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INFLUENCE OF GEOREFERENCE FOR GIS BASED SATURATION EXCESS OVERLAND FLOW MODELLING

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ABSTRACT

The transformation of geographical data (e.g. actual locations and physical characteristics of objects on the Earth surface) into geographic information dealt with complex series of process and procedures. In saturation excess overland flow (SEOF) modelling, streamflow is one of the main physical geographic apprearance within nature of overland flow cycle. Agriculture, mining, industrial, urbanization, recretion and forest harvesting are major potential increases impervious area causing hazardous impact towards rate of stormwater infiltrated into soil. Thus the overland flow in a post-development area becomes greater than the pre-development area. Within GIS, all stream networks, surface structures and its properties must be assigned and preserved with coordinate systems and map projections respectively known as georeferencing. Hence, any GIS based hydrologic applications need careful understanding in terms of map projections, coordinate systems and its transformations, scales and grid resolutions while entering spatial data. At present, there is still no unifying evidence available that provides a coherent and satisfactory explaination for the integration of the core GIS based saturation excess mechanisms into the streamflow generating process. Concepts of georeferencing need to be applied while performing GIS based saturation mechanism and to sustain the existing spatial properties of soil and land use. This study aims to visualize the effects of georeferencing system towards determining areas and total overland flow volume generated from Saturation Excess Overland Flow (SEOF) process using topographic wetness index (TWI) and antecedent soil-moisture conditions (AMC). Both factors are analysed by focusing on spatial object preservation techniques of conformal based Rectified Skew Orthomophic (RSO) and equidistant based Cassini-Soldner projections. Local authorities could find the results are useful to evaluate the effectiveness of flood management control, sustainability for long-term development purposes, stream restoration, rehabilitation and relocation of construction projects.

Keywords: GIS, SEOF, TWI, AMC, Map Projection

1.0 INTRODUCTION

Many catchments in Malaysia are now under intense pressure from urban, industrial, and infrastructural development where downstream receiving water bodies such as rivers, lakes, ponds, reservoirs, and estuary and coastal waters have become sensitive to increased rates and volumes of runoff and pollutant discharge (MSMA, 2000). Monsoon and flash flood have been dominating the entire urban areas, such as in Penang Island, upper Kinta Valley, Linggi Basin, Malacca Basin, East Coast of Kelantan, Terengganu, Pahang and Johor (PSKL, 2005). Urbanization increases the percentage of impervious area in a watershed, thus the surface runoff in a post-development area becomes greater than in that in pre-development area particularly in the western states of the Peninsular of Malaysia. The problems become even more aggravated by frequent intense rainfalls, the physiological nature of basins and the pattern of urbanisation with relatively poor urban services.

GIS are very well adapted for spatial data organization, visualization, querying, analysis and helpful in the context of hydrologic simulation and modelling of spatial phenomena (e.g. floods, subsurface flow, evapotranspiration and groundwater flow) (Rana, 2004; Drummond *et al.*, 2007). The use of GIS in overland flow modelling has given benefits to expand various kinds of simulation basis, spatial representation and temporal representation models to display results based on site specific measurements and experiments (Garbrecht *et al.*, 2001; Dingman, 2002; Goodchild, 2003). Streamflow is one of the major basin-scale phenomenon in the hydrologic cycle. A streamflow derives integrated results from various upland flow sources in response of rainfall and other water inputs. At present, the large variation and behaviour of drainage basins causes difficulties to produce general relationships, to identify and quantify the physical geographic characteristics that results the simulated hydrograph (Brutsaert, 2005).

SEOF occur when the soil becomes saturated, and any additional precipitation or irrigation causes runoff (Juracek, 1999; Walter *et al*., 2003; Brutsaert, 2005). Areas prone to saturation have a high ground water table, which may increase surface runoff, different path of sediments and pollutants movement into surface water systems (Ward and Trimble, 2004). Soil texture, heterogeneity, cracks, bulk density and surface condition influences the water movement and generates the SEOF process. Modelling accurate representation of GIS based SEOF requires significant dealt with the GIS core component, which is the georeferencing system. The ellipsoid and plane are selected as datum, and consists of preserving one of the spatial properties (shape, area, distance and directions) before modelling is performed. Christopherson (2005) and Galati (2006) stated the main component of any GIS usage is the adaption of georeferencing systems to retrieve the actual positions of each features on the real world. It is about how coordinates tie the real world into its projected electronic image in the computer (Sickle, 2004). Projections of a map are crucial for implementing GIS based streamflow generating process (mainly SEOF), which influence the shape and location of adjacent hydrologic spatial objects of land use, soil and hydraulic properties such as hydraulic conductivity, soil moisture deficit, capillary suction and soil porosity.

To simulate the area and volume of SEOF process on watersheds, many hydrologic and watershed models have been developed and integrated with GIS techniques such as TOPMODEL (Ambroise *et al*., 1996), Soil Moisture Routing Model – SMRM (Frankenberger *et al*., 1999), Hydrogeomorphic Steady State model – HGSS (Willgoose and Perera, 2001) and Kinematic Runoff and Erosion Model – KINEROS (Semmens *et al*., 2002). These models can be used to estimate the dynamics of surface and subsurface saturated areas on the basis of storage discharge relationships established from a simplified steady state theory for downslope saturated zone, high surface runoff responses and impacts towards land use management. However, there has been a lack of sincerity on focusing the importance of georeferencing while constructing SEOF modelling, which are the core of GIS usage; and conceptual of GIS based infiltration mechanism (Garbrecht *et al*., 2001; Christopherson, 2005).

Escobar *et al.* (1999) stated the functions of GIS include data entry, data display, data management, information retrieval and analysis. The first two functions of GIS are crucial to ensure spatial layers are correctly projected and positioned. The physical aspect of data entry and data display is the process of mapping, scale and projection of spatial layers. Christopherson (2005) mentioned that the beginning component of any GIS is a coordinate system, which establishes reference points against which to position data. If data are available in one map projection and required in specialised GIS software can perform the transformation into the new projected reference frame. Knowledge of map projections is perhaps the main subject that a civil engineer most lacks when entering the GIS field (Garbrecht *et al.,* 2001). The flow mechanism in reparian areas and headwater basins has been the subject of intense research in the past few decades. Georeferencing process, SEOF mechanism and their interactions is not only essential to describe streamflow generation, but it is also the key to a better understanding of solute transport in the human environment and of the evolution of landforms and erosion.

This paper describes the influence of coordinate system and map projection for GIS based SEOF modelling to determine areas and total overland flow discharge within SEOF boundaries using conformal based RSO and equidistance based Cassini-Soldner map projections. The concepts of georeferencing and SEOF mechanism are explained in Section 2. The experiment of determining areas and overland flow volume within SEOF boundary are highlighted in Section 3. The outlook of SEOF within RSO and Cassini-Soldner are explained in

Section 4, while the conclusion and further development of SEOF process are stated in Section 5.

2.0 GIS FOR SEOF MODELLING

Soils and topographic features are fundamental to the partitioning of water inputs at the earth surface. There is a maximum limiting rate at which a soil in a given condition can absorb surface water input (Horton, 1933). Important factors of infiltrations include soil surface conditions, subsurface conditions, hydrophobicity, and flow characteristics of fluid and factors that influence surface and subsurface conditions (Ward and Trimble, 2004). The identification of potential runoff-contributing areas in a basin can provide guidance for the targeting of BMP's to reduce runoff and meet TMDL requirements. Implementation of BMP's within potential runoff-contributing areas is likely to be more effective at reducing constituent loads compared to areas less likely to contribute runoff.

The spatially distributed hydrologic modelling serves an efficient method to identify hydrological impacts due to urbanization on land cover. SEOF modelling deals with the distribution and concentration of water as it moves through the soil surface. GIS is capable to serve hydrologic modellers to input data and present the output of hydrological process and impacts. GIS has been applied in various water management based application such as rainfall runoff modelling, water quality monitoring, assessing non-point source pollution and urban/rural stormwater management (Wilson *et al.*, 2000).

GIS have embedded new integration techniques to develop and run fully distributed model efficiently. The development of overland flow and NPS models such as Agricultural Nonpoint Source Pollution Model (AGNPS) (Young *et a*l., 1987), Soil and Water Assessment Tool – SWAT (Arnold *et al*., 1990; Neitsch *et al*., 2001), Kinematic Runoff and Erosion Model – KINEROS (Semmens *et al*., 2002), Storm Water Management Model (SWMM) (Rossman, 2004) and Long-Term Hydrologic Impact Assessment – L-THIA (Bhaduri *et al*., 2000) successfully implemented GIS techniques in terms of spatial extent. Moreover, GIS has also allowed users to run more traditional lumped models more efficiently and to include at least some level of spatial effects by partitioning entire watersheds into smaller sub-watersheds. For example, HEC-HMS, SWAT and L-THIA have been linked to GIS, incorporates Soil Conservation Service (SCS) techniques to predict surface water flows. In addition to provide appropriate modelling results within GIS, this paper focuses on the core usage of GIS by implementing physical characteristics of map projection to visualize significant preservation of spatial objects to deliver proper geographic information of infiltration rate, saturated zone, overland flow and height of water table for entire basin.

2.1 SEOF Process and Determination

Overland flow is most commonly occurs relatively small portions of the land surface that are highly possible to be saturated. Additional precipitation that falls on the saturated land surface becomes overland flow, known as saturation-excess overland flow. The total precipitation amount and the physical characteristics of land surface such as land use type, soil depth and upslope of entire basin area are the significant components that cause overland flow (Ward and Trimble, 2004). The spatial extent of areas that are saturated from below fluctuates in response to changes in basin wetness over time and space, and the resulting temporal variations in the extent of surface saturation in a catchment have been termed the Variable Source Area (VSA) (Freeze and Cherry 1979). However, the generation of SEOF is contrast with the infiltration excess overland flow (IEOF) process, which depends on soil type, soil porosity, infiltration rate and rainfall intensity (Wolock, 2003; Tarboton, 2003; Smith and Goodrich, 2005).

SEOF comes from two different sources, direct precipitation on saturated areas formally known as (DPSA) and return flow which comes out if the rate of interflow entering a saturated area from upslope exceeds the capacity for interflow to leave the area by flowing downhill through the soil (Tarboton, 2003). Land surface that often become saturated has high possibilities due to rise of ground water table and interception of grassland, vegetation coverage and highly compacted soil. During periods of enhanced rainfall, interflow will be higher and often expand the extent of saturation around saturation-prone areas; conversely, dry periods will decrease interflow and extent of saturation (Qin *et al*., 2007).

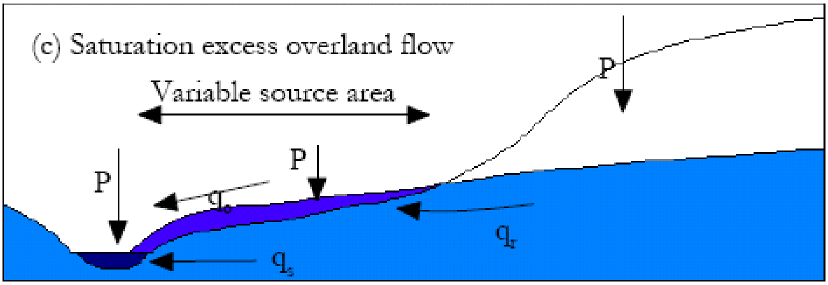


Figure 1: Saturation Excess Overland Flow mechanism

Source : Following Beven, (2000)

Areas that generates the SEOF are observed by focusing on combined effects of basin topographic structures and Antecedent soil Moisture Conditions (AMC). Topographic Wetness Index (TWI) is an index that quantifies the effects of topographic structure towards SEOF (Qin *et al*., 2007), while Antecedent Moisture Condition (AMC) is an indicator of watershed wetness and availability of soil moisture storage prior to a storm and can have a significant effect on overland flow volume. The wet AMC condition signs that areas with lower TWI values may be saturated and also contribute to SEOF (Brutsaert, 2005).

2.2 SEOF Computation: TWI and AMC

In this study, the estimation of SEOF is performed using TWI digital coverage extracted from Digital Elevation Models (DEMs) projected under RSO and Cassini-Soldner system. Computation of TWI is done by assigning ln (*a/S*) for all points in a basin, where *ln* is the natural logarithm, *a* is the upslope area per unit contour length, and *S* is the slope at that point as stated in equation (1), (2) and (3). Elevation differences among the grid cells in the DEM were compared and used to create a flow-direction grid. Flow accumulation grid is used to compute the number of upslope cells that drains into each cell.

a = (number of upslope cells + 0.5) x (grid-cell length) (1)

S = (change in elevation between neighboring grid cells) / (horizontal distance between centers of neighboring grid cells) (2)

TWI = ln (a/S) (3)

SEOF are determined using equal-interval approach with six thresholds TWI values that visualize from high to low possibilities areas. To determine overland flow volume originated from SEOF, the Infiltration Excess Overland Flow (IEOF) processes are first excluded from the basin area. Distribution of SEOF flow is based on the delivery of surface water input in excess of the hydraulic conductivity on the soil surface and duration of precipitation must be longer than the time required saturating the soil surface (Freeze and Cheery, 1979; Brutsaert, 2005). Infiltration rate of entire basins are calculated using physically based Green-Ampt method.

$$f = K(H_o + S_w + L)/L \tag{4}$$

where f is the infiltration rate at time t, f_o is the infiltration rate at time zero, f_c is the final constant infiltration capacity and γ is a best-fit empirical parameter. According to MSMA (2001), recommended value for γ is 4/hour. Total volume of infiltration, F after time t is calculated as :

$$f = K_s\,(1 + [\Psi\theta\,/\,F]) \tag{5}$$

where Ks is the saturated hydraulic conductivity, Ψ is average capillary suction in the wetted zone, θ is soil moisture deficit (dimensionless), equal to the effective soil porosity times the difference in final and initial volumetric soil saturations and F = depth of rainfall that has infiltrated into the soil since the beginning of rainfall.

2.3 Georeferencing: Map Projection in Malaysia

Galati (2006) stated the main component of any GIS usage is the adaption of georeferencing systems to retrieve the actual positions of each features on the real world. It is about how coordinates tie the real world into its projected electronic image in the computer (Sickle, 2004). Information regarding georeferencing and its transformation are the main key points that civil engineers and hydrologists lack while using GIS approach (Garbrecht et al., 2001). Loxton (1980) stated the represented spatial features with more than 10 km^2 on projected map are distorted. Cartographers have long complained about the poor quality of the output from GIS, which generally today is not due to limitation of the GIS itself, but to lack of understanding cartographic principles by users (Forrest, 2003).

In Malaysia, there are two types of projections used to display spatial data; the Rectified Skew Orthomophic (RSO) and Cassini-Soldner. Topographic layers are displayed in RSO projections, while cadastral lot layers are projected in Cassini-Soldner. The Malayan Revised Triangulation (MRT) is the coordinate system used for mapping in Peninsular Malaysia, based on the old Repsold Triangulation datum and computed using data collected mainly in the period 1948 to 1966 using the Modified Everest ellipsoid. Coordinates in this system are known as MRT48 coordinates which represent a unified datum and albeit distorted (Kadir *et al.,* 2003). The Mercator projection is one of the most common cylindrical projections, and the equator is usually its line of tangency (Wan Abdul Aziz *et al.*, 1998).

The SEOF process depends significantly with soil properties and land use. Performing transformation between RSO and Cassini-Soldner projection by using equation (9), (10), (11) and (12) causes distortion on the shape, areas, distance and direction of the original position

(Wan Abdul Aziz *et al.*, 1998) of each soil and landuse properties. The RSO projection is characterised as conformal based system, which preserve the shape of spatial objects, but other physical parts of area, distance and direction are distorted. The Cassini-Soldner projection is an equidistance based system with distance between each features on the map is preserved, while the shape, area and angle are distorted.

2.4 Transformation between RSO and Cassini-Soldner Projections

The RSO is an oblique Mercator projection. The RSO provide an optimum solution in the sense of minimizing distortion whilst remaining conformal for Malaysia (Kadir *et al.,* 2003). Cassini-Soldner projection system for the Peninsular is based on several local datums and realized by their published equations and coordinate of their respective State origin. The existing Cassini-Soldner projection for cadastral mapping is based on the MRT system referenced to the Modified Everest ellipsoid. It is useful for mapping areas with limited longitudinal extent. It has a straight central meridian along which the scale is true, all other meridians and parallels are curved, and the scale distortion increases rapidly with increasing distance from the central meridian. The geographic coordinate system, which is represented in latitude and longitude value is not a projected map (Wan Abdul Aziz *et al.*, 1998). Map projections use latitude and longitude values to reference parameters such as the central meridian, the standard parallels, and the latitude of origin.

Transformation of coordinate system between RSO and Cassini-Soldner are done in two methods; the general way or the polynomial equation. General transformation is done by changing a coordinate in its existing projection to the geographical coordinates as in (6); and recomputes them to the coordinate grid into the targeted map projection.

$$(X,Y) \text{-->} (Q,L)P \text{-->} (x,y)p \quad (6)$$

The polynomial solution is used when the numbers of coordinate points are high. In this method, a relationship is established as follows :

$$X = C_1 + x.C_2 + y.C_3 + xy.C_4 + x^2.C_5 + y^2.C_6 + ... \quad (7)$$

$$Y = D_1 + x.D_2 + y.D_3 + xy.D_4 + x^2.D_5 + y^2.D_6 + ... \quad (8)$$

where x,y is the coordinates in the existing map projection; X,Y is the coordinates in the targeted map projection and C_i,D_i is the parameters of the transformation of the projections. Transformation of RSO into Cassini-Soldner coordinate system is done by using the equation in (9) and (10). The reverse process of coordinate system transformation from Cassini-Soldner to RSO is performed using the equation in (11) and (12).

$$N_{cs} = N_0cs + X - (R_1 + xA_1 + yA_2 + xyA_3 + x^2A_4 + y^2A_5) \quad (9)$$

$$E_{cs} = E_0cs + Y - (R_2 + xB_1 + yB_2 + xyB_3 + x^2B_4 + y^2B_5) \quad (10)$$

where X = N_{rso} - N_{0rso}; Y = E_{rso} - E_{0rso}; x = X/10000, y = Y/10000; N_{rso}, E_{rso} is state coordinate in RSO; N_{0rso}, $E_{0rso}$is the state origin coordinate in RSO; $N_o$cs, E_0cs is state origin coordinate in Cassini-Soldner; R_i, A_i, B_i where i = 1,2,..5 are the transformation parameters.

$$N_{RSO} = N_0RSO + X + R_1 + xA_1 + yA_2 + xyA_3 + x^2A_4 + y^2A_5 \quad (11)$$

$$E_{RSO} = E_0RSO + Y + R_2 + xB_1 + yB_2 + xyB_3 + x^2B_4 + y^2B_5 \quad (12)$$

where X = N_{cs} - N_{0cs}; Y = E_{cs} - E_{0cs} ; x = X/10000, y = Y/10000; N_{cs}, E_{cs} is state coordinate in Cassini-Soldner; N_{0cs}, $E_{0cs}$is the state origin coordinate in Cassini-Soldner; N_oRSO, E_0RSO is state origin coordinate in RSO; R_i, A_i, B_i where i = 1,2,..5 are the transformation parameters.

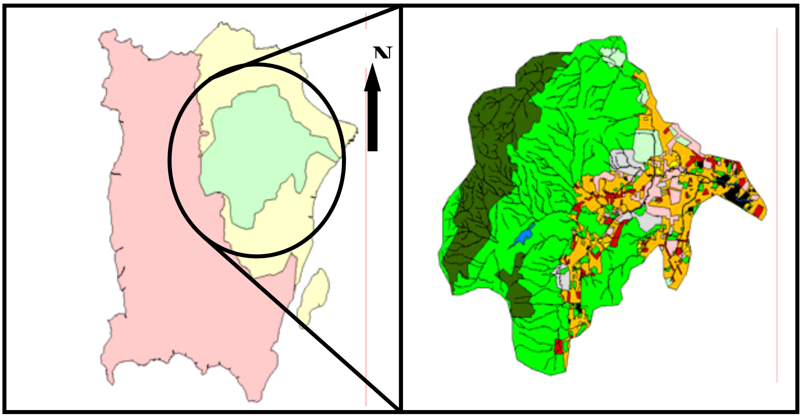
3.0 THE SEOF EXPERIMENT

The Sungai Pinang basin is located between Latitude from 5° 21' 32" to 5° 26' 48" and Longitude from 100° 14' 26" to 100° 19' 42". Sungai Pinang is the main river system in the Penang Island with the catchment size approximated 51 km^2, as illustrated in Figure 2. Sungai Pinang basin has been selected to determine area and volume of SEOF process due to continuity of development that had affected the physical characteristics of land use and soils; degrading and increase the water quality and water quantity respectively of the entire basin (Mohamad Zaki Abdullah, 1999; WQI Report, 2006). Moreover, flash flood and water pollution are the main problems occurred in highly urbanized area such as Georgetown, Jelutong and Air Itam (WQI Report, 2006)

In this study, the procedure for linking GIS with TWI, AMC and infiltration rate involves the following steps: (1) acquisition and development of GIS map data layers of Sungai Pinang basin within RSO and Cassini-Soldner projections; (2) preprocessing of model input data and parameters and computation of TWI, AMC and Green-Ampt model results and (3) postprocessing of all infiltration components results to the GIS for spatial display and analysis of SEOF area and volume of overland flow. The TWI, AMC and Green-Ampt model parameters are linked into PC-based GIS package called ArcView GIS to store, analyze and displaying GIS based SEOF process modeling results.

Digital topography maps with 1 : 25 000 scale are used to extract layers of Buildings, Contours, and River network. The land use map for the year 2007 and soil map published in 1968 is obtained from Department of Agricultural to evaluate the soil condition at Sungai Pinang basin. In this study, the 60 minutes precipitation data dated on 18th of June 2006 were used to determine overland flow generated from SEOF area using TWI and AMC indicators. Further derivation of precipitation coverage and slope for entire basin is obtained through interpolation process. Topographic information such as slope, aspect, flow length, contributing area, drainage divides and channel networks can be reliably extracted from Digital Elevation Model (DEMs) using 5 meter resolution. Square-grid DEMs are used due to simplicity, processing ease and computational efficiency.

(a)



(b)

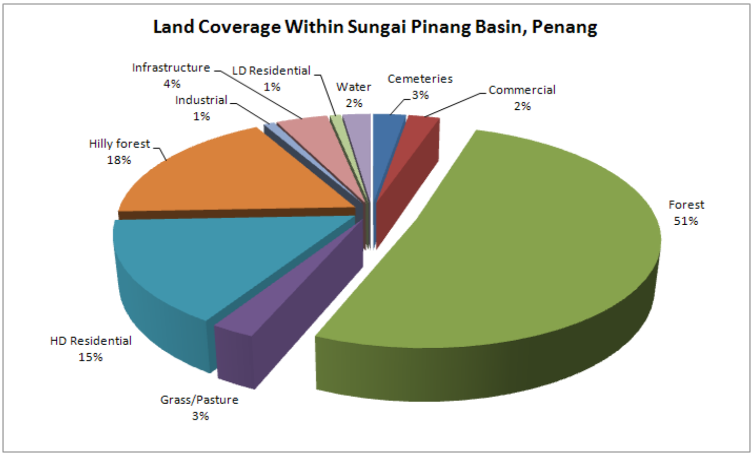


Figure 2: Location of Sungai Pinang Basin (a) and its Land use for the Year 2007 (b)

3.1 Determining Potential SEOF Area

In order to obtain potential SEOF areas, each vector data layers are converted into raster based layers with resolution of 20 meter and 5 meter grid cell within RSO and Cassini-Soldner projections. Analysis is performed into two phases. The first phase is to model spatial data layers by overlaying layers of Precipitation, Landuse, Slope, Soils, Buildings and Road network based on criteria mentioned by Freeze and Cherry (1979), Juracek (1999), Ward and Trimble (2004), Brutsaert (2005) and Qin *et al*. (2007) and to map potential SEOF area. The second phase is to intersect mentioned layers to map potential location of SEOF and its area. Schematic diagram for determining SEOF area is illustrated in Figure 3.

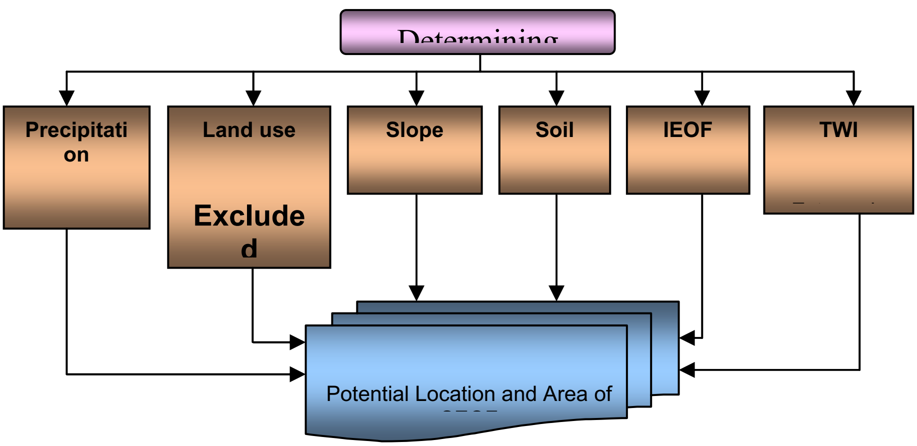


Figure 3: Schematic diagram for determining SEOF area

3.2 Computation of Overland Flow Volume within SEOF Area

Saturated soil causes continuous surface water input are converted into form of overland flow. Total of overland flow within SEOF areas are computed by subtracting rainfall volume with the soil-permeability values that represent rainfall intensity based on equal-interval approach using the rainfall data recorded on 18th of June, 2006 with duration of 60 minutes for each grid cell. An equal-interval approach was used to select six threshold TWI values that represented a range of wet-to-dry antecedent soil-moisture conditions. In Sungai Pinang basin, the TWI ranges from 1.0 to 21.8. Due to approximate 95 percent of the basin has a TWI of 14.8 or less, the effective range used in this study were 1.0 to 14.8. Thus, the threshold TWI values, representing extremely wet, very wet, wet, moderate, dry and very dry AMC were set at 3.45, 5.9, 9.2, 8.35, 10.8 and 14.8 respectively. Lower TWI thresholds indicate wetter AMC and potentially may contribute SEOF. The TWI values from extremely wet to moderate condition are selected to compute overland flow.

4.0 POTENTIAL SEOF AREAS

The experiment on determining SEOF areas are illustrated from Figure 4 to 8. Layers of Slope, Precipitation, Soil type and Land use are intersected together and exclude the IEOF area to map the potential areas of SEOF. The SEOF area rated by Extreme, Very High, High and Moderate using conformal RSO and equidistance Cassini-Soldner projections are illustrated in Figure 8.

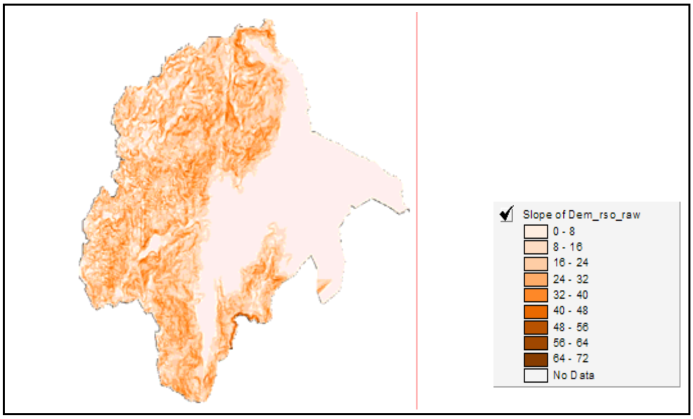


Figure 4: Slope coverage in Sungai Pinang basin

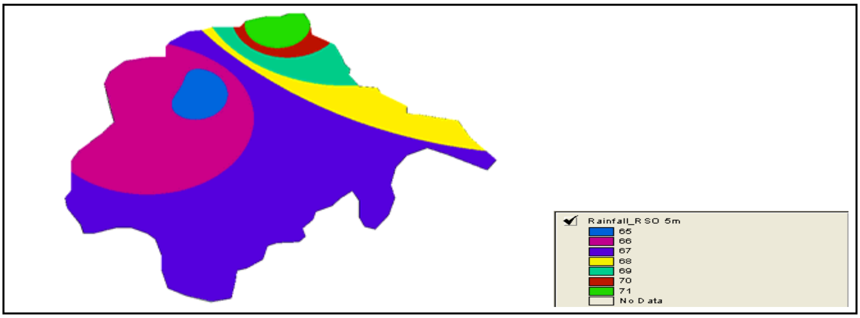


Figure 5: Rainfall Depth coverage in Sungai Pinang basin

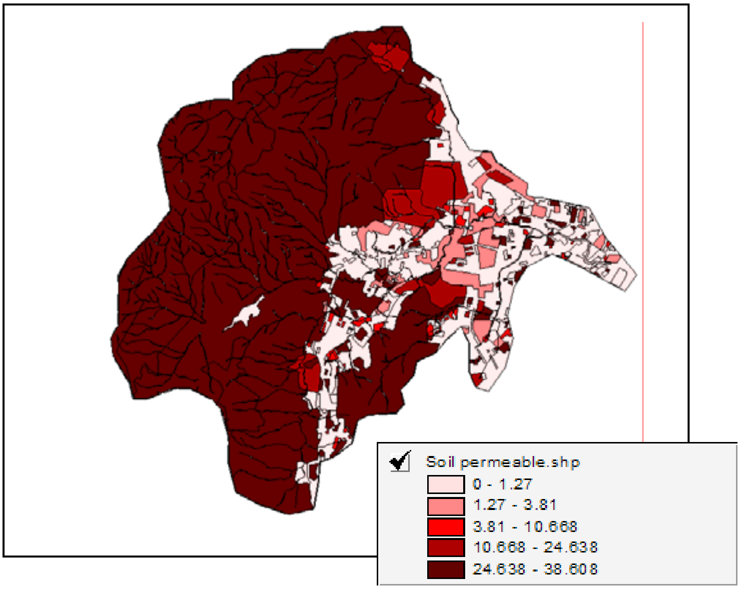


Figure 6: Soil permeable in Sungai Pinang basin

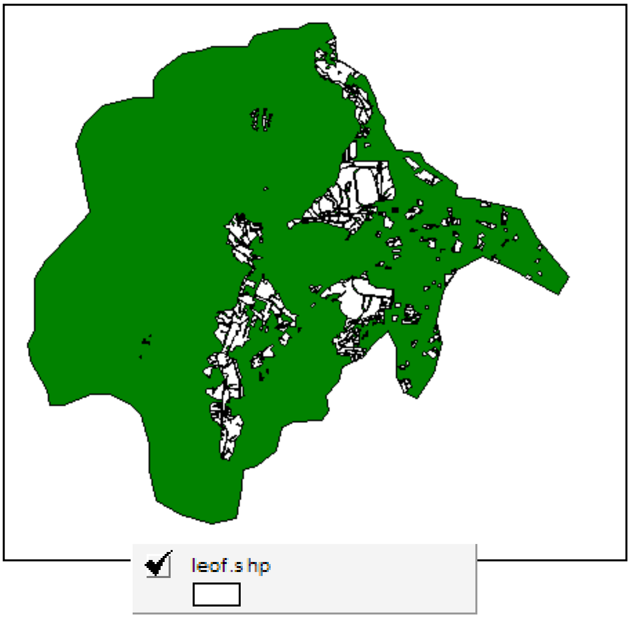


Figure 7: Potential IEOF area within Sungai Pinang basin

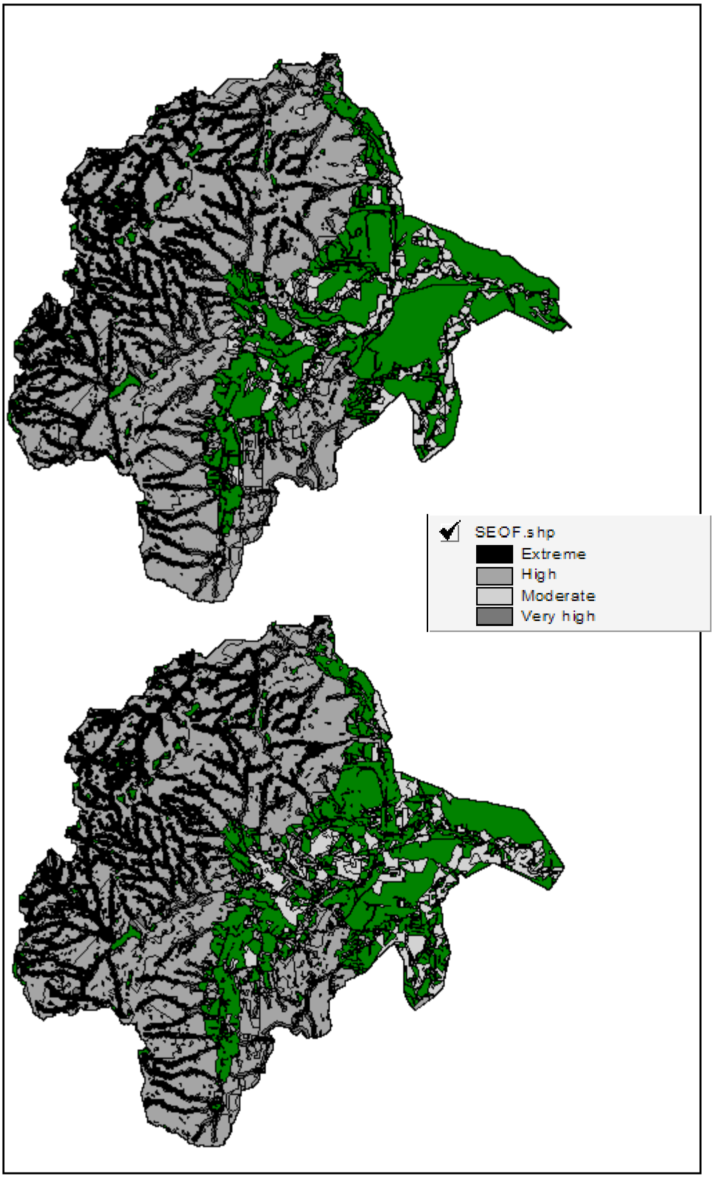


Figure 8: Potential area of SEOF within Sungai Pinang basin based on conformal RSO (left) and equidistance Cassini-Soldner (right) map projections

Approximately 36.6 km^2 of SEOF areas is identified. Most of the SEOF coverage in Figure 8 lies in upper hills, stream networks and downslope areas, mainly in Sungai Air Terjun sub-catchment, areas of Paya Terubong, Air Hitam, Kebun Bunga, partly in Gelugur and Jelutong. The differential SEOF area computed under RSO and Cassini-Soldner map projections are summarised in Table 2. The location of SEOF lies on the humid to semi-arid regions, which are the major controls on the overland flow occurrence, based on climate data, land use, soil topography and rainfall characteristics as stated by Tarboton (2003). SEOF computation using conformal RSO projection indicates that High potential of SEOF area dominate the Sungai Pinang basin with 61.10 percent, followed by Very High, Moderate and Extreme SEOF areas with 14.81 percent, 12.87 percent and 11.21 percent respectively. Within equidistance Cassini-Soldner map projection, High potential of SEOF area also dominate the Sungai Pinang basin with 60.5 percent which slightly lower than the conformal RSO projection. The rest are followed by Extreme, Very high and Moderate SEOF areas with 14.74 percent, 12.98 percent and 11.77 percent which are different than conformal based RSO projection.

5.0 SEOF VOLUME

The resulted computation of overland flow within SEOF areas is illustrated in Figure 9. The computed overland flow volume is excluded with the overland flow generated from IEOF boundaries. Approximately 1,330,000 m^3 of overland flow volume were recorded within the SEOF boundaries. High overland flow coverage are identified in Air Putih and air Hitam sub-catchment which lies in upper part of hills. Moderate overland flow lies in areas of Paya Terubong, Air Hitam, Sungai Pinang sub-catchment and partly in Gelugur and Jelutong. High potential of SEOF area under conformal RSO map projection contributes 56.18 percent of overland flow, followed by Moderate, Very High and Extreme with 20.11 percent, 12.91 percent and 10.79 percent respectively. Within equidistance Cassini-Soldner map projection, High potential of SEOF area contribute 55.68 percent of overland flow, followed by Moderate, Extreme and Very High with 19.62 percent, 13.64 percent and 11.06 percent respectively, which are different than conformal RSO projection. The differential of SEOF volume computed under conformal RSO and equidistance Cassini-Soldner projections are summarised in Table 2

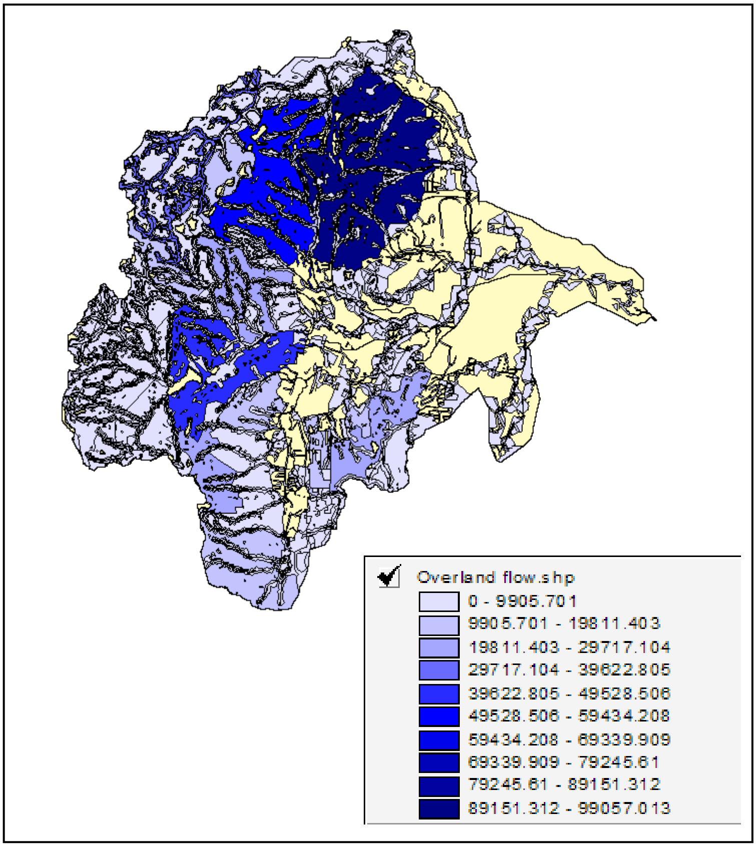


Figure 9: Overland Flow Volume within SEOF area

Table 2: Summary of identified SEOF Area, Precipitation and Overland Flow Volume under Conformal Based RSO and Equidistance Based Cassini-Soldner Projections

Analysis and Results	Projection	
	RSO	**Cassini-Soldner**
1. Total Basin Area (m^2)	**47228924.9870**	**47667124.9879**
Different (m^2)	± 438200.0009	
2. Total SEOF Area (m^2)	**40241371.1660**	**40156731.8275**
Extremely potential (m^2)	**4073402.4075**	**5424829.2037**
Very High potential (m^2)	**5451887.5243**	**4858891.2675**
High potential (m^2)	**23996908.5704**	**24438943.5501**
Moderate potential (m^2)	**6719172.6638**	**5434067.8062**
Different of SEOF Area between RSO and Cassini-Soldner	± 84639.3385	
Different for Extremely potential (m^2)	± 1351426.7962	
Different for Very High potential (m^2)	± 592996.2568	
Different for High potential (m^2)	± 442034.9797	
Different for Moderate potential (m^2)	± 1285104.8576	
3. Total Precipitation Volume within SEOF area (m^3)	**2634151.6814**	**2629335.5388**
Different (m^3)	4816.1426	
4. Total Overland Flow within SEOF (m^3)	**1421891.6002**	**1445097.3802**
Extremely potential (m^3)	**139724.9262**	**182187.6077**
Very High potential (m^3)	**168517.3893**	**149822.8170**
High potential (m^3)	**781474.9565**	**811107.0765**
Moderate potential (m^3)	**332174.3282**	**301979.8790**
Different of Overland Flow Volume between RSO and Cassini-Soldner (m^3)	± 23205.7800	
Different for Extremely potential (m^3)	± 42462.6815	
Different for Very High potential (m^2)	± 18694.5723	
Different for High potential (m^3)	± 29632.1200	
Different for Moderate potential (m^3)	± 30194.4492	

5.1 Discussion

Results show that there are changes on the calculations of potential SEOF area, precipitation and overland flow volume. Selection of different map projection differentiates the SEOF areas. Moreover, computation of TWI and AMC indicate different values of minimum and maximum under RSO and Cassini-Soldner projections. Such conditions are tightly connected with DEMs, where different values of upslope areas are obtained during computation in equation (1), (2) and (3). The alternation of basin shape, size and distance would greatly affect the physical condition and calculations while deriving flow direction, flow accumulation, precipitation depth, overland flow, change of physical soil parameters (soil porosity, conductivity, path of subsurface flow, return flow) with different soil types and amount of overland flow generated in the study area. Developers, local authority and private sectors need to plan a careful monitoring of datasets accuracy for any construction purposes in site-specific area. The analysis conducted however does not account the water balance equation such as evapotranspiration losses, percolation, return flow, groundwater flow, shallow and subsurface flow. The spatial analysis performed on grid based DEM layers may cause significant effect towards SEOF computation. Therefore, great care should be taken when selecting a resolution (cell size) for raster structures, in particular when physical properties of linear and areal features, such as stream networks, boundaries or subcatchment areas are being extracted (Garbrecht *et al.,* 2001).

6.0 CONCLUDING REMARKS

This study presents the influence of georeferencing system for GIS based SEOF data modeling for estimating the potential location of SEOF areas and overland flow volume based on TWI and AMC conditions. A longer duration of precipitation would result significant changes of overland flow volume under different map projections. The spatial layers of soils, land use, precipitation and the runoff coefficient are all important sub-basin parameters, but the soil hydraulic properties and runoff coefficient is, by far, the most difficult parameter to determine. Therefore, it is extremely important to accurately estimate sub-basin runoff coefficients using the best data and most advanced computation methods available. GIS has proven the capability to model, analyze and integrate geographical and hydrological data of SEOF. The cartographic aspects are also highlighted in terms of selecting appropriate map projections for displaying SEOF data modeling results. A thorough understanding need to be addressed in terms of physical geographic in hydrological process, determining the GIS properties such as map projections, scale and coordinate systems before any modeling and data processing can be executed. A map can be drawn at any scale, but it is unclear to what extent existing hydrologic models can be applied at different map projections and scales in the mean of using GIS.

Understanding of SEOF process is crucial to compute runoff volume. Modelers need to specify the importance of considering map distance, size and shape of basin. To obtain much more accurate computation of SEOF areas, infiltration and overland flow volumes, further investigations needed for possible new criteria by examining soil type and its properties, evapotranspiration, channel/macropores roughness and slope condition for numerous location and conducting validation using combinations of GIS and hydrologic algorithms. Although the method involves some identifiable sources of uncertainty, the results nevertheless provide an initial indication of the importance of considering map projections, scales and grid resolutions for an actual use of GIS application over a region. The results obtained would benefits the relevant agencies such as Department of Irrigation and Drainage (DID), Department of Environmental (DOE), Department of Town Planning (DOTP) and Department of Minerals and Geosciences (DMG) to determine flood risk zones, areas of prompt to produce large direct runoff volumes, careful monitoring of NPS runoff pollutant loading, proper development plan and constructions, monitoring water quantity and quality of river networks for analyzing long-term hydrological impact towards land use and soils.

REFERENCES

Ambroise, B., Beven, K., Freer, J. (1996). *Toward a generalization of the TOPMODEL concepts: topographic indices of hydrological similarity.* Water Resources Research 32(7) : pp. 2135–2145.

Arnold, J. G., Williams, J. R., Nicks, A. D., Sammons, N. B. (1990). SWRRB – A Basin-Scale Simulation Model for Soil and Water Resources Management. College Station, Texas : Texas A&M Press.

Bhaduri, B., Harbor J., Engel, B. A., Grove, M. (2000). Assessing Watershed-Scale, Long-Term Hydrologic Impacts of Land-Use Change Using a GIS-NPS Model. Journal of Environmental Management, 26 (6) : pp. 643-658.

Brutsaert, W. (2005). Hydrology : An Introduction. Cambridge University Press, New York. pp. 598.

Christopherson, R. W. (2005). Geosystems : An Introduction to Physical Geography. Pearson Prentice Hall, New Jersey. pp. 1-27.

Christopherson, R. W. (2005). Geosystems : An Introduction to Physical Geography. Pearson Prentice Hall, New Jersey. pp. 1-27.

Dingman, S. L. (2002). Physical Hydrology. Prentice Hall, New Jersey. pp. 607.

Drummond, J., Billen, R., Joao, E., Forrest, D. (2007). Dynamic and Mobile GIS. CRC Press, Taylor and Francis Group. pp. 1-299.

Escobar, F., Hunter, G., Bishop, I., Zerger, A. (1999). Introduction to GIS. http://www.sli.unimelb.edu.au/gisweb/

Forrest, D. (2003). Cartographic Education and Research in the U.K. The Cartographic Journal, 40 (2). pp. 141-146.

Frankenberger, J. R., Brooks, E. S., Walter, M. T., Walter, M. F., Steenhuis, T. S. (1999). A GIS-based variable source area model. Hydrological Processes 13(6) : pp. 804–822.

Freeze, R. A. and Cherry, J. A. (1979). Groundwater. Prentice-Hall, Englewood Cliffs, New Jersey. pp. 604.

Galati, S. R. (2006). Geographic Information Systems Demystified. Artech House, London. pp. 61-151.

Garbrecht, J., Ogden, F. L., DeBarry, P. A., Maidment, D. R. (2001). GIS and Distributed Watershed Models. I : Data Coverages and Sources. Journal of Hydrologic Engineering. pp. 506-514.

Goodchild, M. F. (2003). Geographic Information Science and Systems for Environmental Management. Annual Revision Environment Resources. 28 : pp. 493-519.

Horton, R. E. (1933). The Role of Infiltration in The Hydrologic Cycle. Transactions American Geophysical Union, (14), pp. 446–460.

Juracek, K. E. (1999). Estimation of Potential Runoff Contributing Areas in Kansas Using Topographic and Soil Information. U.S. Geological Survey Water-Resources Investigations Report 99-4242, pp 11.

Kadir, M., Shahrum, S., Kamaludin, O., Ghazali, D., Abdullah, H. O. (2003). Geocentric Datum GDM2000 for Malaysia: Implementation and Implications. pp. 1-15.

Loxton, J. (1980). Practical Map Projection. John Wiley & Sons Ltd. pp. 131.

Mohamad Zaki Abdullah. (1999). Georgetown Conurbation Flood Mitigation Project. Proceedings of the National Conference on Rivers. pp. 136-142.

MSMA. (2000). Manual Saliran Mesra Alam. Vol. 1 – 20. Department of Irrigation and Drainage, Malaysia.

Neitsch, S. L., Arnold, J. G., Kiniry, J. R., Williams, J. R. (2001). Soil and Water Assessment Tools Version 2000. User Manual.

PSKL. (2005). Pelan Struktur Kuala Sumpur. Dewan Bahasa dan Pustaka. http://www.dbkl.gov.my/pskl2020/index.htm

Qin, C., Zhu, A., Yang, L., Li, B., Pei, T. (2007). Topographic Wetness Index Computed using Multiple Flow Direction Algorithm and Local Maximum Downslope Gradient.

Rana, S. (2004). Topological Data Structures for Surfaces - An Introduction to Geographical Information Science. John Wiley & Sons Ltd. pp. 1-183

Rossman, L. A. (2004). Storm Water Management Model. User Manual Version 5.0. Environmental Protection Agency, USA.

Semmens, D. J., Hernandez, M., Miller, W. P., Goodrich, D. C., Miller, S. N., Kepner, W. G. (2002). Documentation and User Manual : AGWA and KINEROS Version 1.32.

Sickle, J. V. (2004). Basic GIS Coordinates. CRC Press. pp. 200.

Smith, R. E. and Goodrich, D. C. (2005). Rainfall Excess Overland Flow. Encyclopedia of Hydrological Sciences.

Tarboton, G. D. (2003). Rainfall-runoff Process. Utah State University. pp. 159.

Walter, M, T., Mehta, V. K., Marrone, A. M., Boll, J., Gerard-Marchant, P., Steenhuis, T. S., Walter, M. F. (2003). Simple Estimation of Prevalence of Hortonian Flow in New York City Watersheds. Journal of Hydrologic Engineering. 8(4). pp. 214-218.

Wan, A, Z., Md. Nor, K., Mustofa, D. S. (1998). Map Projection : Second Edition. University Technology Malaysia. pp. 103.

Ward, A. D. and Trimble, S. W. (2004). Environmental Hydrology – Second Edition. Lewis Publishers. pp. 464.

Willgoose, G. and Perera, H. (2001). A Simple Model of Saturation Excess Runoff Generation Based on Geomorphology, Steady State Soil Moisture. Water Resources Research. 37(1) : pp. 147-155.

Wilson, J. P., Mitasova, H., Wright, D. (2000). Water Resources Application of GIS. Journal of Urban and Regional Information Systems Association. pp. 61-79.

Wolock, D. M. (2003). Infiltration Excess Overland flow estimated by TOPMODEL for the conterminous United States. http://water.usgs.gov/GIS/metadata/usgswrd/XML/ieof48.xml

WQI Report. (2006). The Study of Pollution Prevention and Water Quality Improvement of Sungai Pinang, Pulau Pinang. Unpublished.

Young, R.A., Onstad, C. A., Bosch, D. D., and Anderson, W.P. (1987). AGNPS, Agricultural Non-Point Source pollution model: A large watershed analysis tool. USDA. ARS Conservation Research Report. pp. 35, 77.