



# The Impact of Rapid Urban Growth on Potential Groundwater Pollution in Ngemplak Sub-District, Sleman District

**Rivi Neritarani<sup>1</sup>**

Department of Urban and Regional Planning, Universitas Amikom Yogyakarta, Yogyakarta, Indonesia

**Sadewa Purba Sejati**

Department of Geography, Universitas Amikom Yogyakarta, Yogyakarta, Indonesia

Received : 21 January 2021

Accepted : 23 July 2021

Available Online : 31 August 2021

**Abstract:** Ngemplak Sub-District is one of the administrative regions in Sleman Regency which has experienced quite intensive urban development. Based on several studies, this region experienced a fairly rapid change in landuse. This landuse changes has resulted in pressure on the natural resources in this region, especially water resources. The study aims to develop a strategy to maintain the sustainable function of land resources in the midst of massive land changes in Ngemplak Sub-District. This research uses landuse comparative method at two different times to identify rapid urban growth. Whereas to identify potential groundwater pollution, this research uses the GOD method which is use three parameters, they are groundwater occurrence (G), overall aquifer class (O), and depth to water table (D). Based on the results of data processing, there was an increase in built-up area in Ngemplak Sub-District from 2006 to 2015 amounting to 235. 58 hectares. This increase in built-up area is a trigger factor for the emergence of environmental problems, namely the exploitation of water resources found in this region. Based on the results of data processing using the GOD method, the overall potential groundwater pollution in the Ngemplak Sub-District is included in the extreme class.

**Keywords:** groundwater; potential groundwater pollution; rapid urban growth

## Introduction

Ngemplak Sub-District is one of the administrative regions in Sleman District which is 35.71 km<sup>2</sup> large and consists of 5 villages. Ngemplak Sub-District is located adjacent to Cangkringan Sub-District on the north side, adjacent to Klaten District on the east side, adjacent to Kalasan Sub-District and Depok Sub-District on the south side, and adjacent to Ngaglik District on the west side. Ngemplak Sub-District is an administrative area located in Sleman Regency, Special Region of Yogyakarta, and a little part of its area is included in the Yogyakarta Urban Area (*Kawasan Perkotaan Yogyakarta/KPY*). As a small part of KPY, the urbanization processes in this Sub-District has become more intensive. This conditions also emphasized by the location of its Sub-District that directly adjacent to Depok Sub-

---

<sup>1</sup> Corresponding Author: Department of Urban and Regional Planning, Universitas Amikom Yogyakarta, Indonesia  
Email: rivi.neritarani@amikom.ac.id

### How to Cite.

Neritarani, R., & Sejati, S. P. (2021). The impact of rapid urban growth on potential groundwater pollution in Ngemplak Sub-District, Sleman District. *Jurnal Wilayah dan Lingkungan*, 9(2), 198-212. doi:10.14710/jwl.9.2.198-212.

District where there area universities as a trigger for population growth which results in increased space needs in form of settlements.

Several researches of landuse changes in Ngemplak Sub-District have been carried out previously (Devi et al., 2020; Fajri et al., 2013; Hastuti et al., 2016; Hendrayana & Vicente, 2013; Maishella et al., 2020; Sejati, 2021; Sharadqah, 2017; Valent et al., 2020). This is an evidence of the massive changes in landuse in this Sub-District. Landuse changes in generally occur from productive land in the agricultural sector or agricultural land into residential or non-agricultural land (Giyarsih, 2010).

According to a research of landuse changes within a period of fifteen years, especially from 1994 to 2009 in Ngemplak Sub-District, this research explained that, for fifteen years, there had been a change in landuse with a percentage of 38.20% of the Ngemplak Sub-District total area (Nugraha, 2013). The research of massive landuse changes in Ngemplak Sub-District was also stated by (Suminar, 2018). In this research it was explained that, within six years, namely in 2010 to 2016, there had been changes in landuse from agricultural land into settlements with an area of 30.65% of the total area. This research provides the data of massive landuse change of built-up areas in Ngemplak Sub-District.

According to the two researches related to landuse changes in Ngemplak Sub-District, it can be concluded that in the last six years, changes in landuse from agricultural land to non-agricultural land in Ngemplak Sub-District can be said to be relatively more intensive. This is because to achieve 30.65% change of land only takes about six years. Whereas in the previous period, to achieve 38.20% of landuse changes, it took approximately fifteen years. The massive landuse changes in Ngemplak Sub-District are basically inseparable from the factor of population growth which is also relatively fast in the last 5 years. High population growth causes regional services need to be increasingly high along with the increase of the population number. This affects the need of improved regional services in Ngemplak District. Regional service improvement is carried out by increasing development in Ngemplak District. This is supported by regional development programs in Ngemplak District as part of Sleman Smart Regency.

The massive development indicated by the massive processes of landuse change often hides variety negative consequences for the environment (Devi et al., 2020). If it is examined by using a cross-disciplinary field of view, development basically does not only show a positive impact on the welfare of the current generation of society, but also hides negative potential that might be felt in the next generation, especially if the regional planning which is applied in those areas is not according to sustainable development principles. Ngemplak Sub-District, for example, has undergone a process of "urbanization" which results in pressure on its natural resources. Landuse changes without the effort of environmental conservation, population growth, and excessive extraction of groundwater (Sutardi et al., 2017) are somethings that can cause pressure on natural resources in a region.

Groundwater resources are one of the natural resources that have a vital role in people's welfare. In the midst of massive urbanization processes in Ngemplak Sub-District, the preservation of groundwater resources must be maintained so that the benefits of the groundwater can be felt by people across generations. The concept to maintain sustainability of the groundwater resources is to apply zonation-based planning for potential groundwater pollution. Based on the problems of the region, this research tries to identify the impact of the massive urban processes on the potential for groundwater pollution in Ngemplak Sub-District and to develop an appropriate strategy for urban development based on the potential zoning results of groundwater pollution. The study aims to develop a strategy to maintain the sustainable function of land resources in the midst of massive land changes in Ngemplak Sub-District

## Research Methods

### *Rapid Urban Growth Zoning*

Rapid urban growth zonation in Ngemplak Sub-District is the result of data processing from urban growth elements. Urban growth elements can be identified from two things, namely physical morphologic growth and socio-cultural growth (Yunus, 2005). Physical morphologic growth of the city is an urban growth which is characterized by the physical changes in the land and the urban morphology of the city. Whereas socio-cultural growth of the city in is an urban growth which is characterized by social and cultural changes elements such as population, habits, and culture. Identification of rapid urban growth can be done in two methods, they are using spatial approach and using socio-cultural approach (Valent et al., 2020). Spatial approach is using a comparative method of the urban physical changes, whereas socio-cultural approach is using a comparative method of population change in the region.

This research identifies the rapid urban growth in Ngemplak Sub-District by comparing the physical condition of land in different years. This method is done by comparing land use data in the initial year with the final year of Ngemplak Sub-District. The comparison of the data is intended to obtain the built-up area changes extent of two different times. It can be done by overlaying the data of two landuse condition in the different times. The results of the overlaying processes of these two data can be information of urban physical growth Ngemplak Sub-District (see Table 1).

Land use data for two different years were obtained from the interpretation of high-resolution satellite imagery of Ngemplak Subdistrict in 2009 and 2015. The land use data used not only come from remote sensing data but also use secondary data from the Topographic Map of Indonesia (*Peta Rupabumi Indonesia*).

The differences between built-up area in 2006 and 2015 can indicate that there was a built-up areas accretion in Ngemplak Sub-District. This research use nine years time differences which can be shown the different landuse condition of Ngemplak Sub-District intensively. The results of rapid urban growth zonation in Ngemplak Sub-District were then used as the basis for analyzing the impact to potential groundwater pollution in areas which is experienced significant increases of built-up area.

**Table 1. Rapid Urban Growth Zoning of Ngemplak District Data**

| No. | Data  | Data Type | Source  |
|-----|---|-----------|---|
| 1   | Built-up area distribution of Ngemplak Sub-District in 2006 | Primary   | Indonesian Topographical Map, Pakem and Cangkringan Sheets in 2006                |
| 2   | Built-up area distribution of Ngemplak Sub-District in 2015 | Primary   | High-resolution satellite imagery interpretation of Ngemplak Sub-District in 2015 |
| 3   | Population data of Ngemplak Sub-District in 2006 and 2015   | Secondary | Statistics Central Bureau (BPS): Ngemplak Sub-District in Figures 2006 and 2015.  |

### *Potential Groundwater Pollution Zoning*

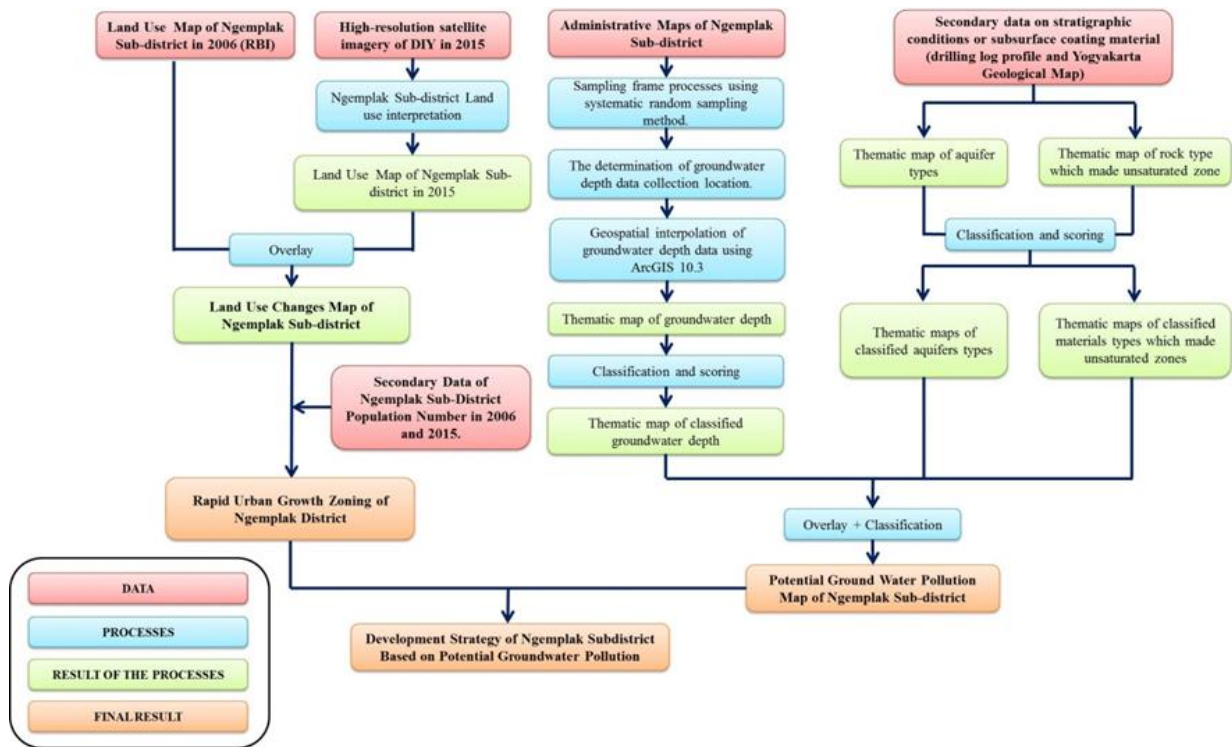
Potential groundwater pollution zoning is a geospatial product that informs the condition of a region related to the potential for groundwater pollution. The potential of groundwater pollution itself can be interpreted as the ability of a region based on the ease of the groundwater itself to be polluted. The geospatial method which can be used to assess the potential of groundwater pollution is the GOD method (Boulabeiz et al., 2019; Djoudi et al., 2019; Sartika et al., 2020; Sharadqah, 2017). The method use three parameters, they are Groundwater occurrence (G) or the type of aquifer, Overall aquifer class (O) or the type of rock which made unsaturated zone, and Depth to water table (D) or depth of groundwater.

Groundwater occurrence (G) is indicated by the type of aquifer. The unconfined aquifer which is only limited by one waterproof layer cause the groundwater less protected. Overall aquifer class (O) is indicated by the type of rock which made unsaturated zone. The unconsolidated material has high water absorbing into soil layer. If the absorbed water is contaminated (become a liquid pollutant), groundwater will be polluted as well. Depth to water table (D) is indicated by the depth of groundwater. The shallow groundwater can be polluted easily.

The data of aquifer and rock type of unsaturated zone are obtained from groundwater drilling log profiles as the secondary data, while the primary data which is used in this research are the depth of groundwater data. The data is processed into three thematic maps, they are maps of aquifer type, maps of rock type on unsaturated zone, and maps of groundwater depth. The final product is processed by overlaying those three maps using ArcGIS 10.3. Schematically, the flow of potential groundwater pollution definition in Ngemplak District can be seen in Figure 1. Whereas the details of the data which is used to definite the potential groundwater pollution in Ngemplak District can be seen in the Table 2.

**Table 2. Potential Groundwater Pollution Zoning Data**

| No. | Data   | Data Type | Source   |
|-----|--|-----------|--|
| 1   | Depth of groundwater   | Primary   | Direct measurements of residents' wells                              |
| 2   | Stratigraphic profile/ Wells drilling logs profile                 | Secondary | Water Supply Project of the Ministry of Public Works, Sleman Regency |
| 3   | Indonesian Topographical Map, Pakem and Cangkringan Sheets in 2006 | Secondary | Geospatial Information Agency (Badan Informasi Geospasial)           |



**Figure 1. Research Flow Chart**

The method and technical analysis of the impact of rapid urban growth on potential groundwater pollution in Ngemplak Sub-District can be seen in Figure 1.

## Results and Discussions

### *Urbanization Processes of Ngemplak Sub-District*

The urbanization process is one of the processes which take place intensively in Ngemplak Sub-District. The urbanization process in Ngemplak Subdistrict is concluded as rapid urban growth processes. Urban growth which occurs in Ngemplak Sub-District can be divided into two type, they are urban physical morphologic growth and socio-cultural growth.

Urban physical morphologic growth is an urban growth which is characterized by the physical changes in the land and the urban morphology of the city. Urban physical morphologic growth that occurs in Ngemplak Sub-District can be seen from landuse changes. Landuse changes referred to changes of unbuilt-up area into built-up land. Based on the results of the built-up area identification of Ngemplak Sub-District in 2006 and in 2015, it can be seen that there was a significant increase of built-up area (see Table 3 and Table 4).

In 2006, built-up area in Ngemplak Sub-District reached 992.98 hectares or 27.19% of the total area. The built-up area in Ngemplak Sub-District in 2006 mostly clustered in a straight pattern following the road network. In 2006, the built-up area dominated the south side of Ngemplak Sub-District which adjacent with Ngaglik Sub-District and Kalasan Sub-District. These three Sub-Districts are included in the Yogyakarta Urban Area (KPY). This resulted in the development intensity of the built-up area becoming rapidly occurs. The trigger factor for the development here is the fulfillment of regional service needs as part of Yogyakarta Urban Area (KPY)

**Table 3. Ngemplak Sub-District Land Use in 2006**

| No. | Land Use        | Width (Hectares) | %      |
|-----|-----------------|------------------|--------|
| 1   | Built-Up Area   | 992.98           | 27.19  |
| 2   | Unbuilt-Up Area | 2659.62          | 72.81  |
|     | <b>TOTAL</b>    | 3652.60          | 100.00 |

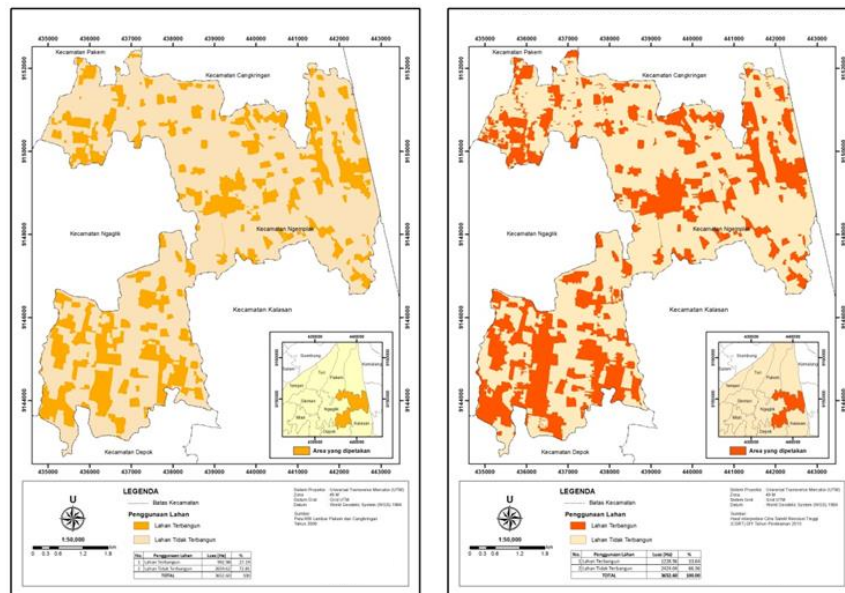
In 2015, built-up area still dominated the south side of Ngemplak Sub-District. As in 2006, built-up area dominated the south side which adjacent with Ngaglik Sub-District and Kalasan Sub-District as part of Yogyakarta Urban Area (KPY). Therefore, there was an increase in width of built-up area of Ngemplak Sub-District in 2015. In contrast to the built-up area in 2006, in 2015 built-up area of Ngemplak Sub-District increased to 1228.56 hectares or reached 33.64% of total area. The increase of built-up area in Ngemplak Subdistrict in 2015 mostly occurred on the south side. However, based on the process of land use changes from unbuilt-up areas into built-up areas, more changes occur on the north side. The amount of unbuilt-up area which has changed into more developed area is relatively on the north side of Ngemplak Sub-District. The trigger for this is basically due to the large amount of unbuilt up area in this side, so that the development of settlements is focused on lands that have not been built yet.

Accroding to the data in 2006 and 2015 (see Table 3 and Table 4), it can be concluded that in nine years, there were an incrase of built-up area in Ngemplak Sub-District amounting to 235.58 hectares. The comparison of the increase in built-up land area is based on spatial analysis in two different years. The nine year range is a time span that is close enough to see the massive change of unbuilt-up area into built-up area. The spatial

comparison of the built-up area distribution of Ngeemplak Sub-District in 2006 and 2015 can be seen in Figure 2.

**Table 4. Ngeemplak Sub-District Land Use in 2015**

| No. | Land Use        | Width (Hectares) | %              |
|-----|-----------------|------------------|----------------|
| 1   | Built-Up Area   | 1228.56          | 33.64          |
| 2   | Unbuilt-Up Area | 2424.04          | 66.36          |
|     | <b>TOTAL</b>    | <b>3652.60</b>   | <b>3652.60</b> |



**Figure 2. Comparison of Built-Up Area Distribution of Ngeemplak Sub-District in 2006 - 2015**

The study of built-up area changes of Ngeemplak Subdistrict can also be assessed based on agricultural land (wetland) data which is found in this region. Based on land use data in Ngeemplak Subdistrict, in the span of 5 years, namely from 2012 to 2017 there were changes in land use from agricultural land (wetland) to non-agricultural land. This can be indicated by the reduced area of paddy fields found in Ngeemplak Sub-District. In 2012, the area of agricultural land in Ngeemplak Subdistrict reached 10.84 km<sup>2</sup>, whereas in 2017, it reached 17.19 km<sup>2</sup>. This shows that there is a reduction of agricultural in Ngeemplak Sub-District by 3.65 km<sup>2</sup> which in 2017 turned into non-agricultural land. This shows that the conversion of agricultural land in Ngeemplak Subdistrict into non-agricultural land is relatively intensive.

The urbanization process in Ngeemplak District not only can be seen from the morphological physical growth of the Sub-District, but also can be seen from socio-cultural growth. Socio-cultural growth in Ngeemplak Sub-District occurred from a significant increase in population. Based on data from Ngeemplak Sub-District in Figures 2018, it is known that in 2017 the population number recorded in this Sub-District reached 65,951 people consist of 33,007 males and 32,944 females. With the total area of the Sub-District reaching 35.71 km<sup>2</sup>, the population density in Ngeemplak Sub-District is relatively high, reaching 1,847 people per km<sup>2</sup>. This population has increased significantly in the span of 5 years. In 2012, it was recorded that the population number of Ngeemplak Sub-District reached 56,869 people. It shows that population growth rate of Ngeemplak Sub-District for 5

years from 2012 to 2017 reached 3%. This significant population growth also has an impact on land use change in Ngemplak Sub-District. This is because the more population in a region, the more of space for housing will be increased. So that it is possible for the changes of land to be quite intensive in Ngemplak Sub-District. The relatively high intensity of land use change is an indicator of rapid urban growth.

Based on the analysis of urban processes that occurred in Ngemplak Sub-District, basically it can be seen that the growth of a city is marked by the increase of built-up area. This built-up area increase is a trigger factor for the emergence of new environmental problems, especially the exploitation of water resources found in Ngemplak Sub-District. Water resources exploitation is not only about water use problems but also waste produced problems.

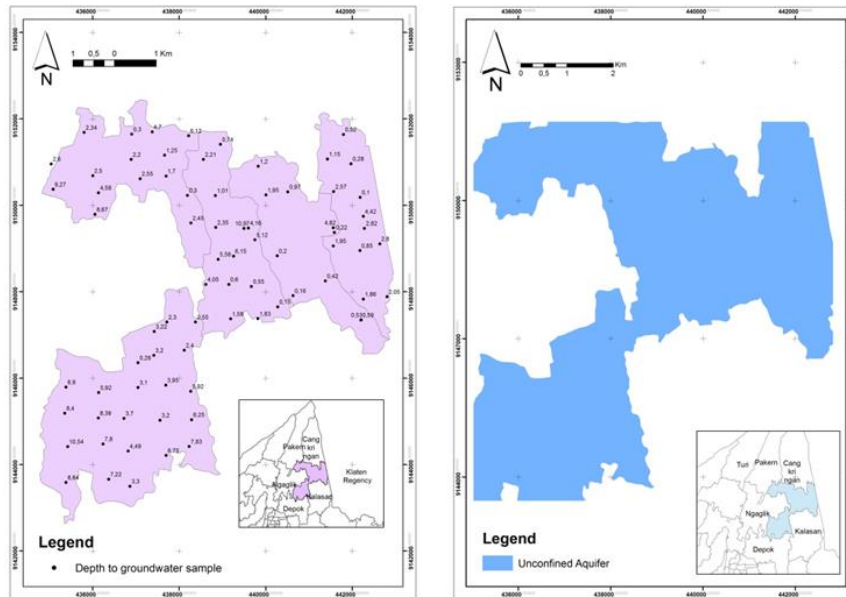
The problem of excessive water usage become one of the problems that always resurface when the amount of built-up area become wider. This is because the need for clean water for households will increase along with the increase population living in the area. The new problem here is the problem of household waste that is also produced as the result of the household activities. The wider built-up areas, it causes number of household activities in a region increase. The increasing number of household activities in a region, water needs will be increased and more waste will be produced. The waste produced by a household is one of the problems comes along with the occurrence of groundwater pollution. This is possible if the waste produced is not managed properly and it is only absorbed into the soil.

#### ***Potential Groundwater Pollution in Ngemplak Sub-District***

As stated in the introduction section, that the potential groundwater pollution is the ability of a region based on the ease of the groundwater itself to be polluted (Vrba et al., 1994). Natural physical aspects are usually used to evaluate an area if it is associated with potential groundwater pollution. This research use three natural physical aspects found in the Ngemplak Sub-District to conduct an identification of the potential groundwater pollution. Among the physical aspects used in this research are groundwater occurrence, natural material conditions in the overlying lithology zone, and depth to groundwater table. The selection of the three physical aspects is certainly based on the method to conduct an identification or evaluation of the potential groundwater pollution. This research use GOD method to identify potential groundwater pollution. Naming of GOD method takes natural parameters elements that are used to assess the potential groundwater pollution. G is an acronym of groundwater occurrence, O is taken from overlying lithology (the conditions of natural material in unsaturated groundwater zone), and D is an acronym of depth to water table (depth of groundwater)(Vrba et al., 1994).

The type of aquifer (groundwater occurrence) in Ngemplak Sub-District has a uniform condition, namely the unconfined aquifer. The existence of unconfined aquifers in Ngemplak Sub-District can be explained by the number of excavated wells made by the local community to access groundwater. The distribution of wells in Ngemplak Sub-District can be seen in Figure 3. The distribution of wells on the map originated from the primary data on the location of the well samples determined by systematic random sampling method. According to theoretical studies, unconfined aquifers are layers of aquifers which are only limited by one waterproof layer. The waterproof layer is at the bottom of the aquifer. The unconfined aquifer layer causes groundwater can be accessed by making wells. The existence of unconfined aquifers causes groundwater to be accessible easily. However, because the impermeable layer is only at the bottom of the aquifer, unconfined aquifers can be more vulnerable to groundwater pollution by various activities carried out on the surface. Pollutants in the form of liquid waste will be easier to enter under the soil surface to reach the saturation zone of groundwater. Therefore, in determining the

potential groundwater pollution using the GOD method, if an area has an unconfined aquifer system, the score is at the highest number, which is 1 point. Ngemplak Sub-District has a uniform aquifer type, so from the geospatial data for the type of aquifer also does not vary. The geospatial data regarding the type of aquifer in Ngemplak Sub-District can be seen in Figure 3.



**Figure 3. Distribution of Wells and Groundwater Occupancy in Ngemplak Sub-District**

The natural physical parameter that influences the determination of potential groundwater pollution is overlying strata. These parameters indicate the lithological conditions or natural material layers under the soil surface in the unsaturated groundwater zone. To identify the layers, three drill data containing information about stratigraphy or natural material layers under the surface were used. The three drill data which is used in this research are secondary data. The three data which is used are drilling records data for water supply that has been carried out in Juluh, Kenthingan, and Pakembinangun Sub-District. Two of three drilling records data are located within area of Ngemplak Sub-District, but there is one supplementary data located in Pakem Subdistrict which is still adjacent to the administration area of the Ngemplak Sub-District. The result of drilling records data interpretation which is used in this research can be seen in Table 5.

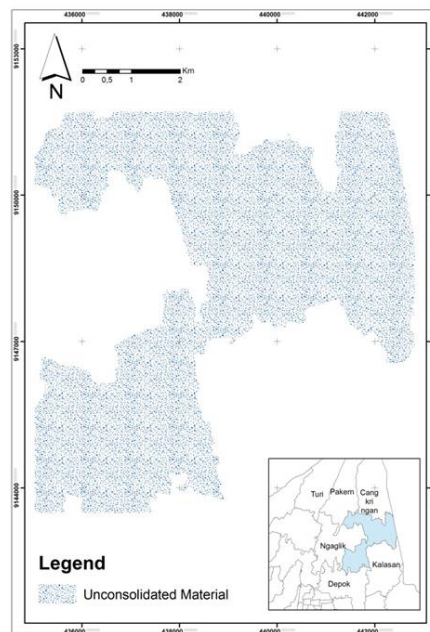
According to the information in the Table 5, it can be seen that natural material under the soil surface which is also a constituent material in the unsaturated groundwater zone is dominated by material that is loose or unconsolidated material, such as sand of various sizes and gravel. Based on this identification, if it is associated with the GOD method, these materials are classified into unconsolidated material classes. The material has the ability to easily absorb water, so the score is a maximum score, 1 point. The overlying strata map of Ngemplak Sub-District can be seen in Figure 4.

The next natural physical parameter is depth to groundwater table. Depth of groundwater is the distance between the land surface to the groundwater level in the water saturation zone. This parameter can be easily observed and measured in an area that has an unconfined aquifer. The measurement location is carried out on wells made by residents to access groundwater. Distribution of measurement locations can be seen in the previous image.



**Table 5. Natural Material in Ngemplak Sub-District**

| Drilling Location                 | Material                             | Depth (m)   |           |
|-----------------------------------|--------------------------------------|-------------|-----------|
|                                   |                                      | From (m)    | Until (m) |
| Pakembinangun, Sleman (PPAB,1984) | Soil                                 | 0           | 1.5       |
|                                   | Coarse sand and fine gravel          | 1.5         | 5.5       |
|                                   | Fine gravel                          | 5.5         | 8         |
|                                   | Coarse sand and medium sand          | 8           | 21        |
|                                   | Fine gravel                          | 21          | 22.5      |
|                                   | <b>Andesit</b>                       | <b>22.5</b> | <b>45</b> |
| Jelapan, Sleman (PPAB,1995/1996)  | Soil                                 | 0           | 1         |
|                                   | Fine sand and coarse sand            | 1           | 32        |
|                                   | Medium sand and coarse sand          | 32          | 40        |
|                                   | Fine sand                            | 40          | 42        |
|                                   | Medium sand and coarse sand          | 42          | 54        |
|                                   | Medium sand                          | 54          | 56        |
|                                   | Fine sand and coarse sand            | 56          | 58        |
|                                   | Fine sand and medium sand            | 58          | 64        |
|                                   | <b>Clay</b>                          | <b>64</b>   | <b>66</b> |
|                                   | Kenthingan, Sleman (PPAB, 2000/2001) | Soil        | 0         |
| Fine sand and medium sand         |                                      | 5           | 13        |
| Fine sand, medium sand, clay      |                                      | 13          | 26        |
| Fine sand and medium sand         |                                      | 26          | 40        |
| Fine sand, coarse sand, clay      |                                      | 40          | 42        |
| Fine sand and medium sand         |                                      | 42          | 44        |
| Fine sand and coarse sand         |                                      | 44          | 52        |
| Fine sand and medium sand         |                                      | 52          | 55        |
| <b>Clay</b>                       |                                      | <b>55</b>   | <b>57</b> |



**Figure 4. Distribution of Material Types in the Overlying Strata Zone**

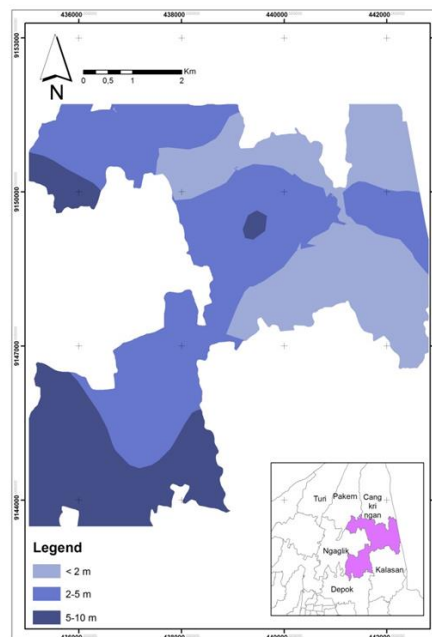
The location of depth groundwater measurement is determined by systematic random sampling method. Groundwater depth in Ngemplak Sub-District are varies. The

primary data shows that groundwater depth is in the range of less than 1 meter to more than 9 meters. Geospatial data on the groundwater depth which is initially a point data is interpolated with the Kriging method to obtain spatial information. This information can be seen in Fig 5. According to primary data range, the depth of groundwater in Ngemplak Sub-District is classified into three classes, they are less than 2 meters depth, 2 to 5 meters depth, and more than 5 meters depth. This classification refers to the depth classification contained in the GOD method, and it can be scored. The details of scores for each class of groundwater depth can be seen in the Table 6.

**Table 6. Details of Depth to Groundwater Table Scores**

| No | Depth to Groundwater Table | Score |
|----|----------------------------|-------|
| 1  | < 2 meter                  | 1     |
| 2  | 2-5 meter                  | 0,9   |
| 3  | 5-10 meter                 | 0,8   |

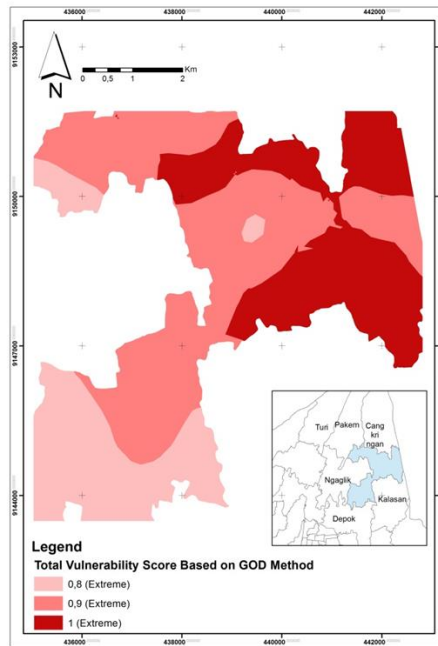
Based on the Table 6, the deeper the water table is, the smaller the score will be. It can be applied otherwise. The scoring process is based on the assumption that the deeper groundwater surface is, the more pollutant coming from the ground surface to reach the groundwater. Otherwise the more shallow groundwater surface is, the pollutants originating from the ground will be closer to reach the groundwater surface. Ngemplak Sub-District was dominated by the depth of groundwater in a range of less than 2 meters and in the range of 2 to 5 meters (see Figure 5).



**Figure 5. Distribution of Depth to Groundwater Table in Ngemplak Sub-District**

The results of three natural physical parameters study in Ngemplak Sub-District were used as a basis for potential groundwater pollution modeling. The analysis technique of geospatial data which is used in this research is overlaying method. The process is carried out by combining information about the type of aquifer (groundwater occurrence), natural material of unsaturated groundwater zone (overlying material), and depth to groundwater

table. The technique is executed by multiplying each score that has been included in each thematic map. Spatial distribution regarding the potential groundwater pollution in Ngemplak Sub-District can be seen in Figure 6.



**Figure 6. Distribution of Potential Groundwater Pollution in Ngemplak Sub-District**

Based on the results of the score classification, the overall potential groundwater pollution in Ngemplak Sub-District is included in the extreme class. The range values stated 'very high' based on the classification of the GOD method is from 0.8 to 1 point. Ngemplak Sub-District has a final score of 0.8; 0.9; and 1 point. Despite having a difference final score, however all area of Ngemplak Sub-District are included in one class. Natural factors that cause a high score of potential groundwater pollution in Ngemplak Sub-District are unconfined and unconsolidated material types of aquifers. While the final score variation is more due to groundwater depth variations which the research area is classified into three classes of groundwater depth. The percentage of potential groundwater pollution area in Ngemplak Sub-District can be seen on the Table 7.

**Table 7. Percentage of Potential Groundwater Pollution Area in Ngemplak Sub-District**

| No | Final Score | Potential Groundwater Pollution Classification | Width (km <sup>2</sup> ) | %    |
|----|-------------|--|--------------------------|------|
| 1  | 0,8         | <i>Sangat tinggi</i> (Extreme)                 | 8                        | 22,8 |
| 2  | 0,9         | <i>Sangat tinggi</i> (Extreme)                 | 16                       | 45,7 |
|    | 1           | <i>Sangat tinggi</i> (Extreme)                 | 11                       | 31,5 |

The potential groundwater pollution can not be evaluated by using only one natural parameter. The three natural parameters used in the GOD method are interrelated. The existence of unconfined aquifers certainly has a positive and negative impact on potential groundwater pollution. Groundwater in Ngemplak Sub-District is easily accessible, for example by making dug wells, because of the unconfined aquifers existence. However, because in this layer is only limited by one waterproof layer, which is at the bottom of the

aquifer, the upper part becomes less protected. The potential pollution will be higher if it is associated with material in an unsaturated water zone that is loose. Natural material sourced from young Merapi volcano sediment is dominated by sand and gravel with abundant space between grains. The vertical layer composed by loose material will be easily traversed by water coming from the ground surface through an infiltration and percolation process because water is able to freely move in the spaces between the grains. If pure rainwater infiltrate into undersurface, it will certainly have a beneficial impact on groundwater reserves. However, if the water which seeps or moves towards the saturation zone of groundwater is contaminated water, it will have a negative impact on groundwater conservation in Ngemplak Sub-District. The depth of groundwater from the ground surface also has a very important influence on the potential groundwater pollution. Liquid pollutants that permeate through the process of infiltration and percolation will easily reach the water saturation zone if the groundwater is shallow. In a uniform natural state, for example a uniform type of aquifer and uniform conditions in the unsaturated zone, the depth of the groundwater will make it the most influential factor to determine the final score in the potential groundwater pollution model.

### ***Development Strategy of Ngemplak Sub-District***

Based on the results of the physical parameters processing, it can be seen that the entire area of Ngemplak Subdistrict has the extreme potential groundwater pollution. Even though all regions have the extreme potential groundwater pollution, there is a correlation with the possibility of groundwater pollution (on a scale of 1.0). Based on the results of data processing, it can be seen that the most extreme of potential groundwater pollution (on a scale of 1.0) is on the north side of Ngemplak Sub-District. This is caused naturally, the ability of the land to evaluate the non-polluted groundwater is still possible for groundwater pollution to occur. The possibility of groundwater pollution occurs if there are liquid pollutants that can seep through the infiltration process. Based on this problem, then basically the presence of liquid pollutants becomes the main potential pollutant for groundwater in Ngemplak Sub-district.

Liquid pollutant is one of the results of waste formed from household activities in Ngemplak Sub-District. Based on the analysis of land use in Ngemplak Sub-District, the north side of Ngemplak Sub-District is an area which has intensive urban process. This shows that there is a correlation between the intensive urban process and the potential for groundwater pollution. Because basically this intensive urban process will produce liquid pollutants which are the main pollutant factor in Ngemplak Sub-District. Therefore, a development planning strategy for the Ngemplak Sub-District is needed to minimize the potential groundwater pollution.

The regulation about groundwater management in Sleman District is included in Local Government Regulation Number 4 of 2014 (Government of Sleman Regency, 2014; Government of Sleman Regency, 2017) about groundwater management. According to the regulation, groundwater management processes divided into six stages, namely planning, implementation, monitoring and evaluation, conservation, utilization, and control of destructive power. According to the regulation, groundwater utilization stage is carried out by considering the sustainability of groundwater. Utilization of groundwater is determined by prioritizing the use of groundwater in the deep aquifer which the extraction processes does not exceed the carrying capacity of aquifers. This is intended to preserve groundwater in Sleman District. If groundwater utilization exceeds the carrying capacity of existing aquifers, it is possible to decrease the groundwater level and result in a lack of groundwater.

The groundwater utilization stage in Local Government Regulation Number 4 of 2014 (Government of Sleman Regency, 2014) basically also correspond with the monitoring and evaluation stages. The monitoring and evaluation stage here is to monitor the quality and quantity of groundwater Sleman District. Monitoring processes of groundwater quantities is indicated by controlling the groundwater utilization so that it does not exceed the carrying capacity of existing aquifers. While monitoring processes of groundwater qualities can be interpret from potential groundwater pollution that possible to occur in Sleman District. The process of controlling groundwater pollution that occurs in Sleman District is basically done by considering the main pollutant factors. The main pollutant factors come from human activities in Sleman District, both in the form of industrial activities and household activities.

Development planning strategy of Ngemplak Sub-District according to the potential groundwater pollution, basically the management of wastewater is needed, especially those from households. According to Ministerial Regulation of Environment Number 01 of 2010 about Water Pollution Control Procedures (Ministry of Environment, 2010), one of the strategies used to control the occurrence of groundwater pollution is to build waste water management facilities and infrastructure. Basically the management of household wastewater is very necessary to overcome the occurrence of groundwater pollution due to the absorption of wastewater directly into the soil. Therefore, it is necessary to establish an independent Wastewater Management Plans (Instalasi Pengelolaan Air Limbah/ IPAL) for each household. This independent IPAL can then be distributed to communal IPAL that accommodate one settlement. So that water that is absorbed into the soil has gone through filtration and is not a pollutant.

According to Ministerial Regulation of Environment Number 01 of 2010 (Ministry of Environment, 2010) about Water Pollution Control Procedures, the strategy used to control groundwater pollution is not only physically by providing and building waste water management facilities and infrastructure. In addition to physical planning strategies, a social development strategy is also needed. Society is the subject of the perpetrator as well as the object of Ngemplak Sub-District development strategy. In the problem of groundwater pollution in Ngemplak Sub-District, basically the role of the community is very much needed. Based on the existing problems, groundwater pollutants originating from household waste become the trigger for the emergence of potential groundwater pollution. Therefore, community empowerment in managing household waste independently is one of the strategies that can be applied in Ngemplak Sub-District. Community empowerment in managing household waste independently can be done through pilot activities of making wastewater management infrastructure and facilities, assistance and socialization to the community regarding the household waste management, as well as developing investment potential with household waste management. In addition, social development strategies which can be applied in Ngemplak Sub-District are by encourage people to use septic tanks which are in accordance with sanitation requirements. This is intended to encourage community self-reliance in the household wastewater management. Another strategy from the social side is to form a self-help group called *Kelompok Swadaya Masyarakat (KSM)* or community cadres in household wastewater management. This is intended to realize the independence of the community in managing household wastewater.

## **Conclusion**

Based on the results of research on the impact of rapid urban growth on potential groundwater pollution in Ngemplak Sub-District, it can be concluded that the urban process occurred which was relatively intensive in Ngemplak Sub-District in the last 10

years which was marked by an increase in built-up area within a period of 10 years. The urban process in Ngemplak Subdistrict results in increased pressure on water resources which is characterized by the potential groundwater pollution. Potential groundwater pollution in Ngemplak Sub-District is included in the extreme classification based on the parameters of the physical condition of the land. The main factors that influence the emergence of potential groundwater pollution in Ngemplak Sub-District are pollutants produced from household waste as an impact of the increase in built up area of Ngemplak Sub-District. The development strategy that should be applied to minimize the potential groundwater pollution is by managing wastewater, especially household waste by utilizing community empowerment. On the other hand, it is necessary to control the landuse change, so that it can reduce the rate of massive built-up areas growth in Ngemplak Sub-District. Landuse changes control can be carried out by maximizing the role of spatial planning regulations in Ngemplak Sub-District, which are more focused on developing sustainable food agriculture land than on developing settlement areas.

## References

- Boulabeiz, M., Klebingat, S., & Agaguenia, S. (2019). A GIS-based GOD model and hazard index analysis: The quaternary coastal collo aquifer (NE-Algeria). *Groundwater*, 57(1), 166–176. doi:10.1111/gwat.12824.
- Devi, M. K., Gorman, Y. H., & Hidayati, S. R. (2020). Spatial transformation in urban periphery: The case of Yogyakarta. *IOP Conference Series: Earth and Environmental Science*, 592(1). doi:10.1088/1755-1315/592/1/012022.
- Djoudi, S., Boulabiez, F., Pistre, S., & Houha, B. (2019). Assessing groundwater vulnerability to contamination in a semi-arid environment using DRASTIC and GOD models, case of F'kirina Plain, North of Algeria. *IOSR Journal of Environmental Science*, 13(7), 39–44. doi:10.9790/2402-1307013944.
- Fajri, I., Sakur, M., & Wilopo, W. (2013). Potensi air tanah dangkal daerah Kecamatan Ngemplak dan sekitarnya, Kabupaten Sleman, D.I. Yogyakarta. *Prosiding Seminar Nasional Kebumian Ke-6 Teknik Geologi Universitas Gadjah Mada*, 11–12.
- Giyarsih, S. R. (2010). Urban sprawl of the city of Yogyakarta, special reference to the stage of spatial transformation (case study at Maguwoharjo Village, Sleman District). *Indonesian Journal of Geography*, 42(1), 49–60. doi: 10.22146/ijg.15766.
- Government of Sleman Regency. (2014). *Peraturan Daerah Kabupaten Sleman Nomor 4 Tahun 2014 tentang pengelolaan air tanah*. Sleman Regency.
- Government of Sleman Regency. (2017). *Peraturan Daerah Kabupaten Sleman Nomor 6 Tahun 2017 tentang pencabutan peraturan daerah kabupaten sleman nomor 8 tahun 2008 tentang urusan pemerintahan yang menjadi kewenangan pemerintah Kabupaten Sleman, Peraturan Daerah Kabupaten Sleman nomor 4 tahun 2013 tentang usaha pertambangan mineral bukan logam dan batuan, dan peraturan daerah Kabupaten Sleman nomor 4 tahun 2014 tentang pengelolaan air tanah*. Sleman Regency.
- Hastuti, D., Yulianto, T., & Putranto, T. T. (2016). Analisis kerentanan airtanah terhadap pencemaran di dataran alluvial Kota Semarang menggunakan metode GOD dengan memanfaatkan data resistivitas dan data hidrogeologi. *Youngster Physics Journal*, 5(4), 277–290. etrieved from <https://ejournal3.undip.ac.id/index.php/bfd/article/view/14089>.
- Hendrayana, H., & Vicente, V. A. de S. (2013). Cadangan air tanah berdasarkan geometri dan konfigurasi sistem akuifer cekungan air tanah Yogyakarta-Sleman. *Prosiding Seminar Nasional Kebumian Ke-6 Teknik Geologi Universitas Gadjah Mada* (pp 356–370).
- Maishella, A., Dewantoro, B. E. B., & Aji, M. A. P. (2020). Correlation analysis of urban development and land surface temperature using google earth engine in Sleman Regency, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 540(1).doi:10.1088/1755-1315/540/1/012018.
- Ministry of Environment. (2010). *Peraturan Menteri Negara lingkungan hidup nomor 1 tahun 2010 tentang tata laksana pengendalian pencemaran air*. Jakarta, Indonesia.
- Nugraha, R. N. (2013). *Pengaruh perubahan penggunaan lahan terhadap volume resapan air tanah di Kecamatan Ngemplak tahun 1994-2009*. Universitas Negeri Yogyakarta, Yogyakarta.

- Sartika, D., Muhni, A., Rifqan, R., & Putra, H. S. (2020). Groundwater vulnerability to pollution using the gOD method in Banda Aceh City, Aceh Province. *Journal of Aceh Physics Society*, 9(3), 84–90. doi:10.24815/jacps.v9i3.17332.
- Sejati, S. P. (2021). Tingkat fluktuasi air tanah pada jangka pendek di Kecamatan Ngemplak, Kabupaten Sleman, Provinsi Daerah Istimewa Yogyakarta. *Jurnal Teknologi Lingkungan*, 22, 121–129. doi:10.29122/jtl.v22i1.3985.
- Sharadqah, S. (2017). Contamination risk evaluation of groundwater in the canton of Portoviejo-Ecuador, using susceptibility index and two intrinsic vulnerability models. *American Journal of Environmental Sciences*, 13(1), 65–76. doi:10.3844/ajessp.2017.65.76.
- Suminar, R. E. (2018). Dampak pengembangan jalan usaha tani (jut) pada kawasan pertanian di Kabupaten Sleman Provinsi Daerah Istimewa Yogyakarta. *Plano Madani: Jurnal Perencanaan Wilayah dan Kota*, 7(1), 81–88. doi:10.24252/planomadani.v7i1a8.
- Sutardi, A., Suprayogi, S., & Adji, T. N. (2017). Kajian kualitas airtanah bebas antara Sungai Kuning dan Sungai Tepus di Kecamatan Ngemplak, Yogyakarta, Indonesia. *Majalah Geografi Indonesia*, 31(1), 31-38. doi:10.22146/mgi.24230.
- Valent, C. G., Subiyanto, S., & Wahyuddin, Y. (2020). Analisis pola dan arah perkembangan permukiman di wilayah Aglomerasi Perkotaan Yogyakarta (APY), studi kasus Kabupaten Sleman. *Jurnal Geodesi Undip*, 19(2), 78-87.
- Vrba, J., & Zaporozec, A. (1994). Guidebook on mapping groundwater vulnerability. *International Contributions to Hydrogeology*. Retrieved from: <https://agris.fao.org/agris-search/search.do?recordID=US201300287789>.
- Yunus, H. S. (2005). *Manajemen kota: Perspektif spasial*. Yogyakarta: Pustaka Pelajar.