## Coğrafiya elmləri / Geographical Sciences

# THE ROLE OF GEOLOGICAL-GEOMORPHOLOGICAL CONDITIONS IN URBAN DEVELOPMENT

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***Abstract.*** This study examines the geological and geomorphological conditions relevant to urban planning in selected cities and adjoining districts along the Kura River in Azerbaijan. The objective is to identify terrain characteristics and geological constraints that should be considered when assessing land for urban development. The analysis combines published geological and geomorphological information with terrain analysis conducted in ArcMap. Elevation, slope gradient, and slope aspect are examined to characterize spatial differences within the study area. Particular attention is paid to unconsolidated deposits, shallow groundwater, erosion, flooding, waterlogging, salinization, and slope instability. The analysis indicates that predominantly low elevations and gentle slopes offer opportunities for infrastructure development, while drainage conditions and the properties of near-surface materials require site-specific investigation. Low relief alone is insufficient to establish construction suitability, and the effects of slope aspect depend on local environmental conditions and the intended land use. The study provides a preliminary framework for integrating terrain characteristics and geological information into urban planning. Detailed engineering-geological investigations, groundwater monitoring, and hazard assessment are required before individual sites can be considered suitable for construction.

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## 1. Introduction

Urban development transforms the natural environment through changes in land use, surface drainage, groundwater conditions, and the distribution of built infrastructure. These transformations interact with the geological and geomorphological characteristics of the territory. Consequently, urban planning requires an assessment of both the existing terrain and the processes that may affect its stability under changing land-use conditions.

Geological and geomorphological factors influence urban development through several interrelated mechanisms. Lithological composition and the physical properties of near-surface materials affect ground behaviour, while landform configuration influences drainage and the spatial arrangement of infrastructure. Elevation, slope gradient, and slope aspect provide useful information for preliminary terrain assessment. However, these indicators cannot independently establish construction suitability, which also depends on subsurface conditions, groundwater, and exposure to natural hazards.

The Kura River corridor provides an important setting for examining these relationships in Azerbaijan. The geological and geomorphological characteristics of the Kura Depression reflect its tectonic development, sediment accumulation, and subsequent modification by fluvial and other surface processes (Müseyibov, 1998). Within this broader setting, differences in sediment properties, drainage conditions, and landform configuration require attention when assessing individual urban areas. Soil conditions and their ecological characteristics also form part of the environmental context of land development (Mammadov, 1998).

Urban areas along the river and their surroundings may face different combinations of geological and hydrological constraints. In low-lying areas, shallow groundwater and inadequate drainage can complicate land development. On slopes and reservoir margins, instability and erosion may require separate investigation. Rzayev (2013), for example, examined the activity of exogenic geological processes in the slope adjoining the Mingachevir Reservoir dam. Such differences indicate that planning constraints should be assessed at an appropriate

local scale rather than generalized across the entire river corridor.

An earlier study addressed the influence of geological and geomorphological conditions on urban planning in the lower course of the Kura River (Nagiyev, 2023). The present article considers these relationships through the interpretation of geological information alongside mapped elevation, slope gradient, and slope aspect. These terrain indicators provide a basis for identifying spatial contrasts and discussing where more detailed engineering-geological and hydrogeological investigations are needed.

The aim of this study is to assess geological and geomorphological conditions relevant to urban planning in selected cities and adjoining districts along the Kura River. The specific objectives are to characterize the geological and landform setting, examine the spatial distribution of elevation and slope characteristics, and identify the principal constraints that should inform further site assessment. The study is intended to support preliminary planning decisions rather than replace detailed investigations required for the design and construction of individual facilities.

## 2. Materials and methods

The study examines selected cities and adjoining districts along the Kura River in Azerbaijan. The analysis combines published geological and geomorphological information with terrain mapping in a geographic information system. Particular attention is given to elevation, slope gradient, slope aspect, near-surface deposits, and geological processes relevant to urban planning.

### 2.1. Geological and geomorphological information

Published sources were used to describe the geological setting, landform characteristics, soil conditions, and reported exogenic processes within the study area. Regional physical geography and soil assessment literature provided background information for interpreting the terrain (Müseyibov, 1998; Mammadov, 1998). Studies addressing urban planning in the lower Kura area and slope processes near the Mingachevir Reservoir were also considered (Nagiyev, 2023; Rzayev, 2013).

The literature review focused on conditions that may constrain urban development, including erosion, slope instability, flooding, waterlogging, salinization, and ground settlement. Reported processes were distinguished from those that could be assessed directly through terrain mapping. Elevation and slope characteristics were therefore interpreted as preliminary indicators rather than direct measurements of geological hazard or construction suitability.

### 2.2. GIS-based terrain analysis

Terrain analysis was conducted using ArcMap. Elevation, slope gradient, and slope aspect maps were prepared to characterize spatial differences within the study area. Elevation was expressed in metres relative to sea level, slope gradient in degrees, and slope aspect by directional classes, with flat terrain identified separately.

The mapped classes were summarized using percentage distributions to describe the relative extent of different terrain conditions. The resulting maps and diagrams were interpreted together with the published geological information to examine their relevance to drainage, infrastructure placement, and the identification of areas requiring further investigation.

Slope aspect was considered only where a discernible slope was present. In nearly level terrain, aspect values require cautious interpretation because small elevation differences and the resolution of the elevation data can influence the calculated direction.

### 2.3. Interpretation and limitations

The assessment is intended for preliminary urban planning. Terrain characteristics were examined in relation to possible development opportunities and constraints, without assigning definitive engineering suitability classes. Low elevation, gentle slopes, or the presence of Quaternary deposits were not treated as sufficient evidence of favourable foundation conditions.

The analysis does not replace borehole investigations, laboratory testing of ground materials, groundwater monitoring, seismic assessment, or site-specific hazard studies. Its findings should be interpreted within the spatial resolution and accuracy of the input data.

## 3. Results and discussion

### 3.1. Geological and geomorphological conditions

The selected urban areas and adjoining districts along the Kura River exhibit differences in elevation, surface configuration, and geological conditions. These differences influence the spatial distribution of potential constraints on urban development. Low-lying plains constitute the predominant terrain, whereas more elevated and dissected surfaces occur mainly within the northern part of the study area.

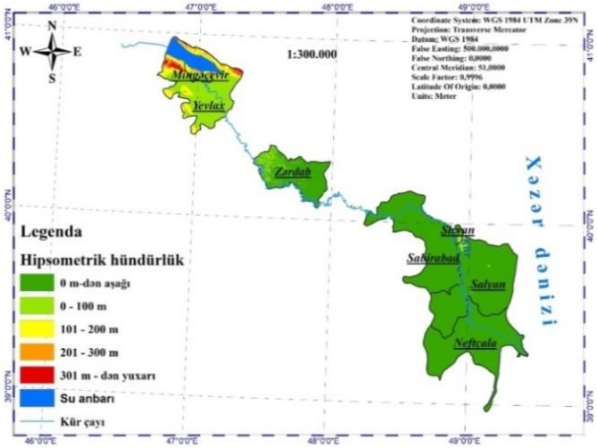
The regional geological context provides a basis for interpreting these terrain characteristics

(Müseyibov, 1998). However, regional geological information and terrain analysis alone cannot establish the engineering properties of individual construction sites. The suitability of unconsolidated deposits depends on their composition, density, thickness, moisture conditions, and interaction with groundwater. Consequently, the presence of Quaternary deposits should not, by itself, be interpreted as evidence of favourable construction conditions.

The terrain analysis addresses three complementary characteristics: elevation, slope gradient, and slope aspect. Together, these indicators support a preliminary assessment of the physical conditions relevant to urban planning.

### 3.2. Elevation characteristics

The elevation analysis demonstrates the predominance of low-lying terrain. The class distribution indicates that approximately 74.8% of the analysed territory lies below sea level, while 19.0% falls within the 0–100 m elevation interval. Thus, approximately 93.8% of the territory lies below 100 m. The remaining classes account for 4.3% at 101–200 m, 1.3% at 201–300 m, and 0.6% above 300 m.




**Map 1.** Elevation distribution within the study area
***Source:*** *Author's GIS analysis.*

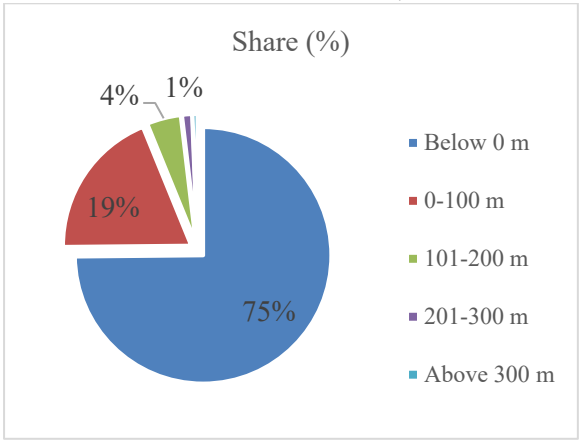


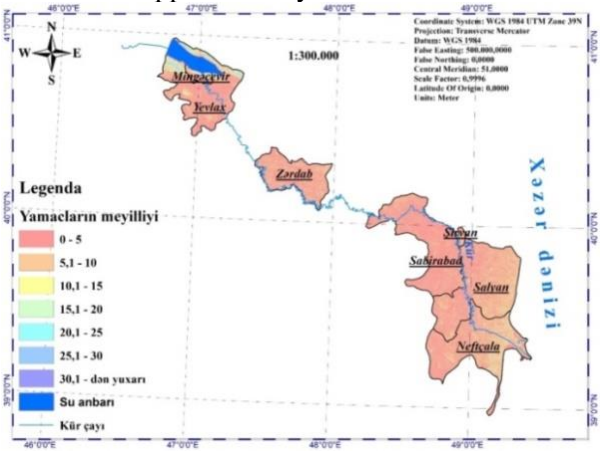

**Diagram 1.** Percentage distribution of elevation classes within the study area
**Source:** Author's calculations based on the elevation analysis.

The predominance of low elevations is relevant to the assessment of surface drainage and possible inundation. Nevertheless, absolute elevation does not independently determine flood exposure or groundwater depth. These conditions also depend on river levels, local drainage, protective infrastructure, sediment permeability, and groundwater dynamics.

Accordingly, the elevation map should be used to identify areas requiring more detailed hydrological and engineering investigation. It should not be treated as a direct map of flood hazard or construction suitability.

### 3.3. Slope characteristics

The slope analysis indicates that gently inclined surfaces dominate the study area. Slopes within the 0–5° class account for approximately 28.2%, while those within the 5–10° class account for 37.7%. Together, these classes represent approximately 65.9% of the analysed territory. Slopes of 10–15° constitute 20.6%, whereas slopes exceeding 15° collectively account for approximately 13.5%.




**Map 2.** Spatial distribution of slope gradients within the study area
**Source:** Author's GIS analysis

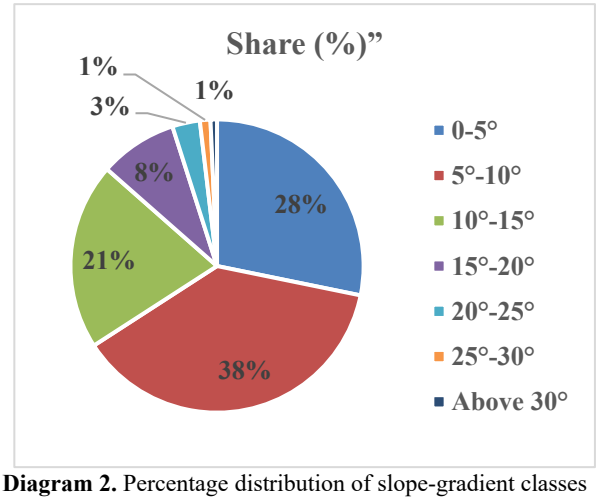


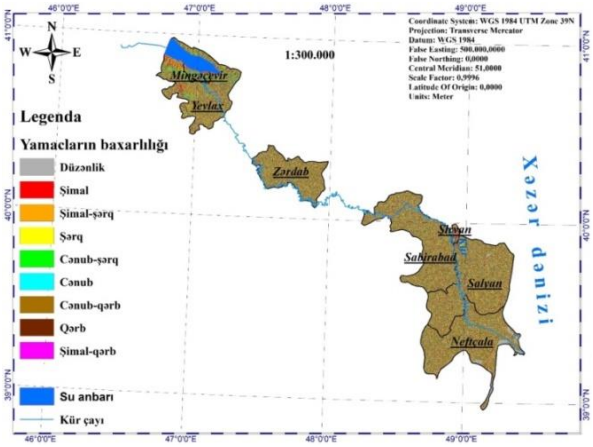

**Diagram 2.** Percentage distribution of slope-gradient classes within the study area.
**Source:** Author's calculations based on the slope analysis.

Gentle slopes may facilitate the spatial arrangement of buildings, transport routes, and utility networks. However, limited surface gradients may also require particular attention to stormwater drainage. The engineering implications therefore depend on the interaction between terrain, soil properties, groundwater conditions, and infrastructure design.

Steeper terrain is more locally distributed and requires separate consideration. Previous research concerning the slopes adjoining the Mingachevir Reservoir demonstrates the relevance of exogenic processes to the regional assessment (Rzayev, 2013). Nevertheless, slope gradient alone does not establish slope instability. Site-specific assessment must also consider lithology, geological structure, groundwater, erosion, and human modification.

### 3.4. Slope-aspect characteristics

The aspect analysis identifies differences in the orientation of inclined surfaces. North-facing slopes account for approximately 19.4% of the analysed territory, while south-facing slopes represent 10.3%. Flat surfaces constitute approximately 12.5%. The remaining directional classes individually account for approximately 9.1–10.0%.




**Map 3.** Spatial distribution of slope aspects within the study area
**Source:** Author's GIS analysis.

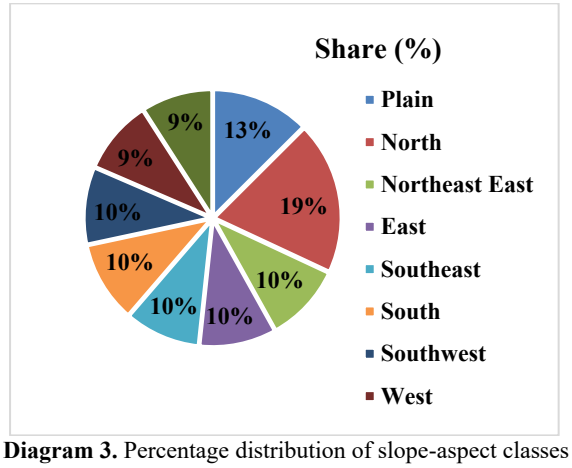



**Diagram 3.** Percentage distribution of slope-aspect classes within the study area
**Source**: Author's calculations based on the aspect analysis.

Slope aspect provides supplementary information for evaluating terrain conditions. However, its interpretation requires particular caution on nearly flat surfaces, where small elevation differences can influence the calculated direction. The aspect map therefore cannot independently justify decisions concerning the location of roads, residential buildings, or public facilities.

### 3.5. Implications for urban planning

The combined analysis indicates that urban planning should distinguish between the constraints associated with low-lying plains and those associated with locally steeper terrain. In low-elevation areas, further assessment should prioritise drainage, groundwater conditions, possible inundation, and the engineering properties of surface deposits. In more inclined areas, attention should focus on slope stability, erosion, and the effects of excavation or additional loading.

The maps provide a preliminary spatial framework for selecting areas for detailed investigation. Their application to specific development projects requires geological surveys, groundwater observations, geotechnical testing, and consideration of existing infrastructure. The principal contribution of the analysis is therefore the identification of terrain characteristics relevant to planning and the clarification of the investigations needed before construction decisions are made.

## 4. Conclusions

The study identifies elevation, slope gradient, and slope aspect as useful indicators for the preliminary assessment of terrain conditions relevant to urban development along the Kura River. Their interpretation alongside published geological information helps identify areas requiring more detailed engineering-geological and hydrogeological investigation.

The analysed territory is predominantly low-lying: approximately 74.8% lies below sea level, and 93.8% lies below 100 m. Slopes of up to 10° account for approximately 65.9% of the territory. These characteristics provide opportunities for infrastructure development but also highlight the importance of assessing surface drainage, groundwater conditions, and the engineering properties of near-surface deposits. Low elevation and gentle slopes alone do not establish construction suitability.

Locally steeper terrain requires particular attention to erosion, slope stability, and the effects of excavation and additional loading. Slope aspect provides supplementary

information, although its interpretation is less reliable on nearly level surfaces and should remain secondary to geological, hydrological, and geotechnical evidence.

The resulting maps and diagrams provide a preliminary basis for directing further investigations and incorporating terrain conditions into urban planning. Before construction decisions are made, this assessment should be supplemented by site-specific geological surveys, geotechnical testing, groundwater monitoring, and hazard analysis. Integrating these investigations with terrain mapping can support more informed land allocation and infrastructure planning.

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## ŞƏHƏRLƏRİN İNKİŞAFINDA GEOLOJİ-GEOMORFOLOJİ ŞƏRAİTİN ROLU

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***Xülasə.*** Tədqiqatda Azərbaycanın Kür çayı boyunca yerləşən seçilmiş şəhərlərində və onlara bitişik rayonlarda şəhərsalma baxımından əhəmiyyət daşıyan geoloji və geomorfoloji şərait araşdırılır. Məqsəd şəhərsalma üçün ərazilərin qiymətləndirilməsi zamanı nəzərə alınmalı relyef xüsusiyyətlərini və geoloji məhdudiyyətləri müəyyənləşdirməkdir. Təhlildə dərc olunmuş geoloji və geomorfoloji məlumatlar ArcMap mühitində aparılmış relyef təhlili ilə birləşdirilmişdir. Tədqiqat ərazisində məkan fərqlərini səciyyələndirmək üçün mütləq hündürlük, yamacların meyilliyi və ekspozisiyası təhlil edilmişdir. Bərkiməmiş çöküntülərə, səthə yaxın qrunt sularına, eroziyaya, daşqınlara, bataqlaşmaya, şoranlaşmaya və yamacların dayanıqsızlığına xüsusi diqqət yetirilmişdir. Təhlil göstərir ki, ərazidə alçaq mütləq hündürlüklərin və azmeyilli səthlərin üstünlük təşkil etməsi infrastrukturun inkişafı üçün imkanlar yaradır. Bununla yanaşı, drenaj şəraiti və səthə yaxın süxur və çöküntülərin xüsusiyyətləri konkret sahələr üzrə ayrıca tədqiqat tələb edir. Yalnız relyefin az parçalanmış olması ərazinin tikintiyə yararlılığını müəyyənləşdirmək üçün kifayət etmir. Yamacların ekspozisiyasının təsiri isə yerli təbii şəraitdən və nəzərdə tutulan torpaq istifadəsindən asılıdır. Tədqiqat relyef xüsusiyyətlərinin və geoloji məlumatların şəhərsalma prosesinə inteqrasiyası üçün ilkin yanaşma təqdim edir. Ayrı-ayrı sahələrin tikintiyə yararlı hesab edilməsindən əvvəl ətraflı mühəndisi-geoloji tədqiqatların aparılması, qrunt sularının monitorinqi və təhlükələrin qiymətləndirilməsi zəruridir.

***Açar sözlər:*** *şəhərsalma, geoloji şərait, geomorfoloji qiymətləndirmə, relyefin təhlili, coğrafi informasiya sistemləri, Kür çayı, Azərbaycan*

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