# Watershed and Catchment Data

**Capacity Development Project for Operationalization of PNG Forest Resource Information Management System (PNG-FRIMS) for Addressing Climate Change**

## 1. Introduction

A watershed refers to a river system, i.e., an area drained by a river and its tributaries. It is sometimes called a drainage basin (National Geographic, 2019). For this project and the development of the PNG-FRIMS, watershed data that is acquired and analysed is predominantly focused on the Watershed Boundary. The watershed boundary delineates the areal extent of surface water drainage to a point, accounting for all land and surface areas. The boundaries of the watersheds can be derived through watershed analysis on remote sensing data.

The watershed boundary in mountainous areas is located on ridge lines and saddleback areas, serving the function of inhibiting the flow of materials and demography, with the capability of separating living zones or cultural zones. In addition, there are cases that these living zones or cultural zones become administrative boundaries. The flow of materials and energy within the watershed acts continuously in the downstream direction, and the watershed becomes an ecosystem. Therefore, a grasp of the watershed boundaries needs to be obtained in order to conduct forest management, secure water resources, predict disasters and perform other such work.

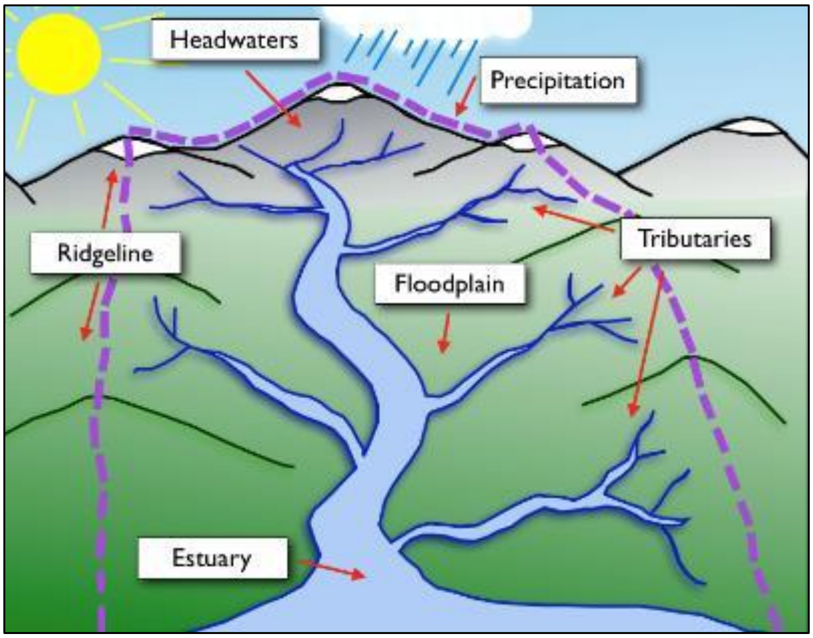



*Fig.1: An illustration showing the different aspects of a watershed. The Watershed Boundary is symbolized with the striped purple line*

*(Image courtesy of the Central Sierra Environmental Resource Centre)*

# 2. Methodology

## Data Acquisition

The primary source of Watershed Boundary Data is Digital Elevation Model (DEM) datasets. A Digital Elevation Model (DEM) is a specialized database that represents the relief of a surface between points of known elevation. By interpolating known elevation data from sources such as ground surveys and photogrammetric data capture, a rectangular digital elevation model grid can be created. (Caliper Mapping & Transportation Software Solutions, 2019)

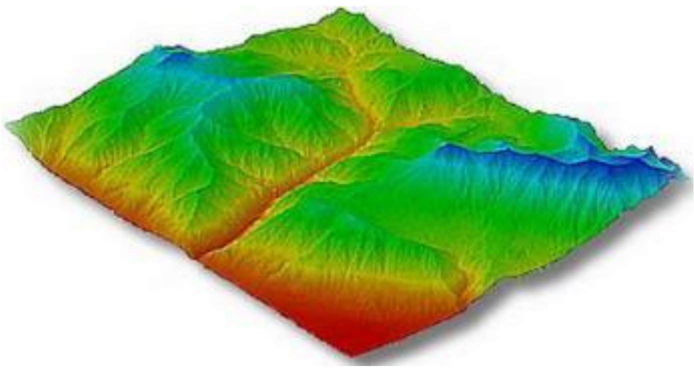


*Fig.2: A 3D representation of a DEM (Image courtesy of the GPS Power)*

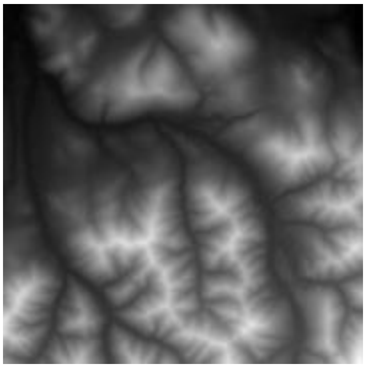


*Fig.3: A 2D representation of a DEM. (Image courtesy of University of Minnesota)*

The dataset that was used in this project was GeoSAR[1] DEM data with a high spatial resolution of 5 meters. It was acquired from the University of Papua New Guinea Remote Sensing Centre. Although the data covered the whole land area of Papua New Guinea, there were a few areas that did not have any data. To cater for the areas with missing data, SRTM DEM data with a resolution of 90 meters was used to supplement the data.

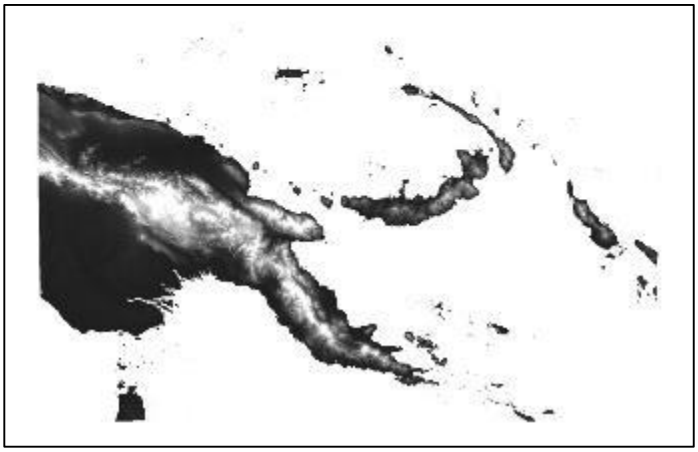


*Fig.4: SRTM 90 meter resolution DEM data covering the whole land area of Papua New Guinea*

[1] GeoSAR: GeoSAR is an airborne dual band interferometric radar system flown by Fugro and capable of producing DSMs and DTMs even in cloudy terrains. The system was used to cover mainland PNG in 2006 and the data from the P Band DTM was acquired by the PNG Government with funding support from the Australian government. The main recipient of the data in PNG was the National Mapping Bureau (NMB) and PNG Forest Authority, both of which were granted use of the data for the objective of sustainable forest management in PNG. (BusinessWire, 2006)

## Procedures

The size of the watershed boundaries were created at three levels, from large watersheds to small watersheds, in consideration of usage at a variety of levels, such as the vegetation boundaries on forest cover classification. The process of creating watershed boundaries is shown in Figure 5.

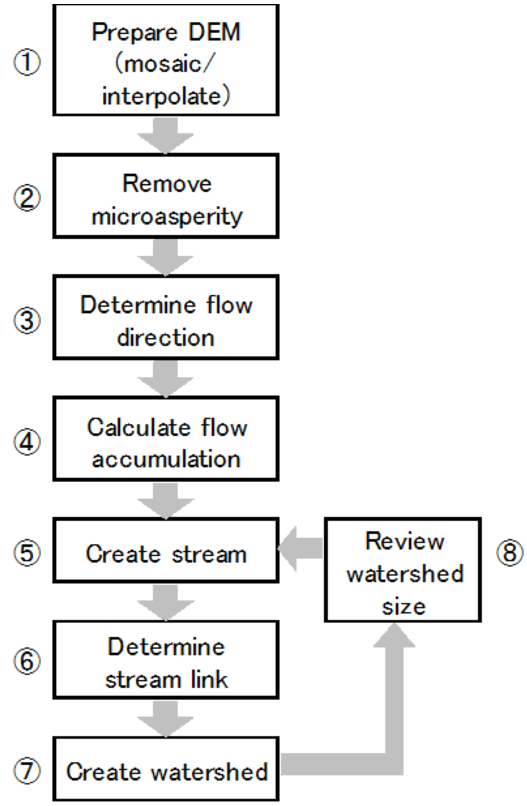



*Fig.5: The Work-Flow Diagram showing the processes involved in generating Watershed data from a DEM.*

**1. Prepare DEM (mosaic/interpolate)**
This process involves firstly "stitching" (mosaicking) together multiple GeoSAR DEMs to form a larger model, and the interpolation of the DEM to estimate values of unknown areas using the SRTM DEM data.

**2. Remove Microasperity**
The DEM will have to be "smoothened" out. This is done to remove small imperfections in the data.

**3. Determine Flow Direction**
The flow direction basically shows where the water is flowing or the direction in which the watershed is drained. This is done by calculating the elevation values of the DEM cells, and comparing each value to its surrounding values.

**4. Calculate Flow Accumulation**
The Flow accumulation is used to determine the path where the majority of the water are being drained to. The volume of Flow Accumulation shows a raster of accumulated flow to each cell, as determined by accumulating the weight for all cells that flow into each down-slope cell. This will highlight the watershed boundaries.

**5. Create Stream**
Once the watershed has been highlighted from the DEM cells, the streams can now be created by assigning them values according to their hierarchical order and creating a stream network.

**6. Determine Stream Link**
This assigns unique values to each of the links in the stream network. This is most useful as input to the Watershed tool to quickly create watersheds based on stream junctions. It can also be useful for attaching related attribute information to individual segments of a stream.

**7. Create Watershed**
This will create the watershed from the output Stream Network and the Calculated Flow Accumulation.

**8. Review watershed size**
Small watershed boundaries were created in a number of different sizes, and the respective watershed boundaries were overlaid with the satellite images in order to determine the watershed size that best

reflects the vegetation boundaries as shown in Figure 6. As a result of a review, the following conditions were established for the respective watershed boundary sizes: Cumulative flow volume of 50,000 cells or more for small watershed boundaries, 500,000 cells or more for medium watershed boundaries and 5,000,000 cells or more for large watershed boundaries.

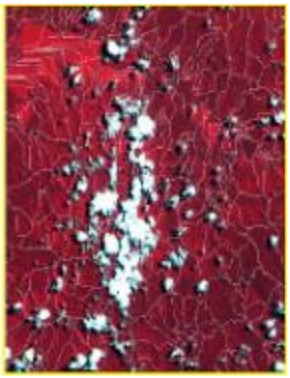
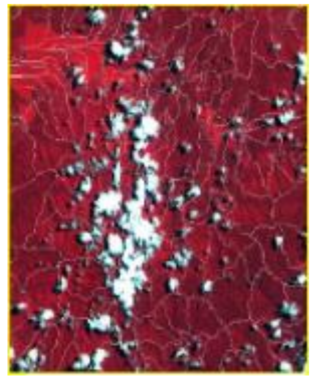
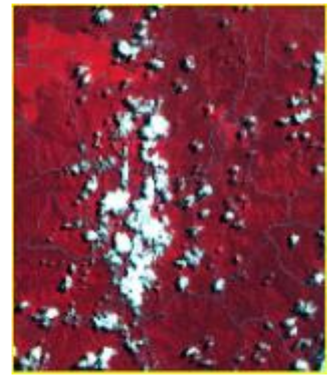
| Watershed Boundary > 50,000 | Watershed Boundary > 100,000 | Watershed Boundary > 500, 000 |
|---|---|---|
|  |  |  |
| ❖ Preferred for Watershed Analysis | ❖ Less preferred for watershed analysis | ❖ Not preferred for watershed analysis |
| ❖ Excellent indicator for vegetation & forest classification especially at high altitude | ❖ Good indicator for vegetation & forest classification at both low and high altitudes. | ❖ Excellent indicator for vegetation & forest classification especially at low altitude. |

*Fig.6: Watershed Boundary sizes for Different Cumulative Flow Volume and Results*

**Note:** The cumulative flow volume for watershed boundary >500,000 is not preferred for watershed analysis since it contains large watershed boundaries, i.e., the larger the watershed boundaries the lesser the number of streams (drainage). However, it is a good indicator of the difference between low and high-altitude vegetation for initial planning of classification, where the vegetation types within the watershed boundary size of >500,000 are classified as low vegetation.

# 3. Results

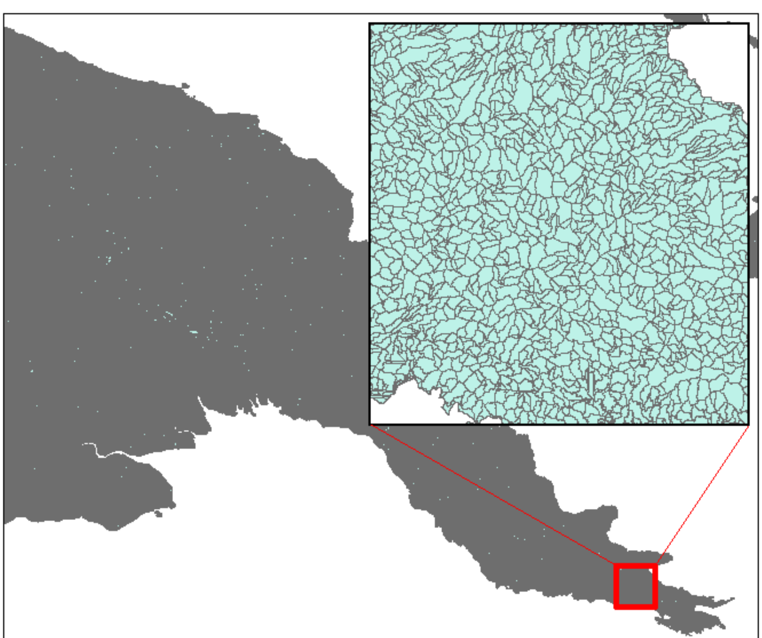


*Fig.7: Sample of PNG Small Watershed Boundaries shapefile created with DEM Data Analysis*

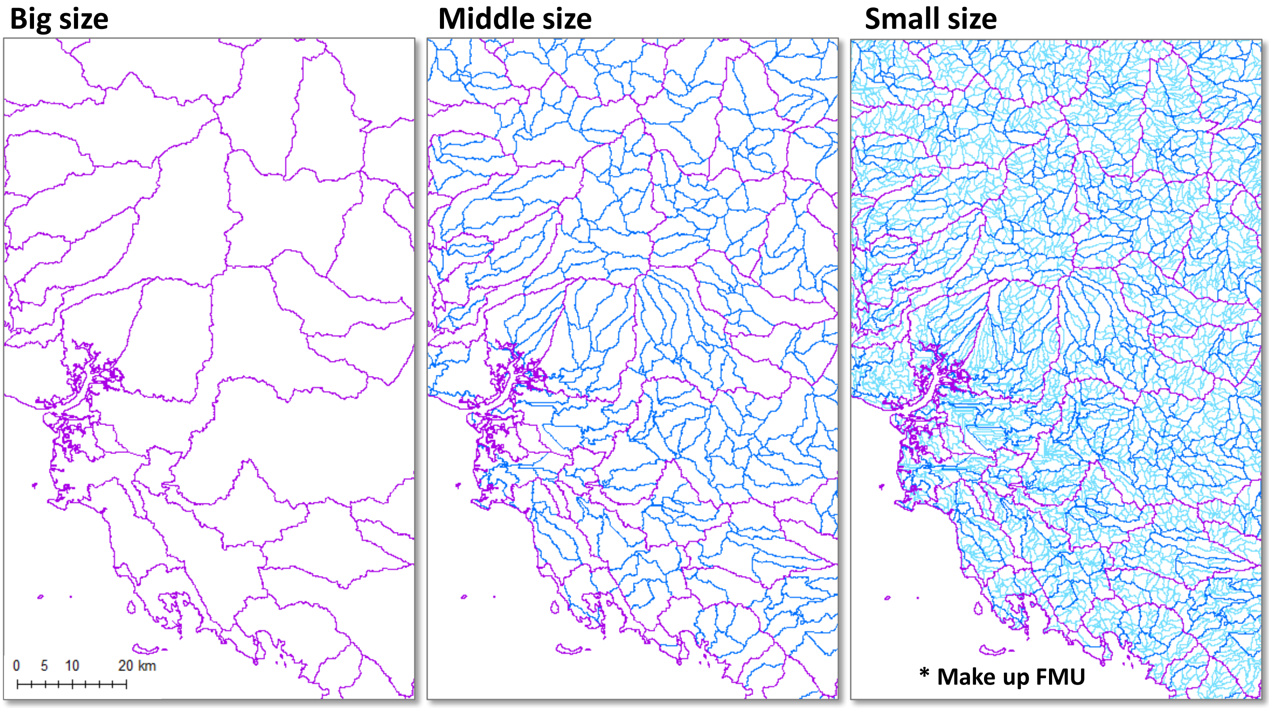



*Fig.8: Three level of Watershed Data of PNG*

**Note**: FMU – Forest Monitoring Unit; a minimum unit of forest at "not too small" scale for replacing legacy 'FMU – Forest Mapping Unit', which was 'too large' in relation to current available technology. The new FMU is being used for monitoring and recording changes of forests in PNG-FRIMS. The small size of the watershed makes up the FMU.

# 4. Discussions

## Issues and Recommendations

As all geographic representation processes are bound to have a few discrepancies, the production of Watershed Boundary Data encountered some minor issues:

1. Since accuracy of watershed data depends on accuracy of DEM data used for analysis, the accuracy of the watershed data in PNG-FRIMS is affected by the accuracy of the GeoSAR data used.

2. Since GeoSAR data was not calibrated well between the flight paths, the developed watershed data has some issues; includes some erroneous polygons.

3. The data does not necessarily mirror real-world watershed boundary, especially at complex topography areas and very gentle slope or flat areas since flow direction comes and goes.

Although the data has some issues, it is beneficial to know watershed information as there is no existing data which has been created using such a high resolution DEM data for the entire land mass of PNG. The main issue here lies in the acquisition of high resolution accurate data, that is able to undergo analysis without decreasing the accuracy of the overall process. Making sure that the DEM data is as accurate as possible before processing, will allow minimal errors that might cascade throughout the entire procedure.

## Applications

Watershed modelling simulates the hydrologic processes in a holistic approach with focus on a individual process or a combination of different processes at a relatively small scale. For instance:

- watershed data can be used to aid in the identification of suitable sites for small scale hydroelectricity dams to support small communities located along the tributaries leading to or exiting from a watershed.
- watershed combined with rainfall data can be used to determine the volume of water in a catchment, which can then be used to help locals identify suitable sites to set up ground water wells when further combined with soil data.
- A popular use of watershed data as used by parties interested in averting or avoiding natural disasters such as floods or landslides is disaster prevention policies/practices, in which case, watershed data combined with various other resources integrated into a Geographic Information System can be used to predict areas vulnerable to such natural disasters
- In Civil engineering, watershed data can be used to determine the flow impact a tributary would have on a bridge, in order to construct a bridge that can maintain its foundation when the flow impact is at its highest.

In Forestry, and particularly in PNG-FRIMS, the three (3) size level of watershed developed in this exercise could be indicators of levels of possible inundation constraints to logging in the planning stage of identifying potential forest development areas. The watershed can also serve as an excellent indicator for vegetation and forest classification at high and low altitude areas.

# 5. References


BusinessWire. (2006, May 31). EarthData Wins $16-Million Contract to Map Papua New Guinea; Company's Radar Mapping System Uniquely Qualified to Map Equatorial Regions Worldwide. Retrieved from BusinessWire: A Berkshire Hathaway Company: https://www.businesswire.com/news/home/20060531005172/en/EarthData-Wins-16-Million-Contract-Map-Papua-New

Caliper Mapping & Transportation Software Solutions. (2019, May 30). Caliper Mapping and Transportation Glossary. Retrieved from Caliper Mapping & Transportation Software Solutions: https://www.caliper.com/glossary/what-is-a-digital-elevation-model-dem.htm

JICA and PNGFA, 2019, 'Forest Monitoring Unit (FMU) in Papua New Guinea Forest Cover Map - JICA-PNGFA Forestry Project 2014-2019 Fact Sheet No.4'. Papua New Guinea Forest Authority, Port Moresby, Papua New Guinea

National Geographic. (2019, May 29). National Geographic Resource Library. Retrieved from Encyclopedic Entry: Watershed: https://www.nationalgeographic.org/encyclopedia/watershed/

Image Links: Fig. 1: https://www.cserc.org/sierra-fun/games/watershed-game/
Fig. 2: https://www.gpspower.net/igo-maps/331765-dem-digital-elevation-model-5.html
Fig. 3: https://www.pgc.umn.edu/data/elevation/



**PNG Forest Authority (JICA Project)**
Address: P.O. Box 5055, Boroko, National Capital District, Papua New Guinea
Email: infor_general@pngfa.gov.pg
JICA Project Site: http://www.jica.go.jp/png/english/activities/activity12.html
Project Facebook Page: https://www.facebook.com/jica.png.forest.monitoring/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