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Monitoring Results Analysis of Shudi Slope Project

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Abstract

The monitoring results of the Shudi landslide indicate that the maximum surface displacement of the slope deformation reaches over 30cm, and the deformation accounted for about 40% of the total deformation in 2019. The annual change rate decreased from 120mm/a in 2019 to 20mm/a in 2022. Although it is still continuing, the slope deformation shows a convergence trend; The longitudinal displacement of the slope is obvious between 1/4 to 3/4, and the displacement direction all points towards the river center, indicating the possibility of overall landslide and shear landslide.

Keywords: slope; deformation; monitoring; shear

For engineering construction, both natural and artificial slopes are very visible. The safety monitoring of slope engineering is an important part of engineering construction. Slope treatment not only affects engineering planning, investment, progress, etc., but more importantly, affects engineering safety. At the same time, it can also lead to more disaster problems. Improper handling can lead to the safety of people's lives and property. At present, there are various safety monitoring methods for slopes, such as using surface monitoring facilities to measure the plane displacement and settlement of monitoring points and understand external deformation; Sensors can be used to monitor the stress and strain inside the rock mass and analyze internal deformation; Use water level holes to monitor the changes in water level on the slope, and at the same time, use inclinometer holes to monitor and determine the internal sliding surface. In terms of monitoring data processing, it can analyze the deformation, velocity acceleration of monitoring points to understand external deformation; Stress analysis, mastering the stress balance of rock mass, and analyzing the potential risks of rock mass; Water level and inclination monitoring, combined with the characteristics of rock and soil, to grasp the changes in the infiltration line of slope soil and possible sliding surfaces, providing a basis for slope treatment; In terms of data analysis, individual points can be independently analyzed to grasp the deformation of feature points; It is also possible to analyze the deformation of multiple cross-sections based on cross-sectional analysis, which is convenient for comparative analysis; It can also monitor the overall analysis of the area, grasp the internal deformation mechanism of the slope through displacement force coupling, guide engineering construction, protect engineering safety and people's property safety.

1. Project Introduction

The Shudi landslide is located on the right bank of the Jinsha River, about 800m downstream of the suspension bridge, about 20km away from the dam site. The Lijiang Ninglang tourist highway has been circling around the landslide multiple times. Distributed at an elevation of 1350m to 1850m, with a length of 1000m, a width of 600m, a thickness of approximately 50m, and a volume of approximately 3000×10^4 m3. The scale of the landslide body is relatively large, and the landslide accumulation body is thick and loose. After the reservoir is filled with water, the front edge of the landslide body is immersed in the reservoir water, and the rock and soil are further saturated or softened by water, resulting in a decrease in its physical and mechanical strength; In addition, due to the relatively developed fault structures from Guoshi to Menhatu in the area, the rock weathering is strong, and the rock mass is broken. Under the action of reservoir water, the stability conditions of the bank slope will further deteriorate, and the landslide body may further revive or disintegrate. Therefore, it is necessary to monitor the slope.

2. Deformation Monitoring Design

The deformation monitoring of the slope surface is carried out by embedding observation piers and using a meas uring robot to observe according to the polar coordinate difference method. The specific layout of the points is divided into four sections, they are A-A'，B-B'，C-C' and D-D', with sections A-A' and D-D' located in the middle of the landslide mass, and sections B-B' and C-C' located on both sides, the section line runs through the landslide body from high to low and is approximately perpendicular to the Jinsha River, as shown in Figure 1.

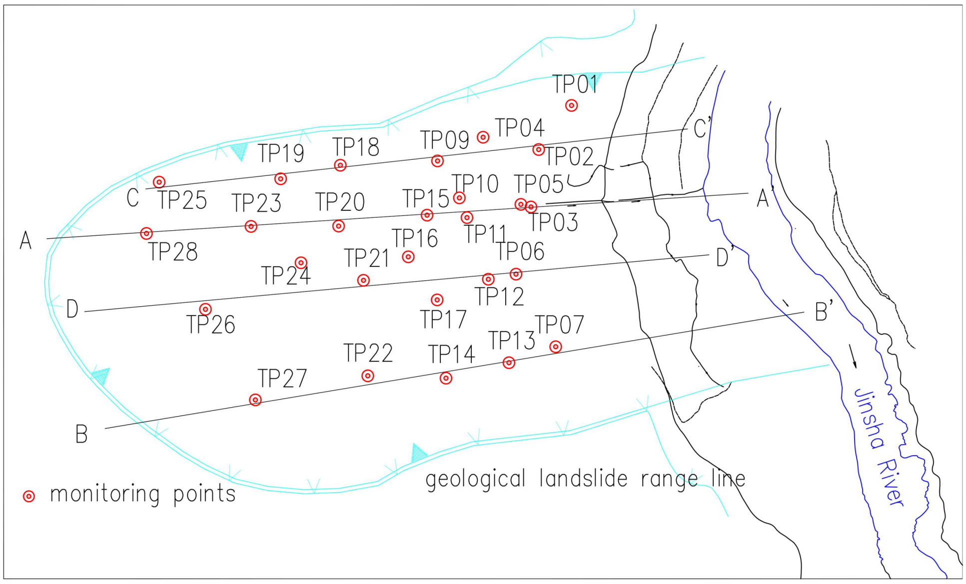

Figure 1. Layout of Monitoring Points

3. Analysis of cross-sectional monitoring results

After data preprocessing, the displacement of each point was calculated and analyzed into four sections. The specific deformation process lines are shown in Figures 2 to 5. At the same time, to better reflect the displacement characteristics, the feature points with the largest displacement on each section were selected. The annual cumulative displacement of each feature point is shown in Table 1, and the annual displacement increment and proportion statistics are shown in Tables 2 to Table 3. The comparison of annual displacement increment is shown in Figure 6.

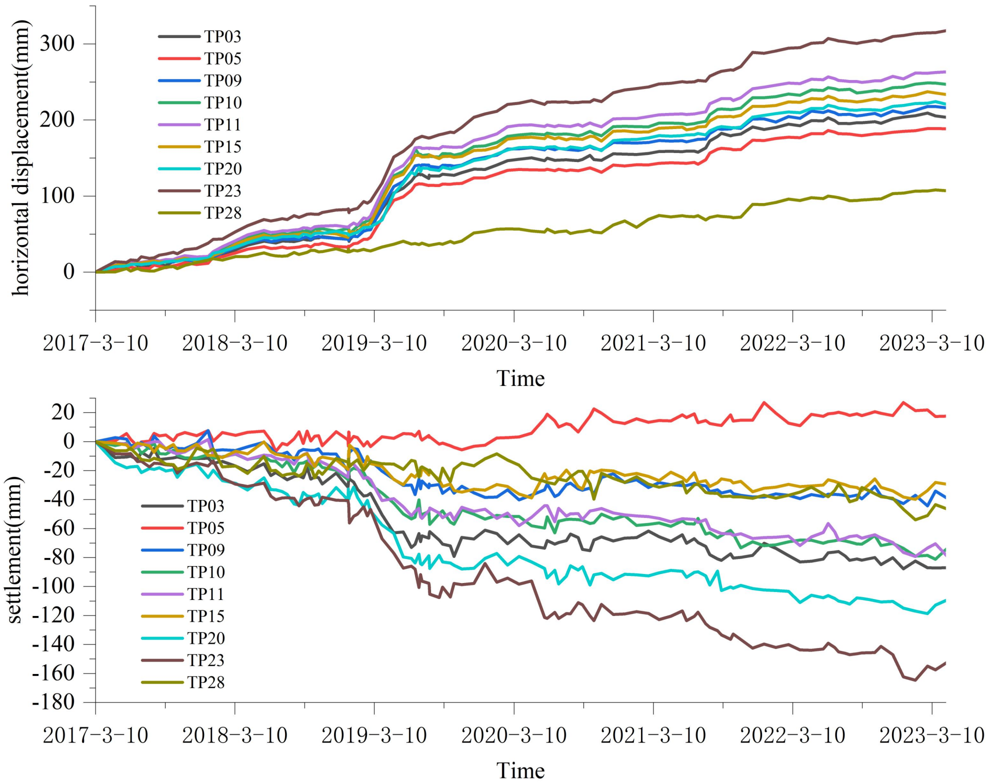

Figure 2. Horizontal displacement and settlement VS time on Section A-A'

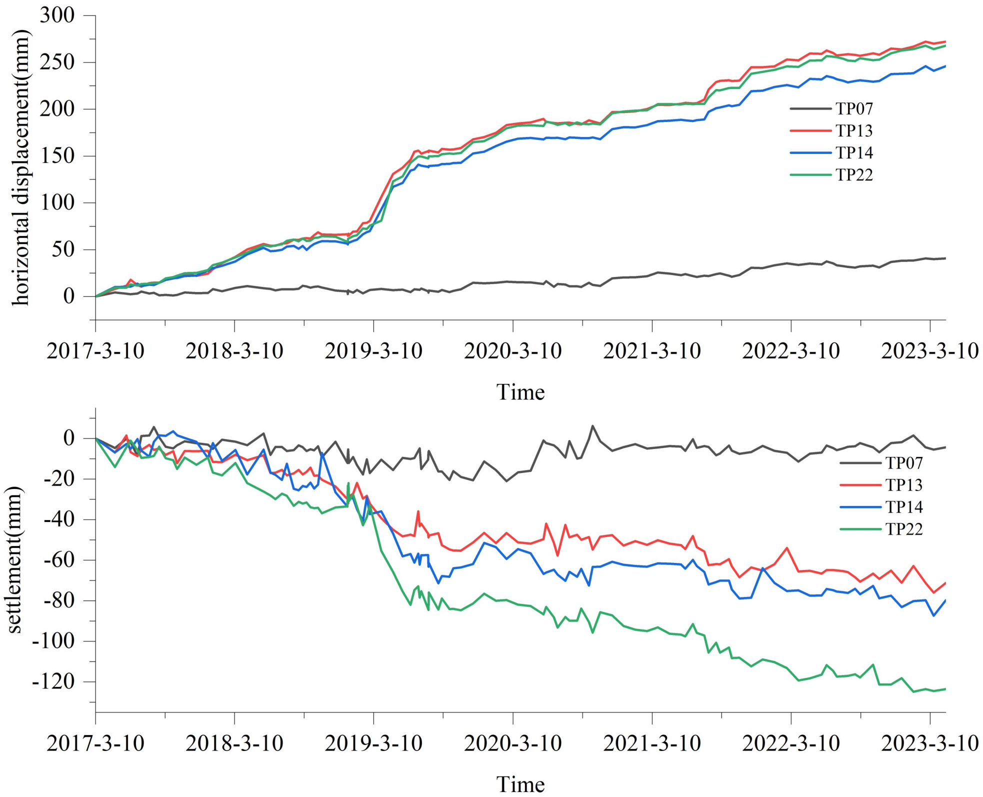

Figure 3. Horizontal displacement and settlement VS time on Section B-B'

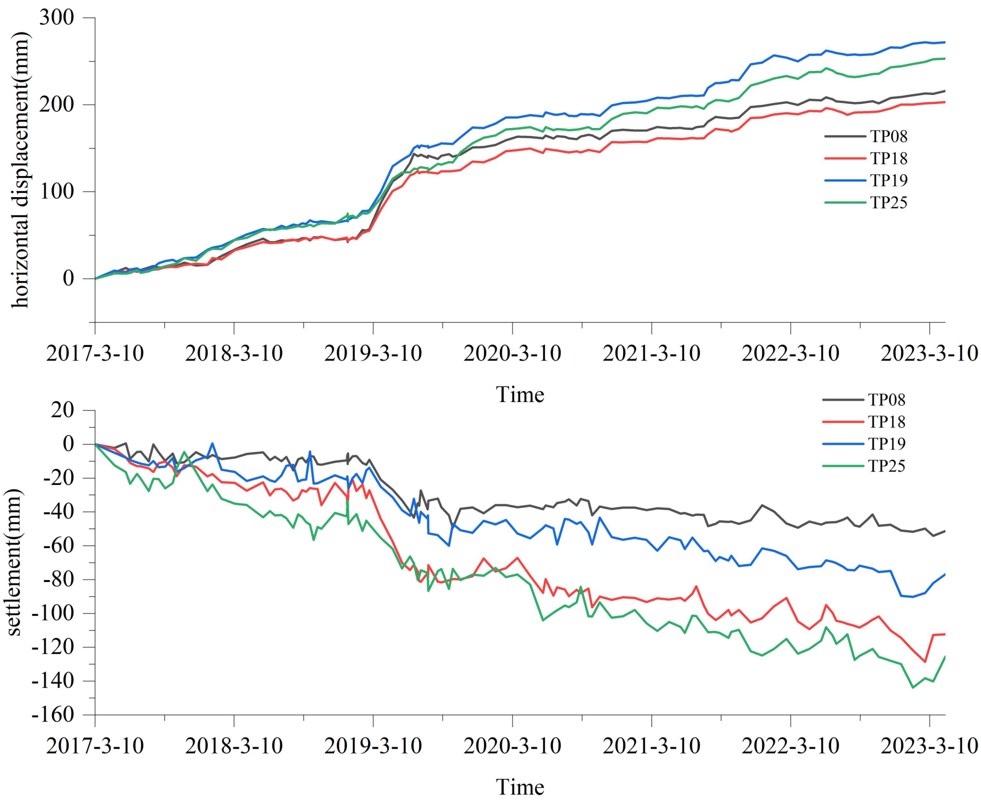

Figure 4. Horizontal displacement and settlement VS time on Section C-C’

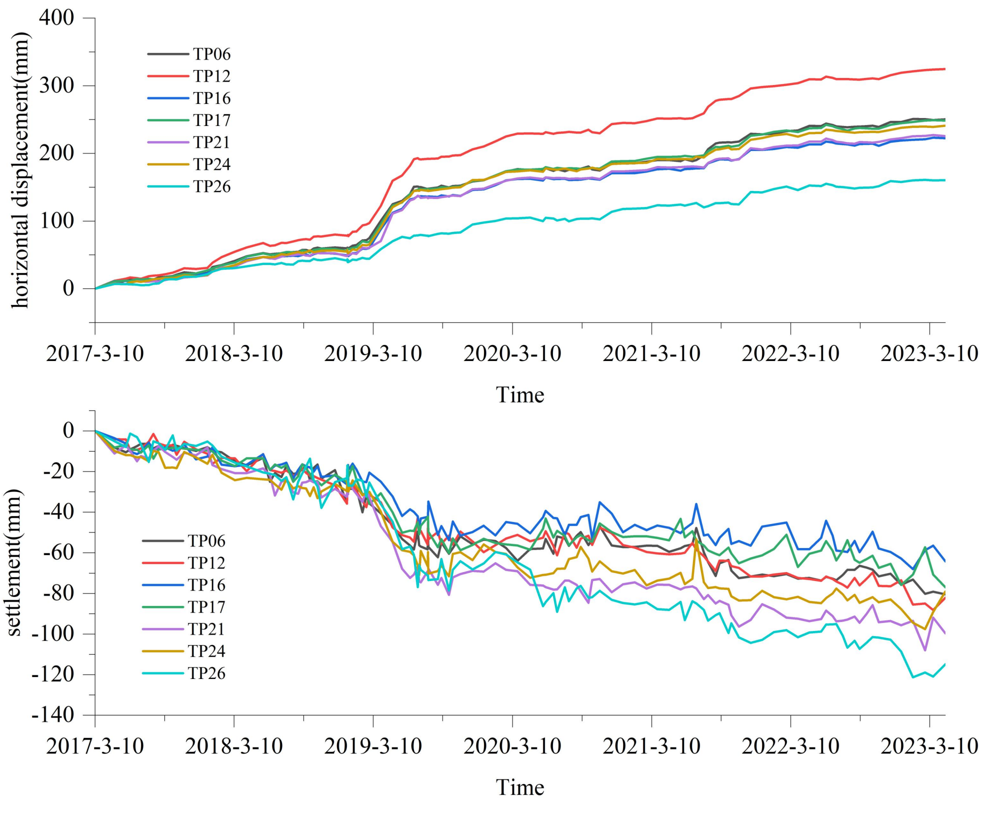

Figure 5. Horizontal displacement and settlement VS time on Section D-D’

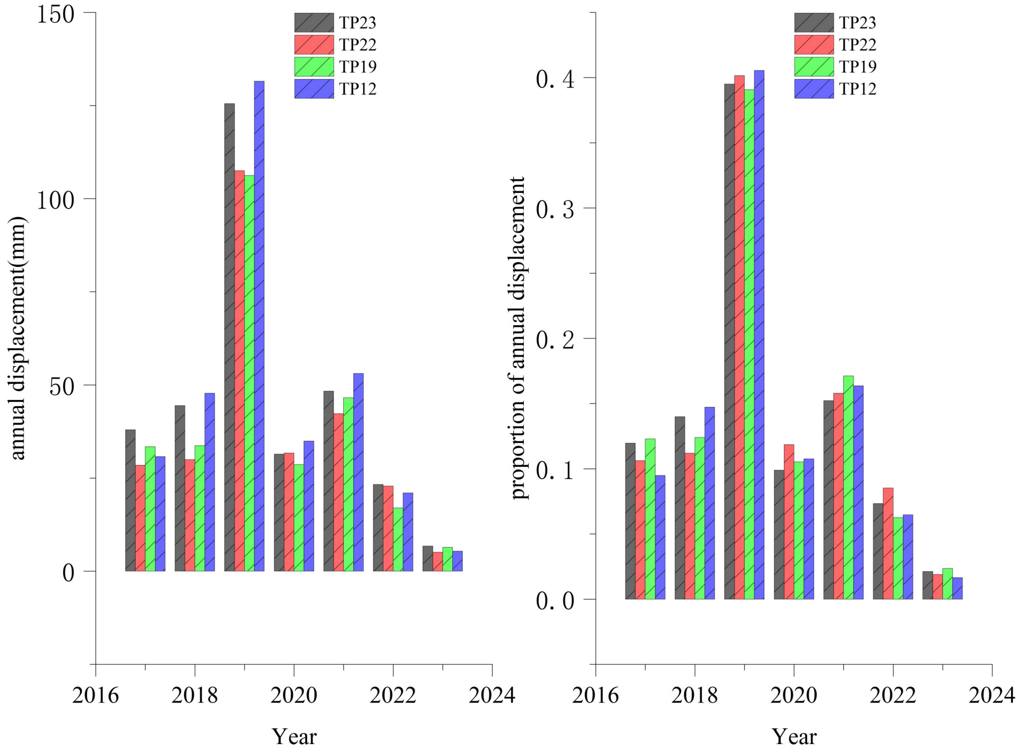

Figure 6. Comparison of Annual Displacement Increments of Feature Points

Table 1. Statistical Table of Annual Cumulative Displacement of Characteristic Points (mm)

Point / year	TP23	TP22	TP19	TP12
2017	38.0	28.4	33.4	30.8
2018	82.4	58.4	67.1	78.5
2019	207.9	165.8	173.3	210.1
2020	239.3	197.6	202.0	245.0
2021	287.7	239.8	248.5	298.1
2022	310.9	262.7	265.5	319.1
2023	317.7	267.7	271.9	324.4

Table 2. Statistical Table of Annual Displacement Increment of Characteristic Points (mm)

Point / year	TP23	TP22	TP19	TP12
2017	38.0	28.4	33.4	30.8
2018	44.4	29.9	33.7	47.8
2019	125.5	107.5	106.2	131.5
2020	31.4	31.7	28.6	34.9
2021	48.3	42.3	46.5	53.1
2022	23.3	22.8	17.0	21.0
2023	6.7	5.1	6.4	5.4

Table 3. Statistical Table of the Proportion of Annual Displacement to Total Displacement of Each Characteristic Point as of 2022

Point / year	TP23	TP22	TP19	TP12
2017	12.2%	10.8%	12.6%	9.6%
2018	14.3%	11.4%	12.7%	15.0%
2019	40.4%	40.9%	40.0%	41.2%
2020	10.1%	12.1%	10.8%	10.9%
2021	15.5%	16.1%	17.5%	16.6%
2022	7.5%	8.7%	6.4%	6.6%

From the above process line, statistical table, and displacement increment comparison chart, it can be seen that:

① The plane displacement deformation of the entire slope is mainly significant in the middle, with the maximum plane displacement exceeding 30cm. The deformation rate from 2020 to 2023 is significantly lower than that from 2018 to 2019; As of the end of 2022, the maximum annual variation of all displacements occurred in 2019, accounting for about 40% of the total displacement. The maximum point on the monitoring section had a variation of over 10cm in 2019; But all section displacements continue.

② The maximum displacement points of the A~D monitoring section are TP23, TP22, TP19, and TP12, respectively. Among these points, the A~C section occurs in the upper middle part, while the D section is slightly lower in the middle part of the slope, indicating the obvious possibility of the slope pushing landslide.

③ The process lines of the four sections are similar, indicating the existence of overall deformation. The entire slope is roughly parallel to the Jinsha River and runs through the slope along the line connecting points TP14 and TP17, and these points are located in the middle of the slope, with obvious deformation. There is a possibility of a push type landslide on the slope.

4. Overall analysis of slope monitoring

Sectional analysis can reflect the changes in various sections of the entire slope, but it cannot well reflect the overall changes of the entire slope. Use the displacement vector map and contour map of each monitoring point on the slope to study the overall deformation trend of the slope, as shown in Figures 6-7.

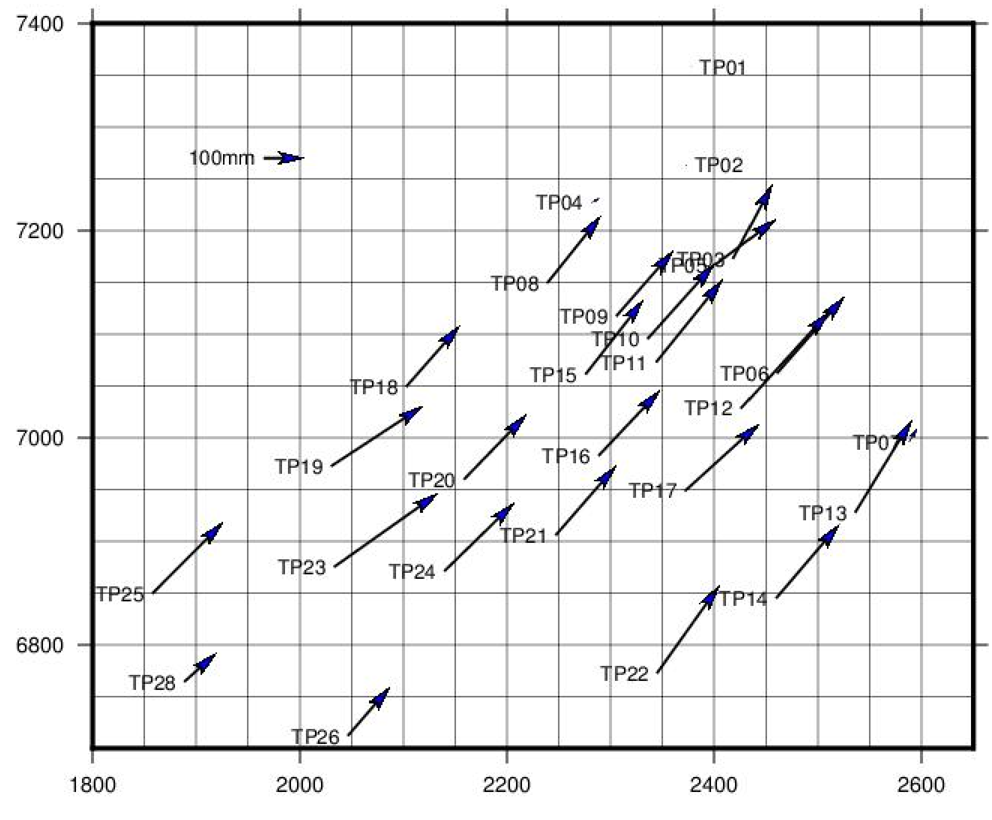

Figure 6. Displacement Vector Map of Each Monitoring Point on the Slope

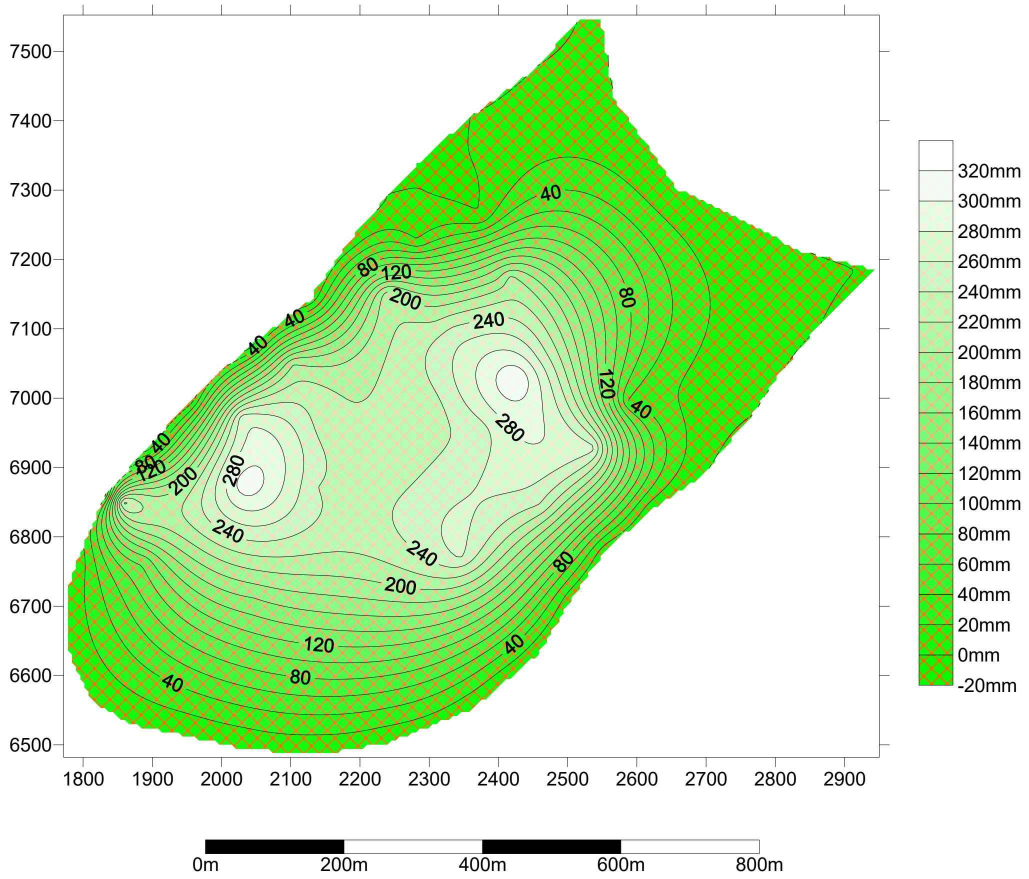

Figure 7. Contour map of slope displacement

From the displacement vector map and contour map above, it can be seen that:

① The displacement of the slope is located near the monitoring point TP14-TP17 line of the slope, where there are two areas with significant deformation. The high elevation is on the left side of the slope, with an elevation of approximately 1725m; The low elevation is slightly lower than the center of the slope, with an elevation of about 1580m. The entire deformation area is about 1/4-3/4 of the longitudinal length of the slope, and the displacement direction of the slope monitoring points is consistent, all pointing towards the direction of the river center.

② Facing the Jinsha River, the gradient of contour changes on the left side of the slope is perpendicular to the direction of the slope along the slope. There is a large ditch on the left side of the slope, and there may also be tensile cracks in the lateral direction of the slope, as well as the possibility of local lateral landslides.

③ From the overall deformation perspective, there may be a possibility of direct shear landslides in the middle of the slope.

5. Monitoring Conclusion and Suggestions

Based on the above analysis, the following conclusions can be drawn:

① The overall plane displacement of the current slope has reached a maximum of over 30cm, and the deformation in the middle of the slope is obvious. Unlike most riverbank slopes, which are caused by traction landslides due to river water erosion, there is a great possibility of backward sliding on the slope.

② There is a possibility of local lateral landslides on the slope.

③ The main displacement of the slope is located in the middle of the slope, and there is a possibility of direct shear from the middle of the slope.

Although the overall deformation rate of the slope has decreased compared to previous years, most points are still slowly deformed and the displacement is still increasing; If a landslide or shear failure occurs on the slope, it will inevitably lead to adverse effects such as blockage of the Jinsha River channel. Therefore, it is still necessary to strengthen slope monitoring and inspection, and provide certain engineering protection for the slope.

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