Risk Assessment: Hazardous Water Resource Area in Bali, Indonesia from Mt. Agung Volcano Eruption using 30-meter resolution LiDAR DEM’s

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Introduction

Since August, 2017, Mt. Agung in Bail, Indonesia has been showing signs of volcano eruption which also last occurred in year 1963 & 1964 and caused thousands of deaths. As the sign of eruption became more significant, Indonesia's disaster mitigation agency had raised the alert to the highest level four on Bali's Mt. Agung volcano and warned residents in 8-10 km radius around the volcano to evacuate immediately. (http://news.abs-cbn.com/overseas/11/27/17/indonesia-raises-alert-to-highest-level-4-on-bali-volcano)

Many hazard assessments on lahar and tephra have been done, however, there has not been many researches on water pollution assessments. Indonesia is the fourth most populous country in the world with 258 million inhabitants. However more than 27 million Indonesians lack safe water, and 51 million lack access to improved sanitation facilities. (https://water.org/our-impact/indonesia/)


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The goal of this project is to provide assessment where there might be a water pollution caused by ashes in Bali, Indonesia using 30-meter resolution LiDAR DEM data. To do this, we need to identify all residential areas water streams and how far ashes will blow. Environmental factors and administrative factor such as wind, weather and location of water treatment plant are important factors to consider however due to lack knowledge, these factors will be neglected.

Data Collection

The following files were collected for this assessment.

Layer Name	Source	Description	File Type
DEM	USGS: ASTER Global Digital Elevation Model V002	The data are posted on a 1 arc-second (approximately 30–m at the equator) grid and referenced to the 1984 World Geodetic System (WGS84)/ 1996 Earth Gravitational Model (EGM96) geoid. https://gdex.cr.usgs.gov/gdex/	Aster
Populated Places	National Geospatial-Intelligence Agency	The text files contained lat., long., full name of the city, etc http://geonames.nga.mil/gns/html/namefiles.html#I	Text

Table 1: Information on collected data

Data processing

Preprocessing

1. Change symbology

   -DEM's properties

   – For better view of elevation, I classified the elevation with interval size of 20m and excluded value of 0 for future usage creating contour line. (Figure 2)

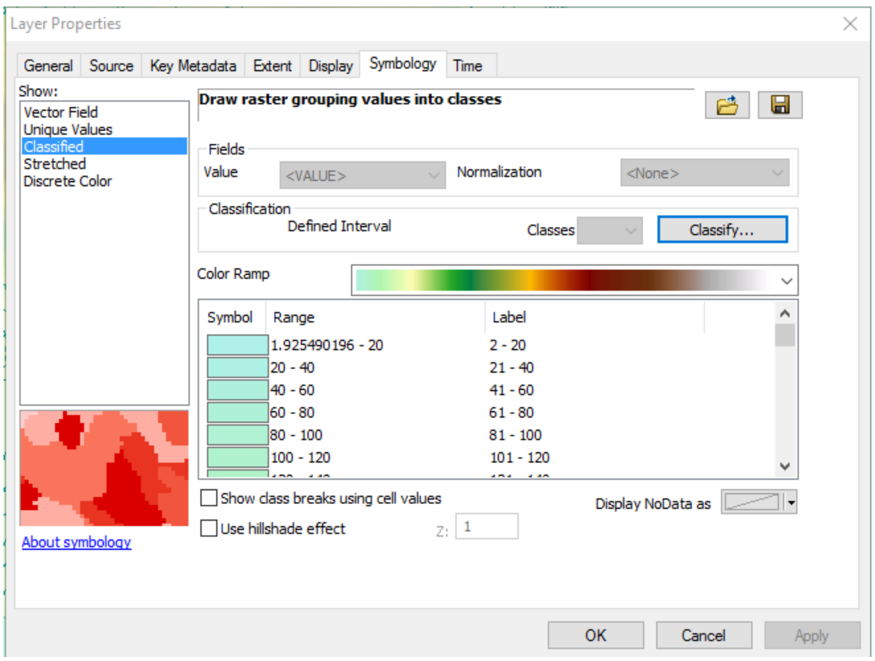


Figure 1: Properties of DEM layer

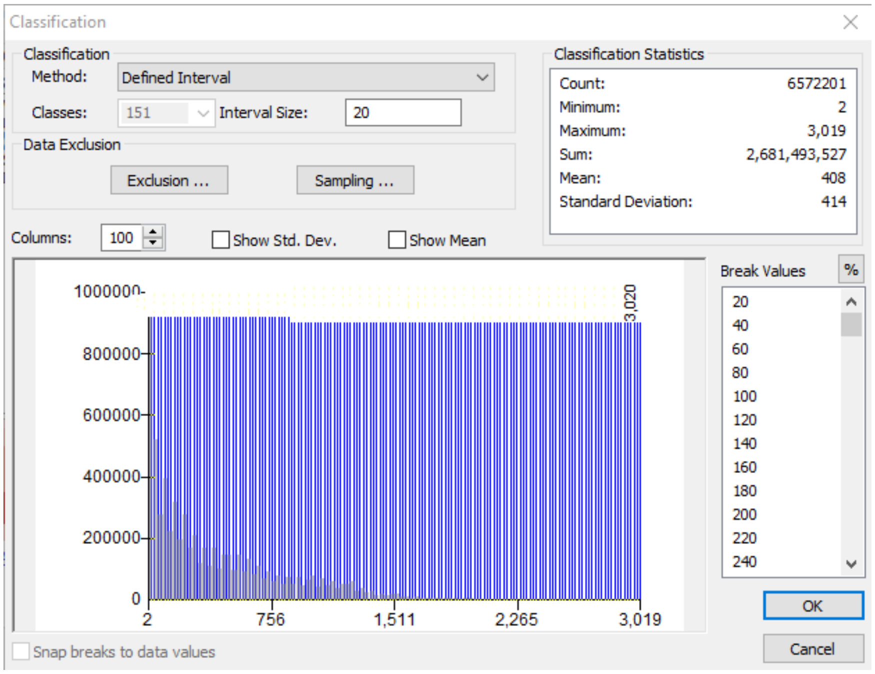


Figure 2: Classification properties of DEM layer

2. Create hillshade

-Hillshade (Spatial Analyst – Surface)

-z factor's default value was 1 but changed it to 0.000009 (Figure 3)

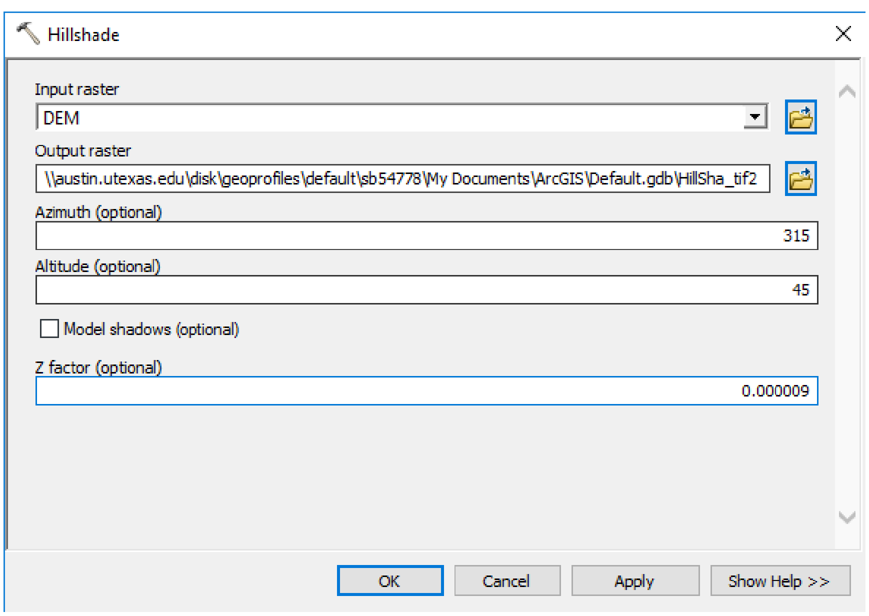


Figure 3: Creating a hillshade raster using hillshade tool

3. Create contour line for coastline

- Raster Calculator (Spatial Analyst – Map Algebra)

- True value was set to greater than 1 to differentiate inland from seawater. (Figure 4)

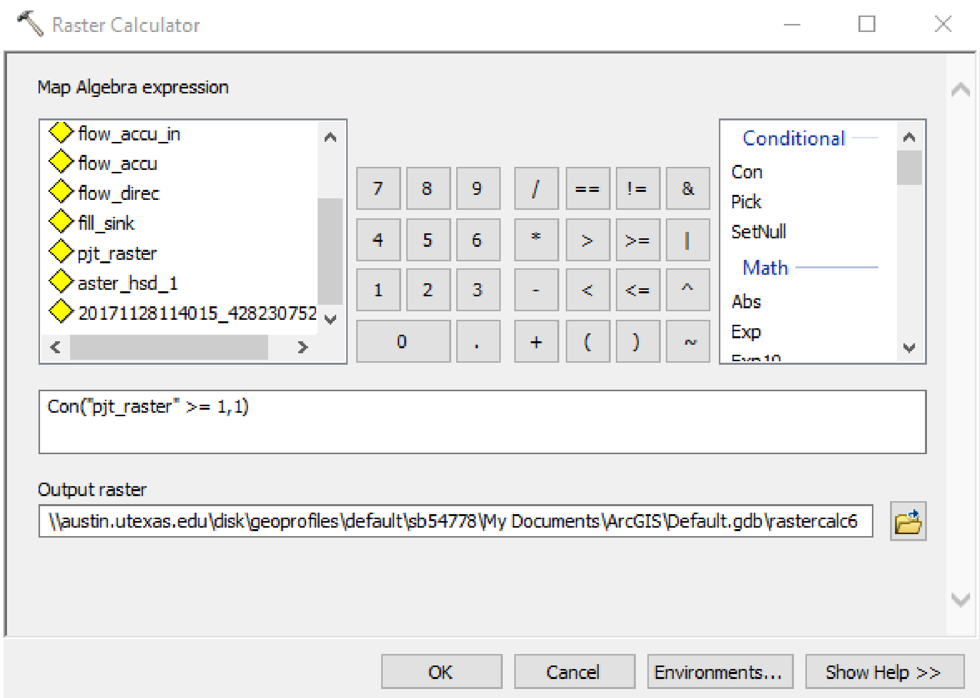


Figure 4: Create binary feature using raster calculator

Figure 5: Polygon shapefile of Bali Island

4. Project raster into appropriate coordinate system

   - Project Raster (Data Management – Projection and Transformation - Raster)

   - To: Indonesian_1974_UTM_Zone_50S

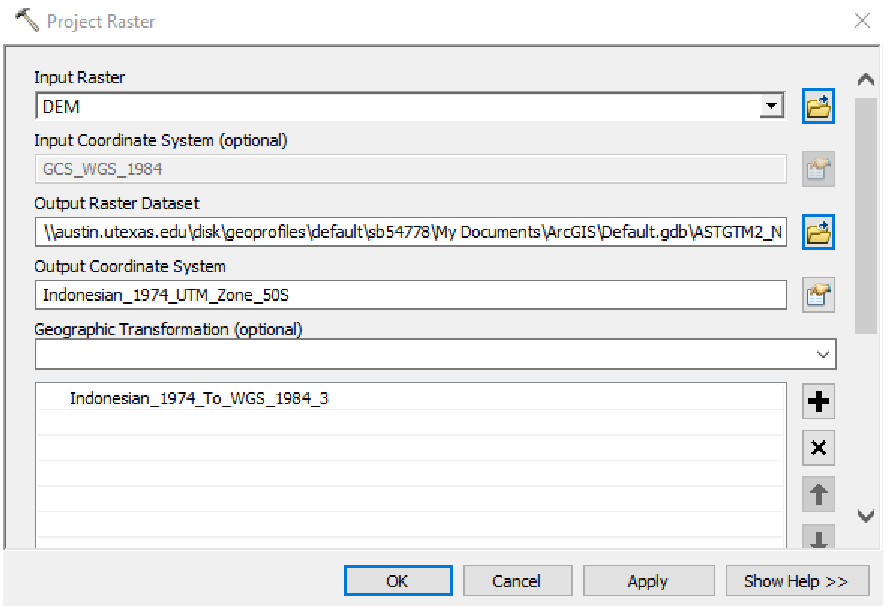


Figure 6: Changing raster's coordinate system

ArcHydro

In this section, I used hydrology tool to take the DEM and created stream water flow based on flow accumulations from flow directions. This is a very powerful tool when you don't have inland water raster data. To get the data using hydrology tool, following steps were proceeded:

1. Fill

- Fill (Spatial Analyst – Hydrology)

- Most DEMs have artificial gaps, or pits, from when they were first created. The cells that make up a pit have no downstream cells around it, so unless these pits are filled, they will become sinks and will isolate some portions of the watershed and will influence their flow accumulations. It is important to produce a new DEM that will fill these pits by increasing the elevation of the pour point until that pit will drain to neighbor.

(http://www.geo.utexas.edu/courses/371c/project/2016F/Munoz_GIS_Project.pdf)

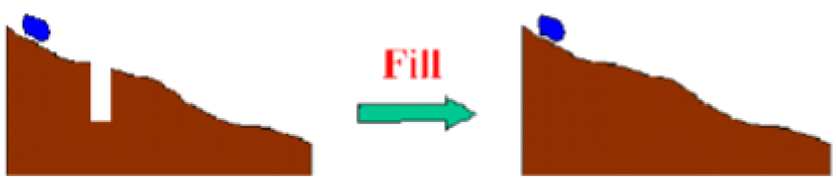


Figure 7: Principle of fill tool

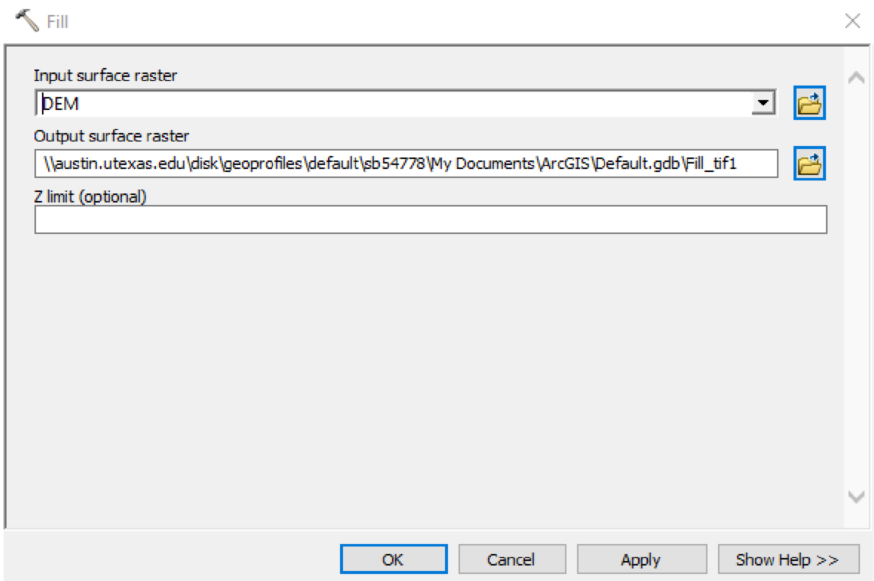


Figure 8: Creating new DEM raster using fill tool

2. Flow Direction

- Flow Direction (Spatial Analyst – Hydrology)

- Flow direction of the raster cells are created using the accumulation of directions of lowest neighbors adjacent to a raster cell. The flow direction raster will look like the raster shown below, with an 8 value raster table with the values, 1,2,4,8,16,31,64, and 128. These numbers correspond to the flow direction explained below.

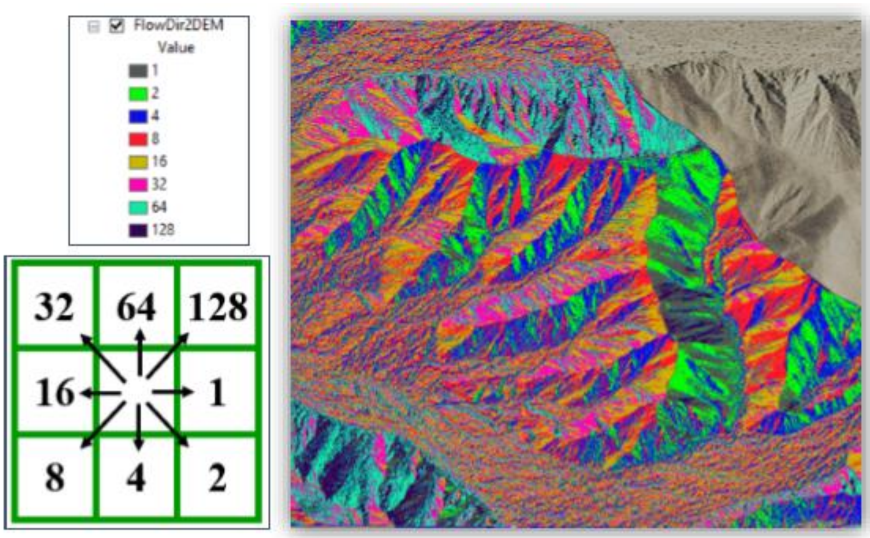


Figure 9: Principle of flow direction tool

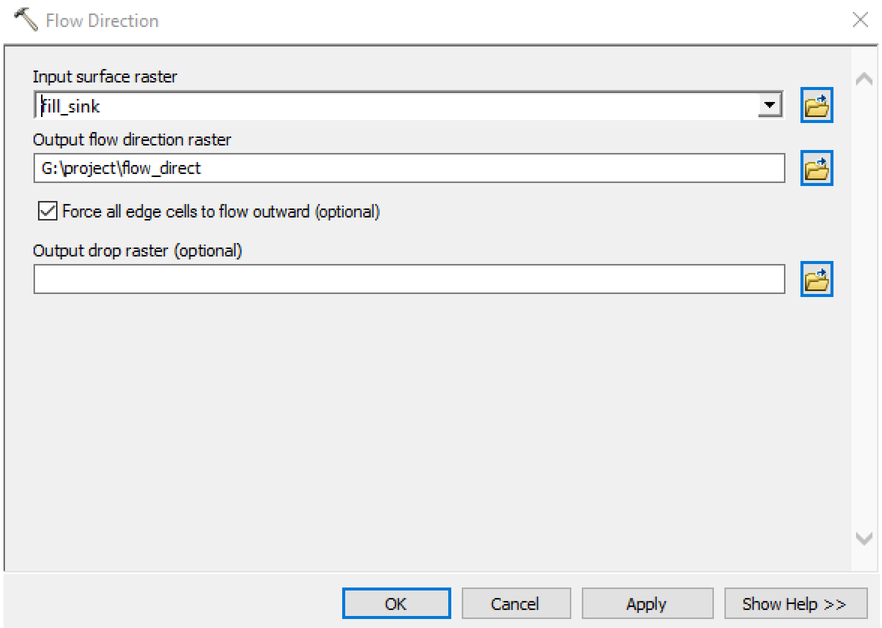


Figure 10: Creating flow direction raster

3. Flow Accumulation

- Flow Accumulation (Spatial Analyst – Hydrology)

- Raster of the accumulations of the flow directions.

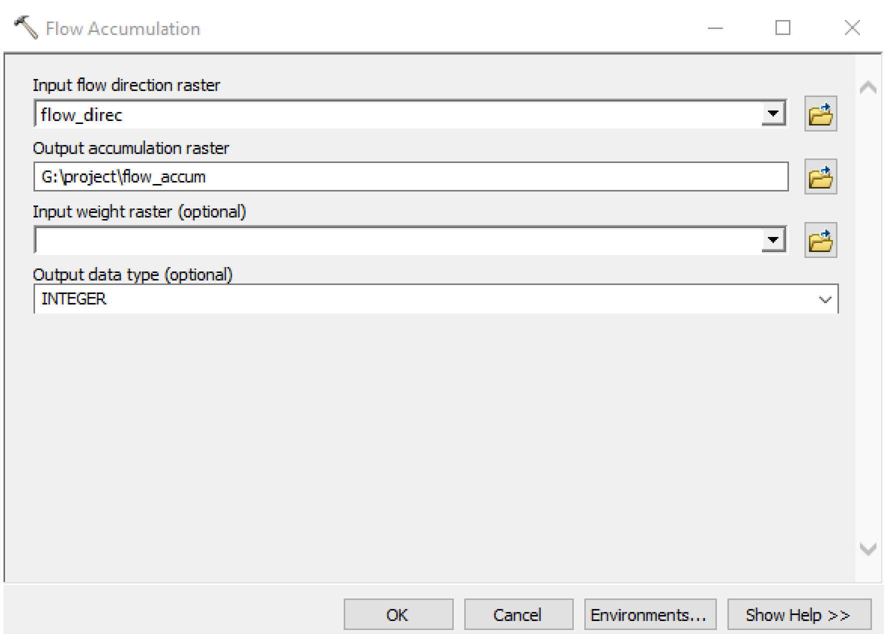


*Figure 11: Creating flow accumulation raster (*output data type was changed to integer)*

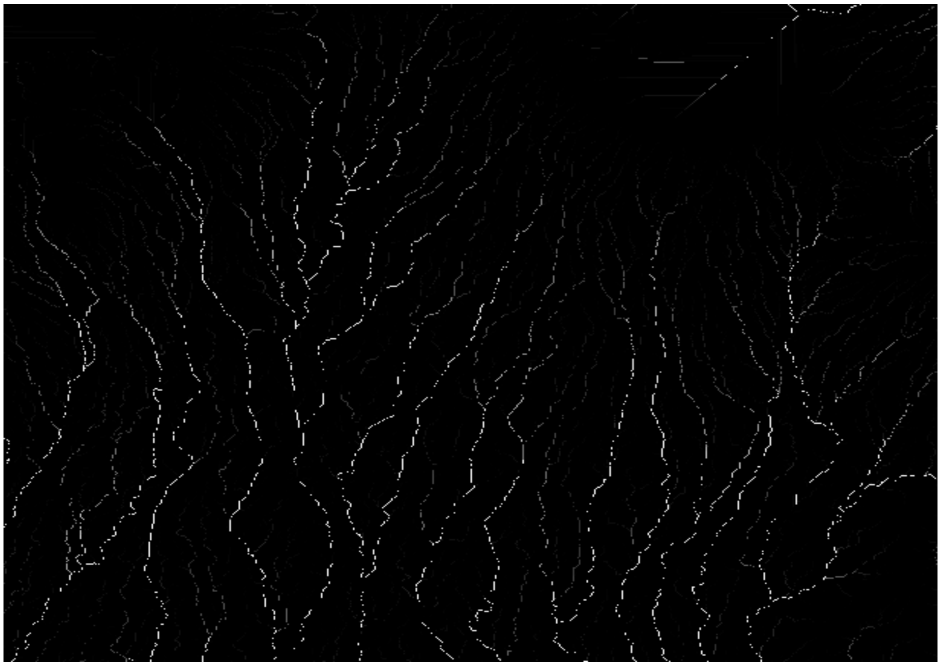


Figure 12: Portion of flow accumulation raster

4. Masking flow accumulation raster into Bali Island polygon

   - Extract by Mask (Spatial Analyst – Extraction)

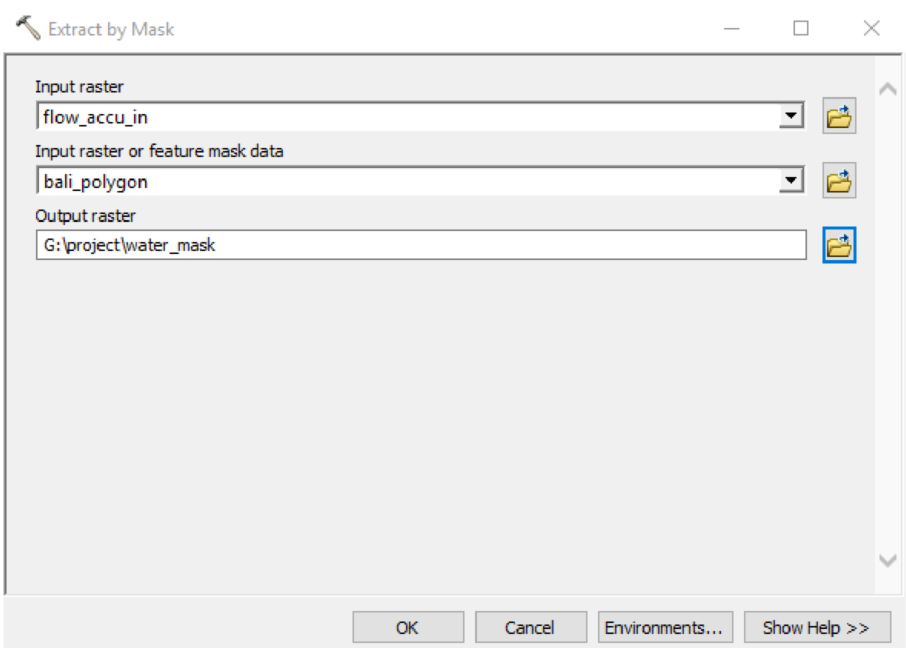


Figure 13: Masking flow accumulation raster to Bali Island

5. Stream Raster

- Raster Calculator (Spatial Analyst – Map Algebra)

- Any flows with greater value than 2000 was considered as stream.

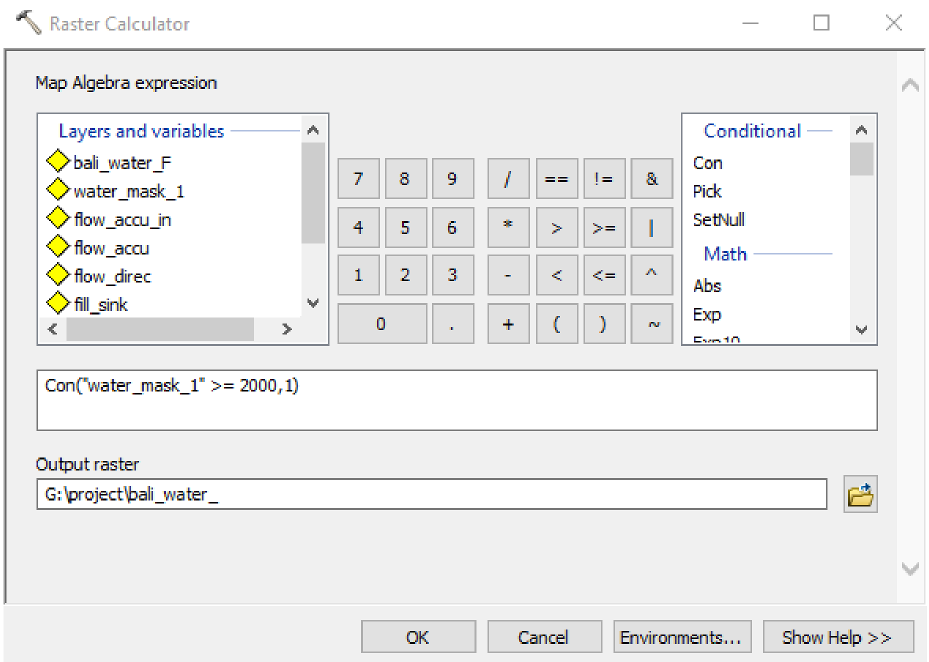


Figure 14: Creating stream raster using raster calculator tool

6. Stream Polyline Feature

- Stream to Feature (Spatial Analyst – Hydrology)

- This tool was used to separate stream raster into individual polylines.

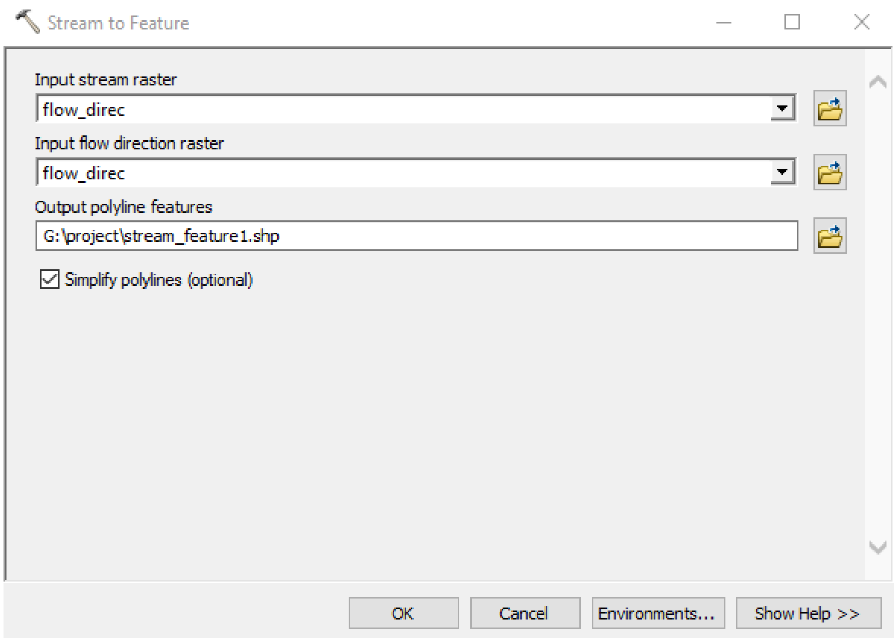


Figure 15: Creating polyline feature of stream raster using stream to feature tool

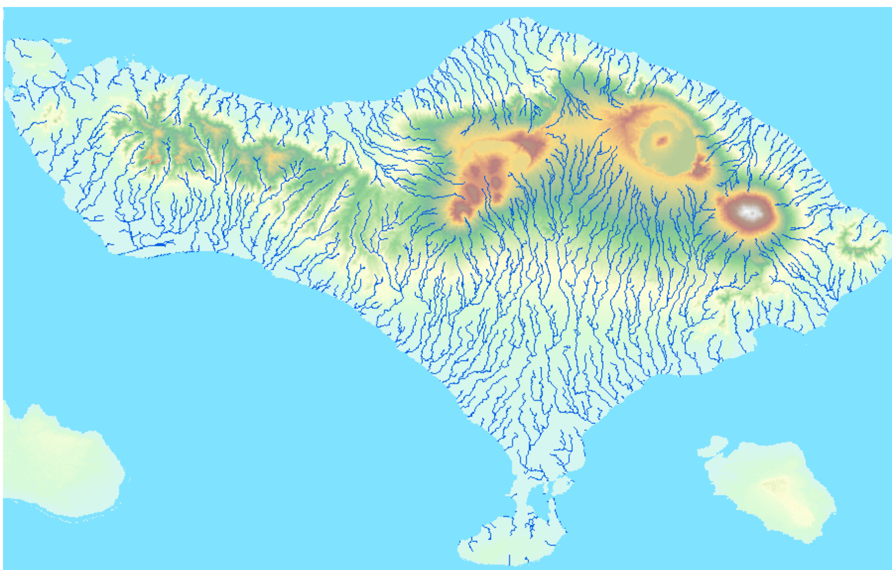


Figure 16: water stream polyline created from flow accumulation raster

Populated Place

This part contains creating a buffer zone from Mt. Agung, loading populated places data, clipping data to buffer zone.

1. Mt. Agung

   - Go To XY & Convert Graphics to Features

   - Located a point at 115.507, -8.343 Decimal Degrees as a Mt. Agung. And converted the graphic data to feature data.

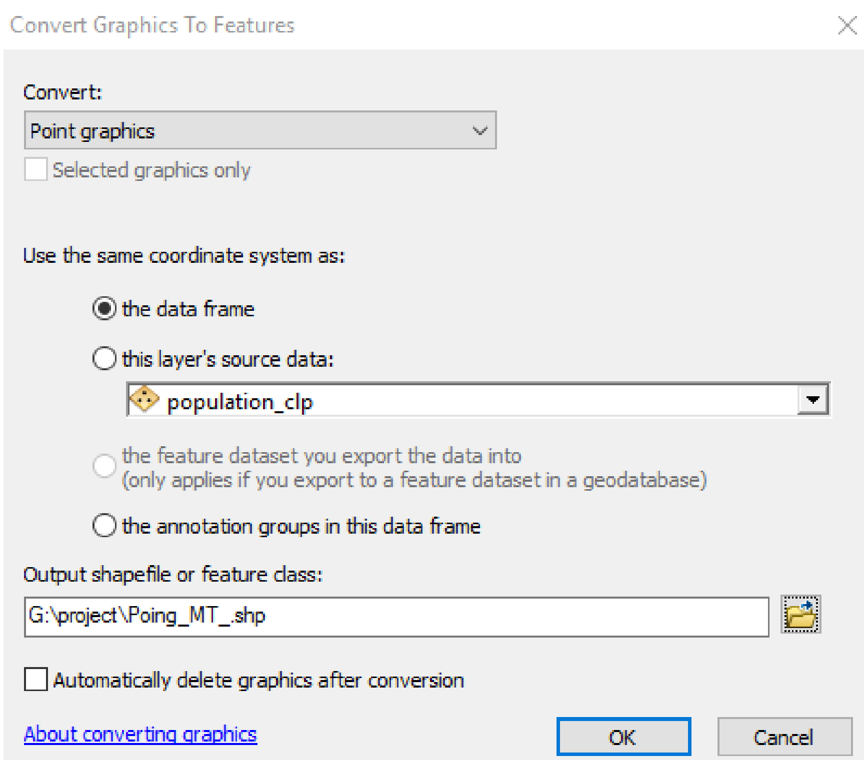


Figure 17: Converting graphic data of Mt. Agung into feature data

2. Create Buffer Zone

   - Buffer (Analysis – Proximity)

   - Created 2 buffer zone. 12km buffer zone is created because the Authorities imposed 12km exclusion zone and issued highest level of alert following hundreds of tremors and signs of magma rising to surface. 60km buffer zone is created because 20~30cm of volcanic ash rained in some parts of Bali that were 70km away from Mt. Agung in year 1964. However, experts expect this volcano eruption to be smaller than the one in year 1964. Therefore, the distance was reduced to 60km rather than 70km. (http://www.news.com.au/travel/travel-advice/health-safety/everything-you-need-to-know-about-the-volcanic-ash-cloud/news-story/9e57189b4bcccbc8f54886f470719f9e)

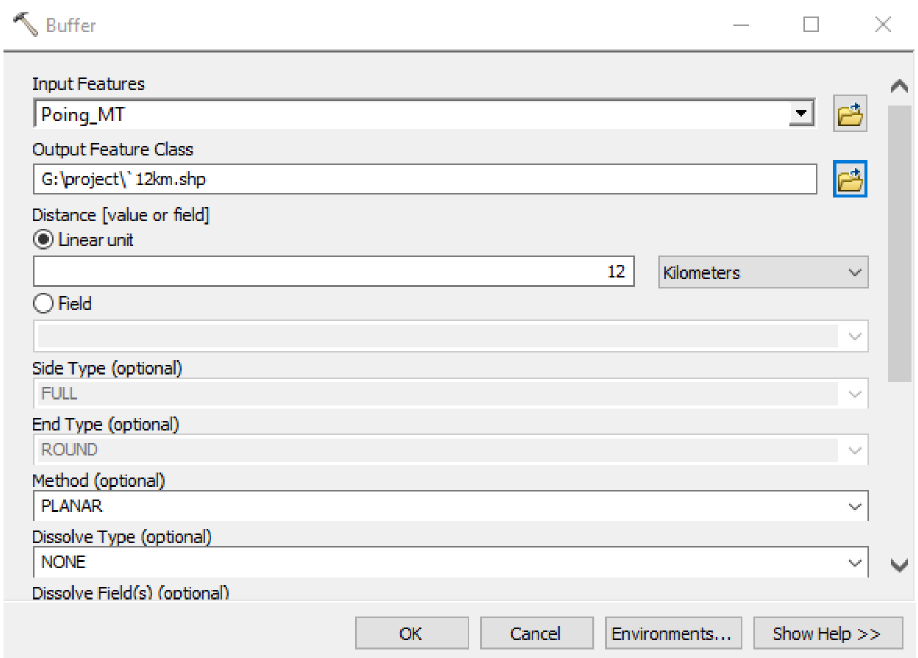


Figure 18: Creating 12km Buffer zone from Mt. Agung

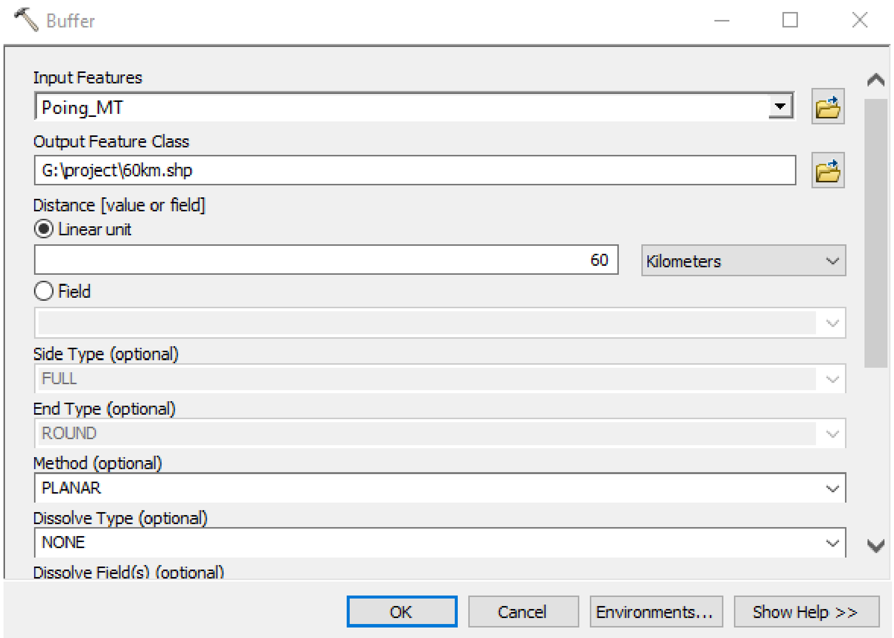


Figure 19: Creating 60km Buffer zone from Mt. Agung

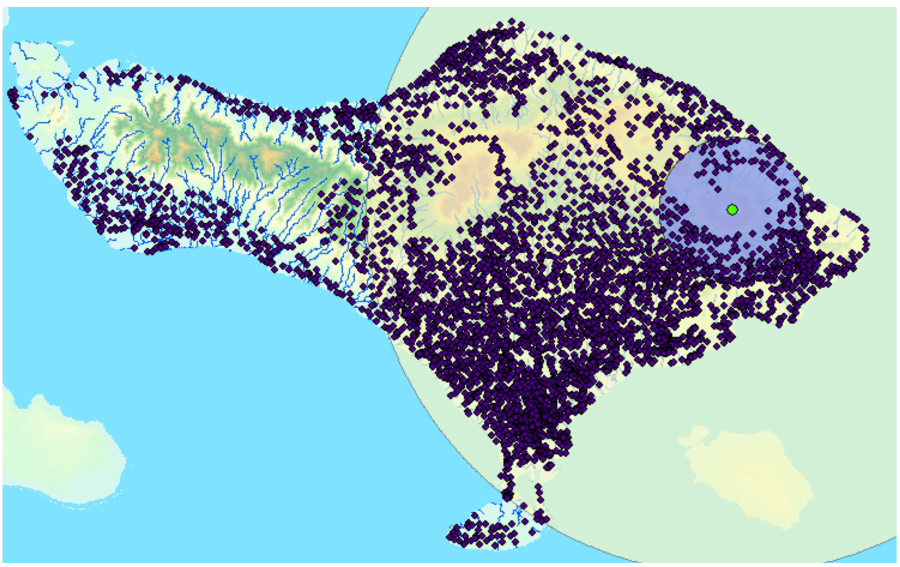


Figure 20: Display of 12km and 60km buffer zone from Mt. Agung

3. Populated Places

- Initial text file data contained 300858 populated places in Indonesia.

- Using excel, all the populated places in Indonesia was brought to ArcMap and the data was clipped to Bali Island polygon.

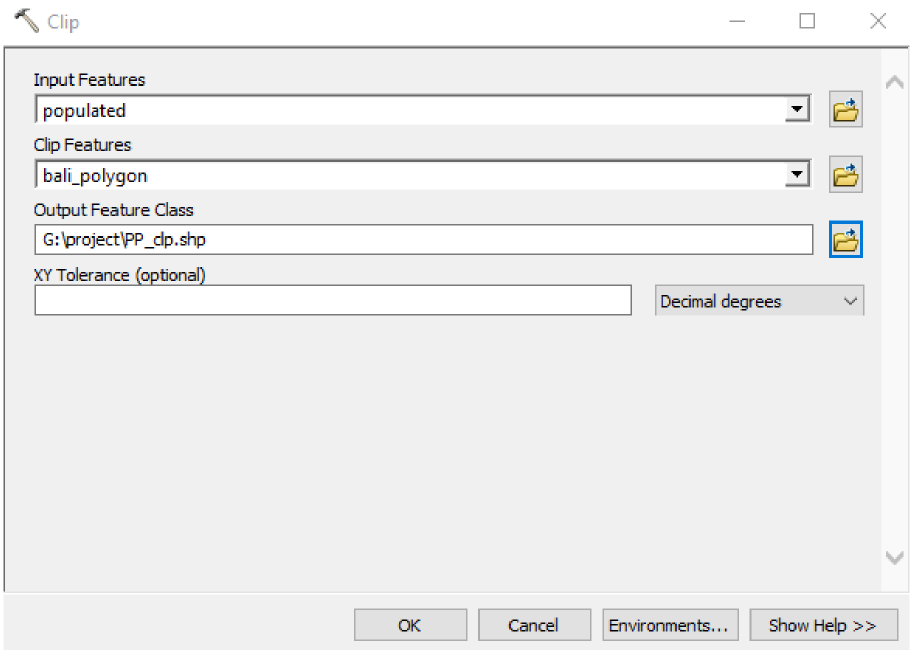


Figure 21: Clipping populated places in Indonesia to Bali Island polygon

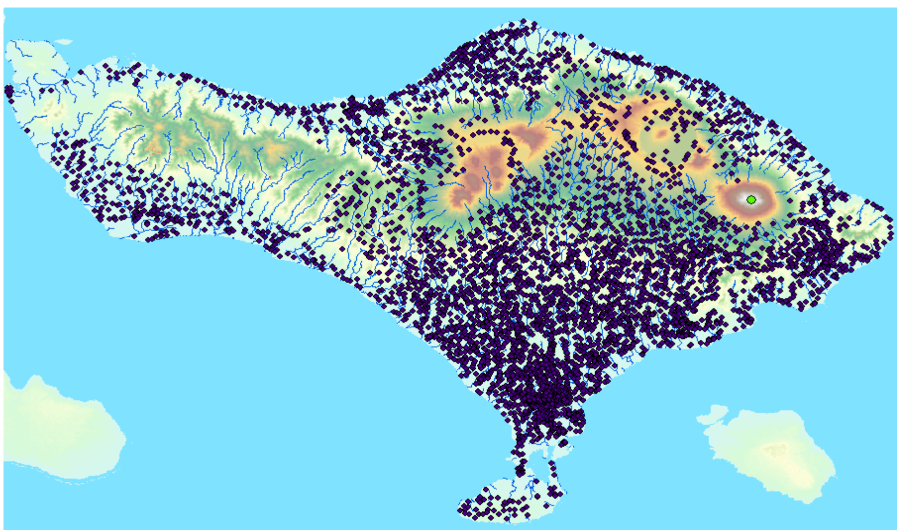


Figure 22: Populated Places in Bali Island

4. Eliminate Duplicates

- Delete Identical (Data Management – General)

- Original file contained many identical points. Using Military Grid Reference System value, where different point cannot share same value, duplicate points were deleted. The number of points were reduced to 4590.

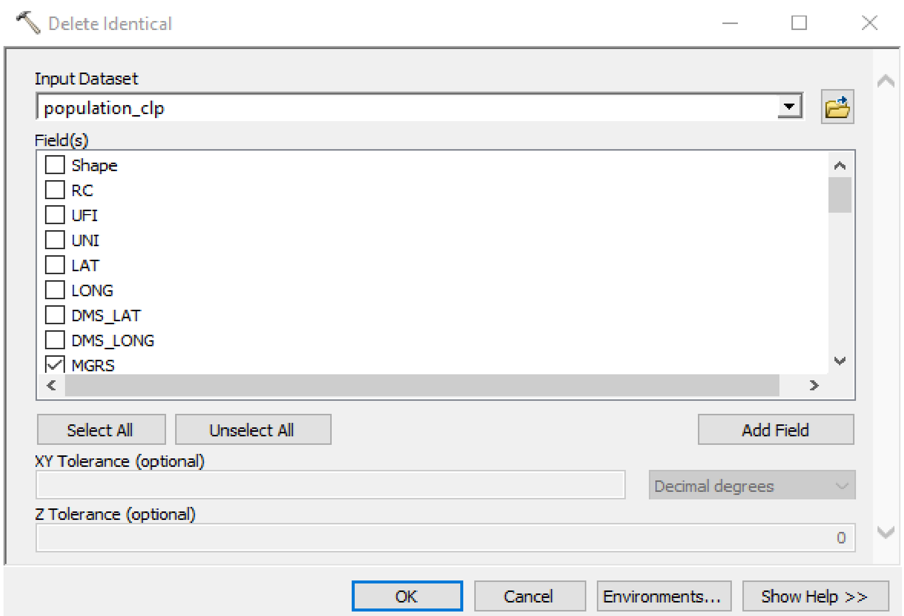


Figure 23: Deleting same points

5. Populated places in 12km buffer zone and 60km buffer zone

- Clip (Analysis – Extract)

- The number of populated places in 12km buffer zone was 250.

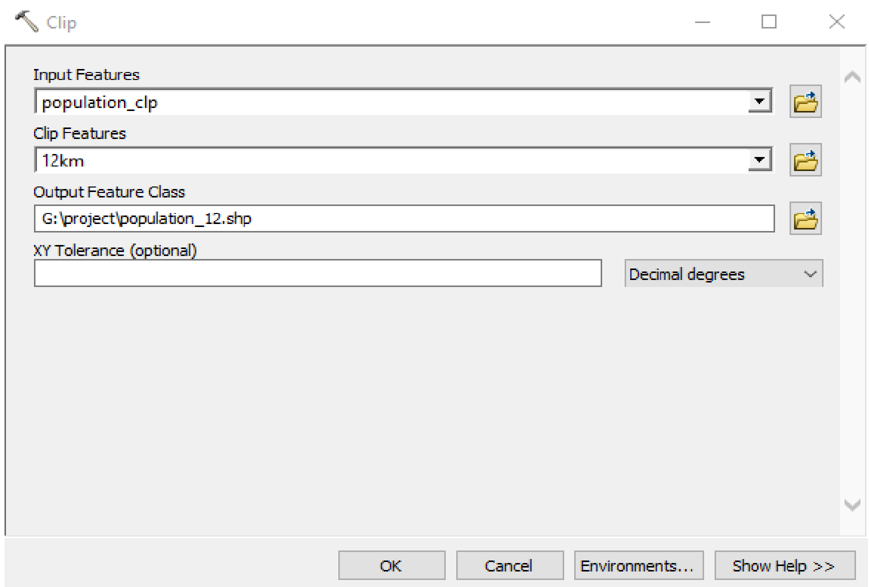


Figure 24: Clipping populated places to 12km buffer zone

- The number of populated places in 60km buffer zone was 4036.

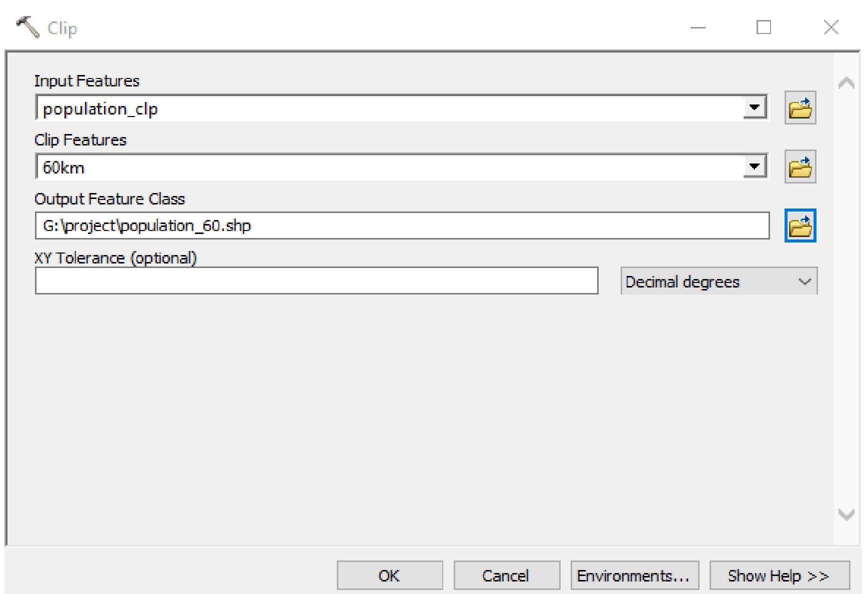


Figure 25: Clipping populated places to 60km buffer zone

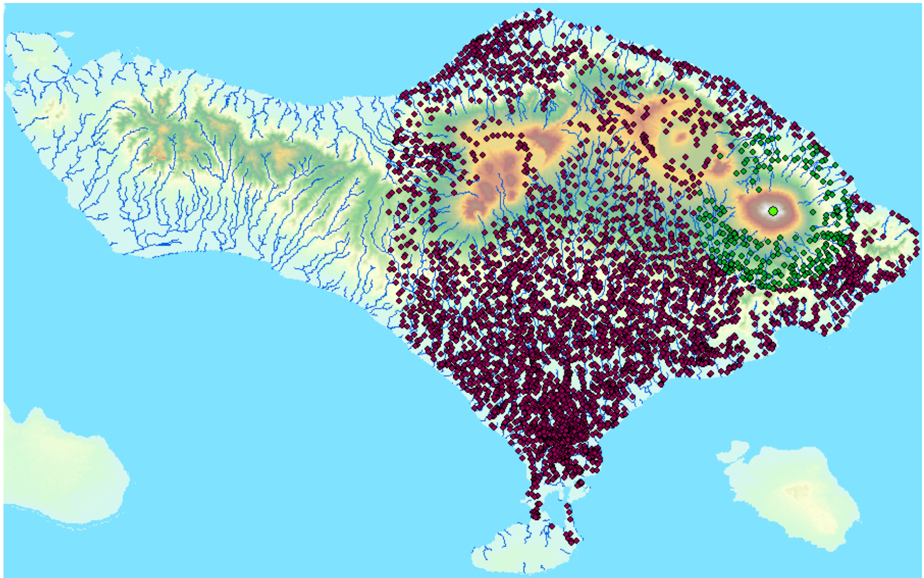


Figure 26: Display of populated places in 12km buffer zone (green) and 60km buffer zone (red)

6. Polluted Water Stream

- Select By Location

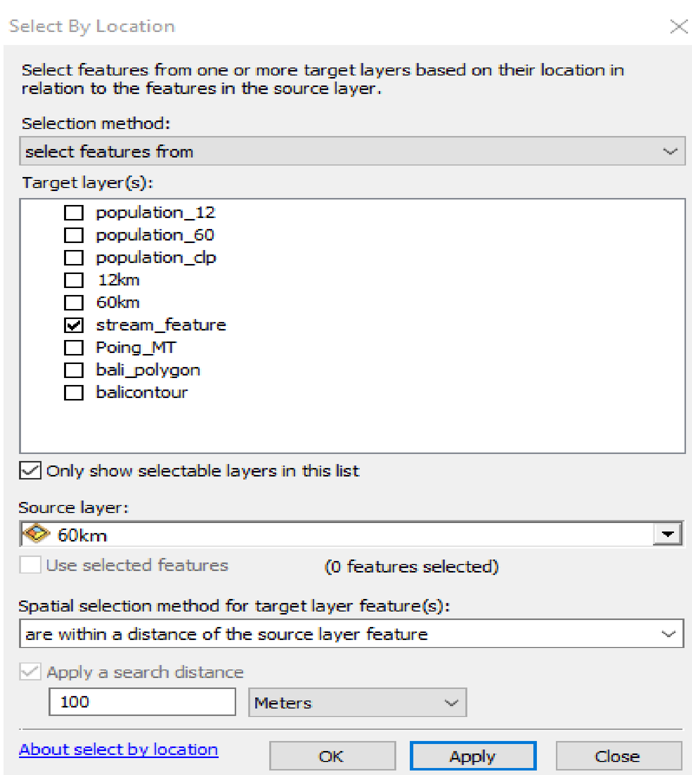


Figure 27: Selecting water streams that are within 60100 meters from Mt. Agung

Conclusion

Indonesia's less developed water sanitization system and high ratio of people who uses open water tank in Bali Island tells that heavy ash falls and magmas are not the only threat to the people living in a small village near Mt. Agung.

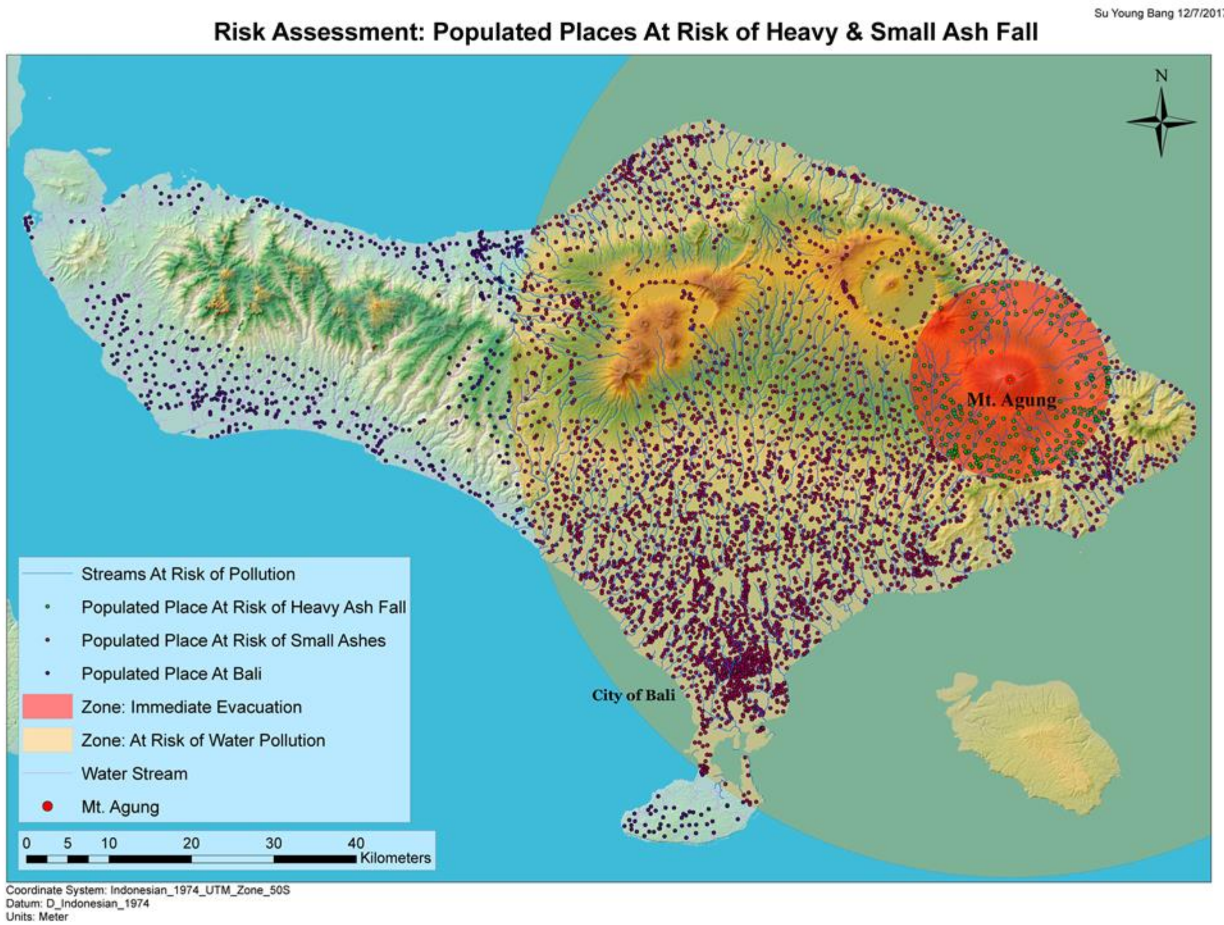
Due to lack of sufficient data of actual number of people living in each village, accurate number of population who are at risk of heavy ash fall and exposed to contaminated water was not able to be calculated. However, approximate number of populated places that are at risk are listed below. (Table 2)

# of Populated Places in Bali Island	4590
# of Populated Places within 12km from Mt. Agung	250
# of Populated Places within 60km from Mt. Agung	4036

Table 2: Result of number of Populated Places

There is no doubt that people living within 12km from Mt. Agung should be immediately evacuated and draw more attention, however, the people living 50~70km should also be immediately informed and be award of the fact that they are also at risk from ashes blowing from the volcano end up contaminating their water resources.

Final Map


Su Young Bang 12/7/2017
Risk Assessment: Populated Places At Risk of Heavy & Small Ash Fall
N
Mt. Agung
City of Bali
Streams At Risk of Pollution
Populated Place At Risk of Heavy Ash Fall
Populated Place At Risk of Small Ashes
Populated Place At Bali
Zone: Immediate Evacuation
Zone: At Risk of Water Pollution
Water Stream
Mt. Agung
0 5 10 20 30 40
Kilometers
Coordinate System: Indonesian_1974_UTM_Zone_50S
Datum: D_Indonesian_1974
Units: Meter

References

1. Stewart, C., Johnston, D., Leonard, G., Horwell, C., Thordarson, T., & Cronin, S. (2006). Contamination of water supplies by volcanic ashfall: A literature review and simple impact modelling. Journal of Volcanology and Geothermal Research, 158(3-4), 296-306.
2. Ayris, P. M., and Delmelle, P. (2012) The immediate environmental effects of tephra emission. Bulletin of Volcanology, 74(9), 1905-1936
3. Cronin, S. J., Sharp, D. S. (2002). Environmental impacts on health from continuous volcanic activity at Yasur (Tanna) and Ambrym, Vanuatu. International Journal of Environmental Health Research, 12 (2), 109-123.

Citing Internet Sources

1. Help. (n.d.). Retrieved December 07, 2017, from http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-flow-direction-works.htm
2. Program, V. H. (n.d.). Retrieved December 07, 2017, from https://volcanoes.usgs.gov/volcanic_ash/water_supply.html
3. Biz-Gis. (n.d.). Retrieved December 07, 2017, from http://www.biz-gis.com/index.php?document_srl=12498&mid=paper