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Geophysical Changes Analysis of Patalan River using High Resolution Satellite Imageries of Google Earth

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Abstract: ***The study aimed to determine the geophysical changes of the river outlet, riverbank and coastlines in Patalan, Pangasinan. Clear satellite imageries were analyzed in Google Earth from 2004 to 2014. The actual measurements were gathered using South Total Station (NTS-362R6L) in September 2015. The insight of the residents regarding the feature changes of the river and coast was obtained through one on one interview. Root Mean Square Errors (RMSE) were computed to determine horizontal positioning and measurement accuracy of Google Earth Satellite Imageries. To perceive changes of the sea level, historical data (2004-2015) from online tides and currents predictions were also analyzed. Results revealed that Patalan river outlet decreased in width size due to natural factors and human activities. There was increased in width of Patalan riverbanks which could be due to natural calamities and weak bank resistance brought by frequent flooding caused by heavy rains. The coastlines of the Patalan River moved landward due to natural occurrences and increased in population. Rise in sea level is also a probable cause wherein according to prediction, heights of low tides in Pangasinan Gulf is increasing overtime. The computed RMSE is low which indicates measurement and positional accuracy of Google Earth.***

Keywords: Remote Sensing, Change Detection, Flood

I. INTRODUCTION

Pangasinan is located on the western area of the island of Luzon along the Lingayen Gulf and South China Sea. A crescent-shaped province that occupies 5,368.82 square kilometers of verdant farmlands, hills, forest and rivers. To the east, it is bounded by the mighty Cordillera Mountains, the Zambales ranges to the west, the rice plains of Tarlac to the south and Lingayen Gulf and the China Sea to the north [1](Pangasinan Province Info). It encloses the Lingayen gulf, a semicircular embayment with an area of about 2,100 km2 [2](McManus, 1990). The terrain of the province is typically flat, with a few being mountainous. Several rivers traverse the province and one of those is the Patalan River. Low lying areas in Pangasinan are always prone to flooding during typhoons due to its geographic location. Local topography, including lengthy river and ocean coastlines, dense urban development patterns, the capacity of our aging sewer system and increasingly extreme weather are some of the biggest causes of flooding. Floods can have devastating consequences and have effects on the economy, people and natural resources. In this study, the detection of changes in coastlines, river outlet and riverbanks of Patalan river in Pangasinan through remote sensing from the Google Earth was used.

II. OBJECTIVES OF THE STUDY

This study aimed to determine the geophysical changes of the river outlet, riverbanks and coastlines in Patalan River Pangasinan. The study specifically aimed to:

A. Detect and analyze the geophysical changes in the river outlet, riverbanks and coastlines through satellite imageries;
B. etermine the causes of geophysical changes in the river outlet, riverbanks and coastlines and;
C. Determine the positional accuracy and measurement of Google Earth in the study areas.

III. MATERIALS AND METHODS

Satellite imageries of the Google Earth from 2004 to 2014 in Patalan River in Pangasinan, were used in the analysis to identify changes. Clear images of the river outlet, coastlines and riverbanks were analyzed quantitatively. Moreover, the actual measurement

were gathered in September 2015. The methodology used in gathering data in different study sites such as river outlet, coastline and riverbank of the watershed are as follows:

A. River Outlet

The distances of the river outlet for years 2004 to 2014 were measured. Only clear images on the historical views of the Google Earth were analyzed. Gathered data from Patalan River were compared from 2004 to 2013, where in 2004 is the basis of comparison.

B. Riverbank

The width of the riverbank was measured every 500m from the outlet of the river to upstream. Data were gathered using only the clear historical views of the Google Earth for the years 2004 to 2014. Sampling points of the latest Google Earth images were also recorded for field validation.

C. Coastline

Data were gathered from North and South coastlines of the rivers. The coastline in 2004 was the basis of the measurement for the Patalan River. Coastlines were measured every 500 meters from the coastline near the outlet of the river up to the coastline of the nearby river. Images were analyzed if the changes were moving seaward or landward.

D. Field Validation

Coordinates of every sampling points of the latest Google Earth images were recorded for field validation. The actual distances were measured on September 2015 by the LiDAR1 researchers using South Total Station (NTS-362R6L).

E. Root Mean Square Error (RMSE) Computation

RMSE measures how much error there is between two datasets, usually compares a predicted value and an observed value. In this study, coordinates gathered during the field validation were plotted in Google Earth and measured to compare with the validated measurement. RMSE takes the difference for each Google Earth Measurements (predicted value) and Field Validated Measurements (observed value) and the results squared to have a positive value. Then divide the sum of all values by the number of observations, which is then be square-rooted to have the Root Mean Square Error. Below is the formula used for RMSE:

where x_p = predicted value
x_o = observed value
N = number of sample

$$RMSE = \sqrt{\frac{1}{N}\sum_{p=1}^{N}(x_p - x_o)^2}$$

F. Community Survey on Coastline and River Changes of the Patalan River

A questionnaire regarding river and coastal changes was constructed specifically to determine the natural occurrences and the natural features of the area. Twelve points were strategically selected along the river and the coastline to form focused groups that provided the most useful data. Focused groups were formed by selecting residents residing at least a decade in the area for them to describe the historical changes and natural occurrences in the area. The community survey was conducted on September 15-17, 2015 in Patalan River in Pangasinan.

G. Analyzing Sea Levels

The historical record from tide gauges of Bolinao, Philippines Tide Chart at online tides and currents predictions [3](Online Tides WorldView) for the years 2004 to 2015 were gathered to perceive the changes of the sea level. Records of the low tide and high tides per day were determined. Gathered data was compared and analyzed and see the flow of tide within a decade data.

IV. RESULTS AND DISCUSSIONS

A. Patalan Watershed

Patalan watershed is one of the major watersheds in the island of Luzon in the Philippines. It covers about 31,222.66 ha. The upper portion of Patalan river which lies between 16°14'00" to 16°24'30" N and 120°30'45" to 120°38'50" E covers about 14,302 hectare. It covers six barangays of Tuba (Camp 1, Tabaan Sur, Twin Peaks, Camp 3, Camp 4, and portion of Poblacion), small portions of Barangays Virac and Ampucao in Itogon, Benguet and 25 barangays in the southern part of Baguio City. On the other hand, in the

La union side (Pugo, Rosario and Sto. Tomas) and Pangasinan side (Sison, Pozzorubio, San Jacinto and San Fabian) the river covers about 16,920.66 hectares [4](Lopez et al., 2011). The river originates in the southeastern portion of Baguio City and traverses the municipality of Tuba, Sison, Pozorrubio, San Jacinto, Mangaldan which empties into the Lingayen Gulf at the border between San Fabian and the city of Dagupan (Figure 1).

Figure 1. Patalan Watershed

B. Patalan River Outlet

Result of the study showed that there was a decreased and increased of width size of the Patalan river outlet. Figure 2 shows that in 2004, the width of the river outlet is 648m but the width decreased in size in 2006 (305m). However, the width increased again in size in the years 2010 (585m) and 2013 (641m), respectively. These changes in size overtime are due to numerous factors such as natural and human interventions. The changes of its size are perhaps due to sedimentation/accretion and erosion. Moreover, during the actual ground validation in November, 2015 the width size decreased again to 475m that maybe due to sedimentation which occurred in the area

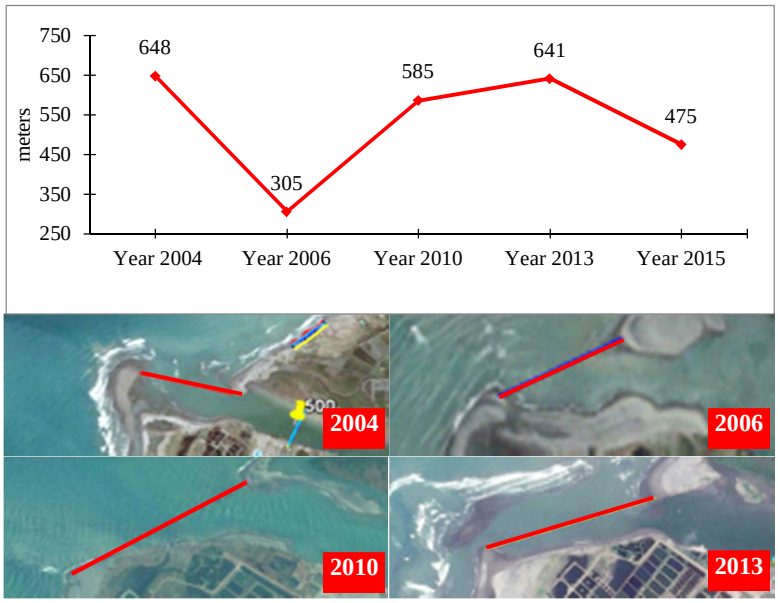

Figure 2. Satelite images of the Patalan river outlet showing its width size in different years (2004 -2013)

These occurrences maybe due to erosion of the left side of the river outlet that happened because of high velocity of the river flow during typhoons and heavy rains and sedimentation/accretion from transport of soil materials.

These erosion and sedimentation/accretion processes played active roles in the changes of the Patalan river outlet from 2004 to 2015. Mines and Geoscience Bureau [5](MGB, 2004) reported that the upper portion of the river is silted and is occasionally dredged. It is also been the drainage of mine tailings from copper and gold mines in Tuba, Benguet [2](McManus, 1990). The landslides along Kennon Road [5](MGB, 2004) including quarrying and aggregates crushing plants in riversides released silt and sand into the river [6](Cadalig, 2015). During rainy season, mine tailing discharge affected the farmlands along the floodplains of Patalan river [2](McManus, 1990).

C. Patalan Riverbank

Generally, Patalan Riverbank increases in width size (see Figure 3). It shows that the riverbank widened overtime due to river embankment erosion. This bank erosion was possibly brought by natural calamities and or weak bank resistance. According to [7]Wanquan et al. (2013) low flows and flood flows caused high lateral channel erosion rates in sand-bank Rivers which contribute to increased suspended sediment loadings. Soil condition is also a contributory factor in severe erosion. It was also stated by [4]Lopez et al. (2011) that the Patalan river watershed contributes high volume of flood waters to low lying areas during heavy rainfall/adverse weather conditions.

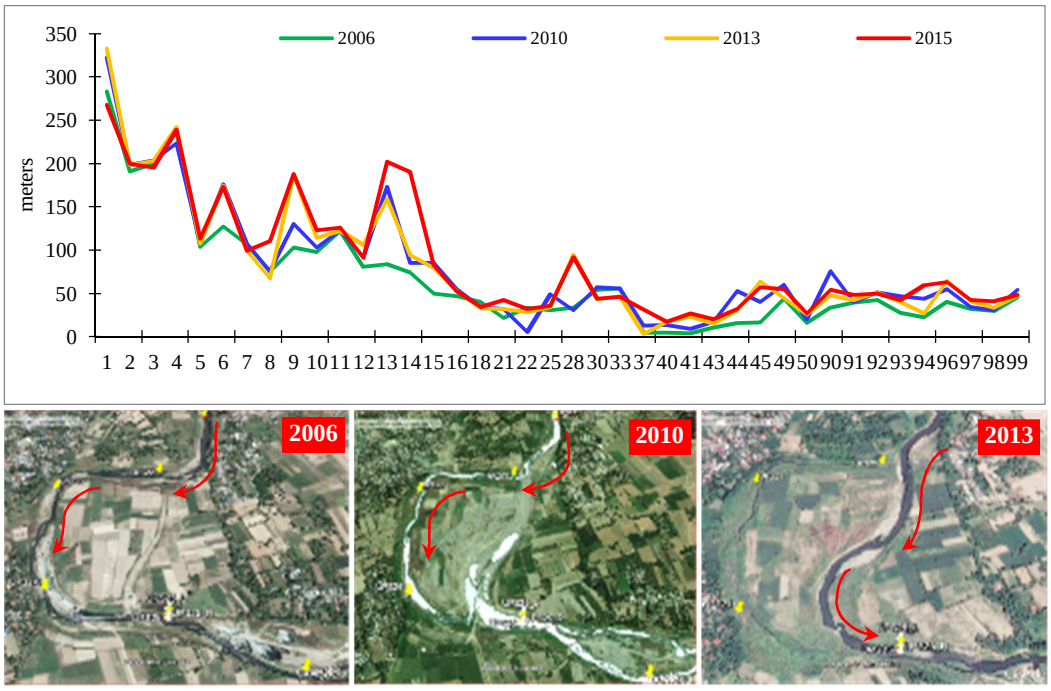

Figure 3. Patalan riverbank in 2006, 2010 and 2013

Moreover, mobility or the shifting in the position of the riverbank (Figure 3) was also observed in the upper upstream of the river specifically in curved areas like in data points 22 to 25 and 94, respectively. The shifting could be due to erosion and sedimentation of the loss soils from the nearby agricultural farm lands and communities.

The river overflows especially during strong rains and typhoons. Moreover, according to the study at Syhan river in Turkey using two winter images of Landsat acquired in 1972 and 2002 showed that significant changes occurred especially around river mouths, in the form of accretion and erosion [8](Alphan, 2005).

D. North Coastline of Patalan River

The north coastline of the Patalan River shows big changes through time, specifically near the river outlet which are data points 1 and 2 where there is a decrease in width size (Figure 4). The extent of changes in the coastline indicates that the coastline changed physically. It moves landward from 2004 to 2015. The type of sand in the coastal area was coarse. The coast was described by the residents as flat and wide. Most of the time, the presence of strong winds was observed by the residents in the coastal area. A destructive wind was also observed during typhoons which contribute to the erosion in the coastal area.

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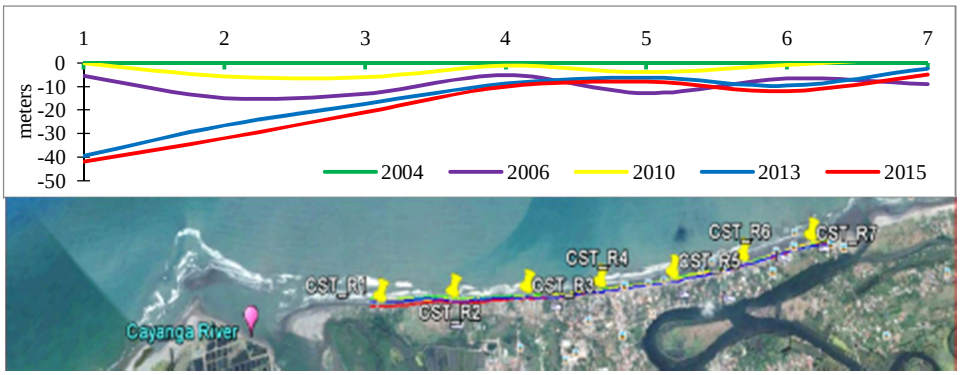

Figure 4. North coastline of the Patalan River

Coastline changes mostly occur as a result of large-scale landscape transformations in the upper basin that determine the quality and amount of the material transported into the sea [8](Alphan, 2005). It was stated in the [9]Philippine Development Plan (2011-2016) that sedimentation in coastal areas due to unsustainable land use in upland areas continues to threaten coastal ecosystems. Changes in the coastal landscape are, thus, the function of not only in situ alterations but also external factors such as land use/cover changes at watershed scale that result from human activities [8][10](Alphan, 2005 and Kaki et al., 2011). Based on the 2010 Census of Population and Housing (CPH), the province of Pangasinan posted a total population of 2,779,862 persons as of May 1, 2010, larger by 345,776 persons counted in the 2000 CPH. The increased in the population count from 2000 to 2010 translated to an average annual population growth rate of 1.34 percent [11](PSA-NSO, 2010). As population increased, the needs and living space also increases which affects the environment.

E. South Coastline of Patalan River

The south coastline of Patalan river decreased in size through the years. From 2004, the coastline eroded up to 19 meters in width size. Heavy rains brought by the southwest monsoon, or "habagat" on August 2013, caused severe flooding in the city that caused some soil particles and debris to accumulate near the coastlines which can be observed in Figure 5 wherein point 1 to 3 of the coastline accreted.

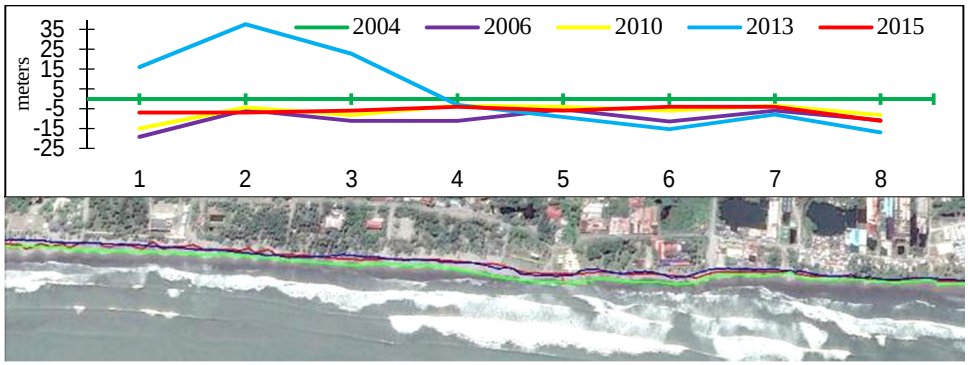

Figure 5. South coastline of the Patalan River

The area according to the residents was hit by several typhoons every year which brought high waves with a height of up to 3 meters constantly weathering the coastlines. Frequent rains were also observed in the area which also cause the frequent release of water from San Roque Dam that caused flooding especially to low-lying areas. Moreover, some parts of the city had been declared under state of calamity due to severe flooding caused by continuous rains.

Because of natural or sometimes anthropological causes coastline evolves in a context of erosion and accumulation [10](Kaki et al., 2011). It was also stated that most of the coastline is under erosion and retreat which are also the results of erratic changes in the climate [12](Capili et al., 2005). The rate of erosion along the shoreline can be attributed to a combination of agents such as river entrenchment, delta deforestation and change of land use, construction of high dams in the river course and the capture of sediments in their basins, compaction and subsidence of the loose delta sediments.

F. Root Mean Square Error

The computed RMSE in Patalan River Watershed outlet, riverbank and coastlines show negligible differences between the measured data during the on-site validation and the measured data plotted in the Google Earth. The RMS Error computed for the river outlet is 1.1 meter while for the north coast is 0.33 meter. However, 0.5 meter is the computed RMSE for the riverbank. These results show that, location can be accurately located using Google Earth high resolution imageries. According to [13]Tewksbury, (2015) reconnaissance using Google Earth provides a virtually cost-free strategy for collecting enough data. This enables target critical areas for field data and sample collection to test structural interpretations and to acquire ground truth for more accurate mapping in inaccessible areas.

G. Patalan River Major Features

The characteristic of soil around the river was described as sandy and clay. The river water is flowing and clear. However, during rainy season, the muds in the river and the surroundings of the river were disturbed which caused the appearance of the river water to be opaque. The residents rely on deep-well for water source. Mostly, mangroves, patupar, mango, banana, calapini, kawayan and ipil were found planted near the riverbank. Installation of fish pens within the river were observed as the human activity in the area.

H. Coastlines of Patalan River Major Features

The type of sand in the coastal area was coarse. The coast was described by the residents as flat and wide. The normal wave height of the ocean reached up to 0-2 meters while during typhoons and rainy season, the wave height reached up to more than 4 meters which were resulted to severe erosion and slightly steep coast. Most of the time, the presence of strong winds were observed by the residents in the coastal area. A destructive wind was also observed during typhoons which contribute to the erosion in the coastal area.

I. Natural Disasters Occurring in the Area

Calamities were experienced by the residents near the Patalan River. The respondents said that they were usually hit by strong typhoons every year since the Philippines sit astride the typhoon belt, and the country suffers an annual onslaught of dangerous storms from July through October. Some typhoons found to be very destructive which were resulted to floods, overflowing of river, erosion and hurricane. The calamities passed through the area often changed and affect the natural features of the river including erosion that caused the enlargement of the river width.

V. CONCLUSIONS

Study showed that significant changes occurred in the width size of the Patalan river outlet. These changes in size overtime were also due to numerous factors caused by natural and human interventions such as quarrying, mine tailings and crushing plant discharge. The significant changes around the river mouths was due to erosion of the left side of the river outlet caused by high velocity of the river flow during typhoons and heavy rains while sedimentation/accretion was from transport of soil materials.

The Coastlines of the Patalan River shows big changes through time, specifically near the river outlet. The coastline moves landward. This occurrence was a result of large-scale landscape transformations in the upper basin. Increase in population may also contribute to changes in coastal landscape as living space also increases which affects the environment.

Generally, Patalan Riverbank widened in width size overtime due to river embankment erosion that was possibly brought by natural calamities and or weak bank resistance. Mobility or the shifting in the position of the riverbank was also observed in the upper upstream that could be due to erosion and sedimentation of the loss soils from the nearby agricultural farm lands and communities.

Computed RMSE in Patalan River Watershed outlet (101 m), riverbank (0.5m) and coastlines (0.33m) show negligible differences. These results show measurement and positional accuracy of Google Earth in the study area.

Past and present situations regarding coast and river of the Patalan were also gathered through one on one interview with the residents. It shows in the result that the characteristic of the soil (coarse sandy and clay) around the river, human activities and calamities affects the natural features of the river.

VI. ACKNOWLEDGEMENT

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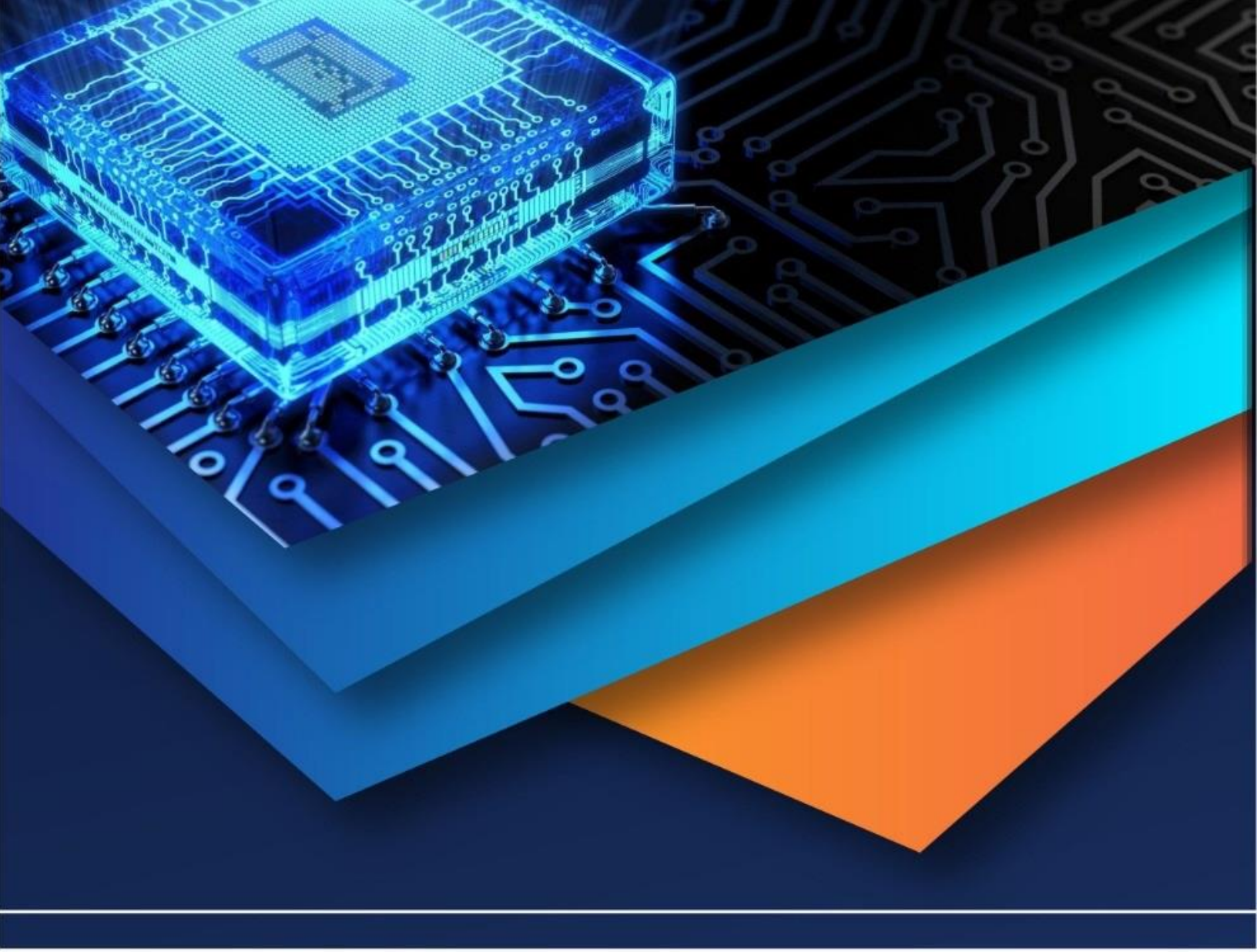

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