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On the issue of formalization of the creation of special geotechnical maps

Abstract. Today in the scientific and technical literature of Kazakhstan as well as abroad there are a significant amount of works which have been devoted to engineering-geological mapping. By means of specialized maps it is obviously possible to assess geological profile of building ground in general, and separate sites of project facilities. The assessment of geological profile of territory of cities is impossible without geoinformation technologies at the present time. Improvement of mapping services and technologies of GIS software are widely used for engineering-geological mapping, development plan of territories, forecasting dangerous natural processes and assessment of various risks. However introduction of geoinformation technologies and special engineering-geological mapping in the Republic Kazakhstan is underdeveloped and does not play a leading role in engineering practice. The article addresses formalization of the process of creating special geotechnical maps in GIS as a certain step-by-step description of the process, based on a number of principles that determine the characteristics of map indicators and the methods of mapping. Special geotechnical maps are a basis for the decision of practical problems connected with an arrangement of constructions on the building ground, a detailed planning and project formulation of building blocks. The analysis of the existing methods of assessing geological profile of the built-up territory of the city was given in order to optimize the survey and engineering work on the construction of foundations, an example of the developed geoinformation database for the analysis of geotechnical properties of soils and the development of special geotechnical maps was given in addition. Also examples of types and the reasons of deformations of buildings and constructions caused by variations in the bases of foundations , besides the research works of the authors who developed their own methods of conducting engineering and geological surveys and special geotechnical maps have been analyzed and the concepts as «engineering-geological maps», «special geotechnical maps» have been defined.

Keywords: formalization, special geotechnical maps, geoinformation system, engineering-geological surveys, deformations of buildings and constructions, engineering-geological conditions, geoinformation database, engineering-geological maps.

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Introduction

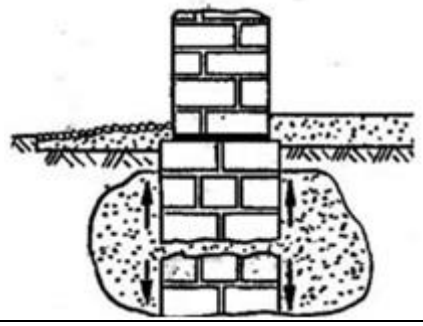
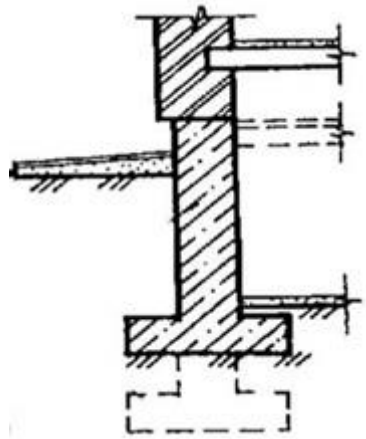
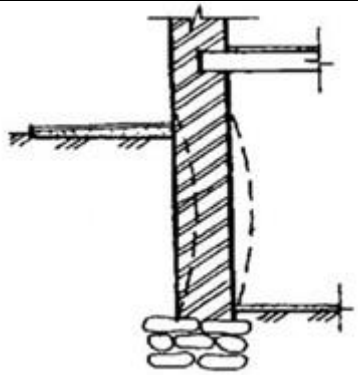
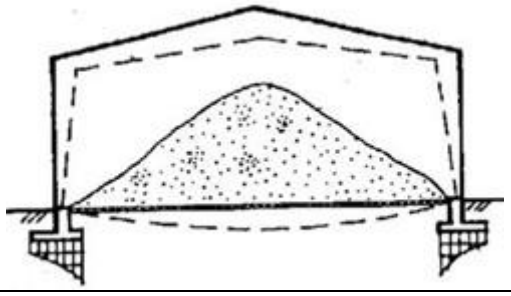
The modern construction system is organized in such a way that engineering and geological surveys, development of building projects, design of bases and foundations, work on their arrangement are carried out by organizations that poorly coordinating with each other. Their joint work is regulated by the provisions of normative documents [1 -**], unified throughout the territory of the Republic of Kazakhstan, which are not fully observed. And, despite the large volume of construction, on the territory of cities, full-scale observations of the precipitation of buildings from the moment of their construction are carried out extremely rarely and commonly for a short time. In general, design engineers return to the design objects only in cases of damage to structures caused by changes in the foundations that lead to deformations of constructions. Examples of some deformations are given in Table 1.

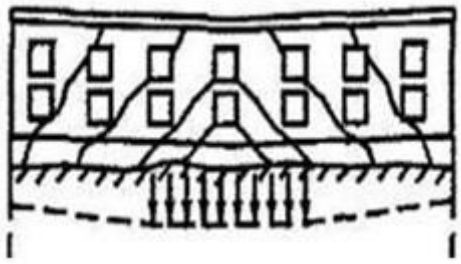
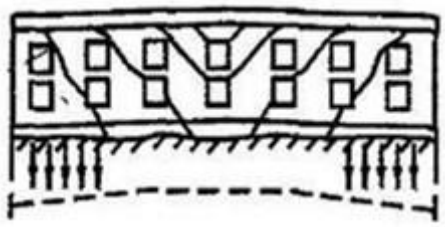
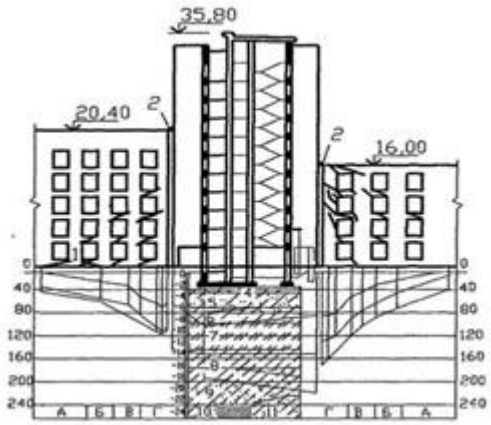
In these cases, verification calculations give little, since observations organized after the occurrence of damage do not have sufficient information content. This leads to the fact that in most cases, designers and researchers do not have full-fledged materials based on which it is possible to

check and correct the calculations of the bases, to make a reasonable choice of the precipitation forecast method considering the specific engineering and geological conditions of the region [2].

Table 1

Types and causes of deformation of structures of buildings and structures

Deformation diagram constructions	Type and reasons deformation
	Breakng the foundation. *Possible causes of damage* - frost heaving of base soils with incorrect foundation arrangement; - moistening of soils due to a rise in the level of groundwater or flooding of the territory and frost heaving of base soils.
	Inadmissible deformations of the base. *Possible causes of damage:* - insufficient support area of the foundation sole; - emergency soaking of base soils; - additional loading due to the superstructure; - the presence of highly compressible soils at the base.
	Deformations of the building foundation wall *Possible causes of damage:* - loss of strength of a brick wall; - additional load on the base surface in the immediate vicinity of the building; - frosty heaving of the soil due to improper operation of the basement.
	Deformation of the frame when overloading the floor *Possible causes of damage:* - exceeding the permissible values of temporary long-term loads.

	Building deflection *Possible causes of damage:* - incorrect structural solution of foundations on heterogeneous soils; - softening of soils in the middle of the building; - frosty heaving of soils under the ends of the building.
	Building bend *Possible causes of damage:* - incorrect constructive solution of foundations on heterogeneous soils; - softening of soils under the ends of the building; - frosty heaving of soils in the middle of the building.
	Distortion of old buildings due to the construction of a new building - inserts *Possible causes of damage:* - incorrect structural solution of the foundations in the place where the new building adjoins the old ones

The construction of the foundation is determined by the climatic conditions of the construction site, the type of structure, loads and various effects (deformation, aggressive, etc.), the capabilities of the construction organization and other less significant factors. But, in addition to the above conditions, the choice of engineering and geological conditions is also of great importance [3].

When designing foundations, several options for their structures are first assigned. Sometimes, with the same design options, different methods of preparing the base are taken.

Caked fill soils and dumps of soils from coarse sands, gravelly and crushed stone soils can be used as natural bases.

The main methods of preparation of foundations on bulk soils are surface compaction with heavy rammers; ramming of foundation pits; the device of pillows; surface compaction with vibrating machines; deep compaction by punching boreholes, cutting of bulk soils with deep foundations.

For the convenience of preliminary designation of foundation structures, depending on the engineering and geological conditions of the site, the known types of soils are schematically subdivided according to their physical and mechanical characteristics and their layers in depth into separate types. The subdivision of soils according to their physical and mechanical characteristics is conditional since the same soil can be strong for low-rise buildings and fragile for multi-storey buildings. However, the conditional division of soil layers into separate schemes makes it easier to choose options. Experience shows that in the practice of surveying and designing quarterly urban development, the type of soil and geological conditions are not sufficiently considered. This leads to the irrational use of the natural

resources of the foundations for the construction of reliable and sustainable buildings and structures. This problem arises during the construction of buildings and structures on the territory of cities.

Considering the massive nature of modern construction of buildings and structures on various types of soils, it must be recognized that the development of new principles for the formation of building blocks in such conditions can give a significant economic effect [3].

For a more complete description of the issue under consideration, the research works of some authors were studied [1, 4-8], who, when achieving their goals, solved the problems of optimizing the choice of building structures under various engineering and geological conditions.

For example, in the dissertation «Analysis of geotechnical properties of soil in Astana city for optimization of lengths of piles» [1] of the applicant for the academic degree of PhD, the author N. Alibekova performed several tasks to achieve the following goal: Study and analysis of the geotechnical properties of soils in the city of Nur-Sultan (Astana) to optimize pile lengths in conditions of a variety of soil strata. The applicant completed such tasks as: generalization and analysis of methods for studying and assessing the geotechnical properties of soils the foundations of pile foundations; developing a method for assessing engineering and geological conditions; creating a geoinformation database. Using the program «Geoinformation database», an assessment of engineering and geological conditions in the built-up area of the city Nur-Sultan (Astana) was made, engineering-geological maps of Quaternary sediments and bedrocks, deposited in the city Nur-Sultan (Astana), were developed, special geotechnical zoning maps for 8 types of foundations and optimization of the lengths driven piles; the values the bearing capacity of driven piles, determined according to the calculation data and field tests, were compared; a coefficient of reliability is proposed for determining the bearing capacity of driven piles. Recommendations on the use of the program «Geoinformation database» and geotechnical zoning map are offered

In the dissertation «Features of the methodology of engineering a.nd geological surveys in the conditions of dense urban development: on the example of the city of Moscow» [4] for the degree of candidate of technical sciences, the author E. Vorontsov carried out an analysis of the current state of the engineering and geological surveys (EGS) in urban areas, developed a research methodology and characteristics of the studied objects, determined the influence of dense urban development on the conduct of IGI, outlined fundamental approaches to the EGS technique in dense urban development and developed the main provisions of the recommended methodology EGS for the construction and reconstruction of buildings and structures in dense urban areas. The main idea of the applicant's work was to take into account the influence of the existing dense urban development in the EGS methodology on obtaining the necessary and sufficient information about the engineering and geological conditions of the projected construction (reconstruction) of buildings and structures, as well as construction objects in the zone of influence.

Author N. Tyunina in her thesis for the degree of candidate of geological and mineralogical sciences «Features of the application of the method of engineering-geological analogies in surveys in urban areas: the example of the city Moscow» [5] analyzed the current state of the theory and practice of applying the method of analogies in engineering geology, developed a research methodology and gave a characterization of the studied objects, developed the basic theoretical provisions for the application of the method of engineering and geological analogies (EGA) in surveys in urban areas, including: studying the natural and technical system «Geological environment – Construction object – Urban environment», determining the value of engineering and geological the study of the territory for the use of the EGA method, consideration of the concept and principles of applying the EGA method in surveys in urban areas. In addition, the study by the author of the features the EGA method in relation to the research tasks allowed the applicant to develop recommendations for the use of the EGA method in surveys in urban areas.

Author S. Akhazhanov in his dissertation for the degree of Doctor of Philosophy «Development of a geoinformation database for installation of bored piles in Nur-Sultan» [6] defined the purpose of the

work, namely: The creation of a geoinformation database of bored piles, considering the engineering-geological environment of Nur- Sultan. The applicant completed several tasks and received the following scientific results: using the program «Geographic Information Database» [1], a special geotechnical map was developed to optimize the lengths of bored piles; the values of the bearing capacity of bored piles, determined from the calculation data and field tests, were compared; the coefficient of reliability is proposed for determining the bearing capacity of bored piles.

The dissertation for the degree of candidate of technical sciences, the author K.Kh. Nguyen «Methodology for choosing the optimal foundations for high-rise buildings in the conditions of Ho Chi Minh City» [7]. The applicant initially studied the geographic and geological conditions of the city of Ho Chi Minh City, engineering-geological zoning for the selection of the optimal foundation, principles and experience of engineering-geological zoning, analyzed the experience of constructing foundations for high-rise buildings and foreign experience in constructing fondations for high-rise buildings, including in Vietnam. Further, the author analyzed and compared methods for determining the settlement of foundations and selected the optimal parameters of the foundation in the city. As a result, a geotechnical map was drawn up on the optimal type of foundations for multi-storey buildings in the soil conditions of Ho Chi Minh City.

The authors I. T. de Sena Nola, L.M. Zuquette in their scientific publication «Procedures of engineering geological mapping applied to urban planning in a data-scarce area: Application in southern Brazil» [8] defined the goal of the work, namely: to verify the efficacy of procedures, methods and classification schemes based on engineering geological mapping principles to generate data and maps for urban planning, restructuring (rehabilitation) and engineering projects. First, the mapping criteria, characterization methods and classification procedures were selected for the mapping and engineering geological classification of the natural geological materials and anthropogenic deposits. The results obtained for the study area provide users with data to foresee construction-related challenges (cost of engineering works, manmade slope instability and the planning of detailed geological geotechnical investigations to obtain more specific data) and environmental problems (natural slope instability, inadequate conditions for sustainable urban drainage systems). 2 complex zones were identified and delineated that are characterized by high diversity and spatial variability of the natural geological materials associated with anthropogenic deposits and morphological changes.

These studies have made a serious contribution to the methodology of engineering and geological surveys and the development of special geotechnical maps.

Currently, one of the most urgent tasks in cartography is still the formalization of the mapping process, considering the widespread use of computer technologies and GIS technologies.

According to some authors, the introduction of formal procedures in cartographic work makes it possible to automate the daily and labor-intensive stages of mapping, thereby freeing up time for experimentation and creativity in the field of cartographic modeling and map design [9].

In the general case, formalization [10] means the representation of any area content (reasoning, evidence, classification procedures, information retrieval of scientific theories) in the form of a formal system or calculus. According to some authors, the choice of suitable presentation forms is one of the first steps in formalizing and building a model. The second and probably the most difficult step in the entire process of formalizing the model should focus on the methods and rules that bind the data being processed. In the process of formalization, it is better to use tabular data of statistical studies. Text data is the least suitable for formalization.

Classification of engineering-geological maps. Engineering-geological maps [11] – type of geological maps, which show all the most important geological factors considered in planning, design, construction, operation of structures and other engineering activities, as well as in predicting changes in the geological environment under the influence of engineering and economic activities. Geotechnical maps show the age, genesis, conditions of occurrence, composition, structure and physical and mechanical properties of rocks and complexes and their distribution geomorphological characteristics of the territory,

hydrogeological conditions, and geodynamic phenomena. Maps are accompanied by sections, tables, text explanations (Fig. 1).

Geological mapping consists in the systematic and comprehensive study of natural and artificial outcrops of rocks to determine their composition of origin, age and forms of occurrence and plot their distribution on a topographic map.

Geological maps represent an image on a topographic map using conventional signs of distribution and conditions of occurrence of rocks on the earth's surface, divided by age and composition. Maps are one of the most important results of geological mapping but can also be compiled based on processing materials accumulated during geological research [11].

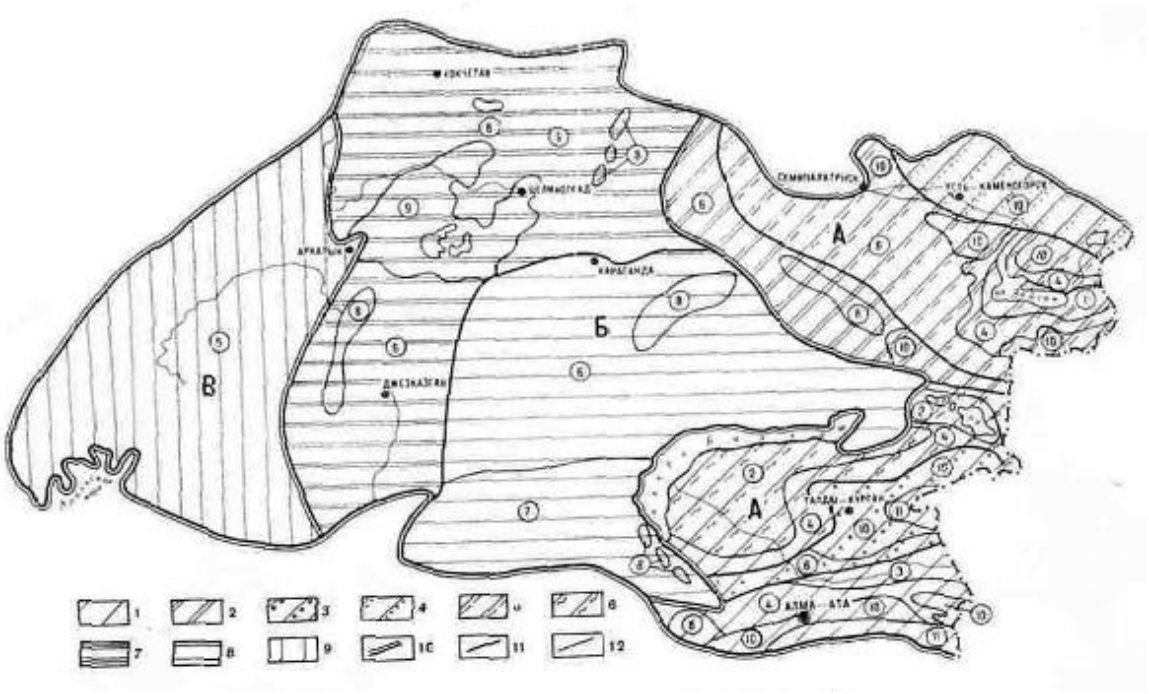


Figure 1. Example of the scheme of engineering and geological zoning of Kazakhstan

Engineering-geological regions of the first order: 1- Ore belt of Kazakhstn, 2- Kazakh shield; 3- Turan plate. Engineering-geological regions of the second order: 1 - North Tien Shan; 2 - Chingiz-Tarbagatai. 3- Dzungarian; 4 - Altai: 5 - Irtysh-Zaisan; 6 - Alakol-Balkhash; 7 - Kokshetau-Ulytau; 8 - Central Kazakhstan; 9- Turgai; 10 - first-order regional boundaries; 11 - second-order regional boundaries; 12 - boundaries of engineering and geological areas. The circles indicate geotechnical areas.

Maps of engineering-geological conditions are the most numerous of the published engineering-geological maps. They reflect the main natural factors that determine the engineering and geological situation and affect the conditions of design, construction, and operation of engineering structures. According to their content, maps of engineering and geological conditions are divided into synthetic and analytical one.

Synthetic maps comprehensively characterize the geological structure of the area, the nature of the rocks composing it (composition, state, conditions of occurrence, properties), relief (primarily its morphological and morphometric features), geocryological conditions (distribution of frozen, thawed and unfrozen strata, their temperature, thickness of frozen rocks, their cryogenic structure, depth of seasonal thawing-freezing, etc.), hydrogeological features (types, patterns of distribution, depth of occurrence, water availability and regime groundwater, its composition and mineralization, aggressiveness towards building materials, etc.) and modern geological processes and phenomena [12].

The analytical maps give a characteristic of one or more components of the engineering-geological situation. These can be geological processes or a single process, fracturing, the depths, and types of seasonal freezing and thawing, the iciness of soils, the thickness of permafrost rocks, the salinity of soils, the depth of groundwater, etc.

Both synthetic and analytical maps of engineering and geological conditions can be both general and special for their purpose. On the general maps, the components of engineering and geological conditions, as already noted, are selected, schematized, and characterized in accordance with the requirements of regulatory documents, without considering the requirements of any particular type of construction [12].

Methodology for creating special geotechnical maps

It is important for the study that engineering-geological cartography developed in the USSR for more than half a century, but specialized maps have not yet received sufficient development in the practice of surveys and design. One of the reasons is that the majority of engineering-geological maps are still extremely difficult for non-specialists (not geologists), hence the reason for their poor use in design and construction practice [13].

For a specific construction site or several of its homogeneous types, special geotechnical maps are created, considering the specific needs of construction, in particular, the arrangement of foundations for geological-ecological and urban zoning. According to them, it is possible to assess the engineering-geological state of the construction site as whole and individual sections of the projected structures, as well as to determine the exploration plan for experimental works and the organization of stationary observations [1].

For optimal use of the geological environment, considering many years of construction experience, special geotechnical maps can be developed using the program «Geoinformation Database» [1].

The following is the order of construction of maps [14]:

1. The graphical module of the program «Geoinformation Database» shows the existing exploration boreholes and probing points.

2. The line of the engineering-geological section is set (with automatic inclusion of the boreholes required for this). The user can change this set of boreholes, adding or removing them in the dialog mode, as well as redefine the cut line and create a new set of boreholes from the very beginning.

3. The stratigraphic boundaries of rocks are determined and engineering-geological elements (EGE) are distinguished.

4. Information on all the boundaries of the EGE is included in a specific folder. Both the coordinates of the EGE and their boundaries are marked. It is also possible to graphically edit the EGE borders or add new ones at any time.

5. Based on the processed information, maps of quaternary sediments and bedrock are constructed (Fig. 2a, b).

6. Based on the graphical analysis of engineering-geological sections, it is possible to build a zoning map by type of foundation (Fig. 2c).

The results of the development of special geotechnical maps

Special engineering and geological mapping for applied purposes – the development of urban development projects taking into account the factors of foundation construction – still does not play a significant role in the design practice in Kazakhstan. The reasons for this, according to L. G. Zavarzin, are [15]:

1) insufficiently developed methodology for drawing up special maps. In some cases, they are excessively complex and difficult to read, in others they are too primitive, not revealing the connection of natural phenomena;

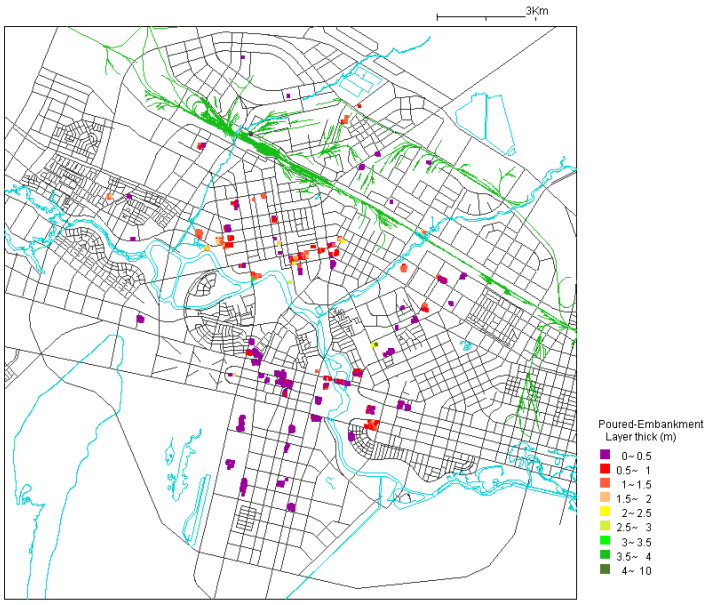
2) lack of awareness of the majority of builders and designers about what a specialized engineering and geological map gives, which systematizes survey data by area and allows for a much faster and more objective assessment of the construction area;

3) geological engineers, not seeing the interest of architects and designers in such maps and not receiving tasks for their implementation, do not take the initiative to compile them themselves.

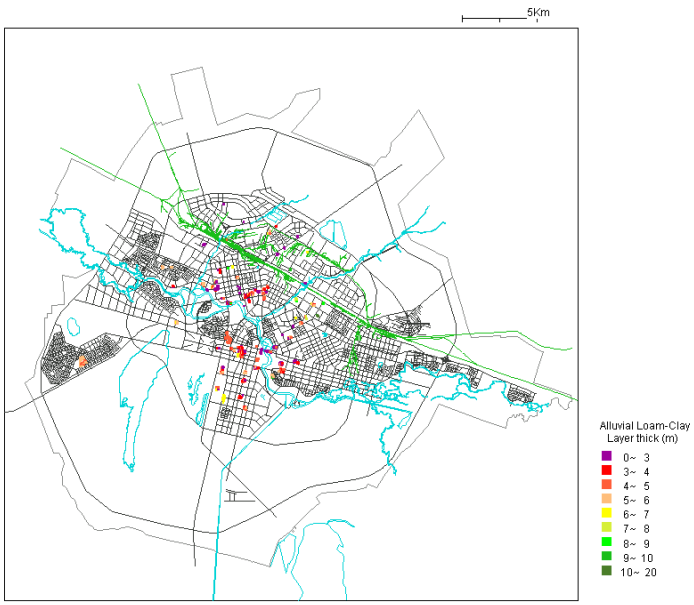
Although the current state of engineering and geological mapping of Kazakhstan has a theoretical and practical basis for the development of special geotechnical maps [1].

For example, using the geotechnical GIS «Geoinformation Database of Astana» for the first time, special geotechnical maps of the occurrence of quaternary deposits and bedrock soils and zoning maps by base type and optimization of the length of driven piles for buildings of the 2nd (normal) level of responsibility, taking into account the type of base (Fig. 2) [14, 16] were created, which were developed on the basis of the methodology for construction purposes [14]:

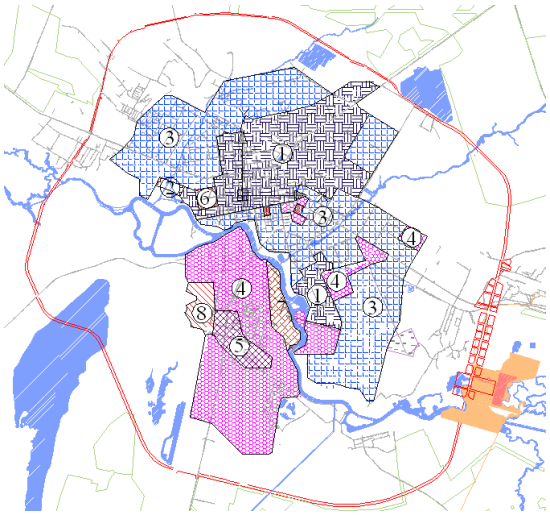
1) the purpose of the map is determined, i.e. the construction event for which the map is being compiled is indicated (engineering training, engineering network design, foundation and foundation design, zero-cycle work, etc.);



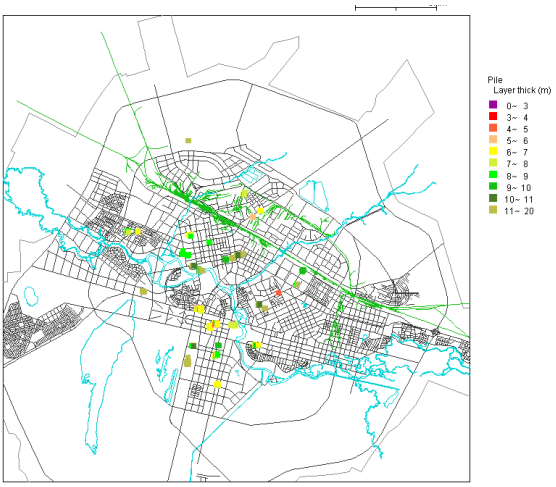
a) map of the occurrence of technogenic deposits displaying their power



b) map of occurrence of alluvial deposits displaying their power



c) geotechnical zoning map by type of foundation



d) geotechnical zoning map to optimize the lengths of driven piles

Figure 2. Special geotechnical maps of the city of Nur-Sultan (Astana)

2) the main construction factors related to soils and which are the main ones for the justification of this construction are established;

3) archival materials of engineering and geological surveys on the territory of the development are studied and selected, which are useful for drawing up a map;

4) the identification of soils by their age, origin, composition, condition is performed; separate varieties of sediments (for example, quaternary) are distinguished;

5) complexes of combining soils are formed; sections of soil strata are drawn up; soil arrays of one or another type of addition are outlined in area;

6) a soil map and its symbols are compiled; tables of generalized soil properties are given; recommended construction measures are noted.

Conclusion

As a result of the study, material was obtained, the analysis of which made it possible to conclude that the capabilities of cartographic systems are absolutely sufficient to create simple in terms of content and design, but informative maps of natural resources for unprepared users.

Along with this, it should be noted that the developed technological sequence for the formalized creation of special geotechnical maps for extensive coverage of users, allows you to optimize the types of foundations depending on the location of construction objects on the appropriate soil conditions of urban development, as well as to quickly receive the necessary information for the purpose of substantiating design work in construction and planning the development of the city territory.

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Арнайы геотехникалық карталарды құруды рәсімдеу мәселесі бойынша

Аңдатпа. Бүгінгі күнге дейін ғылыми-техникалық әдебиеттерде, біздің елде де, шетелде де инженерлік-геологиялық картаға арналған жұмыстардың айтарлықтай саны бар. Мамандандырылған карталардың көмегімен жалпы құрылыс алаңының инженерлік-геологиялық жағдайларын және жобаланған құрылымдардың жекелеген учаскелерін бағалауға болады. Қазіргі

уақытта қалалар аумағының геологиялық жағдайларын бағалау геоақпараттық технологияларсыз мүмкін емес. Геоақпараттық жүйелер өнімдерінің картографиялық қызметтері мен технологияларын жетілдіру инженерлік-геологиялық карта жасау, аумақтарды дамытуды жоспарлау, қауіпті табиғи процестерді болжау және әртүрлі тәуекелдерді бағалау үшін кеңінен қолданылады. Алайда, Қазақстан Республикасында геоақпараттық технологиялар мен арнайы инженерлік-геологиялық картаны енгізу дамымаған және жобалау тәжірибесінде маңызды рөл атқармайды. Мақалада кескінделген индикаторлардың сипаттамаларын анықтайтын бірқатар принциптерге және карталарды құрастыру әдістемесіне сүйене отырып, арнайы геотехникалық карталарды құру процесін белгілі бір кезеңдік сипаттама ретінде қарастырылады. Арнайы геотехникалық карталар құрылымның құрылыс алаңында орналасуына байланысты практикалық мәселелерді шешуге, егжей-тегжейлі жоспарлау мен жобаларды құруға негіз болады. Іргетастарды орналастыру бойынша іздестіру және жобалау жұмыстарын оңтайландыру мақсатында қалада орналасқан аймақтың инженерлік-геологиялық жағдайларын бағалаудың қолданыстағы әдістеріне талдау жасалды және геоақпараттық мәліметтер жиынтығын топырақтың геотехникалық қасиеттерін талдау және арнайы геотехникалық карталарды жасау әзірленіп берілген. Сонымен қатар, іргетастардың өзгеруінен және шөгуінен туындаған ғимараттар мен құрылымдарының деформацияларының түрлері мен себептерінің мысалдары қарастырылып, оның үстіне инженерлік-геологиялық зерттеулер мен арнайы геотехникалық карталарды жүргізудің өзіндік әдістерін жасаған авторлардың ғылыми-зерттеу жұмыстары талданды, «инженерлік-геологиялық карталар», «арнайы геотехникалық карталар» ұғымдарына анықтама берілген.

Түйін сөздер: рәсімдеу, арнайы геотехникалық карталар, инженерлік-геологиялық жағдайлар, геоақпараттық технологиялар, геоақпараттық жүйелер, ғимараттар мен құрылыстар құрылымдарының деформациялары, инженерлік-геологиялық ізденістер, геоақпараттық мәліметтер жиынтығы, инженерлік-геологиялық карталар.

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К вопросу формализации создания специальных геотехнических карт

Аннотация. На сегодняшний день в научно-технической литературе как у нас, так и за границей имеется значительное количество работ, которые были посвящены инженерно-геологическому картированию. При помощи специализированных карт представляется возможным давать оценку инженерно-геологических условий строительной площадки в общем, и отдельных участков проектируемых сооружений. Оценка геологических условий территории городов в нынешнее время невозможна без геоинформационных технологий. Усовершенствование картографических сервисов и технологии ГИС-продуктов широко используются для инженерно-геологического картирования, планирования развития территорий, прогноза опасных природных процессов, оценки различных рисков. Однако внедрение геоинформационных технологий и специальное инженерно-геологическое картирование в Республике Казахстан недостаточно развито и не играет значительной роли в практике проектирования. В статье рассматривается формализация процесса создания специальных геотехнических карт в ГИС среде как определенное поэтапное описание процесса, основывающийся на ряд принципов, которые определяют характеристики картографируемых показателей и методику составления карт. Специальные геотехнические карты, являются основой для решения практических задач, связанных с расположением конструкции на строительной площадке, детальной планировки и

составлением проектов застройки кварталов. Был приведен анализ существующих методик оценки инженерно-геологических условий застраиваемой территории города с целью оптимизации изыскательских и проектных работ по устройству фундаментов, приведен пример разработанной геоинформационной базы данных для анализа геотехнических свойств грунтов и разработки специальных геотехнических карт. Также рассмотрены примеры видов и причин деформаций конструкций зданий и сооружений, вызванных изменениями в основаниях фундаментов, кроме того, проанализированы научно-исследовательские работы авторов, которые разработали собственные методики проведения инженерно-геологических изысканий и специальные геотехнические карты, дано определение понятиям «инженерно-геологические карты», «специальные геотехнические карты».

Ключевые слова: формализация, специальные геотехнические карты, инженерно-геологические условия, геоинформационные технологии, геоинформационная система, деформации конструкций зданий и сооружений, инженерно-геологические изыскания, геоинформационная база данных, инженерно-геологические карты.

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