Bulletin of the Maritime Institute

Gdańsk, 1994, 21, 1

Marek Inerowicz, MSc., Eng.

Department of Geoengineering and Geoecology
Maritime Institute, Gdańsk, Poland

SOME ENVIRONMENTAL SITE INVESTIGATION METHODS

Abstract

The paper contains the description of the tools and methods used in the environmental site investigation in Norway as well as the author's remarks related to the Polish soil conditions.

1. INTRODUCTION

The work presented in this paper was performed within the framework of Polish-Norwegian joint project 'Contaminated Sites and Remedial Action in Gdańsk and Koszalin Region'.

In November 1993 the author participated in the Norwegian Geotechnical Institute project concerning the determination of pollution in the subsoil, related to the construction of the road embankment near Lillestrom, Norway. In the past the site was polluted by impregnates used to the wood processing.

The methods and tools applied in this project are described in the paper. Some remarks related to the Polish soil conditions are discussed.

2. SOME METHODS IN GEOTECHNICAL AND ENVIRONMENTAL SITE INVESTIGATION

2.1. GEORADAR

Principle

Georadar as the new tool for detecting and mapping hidden objects finds wide application in environmental and geotechnical investigations. Here are some of the applications reported by NGI:

- location of buried objects such as pipes, cables, waste containers;
- mapping of waste disposal, archeological sites, topography and stratigraphy of bedrock;
- rock and concrete quality control (mapping of fracture zone in bedrock, cracks and steel bars in concrete);
- detecting voids in foundations, rocks or under pavement.

The georadar idea is based on the measurement of the electrical property i.e. conductivity of the tested medium.

Generally, the georadar consists of the following main units: transmitter, receiver, transmitting and receiving antenna and data acquisition computer. Electromagnetic wave generated by georadar transmitter is radiated by transmitter antenna to the surface and then reflected when it meets any obstacle. The reflection of electromagnetic wave is received by the antenna and sent to the receiver. Distance to the obstacle can be determined by the measurement of wave speed and travelling time. The antennas are moved along the design profile while distance between them are constant. This method is used for scanning two dimensional picture and is known as reflection measurement.

Another method, the tomographic inversion technique, is used to obtain the image of hidden or buried objects. In this case one antenna is placed at a fixed position (e.g. inside a borehole or at one side of the object) while the other one changes position. By scanning the area from different directions it is possible to determine the shape of the buried object.

Fig.1 Commercial georadar equipment.

The main difficulty in using georadar is the fact that some media may strongly attenuate electromagnetic wave. It means that the georadar can detect subsurface features at the distance of a few meters in height attenuation materials such as clay, to several tens of meters in low attenuation material such as sand, rock and fresh water. The lowest detection distance, about 10 cm, occurs in the sea water.

The georadar developed at NGI uses frequency synthesized signals. The advantage of using this system is the possibility to vary the bandwidth of the radar signal by software, so that the signal frequency is tuned up to perform the best detection. The signal is generated and received by a network analyzer (HP8753). During measurement 201 frequency samples which cover the desired signal bandwidth are radiated in sequence. The magnitude and phases of the echo at those frequency samples are received, also sequentially by a network analyzer and recorded by data acquisition computer. Software written in ASYST language efficiently computes signal processing and display the results. To remove the difficulties caused by cable radiation, an optical link from the network analyzer to the antennas is used. Another important factor of the georadar system is the quality of the antenna. Therefore specially shaped flat-plate, wire and horn antennas are designed to cover the allotted frequency range.

The application of a commercial georadar (Fig.1) to primary road construction site investigation project in Lillestrom has been observed by the author. The main aim of this georadar investigation was determination of the old streambed location which is probably the main channel of kerosene contamination outflow to the existing river.

It should be noted that the georadar service and data analyses require very experienced personnel. In Poland the georadar method is very rarely known but deserves to be widely propagated. Specific potential application of the georadar is presented in the next chapter.

Some proposed georadar applications

The author would like to point out that an important georadar application was not mentioned in the publications he reviewed. That is the adoption of georadar features to determine the directions and boundaries of the ground water or contamination migration in time.

One feature of electromagnetic waves in the range of the frequencies used by the georadar, is the very high attenuation in salt water. It means that the waves will have very shallow penetration into salt water, which thereby gives a clear reflection to the radar receiver. This feature can be utilized for practical purposes. In one case the salt water can be used as a tracer to detect the flow of the water or for mapping all kinds of cracks in solid material. Injection of the salt water into ground allows the detection of spreading of water in the investigated area by georadar. Moreover, if the ground water level is known it is possible to estimate the content of salt by comparing the detection distance relative to the ground water level. It will be necessary to find out the correlation between detection distance and salt content in the water.

The new georadar application proposed above could also be adopted to determine the spread of contaminated water in the vicinity of the copper tailings reservoir Żelazny Most in Poland. The salt water from the copper mines is retained in the reservoir and migrates towards the outside of the reservoir. It seems possible to estimate the salt content in the ground water by comparing of the known water level and variation of radar detection distance. Determination of phreatic line in the mass of tailings and the dam is also very important for dam stability calculation.

It should be mentioned that the reservoir area in the case of Żelazny Most is about 13 km^2. On such a huge area the georadar method would be a very efficient tool.

2.2. COMBINED SOIL INVESTIGATION

In Norway an ordinary soil investigation starts with sounding to measure depth to the bedrock and to obtain a picture of relative variation in soil strength. Based on these soundings, locations are chosen where it is necessary to obtain further information, depending on the geotechnical problems involved. Soil sampling and vane boring are then performed to determine soil strength and other geotechnical properties. It can also be combined with wells installation to measure ground water level and ground water quality.

Rotary pressure sounding

This method used today by nearly all Norwegian geotechnical institutions and consulting companies was designed and developed by NGI and the Norwegian Public Road Administration in 1967. About 70% of all sounding for investigations of road and bridge projects are performed as rotary pressure sounding because it requires less work effort, less cost and provides more geotechnical information, compared to the traditional methods. Overall cost by rotary pressure sounding is about half the cost of weight soundings.

Rotary pressure sounding is operated by a multipurpose drilling rig (Fig.2). The sounding set consists of a twisted flat bit with an eccentric hard welded seam (Fig.3) extended by rods with flush coupling.

Bit with extension rods is forced into the ground (Fig. 4) at a constant rate of penetration (3 m/min) and at constant rotation (25 RPM).

The trust necessary to maintain the constant speed of penetration is measured and plotted versus depth (Fig. 6).

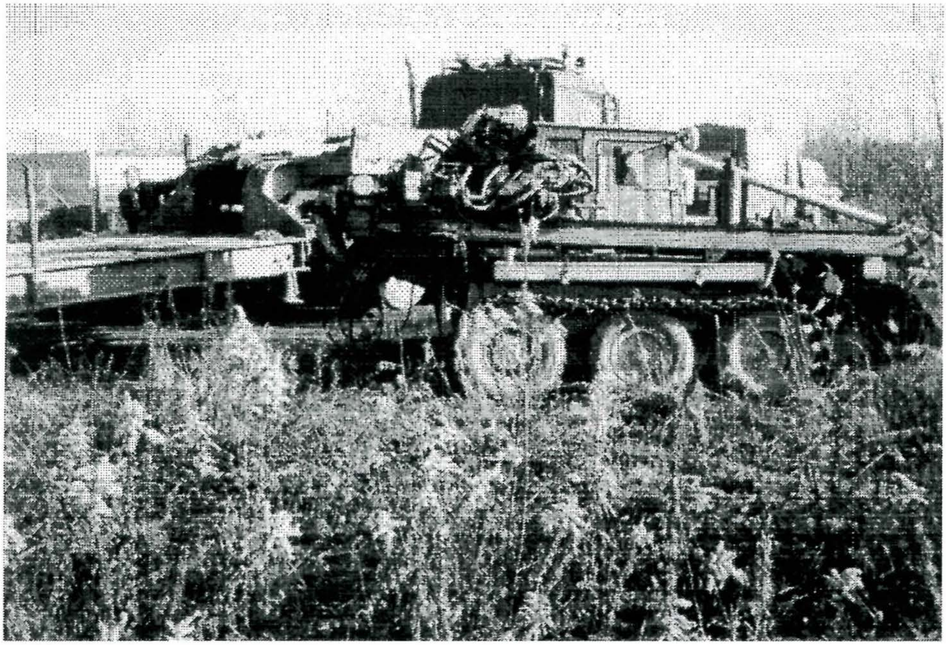

Fig.2 Multipurpose drilling rig GEONOR AB-4.

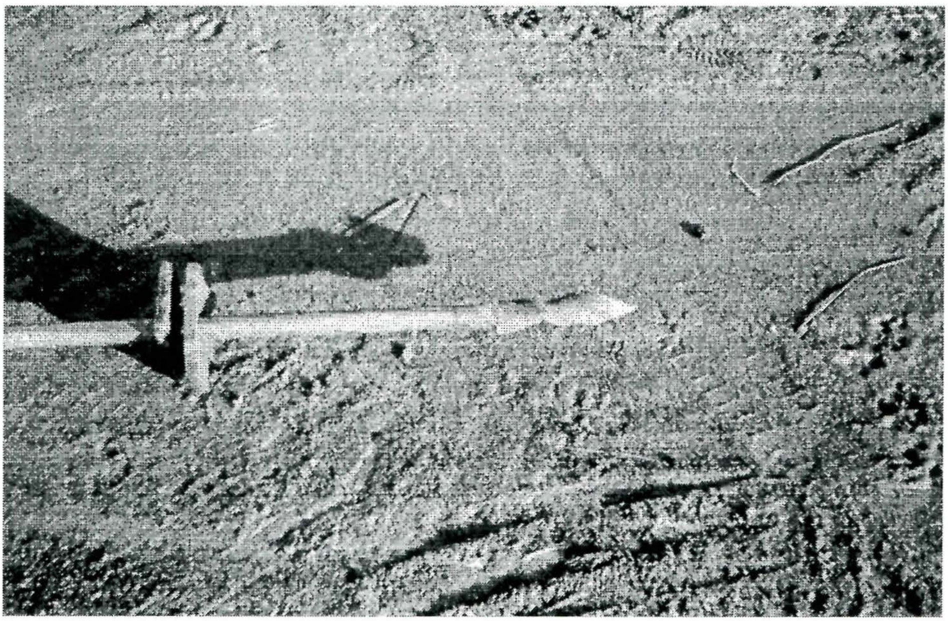

Fig.3 Rotary pressure sounding bit.

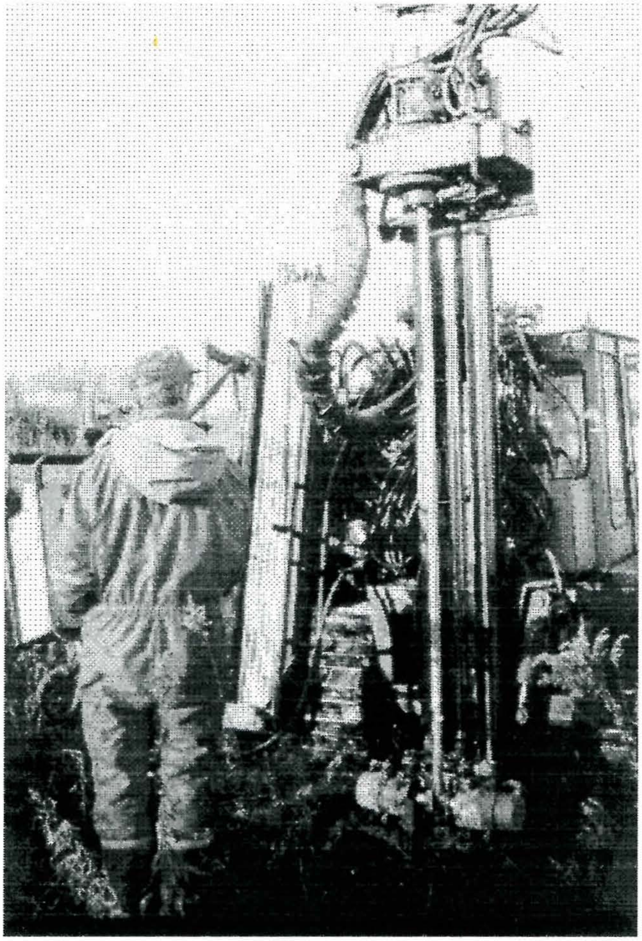

Fig.4 Extension rod forced into the ground.

To penetrate harder layers water flushing by the bit or percussion is used. For penetration of all kinds of soil, boulder and rock, a drill bit for rock with percussion and water or air flushing is applied.

The sounding curves (Fig. 6 - from Lillestrom project) provide a basis to determine soil stratification, types of penetrated materials, sensitivity of clay deposits and selection of the undisturbed sampling locations. Soil layers are easily located, especially when the tip penetrates from clay into sandy soil and vice versa.

It has generally been stated, that no sampling is carried out without prior soundings, and on the other hand sounding are not considered of any value without sampling.

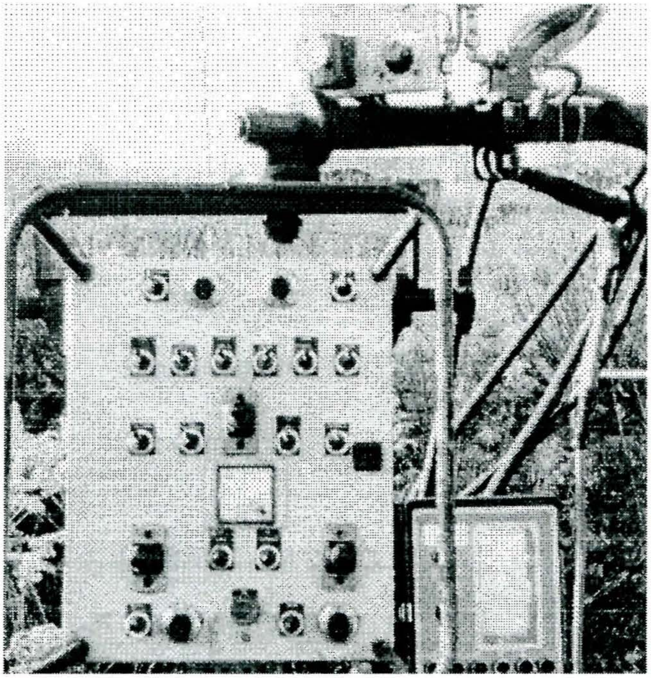

Fig.5 Control panel with mechanical and electronic registration unit.

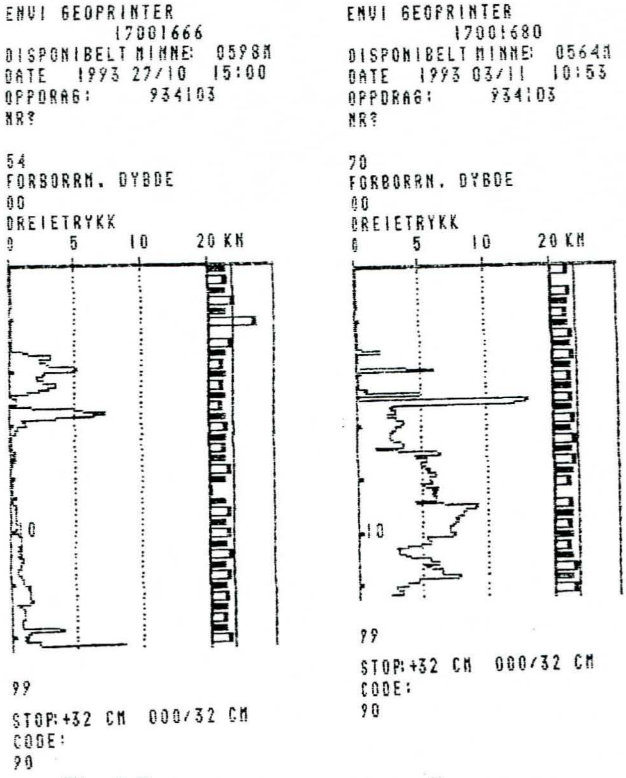

Fig.6 Rotary pressure sounding curves.

Disturbed sampling

This simple but very useful drilling tool (Fig. 7) operated by means of the multipurpose drilling rig can for example be used to:

- penetration and extraction of disturbed soil samples (Fig.8),
- penetration of the topsoil to the depth from where undisturbed sample will be carried out,
- drill the hole for well installation.

Auger sampling allows after sample extraction on primary identification of contaminated layer.

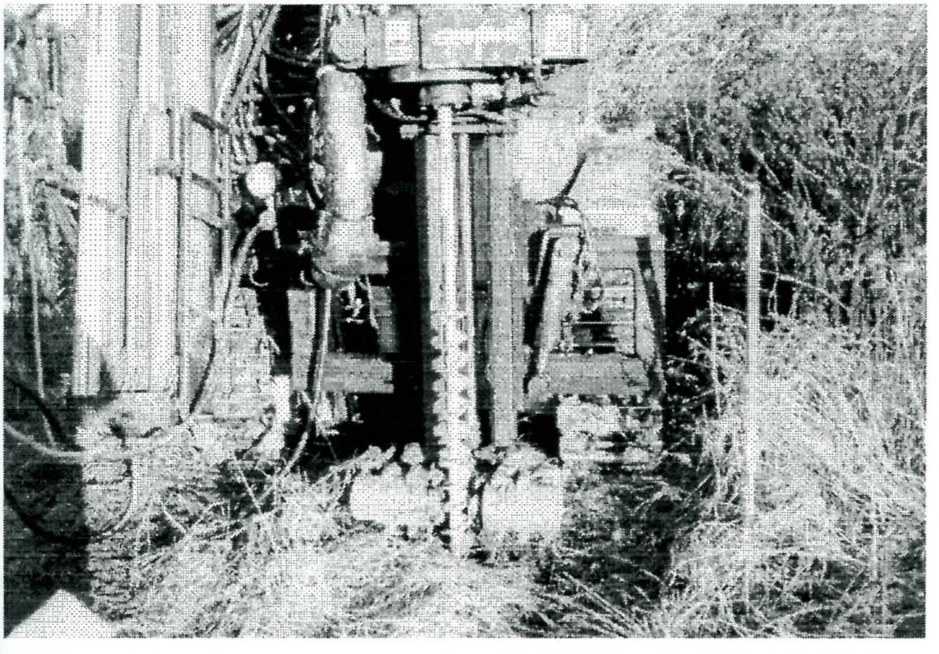

Fig.7 Auger drill operated by multipurpose drill rig.

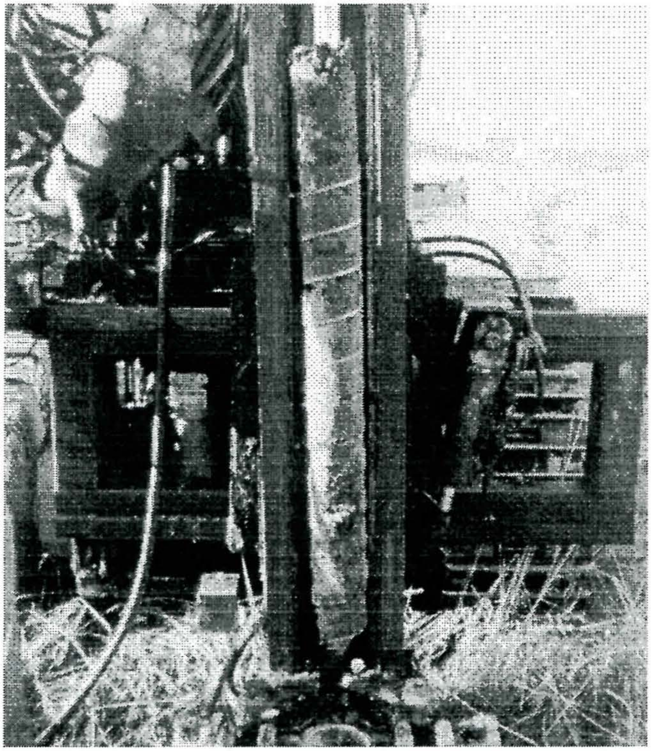

Fig.8 Auger drill filled up with extracted disturbed sample.

Undisturbed sampling

NGI has designed a 54-mm thin-walled sampler, with a removable plastic liner sample cylinder and rubberized piston (Fig. 9) remaining in tube after sampling. Sampling is carried out by the multipurpose drilling rig.

The locations for undisturbed sampling are assigned based on results from earlier soundings (georadar, rotary pressure sounding, vane boring). After penetration of topsoil with auger, the sampler is lowered with extension pipes and inner extension rods (Fig.10). During driving of the sampler to the required depth, the piston rod is locked into position by a counterclockwise threaded spindle. For sampling, the piston rod is released by turning the inner rod and cutting of the soil can start after the inner rod has been firmly fixed at the surface.

The penetration speed during sampling should be kept constant, based on NGI experience i.e. 1.0 to 3.0 m/min. Separation of cohesive samples from the subsoil is achieved by rotating the sample three to five turns before slowly lifting it up to the surface.

During retrieval of the sample, a conical ball clamp locks the piston rod into position and carries the weight of the inner rods. Once out of the hole, the sample tube is removed from the sampler while the piston remains in the tube on top of the sample and serves as the upper seal until extrusion in the laboratory. For transportation and storage rubber caps secured by hose clamps seal off each end of the sample tube.

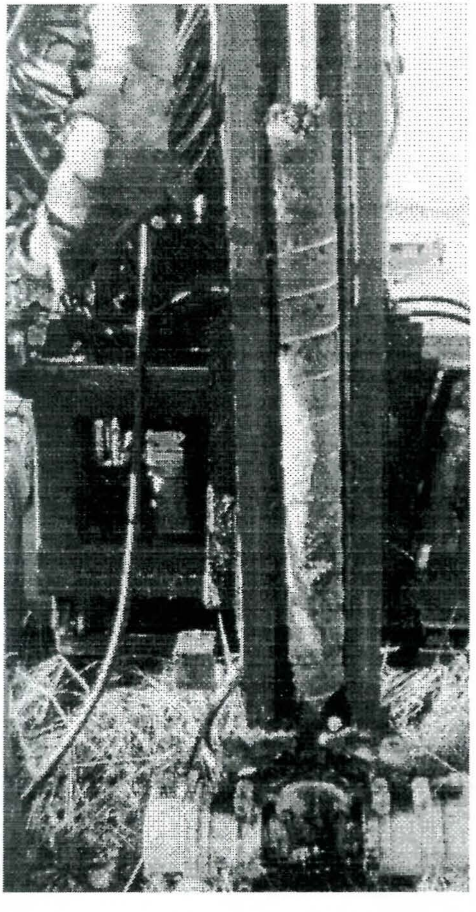

Fig.9 NGI 54-mm sampler.

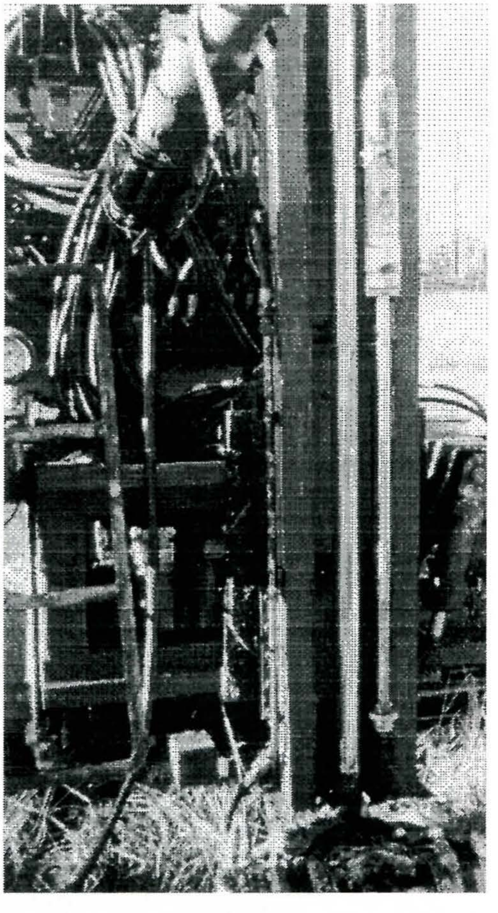

Fig.10 Extension pipe and inner rod-NGI sampler.

Well installation

To determine ground water level and retrieve contaminated water samples it is necessary to install wells (Fig. 11). The NGI well used for taking samples of contaminated water consists of 1000 mm long PCV tubes (Fig. 12) with 60 mm diameter connected by threads. On the bottom is a conical tip with holes for flushing during installation, if necessary, and the top is closed by a cork with an O-ring. The filter is made of the same pipe with 0.3 mm thick slots cut axially around the circumference at the distance of 6 mm from each other. The use of PCV prevents the well's wall from chemical reaction induced by the contaminated water.

A well can be installed in the hole remaining after sampling or be directly pushed down into the hole previously made by rotary soundings. Installation is performed by pushing simultaneously an inner rod which is situated inside the tube and rests on the tip, as the tube holder is fixed to the top of well tube. If pushing down is difficult flushing through the inner rod and the tip can be applied.

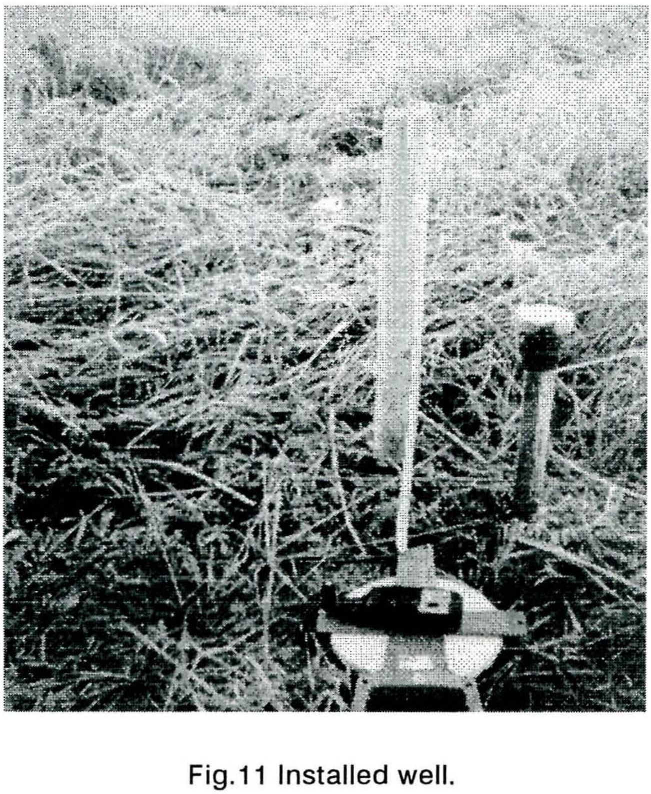

Fig.11 Installed well.

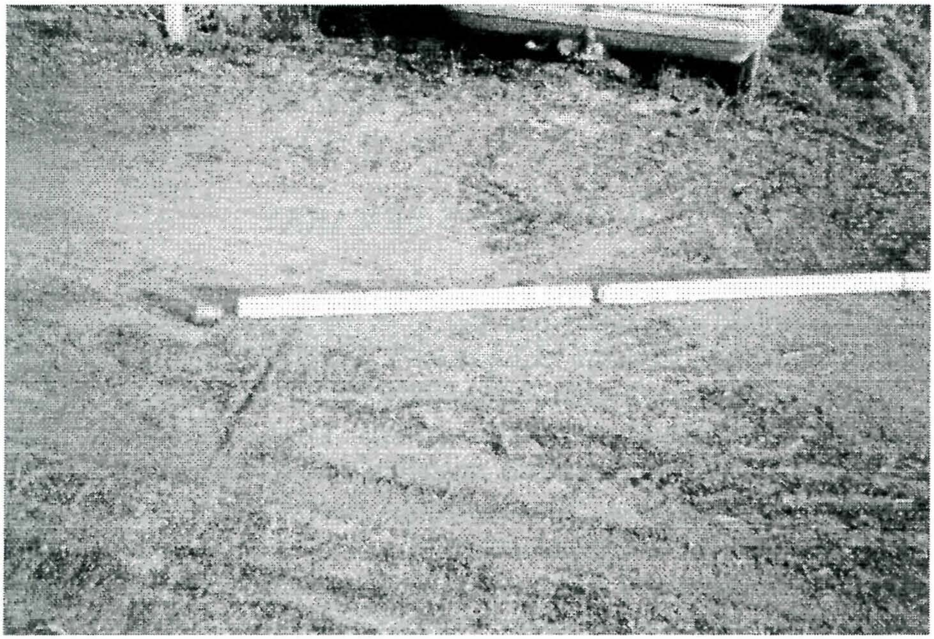

Fig.12 Well's PCV tubes with cork.

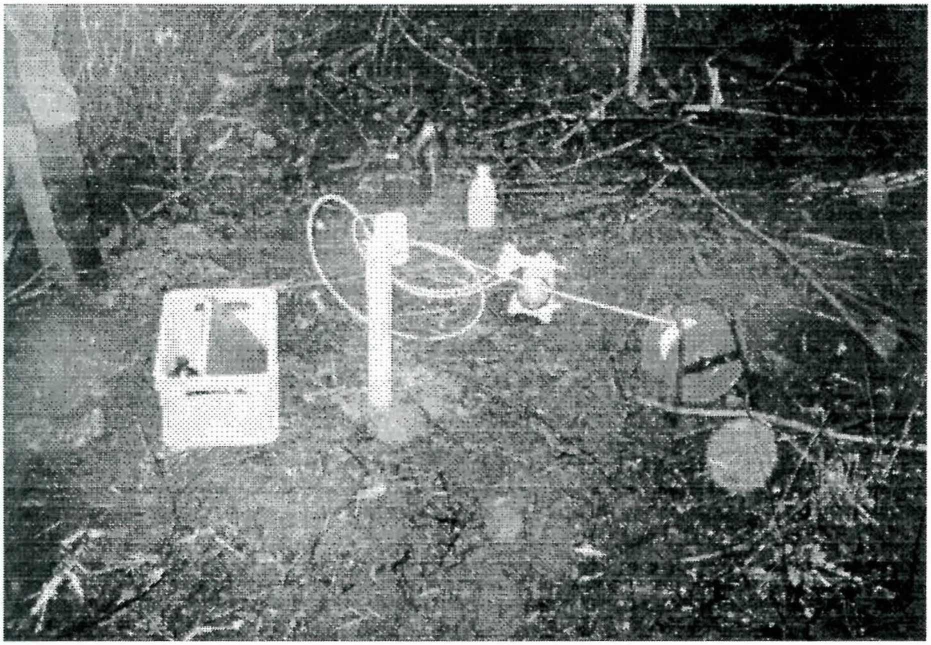

Fig.13 Sampling of water from well.

After installation the well should be rinsed out. To take a water sample, a small vacuum pump sucks water out of the well by disposable hose to the sterilized and neutral container (Fig. 13).

3. AUTHOR'S REMARKS

1. Geotechnical investigations for both purposes are based on the same methods and the equipments. Most fill investigations start with sounding and sampling to determine soil layers, soil types, ground water level and water quality. These results will in most cases provide the basis for choosing the method to be used for further investigation. The ability to penetrate to a given depth, quality and time of the investigation are very important factors. For those investigations using multipurpose drilling rig becomes indispensable. Such small-dimensional multipurpose drilling rig presented in the paper can be used to investigate the all types of soil conditions and methods of testing i.e.:

   - sounding (hydraulic hammering, wash boring, SPT, rotary-pressure sounding)
   - at drilling by auger
   - sampling (undisturbed and disturbed soil sampling up to 60 mm diameter, diamond core drilling)
   - testing (vane borer, CPT, pressure sounding, ground water level and pore pressure measurement, permeability)
   - well's installation

2. The above described investigation by means of rotary pressure sounding seems to be very useful in Polish soil conditions. For the preliminary geotechnical profiling the relation between rotary sounding results and classification of the soil should be known.