Creation of Topographic Maps for the Nuclear Power Plant Construction Site based on Remote Sensing Data

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Abstract

This article focuses on carrying out design work using digital orthophoto maps and digital elevation models (DEM). Creating orthophoto maps and DEMs based on remote sensing data is one of the most relevant issues in current geospatial analysis. In this context, the article presents methods for generating and updating topographic plans at scales of 1:1,000, 1:2,000, and 1:5,000, as well as digital maps at scales of 1:10,000 and 1:25,000 for areas designated for the construction of nuclear power plants. The study emphasizes the use of remote sensing materials (RSM) and the application of specialized geographic information systems (GIS) to analyze terrain changes quickly and produce high-accuracy topographic maps.

1. Introduction

One of the most pressing issues today is the use of remote sensing data to update topographic plans at scales of 1:1,000, 1:2,000, and 1:5,000, as well as digital maps at scales of 1:10,000 and 1:25,000 for the area designated for the construction of the atomic power plant. In the process of updating these maps, existing published cartographic materials are thoroughly analyzed, and territorial changes are identified. Systematic research has revealed that various methods for creating topographic maps have been studied in order to detect and update these changes effectively. It is particularly important to emphasize that in the existing literature, changes between remote sensing materials and topographic maps are evaluated only in qualitative terms, using descriptors such as “many” or “few.” In order to achieve a higher level of accuracy in identifying these changes and to further improve the reliability of the data, a new evaluation scale, allowing both qualitative and quantitative assessments based on a 5-point scale and 100-percent grading,has been developed for the first time. (Table 1)

According to the table above, it was determined that within a 25 km radius of the area planned for the construction of the nuclear power plant, the relief variation is less than 20%, while the change in settlement areas exceeds 40%. As the study progressed, it was conditionally established that the level of exploration of the area planned for the construction of the nuclear power plant corresponds to 3 points or ranges from 40 to 60 percent. Based on this, it was deemed necessary to carry out medium-level processing of the topographic maps of the area intended for the construction of the nuclear power plant using large-scale satellite imagery.

For this purpose, initial topographic, geological, geophysical, hydrogeological, and environmental research was conducted within 10 km and 30 km radii of the proposed nuclear power plant construction site.

In order to develop 1:10,000 and 1:25,000 scale topographic maps of the planned site, a collection of local topographic maps was assembled, and a cartogram was generated based on them, which is presented in Figures 1–2 below.

Amount of Changes		Changes in Quality Indicators	Level of Modification Required for Geographic and Topographic Bases
In ballads	In percent		
1	0-20	very low	Partial modification required
2	20-40	low	Introduction of low-level modifications
3	40-60	moderate	Moderate-level processing based on large-scale aerospace (remote sensing) materials
4	60-80	high	Extensive processing based on large-scale aerospace remote sensing data
5	80-100	very high	Execution of specialized drone surveys and complete data processing

Table 1. Proposed scale for qualitative and quantitative assessment of changes between remote sensing materials and topographic maps

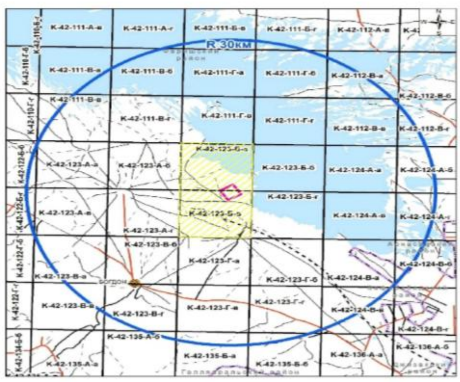


Figure 1. Set of 1:25,000 scale topographic maps of the nuclear power plant area (30 km radius).

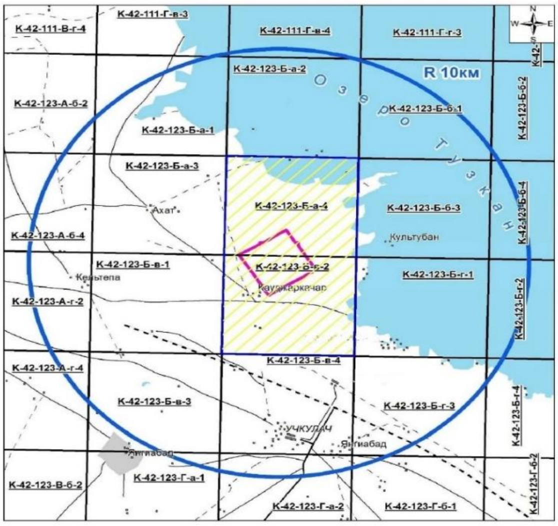


Figure 2. A set of 1:10,000 scale topographic maps of the nuclear power plant (10 km radius).

1.1 Cartogram Development and Terrain Visualization

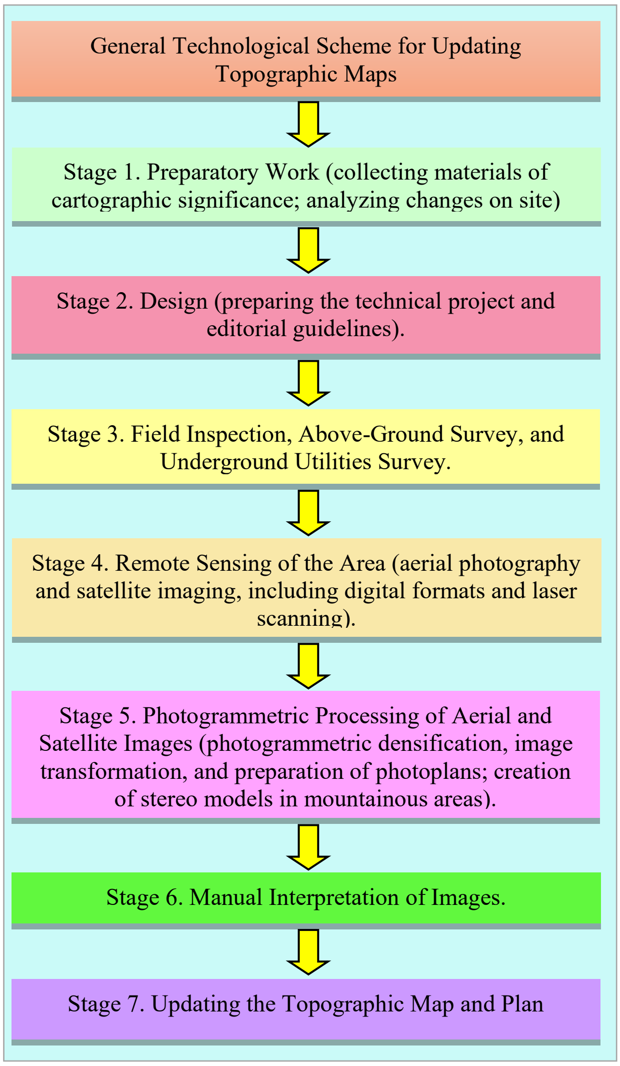


Figure 3. Methodology for updating maps and plans.

A cartogram of topographic maps for the area planned for the construction of the nuclear power plant was generated, which includes 56 sheets at a scale of 1:25,000 within a 30 km radius, and 30 sheets of 1:10,000 scale topographic maps within a 10 km radius.

Based on the developed methodology, aerial images of the area were initially captured using unmanned aerial vehicles (UAVs). These aerial photographs were used to visualize the site and construct the terrain relief. It was determined that the use of contour lines is the most effective method for accurately representing a high-resolution model of the area designated for the construction of the nuclear power plant.

1.2 Field Geodetic Work and Data Processing

Utilizing data obtained from drones and UAVs in the creation of the required topographic maps and plans not only increases work efficiency but also ensures high spatial accuracy.

Such operations are carried out in two stages. In the first stage, various geodetic and aerial photographic tasks are performed directly on-site. In the second stage, the results of geodetic measurements are processed and the images are interpreted. The boundary coordinates of the nuclear power plant study area are downloaded in “DXF” format using GNSS technology. Subsequently, special ground control points (GCPs or markers) are installed on-site using GNSS equipment.

When conducting field measurements, it is advisable to develop a specific strategy. This includes determining the location of existing geodetic points within the area, identifying their class or grade, and obtaining information on the most recent verification and any changes that may have occurred.

Geodetic work plays a critical role in organizing aerial photography and improving its accuracy. The geodetic measurements in this study were carried out as follows:

1. Identification of existing geodetic points in the area. GNSS instruments were used to enhance the spatial positioning accuracy of objects. After obtaining the coordinates of the nuclear power plant boundary using GNSS, the area’s limits were clearly defined.
2. Visual identification of geodetic points in the field and determination of their coordinates using GNSS equipment.

Calibration work was carried out to evenly distribute errors between the points. GNSS instruments were mounted on each geodetic point, and at least 15 minutes of measurement in RTK (Real-Time Kinematic) mode was conducted.

The data obtained at each point were compiled, and errors were processed using Trimble Business Center software. The results are presented in Figure 4.

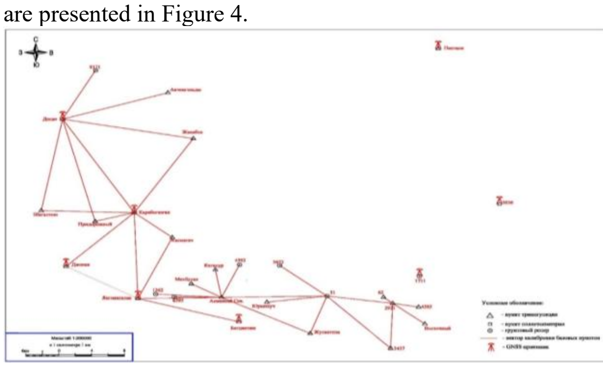


Figure 4. Calibration scheme between geodetic points.

2. Methods

2.1 Error Analysis and Elevation Mark Selection

In the Trimble Business Center software, it is possible to view both the maximum and average errors, as well as determine the error associated with each measured point. Due to the lack of sufficient stationary contours that could serve as markers in the terrain, the selection of designated elevation marks is carried out prior to the flight.

2.2 Geodetic Control Network and Markers

In this project area, a total of 403 markers were identified, and 12 geodetic control points were established. These 12 points of the geodetic network were interconnected using 4th-class leveling, which was employed to develop a digital elevation model. On average, 2.6 markers per square kilometer were installed (Table 2), amounting to 403 markers in total. They were numbered according to the following scheme: AS-001 to AS-024, AS1 to AS23, and AS39 to AS403.

The coordinates of the marked points (X, Y, Z) were determined in real time using RTK mode with GNSS receivers.

Requirement	Field Survey				Linear Survey		
	1:5000	**1:2000**	**1:500**	**1:500+**	**1:5000**	**1:2000**	**1:500**
Number of Points per 1 km²	**0,5**	**2**	**6**	**10**	**0,5**	**2**	**6**
Accuracy of Measured Point Coordinates	20 cm	**10 cm**	**5 cm**	**3 cm**	**20 cm**	**10 cm**	**5 cm**

Table 2. Point density and accuracy

3. Marker Installation and UAV Survey Preparation

3.1 Marker Design and Visibility

The marker installation process followed the below technology: A 50 cm diameter circle was drawn on the ground, and a smaller circle with a radius of 10 cm was marked inside it using alabaster. These types of markers were clearly identified in digital images at a resolution of 4–5 pixels, ensuring accurate decoding.

3.2 Survey Preparation and UAV Deployment

This approach forms the basis for planning UAV-based aerial surveying operations for generating and updating topographic plans at scales of 1:1,000, 1:2,000, and 1:5,000, as well as digital maps at scales of 1:10,000 and 1:25,000 (Figure 5).

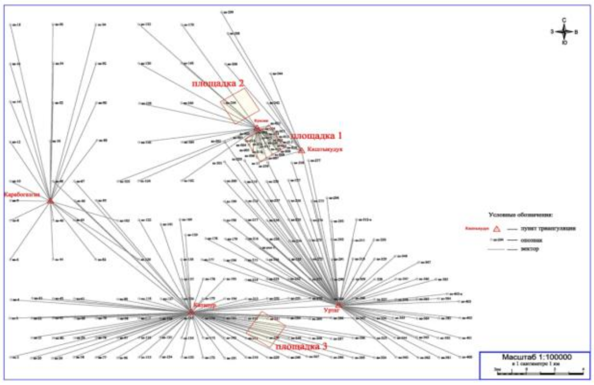


Figure 5. Calibration scheme between ground control points (GCPs) and geodetic reference points.

During the research, the mean square error of the elevation points in the geodetic network, according to the scale of the constructed map (plan), did not exceed 0.1 mm, and the deviation of the relief section did not exceed 0.1 of the accepted contour interval (Figures 6–7).

Figure 6. View of ground control points (GCPs) collected in the field.

The distances between the control points were determined in accordance with specific regulations based on the working scale, as outlined in ShNQ 01.02.22-19. The number of control points and the distances between them were established according to the required scale specified in the project assignment (Table 2).

For aerial photography operations using drones at specified scales, the UZGASHKLITI State Unitary Enterprise employed the Geoscan 201 unmanned aerial vehicle (UAV) to produce and update topographic plans at scales of 1:1,000, 1:2,000, and 1:5,000, as well as digital maps at scales of 1:10,000 and 1:25,000. A methodology was developed for creating master plans and updating maps using these UAVs.

To obtain spatial data (MZM data) using unmanned aerial systems for map updating, the following steps were initially carried out:

- Obtaining technical requirements and specifications;
- Collecting and systematizing relevant data;
- Acquiring cartographic or photographic materials and generating a list of point coordinates;

- Analyzing the natural and geographical characteristics of the study area, including forest cover, terrain, water bodies, and average temperature;
- Obtaining special permits for conducting the flight;
- Selecting ground points and determining their coordinates for identifying horizontal and vertical control marks;
- Performing technical inspections of equipment and preparing for flight;
- Ensuring safety measures during aerial photography missions.

Figure 7. View of ground control points (GCPs) on the orthophotoplan.

After completing the abovementioned procedures in the area planned for the construction of the nuclear power plant, ground control points (GCPs) were installed. Each installed marker was sequentially numbered from 1 to 500.

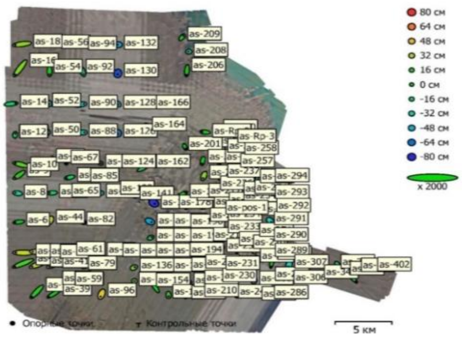


Figure 8. Location of ground control points (GCPs) within the area.

The installed points were marked in black as dots, while the control positions were represented in an elliptical shape. Aerial photography of the site was carried out from six flight stations.

For UAV-based aerial surveying of the territory, the area was divided into smaller zones, and 21 flight missions were conducted using a multi-route method (Figure 9).

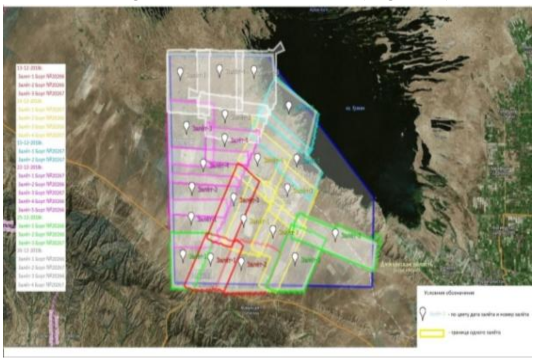


Figure 9. Scheme of flight routes.

4. UAV Flight Operations and Data Collection

4.1 Flight Planning and Control

The flight control program for the unmanned aerial vehicles (UAVs) was carried out as follows. From the ground control station, the operator defines the survey area and sets the UAV flight altitude (H = 340–880 meters) and spatial resolution. The flight mission is calculated using a specialized software application. The Geoscan Planner software was extensively used to monitor these flight operations. This software allows real-time monitoring of conditions affecting the aerial survey process.

4.2 Data Processing and Change Detection

The data obtained from UAVs was used for updating maps and monitoring changes on the ground. A specialized technology was developed to detect newly constructed and altered objects, as well as to assess the degree of spatial change in the area.
This technological scheme covers the full workflow for processing aerial images of the nuclear power plant (NPP) site captured by UAVs. It includes the following processes: selecting appropriate software, organizing photos into a grid structure, processing the imagery in Agisoft PhotoScan, generating an orthophotoplan using GIS software, converting data into vector format, vectorizing the topographic map layers, creating the orthophotoplan of the site, and exporting the updated topographic layers into the NPP mapping database (Figure 10).

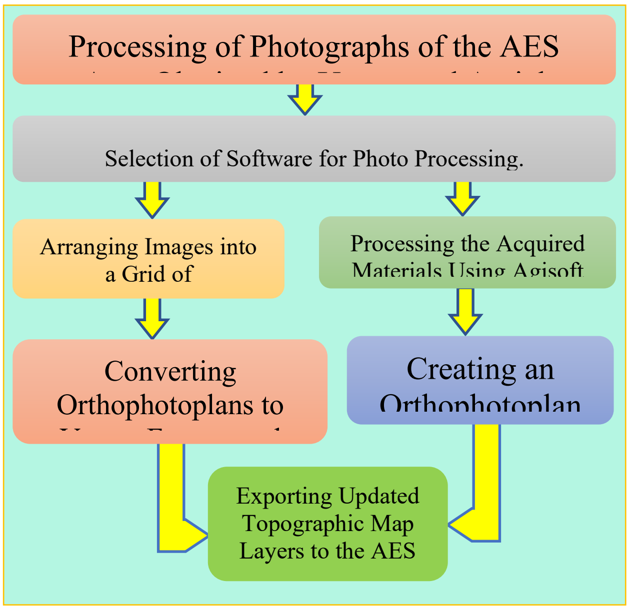


Figure 10. Technological scheme for processing images obtained from unmanned aerial vehicles (UAVs).

Additionally, the aerial photographs obtained via UAVs were processed using the Agisoft Metashape software. In the development of 1:1,000, 1:2,000, and 1:5,000 scale topographic plans for the area designated for the construction of the nuclear power plant (NPP), the images were imported and marked within the Agisoft Metashape environment.

Special attention must be paid to the format of the photos being uploaded into Agisoft Metashape, as the software supports the following formats: JPEG, TIFF, PNG, BMP, PPM, OpenEXR, and JPEG Multi-Picture.

The photographs uploaded into Agisoft Metashape are organized into a separate folder and systematically prepared for processing (Figure 11).

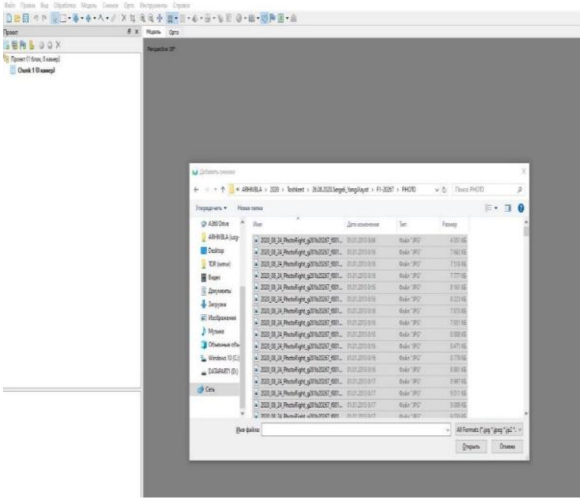


Figure 11. View of the folder containing the images.

The uploaded photographs are aligned with each other through mutual stitching within the software. The process of aligning or properly positioning the images is monitored through a dialog window in **Agisoft Metashape**.

Agisoft Metashape allows for the generation and visualization of **dense point clouds**. Based on the calculated camera positions, the software estimates elevation values for concave and convex surfaces and automatically places the required elevation points between them. The dense point cloud can be edited and classified using the tools available within Agisoft Metashape.

It is also possible to export these dense point clouds for further analysis in other specialized software packages (Figure 12).

Agisoft Metashape allows users to generate and visualize a Digital Elevation Model (DEM). Agisoft PhotoScan also provides the capability to calculate elevation points, distances, areas, and volumes, as well as to create elevation profiles along user-defined paths. Contour lines can be generated and displayed either on the DEM or on the orthomosaic via the Ortho tab.

A DEM is calculated only for georeferenced models, so a coordinate system must be assigned to the model before building the DEM (Figure 13).

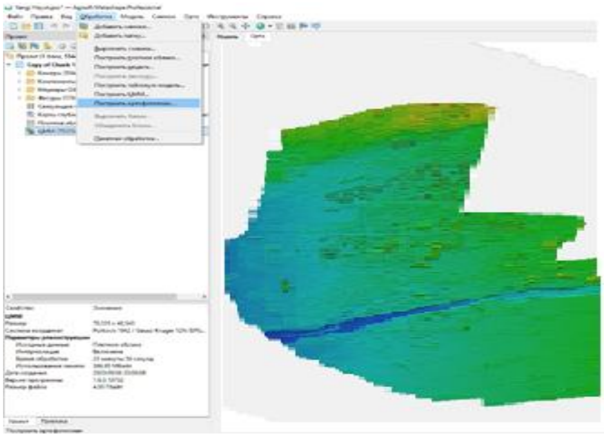


Figure 12. Generation of the dense point cloud.

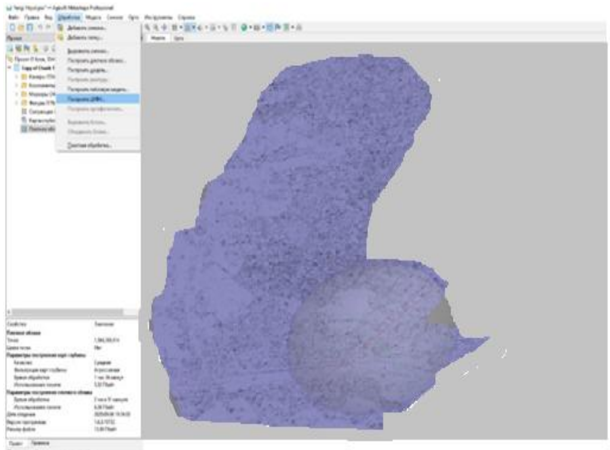


Figure 13. Stage of generating the digital elevation model (DEM) of the area.

Agisoft Metashape provides the capability to export results. The three-dimensional models created using this software are exported to other programs for the purpose of generating topographic maps of the area. AutoCAD Civil 3D software is widely used for creating these topographic maps. For this purpose, all models developed in Agisoft Metashape were exported to AutoCAD Civil 3D to facilitate the production of the area's topographic maps (Figure 14).

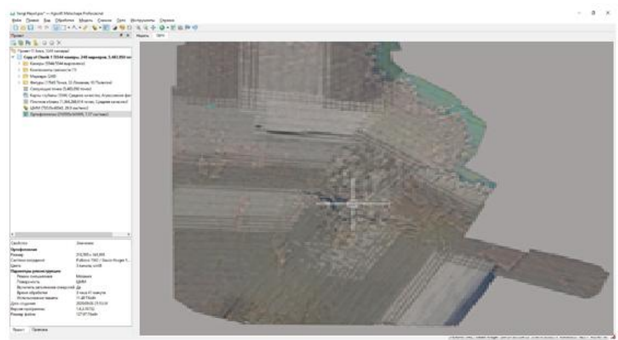
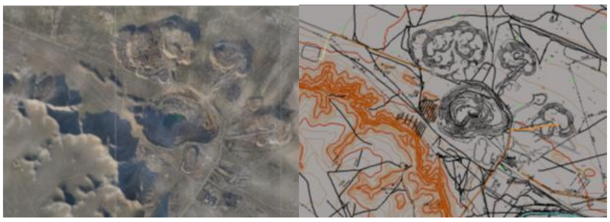


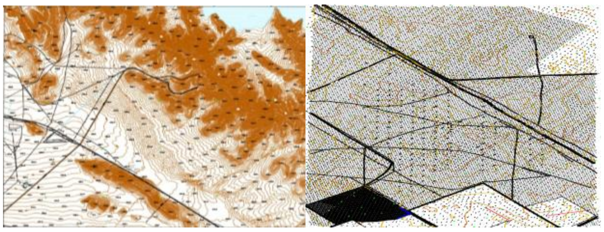
Figure 14. Orthophotoplan of the area planned for construction.

The orthophotoplan of the area planned for construction was exported from Agisoft Metashape to AutoCAD Civil 3D, where the topographic plan of the area was created (Figures 15 a and b, 16 a and b).



(a) (b)

Figure 15. Topographic plan 1:1,000 (b) created based on the orthophotoplan (a).



(a) (b)

Figure 16. Topographic plan created based on the orthophotoplan. (a) 1:5,000 topographic survey, (b) 1:2,000 topographic survey

5. Conclusion

In this study, high-accuracy topographic plans at scales of 1:1,000, 1:2,000, and 1:5,000 were created for the area designated for the construction of nuclear power plants using data obtained from the Geoscan 201 unmanned aerial vehicle (UAV). Additionally, a methodology for developing these plans was established.

Based on the data acquired from the Geoscan 201 UAV, topographic maps at scales of 1:10,000 and 1:25,000 for the planned construction area were also updated.

References

Abduazizov, A., Qorabayev, Kh.A., Kazakov, A.N., Burkhanov, U.T. (2022). Establishment of geodynamic polygons through state geodetic control networks in the construction of nuclear power plants. *Problems of Architecture and Construction*, No. 1-S, pp. 114–117.

Sauidqosimov, S.S. (2011). *Geoinformation Systems Technology*. Tashkent: Iqtisod-Moliya, 161 p.

Allanazarov, O.R., Koraboyev, Kh.A., Abduvaliyev, A.A., Khalmuradova, M.O. (2022). Monitoring of displacements and deformations in geodynamic polygons based on modern technologies. In: *Risks and Problems of Rational and Safe Use of the Subsoil in the Era of Digitalization and Transformation of the 21st Century*. Tashkent: TSTU, pp. 161–166.

Berlyant, A.M. (1997). *Geoinformational Cartography*. Moscow: Avstriya Publishing, 198 p.

Nuclear Power Plant in the Republic of Uzbekistan. Power Units 1 and 2. Engineering Survey Program for the Preparation of Design Documentation. UZB.0120.0.0.ES.DC0004 Book 2. (2019). Moscow: JSC Atomenergoproject, 186 p.

Abdullaev Z., Allanazarov O., Khikmatullayev S., Aynaqulov Sh., Oymatov R. Forecast of changes in land areas, population growth, dynamics of construction of buildings and structures. *E3S Web of Conferences* 458, 08001 (2023) EMMFT-2023.