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Research paper

Use of geophysical techniques for organic soil detection in planned engineering works

Grzegorz Pacanowski[1], Anna Lejzerowicz[2], Marta Sokołowska[3], Maciej Maślakowski[4]

Abstract: Accurate detection and characterization of organic soils play a crucial role in ensuring the stability and safety of infrastructure projects, particularly linear constructions such as highways, railways, and pipelines. Due to their high compressibility and variable properties, organic soils pose significant challenges for geotechnical design and foundation engineering. While borehole investigations provide localized data points, they often fail to capture the continuous spatial variability of these soils, leading to potential uncertainties and construction risks. This study demonstrates the advantages of integrating geophysical techniques, with a focus on Electrical Resistivity Tomography (ERT), to achieve detailed mapping of organic soil layers. Through several case studies from Poland's major infrastructure developments, the paper illustrates how geoelectrical methods complement traditional borehole data to enhance soil profiling accuracy. The combined approach enables early identification of problematic zones, optimizing investigation efforts, and reducing unexpected complications during construction. Challenges related to similar resistivity signatures of organic soils and adjacent deposits are addressed by careful interpretation and supplementary methods when necessary. The findings confirm that geophysical surveys are cost-effective, non-invasive tools that significantly improve the reliability of geotechnical models, particularly for extensive linear projects where comprehensive direct testing is impractical. This integrated methodology supports better foundation design choices and mitigates risks associated with weak, organic soil layers.

Keywords: Electrical Resistivity Tomography (ERT), geophysical methods, geotechnical investigations, infrastructure design, organic soils, weak soils detection

[1]DSc., Eng., Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warsaw, Poland, e-mail: grzegorz.pacanowski@pgi.gov.pl, ORCID: 0000-0001-9045-3262
[2]PhD., Warsaw University of Technology, Faculty of Civil Engineering, Al. Armii Ludowej 16, 00-637 Warsaw, Poland, e-mail: anna.lejzerowicz@pw.edu.pl, ORCID: 0000-0002-1350-0632
[3]PhD., Polish Geological Institute – National Research Institute, Rakowiecka 4, 00-975 Warsaw, Poland, e-mail: marta.sokolowska@pgi.gov.pl, ORCID: 0000-0002-5262-1031
[4]PhD., Warsaw University of Technology, Faculty of Civil Engineering, Al. Armii Ludowej 16, 00-637 Warsaw, Poland, e-mail: maciej.maslakowski@pw.edu.pl, ORCID: 0000-0002-2946-1594

1. Introduction

The identification of weak soils plays a pivotal role in geotechnical investigations, as such soils can significantly affect the safety, durability, and cost-effectiveness of infrastructure projects. Among weak soils, organic soils are particularly critical due to their distinct physical and mechanical properties, such as high compressibility, low shear strength, and sensitivity to changes in water content. If not properly accounted for during the design and construction phases, these properties may lead to excessive settlement and stability problems.

Organic soils typically develop in specific geological settings such as river valleys, peat bogs, deltas, and drainless depressions, where organic matter accumulates over thousands of years. Their spatial distribution is often complex and heterogeneous, making it difficult to accurately delineate their boundaries and thickness. This presents particular challenges for linear infrastructure projects – such as highways, railways, and pipelines – where the route length demands extensive and efficient subsurface characterization.

The integration of geophysical data with borehole information enables a more comprehensive understanding of the distribution of organic soils, supporting the development of safer and more cost-effective foundation solutions. This paper focuses on the application and effectiveness of geoelectrical methods for detecting organic soils in various Polish infrastructure projects, highlighting practical workflows and demonstrating how early-stage geophysical surveys can help mitigate construction risks.

In this study, the practical workflow refers to a standardized sequence of steps applied during geotechnical investigations that integrate geophysical methods with traditional site exploration. This workflow includes: (1) a preliminary desk study and analysis of geological maps and terrain models to identify zones potentially underlain by organic soils; (2) acquisition of geophysical data, primarily Electrical Resistivity Tomography (ERT), to provide continuous subsurface imaging; (3) verification of geophysical anomalies through targeted boreholes, sampling, and laboratory testing; and (4) iterative reinterpretation and integration of geophysical and geotechnical data to produce reliable models of soil distribution and properties. Presenting these steps at an early stage of a project enables more accurate risk assessment and facilitates cost-effective foundation design.

2. Identification of organic soils

One of the primary goals of geotechnical investigations is to identify soils that require special design considerations to avoid construction or operational problems. Organic soils are particularly critical due to their susceptibility to large deformations under load. Even minimal organic content can noticeably alter soil mechanical properties. In Poland, soils containing $\geq 2\%$ of organic matter are classified as organic [1]. However, classification thresholds vary internationally: in Germany, the limit is 3% for sands and 5% for fine soils, while in France, soils with less than 10% organic matter are still considered poorly organic [2]. Regardless of the specific threshold, the presence of organic material invariably affects soil behaviour and requires customized geotechnical solutions.

Organic soils are generally characterized by high moisture, low density, low strength, and high compressibility. They are also sensitive to sampling disturbances, show anisotropic properties, and are challenging to test with standard methods [3]. In Poland, typical organic soils include peat, gyttja, organic silts, and humus-rich soils, primarily from the Holocene and Pleistocene age. According to European standard PN-EN ISO 14688-1 [4], these include peat, humus, gyttja, and dy. These soils frequently occur in interbedded sequences with mineral soils, which complicates their identification and classification.

Often referred to as "weak" or "non-bearing," the load-bearing capacity of organic soils is relative and depends on factors such as structure weight, foundation type, and loading conditions. The term "weak soils" is imprecise; a more appropriate term would be "soils unsuitable for direct foundation," which highlights the need for alternative foundation strategies rather than implying intrinsic weakness [5]. Historically, weak soils have been classified based on a compressibility modulus below 1 MPa or a deformation modulus below 5 MPa, with undrained shear strength up to 50 kPa [6, 7]. Internationally, the term "soft soils" refers to young clays or silty clays, whereas organic soils are typically treated as a separate category.

Organic soils are easily identified in visible peat bogs, and their lateral extent can often be approximated using satellite imagery. However, deeper deposits, such as those in large river valleys, particularly when reaching considerable thicknesses (e.g., over 22 meters in the Vistula River delta). Organic soils may also occur within young glacial clays, interglacial deposits, landslide zones, and post-mining depressions. When boreholes are spaced too widely, such layers may be missed, leading to unexpected and costly complications during construction (Fig. 1).

Fig. 1. Unexpected occurrence of thick organic soil layer (violet frame) during construction stage (based on: [8])

The presence of organic soils does not necessarily pose engineering problems if their extent and properties are well characterized. For thin layers, removal and replacement may be sufficient. In the case of thicker deposits, viable solutions include preloading, consolidation, ground improvement techniques, or the use of deep foundations such as piles. Accurate testing of key physical and mechanical properties – particularly permeability and consolidation behaviour – is essential for appropriate design.

Geophysical techniques, especially Electrical Resistivity Tomography (ERT), provide valuable support by detecting electrical resistivity contrasts that that reflect variations in soil composition and moisture content. Organic soils typically show low resistivity values due to their high moisture content and presence of organic matter, which allows them to be distinguished from mineral soils. When calibrated with borehole data, geophysical surveys can accurately delineate the lateral and vertical extent of organic soil layers. This supports the design of targeted foundation solutions, including soil replacement, consolidation strategies, or deep foundation systems.

2.1. Geophysical methods for detection of organic soils

The detection and characterization of organic soils remain challenging in geotechnical engineering due to their heterogeneous nature, high compressibility, and variable mechanical properties. Traditional borehole investigations provide point-specific data but often fail to capture the lateral variability and spatial extent of organic deposits. To overcome these limitations, geophysical methods have been increasingly applied to improve subsurface imaging and support the identification of organic soils.

Organic soils typically contain a high proportion of decomposed plant material, resulting in low bulk density and shear strength, high moisture content and variable hydraulic conductivity. They also exhibit strong contrasts in electrical conductivity compared to mineral soils, as well as distinct seismic velocity signatures due to low stiffness. These physical and mechanical characteristics influence geophysical responses and form the basis for effective detection and characterization. A range of geophysical techniques may be employed to identify organic soils, including:

- **Ground Penetrating Radar (GPR)**

Ground penetrating radar (GPR) employs high-frequency electromagnetic waves to image subsurface structures by detecting contrasts in dielectric permittivity. Organic soils often generate strong radar reflections due to differences in moisture content and composition compared to underlying mineral soils. GPR is particularly effective for shallow investigations, typically up to depths of 5 to 10 meters, making it suitable for mapping organic soil layers and indetifying buried features. The method offers a high spatial resolution for shallow depths and enables rapid data acquisition. It is especially useful for detecting subsurface interfaces, discontinuities and changes in layering. However, GPR penetration s significantly limited in conductive or water-saturated soils, where signal attenuation reduces penetration depth. Additionally, interpretation of GPR data requires specialized experience and calibration with ground-truth information such as borehole logs or sample data [9–11].

- **Seismic Methods (MASW, ReMi)**

Seismic surface wave techniques, such as Multichannel Analysis of Surface Waves (MASW) and Refraction Microtremor (ReMi), are used to measure shear wave velocity (Vs) profiles, which correlate directly with soil stiffness and density. Organic soils typically exhibit notably low Vs values, allowing for their identification and mechanical characterization. These seismic methods provide key dynamic soil parameters that are essential for seismic response analysis, foundation design, and ground improvement planning. Their main advantages include a direct relationship to mechanical properties and applicability across a range of site conditions in a non-invasive manner. However, these methods require specialized equipment and operator expertise, and their resolution generally decreases with depth [11–13].

- **Electromagnetic methods (conductivity profiling – GCM)**

Geophysical Conductivity Meter (GCM) allow for the measurement of ground electrical conductivity without the need for direct contact with the surface, allowing for rapid surveying over large areas. Organic soils typically exhibit elevated electrical conductivity (and correspondingly reduced resistivity) due to their high moisture content, which facilitates their detection and lateral mapping. GCM methods are often integrated with other geophysical techniques to improve interpretation accuracy. Their advantages include rapid coverage of extensive areas, elimination of contact electrodes, and suitability environments with shallow standing water or mildly waterlogged conditions-settings where other geophysical methods may be difficult to apply. However, the limitations of conductivity profiling with GCM include a relatively shallow depth of investigation and sensitivity to surface conditions and anthropogenic noise, which may affect the quality and reliability of the results [11, 14, 15].

- **Electrical Resistivity Tomography (ERT)**

Electrical Resistivity Tomography (ERT) measures subsurface resistivity by injecting electrical current into the ground and recording the resulting potential differences. Organic soils generally exhibit lower resistivity compared to mineral soils due to their high moisture and organic content. ERT produces two- and three-dimensional images of the subsurface resistivity distribution, which enables the mapping of both the thickness and lateral extent of organic soil layers. Numerous studies have confirmed the effectiveness of ERT in delineating peat layers beneath infrastructure sites and guiding targeted sampling efforts [10,12,13,15]. The method offers high spatial resolution and is particulary sensitive to variations in moisture and organic content. Additionally, ERT is non-invasive and relatively efficient in field implementation [16–18]. However, interpretation of ERT data can be complicated by soil heterogeneity and variations in salinity. Moreover, the depth of investigation depends on electrode spacing and ground conductivity.

Combining multiple geophysical techniques overall improves reliability by leveraging complementary sensitivities. For example, electromagnetic induction (EMI) techniques are effective for mapping lateral conductivity variations, ERT and ground-penetrating radar (GPR) provide vertical profiling, while seismic methods deliver mechanical property estimates. Integration with borehole data and in-situ sensors allows for calibration and validation, thereby reducing uncertainty in subsurface models [10–12].

While ERT remains the primary method for organic soil detection, seismic surveys, such as crosshole and downhole tests, offer valuable information on soil stiffness and consolidation behaviour. These mechanical parameters are critical for evaluating deformation potential under loading. The Polish Railway Guideline [19] recommends including seismic wave velocity measurements in geotechnical investigations to improve the assessment of weak soils. When integrated with resistivity data, seismic methods provide a more comprehensive understanding of subsurface conditions, supporting safer and more cost-effective foundation designs.

3. Examples of ERT applications for identifying organic soils

In all presented cases, Electrical Resistivity Tomography (ERT) was identified as the most suitable method for detecting organic soils, with a standard electrode spacing of 2 meters. Based on extensive experience gained during large-scale road construction projects in Poland, the following standardized procedure has been developed for geotechnical investigations related to linear infrastructure: (1) **analysis of geological maps** to identify zones potentially affected by organic soils or other problematic ground conditions, (2) **execution of geophysical surveys**, primarily using ERT, along the selected sections, (3) **implementation of geotechnical investigations**, including boreholes, soil sampling, and field testing, to verify and calibrate geophysical results, and (4) **reinterpretation of geophysical data** based on ground-truth data obtained from boreholes and in-situ testing. Conducting geoelectrical surveys at an early stage of the project has proven to be an effective strategy – particularly in identifying high-risk zones that warrant further verification through drilling and detailed sampling. The following section presents selected examples of ERT-based geoelectrical surveys performed as part of infrastructure development projects in Poland.

It is important to note that the presented examples cover both pre-investment surveys and investigations carried out during construction. Pre-investment surveys primarily focused on risk identification and route optimization, while surveys conducted during construction were aimed at verifying soil conditions in critical zones and guiding soil reinforcement strategies. This distinction highlights the adaptability of ERT at different project stages.

3.1. Detection of organic soils in a conceptual-phase survey: A2 Highway case study

The A2 highway is one of Poland's major transportation routes, connecting the country's western and eastern borders. Although construction is still ongoing, the final eastern section is currently in the design phase. Due to the highway's extensive alignment across diverse geological regions, numerous occurrences of organic soils have been identified along its route – particularly in areas crossing river valleys and depressions within glacial formations. Figure 2 presents a selected segment of a geoelectrical cross-section acquired during the conceptual phase of the project, prior to any drilling activities. Based on geological map analysis [20], zones with a high likelihood of organic soils were identified, and targeted geophysical investigations were conducted to delineate their extent and thickness.

The western part of the cross-section (Fig. 2) begins with sandy deposits (unit 2b), exhibiting resistivity values exceeding 60 $\Omega \cdot$ m. These values correspond to fluvioglacial sands and gravels (unit A on the geological map). At kilometer 580+020, resistivity values in the near-surface layer decrease significantly ranging between 20 and 40 $\Omega \cdot$ m. This low-resistivity zone extends to a depth of approximately 6 meters and has been interpreted as organic soils (unit 1), primarily composed of humus-rich sands and silts resting directly on glacial tills (unit 3). Subsequent geotechnical drilling confirmed the presence of these organic soils, demonstrating a strong agreement between geophysical interpretation and borehole data.

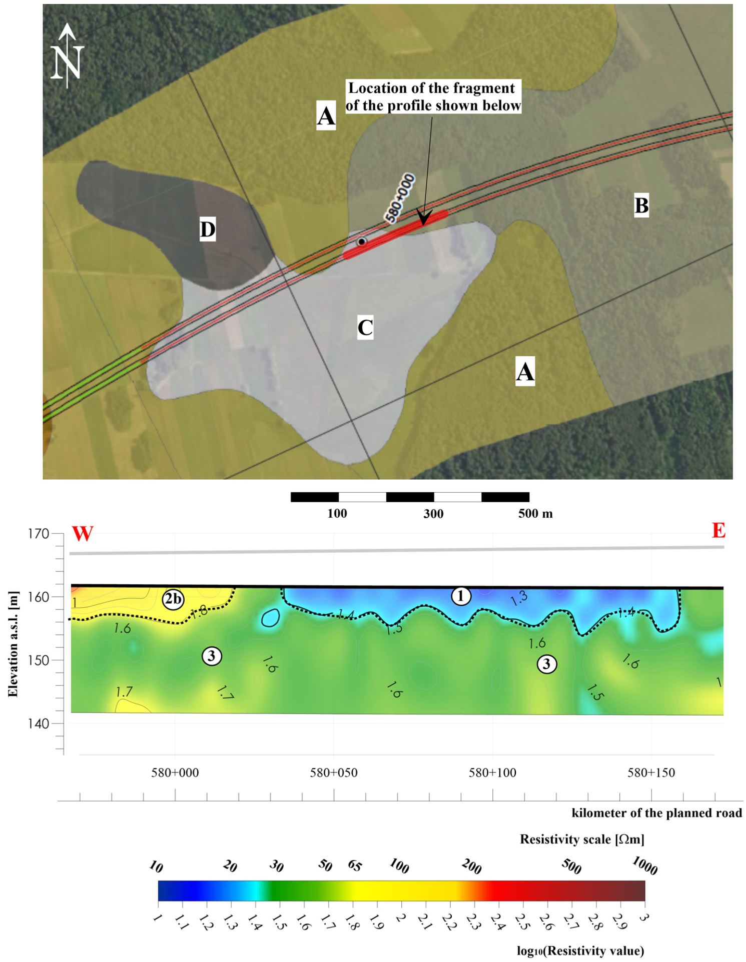

Fig. 2. Geoelectrical cross-section along chosen A2 section in comparison to geological archive map (based on: [20]). Geological map explanations: A – fluvioglacial sands and gravels, B – humus sands and silts, C – organic silts, D – peats; ERT profile units: 1 – organic soils, 2b – sands and gravels under water, 3 – glacial tills

3.2. Integration of DTM, geological maps, and ERT in early-stage investigations: S11 Expressway example

The S11 expressway, located in northern Poland, was subject to geophysical surveying prior to any direct geotechnical investigations. The initial step involved analysis the geological map [21] and a digital terrain model (DTM) to identify areas potentially underlain by organic soils (Fig. 3). Based on this information, a preliminary interpretation of the geoelectrical data was carried out, highlighting potential zones of organic soil occurrence. This interpretation guided the planning and positioning of borehole for subsequent verification.

Figure 3 illustrates the complex terrain morphology typical of young glacial formations, featuring numerous hollows and valleys within a glacial upland crossed by the planned expressway. These depressions are often filled with organic soils. The geophysical surveys aimed to confirm the lateral extent and to estimate the thickness of these deposits. Despite the relatively coarse scale of the geological map (1:25 000), a strong correlation was observed between mapped geological boundaries and geophysical signatures.

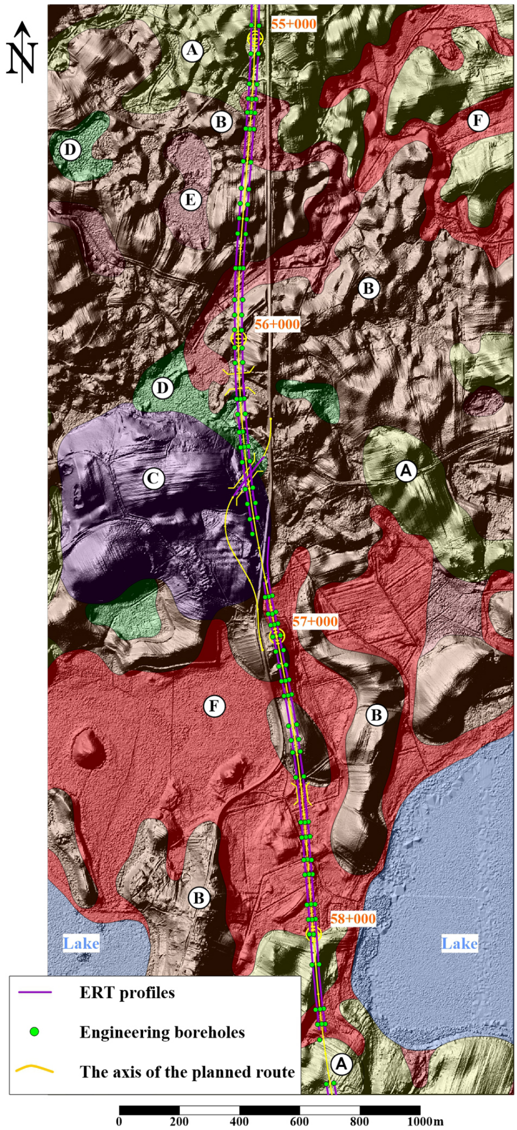

Fig. 3. Compilation map including DTM, geological units and S11 course: A – sands and gravels, B – glacial tills, C – silts and clays, D – organic silts, E – organic clays, F – peats

The geoelectrical imaging confirmed the area's geological complexity. Two specific sections were selected for detailed analysis (Fig. 4): the first between kilometres 55+200 and 55+420, and the second between 56+810 and 56+970 – both zones where organic soils were suspected. In the first section, resistivity values below 30 Ω · m were interpreted as indicative peat deposits. However, comparison with borehole data revealed a more complex geology, making the interpretation of subsurface structure ambiguous. The main challenge was that the organic soils were underlain by glacial tills, which exhibited similarly low resistivity values, making it difficult to differentiate between the two based solely on geoelectrical profiles. The geophysical data in this section displayed irregular resistivity patterns with sharp gradients, characteristic of heterogeneous glacial environments where tills are intermixed with clays, sands, and silts. As a result, detailed borehole investigations were necessary for a reliable interpretation of weak soil layers.

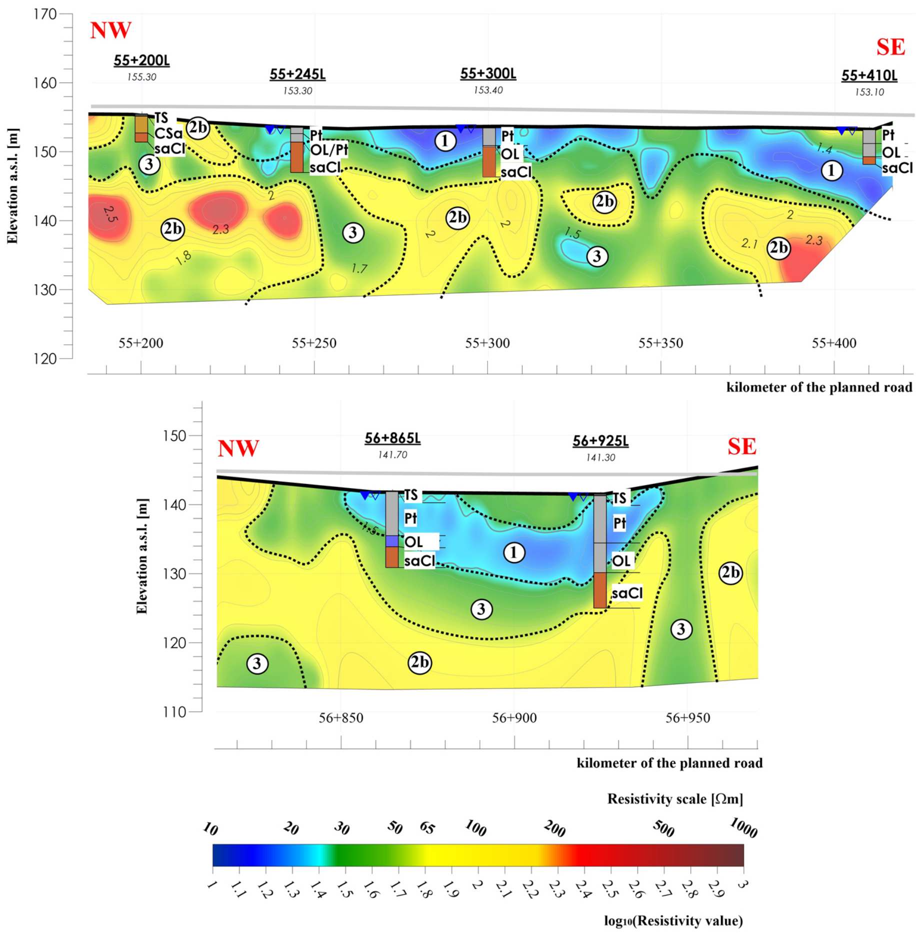

Fig. 4. Geoelectrical cross-sections of chosen sections along S11 expressway, northern Poland. ERT cross-sections legend: 1 – organic soils, 2b – fluvioglacial sands and gravels under water, 3 – sandy clays and clays

To address the difficulty of differentiating organic soils from glacial tills with similar resistivity values, additional boreholes and laboratory analyses of soil samples were performed. In selected locations, seismic surface wave measurements (MASW) were also integrated to provide shear wave velocity data, which allowed for distinguishing soft organic deposits from stiffer tills. This multimethod approach, combining resistivity, seismic velocity, and direct sampling, significantly reduced interpretation uncertainty and improved the reliability of subsurface models.

A similar scenario was observed in the second cross-section (Fig. 4). However, in this case, the low-resistivity zone (< 25 $\Omega \cdot$ m) was more clearly defined and significantly thicker. Borehole data confirmed the presence of organic soils (unit 1), underlain by glacial tills and fluvioglacial sands.

3.3. Identifying complex organic deposits in deglaciated landscapes: ERT surveys along the S16 Expressway

This example also comes from northern Poland, specifically the Mazury region. The geology of this area reflects conditions characteristic of the most recent deglaciation period and consists primarily of glacial tills, fluvioglacial sands, and a significant presence of organic soils – mainly peats – located in river valleys and around lake basins (Fig. 5).

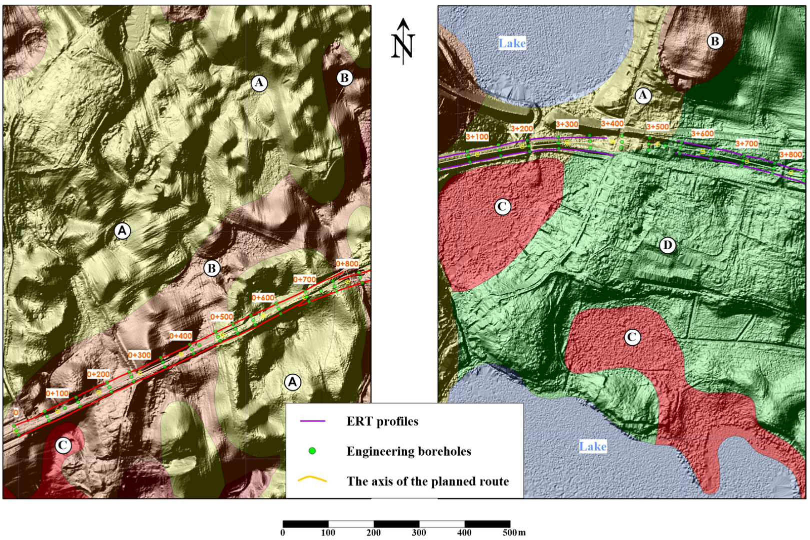

Fig. 5. Geological maps and ERT cross-sections. Legend for geological maps:
A – sands and gravels, B – glacial tills, C – peats, D – clays, silts and lacustrine sands

Figure 6 presents two ERT cross-sections. The upper profile covers a segment between 150 and 350 meters along the planned expressway alignment and reveals complex surface morphology and subsurface geology. Notably, the initial borehole logs did not include the zone where organic soils were subsequently detected. The first two boreholes were located at 0+196O and 0+265O, approximately 70 meters apart. Following the geophysical survey, which indicated the presence of organic soils, an additional borehole was drilled at 0+226O to verify the interpretation and collect representative samples. The ERT results revealed a relatively small zone of organic soils (unit 1), interpreted as peat deposits, with a thickness of up to 10 meters. The discovery of such previously undetected organic soils highlights the potential limitations of conventional borehole spacing and the importance of geophysical pre-screening. Unexpected organic deposits can pose significant engineering challenges during construction (see also Fig. 1). In addition to detecting organic soils, the geoelectrical imaging provided valuable insight into the geological heterogeneity of the profile, revealing steep and abrupt resistivity contrasts indicative of transitions between materials with markedly different mechanical properties. This case underscores the importance of calibrating geophysical results with borehole data, and, where appropriate, supplementing the interpretation with additional methods such as seismic surveys.

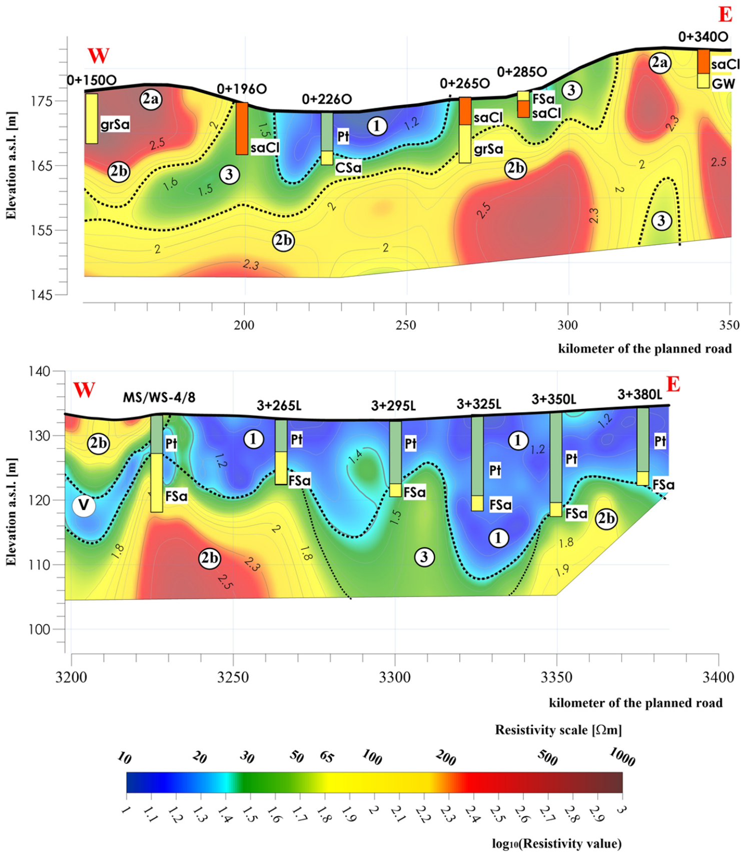

Fig. 6. Two examples of geoelectrical profiles for S16 expressway (northern Poland). ERT profiles legend: 1 – organic soils, 2a – sand, sand and gravels, 2b – sands and gravels under water, 3 – sandy clays and clays

The lower cross-section in Figure 6 spans kilometres between 3+200 and 3+400 along the planned route, where the expressway descends approximately 40 meters into a river valley situated between two lakes. In this section, there was excellent agreement between ERT results and borehole data. A low resistivity zone ($< 15\ \Omega \cdot m$) was identified directly above sandy clays and clays (unit 3). In the lower portion of the profile, sandy deposits (unit 2b) were mapped and subsequently confirmed by borehole drilling. Organic soils identified in the boreholes included peats, gyttja, and organic silts. Furthermore, the ERT data revealed significant variability in the bottom boundary of the organic layer, exhibiting an undulating pattern that would not have been captured by borehole data alone. This emphasizes the added value of continuous geophysical profiling in geologically complex environments.

3.4. Spatial modelling of organic layer thickness based on ERT: S5 Expressway

The final example concerns the S5 expressway, located in central Poland. At the time of the geophysical survey, road construction was already underway. The primary objective of the survey was to accurately delineate the boundaries of organic soils in order to assess the extent of required soil reinforcement. Geologically, the area is covered by young glacial deposits, including sands, gravels, silts, and humus-rich sands (Fig. 7). These humus-rich sands were later identified as a substantial peat layer, which was confirmed through borehole investigations.

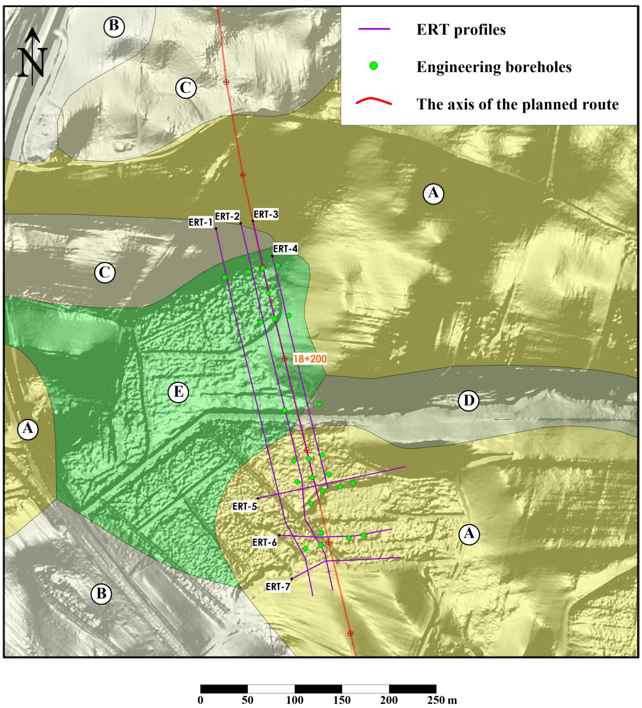

Fig. 7. Location of ERT profiles on geological map. A – fluvioglacial sands and gravels (sandur), B – lacustrine sands and silts on fluvioglacial sands and gravels, C – silts and sands of kemes, D – humic sands, E – lacustrine sands, silts and clays

In the geoelectrical cross-sections (Fig. 8), this low resistivity layer (unit 1) is clearly visible, with its base exhibiting considerable elevation variation. This case also illustrates certain discrepancies between borehole data and geophysical interpretations. The boreholes had been drilled well before the geophysical survey, and their exact locations were uncertain due to unclear positioning methods. As a result, the geophysical data were considered more reliable in this instance. It is important to note that geophysical profiles are always precisely georeferenced using professional land surveying methods (geodetic measurements). Integration of geophysical results with selected archival borehole data enabled the construction of a generalized spatial model (Fig. 9) illustrating the thickness of organic deposits and the elevation of the top surface of the underlying mineral formations. The resulting model allowed for the identification of zones with the highest accumulation of organic sediments and provided a more detailed visualization of the spatial variability of the geological structure within the study area.

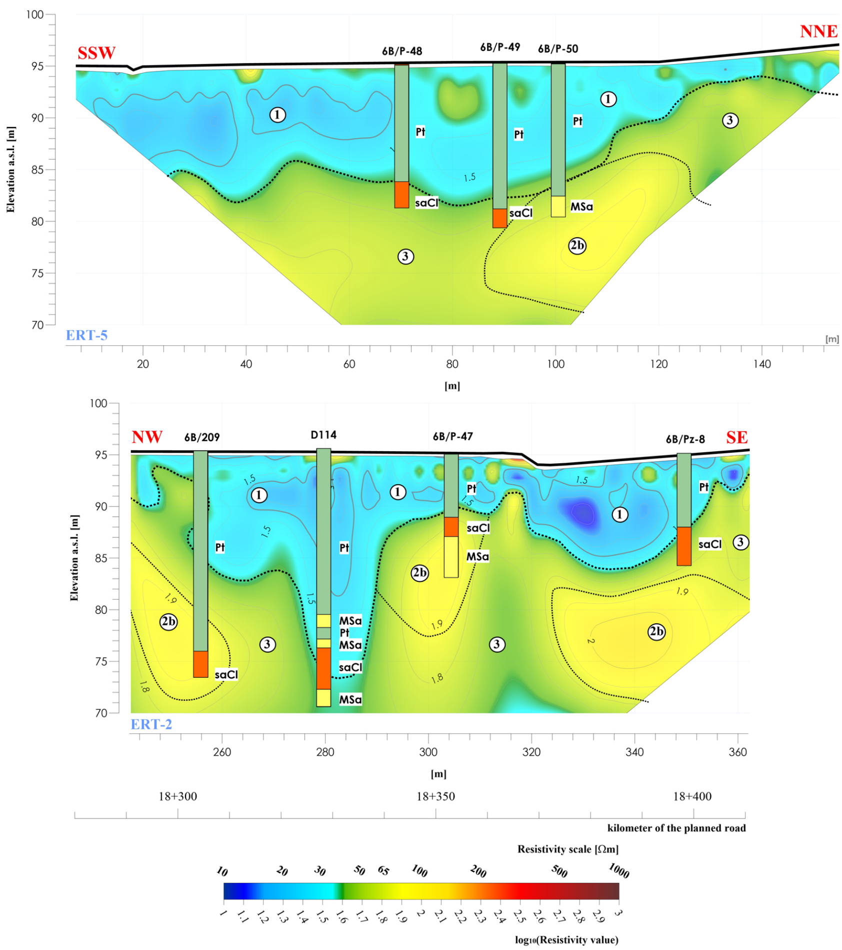

Fig. 8. The examples of geoelectrical cross-sections for S2 expressway (central Poland). ERT profiles legend: 1 – organic soils, 2b – water-saturated sands and gravels , 3 – glacial tills

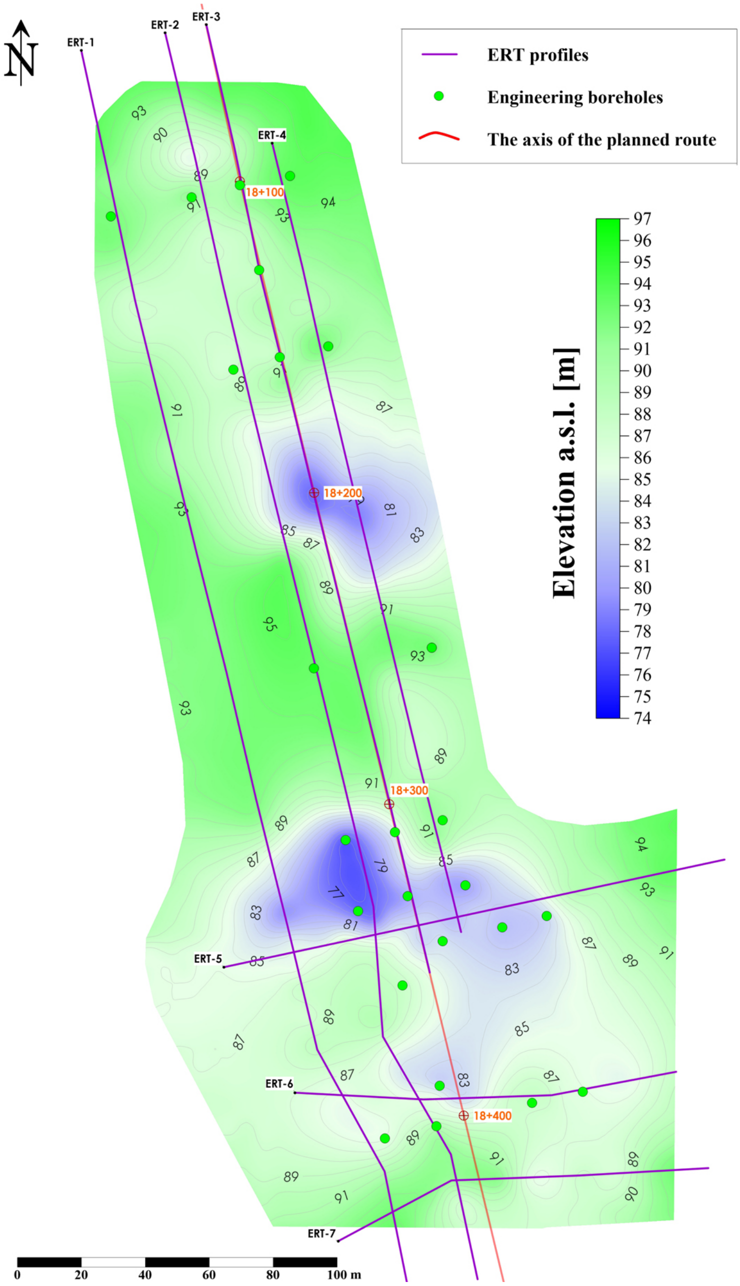

Fig. 9. Map of the base of organic deposits, developed based on geophysical surveys and archival borehole data

4. Summary and conclusions

Geophysical investigations, with Electrical Resistivity Tomography (ERT) at the forefront, have become essential tools in detecting and characterizing organic soils in geotechnical projects. Unlike traditional borehole methods, which provide only discrete, point-specific data, geophysical techniques offer semi-continuous, high-resolution images of the subsurface, offering a more effective representation of spatial variability. This advantage is especially important in linear infrastructure projects such as roads, railways, and pipelines, where the long alignment and high drilling costs necessitate efficient, targeted investigation strategies.

Organic soils present significant engineering challenges due to their high compressibility, low shear strength, and sensitivity to moisture changes. These properties demand specialized foundation solutions. Accurate delineation of their lateral and vertical extent is crucial to mitigate risks such as excessive settlement, structural instability, and costly delays during construction. While boreholes remain indispensable for ground truthing, their limited spatial coverage often leaves uncertainties that can be that can be reduced through the integration of geophysical data.

ERT exploits the contrast in electrical resistivity between organic soils – characteristically low in resistivity – and underlying or adjacent mineral soils, which typically exhibit higher values. When combined with borehole information, this integrated approach yields a more comprehensive and reliable subsurface model, minimizing the likelihood of encountering unforeseen ground conditions during construction. Complementary geophysical methods, such as seismic surveys, further enhance understanding by providing dynamic soil parameters like stiffness and consolidation characteristics, which are critical for ground improvement and foundation design.

Case studies from Poland, including the A2 highway, S11, S5 and S16 expressways, as well as the Vistula River delta region, demonstrate the practical benefits of incorporating geophysical techniques into the geotechnical workflow. These examples highlight ERT's capability to delineate organic soil layers within complex geological settings, including glacial terrains and areas with variable morphology. The ability to detect irregular and undulating boundaries – often missed by borehole investigations alone – supports better-informed engineering decisions, such as the need for soil replacement, consolidation, or deep foundations.

Additionally, the non-invasive and cost-effective nature of geophysical methods makes them suitable for both early-stage investigations and continued monitoring throughout construction. This proactive approach allows engineers to track and manage evolving subsurface conditions, thereby enhancing safety, reliability, and cost efficiency while minimizing risks and avoiding schedule disruptions.

In conclusion, the integration of geophysical techniques with traditional geotechnical methods represents a best practice in the detection and management for organic soils. As geophysical technologies and data interpretation techniques continue to advance, their role in modern geotechnical engineering will likely expand – further improving the precision, reliability, and applicability of subsurface investigations in increasingly complex ground conditions.

Geophysical investigations, with Electrical Resistivity Tomography (ERT) at the forefront, have become essential tools for detecting and characterizing organic soils in geotechnical projects. Unlike traditional borehole methods, which provide only discrete, point-specific data, geophysical techniques deliver semi-continuous, high-resolution images of the subsurface, offering a more effective representation of spatial variability. This advantage is particularly valuable in linear infrastructure projects such as roads, railways, and pipelines, where long alignments and high drilling costs necessitate efficient and targeted investigation strategies.

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ERT exploits the contrast in electrical resistivity between organic soils – characteristically low in resistivity – and underlying or adjacent mineral soils, which typically exhibit higher values. When calibrated with borehole information, this integrated approach yields a more comprehensive and reliable subsurface model, minimizing the likelihood of encountering unforeseen ground conditions. The main advantages of ERT for organic soil detection can be summarized as follows: (1) high sensitivity to contrasts in soil moisture and organic content, enabling reliable delineation of organic deposits; (2) continuous two- and three-dimensional imaging, overcoming the limitations of point-specific borehole data; (3) flexibility of application at different project stages, from early planning to construction monitoring; and (4) non-invasive and cost-effective character, allowing efficient surveys along extensive infrastructure alignments.

Complementary geophysical methods, such as seismic surveys, further enhance the understanding of subsurface conditions by providing dynamic soil parameters like stiffness and consolidation characteristics, which are critical for ground improvement and foundation design.

Case studies from Poland, including the A2 highway, S11, S5, and S16 expressways, as well as the Vistula River delta region, demonstrate the practical benefits of incorporating geophysical techniques into the geotechnical workflow. These examples highlight the capability of ERT to delineate organic soil layers within complex geological settings, including glacial terrains and areas with variable morphology. The ability to detect irregular and undulating boundaries – often missed by borehole investigations alone – supports better-informed engineering decisions, such as the need for soil replacement, consolidation, or deep foundations.

Furthermore, the suitability of geophysical methods for both early-stage investigations and continued monitoring during construction represents an important advantage. Repeated ERT surveys, for example, can reveal progressive changes in resistivity associated with variations in moisture content, providing valuable early warnings for potential geotechnical risks. Such monitoring has proven effective in practice, for instance in road embankment projects where post-rainfall resistivity decreases indicated the need for drainage improvements. This proactive approach allows engineers to track and manage evolving subsurface conditions, thereby enhancing safety, reliability, and cost efficiency while minimizing risks and avoiding schedule disruptions.

In conclusion, the integration of geophysical techniques with traditional geotechnical methods represents best practice in the detection and management of organic soils. As geophysical technologies and interpretation techniques continue to advance, their role in modern geotechnical engineering will likely expand, further improving the precision, reliability, and applicability of subsurface investigations in increasingly complex ground conditions.

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Wykorzystanie metod geofizycznych do wykrywania gruntów organicznych w planowanych pracach inżynieryjnych

Słowa kluczowe: badania geotechniczne, grunty organiczne, metody geofizyczne, projektowanie infrastruktury, tomografia elektrooporowa (ERT), wykrywanie gruntów słabych

Streszczenie:

W artykule omówiono praktyczne wykorzystanie tomografii elektrooporowej (ERT) do wyznaczania zasięgu i miąższości gruntów organicznych w projektach drogowych, takich jak autostrady czy drogi ekspresowe. Podkreślona została problematyczność gruntów organicznych, które ze względu na wysoką ściśliwość i zmienność litologiczną stanowią istotne wyzwanie w projektowaniu i realizacji inwestycji budowlanych. Metody geoelektryczne, zwłaszcza ERT, umożliwiają wczesne rozpoznanie tych stref przed wykonaniem wierceń, co jest kluczowe dla infrastruktury liniowej, takiej jak drogi, koleje czy rurociągi. Wczesna identyfikacja gruntów organicznych pozwala na optymalizację dokumentacji geologiczno-inżynierskiej, minimalizację ryzyka oraz redukcję kosztów związanych z potencjalnymi opóźnieniami i koniecznością wzmacniania podłoża. Przykłady badań pokazują, że wyniki ERT w połączeniu z danymi z wierceń umożliwiają precyzyjne określenie przebiegu stref gruntów organicznych. W przypadku autostrady A2 i drogi ekspresowej S11, analizy elektrooporowe skutecznie wskazały obszary niskooporowe, co pozwoliło na korektę rozmieszczenia otworów wiertniczych. Podobnie w badaniach dla trasy S16 tomografia elektrooporowa wykryła nawet niewielkie strefy występowania torfów o znacznej miąższości, natomiast analiza przekrojów dla trasy S5 wykazała, że model elektrooporowy precyzyjniej odzwierciedlał rozprzestrzenienie torfów niż pojedyncze otwory wiertnicze. Omówiono również znaczenie integracji wyników geofizycznych z danymi otworowymi, podkreślając, że badania elektrooporowe często wskazują na konieczność wykonania dodatkowych wierceń w strefach o skomplikowanej budowie geologicznej. Podkreślono, że metody geofizyczne, odpowiednio zintegrowane z badaniami inwazyjnymi, stanowią kluczowy element procesu dokumentowania podłoża w projektach infrastrukturalnych. Artykuł wskazuje na istotną rolę badań elektrooporowych w identyfikacji gruntów organicznych i optymalizacji procesów geotechnicznych w projektach budowlanych. Wnioski płynące z badań podkreślają skuteczność zastosowania metody ERT w wczesnym wykrywaniu stref problematycznych. Zwrócono także uwagę na konieczność ścisłej korelacji wyników badań geofizycznych z danymi wiertniczymi, co pozwala na dokładniejszą interpretację budowy geologicznej i lepsze planowanie inwestycji.

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