



Resources Estimation on further Exploration activities in PT. Trimegah Bangun Persada (Harita Group) Kawasi Village, South Halmahera District, North Maluku

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Abstract

PT. Trimegah Bangun Persada intends to do mining activity at the north part of IUP as the south and west parts have already been mined. This research aimed at producing natural resources of laterite nickel in the advanced exploration activity of Tangkuban Block. Besides, it also compared and determined the estimation methods having a good correlation with drilling results. Tangkuban Block carried out core drilling within total drill numbers of 286 spots and space distance 25 meters at the block area 22.16 Ha. This research began with determining the geological domain consisting of limonite, saprolite, and bedrock through a geo-statistical approach. After that, the researcher estimated nickel resources by three methods namely ordinary kriging, inverse distance weight, and nearest neighbor point. The result of estimation by ordinary kriging obtained a total volume of limonite layer 1,345,313 m³ with the content average of 1%, while the total volume of saprolite layer was 1,850,000 m³ 1.64%.

1. Introduction

Laterite nickel is one of popular mining commodity used for electronic battery because of it lithium content. Nickel laterite can be extracted from earth used the open cast mining method. Before extracted, nickel laterite needs prospecting and sampling to determine its value and grade.

Prospecting is the activity for surveying and collecting data or information about the existence of mining commodities [1]. One of the prospecting methods is drilling exploration. Drilling is used to determining the geological domain and minerals grade [2]. Geological domain and minerals grade used for estimated distribution of minerals grade. For volume estimated used three methods: Inverse Distance Weight, Nearest Neighbour Point, and Ordinary Kriging.

Based on the above, a detailed prospecting activity was conducted to determine the amount of laterite nickel resources in the Tangkuban block. This study will compare three estimated methods that are Ordinary Kriging, Inverse Distance Weight, and Nearest Neighbor Point.

2. Methodology

The data used are data from further exploration of the Tangkuban block drilling activities as many as 286 drill points resulting in a sample of 4,967.

2.1. Data Analysis

The IDW method determines the sample weight (w) as a function of the sample distance to the estimated block [4]. The formula for this method is:

$$\hat{Z} = \frac{\sum_{i=1}^n \frac{1}{d_i^k} x_{zi}}{\sum_{i=1}^n \frac{1}{d_i^k}} \dots\dots\dots(1)$$

Where :

- \hat{Z} : Estimated point value
- d_i : The distance between point i and the estimate
- k : Power (1, 2, 3, 4,, n)
- Z_i : The value of the i-estimator point

The estimation of reserves using the nearest neighbor point (NNP) method is based on a block model framework. In general, the calculation method using the NNP method gives the same results as the manual section method, but the results of this assessment can be used directly in mine planning using a computer [3].

Things that need to be considered in kriging [3] :

$$Z^* = \sum_{i=1}^n \lambda_i Z_i \dots\dots\dots(2)$$

$$\sum_{i=1}^n \lambda_i \bar{\gamma}(v, v) + \mu = \bar{\gamma}(v, V) \dots\dots\dots(3)$$

Where:

- Z^* = estimated grade
- $\bar{\gamma}(v, v)$ = Expresses the average value $\bar{\gamma}(h)$ if one end of the vector h shows the v (x) domain as well
- $\bar{\gamma}(v, V)$ = Expresses the average value $\bar{\gamma}(h)$ if one end of the vector h shows the V (x) domain or block while the other shows the v (x) or point domain
- λ_i = Weight value at point i
- Z_i = The value of the weighted sample content/thickness
- μ = Langrange multiplier

2.2 Validation

If we have measurement data for variable X and tell us that it has something to do with the second variable, namely Y, then this pair of data is called a bivariate population so there are two main questions, namely:

- a. is there a relationship between the two variables in the bivariate population?
- b. if there is a relationship, how do we express the relationship in an equation?

This is a very common problem and a graph that is presented as a representation of Y and X (in a cross-cartesian axis system) in statistics is called a scatter diagram [4], [5]. The equation for the linear regression line is presented in simple form:

$$Y = a + b X \dots\dots\dots(4)$$

Where:

- Y = Bound Variable
- X = Independent Variable
- a = Regression Constant
- b = Regression Constant constants a and b are calculated based on the equation

3. Results

3.1. statistical analysis

In estimating nickel resources, the statistics of all data samples must be known in advance to find out whether the sample has one population or more than one population which is determined by the frequency distribution and linear regression of the drill data sample.

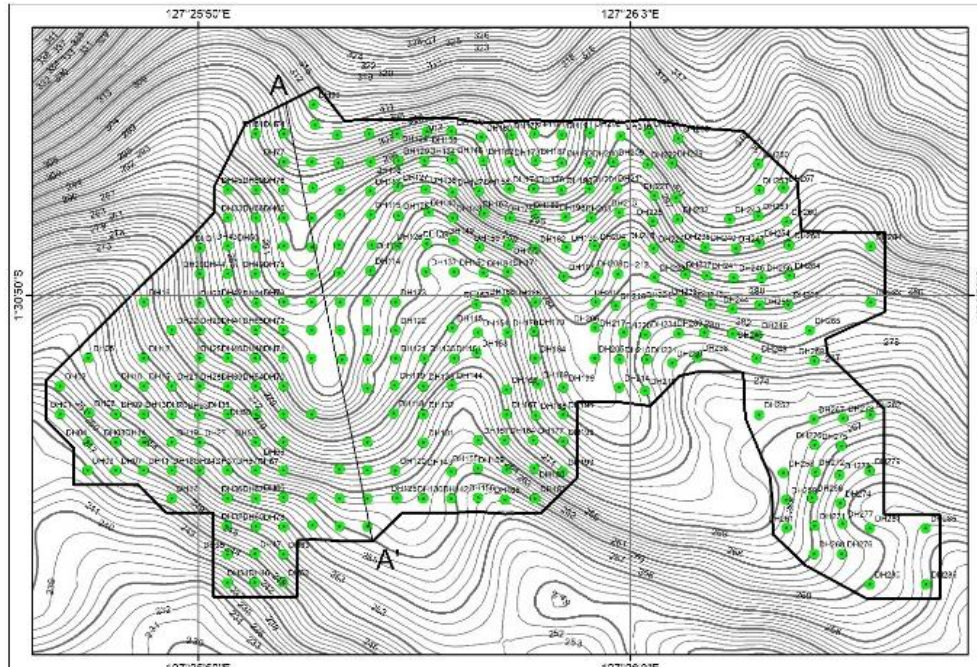


Figure 1. The Distribution of Drill Holes

Statistical analysis starting from the minimum data, the maximum to the sample variance, is more clearly seen in the table below.

Table 1. Statistical analysis of sample data

Statistics	Ni
Amount of data (n)	4,738
Minimum	0.120
Maximum	3.614
Mean	1.233
Standard Error	0.009
Median	1.160
Mode	0.870
Deviation	0.606
Kurtosis	-0.654
Skewness	0.312
Variance	0.367

Based on the statistical analysis above, it can be seen that the data in the standard deviation table is quite large, this shows that the thickness sample distribution tends to be uneven while the CV value is > 0.5 , which indicates that the sample is quite heterogeneous. Figure 1 shows a map of the distribution of drill holes at the research location.

3.2. Nickel Resources estimate

Estimation of laterite nickel resources uses three resource estimation methods, namely the Inverse Distance Weight, Nearest Neighbour Point, and Ordinary Kriging methods. The nickel resource estimation is carried out based on the geological domain, which means that the estimation of nickel

resources separately in the limonite and saprolite layers. Meanwhile, the bedrock layer resource was not estimated because it is a layer containing a very low nickel content.

a. Inverse Distance Weight (IDW)

The estimation of laterite nickel resources using the inverse distance weight method on the limonite layer, the maximum distance estimation of the grade was limited to 51.27 meters based on the nickel variogram analysis. The total blocks formed were 8,647 blocks.

The resource estimation using the inverse distance weight method for the limonite layer obtained a total volume of 1,395,094 m³ with a minimum grade of 0.32%, a maximum of 2.17% with an average grade of 1%. The estimation results of limonite layer nickel resources using the IDW method are as follows.

Table 2. IDW Method Limonite Coating Nickel Resource Report

Ni Range	Volume	%Ni
0.3 -> 0.4	3,437.5	0.32
0.4 -> 0.5	3,593.8	0.46
0.5 -> 0.6	17,968.8	0.55
0.6 -> 0.7	68,281.3	0.65
0.7 -> 0.8	135,312.5	0.75
0.8 -> 0.9	214,687.5	0.85
0.9 -> 1.0	263,750.0	0.94
1.0 -> 1.1	268,125.0	1.04
1.1 -> 1.2	164,531.3	1.14
1.2 -> 1.3	92,812.5	1.24
1.3 -> 1.4	57,812.5	1.34
1.4 -> 1.5	26,406.3	1.44
1.5 -> 1.6	19,843.8	1.54
1.6 -> 1.7	4,687.5	1.65
1.7 -> 1.8	6,562.5	1.76
1.8 -> 1.9	937.5	1.86
1.9 -> 2.0	625.0	1.96
2.0 -> 2.1	625.0	2.00
2.1 -> 2.2	1,093.8	2.17
Total	1,351,094.0	1.00

In the saprolite layer, the maximum distance assessment is limited to 67.78 meters based on nickel variogram analysis. The total blocks formed are 11,895 blocks.

The resource estimation using the inverse distance weight method for the saprolite layer obtained a total volume of 1,858,594 m³ with a minimum grade of 0.36%, a maximum of 2.91% with an average grade of 1.64%. The estimation results of saprolite layer nickel resources using the IDW method are as follows.

Table 3. IDW Method Saprolite Coating Nickel Resource Report

Ni Range	Volume	%Ni
0.3 -> 0.4	3,281.3	0.36
0.4 -> 0.5	5,312.5	0.44
0.5 -> 0.6	5,781.3	0.55
0.6 -> 0.7	8,593.8	0.65
0.7 -> 0.8	15,937.5	0.74
0.8 -> 0.9	21,406.3	0.85
0.9 -> 1.0	38,906.3	0.95
1.0 -> 1.1	46,250.0	1.05
1.1 -> 1.2	75,156.3	1.15
1.2 -> 1.3	105,000.0	1.25
1.3 -> 1.4	139,062.5	1.34

Ni Range	Volume	%Ni
1.4 -> 1.5	145,781.3	1.45
1.5 -> 1.6	181,562.5	1.55
1.6 -> 1.7	190,781.3	1.64
1.7 -> 1.8	197,031.3	1.74
1.8 -> 1.9	180,937.5	1.85
1.9 -> 2.0	182,500.0	1.94
2.0 -> 2.1	133,125.0	2.04
2.1 -> 2.2	85,156.3	2.14
2.2 -> 2.3	46,718.8	2.24
2.3 -> 2.4	21,718.8	2.34
2.4 -> 2.5	13,281.3	2.43
2.5 -> 2.6	6,718.8	2.54
2.6 -> 2.7	5,156.3	2.65
2.7 -> 2.8	1,718.8	2.76
2.8 -> 2.9	1,093.8	2.84
2.9 -> 3.0	625.0	2.91
Total	1,858,594.0	1.64

b. Nearest Neighborhood Point (NNP)

Estimation of laterite nickel resources using the nearest neighbor point method on the limonite layer, the maximum distance of the estimated grade is limited to 51.27 meters based on nickel variogram analysis. The total blocks formed were 8,603 blocks.

The resource estimation using the nearest neighbor point method for the limonite layer obtained a total volume of 1,344,219 m³ with a minimum grade of 0.26%, a maximum of 2.21% with an average grade of 0.99%. The estimation results of the limonite layer nickel resource using the NNP method are as follows.

Table 4. NNP Method Limonite Coating Nickel Resource Report

Ni Range	Volume	%Ni
0.2 -> 0.3	937.5	0.26
0.3 -> 0.4	9,687.5	0.35
0.4 -> 0.5	13,593.8	0.46
0.5 -> 0.6	43,125.0	0.55
0.6 -> 0.7	119,062.5	0.64
0.7 -> 0.8	152,656.3	0.74
0.8 -> 0.9	195,781.3	0.85
0.9 -> 1.0	208,125.0	0.94
1.0 -> 1.1	174,375.0	1.05
1.1 -> 1.2	138,125.0	1.14
1.2 -> 1.3	88,437.5	1.24
1.3 -> 1.4	72,343.8	1.34
1.4 -> 1.5	44,843.8	1.44
1.5 -> 1.6	41,718.8	1.54
1.6 -> 1.7	9,843.8	1.65
1.7 -> 1.8	14,843.8	1.75
1.8 -> 1.9	4,375.0	1.84
1.9 -> 2.0	4,062.5	1.92
2.0 -> 2.1	3,593.8	2.02
2.1 -> 2.2	3,437.5	2.15
2.2 -> 2.3	1,250.0	2.21
Total	1,344,219.0	0.99

In the saprolite layer, the maximum distance assessment is limited to 67.78 meters based on nickel variogram analysis. The total blocks formed are 11,895 blocks.

The resource estimation using the nearest neighbor point method for the saprolite layer obtained a total volume of 1,858,594 m³ with a minimum grade of 0.26%, a maximum of 3.44% with an average grade of 1.64%. The estimation results of saprolite layer nickel resources using the NNP method are as follows.

Table 5. NNP Method Saprolite Coating Nickel Resource Report

Ni Range	Volume	%Ni
0.2 -> 0.3	6,718.8	0.26
0.3 -> 0.4	20,625.0	0.34
0.4 -> 0.5	32,343.8	0.45
0.5 -> 0.6	28,281.3	0.54
0.6 -> 0.7	21,093.8	0.65
0.7 -> 0.8	32,187.5	0.75
0.8 -> 0.9	41,093.8	0.84
0.9 -> 1.0	59,531.3	0.95
1.0 -> 1.1	62,656.3	1.04
1.1 -> 1.2	72,187.5	1.14
1.2 -> 1.3	85,000.0	1.24
1.3 -> 1.4	105,937.5	1.34
1.4 -> 1.5	88,750.0	1.45
1.5 -> 1.6	137,343.8	1.54
1.6 -> 1.7	147,500.0	1.65
1.7 -> 1.8	133,281.3	1.74
1.8 -> 1.9	152,812.5	1.84
1.9 -> 2.0	133,281.3	1.94
2.0 -> 2.1	169,062.5	2.04
2.1 -> 2.2	92,812.5	2.15
2.2 -> 2.3	74,218.8	2.24
2.3 -> 2.4	46,562.5	2.35
2.4 -> 2.5	43,125.0	2.44
2.5 -> 2.6	22,812.5	2.55
2.6 -> 2.7	17,031.3	2.65
2.7 -> 2.8	3,593.8	2.75
2.8 -> 2.9	12,656.3	2.84
2.9 -> 3.0	7,031.3	2.95
3.0 -> 3.1	4,375.0	3.02
3.1 -> 3.2	1,875.0	3.15
3.2 -> 3.3	1,406.3	3.2
3.4 -> 3.5	1,406.3	3.44
Total	1,858,594.0	1.64

c. Ordinary Kriging (OK)

The estimation of laterite nickel resources using the ordinary kriging method in the limonite layer, the maximum distance of the estimated grade is limited to 51.27 meters based on nickel variogram analysis. The total blocks formed were 8,610 blocks.

The resource estimation using the ordinary kriging method for the limonite layer obtained a total volume of 1,345,313 m³ with a minimum grade of 0.32%, a maximum of 2.17% with an average grade of 1%. The estimation results of the limonite layer nickel resource using the OK method are as follows.

Table 6. OK Method Limonite Coating Nickel Resource Report

Range Ni	Volume	%Ni
0.3 -> 0.4	3,437.5	0.32
0.4 -> 0.5	3,906.3	0.47
0.5 -> 0.6	20,937.5	0.56
0.6 -> 0.7	71,093.8	0.65
0.7 -> 0.8	129,531.3	0.75
0.8 -> 0.9	215,781.3	0.85
0.9 -> 1.0	264,531.3	0.95
1.0 -> 1.1	247,812.5	1.04
1.1 -> 1.2	168,750.0	1.14
1.2 -> 1.3	97,187.5	1.24
1.3 -> 1.4	57,343.8	1.34
1.4 -> 1.5	30,781.3	1.44
1.5 -> 1.6	17,812.5	1.54
1.6 -> 1.7	5,625.0	1.64
1.7 -> 1.8	6,406.3	1.76
1.8 -> 1.9	2,187.5	1.84
1.9 -> 2.0	312.5	1.94
2.0 -> 2.1	937.5	2.01
2.1 -> 2.2	937.5	2.17
Total	1,345,313.0	1

In the saprolite layer, the maximum distance assessment is limited to 67.78 meters based on nickel variogram analysis. The total blocks formed are 11,840 blocks.

The resource estimation using the ordinary kriging method for the saprolite layer obtained a total volume of 1,850,000 m³ with a minimum grade of 0.36%, a maximum of 2.91% with an average grade of 1.64%. The estimation results of saprolite layer nickel resources using the OK method are as follows.

Table 7. OK Method Saprolite Coating Nickel Resource Report

Range Ni	Volume	%Ni
0.3 -> 0.4	3,125.0	0.36
0.4 -> 0.5	3,593.8	0.44
0.5 -> 0.6	4,375.0	0.55
0.6 -> 0.7	4,843.8	0.64
0.7 -> 0.8	10,781.3	0.75
0.8 -> 0.9	17,031.3	0.84
0.9 -> 1.0	33,750.0	0.95
1.0 -> 1.1	42,031.3	1.05
1.1 -> 1.2	72,500.0	1.15
1.2 -> 1.3	112,187.5	1.25
1.3 -> 1.4	139,843.8	1.34
1.4 -> 1.5	168,125.0	1.45
1.5 -> 1.6	186,718.8	1.55
1.6 -> 1.7	198,281.3	1.65
1.7 -> 1.8	212,187.5	1.75
1.8 -> 1.9	193,281.3	1.85
1.9 -> 2.0	172,187.5	1.94
2.0 -> 2.1	126,093.8	2.04
2.1 -> 2.2	76,562.5	2.14
2.2 -> 2.3	40,000.0	2.24
2.3 -> 2.4	15,156.3	2.33
2.4 -> 2.5	10,000.0	2.44

Range Ni	Volume	%Ni
2.5 -> 2.6	3,125.0	2.53
2.6 -> 2.7	2,656.3	2.65
2.7 -> 2.8	468.8	2.78
2.8 -> 2.9	625.0	2.83
2.9 -> 3.0	468.8	2.91
Total	1,850,000.0	1.64

3.3. Estimation Validate

Validation of resource estimates is carried out to compare and determine the estimation results with what method will be used for reporting the nickel laterite resources of the Tangkuban block. All methods used will be compared with the results of the drilling which have been composited based on the distribution at X, Y, and Z coordinates.

To determine the method used as resource reporting, correlation regression is used to determine which method has a correlation coefficient that is closest to 1.

The following is the regression correlation of the estimation method with the composite drilling results which is calculated based on the distribution on the X, Y, and Z coordinates.

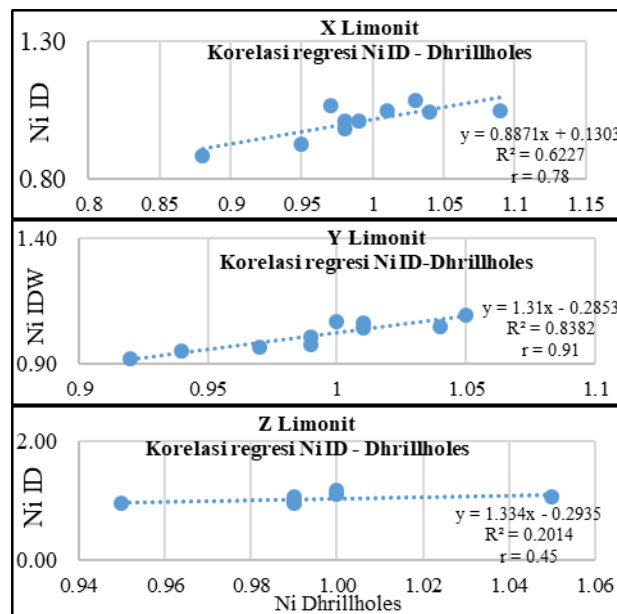
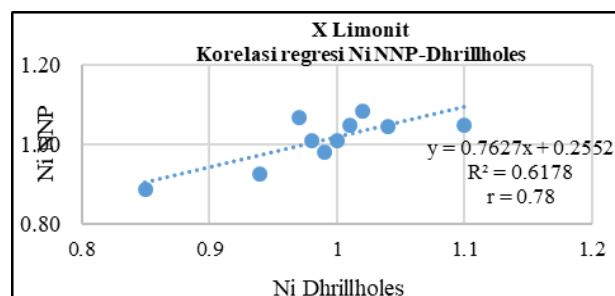


Figure 2. Correlation of IDW-Dhrillholes Ni Limonite Estimation Regression Based on the Distribution at X, Y, and Z Coordinates

The results of the regression correlation of the IDW method of nickel laterite estimation with the distribution of nickel content based on the results of drilling in the limonite layer calculated along the X, Y, and Z coordinates obtained a regression correlation at X coordinates 0.78, Y 0.91 and Z 0.45. If average, the regression correlation value is 0.713



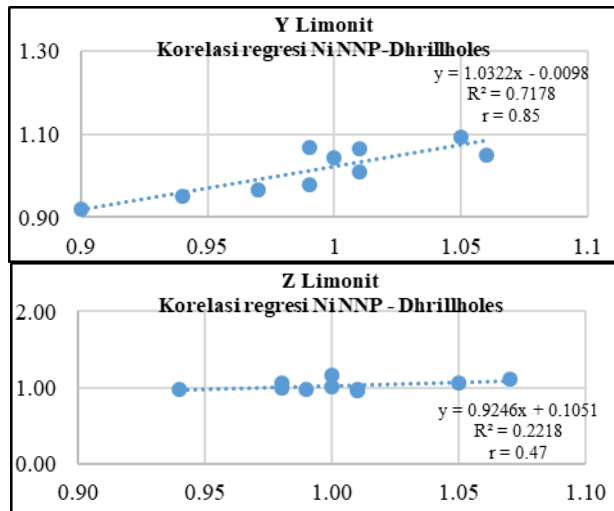


Figure 3. Correlation of NNP-Dhrillholes Ni Limonite Estimation Regression Based on the Distribution at X, Y, and Z Coordinates

The regression correlation results of the NNP method nickel laterite estimation with the distribution of nickel content based on the results of drilling in the limonite layer calculated along the X, Y, and Z coordinates obtained a regression correlation at X coordinates 0.78, Y 0.85, and Z 0.47. If average, the regression correlation value is 0.7.

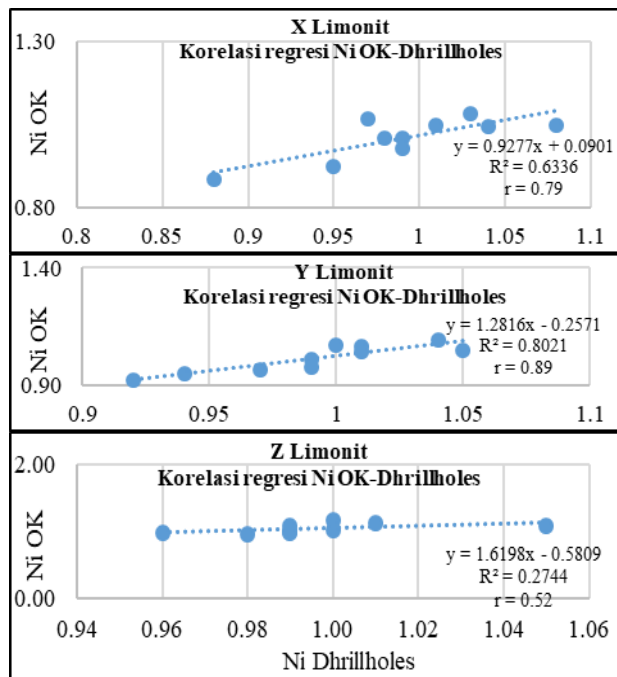


Figure 4. Correlation of OK-Dhrillholes Ni Limonite Estimation Regression Based on the Distribution at X, Y, and Z Coordinates

The regression correlation result of the OK method nickel laterite estimation with the distribution of nickel content based on the drilling results in the limonite layer which was calculated along the X, Y, and Z coordinates obtained a regression correlation at X coordinates 0.79, Y 0.89, and Z 0.52. If average, the regression correlation value is 0.73.

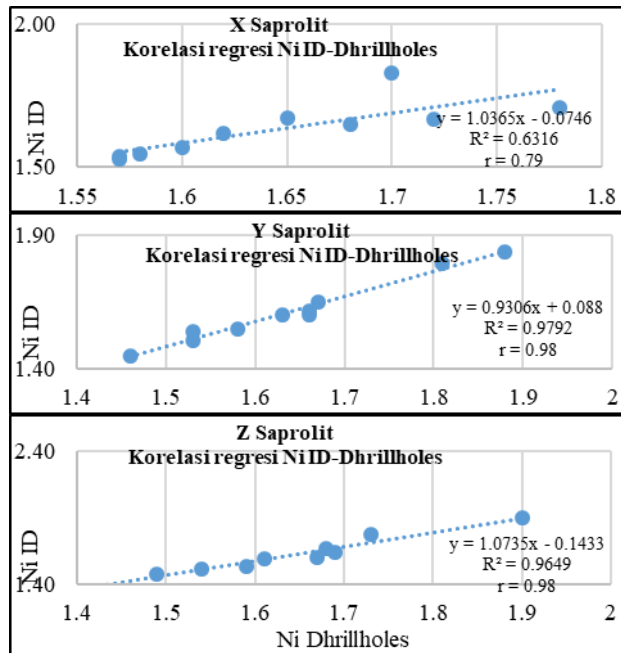


Figure 5. Correlation of IDW-Dhrillholes Ni Saproilit Estimation Regression Based on the Distribution at X, Y, and Z Coordinates

The results of the regression correlation of the IDW method of nickel laterite estimation with the distribution of nickel content based on the drilling results in the saprolite layer calculated along the X, Y, and Z coordinates obtained a regression correlation at X coordinates 0.79, Y 0.98 and Z 0.98. If average, the regression correlation value is 0.916.

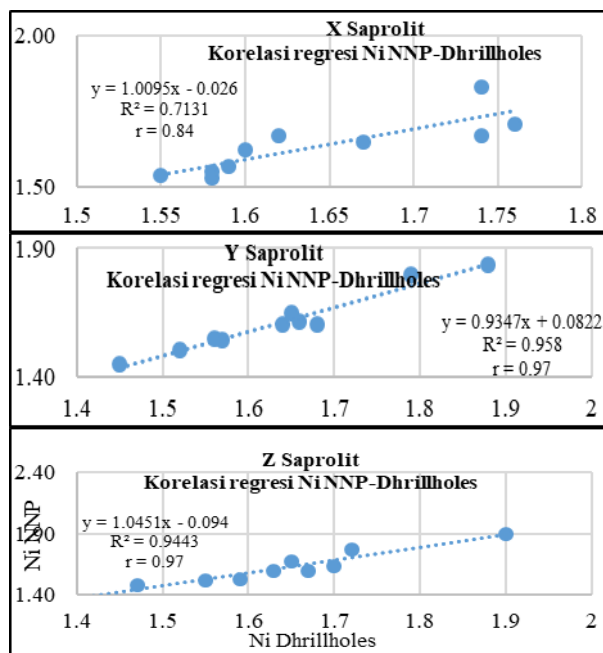


Figure 6. Correlation of NNP-Dhrillholes Ni Saproilit Estimation Regression Based on the Distribution at X, Y, and Z Coordinates

The results of the regression correlation of the NNP method nickel laterite estimation with the distribution of nickel content based on the drilling results in the saprolite layer which was calculated along the X, Y, and Z coordinates obtained a regression correlation at X coordinates 0.84, Y 0.97 and Z 0.97. If average, the regression correlation value is 0.926.

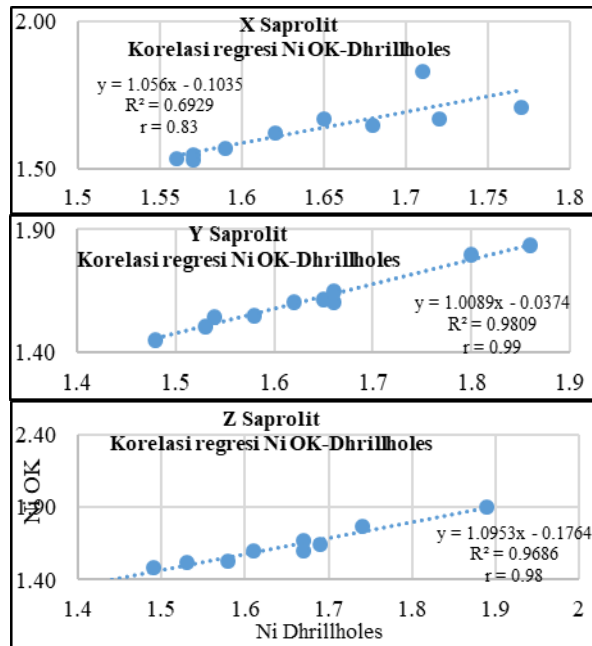


Figure 7. Correlation of OK-Dhrillholes Ni Saproilit Estimation Regression Based on the Distribution at X, Y, and Z Coordinates

The regression correlation result of the OK method of laterite nickel estimation with the distribution of nickel content based on the drilling results in the saprolite layer which was calculated along the X, Y, and Z coordinates obtained a regression correlation at X coordinates 0.83, Y 0.99 and Z 0.98. If average, the regression correlation value is 0.933.

4. Discussion

The regression correlation results show that the estimation using the ordinary kriging method is the best correlation with the drilling results in the limonite and saprolite layers. Then the reporting of laterite nickel resource estimates in the Tangkuban block uses the ordinary kriging estimation method.

Table 8. OK Method Saproilit Coating Nickel Resource Report

Geological Domain	IDW	NNP	OK
Limonit	0,713	0,7	0,73
Saproilit	0,916	0,926	0,933

PT. Trimegah Bangun Persada – block Tangkuban has nickel resources of 1,345,313.0 m³ with a minimum grade of 0.32%, a maximum of 2.17%, and an average nickel grade of 1%. While the saprolite layer is 1,850,000.0 m³ with a minimum content of 0.36%, a maximum of 2.91%, and an average nickel grade of 1.64%. The distribution of limonite and saprolite layers is shown in figure 8 and figure 9 below.

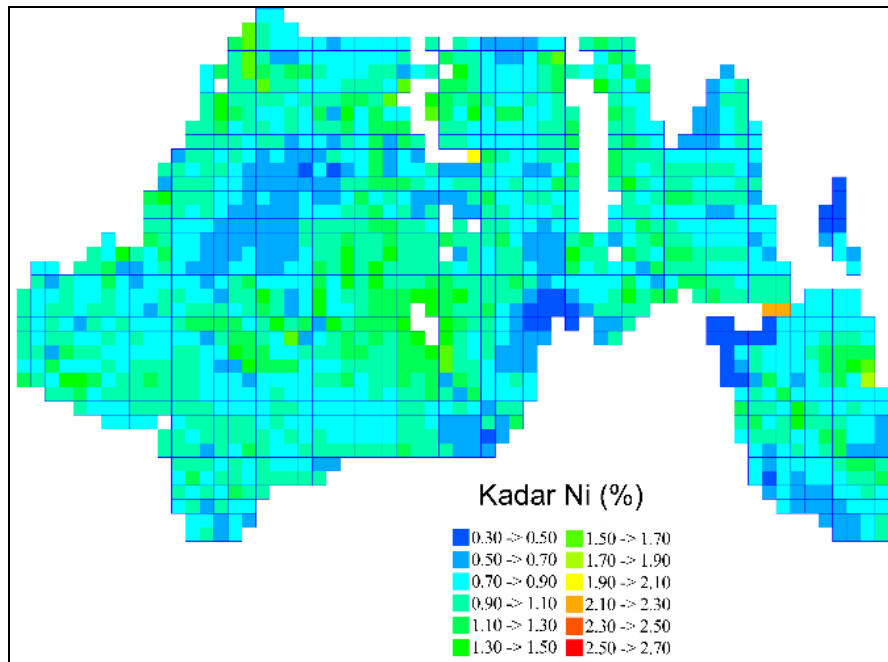


Figure 8. Distribution of Limonite Layer Nickel Content

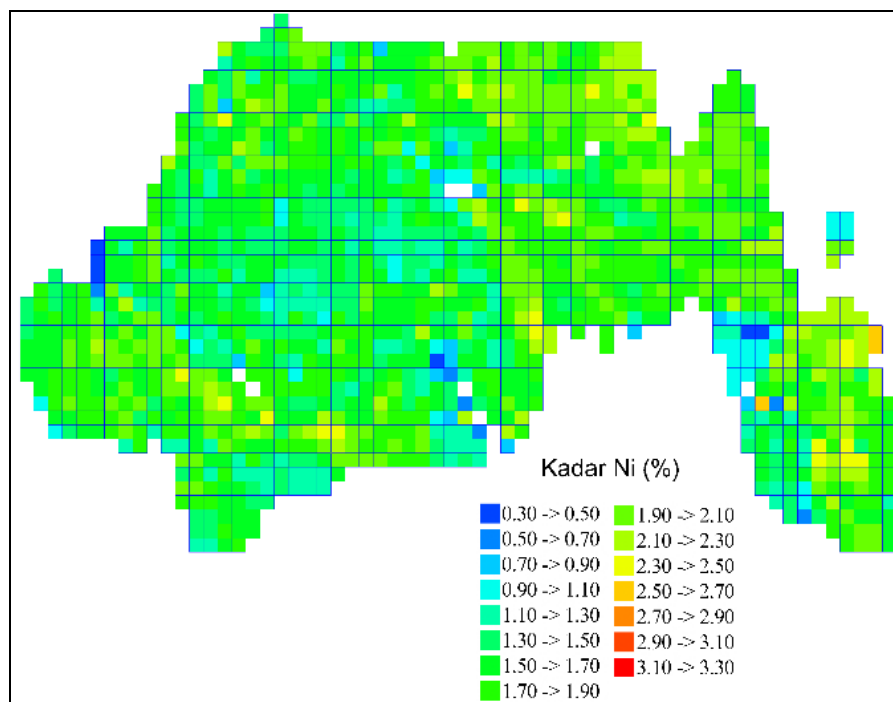


Figure 9. Distribution of Saprolite Layer Nickel Content

5. Conclusion

Tangkuban block is an advanced exploration activity of PT. Trimegah Bangun Persada has nickel resources of 1,345,313.0 m³ with a minimum grade of 0.32%, a maximum of 2.17%, and an average nickel grade of 1%. While the saprolite layer is 1,850,000.0 m³ with a minimum content of 0.36%, a maximum of 2.91%, and an average nickel grade of 1.64%.

Determination of the appropriate estimation method in the Tangkuban block is based on the regression correlation of the estimation results with the results of the composite drilling which is measured based on the distribution at the X, Y, and Z coordinates. It is then obtained that both the limonite and saprolite layers use the ordinary kriging estimation method because they better correlation than inverse distance weight and nearest neighbour point.

In further progress of the Tangkuban block of PT. Trimegah Bangun Persada is suggested to develop some design of mining plan by according to several sources [6]–[8]

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