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Measurement of The Tachymetric System on The Grounds of The Sultan Alauddin Grand Mosque, UIN Alauddin Makassar

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ABSTRACT

The planning of exterior spaces or the landscape of a building is crucial as it marks the beginning of the development process. Understanding the site situation, including its components, significantly influences decision-making related to design concepts, which supports the success of the overall design, particularly for public buildings such as mosques. A well-planned landscape enhances aesthetic value and provides greater comfort for visitors who come to worship. However, before planning the landscape, it is necessary to conduct land measurements, such as using a tachymetric system with a Digital Theodolite. This study aims to produce precise images of the mosque space's layout, shape, site components, and site area. The research employs a quantitative descriptive method to process data and generate accurate site maps. The findings indicate that the Sultan Alauddin Mosque at the State Islamic University (UIN) Alauddin Makassar, located on Campus II, Jl. H.M. Yasin Limpo No. 36 Samata, Gowa Regency, has a total site area of 9,192 m², forming an irregular pentagon. Additionally, the measurement results show that the Qibla direction of the Sultan Alauddin Grand Mosque is currently 290.15°, whereas the ideal Qibla direction should be 292.4°.

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1. INTRODUCTION

Places of worship that serve as public spaces, such as mosques, play a central role in the lives of Muslim communities by accommodating various religious activities, including celebrations of holy days, discussions, Islamic studies, and sermons. These functions necessitate proper planning and organization that consider both aesthetic and sustainable ecological principles to support such activities effectively. Therefore, landscape planning, which incorporates elements of vegetation and hardscape, is essential (Simangunsong et al., 2024). The initial step in the landscape planning of a public space involves site measurement and mapping. Site measurement is typically conducted prior to the design phase, as the calculation and area dimensions obtained from field measurements provide critical information (Tribuwhana, 2018). Site mapping aims to determine the location of coordinate points on or below the Earth's surface. This process requires a foundational framework of known coordinate points to bind or control newly identified points. The framework consists of horizontal coordinates (X, Y) and vertical coordinates (Rozaq et al., 2019).

In general, maps serve as tools for obtaining a scientific representation of the Earth's surface through the use of various signs, symbols, and annotations at a specific scale to ensure ease of interpretation. In the context of site observation, the map in question is typically a detailed, small-scale map (Pramono et al., 2020). A map is a conventional representation or miniature depiction of physical (natural) elements of part or all of the Earth's surface on a flat medium at a specific scale. However, because the Earth's surface is curved, it cannot be accurately flattened onto a plane without distortion. Mapping becomes simpler when conducted over relatively small areas (Prasetyo, 2021). Site measurement is a preliminary stage in construction activities, aimed at producing a situational map of the site. This map integrates both horizontal and vertical data dimensions into a single representation, providing comprehensive information for planning and design purposes (Suhendra, 2011).

Surveying and mapping tasks can be conducted using various methods, including terrestrial, photogrammetric, and extraterrestrial approaches. These methods aim to project images of the Earth's surface into topographic map designs at specific scales (Wahyono & Suyudi, 2017). The terrestrial method utilizes ETS (*Electronic Total Station*), which combines an electronic distance measuring device and a digital theodolite, offering high accuracy in determining coordinate points. In contrast, the extraterrestrial method employs GPS (*Global Positioning System*) mapping devices (Ramadhony et al., 2017). GPS provides satellite-based information to users about the coordinates of their location (Santoso & Rais, 2015). Although the procedures and characteristics of terrestrial and photogrammetric methods differ, they produce the same output—a topographic map depicting the relief of the measured Earth's surface (Utomo et al., 2022).

In addition, the polygon method is used to determine the horizontal positions of several points, where each point is interconnected through the measurement of angles and distances, forming a series of points (polygon). This polygon represents a sequential arrangement of lines whose lengths and directions/angles are obtained through field measurements (Purwaamijaya, 2008a).

Polygon measurement plays a crucial role in situational mapping, which involves representing the measured area or region in both horizontal and vertical dimensions within a single map (Fish, 2007). The situational mapping process includes the following measurement steps:

1. Measurement of the Horizontal Framework (angles and distances)
2. Measurement of the Vertical Framework (elevation differences)

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3. Detail Point Measurements (direction, elevation differences, and distances to detail points selected according to the requested scale). (Marselino et al., 2019)

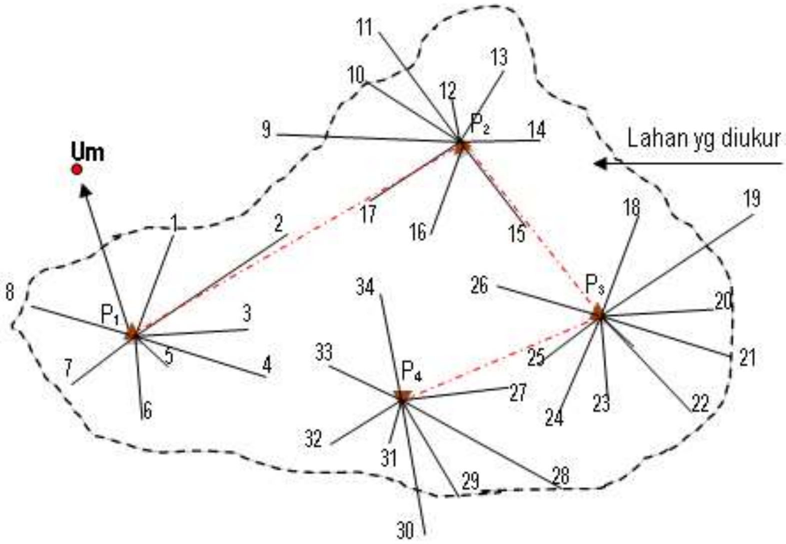

Figure 1. Closed Polygon
Source: (Marselino et al., 2019)

Situational measurements commonly employ the tachymetry method, a mapping technique used to represent irregularly shaped areas with detailed features. This approach captures all elements present on the land's surface within a defined area, including natural features such as land elevations, vegetation boundaries, and river limits, as well as man-made structures like buildings, drainage systems, and fences. The mapping process requires measuring instruments capable of determining directions/angles and distances simultaneously (Nurdiana et al., 2022). A theodolite is used as the primary instrument, placed on a benchmark whose coordinates and elevation are established through baseline framework measurements. These benchmarks serve as reference points for mapping detailed features, which may include both natural and man-made elements (Wulandari, 2018). Coordinates within an area can be obtained using a theodolite. However, to ensure accurate data, the theodolite must be recalibrated each time it is relocated during the measurement process (Rianandra et al., 2015).

The Digital Theodolite is a type of theodolite that automatically displays vertical and horizontal angle readings on the device's monitor screen (Fahik, 2022). It is capable of determining the geographical position (latitude and longitude) of a location using the transit method, which involves measuring the position of the sun from that location. Currently, theodolites remain instrumental in the master planning of modern buildings. In Indonesia, theodolites are also utilized by Islamic astronomers (*ahli falak*) to assist in the rukyatul hilal process for determining the beginning of the Hijri month. Theodolites can measure the altitude and azimuth angles of celestial objects, enabling them to track the movement of the moon with the aid of ephemeris data (Akrim et al., 2019). Furthermore, theodolites are used for determining the Qibla direction by employing their horizontal angle scale with azimuth guidance (0° as the reference point from the North) (Angkat, 2022). The Directorate General of the Religious Courts of the Supreme Court of the Republic of Indonesia and the Badan Hisab Rukyah currently use theodolites to determine the Qibla direction of mosques (Daud, 2019). For Gowa Regency, the Qibla direction is set at 292° (HL, 2020). Specifically, at the location of Campus II of UIN Alauddin Makassar, the Qibla direction is measured at 292.4° using Qibla-finding applications available on the Al-Qur'an Indonesia app for Android smartphones.

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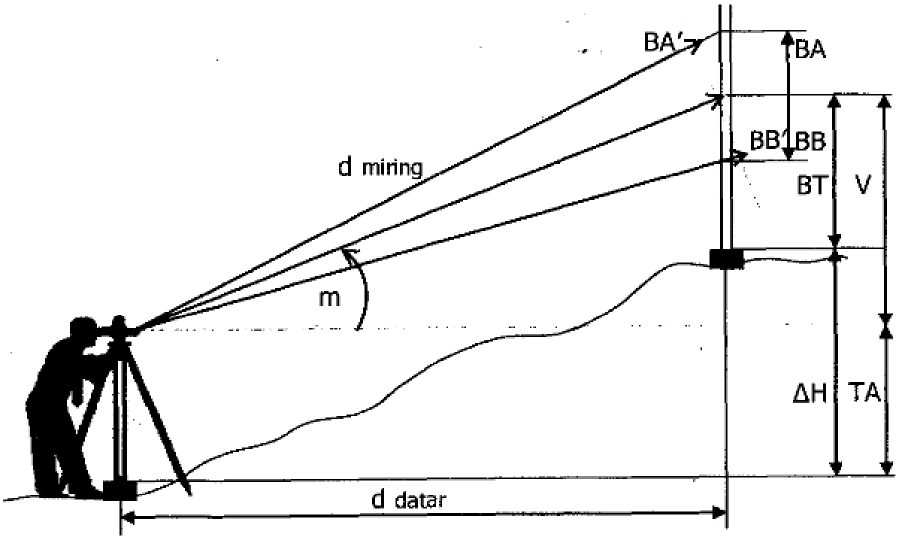
Figure 2. Topcon Theodolite
Source: (Purwaamijaya, 2008b)

The tachymetry method utilizes equipment equipped with optical lenses and digital electronic technology, making the measurement of detailed points relatively faster and easier. Field measurements yield data on staff readings, horizontal angles (magnetic azimuth), vertical angles (zenith or inclination), and instrument height. The tachymetry process produces planimetric positions (X, Y) and elevation (Z) as its final output (Purwaamijaya, 2008b). Differences in elevation and horizontal distances between measurement points in tachymetry are determined indirectly, as field data are based on inclined angles or zenith angles and optical distances.



- Horizontal angle (β) → azimuth (α)
- Inclined angle (m) / zenith angle (z)
- Instrument height from ground surface / benchmark point (TA)
- Staff reading (BT, BA, BB)

Figure 3. Tachymetry Measurement
Source: (Kustarto & Hartanto, 2012)

Surfer is an application developed by *Golden Software Inc*. that is widely used for creating contour maps and visualizing data in three dimensions, which can be viewed from various angles based on grid data. The *Surfer* application is extensively utilized for terrain modeling, surface analysis, contour mapping, watershed (DAS) mapping and 3D visualization, gridding, and calculating volumes from measurement data. In Surfer, irregular X, Y, and Z coordinate points are transformed into a regular grid format. The grid consists of a series of horizontal

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and vertical lines arranged in a square pattern, forming contour maps and 3D models within the Surfer application. The intersection points of these horizontal and vertical lines are used as Z data points, representing the elevation or depth of the measured points (Purwati, 2020).

2. RESEARCH METHODOLOGY

Quantitative research is a systematic investigation of phenomena through the collection of measurable data using statistical, mathematical, or computational techniques. This method often involves collaboration between researchers and statisticians to utilize mathematical frameworks and relevant theories (Abdullah et al., 2021). The methodology encompasses research design, sample selection, data collection, and data analysis. The primary goal is to obtain findings that are both measurable and statistically validated, allowing researchers to either accept or reject a hypothesis based on the study's results (Wajdi et al., 2024).

This study was conducted through several stages to produce a site map. The stages are outlined in the following research flowchart:

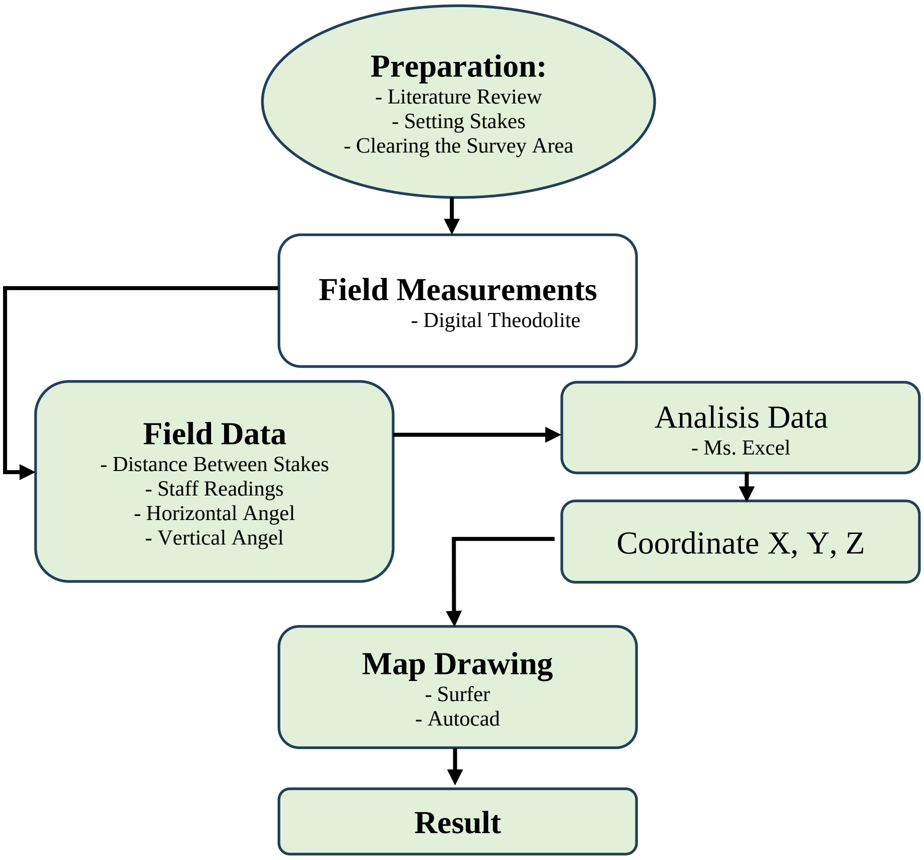

Figure 4. Research Flowchart
Source: Personal Data

a. Stake Installation at the Measurement Location.

The stakes must be a minimum of three (3) to form a closed polygon. Next, field data measurements are carried out using a digital theodolite. The first step is to place the digital theodolite on a tripod above the stake, then adjust the leveling bubble (nivo) and lock the north direction (azimuth). Azimuth is the measurement angle taken clockwise, starting from the north meridian line to the target direction (Wilayah, 2004). The next step is to collect measurement data by filling in the table below:

Table 1. Field Measurement Data

STAKE	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"

Source: Personal Data

b. Field Data Analysis

Field data analysis is conducted to obtain internal angles, vertical angles, optical distances between stakes, elevation differences, and the coordinates of measured points. These calculations are performed using the theodolite data processing formulas (Abidin, 2005), which are as follows:

1. Calculation of Internal Angles for Main Stakes
   SDn = ((SH back – SH front) ordinary + (SH back – SH front) extraordinary) / 2
2. Calculation of Internal Angle Correction Factor
   FKSD = ∑ SDn – (n-2) 180°
3. Calculation of Internal Angle Correction
   $$KSDn = \frac{FKSD}{\sum SDn} \times SDn$$
4. Calculation of Corrected Internal Angles
   SDKn = SDn ± KSDn : where (+) is for KSD (–) and (–) is for KSD (+)
5. Calculation of Internal Angles for Detail Stakes
   SDPDn = (SH detail – SH main stake) front ordinary
6. Calculation of Vertical Angles for Main Stake
   SVn = ((SVn front extraordinary – 270°) + (90° – SVn front ordinary)) / 2
7. Calculation of Optical Distance for Main Stakes
   Dn = (BA – BB) . Cos SVn
8. Calculation of Vertical Angles for Detail Stakes
   SVDn = 90° – SV Detail
9. Calculation of Optical Distance for Detail Stakes
   Ddn = (BA – BB) . Cos SVDn
10. Calculation of Elevation Difference for Main Stakes
    BTn = (BA – BB) . Sin SVn
11. Calculation of Elevation Difference for Detail Stakes
    BTDn = (BA – BB) . Sin SVDn
12. Calculation of Elevation Correction Factor for Main Stakes
    FKBT = Σ BTn / Σ |BTn|
13. Calculation of Elevation Correction for Main Stakes
    KBTn = FKBT . BTn
14. Calculation of Corrected Elevation Difference for Main Stakes
    BTKn = BTn – KBTn
15. Calculation of Stake Heights
    Tn = T(n – 1) + BTK(n – 1)
16. Calculation of Detail Stake Heights
    TDn = Tn + BTDn
17. Calculation of Azimuth for Main Stakes

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AZn = (AZ(n – 1) – SDKn) + 180°

18. Calculation of Azimuth for Detail Stakes
    AZDn = AZ Main Stake + SDPDn
19. Calculation of X Coordinates for Main Stakes
    Xn = Dn . Sin AZn
20. Calculation of X Coordinate Correction Factor
    FKX = Σ Xn / Σ |Xn|
21. Calculation of X Coordinate Correction
    KXn = FKX . Xn
22. Calculation of Corrected X Coordinates
    XKn = Xn – KXn
23. Calculation of X Coordinates on the Map
    Xn = X(n – 1) + XK(n – 1)
24. Calculation of X Coordinates for Detail Stakes
    XDn = (Ddn . Sin AZDn) + Xn Main Stake
25. Calculation of Y Coordinates for Main Stakes
    Yn = Dn . Cos AZn
26. Calculation of Y Coordinate Correction Factor
    FKY = Σ Yn / Σ |Yn|
27. Calculation of Y Coordinate Correction
    KYn = FKY . Yn
28. Calculation of Corrected Y Coordinates
    YKn = Yn – KYn
29. Calculation of Y Coordinates on the Map
    Yn = Y(n – 1) + YK(n – 1)
30. Calculation of Y Coordinates for Detail Stakes
    YDn = (Ddn . Cos AZDn) + Yn Main Stake

The data is analyzed using Microsoft Excel with settings configured to seven (7) decimal places. This level of precision is necessary because the Digital Theodolite uses sexagesimal data, consisting of values in degrees, minutes, and seconds (° ' "). By maintaining seven decimal places, any discrepancies at the seventh decimal place will not affect the accuracy of the calculations.

c. Site Map Drawing

The analyzed data is further processed using *Surfer 14* to generate a polygon model and contour lines of the land. The resulting map is then exported into a DXF file format for editing in *AutoCAD*. In *AutoCAD*, the land map undergoes scale adjustments to ensure accuracy. Once the scale is properly set, the land area can be calculated and further developed into a landscape or exterior space planning design.

3. RESULTS AND DISCUSSION

The Site measurement of the Sultan Alauddin Grand Mosque at UIN Alauddin Makassar obtained field data consisting of 8 main stakes and 66 detail stakes, where the main stakes are the points where the theodolite is set up to target the desired measurement points. The data includes Stake Name, Instrument Height, Staff Readings (Upper Thread, Middle Thread, Lower Thread), horizontal and vertical angles, both ordinary and extraordinary angles. The results of the field measurements can be seen in the following table:

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Table 2. Field Measurement Data for Stake P1

STAKE 1	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S1 - S2	FRONT	143	159,8	143,0	126,2	354	4	10	174	4	40	89	56	10	270	3	30
S1 - S8	REAR		178,0	143,0	108,0	118	40	0	298	38	50	89	25	20	270	34	40
S1 - SD1	FRONT		151,1	143,0	134,9	220	6	50				91	4	0			
S1 - SD2	FRONT		151,5	143,0	134,5	222	46	40				94	2	50			
S1 - SD3	FRONT		151,8	143,0	134,2	228	11	30				93	38	30			
S1 - SD4	FRONT		152,1	143,0	133,9	231	15	40				93	32	0			
S1 - SD5	FRONT		152,7	143,0	133,3	236	59	10				94	3	40			
S1 - SD6	FRONT		154,3	143,0	131,7	246	4	30				93	42	40			
S1 - SD7	FRONT		146,9	143,0	139,1	295	29	10				91	10	10			
S1 - SD8	FRONT		147,2	143,0	138,8	294	15	10				95	37	30			
S1 - SD9	FRONT		148,0	143,0	138,0	292	25	10				94	42	50			
S1 - SD10	FRONT		149,0	143,0	137,0	290	15	30				93	47	50			
S1 - SD11	FRONT		150,0	143,0	136,0	289	7	50				93	29	20			
S1 - SD12	FRONT		152,0	143,0	134,0	285	36	20				93	43	50			
S1 - SD13	FRONT		150,0	143,0	136,0	332	37	20				90	27	50			
S1 - SD14	FRONT		153,2	143,0	132,8	340	33	30				90	5	50			
S1 - SD15	FRONT		171,0	143,0	115,0	108	11	0				89	0	10			
S1 - SD16	FRONT		169,6	143,0	116,4	107	59	40				89	21	40			
S1 - SD17	FRONT		160,5	143,0	125,5	94	34	20				89	22	40			
S1 - SD18	FRONT		153,0	143,0	133,0	60	9	50				89	22	0			
S1 - SD19	FRONT		153,5	143,0	132,5	62	50	10				89	10	20			
S1 - SD20	FRONT		153,9	143,0	132,1	65	17	40				89	14	20			
S1 - SD21	FRONT		158,4	143,0	127,6	73	38	20				89	5	40			
S1 - SD22	FRONT		152,7	143,0	133,3	57	23	20				89	26	20			
S1 - SD23	FRONT		153,5	143,0	132,5	47	20	0				86	23	10			

Table 3. Field Measurement Data for Stake P2

STAKE 2	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S2 - S3	FRONT	148	162,6	148,0	133,4	285	14	20	105	17	50	88	48	10	270	35	40
S2 - S1	REAR		164,8	148,0	131,2	74	40	0	254	38	50	90	3	0	269	56	50
S2 - SD24	FRONT		150,2	148,0	145,8	101	44	40				89	47	50			
S2 - SD25	FRONT		152,5	148,0	143,5	146	58	30				93	10	50			
S2 - SD26	FRONT		153,3	148,0	142,7	149	53	20				93	13	10			
S2 - SD27	FRONT		154,0	148,0	142,0	154	29	20				93	32	40			
S2 - SD28	FRONT		154,9	148,0	141,1	153	43	20				92	23	10			
S2 - SD29	FRONT		157,5	148,0	138,5	153	55	10				93	3	40			
S2 - SD30	FRONT		153,9	148,0	142,1	94	47	10				90	4	50			
S2 - SD31	FRONT		154,3	148,0	141,7	105	59	0				92	15	0			
S2 - SD32	FRONT		154,8	148,0	141,2	112	28	10				92	16	10			
S2 - SD33	FRONT		155,1	148,0	140,9	120	7	30				92	54	50			
S2 - SD34	FRONT		155,8	148,0	140,2	124	27	50				93	3	0			
S2 - SD35	FRONT		157,9	148,0	138,1	132	22	20				92	57	40			
S2 - SD36	FRONT		151,5	148,0	144,5	213	38	0				96	11	0			
S2 - SD37	FRONT		153,5	148,0	142,5	200	28	0				94	2	40			
S2 - SD38	FRONT		156,0	148,0	140,0	249	17	20				92	17	20			
S2 - SD39	FRONT		157,8	148,0	138,2	331	0	40				88	58	20			

Table 4. Field Measurement Data for Stake P3

STAKE 3	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S3 - S4	FRONT	146	169,8	146,0	122,2	63	42	40	243	41	50	89	9	0	270	50	50
S3 - S2	REAR		160,6	146,0	131,4	191	50	40	11	54	50	90	36	0	269	23	50
S3 - SD40	FRONT		150,7	146,0	141,3	291	39	10				91	3	0			
S3 - SD41	FRONT		157,4	146,0	134,6	229	58	10				92	45	20			
S3 - SD42	FRONT		162,0	146,0	130,0	255	48	40				92	5	20			
S3 - SD43	FRONT		162,4	146,0	129,6	251	43	40				92	29	30			
S3 - SD44	FRONT		163,4	146,0	128,6	251	4	20				92	11	10			

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STAKE 3	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S3 - SD45	FRONT		164,0	146,0	128,0	252	6	30				92	2	50			
S3 - SD46	FRONT		164,8	146,0	127,2	251	52	10				91	56	0			
S3 - SD47	FRONT		167,5	146,0	124,5	252	26	0				91	59	30			

Table 5. Field Measurement Data for Stake P4

STAKE 4	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S4 - S5	FRONT	146	168,4	146,0	123,6	294	55	0	114	53	50	89	4	10	270	56	0
S4 - S3	REAR		169,8	146,0	122,2	85	24	30	265	24	40	90	48	40	269	11	10
S4- SD48	FRONT		152,2	146,0	139,8	212	54	50				87	31	30			
S4 - SD49	FRONT		148,6	146,0	143,4	235	12	0				85	18	50			
S4- SD49	FRONT		151,8	146,0	140,2	355	7	50				89	12	30			
S4 - SD50	FRONT		160,5	146,0	131,5	308	46	40				88	44	10			
S4 - SD52	FRONT		159,5	146,0	132,5	309	41	0				89	50	20			

Table 6. Field Measurement Data for Stake P5

STAKE 5	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S5 - S6	FRONT	146	162,0	146,0	130,0	144	25	20	324	26	40	91	6	40	268	53	10
S5 - S4	REAR		168,0	146,0	124,0	234	37	50	54	38	10	90	56	0	269	4	0
S5 - SD53	FRONT		149,7	146,0	142,3	342	43	0				86	3	40			
S5 - SD54	FRONT		150,0	146,0	142,0	233	0	30				90	35	40			
S5 - SD55	FRONT		150,0	146,0	142,0	154	17	50				90	30	20			

Table 7. Field Measurement Data for Stake P6

STAKE 6	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S6 - S7	FRONT	146	164,9	146,0	127,1	130	51	40	310	52	40	90	23	10	269	36	30
S6 - S5	REAR		162,0	146,0	130,0	307	41	0	127	41	30	88	53	10	271	6	40
S6 - SD56	FRONT		151,5	146,0	140,5	174	52	40				90	40	20			
S6 - SD57	FRONT		151,8	146,0	140,2	155	32	30				89	55	50			
S6 - SD58	FRONT		147,3	146,0	144,7	97	42	40				79	13	20			
S6 - SD59	FRONT		147,2	146,0	144,8	99	19	10				89	12	20			

Table 8. Field Measurement Data for Stake P7

STAKE 7	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S7 - S8	FRONT	147	162,0	147,0	132,0	165	7	20	345	6	30	90	21	30	269	38	10
S7 - S6	REAR		166,0	147,0	128,0	333	14	20	153	13	50	89	36	0	270	24	0
S7 - SD60	FRONT		155,4	147,0	138,6	242	25	0				88	33	50			
S7 - SD61	FRONT		154,4	147,0	139,6	233	38	50				89	4	0			

Table 9. Field Measurement Data for Stake P8

STAKE 8	TYPE OF STAKES	INST. HEIGHT (cm)	STAFF READINGS			HORIZONTAL ANGLE						VERTICAL ANGLE					
						ORDINARY			EXTRAORDINARY			ORDINARY			EXTRAORDINARY		
			UT	MT	LT	°	'	"	°	'	"	°	'	"	°	'	"
S8 - S1	FRONT	149	183,8	149,0	114,2	148	56	40	328	57	20	90	33	10	269	26	50
S8 - S7	REAR		164,0	149,0	134,0	241	17	40	61	15	0	89	35	30	270	24	10
S8- SD62	FRONT		153,7	149,0	144,3	344	24	30				89	43	10			
S8 - SD63	FRONT		155,2	149,0	142,8	238	21	30				88	35	50			
S8 - SD64	FRONT		155,5	149,0	142,5	249	26	40				90	12	20			
S8 - SD65	FRONT		152,8	149,0	145,2	181	29	40				87	47	50			
S8 - SD66	FRONT		152,1	149,0	145,9	162	12	10				90	38	50			

Source: Personal Data, 2023

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The field measurement data shows that the azimuth at the first stake is 354°4'10". Subsequently, the site measurement data of the mosque was input and processed in Microsoft Excel using the relevant formulas. The results obtained are as follows:

Table 10. Processed Data from Field Measurements of Main Stake

Formula	1	2	3	4	6	7	10	I BTn I	12
Stake	**SDn**	**FKSD**	**KSDn**	**SDKn**	SVn	Dn	BTn		FKBT
P1	124,5833333	0,1097222	0,0126557	124,5706776	0,0611111	33,5999809	0,0358374	0,0358374	0,0511947
P2	149,3888889		0,0151756	149,3737133	0,8958333	29,1964309	0,4565304	0,4565304	
P3	128,1750000		0,0130206	128,1619794	0,8486111	47,5947792	0,7049806	0,7049806	
P4	150,5027778		0,0152887	150,4874891	0,9319444	44,7940738	0,7286622	0,7286622	
P5	90,2000000		0,0091629	90,1908371	-1,1125000	31,9939680	-0,6212982	0,6212982	
P6	176,8180556		0,0179619	176,8000936	-0,3888889	37,7991293	-0,2565614	0,2565614	
P7	168,1194444		0,0170783	168,1023661	-0,3611111	29,9994042	-0,1890761	0,1890761	
P8	92,3222222		0,0093785	92,3128437	-0,5527778	69,5967608	-0,6714759	0,6714759	
∑ SDn =	**1.080,1097222**		**0,1097222**	**1.080,0000000**			0,1875991	3,6644223	
(n-2) *180=	**1.080,00**						∑ BTn =	∑ I BTn I =	

Table 11. Continued Processed Data Results of Main Stake

13	14	15	17	19	I Xn I	20	21	22	23
KBTn	BTKn	Tn	Azn	Xn		FKX	KXn	XKn	Xn Image
0,0018347	0,0340027	25,0000000	354,0694444	-3,4716506	3,4716506	0,0023138	0,0080325	-3,4796831	0,0000000
0,0233719	0,4331585	25,0340027	24,6957311	12,1982508	12,1982508		0,0282237	12,1700271	-3,4796831
0,0360913	0,6688893	25,4671612	76,5337517	46,2862687	46,2862687		0,1070950	46,1791737	8,6903440
0,0373037	0,6913586	26,1360505	106,0462626	43,0488440	43,0488440		0,0996044	42,9492396	54,8695177
0,0318072	-0,6531054	26,8274091	195,8554255	-8,7411017	8,7411017		0,0202248	-8,7613265	97,8187573
0,0131346	-0,2696960	26,1743037	199,0553319	-12,3407018	12,3407018		0,0285533	-12,3692551	89,0574308
0,0096797	-0,1987558	25,9046077	210,9529658	-15,4297211	15,4297211		0,0357006	-15,4654216	76,6881757
0,0343760	-0,7058519	25,7058519	298,6401221	-61,0814267	61,0814267		0,1413274	-61,2227540	61,2227540
0,1875991	0,0000000	25,0000000	354,0694444	0,4687617	202,5979654		0,4687617	0,0000000	0,0000000
				Σ Xn =	Σ I Xn I =		Σ KXn =	Σ XKn =	

25	I Yn I	26	27	28	29
Yn		FKY	Kyn	Ykn	Yn Image
33,4201490	33,4201490	-0,0010790	-0,0360616	33,4562106	0,0000000
26,5261052	26,5261052		-0,0286227	26,5547278	33,4562106
11,0835162	11,0835162		-0,0119595	11,0954758	60,0109384
-12,3816833	12,3816833		-0,0133603	-12,3683230	71,1064142
-30,7767303	30,7767303		-0,0332092	-30,7435211	58,7380912
-35,7278778	35,7278778		-0,0385517	-35,6893261	27,9945701
-25,7271832	25,7271832		-0,0277606	-25,6994227	-7,6947560
33,3581839	33,3581839		-0,0359947	33,3941787	-33,3941787
-0,2255203	209,0014290		-0,2255203	0,0000000	0,0000000
Σ Yn=	Σ I Yn I =				

Table 12. Continued Processed Data Results of Detail Stake

Formula	**5**	**8**	**9**	**11**	**16**	**18**	**24**	**30**
Stake	**SDPDn**	**SVDn**	**Ddn**	**BTDn**	**TDn**	**AZDn**	**XDn**	**Ydn**
SD1	226,0444444	-1,0666667	16,1971927	-0,3015755	24,6984245	220,1138889	-10,4359976	-12,3870500
SD2	228,7083333	-4,0472222	16,9576057	-1,1998366	23,8001634	222,7777778	-11,5168711	-12,4467695
SD3	234,1222222	-3,6416667	17,5644621	-1,1178867	23,8821133	228,1916667	-13,0921821	-11,7091886
SD4	237,1916667	-3,5333333	18,1654039	-1,1216518	23,8783482	231,2611111	-14,1691213	-11,3674051
SD5	242,9166667	-4,0611111	19,3512882	-1,3739163	23,6260837	236,9861111	-16,2268005	-10,5434007
SD6	252,0055556	-3,7111111	22,5526097	-1,4628037	23,5371963	246,0750000	-20,6148239	-9,1459959
SD7	301,4166667	-1,1694444	7,7983753	-0,1591921	24,8408079	295,4861111	-7,0395124	3,3555808
SD8	300,1833333	-5,6250000	8,3595517	-0,8233440	24,1766560	294,2527778	-7,6217555	3,4337950
SD9	298,3500000	-4,7138889	9,9661750	-0,8218010	24,1781990	292,4194444	-9,2128981	3,8009408
SD10	296,1888889	-3,7972222	11,9736562	-0,7947063	24,2052937	290,2583333	-11,2329776	4,1459204
SD11	295,0611111	-3,4888889	13,9740527	-0,8519696	24,1480304	289,1305556	-13,2023255	4,5796015
SD12	291,5361111	-3,7305556	17,9618591	-1,1711607	23,8288393	285,6055556	-17,2997219	4,8319774
SD13	338,5527778	-0,4638889	13,9995411	-0,1133482	24,8866518	332,6222222	-6,4377647	12,4315058
SD14	346,4888889	-0,0972222	20,3999706	-0,0346157	24,9653843	340,5583333	-6,7900685	19,2367817

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Formula	5	8	9	11	16	18	24	30
SD15	114,1138889	0,9972222	55,9915182	0,9746202	25,9746202	108,1833333	53,1954623	-17,4726331
SD16	113,9250000	0,6388889	53,1966926	0,5932057	25,5932057	107,9944444	50,5946549	-16,4337763
SD17	100,5027778	0,6222222	34,9979361	0,3800865	25,3800865	94,5722222	34,8865602	-2,7898837
SD18	66,0944444	0,6333333	19,9987782	0,2210705	25,2210705	60,1638889	17,3479813	9,9498077
SD19	68,7666667	0,8277778	20,9978084	0,3033858	25,3033858	62,8361111	18,6818401	9,5862822
SD20	71,2250000	0,7611111	21,7980766	0,2895804	25,2895804	65,2944444	19,8028475	9,1106187
SD21	79,5694444	0,9055556	30,7961532	0,4867715	25,4867715	73,6388889	29,5490750	8,6749767
SD22	63,3194444	0,5611111	19,3990697	0,1899857	25,1899857	57,3888889	16,3407656	10,4548211
SD23	53,2638889	3,6138889	20,9582410	1,3236814	26,3236814	47,3333333	15,4107834	14,2040706
SD24	176,5055556	0,2027778	4,3999724	0,0155722	25,0495749	201,2012867	-5,0709134	29,3540473
SD25	221,7361111	-3,1805556	8,9861369	-0,4993440	24,5346588	246,4318422	-11,7162421	29,8631963
SD26	224,6500000	-3,2194444	10,5832707	-0,5952996	24,4387031	249,3457311	-13,3827232	29,7231936
SD27	229,2500000	-3,5444444	11,9770457	-0,7418733	24,2921294	253,9457311	-14,9896263	30,1439860
SD28	228,4833333	-2,3861111	13,7880347	-0,5745417	24,4594610	253,1790645	-16,6777805	29,4662073
SD29	228,6805556	-3,0611111	18,9728898	-1,0146200	24,0193827	253,3762867	-21,6595868	28,0283520
SD30	169,5472222	-0,0805556	11,7999883	-0,0165903	25,0174124	194,2429533	-6,3828825	22,0189400
SD31	180,7444444	-2,2500000	12,5902859	-0,4946737	24,5393291	205,4401756	-8,8880726	22,0867506
SD32	187,2305556	-2,2694444	13,5893329	-0,5385453	24,4954574	211,9262867	-10,6660998	21,9225475
SD33	194,8861111	-2,9138889	14,1816403	-0,7218575	24,3121452	219,5818422	-12,5159374	22,5262047
SD34	199,2250000	-3,0500000	15,5779023	-0,8300355	24,2039672	223,9207311	-14,2854897	22,2354448
SD35	207,1333333	-2,9611111	19,7735636	-1,0228311	24,0111717	231,8290645	-19,0250753	21,2359570
SD36	288,3944444	-6,1833333	6,9592764	-0,7539712	24,2800316	313,0901756	-8,5618995	38,2104302
SD37	275,2277778	-4,0444444	10,9726060	-0,7758329	24,2581698	299,9235089	-12,9895545	38,9298226
SD38	324,0500000	-2,2888889	15,9872345	-0,6390084	24,3949944	348,7457311	-6,5998061	49,1360225
SD39	45,7722222	1,0277778	19,5968467	0,3515680	25,3855708	70,4679533	14,9894560	40,0081036
SD40	227,9416667	-1,0500000	9,3984216	-0,1722544	25,2949069	304,4754184	0,9425755	65,3309395
SD41	166,2583333	-2,7555556	22,7736370	-1,0961095	24,3710517	242,7920850	-11,5634634	49,5983581
SD42	192,1000000	-2,0888889	31,9787354	-1,1663972	24,3007640	268,6337517	-23,2793001	59,2484607
SD43	188,0166667	-2,4916667	32,7689894	-1,4259499	24,0412114	264,5504184	-23,9305346	56,8988740
SD44	187,3611111	-2,1861111	34,7746723	-1,3274662	24,1396951	263,8948628	-25,8871007	56,3125399
SD45	188,3972222	-2,0472222	35,9770221	-1,2860340	24,1811273	264,9309739	-27,1459711	56,8321589
SD46	188,1583333	-1,9333333	37,5785965	-1,2684973	24,1986640	264,6920850	-28,7271128	56,5346124
SD47	188,7222222	-1,9916667	42,9740234	-1,4944281	23,9727332	265,2559739	-34,1364560	56,4568019
SD48	277,9972222	2,4750000	12,3884328	0,5354750	26,6715255	24,0434849	59,9169352	82,4199832
SD49	300,2833333	4,6861111	5,1826175	0,4248240	26,5608745	46,3295960	58,6182289	74,6850576
SD50	60,2138889	0,7916667	11,5988927	0,1602743	26,2963248	166,2601515	57,6244146	59,8394334
SD51	13,8611111	1,2638889	28,9929446	0,6396598	26,7757103	119,9073738	80,0015469	56,6505522
SD52	14,7666667	0,1611111	26,9998933	0,0759217	26,2119723	120,8129293	78,0582229	57,2760784
SD53	198,2944444	3,9388889	7,3825203	0,5083241	27,3357332	34,1498700	101,9630054	64,8476586
SD54	88,5861111	-0,5944444	7,9995694	-0,0829986	26,7444105	284,4415367	90,0719533	60,7331198
SD55	9,8750000	-0,5055556	7,9996886	-0,0705880	26,7568211	205,7304255	94,3457923	51,5315989
SD56	44,0166667	-0,6722222	10,9992429	-0,1290544	26,0452493	243,0719986	79,2507664	23,0133376
SD57	24,6805556	0,0694444	11,5999915	0,0140596	26,1883633	223,7358875	81,0379494	19,6131788
SD58	326,8500000	10,7777778	2,5541356	0,4862008	26,6605046	165,9053319	89,6794261	25,5173276
SD59	328,4583333	0,7944444	2,3997693	0,0332765	26,2075803	167,5136653	89,5762772	25,6515611
SD60	77,2944444	1,4361111	16,7947230	0,4210457	26,3256534	288,2474102	60,7380042	-2,4359776
SD61	68,5250000	0,9333333	14,7980364	0,2410775	26,1456852	279,4779658	62,0921472	-5,2579885
SD62	195,4638889	0,2805556	9,3998873	0,0460280	25,7518800	134,1040110	67,9726023	-39,9361531
SD63	89,4138889	1,4027778	12,3962838	0,3035600	26,0094119	28,0540110	67,0527719	-22,4544007
SD64	100,5000000	-0,2055556	12,9999163	-0,0466390	25,6592130	39,1401221	69,4285494	-23,3113840
SD65	32,5500000	2,2027778	7,5943840	0,2921155	25,9979675	331,1901221	57,5629843	-26,7398001
SD66	13,2583333	-0,6472222	6,1996044	-0,0700347	25,6358172	311,8984554	56,6082053	-29,2540054

Source: Personal Data, 2024

The processed data is further analyzed using *Surfer 14* by inputting the X coordinates into Column A and Y coordinates into Column B for both main and detail stakes. The elevations of the main and detail stakes are entered into Column C in the toolbar's data section by selecting the worksheet, as shown in the figure below:

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	A	B	C
1	0,0000000	0,0000000	25,0000000
2	-3,4796831	33,4562106	25,0340027
3	8,6903440	60,0109384	25,4671612
4	54,8695177	71,1064142	26,1360505
5	97,8187573	58,7380912	26,8274091
6	89,0574308	27,9945701	26,1743037
7	76,6881757	-7,6947560	25,9046077
8	61,2227540	-33,3941787	25,7058519

Figure 5. Data Input in Surfer Application
Source: Personal Data, 2024

The entered data must then be saved in the DAT Data format. Next, select the "Plot" menu on the toolbar to generate the polygon and contour map of the site, as shown below:

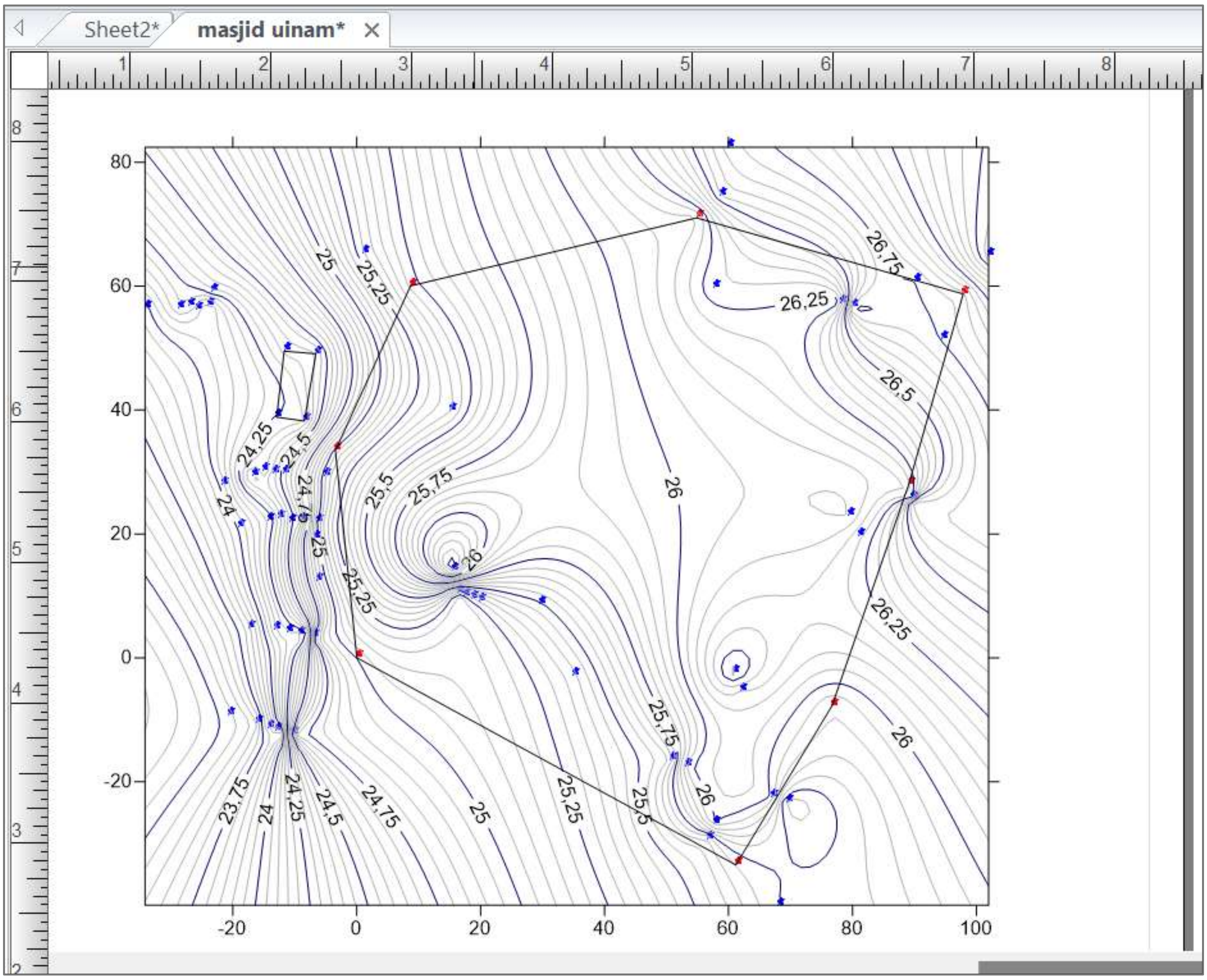

Figure 6. Polygon and Site Contour Map
Source: Personal Data, 2024

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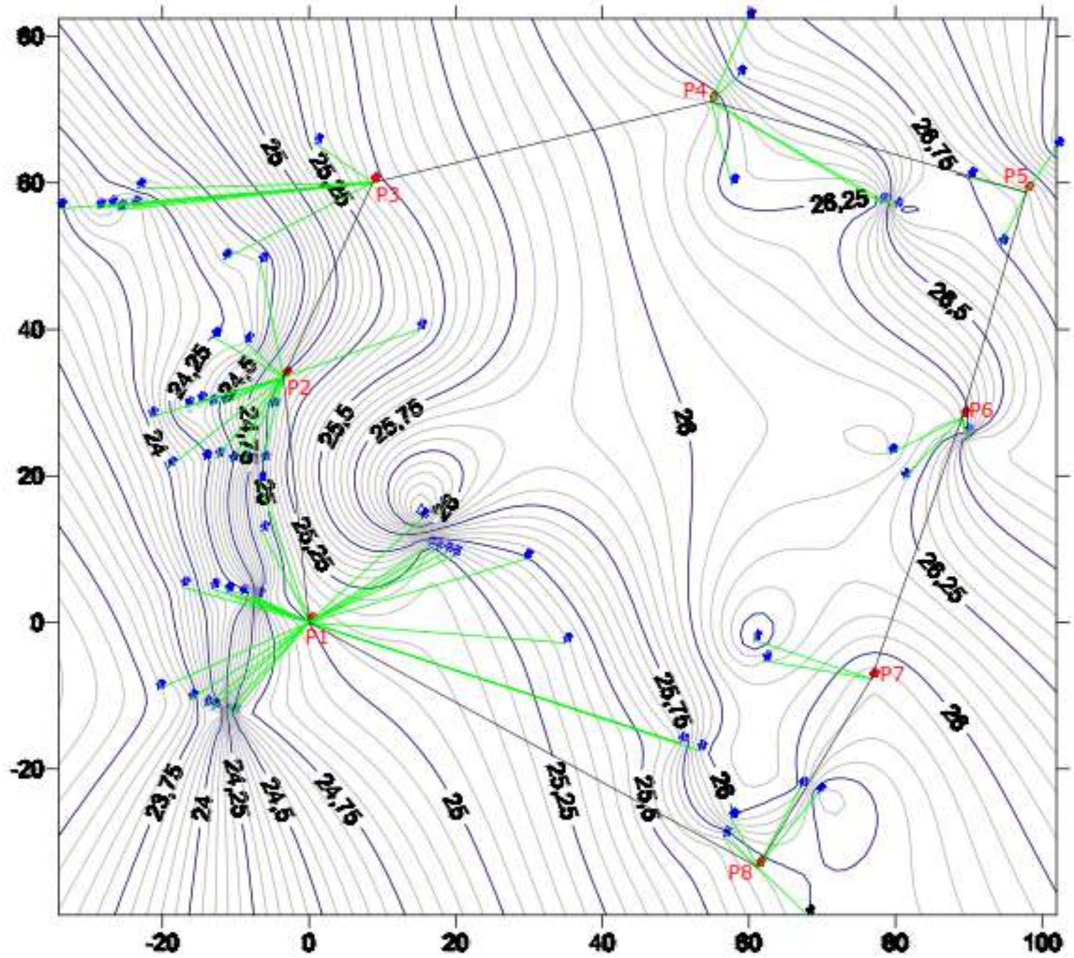

Figure 7. Tachymetry of Mosque Site
Source: Personal Data, 2024

In the image above, differences in contour line thickness can be observed. These contour lines indicate elevation or height differences of the measured site. Based on the image, it is evident that the northeastern area is the highest, while the southwestern area is the lowest. Thicker contour lines represent contour indices at multiples of 0.25 elevation, such as contours at 25.5 and 25.75. Closely spaced contour lines indicate sloping site, while widely spaced contours represent relatively flat areas.

The polygon and contour map were exported into the *AutoCAD* application in DXF file format for editing. The editing process in *AutoCAD* includes adjusting the accuracy of polygon lines to match the measurement points, setting the scale of the map, removing contour lines outside the polygon, adding the mosque's ground floor plan, adding the plan for the ablution area, and completing annotations for roads, fences, pedestrian paths, etc.

The final result of the tachymetry measurement process is a situational map of the mosque site, with a total area of 9,192.27 m². The built-up area (mosque and ablution facilities) covers 3,087.38 m² or 33.6%. These measurement results can serve as a reference for planning the landscape or exterior spaces of the mosque, which are currently unavailable.

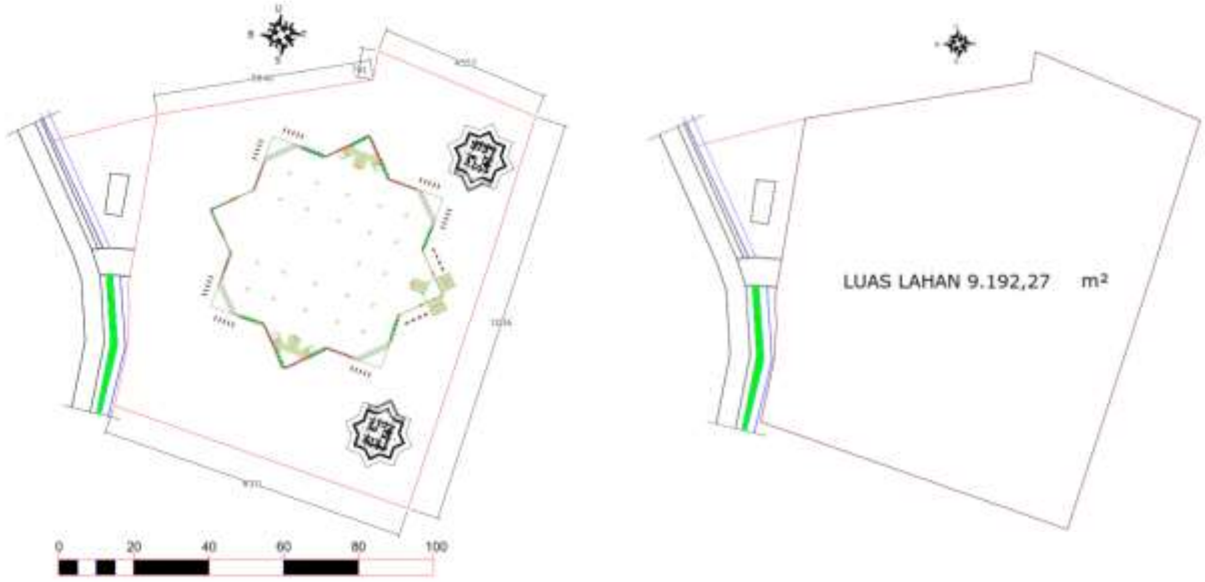

Figure 8. Situational Map of Sultan Alauddin Grand Mosque, UIN Alauddin Makassar
Source: Personal Data, 2024

The remaining 66.4% of the mosque site can be utilized for landscape planning, which will include green open spaces and additional facilities such as parking areas for congregants.

4. CONCLUSION

Tachymetry system measurements are essential prior to planning the landscape of a building. The results indicate that one-third of the site area has been developed, leaving two-thirds to be planned or designed for landscaping. This condition will reduce the green open space in the mosque area to below 50%, primarily due to the significant parking space required to accommodate the mosque’s capacity of over 2,500 congregants. Consequently, additional supporting parking areas around the mosque complex are necessary.

Furthermore, the Qibla direction of the Sultan Alauddin Grand Mosque, UIN Alauddin Makassar, needs to be re-evaluated. The measurement results show that the mosque does not align directly with the Qibla, deviating by 2°15' to the south.

Recommendation

The results of the tachymetry system measurements can serve as a reference for landscape planning of the Sultan Alauddin Mosque, UIN Alauddin Makassar. This includes planning for vegetation, parking areas, vehicle and visitor circulation, and other landscape elements. Additionally, follow-up action from the campus management or mosque committee is necessary to recheck the mosque's Qibla direction.

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