# IDENTIFICATION OF POTENTIAL WATER SOURCE FOR BUTUAN CITY, NORTHEASTERN MINDANAO, PHILIPPINES THROUGH WATERSHED DELINEATION AND CHARACTERIZATION

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**ABSTRACT:** The Taguibo watershed in Butuan City, Caraga Region, Mindanao, Philippines is the sole source of water for domestic, commercial, industrial and agricultural usage. For decades, the watershed had been supplying water to the city. Until now it provides clean and potable water to more than 200,000 individuals in Butuan City, however, as the City turned into a more urbanized community, the demand for sanitary water escalates while the number of supplier remains dormant resulting to intermittent water supply. To address this problem, this study identified possible sources of water for Butuan City by delineating watersheds within its proximity that could supplement the water demands. The identified watersheds and the Taguibo watershed were characterized to assess which of the newly identified watersheds possess similar or greater characteristics to Taguibo watershed. The watershed areas, river slopes, soil textures and curve numbers of the watersheds were the factors considered in identifying potential watersheds. The five identified watersheds along with Taguibo watershed were ranked according to their total weighted scores for each factor. The most suitable supplementary watershed among the five identified potential watersheds was Kolambugan watershed. Kolambugan has the largest area among the four candidates and is approximately three times larger than Taguibo watershed. It also has 100 % silt loam soil class which makes it more suitable to be a watershed. Kolambugan also has the smallest average curve number. Pianing watershed, on the other hand, was at the bottom of the rank since it has a small area, its soil texture is 80% clay and its average curve number is the highest among all the watersheds. With these results, the implementers would be guided on the possible watershed areas that could be explored to be another source of domestic water; which can greatly aid in Butuan City's problem of water supply.

## 1. INTRODUCTION

### 1.1 The Taguibo Watershed

Watershed is a land area drained by a stream or a fixed body of water and its tributaries having common outlet for the surface runoff and is normally delineated topographically along the ridges in a landscape (Department of Environment and Natural Resources, 2008). Since watersheds serve as a basin, one of its major roles is to supply water to its communities. In Butuan City, Caraga Region, Mindanao, Philippines, the Taguibo Watershed is the sole source of water for domestic, commercial, industrial and agricultural usage. Caraga Region is one of the timber corridors of the country because of its abundant timber resources and diverse ecosystem (Amarille & Rebancos, 2015). Associated with its abundance is the generous volume of excess water from the forests that drains to the Taguibo Watershed. On September 1997, it was declared as a Forest Reserve, and presently, it is still the sole watershed identified by the local government to supply more than 40,000 concessionaires or more than 200,000 individuals in Butuan City with clean and potable water.

The Taguibo watershed covers an approximate total drainage area of 75.5 square kilometers (Santillan, Makinano, & Paringit, 2011) and is providing adequate water to Butuan City for the past years. However, as the City continues to develop along with its increase in population, the demand for sanitary and potable water in the City also escalates. Residential buildings, industrial, agricultural and commercial establishments rapidly consume the City and while the water supplier of the City remains dormant, the demand for human consumption of good water quality accelerates which could lead to insufficient water supply in the near future. For an instance, during rainy season the people experiences intermittent water supply since the city's water distributor limits its supply due to the turbidity of the water from the Taguibo Watershed. The everyday lives of the people are greatly affected by this intermittent water supply. With this problem, this study attempted to provide solution by locating and delineating watersheds within the proximity of Butuan City that can be considered as other possible sources of clean and potable water.

The objectives of this study is to delineate and characterize potential watersheds and the current watershed, Taguibo, and compare the results to identify which among the potential watersheds have similar properties to Taguibo watershed and how these characteristic impact the potentiality of each watershed.

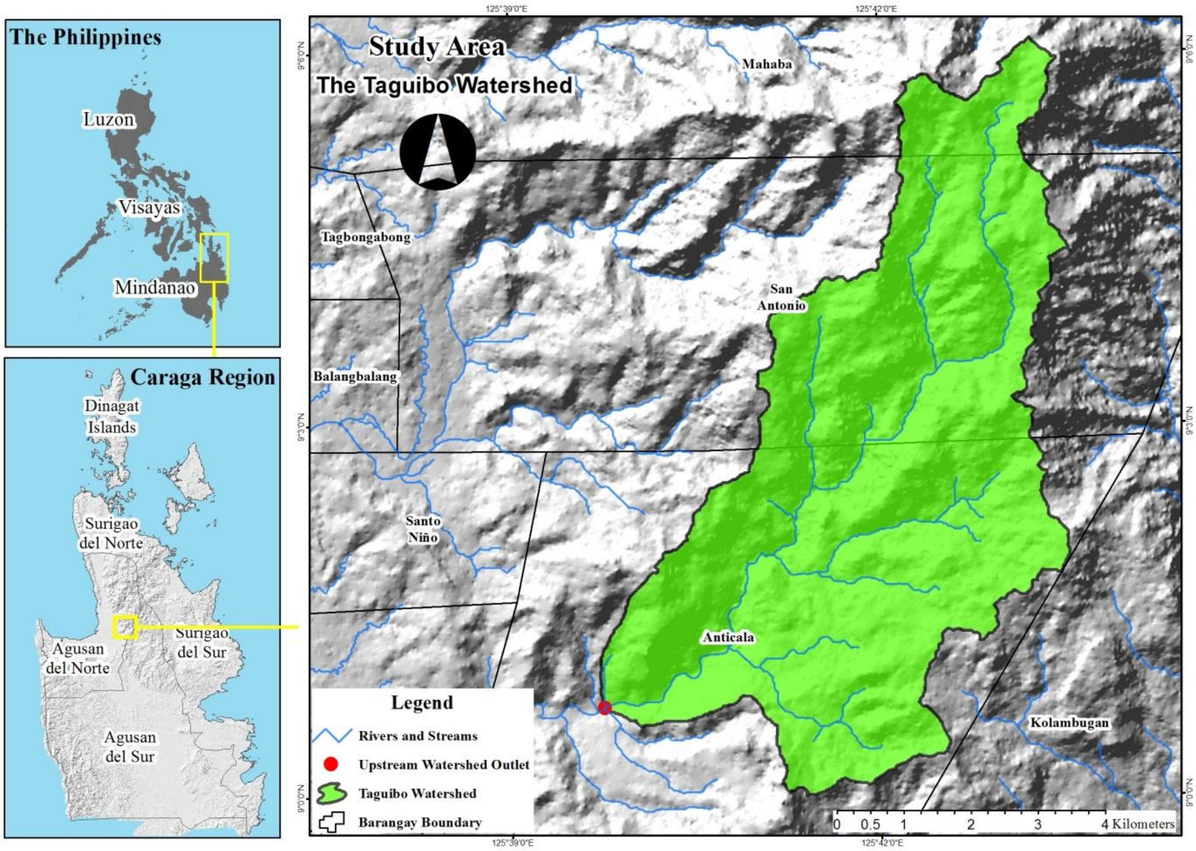


Figure 1. The study area, Taguibo Watershed, located in Barangay Taguibo, Butuan City

### 1.2 Watershed Characterization

Each individual watershed has several remarkable characteristics, which affect its functioning. The characterization of watershed generally describes the nature and components of a watershed (Department of Environment and Natural Resources, 2008). By evaluating the characteristics of a watershed, this study will identify potential watersheds to supplement the water supply of Butuan City. Among the morphological characteristics of a watershed is its drainage area, river slope and runoff potential which considers the land cover of the area and its soil texture or type (Agril. Engineering, 2015) (Watershed Management, 2015). In this study, the potential watershed locations were limited within the proximity of Butuan City.

**1.2.1 Drainage Area:** The size or drainage area of a watershed determines the quantity of rainfall that it receives and disposes (Agril. Engineering, 2015). Watersheds with large drainage areas were preferable since it means it can accommodate more volume of water. A watershed could be classified as either micro, small, medium or large, and those that cover large extents are called river basins (Department of Environment and Natural Resources, 2008).

Table 1. Watershed area classification based on DENR MC 2008-05 (Department of Environment and Natural Resources, 2008)

| | | |
|---|---|---|
| Drainage/River Basin | >1,000 sq. km. | >100,000 ha |
| Large | 500 to 1,000 sq. km. | 50,000 – 100,000 ha |
| Medium | 100 to 500 sq. km. | 10,000 – 50,000 ha |
| Small | 10 to 100 sq. km. | 1,000 – 10,000 ha |
| Micro | <10 sq. km. | <1,000 ha |

**1.2.2 River Slope:** River slope is the degree or percentage of inclination of a river surface. Another factor to be considered in identifying potential watersheds is the river slope. The slope of the river surface affects the speed or velocity at which the water flows (Hawes & Smith, 2005). Steep river slopes could exacerbate surface runoff especially during heavy rainfall (Schoonover & Crim, 2015). Erosion and sedimentation were also observed to zones with high slope (Ramakrishnan, Bandyopadhyay, & Kusuma, 2009; Pandey, Chowdary, & Mal, 2007). As a general, regardless of it's a river or a mountain area, steeper slopes tend to erode easily (Nandi & Shakoor, 2008).

**1.2.3 Runoff Potential:** The runoff or overland flow is referred to as the component of the precipitation that flows on the watershed surface and is produced when the intensity of the rainfall exceeds the soil infiltration rate or when the soil becomes saturated with water and cannot absorb additional rainfall (Department of Environment and Natural Resources, 2008). In surfaces where infiltration capacity is zero such as concrete roads, sidewalks and buildings, or when the soil is already saturated, surface runoff is present. Impervious surfaces increase the runoff potential. For this study, the soil type data from the Department of Agriculture's Bureau of Soils and Water Management was used as a reference. Based on the minimum infiltration rate, soils are classified into four Hydrologic Soil Groups (HSG's) (NCRS, 2007)(See Table 2). Runoff potential is based on soil type and land cover. By identifying the soil type and land cover, the corresponding curve number (CN) for a specific area is computed (NCRS, 2007)(See Table 3). CN values vary with specific land use conditions. Curve number is a method used to determine or estimate the runoff or infiltration from rainfall excess.

Soil type is determined by the amount of sand, silt and clay in a sample according to United States Department of Agriculture (USDA) System. Percentages of sand, silt, and clay categorize soil into different textural classes. Clays have a particle size diameter of < 0.002 mm, silts between 0.002 and 0.05 mm, and sands 0.05 to 2.0 mm (Schoonover & Crim, 2015). The particle sizes of the soil are related to its porosity or its permeability to water or air. Having a smaller particle size, clay is less permeable and more compact compared to sand and silt, which also decreases the ability of plant's roots to penetrate it; hence it may have greater runoff (Hawes & Smith, 2005). Compaction also affects the soil's ability to infiltrate precipitation. Forest with silt soils tends to have more trees, biotic activities and organic matters on surface and less anthropogenic disturbances because of its porosity (Schoonover & Crim, 2015). Organic matters have a high micro porosity degree which allows the soil to infiltrate more precipitation.

Land cover reflects the physical dimension of the Earth's surface and corresponds to the ecosystems notion. The land cover affects or alters the way water move through the drainage basin (Paiboonvorachat & Oyana, 2011). For an instance, a research study showed that the greatest erosion and sedimentation could be located in areas where forests were converted to arable lands (Paiboonvorachat & Oyana, 2011). When considering the land cover of a watershed, forested areas are more suitable than agricultural or bare lands since the latter are more susceptible to erosion and runoff potential (Kosmus, Renner, & Silvia, 2012). The land cover data used in this study was generated by the Geo-SAFER Agusan Project of the Caraga State University.

Table 2. Hydrologic Soil Groups based on Minimum Infiltration Rate (NCRS, 2007)

| Hydrologic Soil Group | Soil Group Description | Example Soil Types/Soil Textures |
|---|---|---|
| A | Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. (High drainage) | Sand<br>Sandy loam<br>Loamy sand<br>Gravel |
| B | Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand. | Loam<br>Silt loam |
| C | Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand. | Sandy clay loam |
| D | Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand. (Poor drainage) | Clay loam<br>Silty clay loam<br>Sandy clay<br>Silty clay<br>Clay |

Table 3. NCRS conversion and CN look-up table of land-cover classes under different HSGs (NCRS, 2007)

| **Surface Classification (based on Land-cover Map)** | **Equivalent NCRS Classification** | ***AMC II CN HSG = A*** | ***AMC II CN HSG = B*** | ***AMC II CN HSG = C*** | ***AMC II CN HSG = D*** |
|---|---|---|---|---|---|
| Barren | Fallow: bare soil | 77 | 86 | 91 | 94 |
| Built-up | Urban and residential districts [CN for A, B, C and D are average of commercial & business (85% impervious), industrial (72% impervious) and residential (65% impervious with 1/8 acre or less floor area) districts] | 82 | 88 | 92 | 93 |
| Cropland | Row Crops and Small Grain, Straight Row, Good [CN is average of these two) | 65 | 76 | 84 | 88 |
| Exposed River Beds (sand and gravel) | Gravel | 76 | 85 | 89 | 91 |
| Forest | Woods (with litter and brush adequately cover the soil) | 30 | 55 | 70 | 77 |
| Grassland | Pasture, grassland, or range (Fair: 50-75% ground cover) | 49 | 69 | 79 | 84 |
| Palm | Woods-grass combination (orchard or tree farm), (Fair: 50-75% ground cover) | 43 | 65 | 76 | 82 |
| Water (Rivers) | None (Rain falling on water is equivalent to 100% runoff hence CN = max = 100) | 100 | 100 | 100 | 100 |

## 2. METHODOLOGY

### 2.1 Overview

This study used geospatial analysis, basin model generation and comparative analysis to obtain its objective. The geospatial component involves extraction of river features from remotely-sensed high spatial resolution images and land cover which were manually extracted by digitization and image classification. The soil classification dataset provided by the Department of Agriculture's Bureau of Soils and Water Management were used to determine the soil textures in a watershed.

The geospatial datasets were used as inputs to basin model generation to delineate subbasins and drainage lines which served as the watershed boundaries and river networks of the watersheds. The basin model generation was the first step in delineating the river/stream network and subbasin of the watershed; followed by model characterization which computes the topographic characteristics of streams and subbasins such as the river and basin slope that were used to estimate hydrologic parameters; and the model parameterization which was done to estimate hydrologic parameters such as the subbasin average and grid-based values using the soil and land cover maps.

The outputs of the previous processes were integrated to each delineated watershed. The values integrated to the watersheds were the area, soil texture, river slope and curve numbers. Each of these watershed properties were treated as a factor in identifying the suitable potential watersheds. Refer to Figure 2 for the study process flow and framework.

### 2.2 Data Gathering and Derivation

**2.2.1: River Features:** The river features that were utilized as input to basin model generation were manually digitized from high resolution satellite images. All the rivers within proximity of Butuan City were considered. The extracted rivers were used as input to basin model generation to define streams and subbasin of a watershed.

**2.2.2 Digital Elevation Model:** A 10-meter digital elevation model provided by the University of the Philippines was used to delineate subbasins and drainage lines. The digitized river and the DEM were inputted in the DEM reconditioning during the basin model generation procedure.

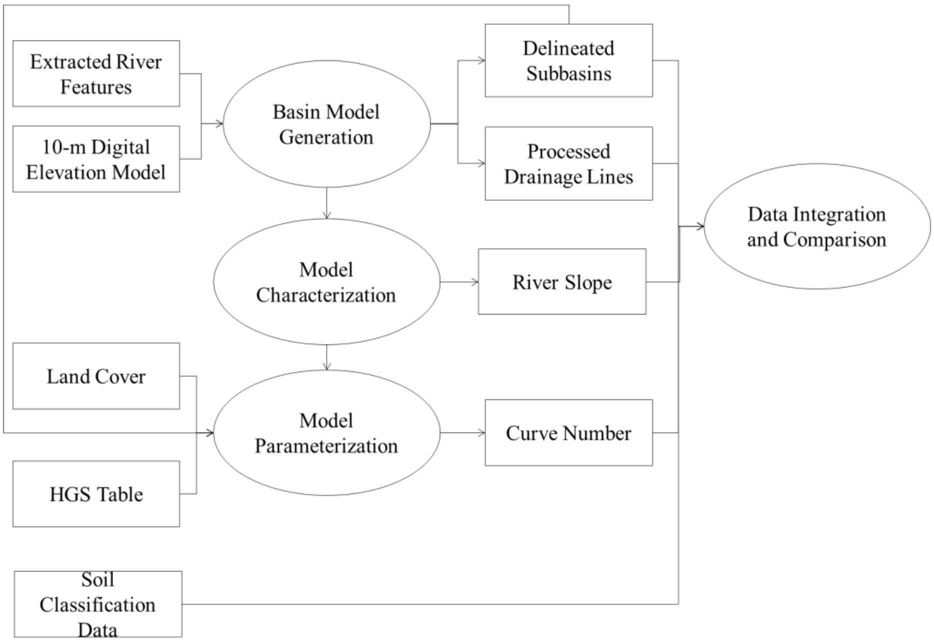


Figure 2. Process Flow Framework in Identifying Potential Watersheds

**2.2.3 Land-cover Map:** The Landsat 8 OLI satellite images which were downloaded from USGS Earth Explorer (http://earthexplorer.usgs.gov/) were classified through Maximum Likelihood (ML) classification to derive a land-cover data. The images used were acquired on March 23, July 13, July 29 and August 30, 2017. Series of steps were executed based on the established procedure of the flood modeling team of the Geo-SAFER Mindanao Program to correct misclassification (Santillan, et al., 2016). The accuracy of the derived land-cover map was 88 percent. The land-cover map was used to obtain land-cover statistics of the basin and was converted to runoff potential (or Curve Number).

**2.2.4 Soil Type Data:** The Philippine soil type data acquired BSWM – DA was utilized to identify the soil textures in a watershed. The soil type data was classified based on the hydrologic soil group (Table 2). The classified HSG Map will be combined with the derived land-cover map to determine the curve numbers of every watershed (Table 3).

**2.3 Data Processing**

**2.3.1 Basin Model Generation:** The digitized rivers and the DEM were utilized as inputs to terrain preprocessing which was executed using the ArcGIS extension, the HEC-GeoHMS. Terrain preprocessing creates grid layers to define the streams and subbasins of a watershed. The defined subbasin boundaries were overlayed with the processed drainage line to identify which subbasins belong to specific watersheds. The high resolution satellite images were also overlayed so that those subbasins occupied with dense built-up structures were excluded in a specific watershed to avoid possible water pollutants that could degrade the water quality of the potential watershed. However, there were still watersheds considered having only minimal built-up areas to maximize the potential of its area. After examining the presence of built-up areas, the subbasins were converted into a single shapefile using the geoprocessing tool in ArcMap, and its area was computed using the calculate geometry.

**2.3.2 Model Characterization:** One of the functions of the HEC-GeoHMS is to compute topographic characteristics of streams and subbasins that are used to estimate hydrologic parameters. The slope characteristic under the HEC-geoHMS toolbar was executed to compute the river slope of every watershed. Slope calculates the maximum rate of change in value from a cell to its neighbors. The maximum change of elevation over the distance identifies the steepest descent from the cell. Also, the basin slope was computed using the ArcHydro Tools to visualize the slope of every watershed.

**2.3.3 Model Parameterization:** Parameterization process was executed after the characterization to estimate the hydrologic parameters of the subbasins such as the curve number grid by utilizing soil type and land-cover map. To compute the curve number grid, the land-cover map and the HSG reclassified soil type data was combined. Each HSG has assigned values for CN developed by NCRS(1986) under a normal antecedent moisture condition. By utilizing the HSG table (table 2), the HSG of every soil type was identified. Each HSG under specific land-cover classes has corresponding curve number assigned to it. The runoff potential per watershed was based on the curve numbers.

**2.3.4 Data Integration and Comparison:** Each delineated watersheds were integrated with the corresponding values of its drainage area, river slope and curve numbers. These morphological characteristics were considered as factors in considering a suitable potential supplementary watershed. In order to identify which of these watersheds are suitable, the values of each watershed characteristic must be compared. Since the value of these datasets represents quantity, it means that these have different level of emphasis or weight to a watershed and it would determine if a candidate watershed is suitable or not to be a supplementary watershed. To put weight on the corresponding quantities for every characteristic of a watershed, a level of measurement was utilized. For an instance, when we consider the size of the watershed as a factor for suitability, the candidate with larger areas should weigh more than the others. The values of each watershed per characteristic were tabulated and classified using the natural breaks (Jenks) classification since this type of classification considers the distribution of data along a number line and considers the natural groupings of data (ESRI, 2017). The data per characteristic were automatically classified into five classes using the classification function in the ArcMap layer properties.

Table 4. Class intervals of area, average river slope and average curve number

| Area (ha) | | Ave. River Slope | | Ave. Curve Number | |
|---|---|---|---|---|---|
| Class | Score | Class | Score | Class | Score |
| 2461 | 1 | 0.05 | 4 | 56 | 4 |
| 2462 - 2985 | 2 | 0.05 - 0.06 | 3 | 57 | 3 |
| 2986 - 4101 | 3 | 0.06 - 0.08 | 2 | 58 - 63 | 2 |
| 4102 - 10850 | 4 | 0.08 - 0.14 | 1 | 64 - 76 | 1 |

All the considered physical properties or factors in identifying potential watersheds were treated equally such that it has equal weights on each watershed. For the six watersheds, their corresponding values for every factor is computed and compared. Since the values vary per watershed, the values were classified into four classes of natural breaks (Jenks). The scores assigned per class in a specific watershed factor was used to account the values per watershed such that bigger score means that the watershed was more suitable when considering the characteristic for which the score was assigned. Take for example the area for a watershed, larger areas are more suitable than smaller ones since a large watershed area means that more volume of water will flow within the basin, thus, supplying more water to the community. The scores of every watershed were computed by adding all the scores of a specific watershed.

The areas of the potential watershed and the Taguibo Watershed were compared and assigned corresponding scores depending on their land area. The areas that belong to the first class is scored one since it has the smallest value. The areas that belong to the second, third and fourth class is scored two, three and four, respectively. A score of four means that it is the most suitable watershed in terms of drainage area.

River slope values along the riverbeds of each watershed were computed during the model characterization process. Low inclination rivers were preferable than steep ones. The river slope average that belong to the first class was scored four since it is more suitable than slopes that belong to the second, third and fourth classes (Pandey, Chowdary, & Mal, 2007; Ramakrishnan, Bandyopadhyay, & Kusuma, 2009).

Runoff potentials were estimated by curve numbers. The watershed with largest curve number were marked one (lowest/least preferable) while the watershed with the least curve number were marked five (highest/most preferable) since as stated in the previous sections, high curve number means high runoff potential which would increase the probability of an erosion and sedimentation in a watershed especially (Ramakrishnan, Bandyopadhyay, & Kusuma, 2009). Also, based on the CN look-up table (Table 3), those with low CN values were found on forests where trees and shrubs are abundant.

## 3. RESULTS AND DISCUSSIONS

There were five identified potential watersheds within Butuan City, namely, Kolambugan, Padiay, Pianing, Simbalan and Guinabsan (Figure 4). The drainage area, average river slopes and curve numbers of the watersheds were shown below. The scores were based on the scores assigned per class for every characteristic.

The Taguibo Watershed has a small area, however, its slope, soil texture and runoff potential justifies its being the current watershed of Butuan City. The five considered potential watershed were evaluated to identify watersheds that have same characteristics with Taguibo to be a source of water for the city.

Among the five potential watersheds, Kolambugan and Simbalan watersheds are the most suitable watershed considering first the area. For the river slope, Pianing were marked with the highest score and though all the slopes of the six watersheds were considerably acceptable, for the purpose of finding the most suitable watershed, all of them were ranked (Figure 6). Considering the runoff potential of every watershed, Kolambugan and Padiay were more suitable followed by Simbalan and Guinabsan, since they got low curve numbers which means that their land cover and soil texture is suitable for a watershed (Figure 5 and 7). Pianing watershed was the least suitable since it had a 76 curve number, the largest curve number among all the watersheds which means that it has more runoff potential and more susceptible to erosions. See Table 5 for the results summary and Figure 3 for the graphical representation.

Table 5. Tabulated summary of the scores per watershed with respect to its properties

| Watershed | Drainage Area (ha) | | Ave River Slope | | Ave CN | | Total Score |
|---|---|---|---|---|---|---|---|
| | Value | Score | Value | Score | Value | Score | |
| Taguibo | 3941.67 | 3 | 0.14 | 1 | 56.09 | 4 | 8 |
| Kolambugan | 10850.03 | 4 | 0.08 | 2 | 55.57 | 4 | 10 |
| Padiay | 2984.94 | 2 | 0.06 | 3 | 56.12 | 4 | 9 |
| Pianing | 2460.67 | 1 | 0.05 | 4 | 76.11 | 1 | 6 |
| Simbalan | 7534.23 | 4 | 0.06 | 3 | 56.50 | 3 | 10 |
| Guinabsan | 4101.23 | 3 | 0.07 | 2 | 62.70 | 2 | 7 |

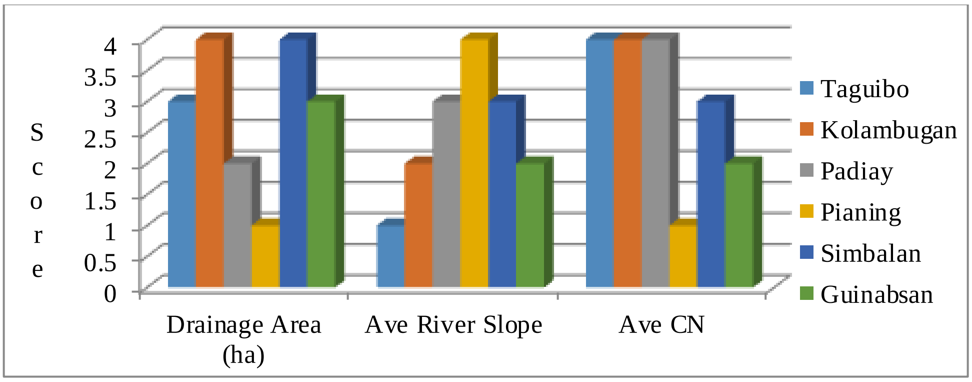


Figure 3. Graphical representation of the total weighted scores of the six watersheds with respect to their areas, river slope and runoff potential.

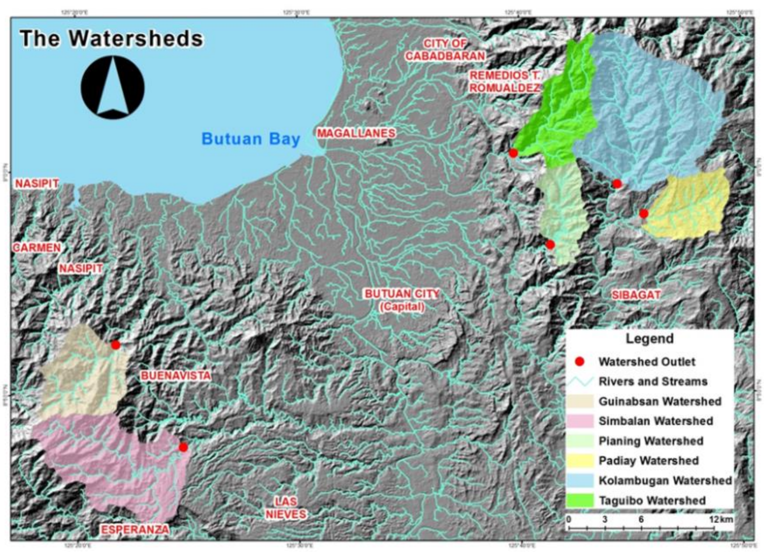


Figure 4. The potential watersheds as identified by delineating river basins

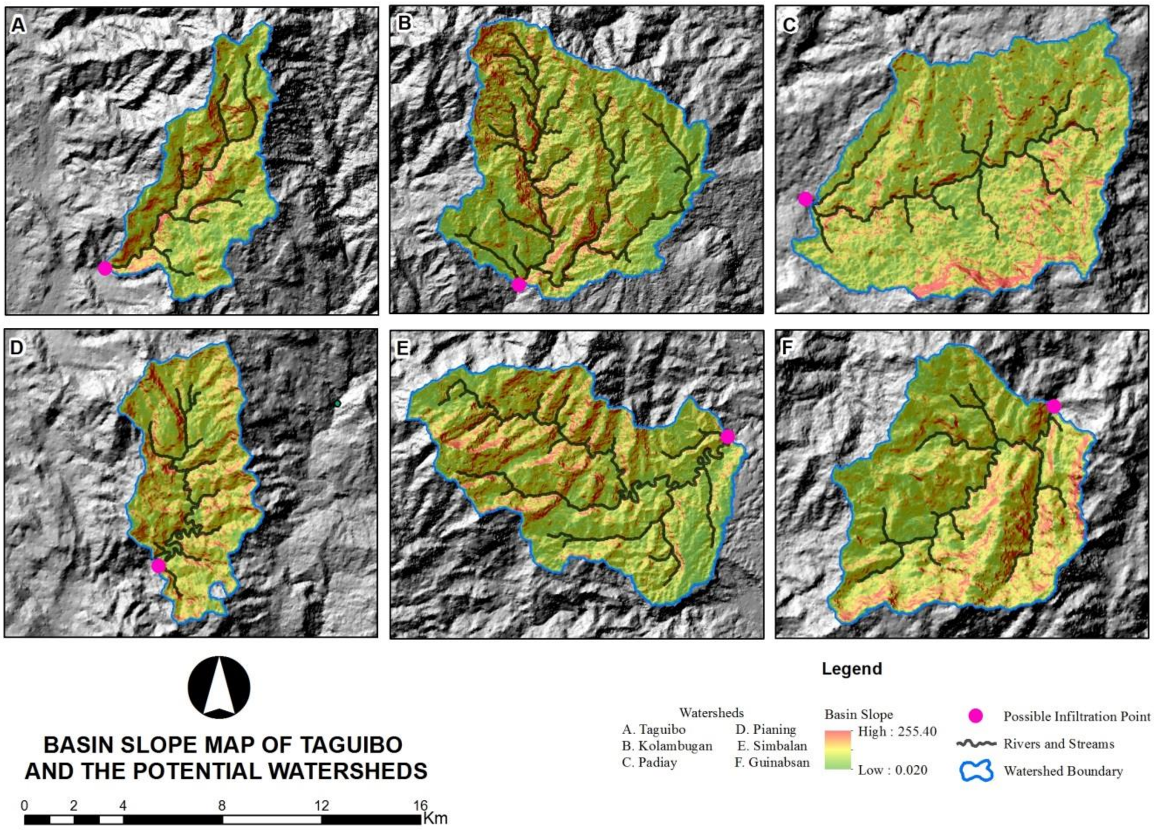


Figure 5. Basin slope map of Taguibo Watershed and the Potential Supplementary Watersheds

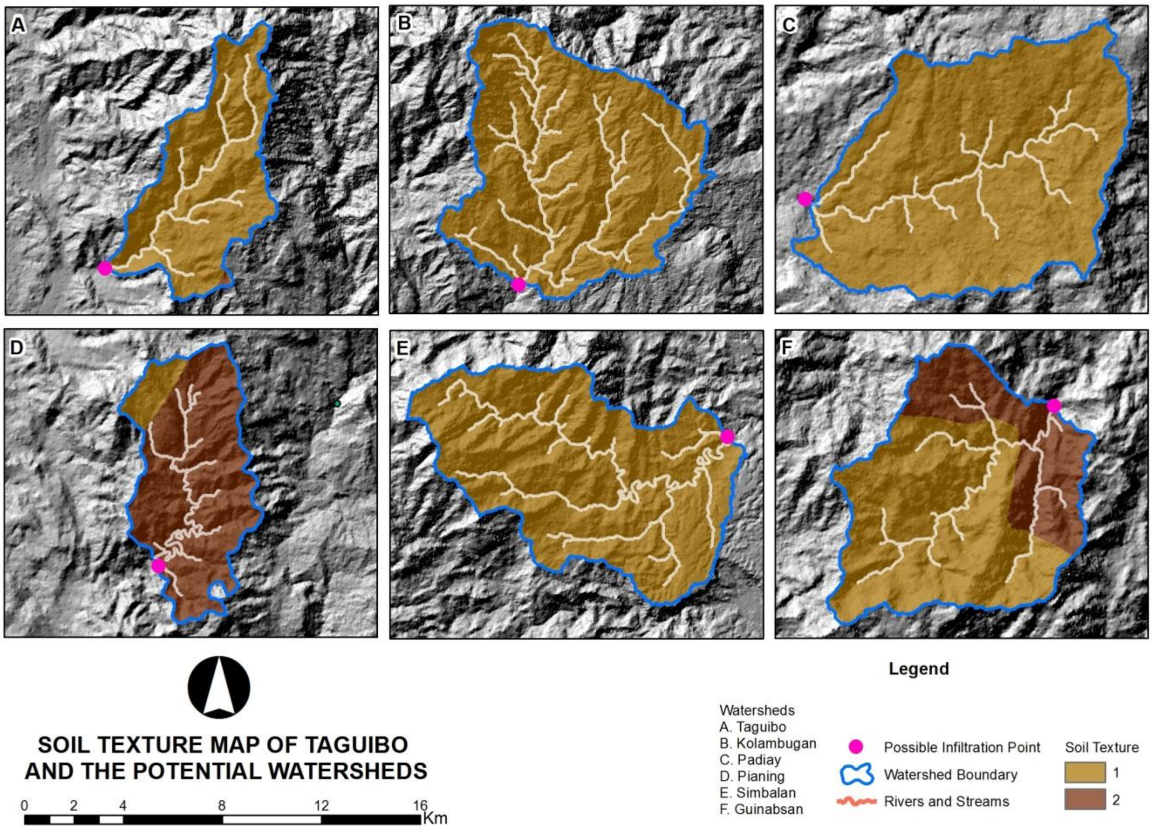


Figure 6. Soil texture map of Taguibo Watershed and the Potential Supplementary Watersheds

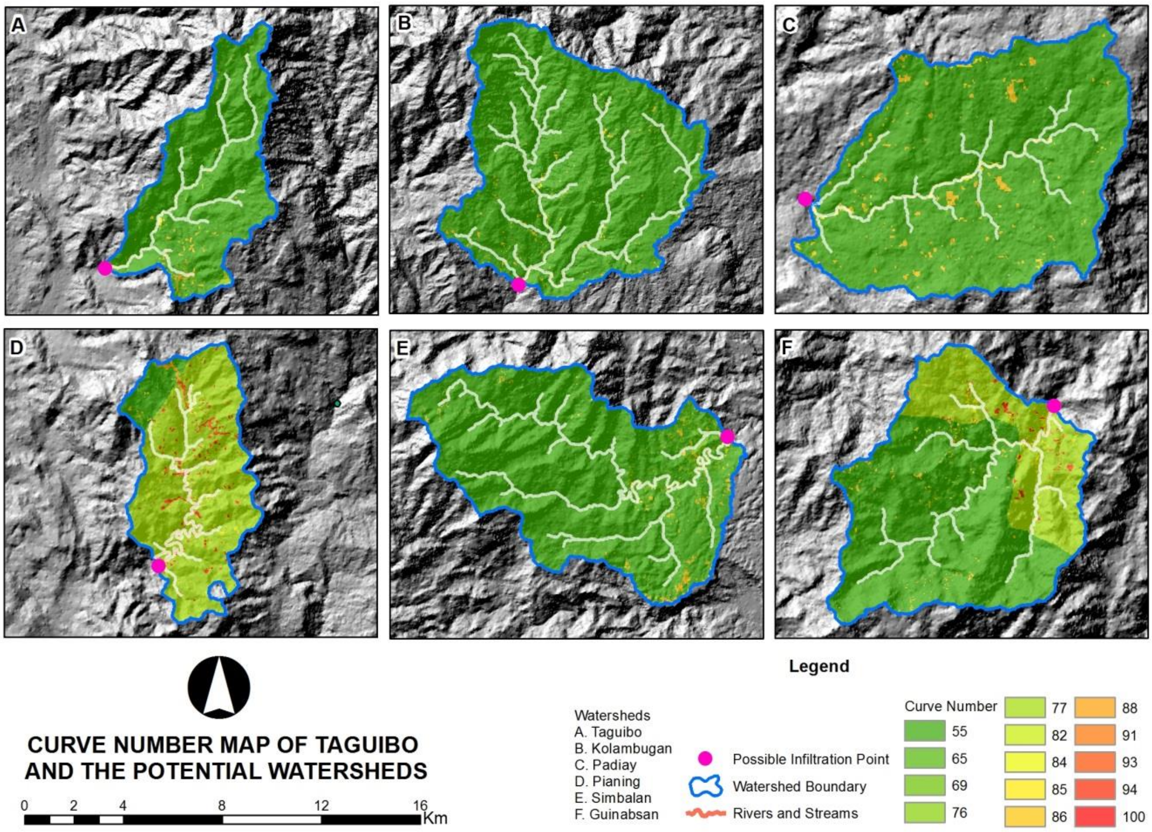


Figure 7. Curve number map of Taguibo Watershed and the Potential Supplementary Watershed

## 4. CONCLUSION

By geospatial analysis, basin model generation and comparative analysis, this study was able to identify potential watersheds within Butuan City. Based on the results, there were five identified watersheds. And through characterization analysis and comparison, the study identified that the most suitable supplementary watershed were Kolambugan and Simbalan Watershed. Padiay watershed is also suitable. However, Pianing ang Guinabsan scores were below to that of Taguibo, and since this study aimed to identify watershed that would equate or exceed Taguibo's characteristic, then only three out of five identified watersheds were suitable.

This study could serve as a guide to the local government of Butuan in identifying potential supplementary watersheds in the future. Future researchers who are interested to continue this study could consider additional characteristics such as the bulk density, the proximity of the watershed to the target community and other physical characteristics of the watershed.

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