USING SEISMIC SURVEY METHODS TO SOLVE ENGINEERING (HYDROTECHNICAL) PROBLEMS

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Abstract. *The development of hydroelectric construction has necessitated a comprehensive study of the rock masses forming the foundations of hydraulic structures. This issue becomes particularly relevant in the case of high dams, which are often accompanied by large reservoirs and are frequently located in areas of high seismic activity. The paper focuses on the role of engineering geophysics – specifically, seismics – in the construction of major structures. As an example, we present a specific project and the methods used for its implementation, namely the studies conducted by the Institute of Geophysics in the design area of the Nenskra Hydropower Plant.*

Key words: *Seismic Survey, Hydropower, Elastic Parameters.*

Introduction

According to the construction and operational project of the hydroelectric power plant (HPP), it is planned to build and operate a 280 MW high-pressure, seasonally regulated HPP in the Samegrelo-Zemo Svaneti region, specifically within the Mestia Municipality [1-5]. The construction is planned in the Nenskra River valley, utilizing the runoff from both the Nenskra and Nakra rivers.

It should be noted that the research was preceded by extensive exploratory work carried out over many years by various design and construction organizations from different countries. The goal of these studies was to select suitable locations for the intake structures and powerhouse of the future hydropower complex. A significant volume of geological and geophysical work was performed for this purpose.

Unfortunately, the results of these works did not allow for the selection of an optimal location for the intake structure. One of the main reasons was that the obtained data did not provide a clear, convincing image of the cross-section for the potential foundation of the future dam. This issue was further complicated by the fact that, based on borehole data from the study area, the thickness of alluvial gravel deposits above the bedrock in some places exceeds 70–80 meters. Under such local conditions, standard impact sources for elastic wave generation (e.g., hammer strikes) become ineffective for seismic investigations.

As a result, a new task was set: to conduct investigations in the designated areas using such methodology and equipment that would allow us to obtain reliable results and gain information about the subsurface structure down to the required depths.

Fieldwork was conducted using a 24-channel seismograph of the GEODE brand, produced by the American company GEOMETRICS, along with a full set of accessories. This equipment fully meets the requirements of the task at hand and is capable of operating with various seismic methods, including the refraction wave method and the common depth point (CDP) method.

Regarding the methodology, both the **refraction wave method** and the **common depth point method** were used.

The **refraction wave method** allows for determining the thickness of both shallow and deeper layers, as well as the velocities of elastic wave propagation through them. The method is based on determining the first arrival times of elastic waves from a source to geophones arranged in a straight line. Therefore, the research objective was to determine the structure of the rock formations [6-11].

Seismic profiling using the refraction wave method was carried out at the study site, providing information to depths of 45–120 meters. In addition to velocities, the density of each layer was also determined from the seismic profiles. Six seismic profiles, each 230 meters in length (totaling 1380 meters), were carried out. Fig. 1 shows the study area and the layout of the seismic profiles.

Fieldwork was conducted in collaboration with the geodesy service and explosives specialists.

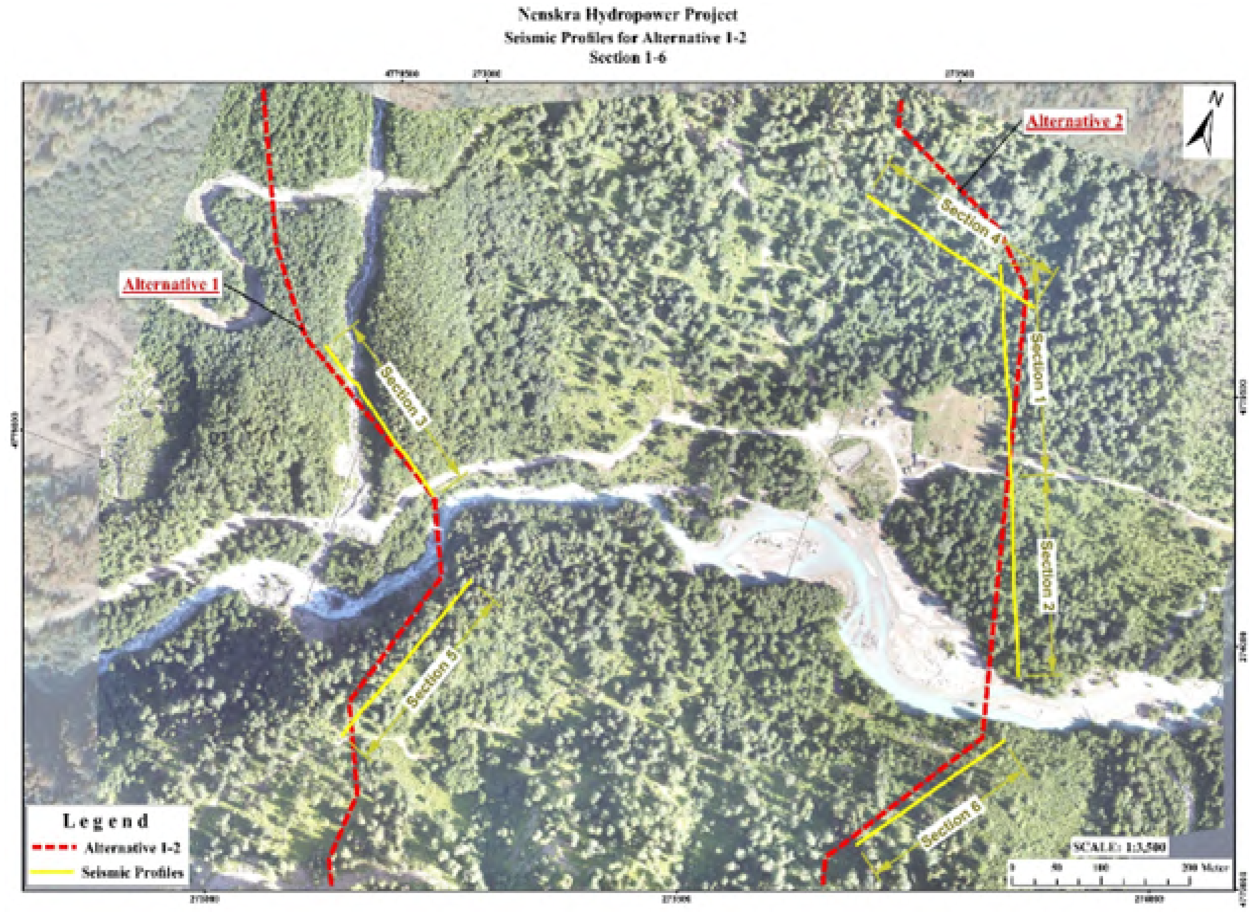


Fig. 1.

Results of Geophysical Surveys in the Nenskra River Valley

In our case, the survey area was quite limited, which posed certain challenges when selecting the survey geometry.

For each profile, 47 seismic impulses were generated – 23 within the profile itself, and 24 from points offset at the beginning and end of the profile. The spacing between both geophones and impulses was 10 meters.

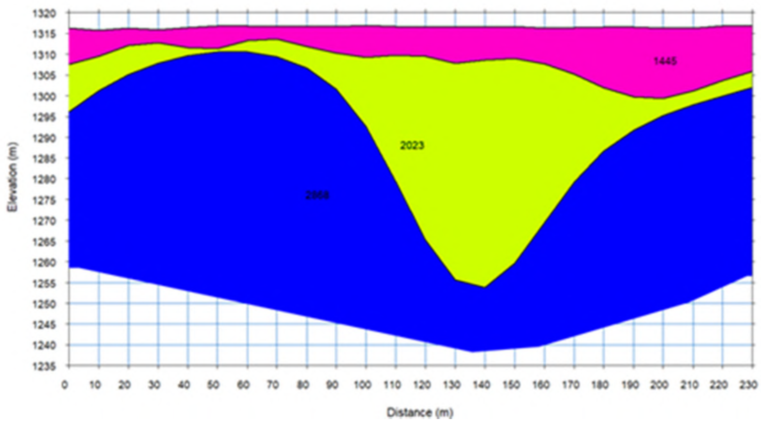
The survey employed 10 Hz geophones, and the seismic waves were induced by small explosive charges (up to 300 grams) in compliance with Georgian safety standards, ensuring the acquisition of clear records. The coordinates for the geophones and shot points were determined by a geodetic team.

Wave registration in both methods was carried out using a 24-channel engineering seismograph of the GEODE brand by the American company GEOMETRICS. Interpretation of the refraction wave method was performed using the licensed **SeisImager** software by the same company, while the **Common Depth Point (CDP)** method used licensed **RadexPro** software.

The acquired seismograms were analyzed, cross-sections constructed, and corresponding density values estimated.

Seismic Profile No. 1

The first superficial layer (Layer 1) extends from the surface to a depth of 3–20 meters, with an average compressional wave velocity of Vp = 1445 m/s and an average density of $\rho = 1.99$ g/cm^3. It is followed by **Layer 3**, which is in a water-saturated state, with a thickness ranging from 1 to 45 meters, an average compressional wave velocity of Vp = 2023 m/s, and an average density of $\rho = 2.16$ g/cm^3. Next is **Layer 4**, observed at depths ranging from 55 to 75 meters, with an average compressional wave velocity of Vp = 2868 m/s and an average density of $\rho = 2.36$ g/cm^3.



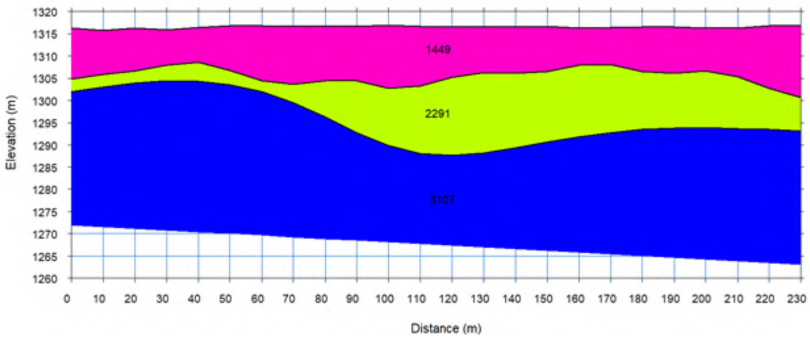
Layer №	*V* m/s	*ρ* g/cm³)
1	*1445*	*1.99*
3	*2023*	*2.16*
4	*2868*	*2.36*

Seismic Profile No. 2

The first near-surface layer (Layer 1) extends from the surface down to a depth of 10–17 meters, with an average compressional wave velocity Vp = 1449 m/s and an average density ρ = 1.99 g/cm³.

It is followed by Layer 3, in a water-saturated state, with a thickness of 2.5–15 meters, an average compressional wave velocity Vp = 2291 m/s, and an average density ρ = 2.23 g/cm³.

Next is Layer 4, observed at depths from 45 to 54 meters, with an average compressional wave velocity Vp = 3107 m/s and an average density ρ = 2.40 g/cm³.



Layer №	*V* m/s	*ρ* g/cm³)
1	*1449*	*1.99*
3	*2291*	*2.23*
4	*3107*	*2.40*

Seismic profiling was conducted using the Common Depth Point (CDP) method. Corresponding seismic-geological cross-sections were constructed, and compressional wave velocities were determined. The report includes cross-sections from two seismic profiles, each 230 meters in length. Fig. 1 shows the study area and the layout of the seismic profiles.

The resulting seismic sections are presented in Fig. 2 and Fig. 3. On these sections, the presumed reflective surfaces observed during the investigation are marked with black contours, based on our interpretation.

Seismic Profiles No. 1 and 2:

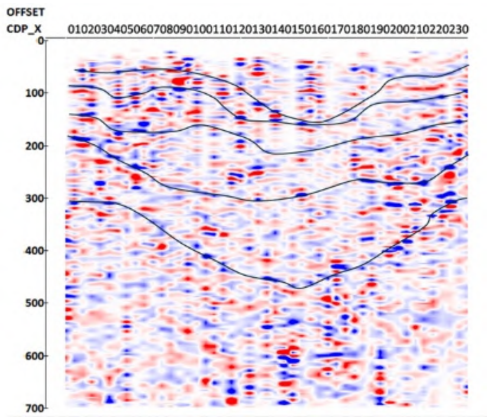


Fig. 2

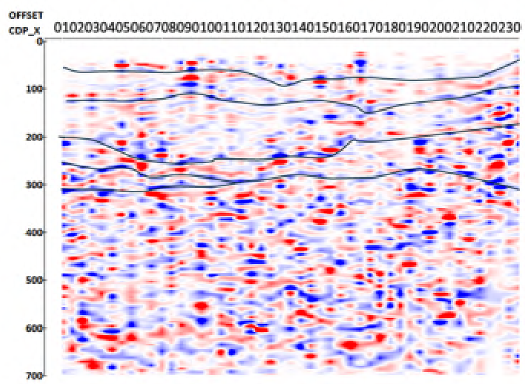


Fig. 3

Conclusion

Based on geophysical parameters, various engineering-geological elements (layers) have been identified, and the distribution of velocity values within them has been determined.

According to the geophysical data, the resulting cross-sections mainly reveal four distinct layers with different physical properties (identification was guided by engineering-geological information):

Layer 1 – Soil layer, loose fill;

Layer 2 – Boulder with clay filler;

Layer 3 – River alluvium, gravel and pebbles;

Layer 4 – Magmatic bedrock, presumably granite, with varying degrees of weathering and fracturing.

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The presumed reflective surfaces observed during the survey are marked on the sections with black contours, based on our interpretation.

The results obtained through the refracted wave method and the Common Depth Point (CDP) method are in good agreement with each other, considering the observed depths.

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