

Computation of D8 Flow Line at Ron Phibun Area, Nakhon Si Thammarat, Thailand

O. Boonklong, M. Jaroensutasinee, and K. Jaroensutasinee

Abstract—A flow line computational technique based on the D8 method using *Mathematica* was developed. The technique was applied to Ron Phibun area, Nakhon Si Thammarat Province. This area is highly contaminated with arsenic 3 and 5. It was found that the technique using *Mathematica* can produce similar results to those obtained from GRASS v 5.0.2.

Keywords—Arsenic contamination, flow line, D8 method, Ron Phibun.

I. INTRODUCTION

THERE are arsenic 3 and 5 contamination which are major cause of skin cancer in Ron Phibun district, Nakhon Si Thammarat [1]. Ron Phibun District, Nakhon Si Thammarat Province was shown in the geographical map at the ratio of 1:50,000 by the Military Survey Department, at the latitude $8^{\circ}00' - 8^{\circ}20'$ N and longitude $99^{\circ}45' - 100^{\circ}3'$ E covers 691.06 km² [2]. Ron Phibun District has 7 Sub-district and Ron Phibun District Sub-district has 16 villages. This is the Sub-district found with the most arsenic in Thailand.

Digital elevation models (DEMs) are readily available data sets that represent the elevation of the earth's surface at discrete points in a regular, rectangular grid. Flow directions based on DEMs are needed in hydrology to determine the paths of water and contaminant movement. Two important distributed quantities that depend on flow directions are the upslope area and specific catchment area.

Grid DEMs consist of a matrix data structure with the topographic elevation of each pixel stored in a matrix node. Grid DEMs are distinct from other DEMs representations such as triangular irregular network and contour based data storage structures. Grid DEMs are readily available and simple to use and hence have seen widespread application to the analysis of hydrologic problems [3]. However, they suffer from some drawbacks that arise from their grided nature. The earliest and simplest method for specifying flow directions is to assign flow from each pixel to one of its eight neighbors, either adjacent or diagonally, in the direction with steepest

downward slope. This method, designated D8 (8 flow directions), was introduced by O'Callaghan and Mark [4] and has been widely used [e.g. 5-8].

In this paper, a new method for calculating flow direction area is presented. We develop a new computational technique to compute theoretical flow line based on D8 method to show arsenic 3 and 5 contaminated in water and follow down river to Ron Phibun basin. Results are used to compare the new method with existing methods.

II. METHODS

In this study, the single flow direction is used representing a continuous quantity between 0 and 2π . This determined the direction of the steepest downward slope on the eight triangular facets formed in a 3×3 pixel window centered on the pixel of interest. The use of triangular facets avoided the approximation involved in fitting a plane and the influence of higher neighbors on down were slope flow. Where the direction did not follow one of the cardinal (i.e. 0, $\pi/2$, π , and $3\pi/2$) or diagonal (i.e. $\pi/4$, $3\pi/4$, $5\pi/4$, and $7\pi/4$) directions, the upslope area was calculated by apportioning the flow from a pixel between the two down slope pixels according to how close the flow angle was to the direct angle to that pixel center. Since only a single number was needed for each pixel to represent the flow field, computer storage was simple and highly efficient.

In this study, *Mathematica* was used to create a DEM which represented the surface topography. The packages of *Mathematica* were used to create a DEM that construct a surface over these points, which were built into triangles by means of a Delaney triangulation. This is an extremely useful way to build a surface since it can do without the data being organized in some special way.

Digitization of the iso-elevation lines (contours) from the topographic maps is required in order to generate a digital elevation model (DEM) for the basin in Ron Phibun district in Nakhon Si Thammarat.

The three packages which were used to create a Digital elevation model were as follows:

```
Need["ExtendGraphics`SurfaceGraphics3D`"]
Need["ExtendGraphics`Delaunay`"]
Need["ExtendGraphics`TriangularInterpolate`"]
```

This is the basis of the package `ExtendGraphics`TriangularInterpolation``, which makes a linear interpolation of an irregular three-dimensional data set. `TrianglePlot[]` will take a list of points, each point of the form

Manuscript received November 30, 2006. This work was supported in part by NRCT, and Complex System research unit, the Institute of Research and Development, Walailak University.

O. Boonklong is with the Faculty of Science, Nakhon Si Thammarat Rajabhat University, Nakhon Si Thammarat, 80000 Thailand. (e-mail: bornanong@hotmail.com).

M. Jaroensutasinee is with the School of Science, Walailak University, Thasala, Nakhon Si Thammarat, 80161 Thailand. (e-mail: jmullica@wu.ac.th).

K. Jaroensutasinee is with the School of Science, Walailak University, Thasala, Nakhon Si Thammarat, 80161 Thailand. (e-mail: krisanadej@gmail.com).

{x, y} and it will plot the triangles which form the Delaunay triangulation. In order to calculate the Delaunay triangulation rapidly a MathLink binary is used. This binary is loaded automatically when the package. ExtendGraphics`Delaunay` is loaded.

GRASS (the Geographic Resources Analysis Support System) is a software raster and vector-based GIS (Geographic Information System), image processing system, graphics production system, and spatial modeling system. GRASS contains many modules for raster data manipulation, vector data manipulation, rendering images on the monitor or paper, multispectral image processing, point data management and general data management. It also has tools for interfacing with digitizers, scanners. GRASS also now has an improved graphical user interface based on Tcl/Tk. Additionally a new multiple attributes/multiple dimensions sites format is implemented, a new three dimensional raster format grid3.

Two new visualization interfaces in the form of Tcl/Tk GRASS and Nviz. Nviz allows users to realistically render multiple surfaces in 3D space, drape GRASS vector files over surfaces, and display sites files either on surfaces or as 3D points. Nviz is meant to be used as a tool for viewing data surfaces in three dimensions using GRASS. Nviz uses raster files as "elevation" and also as attributes of the surfaces (such as color, transparency, etc.). While a true elevation data file used as elevation will produce the most realistic surfaces, users are encouraged to be creative in selecting other types of data to be represented by the vertical dimension. Most continuous (as opposed to discrete) data types will result in a visualization that makes sense. While developing the program, we used chemical concentrations as the elevation file with good visual results [9].

Lin et al. [10] proposed that a watershed can be described with respect to the surface runoff as being the locus of points within an area where runoff produced inside the area perimeter will move into a single watershed outlet. Information about the flow direction is recorded as an attribute of each spatial unit within the watershed to represent the flow direction. The algorithm used to compute flow direction is SFD. SFD is the single-flow direction (SFD) model which defines the flow direction to be the direction of the steepest downslope neighbor in Fig. 1 and Fig. 2. The most interesting method that has been studied is Deterministic 8 method.

D8 method is the classical single flow direction method. D8 method simply adds the accumulated area of every cell to the neighbor cell with the steepest gradient as presented by [4]. This neighbor is called the cell downstream of the center cell. D8 method remains the most frequently used method for determining contributing areas, although it cannot model the flow dispersion.

3	2	4
7	5 ↓	8
7	1	9

Fig. 1 Example of SFD by Arge et al. (2003)

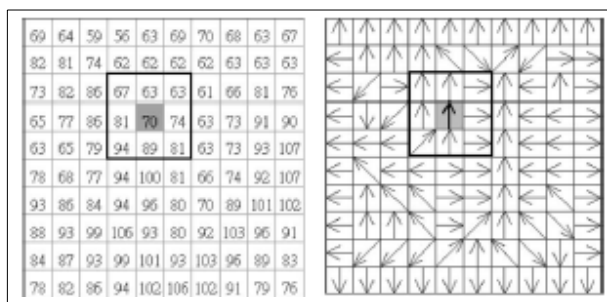


Fig. 2 Provides an example of a DEM and the flow directions are indicated with arrows [9]

In addition, the only algorithm, that has one single flow direction matrix, is D8 method. The flow direction matrix of the D8 method is (simply spoken) the direction to the lowest neighbor cell. Besides, the algorithm used to compute flow direction and the resolution or scale of grid data affects the computation of the index. The elevation data used in computing topographic indices are specified either on a regular grid or at irregularly spaced intervals along contours. The commonly used single flow path method assumes that the contour length is given by the length or resolution of a grid cell. All area accumulated upstream of a given grid cell drain to only one of eight neighboring grid cells, that with the steepest angle descent. This D8 method was developed initially by [4] and has been widely used [5] The method has been termed the D8 method. Noting problems with the traditional maximum descent slope method, Fairfield & Leymaire [11] presented new procedures to determine flow-line direction that give more accurate representations of slope and aspect. They showed that their slope-weighted, stochastic version of the D8 method provided a more realistic representation of flowpath networks.

In summary, Nviz is a GRASS module which allows users to realistically render multiple surfaces in a 3D space, optionally using thematic coloring, draping GRASS vector files over the surfaces, and displaying GRASS site files either draped on the surfaces or as 3D point locations. The Nviz code is part of the standard GRASS source code.

In this paper, a method based on D8 algorithm for calculating flow direction at Ron Phibun area using *Mathematica* is presented. Comparison of the results with GRASS v 5.0.2 software has been discussed.

III. RESULTS AND DISCUSSION

In this study, the single flow direction is used representing a continuous quantity between 0 and 2π . This determined the direction of the steepest downward slope on the eight triangular facets formed in a 3×3 pixel window centered on the pixel of interest. The use of triangular facets avoided the approximation involved in fitting a plane and the influence of higher neighbors on down were slope flow. Where the direction did not follow one of the cardinal (i.e. 0, $\pi/2$, π , and $3\pi/2$) or diagonal (i.e. $\pi/4$, $3\pi/4$, $5\pi/4$, and $7\pi/4$) directions, the upslope area was calculated by apportioning the flow from a pixel between the two down slope pixels according to how close the flow angle was to the direct angle to that pixel center. Since only a single number was needed for each pixel to represent the flow field, computer storage was simple and highly efficient. In this paper, a method based on D8 algorithm for calculating flow direction at Ron Phibun area using *Mathematica* is presented. Comparison of the results with GRASS v 5.0.2 software has been discussed.

This section gives examples of results from our method, which are based on D8 method and from GRASS v 5.0.2 method. The same DEM data were used for both methods. Fig. 3 shows all points in the grid of Ron Phibun area from both methods. Fig. 4 shows that DEMs are needed in hydrology to determine the paths of water. Fig. 5 shows flow directions based on DEMs.

IV. CONCLUSION

This work used Delaunay triangulation. It will turn a set of points into a surface composed entirely of triangles; then we merely need to solve the contour map problem for each triangle in the graph, which is fairly straight forward. We could then pass it through a curve routine to smooth out the straight lines. A nice general way to make contour maps from a set of any points (i.e. you do not need a regular grid) is to calculate the Delaunay triangulation from our set of points, and then doing the contour map is pretty easy. In this work, the Delaunay triangulation created the DEM in order to represent geography of Amphoe Ron Phibun.

The D 8 method is a simple method which can be used to simulate flow directions. The method is the D8 algorithm which assigned a flow direction to the cell in the center by considering the direction of the largest drop in elevation. It can generate stream networks and watershed delineation. Watershed was created based on the DEM, that represented the direction of water flow. We studied computational watershed of Amphoe Ron Phibun.

ACKNOWLEDGMENTS

We thank Dr. Ely Kerman for comments on previous versions of this manuscript. We thank Walailak University for financial supports to this work under Pre-doctoral fellowship and the Complex System Key University Research Unit of Excellence (CX-KURUE) and NRCT grant to O. Boonklong.

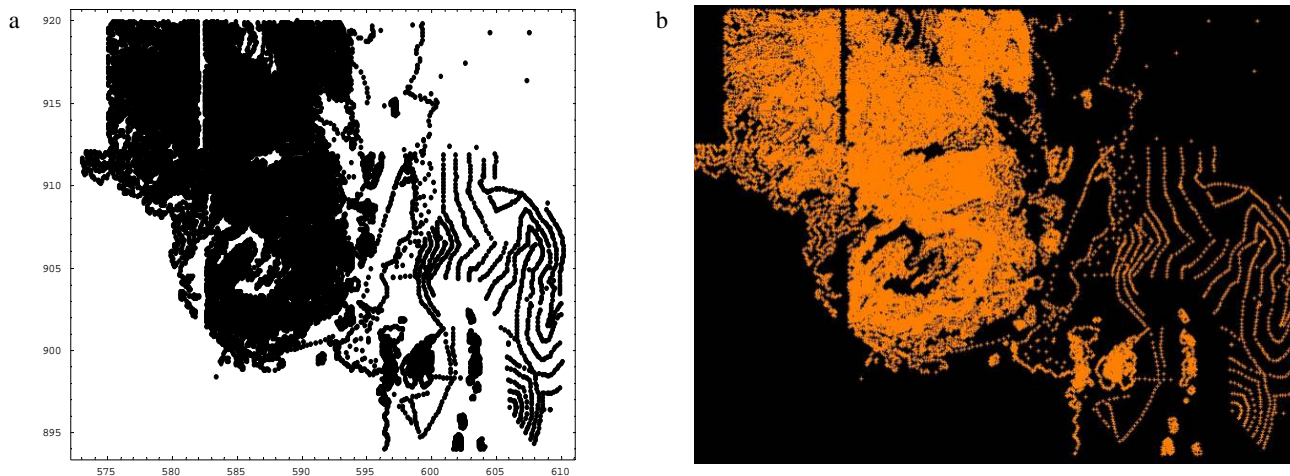


Fig. 3 Coordinate 30,483 points of digital elevation data sets at Ron Phibun District. (a) from our method in *Mathematica* and (b) from GRASS version 5.0.2

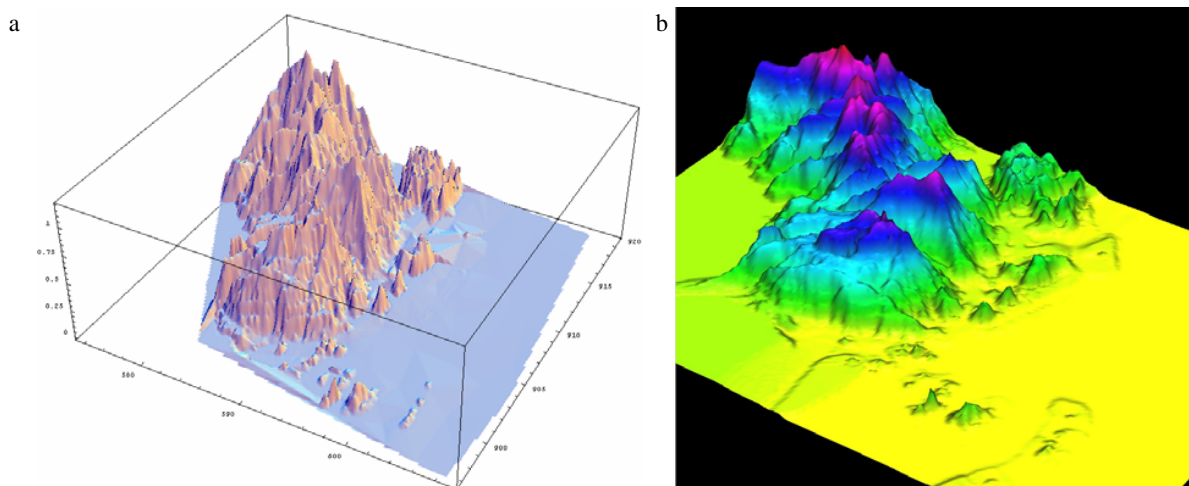


Fig. 4 Digital elevation models (DEMs) at Ron Phibun District (a) from our method in *Mathematica* and (b) from GRASS version 5.0.2

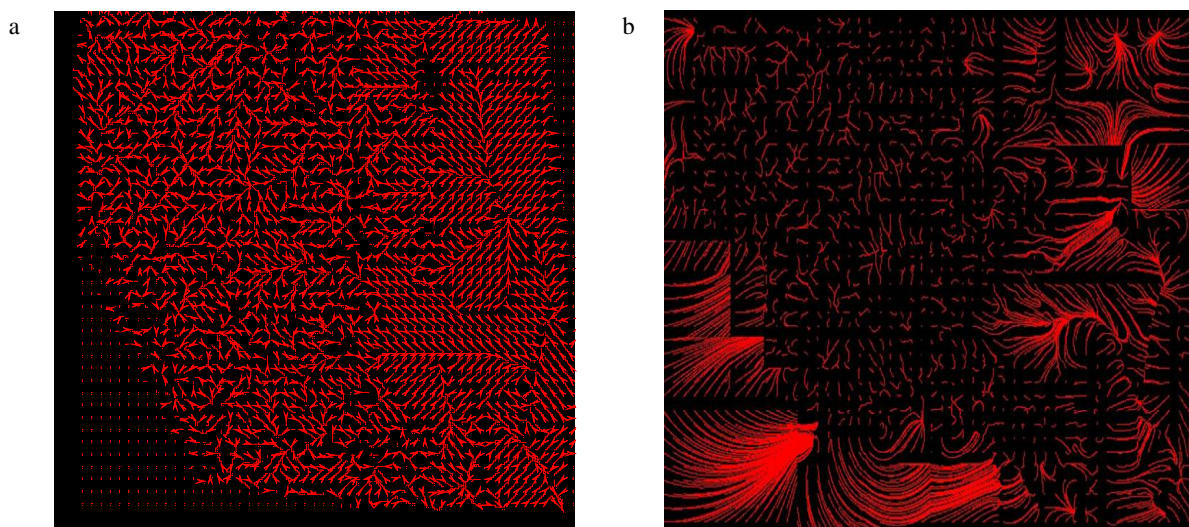


Fig. 5 Flow line (a) from *Mathematica*, and (b) from GRASS version 5.0.2

REFERENCES

[1] JICA (Japan International Cooperation Agency). Final Report on the Environmental Management Planning Survey for Arsenic Contaminated Area of the Nakhon Si Thammarat Province in the Kingdom of Thailand. Mitsui Mineral Development Engineering Co., Ltd. and Kokusaikogyo, Ltd. Thailand, 2000.

[2] S. Tanthawiwat, "Applying Geographical Information System to Locate Areas Risky to Chronic Arsenic Diseases, Case Study, Ron Phibun District, Nakhon Si Thammarat Province" M.Sc. dissertation, Mahidol University, 1996. (in Thai)

[3] I. D. Moore, R. B. Grayson and A. R. Ladson, "Digital Terrain Modelling: A review of Hydrological, Geomorphological, and Biological Applications," *Hydro. Process.*, vol. 5 No. 1, pp. 3-30, 1991.

[4] J. F. O'Callaghan, and D. M. Mark, "The Extraction of Drainage Networks From Digital Elevation Data," *Comp. Vision, Graphics Image Process.*, vol. 28, pp. 328-344, 1984.

[5] S. K. Jenson, and J. O. Domingue, "Extracting Topographic Structure from Digital Elevation Data for Geographic Information system Analysis," *Photogrammetric En. Remote Sensing.* vol. 54, pp. 1593-1600, 1988.

[6] D. M. Mark, "Network Models in Geomorphology, Automated Basin Delineation From Digital Elevation Data," *Geo. Processing.* vol. 2, pp. 299-311, 1988.

[7] D. G. Morris, and R. G. Heerdegen, "Automatically Drained Catchment Boundaries and Channel Networks and their Hydrological Applications," *Geomorphology*, vol. 1, pp. 131-141, 1988.

[8] D. G. Tarboton, "A new method for the determination of flow directions and slope areas in grid digital elevation models," *Water Resources Research*, vol. 33, No. 2, pp. 309-319, 1997.

[9] <http://grass.ict.it>, 2005.

[10] C. Y. Lin, W. T. Lin, and W. C. Chou, "Soil erosion prediction and sediment yield estimation: the Taiwan experience. *Soil Tillage Research.* vol. 68, pp. 143-152, 2002.

[11] J. Fairfield, J. and P. Leymarie, "Drainage networks from grid digital elevation models," *Water Resources Research* vol. 27, 5, pp. 709-717, 1991.