DELINEATION OF MAJOR DRAINAGE BASINS OF MAURITIUS

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ABSTRACT

It is important to delineate the boundaries of drainage basins and watersheds. Mauritius is currently known to be divided into 25 main catchment areas or river basins, each corresponding to a main river, 22 minor ones with coastal zones drained by streams or rivulets. A consistent database of river networks and their catchments can be useful for a wide range of applications, including mapping, monitoring and modelling activities, offering support to a variety of hydrological, agricultural, ecosystem and climate models. In this paper we report the delineation of drainage basins using digital data for drainage basins of Mauritius. The digital method requires digital data of contour lines of elevation and river networks as well as a 3D grid of elevation and a vector map of slope. The digital method yields more accurate results than the conventional method based on paper maps. Based on the digital data (1:100000 and 1:25000 scales), 70 rivers were identified and classified as the major rivers for the island. Our studies also yielded 3 additional catchments located inland, where water drains to pits/lakes. Difficulties were encountered in delineating some basins either due to poor spatial resolution when dealing with flat terrain and/or due to unavailability of data (such as discontinuous river networks).

Keywords: Basins, Catchments, GIS, Delineation, Watersheds

INTRODUCTION

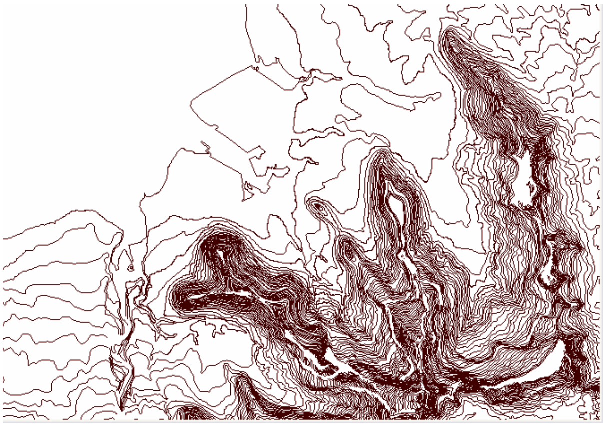
The availability of digital data on rivers and lakes and their drainage basins (catchments), including information on the characteristics of these entities, is important for the analysis of environmental pressures and their impact on water resources. As such pressures on landscapes increase, land managers are continually looking for new methods of managing and monitoring landscape "health." In order to analyse the properties of a landscape, indeed, in order to monitor any object, it is necessary to break that object into manageable units. In the past, landscapes have been managed on an ownership basis. However, experience has shown that the old methods of land management do not make *biological* sense. Most biological processes do not stop at an ownership boundary. Animal species migrate across private and public lands (as long as they can get across the fences). Contiguous forested lands may traverse much ownership. Streams flow across different ownerships and political boundaries. A logical unit of land management is the watershed. The American Heritage Dictionary defines watersheds as: "The region draining into a river, river system, or body of water." Watersheds are always physically delineated by the area upstream from a given outlet point. This generally means that for a stream network, the contributing area goes upstream to stop at a ridgeline. Ridgelines separate watersheds from each other.

Delineation of the boundaries of drainage basins and watersheds is not only important, but it must be also a methodically easy process, where the watersheds for any dam or station can be delineated systematically as the user wishes. Traditional method of delineation of these areas involves a paper map of contours lines of elevation at a suitable topographical scale (2D map of elevation) and river networks. The digital method reported in this paper involves, in addition to the previous two *but now in digital format*, a 3D grid of elevation and a vector map of slope. It is therefore obvious as to why the digital method will yield more accurate results (given that there are more inputs). In the era of the information age, manual delineation of drainage basins using digital data can work side by side with the systematic delineation of drainage basins using GIS software. So, any user planning to delineate watersheds or drainage basins can adopt both methods. In this work, the method of manually delineating drainage basins using digital data has been applied to the island of Mauritius for identifying the major drainage basins.

METHODOLOGY

It is important to define major and minor drainage basins as different definitions are currently in use in the literature. A major drainage basin will be defined here to enclose a complete stand-alone major river and all its tributaries and a minor catchment is one that encloses a minor river with its tributaries. When ridges between major drainage basins have been delineated then the watershed delineation of sub-catchments can be performed. Based on the digital data of rivers from the Ministry of Housing and Land that were produced from 1:100000 and 1:25000 map series, 70 rivers were identified from the 1:100000 map series and these were classified as the major rivers for the island (**Figure 1**). Three additional catchments forming inland water catchments, where water drained to pits and formed lakes, were also identified in this work.

Figure 1 Part of Port Louis on a 1:25000 scale with 10m contours



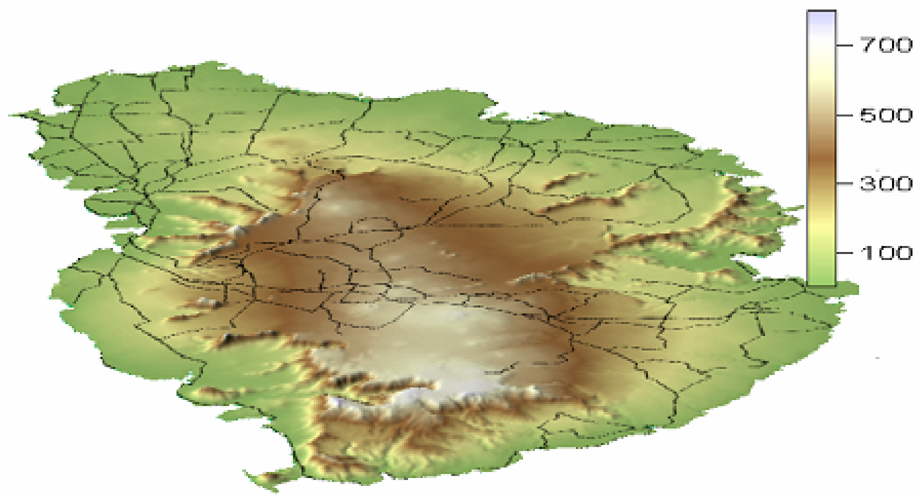
A tangential plane measures the rate of change at a point on a 3D surface at that point; the rate of change thus has a magnitude (called gradient) and a direction (called aspect); the two components measure one property of the surface called slope (Chrisman, 1996). Cayley (1859) provided early mathematical insights into the structure of surfaces. Warntz (1966) applied Cayley's structure to geographic (topographic) surfaces and whose terminology we used. At most places on the 3D surface, slopes are parallel, but at others the slopes converge and diverge (**Figure 2**).

Figure 2 Topology of a surface, labelled with Warntz's (1966) terminology

At the tops of hills (peaks), slopes diverge in every direction. As the slopes continue downhill, they eventually meet the slopes from another hill, causing convergence. Warntz (1966) termed this a course, because in a water-eroded landscape, the streams (watercourses) would end up following this line. Similarly, from peak to peak, there is a line (a ridge) where the slopes diverge. The network of ridges divides the region into a set of areas, the watersheds. The two networks-ridges around watersheds and courses around hills-constitute the topology of the topography. Therefore, the topology of a 3D surface is defined by the local behaviour of the surface-patterns of convergence and divergence. Gravity-powered flow of water (such as rainfall surface runoff) over the 3D surface is strongly controlled by this structure. Water will remain contained by the watershed in which it falls. Ridges create drainage divides that separate river systems from each other. As water flows over the surface, it will converge into the course lines and eventually forms streams. At the lower ends of the flow, the water will fill up any pits, forming lakes.

For Mauritius, the projection of the digital data is Lambert Conical Orthomorphic and the spheroid is Clarke 1880. The false coordinates of origin, Le Pouce, are 1000000m East and 1000000m North. Our 3D grid of elevation and rivers and road networks are based on this false origin and accordingly the x and y coordinates are in meters. Elevation increments in step of 10m (obtained from 1:25000 digital data) from 0 m representing the coastline to reach the highest elevation of 820 m. Digital data used were 10m interval contours, roads and rivers networks. Software used were AutoCAD R14® and Surfer8®, Global Mapper and ArcGIS 8.3. More than 1.2 million of xyz coordinates were software-extracted to form the 10m contours map. These data points were imported in Surfer8® where the geostatistic method Kriging was used to generate a 75X75 m grid for the island. A 3D surface plot was then made from the grid (**Figure 3**).

Figure 3 3D surface plot of Mauritius



RESULTS & DISCUSSIONS

The resulted hydrological basins delineated were classified as physical (laboratory) models, based purely on the hydrological processes occurring on the surface (Barrett and Curtis, 1992). From the 3D surface, the vector maps showing direction and magnitude of slope at points on the 3D surface were generated. The grid data for the island was used to generate the vector map with an overlay of the river networks on the 3D surface. It was possible to delineate the ridgelines between major drainage basins manually by using a digitiser function. The ridgelines delineating the major drainage basins were digitised and saved as CAD polylines consisting of x and y coordinates. The drainage boundaries can be edited and added to the map. The arrow symbol points in the "downhill" direction and the length of the arrow depends on the magnitude, or steepness, of the slope. This is illustrated in Figure 4 for regions where the delineation for the catchments is shown on the 3D surface with rivers, contours and road overlay.

Figure 4a: Region of Grand Sable-Petit Sable showing 3D surface with overlay of vectors, 10m contours, rivers, roads and drainage basins boundaries. The image on the right shows the drainage basins delineated and added to the map (in blue)

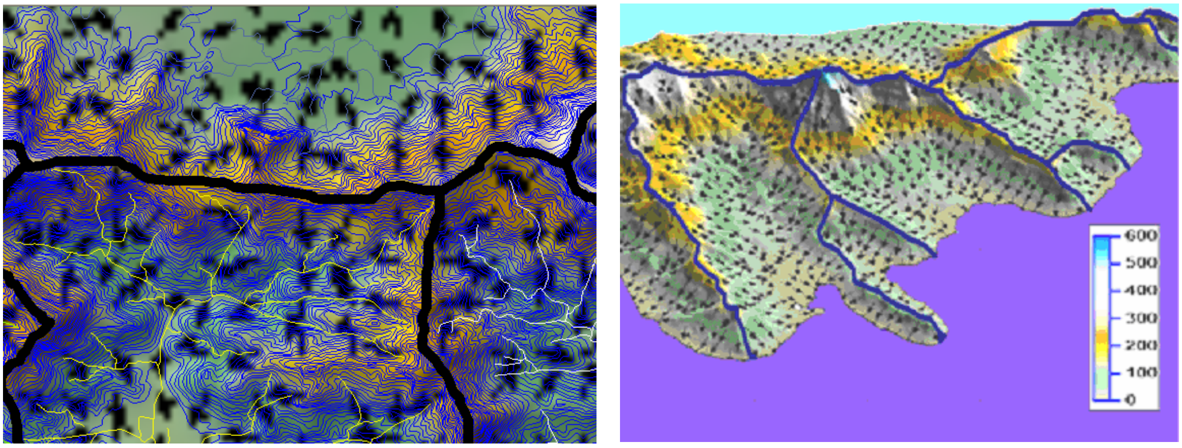
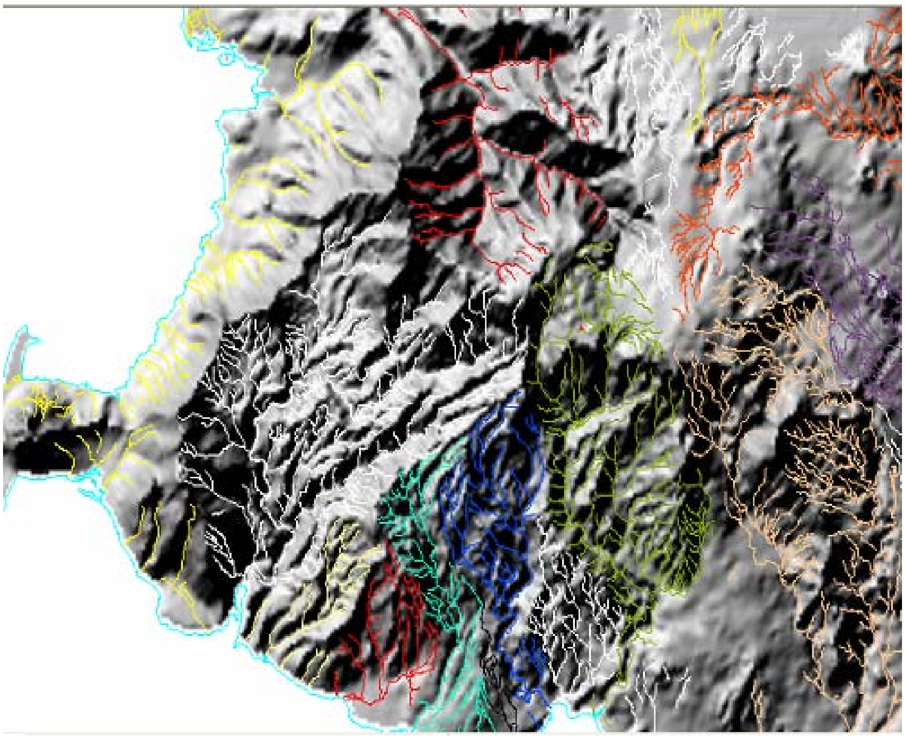


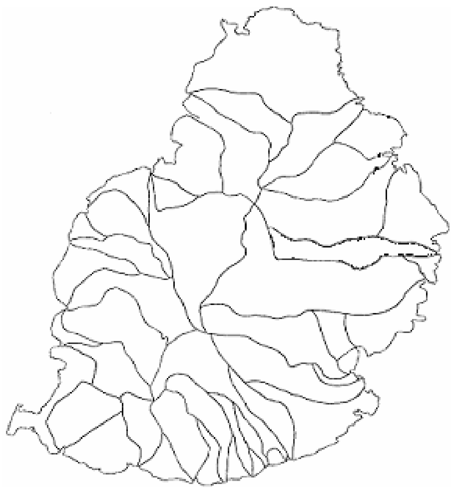
Figure 4b River networks overlaid on Shaded Relief Map



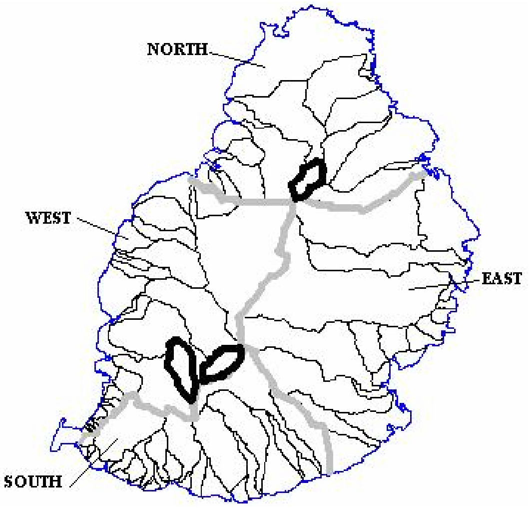
This simple procedure permitted the boundaries of the 73 major drainage basins (shown in **Figure 5**) to be delineated. For coding purposes of the catchments areas, the country was divided into five regions namely: North, East, West, South and Inland (**Figure 5**); the grey lines show the boundaries between the different regions, the normal black lines are the boundaries for the catchments and the bold black lines are the boundaries for the inland catchments. The procedure adopted for labelling the catchments and the full listing of the major rivers and their codes, their catchments, sizes and whether they have been delineated or not will be published elsewhere. The three inland catchments are Mare-aux-Vacoas basin, Mare-Longue basin, and La Nicolière.

Figure 5 Major drainage basins boundaries of Mauritius

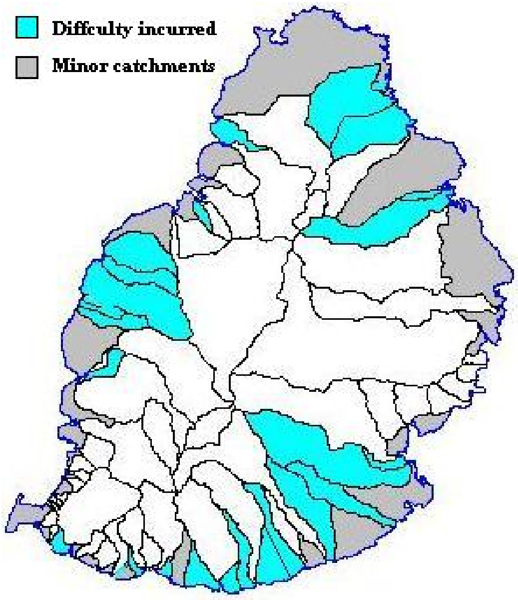
(a) Old catchments (Hydrology Data Book 92-95)



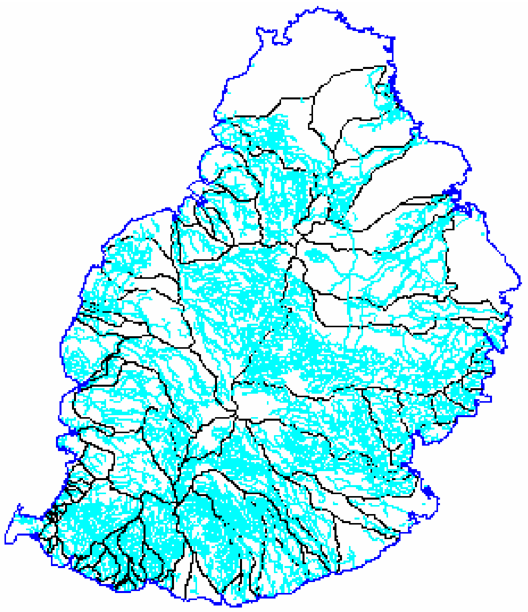
(b) New catchments derived from this work



(c) Major drainage boundaries with all river networks (Cyan lines)



(d) Regions for which difficulties were encountered



Difficulties were encountered in delineating 28 of the 73 major catchments either due to the poor spatial resolution when dealing with flat terrains and/or due to unavailability of data (such as discontinuous river networks). In flat terrain, it was difficult to find a direction for the ridgelines since the vectors did neither converge nor diverge. Therefore, in these areas no ridges were identified by the vectors alones and thus a combination of vectors and contour lines had to be used. This difficulty affected 12% of the catchments delineated (see **Table 1**). Two of the twenty-eight catchments that poses problem was due to lack of accurate data. The presence of imprecise data (such as man-made irrigation channels) in the river network made it difficult to find reasonable and precise path for ridgelines. It was decided not to delete polylines that appeared as irrigation channels because some other polylines appeared to be irrigation channels as well as rivers. In this case the data was left as it was. A future field survey will be set up to check for these imprecise and inaccurate data. Moreover, the latter coupled with the poor spatial resolution when dealing with flat terrains brought about the greatest problem in delineating the boundaries for these catchments. This combination affected 26% of the 73 drainage basins delineated (see **Table 1**). Data of greater precision and accuracy is therefore essential to delineate all the catchments of the island. The 2m contours map actually in preparation by the Ministry of Housings and Lands for certain regions of the island will be useful for this purpose.

Table 1 Delineation status using 10m contours

Regions	**North**	**West**	**South**	**East**	**Inland**	**TOTAL**
No. of major catchments	13	21	23	13	3	**73**
No. of major catchments delineated	4	13	15	10	3	**45**
Problems encountered due to						
Poor spatial resolution of flat terrains	5	0	4	0	0	**9**
Inaccurate data	0	0	2	0	0	**2**
Poor spatial resolution of flat terrains and inaccurate data	**4**	**8**	**2**	**3**	**0**	**17**

CONCLUSION

Paper maps are not the only sources for the manual delineation of drainage basins. Digital data can also be used for this purpose. In this paper a simple methodology has been developed for the purpose. The method has proved to yield more accurate results than the method for paper maps, because the method incorporate the methods of paper maps in addition to using digital data in 3D and vector maps of slope. Our research however revealed two main problems in delineating drainage basins manually using digital data; the poor spatial resolution when handling flat terrains and imprecise and inaccurate data (such as discontinuous river networks) or a combination thereof. Thus, even though the 73 catchments have been successfully delineated, the degree of accuracy for 28 catchments (out of 73) is low. A mosaic of grids made from 10m contours and 2 m contours (for flat terrains) is currently being made together with field surveys to check for discontinuities present in river networks.

ACKNOWLEDGEMENTS

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