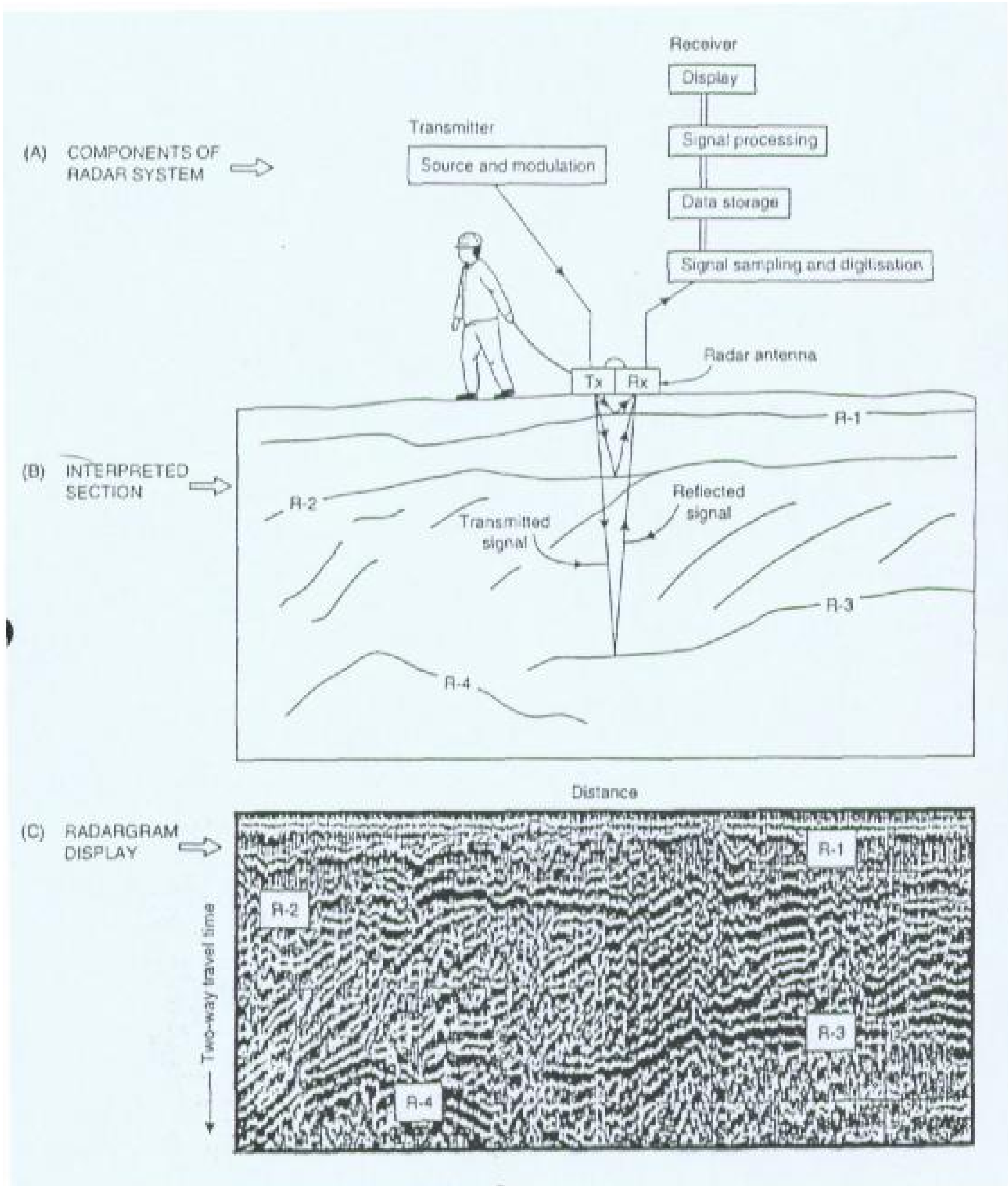
- f ~ 50 MHz - 5 GHz
- v ~ 0.05 - 0.15 m/ns
- λ ~ 1 m - 1cm
- Reach : 0 - 50 λ

Used on surface with one sensor for transmitting and receiving or double system of separate transmitter/receiver Used in boreholes (3D borehole radar, or cross imaging)

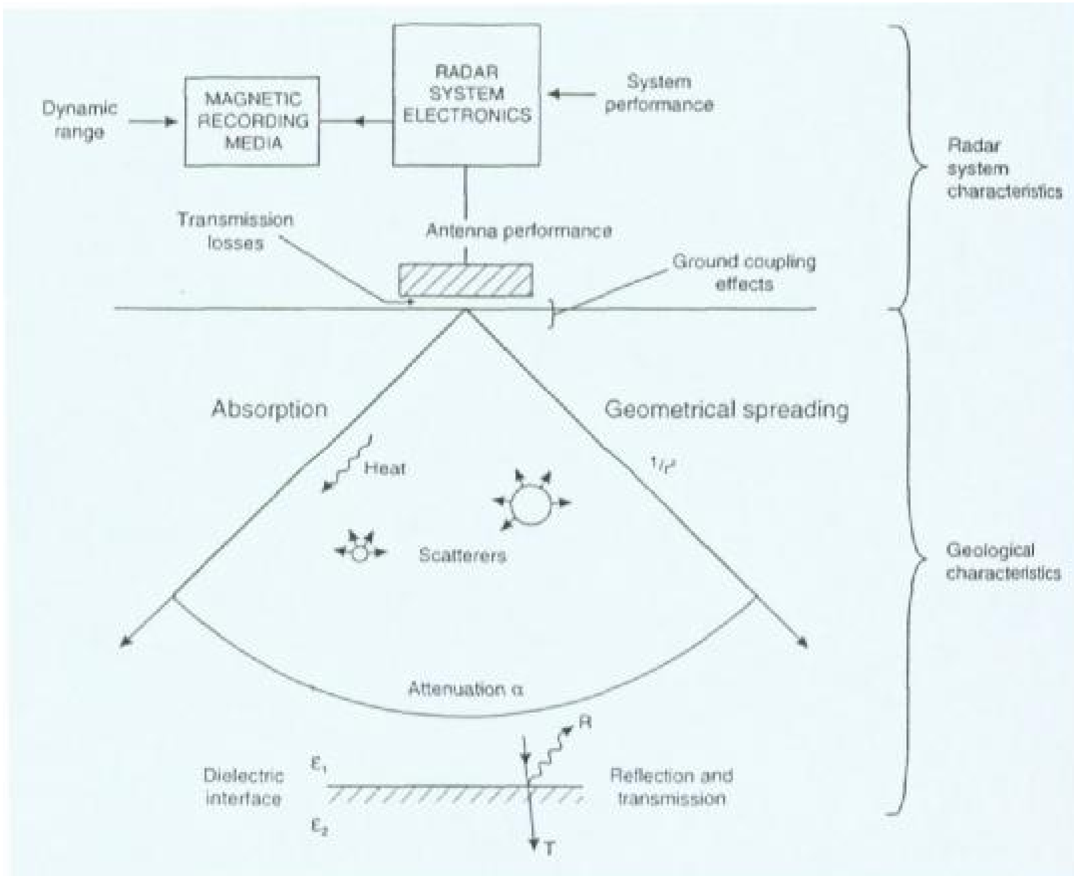
Principles of operation

A radar system comprises a:
signal generator
transmitting / receiving antennae
recording unit





الشكل يوضح النظام الراداري حيث يحتوي على هوائي للإرسال TXوآخر للاستقبالRX



الشكل يوضح المعاملات التي تسبب فقد للطاقة وهي (1) الانعكاس وفقد الطاقة بين الحدود الطبقية، (2) تشتت للطاقة بطريقة عشوائية، ويعرف ذلك بالتشتت أو التبعثر الكمي ، (3) الامتصاص. (4) الانتشار الجيومتري للطاقة.

GPR - application

- Geological
- Environmental
- Glaciological
- Engineering and construction
- Archaeology
- Forensic science

Geological

- Detection natural cavities and fissures
- Subsidence mapping
- Mapping of superficial deposits
- Soil stratigraphy mapping
- Geological structure mapping
- Mapping of faults, dykes, coal seams
- Lake and riverbed sediment mapping
- Mineral exploration and resource evaluation

Engineering and construction

- Road pavement analysis
- Void detection
- Location of reinforcement (rebars) in concrete
- Location of public utilities (pipes, cables, etc)
- Testing integrity of building materials
- Concrete testing

Dielectric constant of radar waves

Material	ε_r
Dry sand/gravel	4-10
Wet sand/gravel	10-20
Dry clay/silt	3-6
Wet clay/silt	7-40
Granite	4-9
Limestone	4-8
Dry salt	5-6
Permafrost	4-5
Glacier ice	3.5
Fresh water	81
Kerosene	2.1

v

What does GPR measure?

GPR systems essentially measure the signal travel time, the time between sending the pulse at the transmitter antenna and the moment the (distorted) pulse is received back at the receiver antenna.
In general one measures not only one peak but a series of peaks related to various objects in the sub-surface. The inhomogeneity of the sub-surface is the main factor that controls the number of peaks that will be returned.

Resolution

In practice, it is often better to accept lower spatial resolution in favour of range where there are many thin layers or scattering targets that are not of primary interest.

Low frequency GPR

1. Deep penetration
2. Low resolution

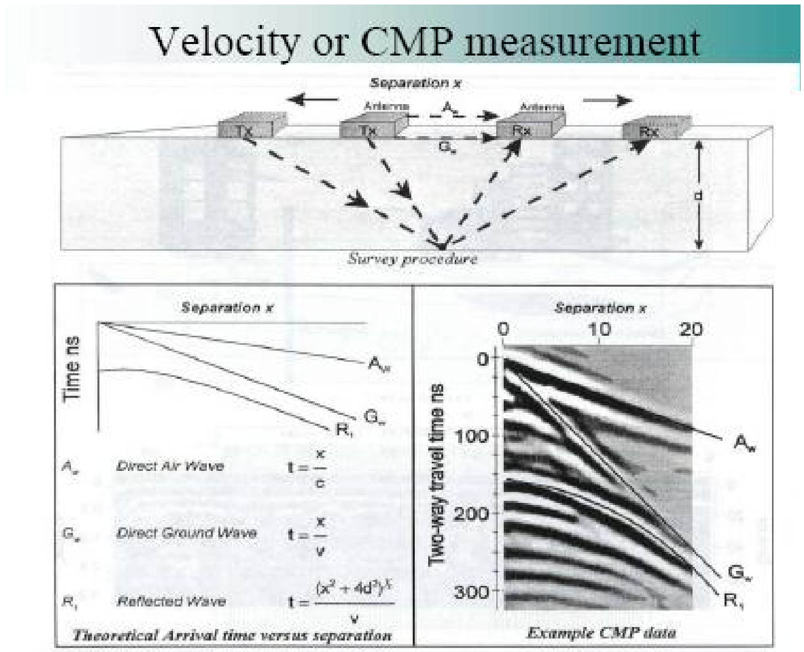
High frequency GPR

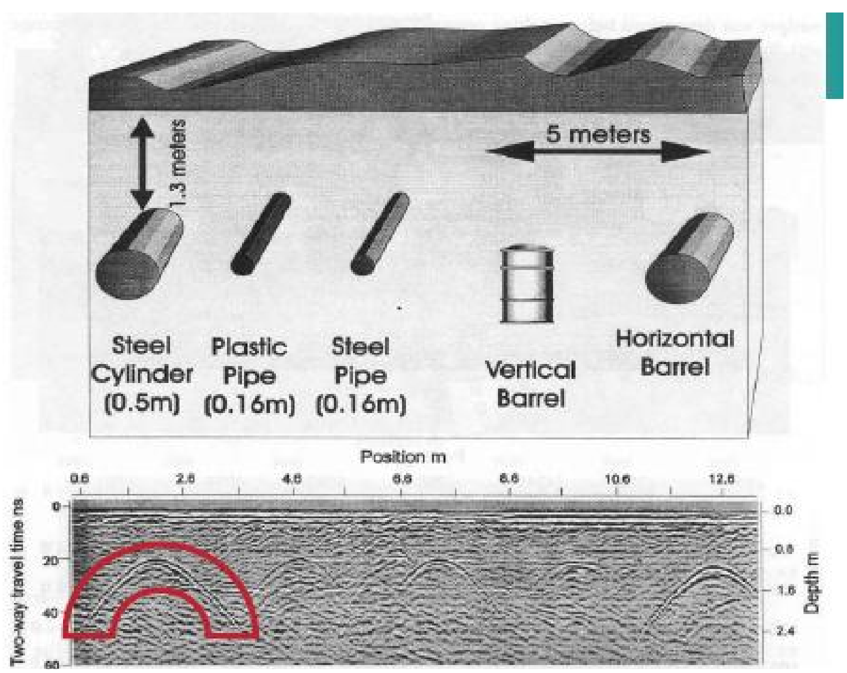
1. Shallow penetration
2. Very high resolution

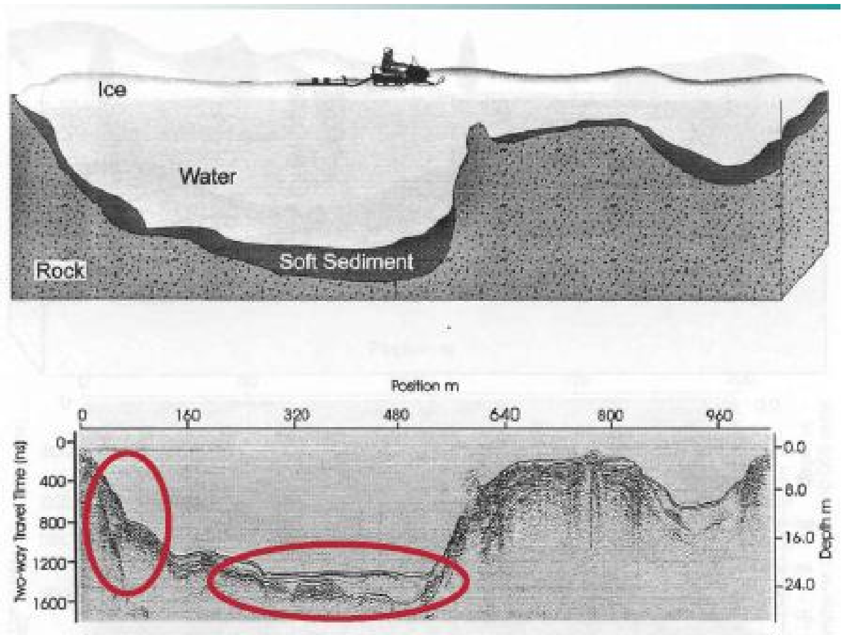
Data processing

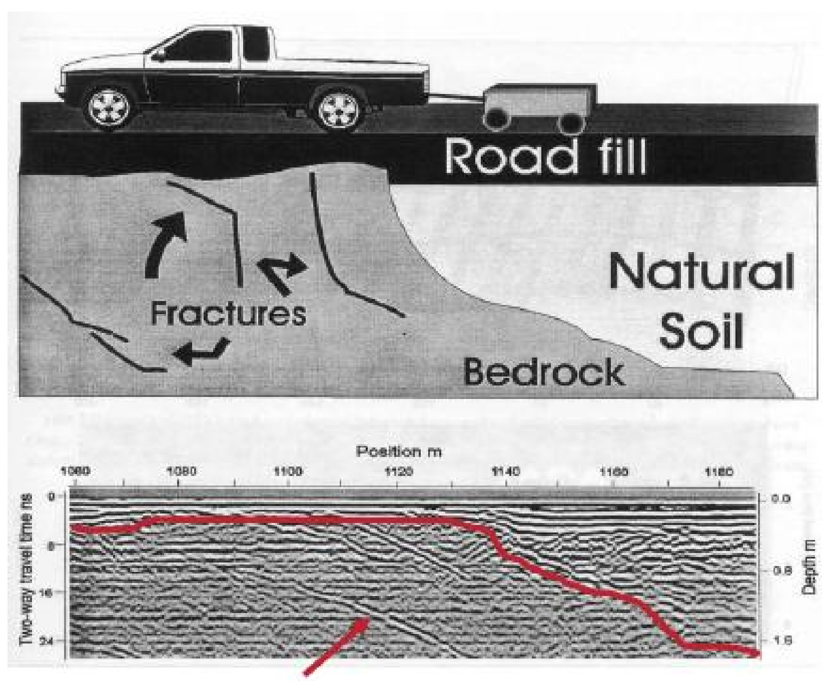
Data processing for GPR is very similar to that used in seismics. Most seismic

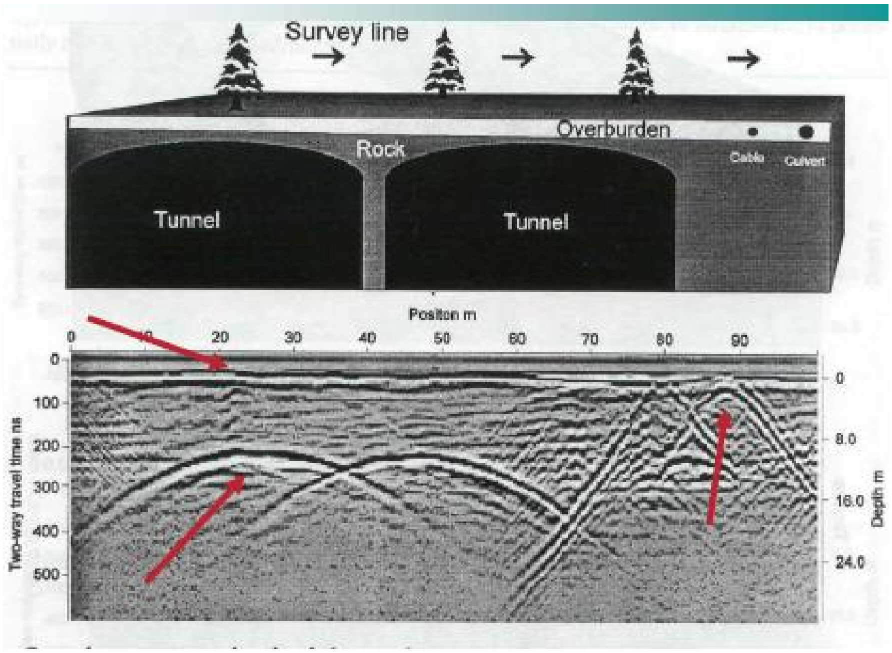
software packages can deal with radar measurements.
Time – depth conversions can be made through estimation of velocity. There are various ways to do this. CMP measurements is just one possibility.



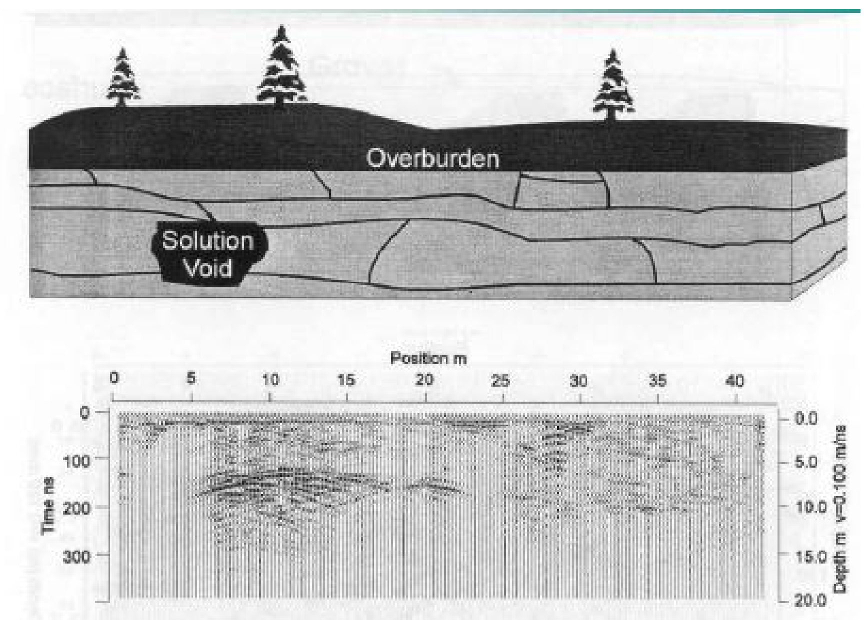



Ice
Water
Soft Sediment
Rock
Position m
0
160
320
480
640
800
960
0
400
800
1200
1600
Two-way Travel Time (ns)
0.0
8.0
16.0
24.0
Depth m

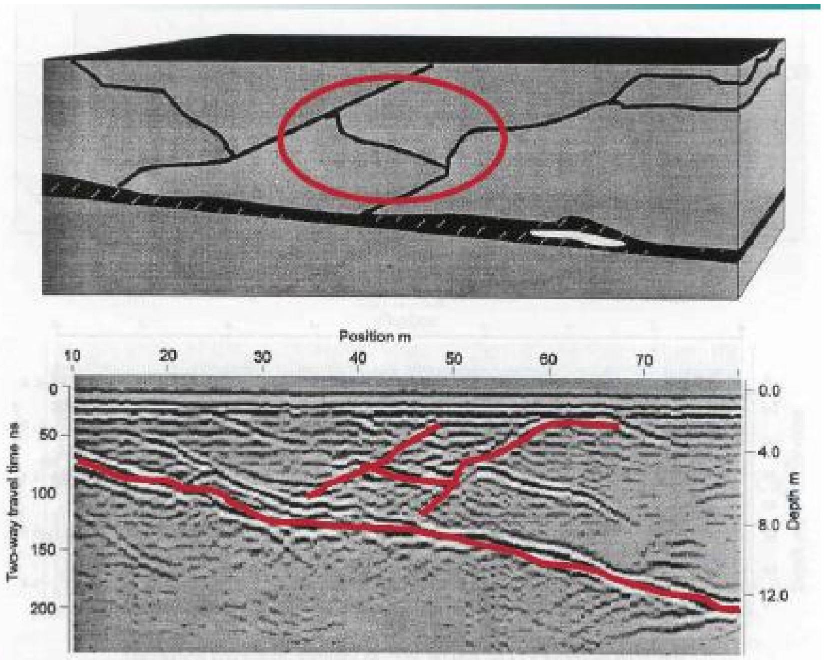

Road fill
Natural
Soil
Fractures
Bedrock
Position m
1060
1080
1100
1120
1140
1160
1180
0
8
16
24
Two-way travel time ns
0.0
0.8
1.6
Depth m



Survey line
Overburden
Rock
Cable
Culvert
Tunnel
Tunnel
Positon m
0
10
20
30
40
50
60
70
80
90
Two-way travel time ns
0
100
200
300
400
500
Depth m
0
8.0
16.0
24.0



Overburden
Solution Void
Position m
0
5
10
15
20
25
30
35
40
Time ns
0
100
200
300
Depth m v=0.100 m/ns
0.0
5.0
10.0
15.0
20.0



Position m
10
20
30
40
50
60
70
0
50
100
150
200
Two-way travel time ns
0.0
4.0
8.0
12.0
Depth m