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GEOTECHNICAL DATA PROCESSING FOR ZONING USING GIS TECHNOLOGIES

ГИС ТЕХНОЛОГИЯЛАРЫН ҚОЛДАНА ОТЫРЫП ГЕОТЕХНИКАЛЫҚ МӘЛІМЕТТЕРДІ ӨҢДЕУ

ОБРАБОТКА ГЕОТЕХНИЧЕСКИХ ДАННЫХ ДЛЯ ЗОНИРОВАНИЯ С ИСПОЛЬЗОВАНИЕМ ГИС-ТЕХНОЛОГИЙ

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zoning, engineering and geological conditions, geoinformation database system, engineering and geological surveys, special geotechnical maps

ABSTRACT
Zoning of territories according to engineering and geological conditions, particularly within urbanized areas, is one of the priority tasks of engineering geology. To address this issue in the city of Pavlodar, a geoinformation database was developed based on materials from engineering and geological surveys. The database includes a city map with X and Y coordinates, as well as borehole log data, which makes it possible to conduct a preliminary analysis of soil conditions before carrying out detailed investigations. On the basis of this information, various engineering and geological maps are generated, including maps of the depth and thickness of Upper Quaternary eolian-deluvial deposits, Neogene lacustrine-alluvial sediments of the Pavlodar suite, as well as zoning maps by basic type.

Түйінді сөздер:
аудандастыру, инженерлік-геологиялық жағдайлар, геоақпараттық мәліметтер базасы жүйесі, инженерлік-геологиялық түсірістер, арнайы геотехникалық карталар

ТҮЙІНДЕМЕ
Инженерлік-геологиялық жағдайларға сәйкес аумақтарды зонирлеу, әсіресе урбанизацияланған аймақтарда, инженерлік геологияның басым міндеттерінің бірі болып табылады. Осы мәселені шешу мақсатында Павлодар қаласында инженерлік-геологиялық ізденістер материалдары негізінде геоақпараттық деректер қоры жасалды. Деректер қорына X және Y координаттары бар қаланың картасы, сондай-ақ бұрғылау журналдарының мәліметтері енгізілді, бұл топырақ жағдайларын егжей-тегжейлі зерттеулер жүргізбестен бұрын алдын ала талдауға мүмкіндік береді. Осы мәліметтердің негізінде әртүрлі инженерлік-геологиялық карталар жасалады. Олардың қатарында төрттік дәуірдің жоғарғы бөлігіндегі эолды-делювиальды шөгінділердің, неоген кезеңінің көлдік-аллювиальды Павлодар свитасының жыныстарының қалыңдығы мен жату тереңдігі карталары, сондай-ақ базалық түр бойынша аудандастыру картасы бар.

Ключевые слова:
районирование, инженерно-геологические условия, система геоинформационных баз данных, инженерно-геологические изыскания, специальные инженерно-геологические карты

АННОТАЦИЯ
Зонирование территорий по инженерно-геологическим условиям, особенно в пределах урбанизированных зон, является одной из приоритетных задач инженерной геологии. Для решения этой задачи в городе Павлодар была сформирована геоинформационная база данных, основанная на материалах инженерно-геологических изысканий. В ее состав вошла карта города с координатами X и Y, а также данные буровых журналов, что обеспечивает возможность предварительного анализа грунтовых условий перед проведением детальных исследований. На базе этой информации создаются инженерно-геологические карты различного назначения, включая карты глубины и мощности верхнечетвертичных эолово-делювиальных отложений, неогеновых озерно-аллювиальных пород Павлодарской свиты, а также карты районирования по базовому типу.

INTRODUCTION

The comprehensive analysis of geotechnical and geological parameters at construction sites represents a fundamental prerequisite for project viability. Geotechnical site conditions encompass the collective elements within the subsurface environment that may influence proposed infrastructure and building systems, including topographical features, subsurface geology, hydrological conditions, soil characteristics and behavior, and potential geohazard phenomena. When structural foundation stability or building integrity concerns arise, site-specific assessments must identify potential subsurface processes that could emerge unexpectedly during or after construction phases. The geotechnical landscape across the nation exhibits considerable variability yet benefits from extensive research documentation, enabling engineering professionals to formulate design solutions with appropriate confidence levels and technical justification (Ledeneeva E.V. 2008).

However, the data of engineering and geological surveys in the regions are practically not generalized and are most often in paper form. As a rule, companies operating in the field of engineering surveys, accumulating impressive archives, are most often not very open in data exchange. All this complicates the conduct of survey work, it is more difficult for prospectors to predict the development of engineering and geological processes, and most importantly, there are cases of duplicate work, and sometimes full-fledged surveys on the same territories.

A geoinformation system is a toolkit with which you can solve problems for which there were no ready-made solutions before. In turn, the collection, generalization, systematization and processing of data about the surrounding world are the main tasks of modern science (Tsypileva T.A. 2010). For rational forecasting of changes in the geological environment in the construction industry, it is advisable to use a geotechnical geoinformation system (GIS), taking into account many years of construction experience. The capabilities of this system allow you to organize the available information, structure it, ensure long-term and safe storage, and most importantly, use the available data in the form of special geotechnical maps.

To ensure an objective evaluation of the engineering and geological environment within the developed part of Pavlodar, a specialized geoinformation database was compiled. This system was constructed using data obtained from engineering and geological surveys conducted across the city’s territory. Its implementation makes it possible to conduct preliminary analysis of regional soil characteristics even prior to undertaking detailed field investigations.

METHODS AND MATERIALS

The assessment of engineering and geological conditions within the urban environment was conducted using a GIS-based methodological framework specifically designed to integrate survey data into a comprehensive spatial model. The initial stage of the work involved the collection and systematization of materials from engineering and geological investigations. These datasets served as the foundation for the development of a geoinformation program for the city of Pavlodar, which was implemented as a two-level architectural system. Within this structure, distinct modules are responsible for system coordination, validation and control of incoming data, information retrieval and analytical processing, as well as database expansion and refinement.

The supervisory level of the system ensures strategic coordination and coherence of operations, while the operational level addresses practical tasks such as data preparation, analysis, and workflow organization. This hierarchical division supports both the reliability and flexibility of the information framework, enabling efficient management of complex geological datasets.

Methodological implementation followed a sequence of integrated procedures. The spatial boundaries of the study area were delineated and translated into a digital environment using AutoCAD. Survey points were subsequently mapped, assigned identification codes, and accurately georeferenced through the registration of X and Y coordinates. The resulting dataset was then consolidated into Excel-based tables, ensuring systematic storage and accessibility for further analytical processing (Alibekova N.T., 2009; Zhussupbekov A.Zh. et al., 2019).

The applied methodology provides not only a structured mechanism for organizing engineering and geological information but also introduces an innovative approach to its representation, enhancing the analytical potential of GIS for urban planning and sustainable development.

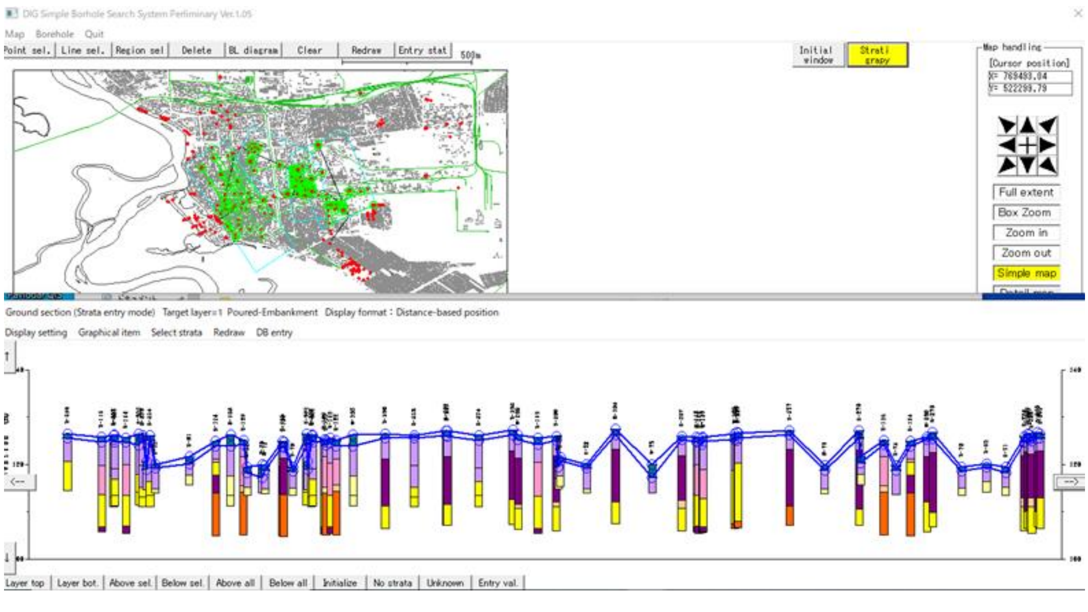

Figure 1. General view of the Geoinformation database program
Note – compiled by the author

The city of Pavlodar is situated in the northeastern part of Kazakhstan, extending along both banks of the Irtysh River (Fig. 2). Geographically, the settlement lies between 41°57' and 54°27' north latitude and between 73°25' and 79°20' east longitude (Greenwich). Its administrative territory encompasses an area of approximately 127.5 thousand square kilometers. Pavlodar region shares borders with East Kazakhstan and Karaganda regions to the south, Akmola and North Kazakhstan regions to the west, and with three Russian regions—Omsk to the north, Novosibirsk to the northeast, and Altai Krai to the east.

At present, Pavlodar functions as a major hub of both industrial activity and cultural development. The industrial profile of the region is largely defined by enterprises within the mining, metallurgical, and energy sectors. Consequently, industrial output is dominated by intermediate goods such as coal, alumina, ferroalloys, and electricity. Owing to its industrial strength and cultural resources, Pavlodar holds the potential to evolve into a leading center not only within Kazakhstan but across Central Asia (Demographic Indicators, 2012; Pavlodar Region, 2010).

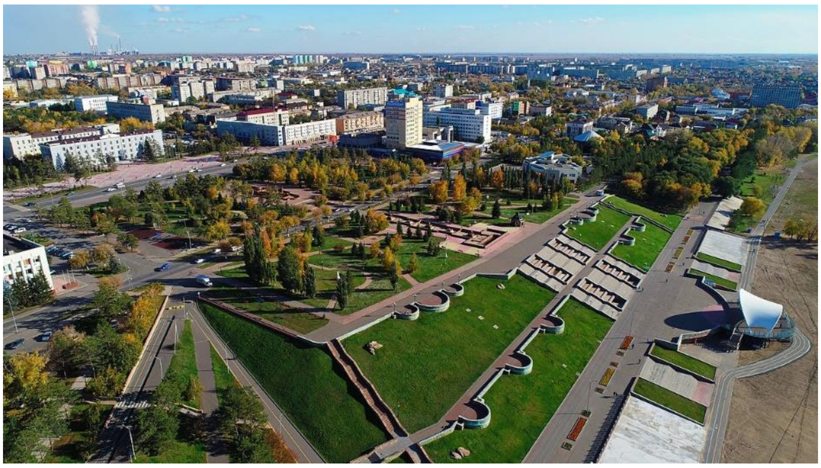

Figure 2. View of Pavlodar City

Note – compiled by the author

From a geological and structural perspective, the Pavlodar region is situated within the transitional zone between two major tectonic formations: the Kazakh folded belt (Saryarka), which accounts for roughly one-quarter of the region's territory, and the West Siberian Lowland. The geological framework of the area is composed of igneous, volcanic, metamorphic, and sedimentary rocks that vary significantly in lithological characteristics. The stratigraphic profile reveals deposits spanning a wide temporal range, including Pre-Paleozoic formations as well as sequences from the Lower, Middle, and Upper Paleozoic, followed by layers of Mesozoic and Cenozoic age (Abisheva, A.K., 2021).

An assessment of the soil conditions within the urbanized areas of Pavlodar was conducted using the Geoinformation Database program. This analysis made it possible to distinguish six principal engineering-geological elements (EGE), which characterize the structural and genetic features of the region's soils (Abisheva, A.K., 2021):

EGE-1 — technogenic deposits (tQIV) represented by the topsoil (EGE-1a) and backfill (EGE-1b) (Figure 3). Topsoil is represented by humus sandy loam with plant roots, the backfill is composed of sandy loam with sand and construction debris of 20%.

EGE-2 — alluvial-deluvial deposits of Upper Quaternary and modern ages (adQII-IV), consisting of carbonated, subsident sandy loam (EGE-2a) from solid to fluid consistency and clay loam (EGE-2b). According to (SP RK 1.02–102-2014), the sandy loam in this layer is a specific soil, when soaked with water it has subsidence properties under household and additional loads. Capacity of this soil is measured from 0.9 up to 10.3 m (Figure 4,5).

EGE-3 — alluvial-deluvial deposits of Upper Quaternary and modern ages of sand (adQII-IV) is located at the depth of 2,5 to 8.0 m (Figure 6). According to the field description, all sands are similar in color, mostly yellow-brown, dense, saturated with water, with single layers of soft-plastic clay, differ only in the amount of the determining fraction according to the granulometric composition.

EGE-4 — deposits of neogene age (N) represented by sand of various size. According to the granulometric composition, the sands of the deposits are medium-sized, coarse (Figure 7). The thickness of the sands increases from south to north and varies from 0.6 to 9.7 m.

EGE-5 — deposits of neogene age represented by sandy clay loam. Brown loam is soft-flowable micaceous, thin-layered with inclusions of marl up to 5-15%, interlayer of clay, fine sand and sandy loam saturated with water, thickness of interlayers up to 1-10 cm.

EGE-6 — deposits of neogene age includes clays (Figure 8) that are represented by lacustrine-alluvial deposits of the Pavlodar suite (EGE-6a), the Aral suite (EGE-6b), the Kulunda suite (EGE-6c). Lacustrine-alluvial deposits of the Pavlodar suite are represented by brown clay and loam, with a thickness of 1.6 to 5.2 m (Figure 8). Lacustrine-alluvial deposits of the Aral suite represented by clay from light gray to gray green, from hard-plastic to semi-hard, ferruginous, manganese, with inclusions of gypsum up to 10% and marl up to 5%. The thickness of clays varies from 2.5 to 16.2 m. Lacustrine-alluvial deposit of the Kulunda suite are represented brownish-gray, greenish-brown, greenish-gray clays, containing calcareous-marl nodules ranging in size from 0.1 to 0.2 cm and interlayers of sand. Clay thickness varies from 0.5 to 7.6 m.

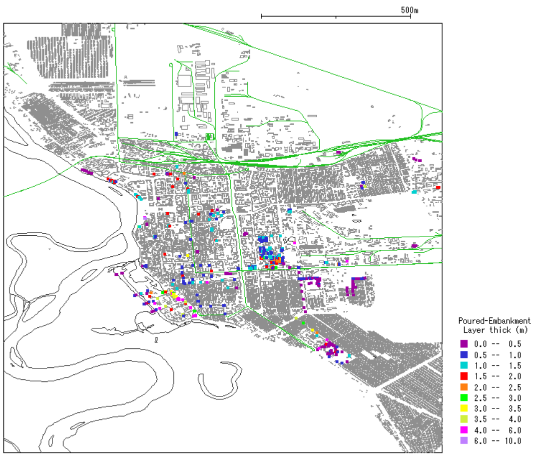

Figure 3. Thickness of technogenic deposits

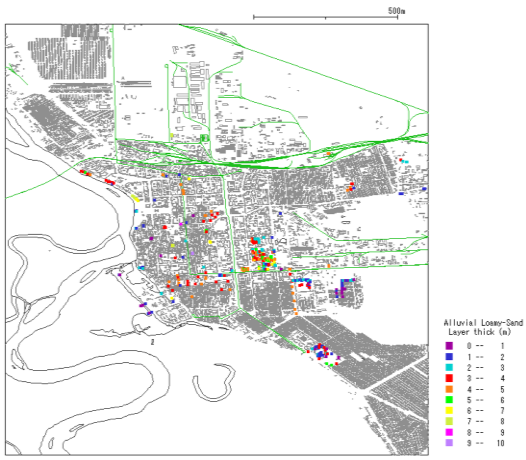

Figure 4. Thickness of alluvial deluvial loamy sand

Note – compiled by the author

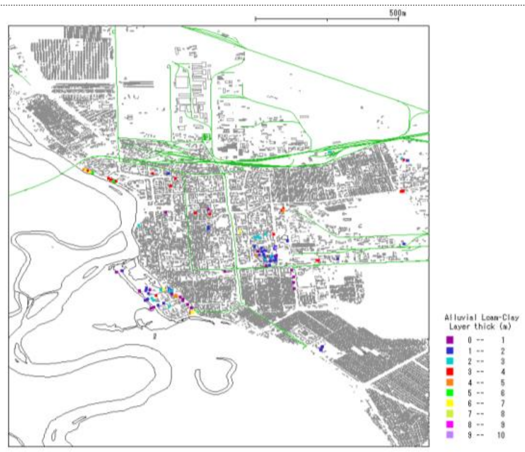

Figure 5. Thickness of alluvial deluvial loam clay soils

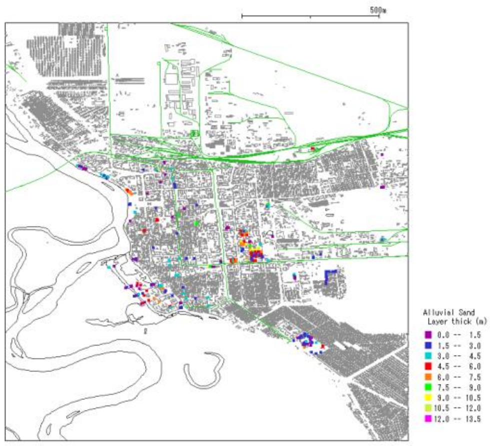

Figure 6. Thickness of alluvial deluvial sand

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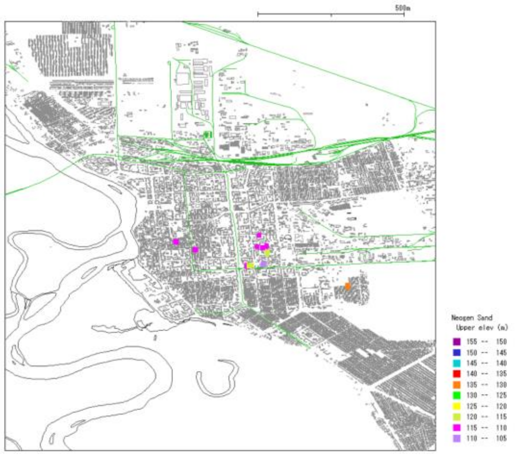

Figure 7. Upper elevation of neogen sand

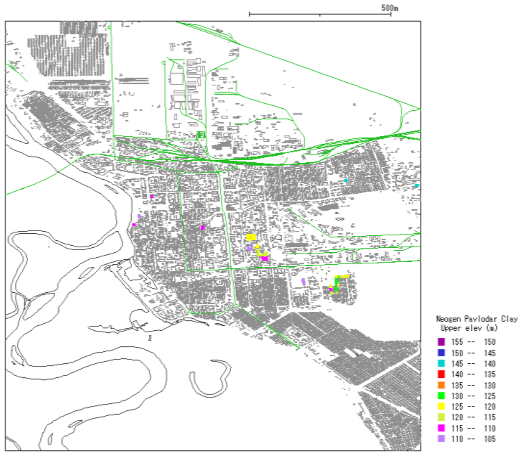

Figure 8. Upper elevation of neogen clay of Pavlodar suite

Note – compiled by the author

CONCLUSION

Although geoinformation technologies are still evolving, their current state already makes it possible to take advantage of the strengths offered by different software solutions. The creation and application of a geoinformation system in the sphere of urban planning in Kazakhstan provides an opportunity to streamline geotechnical activities and improve their efficiency. Present practice demonstrates that, during the evaluation of built-up areas and the decision-making process in design, considerable financial, material, and labor resources are often spent inefficiently. This is largely due to excessive caution in foundation projects, where past construction experience is insufficiently taken into account. The introduction of the "Geoinformation Database" program, together with the use of specialized geotechnical maps, enables rapid access to essential data. Such tools support the substantiation of design solutions in construction and assist in the rational planning of urban development.

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