

Environmental Geophysics Applications for Sustainable Management and Pollution Detection

Roland Burgmann*

Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, Vancouver, Canada

DESCRIPTION

Environmental geophysics is a specialized field that applies geophysical methods to investigate and manage the Earth's near-surface environment in a sustainable and non-invasive manner. It focuses on understanding subsurface conditions that affect human health, infrastructure, and ecosystems by using indirect techniques that do not require extensive digging or drilling. This approach is essential for assessing environmental hazards, monitoring pollution, managing natural resources, and supporting land-use planning while minimizing ecological disturbance.

The primary goal of environmental geophysics is to detect and characterize subsurface features such as soil layers, groundwater zones, contaminant plumes, buried objects, and geological hazards. It achieves this by measuring physical properties of the Earth's near surface such as electrical conductivity, magnetic susceptibility, density, and seismic velocity and interpreting variations that reveal hidden environmental conditions. The use of non-destructive methods allows for rapid, cost-effective, and spatially extensive investigations, which are crucial for environmental management in both urban and rural settings.

Among the most widely used techniques in environmental geophysics is Electrical Resistivity Tomography (ERT). This method involves introducing an electrical current into the ground *via* electrodes and measuring the resulting voltage differences to determine the subsurface resistivity distribution. Since contaminants like heavy metals, hydrocarbons, or saline water usually increase conductivity, ERT is highly effective for mapping pollution plumes emanating from landfills, industrial sites, or leaking underground storage tanks. Additionally, ERT can identify variations in soil moisture content, groundwater depth, and stratigraphy, helping to delineate aquifers and monitor their quality.

Ground-Penetrating Radar (GPR) is another popular environmental geophysical method. GPR uses high-frequency electromagnetic pulses that reflect off subsurface structures and objects. It is capable of producing detailed images of shallow subsurface layers and detecting buried utilities, archaeological

remains, and voids such as sinkholes. GPR is favored for its high resolution and fast data acquisition, although its effectiveness depends on soil type highly conductive or clay-rich soils can attenuate the radar signal and limit penetration depth.

Seismic methods are also integral to environmental geophysics, particularly seismic refraction and surface wave techniques. These methods analyze how elastic waves travel through soil and rock to infer mechanical properties like stiffness, layering, and the presence of voids or fractures. Such information is critical for geotechnical site investigations, assessing earthquake hazards, and identifying subsurface anomalies that may influence construction or environmental safety. For example, seismic surveys can help determine the depth to bedrock or the extent of soft, unstable sediments prone to liquefaction during earthquakes.

Electromagnetic (EM) surveys are extensively applied in environmental investigations due to their ability to rapidly measure ground conductivity variations. EM methods generate time-varying magnetic fields that induce electrical currents in the subsurface, with sensors detecting the secondary magnetic fields produced. These techniques are particularly useful for identifying buried metal objects, monitoring saline water intrusion, mapping soil salinity in agricultural lands, and detecting contaminant migration. EM surveys are often combined with other geophysical methods to provide a comprehensive understanding of subsurface conditions.

Magnetic surveys, though traditionally used in mineral exploration, have valuable applications in environmental geophysics. They detect subtle variations in the Earth's magnetic field caused by ferrous objects, buried drums, landfill waste, and infrastructure. Magnetic data can reveal contamination sources and support site characterization efforts by locating buried debris or identifying anthropogenic disturbances.

One of the most important applications of environmental geophysics is groundwater exploration and management. Freshwater resources are under increasing stress due to pollution, overuse, and climate change, making it essential to understand aquifer properties and monitor water quality.

Correspondence to: Roland Burgmann, Department of Earth, Ocean, and Atmospheric Sciences, University of British Columbia, Vancouver, Canada, E-mail: sdev897789@eos.ca

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Geophysical methods such as ERT, EM, and seismic surveys help delineate aquifer boundaries, detect groundwater flow paths, and identify zones of contamination or saltwater intrusion. This knowledge supports sustainable water resource management, protects drinking water supplies, and guides remediation efforts.

Environmental geophysics also plays a crucial role in waste management and brownfield redevelopment. Many industrial and urban sites contain buried contaminants and abandoned infrastructure that pose risks to health and the environment. Geophysical surveys can quickly locate buried waste, map contamination extents, and monitor the integrity of containment systems. This information assists in risk assessment, cleanup planning, and regulatory compliance, ultimately facilitating the safe reuse of degraded lands.

As urbanization and infrastructure development expand, environmental geophysics provides valuable tools for geotechnical investigations. Before construction, geophysical surveys assess soil and rock properties, detect subsurface hazards, and guide foundation design. This reduces construction risks and costs while ensuring structural stability. Additionally, environmental geophysics aids in monitoring the health of critical infrastructure such as dams, levees, and tunnels, helping to detect internal flaws, seepage, or deterioration.

Advancements in technology and data processing are continuously enhancing the capabilities of environmental geophysics. The integration of geophysical data with Geographic Information Systems (GIS), remote sensing, and environmental modeling allows for more comprehensive and dynamic analyses. Furthermore, machine learning and artificial intelligence are increasingly applied to automate data interpretation, recognize patterns, and predict environmental changes, making investigations faster and more accurate.

CONCLUSION

In conclusion, environmental geophysics is an indispensable tool for sustainable environmental management. By providing non-invasive, high-resolution insights into the subsurface, it supports pollution detection, groundwater protection, land-use planning, and hazard mitigation. Its multidisciplinary nature and technological advancements make it essential for addressing the complex environmental challenges faced by modern society, promoting a healthier and safer planet for current and future generations.