GIS Analysis for flood Hazard Mapping: Case Study; Segamat, Johor, West Malaysia

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Abstract

Although a natural disaster is the consequence of the combination of a natural hazard and human activities, human vulnerability, caused by the lack of appropriate emergency management, leads to financial, structural, and human losses. Malaysia is fortunate to be freed from natural disaster such as earth quake, volcano and typhoon. However, the most severe natural disaster experiencing in Malaysia is flood. Two major type of flood occur in this country are monsoon flood and flash flood. The monsoon flood occur mainly from Northeast Monsoon which prevails during the months of November to March with heavy rains to the east coast states of the Peninsula, northern part of Sabah and southern part of Sarawak. This study aims to highlight the potential usage of GIS techniques and analysis for floodplain and flood hazard mapping. The study area is the Segamat District, Johor, Southern part of West Malaysia. By using Autocad Map 2004 and Arcview 3.1, several GIS analysis using spatial analysis have been performed for floodplain mapping. The results obtained can be used by Local authorities or other flood related organizations for flood management, mitigation and control.

1.0 Introduction

A natural disaster is the consequence of the combination of a natural hazard (a physical event e.g. volcanic eruption, earthquake, landslide, flooding, etc.) and human activities. Human vulnerability, caused by the lack of appropriate emergency management, leads to financial, structural, and human losses. The resulting loss depends on the capacity of the population to support or resist the disaster, their resilience. A natural hazard will hence never result in a natural disaster in areas without vulnerability, e.g. strong earthquakes in uninhabited areas. The term *natural* has consequently been disputed because the events simply are not hazards or disasters without human involvement. The degree of potential loss can also depend on the nature of the hazard itself, ranging from wildfires, which threaten individual buildings, to impact events, which have the potential to end civilization.

A natural hazard is an event that has an effect on people resulting from the natural processes in the environment. Some natural hazards are related - earthquakes can result in tsunamis, drought can lead directly to famine and disease, flooding may cause the damage to properties and lives and so on. A hazard is a potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can also include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological and biological) or induced by human processes (environmental degradation and technological hazards). Hazards can be single, sequential or combined in their origin and effects. Each hazard is characterised by its location, intensity, frequency and probability.

Floods are conditions with the potential to cause damage and loss. Knowing this destructive potential and understanding the possible impact is a central condition for flood preparedness. On the other hand danger is used as a synonym for an imminent Hazard, threatening objects or individuals of a community. In this sense the term refers to the potentially damaging event that may harm individuals or cause material losses or damages to the environment. A disaster is a sudden and unexpected event which disrupt the functioning of a community or a society and causes widespread human, material, economic or environmental losses. Assistance from outside may be needed as the ability of the affected community or society to cope with may be exceeded. Flood related risk refers to the probability of harmful consequences, or expected losses resulting from interactions between natural hazards and vulnerable conditions. Harmful consequences can refer to death or injuries, losses on property or livelihoods, disruptions concerning the economic activity or environmental damages. *(http://flows.wb.tu-harburg.de/index.php?id=238)*

Floods are the major disaster affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems. It causes damage to lives, natural resources and environment as well as the loss of economy and health. The impact of floods has been increased due to a number of factors, with rising sea levels and increased development on flood plain.

GIS have been recognised as a powerful means to integrate and analyse data from various sources in the context of comprehensive floodplain management. Adequate information and prediction capability is vital to evaluate alternative scenarios for flood mitigation policies and to improve decision making processes associated with flood management. This comprehensive approach to flood problems is more than an attitude or a philosophical starting point. It makes use of specific technological tools conceived to be used by different actors, some of them being nonexperts in flood analysis. These tools, based on GIS, are very appropriate for a participatory approach to flood policy formulation and floodplain management because they help communicating with the public in a scientifically correct and yet rather simple manner. (http://cat.inist.fr/?aModele=afficheN&cpsidt=17916)

The main focus of this article is to highlight the capabilities of GIS analysis in identifying topographic and landcover factors related to flooding, floodplain mapping, mitigation and control as well as cost estimation for property damaged by flood in Malaysian situation. The study area is Segamat District, Johor. The purpose of this paper is to describe the use of a geographic information system (GIS) in flood management efforts for disaster preparedness, mitigation, and response, and summarize an ongoing effort to build a GIS-based decision support system for the southern part of Malaysia (Segamat, Johor).

2.0 Flood causes, mitigation and control

A flood is an overflow of water, an expanse of water submerging land, a deluge. In the sense of "flowing water", the word is applied to the inflow of the tide, as opposed to the outflow. There are many causes of flood such as coastal flood, urban (flash flood) and in the flood plain areas where many rivers flow. Since prehistoric time man has lived by the seas and rivers for the access to cheap and quick transportation and access to food sources and trade; without human populations near natural bodies of water, there would be no concern for floods. However fertile soil in a river delta is subject to regular inundation from normal variation in precipitation.

Floods from the sea can cause overflow or overtopping of flood-defences like dikes as well as flattening of dunes or buffs. Land behind the coastal defence may be inundated or experience damage. Floods from sea may be caused by heavy storm, high tide, a tsunami, or a combination thereof. As most urban communities are located near the coast, this is a major threat around the world.

Many rivers that flow over relatively flat land border on broad flood plains. When heavy deposition of silt on the rich farmlands and can result in their eventual depletion. The annual cycle of flood and farming was of great significance to many early farming cultures, most famously to the ancient Egyptians of the Nile river and to the Mesopotamians of the Tigris and Euphrates rivers .

When the slope down which a river runs has become very slight, it is unable to carry the sediment brought from higher regions nearer its source, and consequently the lower portion of the river valley becomes filled with alluvium. Since, in times of flood, the rush of water in the high regions tears off and carries down a greater quantity of sediment resulting in planation, with aggradation. That is, they may be due to a graded river working in meanders from side to side, widening its valley by this process and covering the widened valley with sediment. Or the stream -- by cutting into another stream (piracy), by cutting through a barrier near its head waters, by entering a region of looser or softer rock, and by glacial drainage -- may form a flood plain simply by filling up its valley (alluviation only). Any obstruction across a river's course, such as a band of hard rock, may form a flood plain behind it, and indeed anything that checks a river's course and causes it to drop its load will tend to form a flood plain. Still, flood plains are most commonly found near the mouth of a large river, such as the Rhine, the Nile, or the Mississippi, where there are occasional floods and the river usually carries a large amount of sediment. "Levees" are formed, inside which the river usually flows, gradually raising its bed above the surrounding plain. Occasional breaches during floods cause the overloaded stream to spread in a great lake over the surrounding country, where the silt covers the ground in consequence.

In modern geographic or geospatial studies, a **flood plain** is defined as a plain formed of sediment, typically dropped by a river. The emergence of this new science is mainly focus on five themes which is known as the **“Five Themes of Geography**”. This is mainly related to:

- ***Location*** – Where is it?
- ***Place*** – What is it like?
- ***Human/Environment Interaction*** – How is the Environment affected by humans? How does the Environment affect humans?
- ***Movement*** – How are places connected?
- ***Region*** – How and why is one area similar to another? How do areas differ?

This leads us to think and better understanding the nature of the occurrence, affected areas and the amount of damage caused by natural disaster **spatially**.

3.0 Flood studies in Malaysia

In recent years, severe flooding has occurred in several parts of Malaysia, both as localised flash floods and as basin-wide floods on major river systems. Some of the badly affected areas are situated at the river basins in Penang (Juru River Basin), Pahang (Pahang River Basin), Terengganu (Setiu River Basin) and Perak (Kinta River Basin). By their nature, floods are generated by the random coincidence of several meteorological factors but man's use of the river catchment also has an impact upon the severity and consequences of the events.

Malaysia is fortunate to be freed from natural disaster such as earth quake, volcano and typhoon. The most severe natural disaster experiencing in Malaysia is flood. Two major type of flood occur in this country are monsoon flood and flash flood. The monsoon flood occur mainly from Northeast Monsoon which prevails during the months of November to March with heavy rains to the east coast states of the Peninsula, northern part of Sabah and southern part of Sarawak. Some of the recorded flood experiences in the country occur in 1926, 1931, 1947, 1954, 1957, 1963, 1965, 1967, 1969, 1971, 1973, 1983, 1988, 1993, 1998 and 2001. Report from Department of Irrigation and Drainage stated that about 29,000 sq. km or 9% of total land area and more than 4.82 million people (22%) is affected by flooding annually. Damage cause by flood is estimated about RM915 million. While monsoon flood is govern by heavy and long duration rainfall, more localised flooding which covers a large area has been reported in recent years. Flood of October 2-6, 2003 that affected a large area in the northwestern part of the Peninsula covering states of Kedah, Penang and Northern Perak. Flash flood is reportedly occurring quite rapid such as two events occur in April 2002 and October in Kuala Lumpur which has been recognised due to uncontrolled development and activities within the catchment and flood plain (*Abd Jalil And Aminuddin*). Large floods had damaged properties, public utilities, cultivation, lost of lives and also caused hindrance to social and economic activities. Average annual flood damage is as high as RM100 millions. In February, 2006 Shah Alam was heavily flooded due to poor drainage system caused by surrounding development activities. In October 2006, Kelang area as well as Kedah & Perlis were severely flooded which was reported caused property damage and lost of millions of Ringgit. Figure 1 illustrates the flood prone areas in Malaysia.

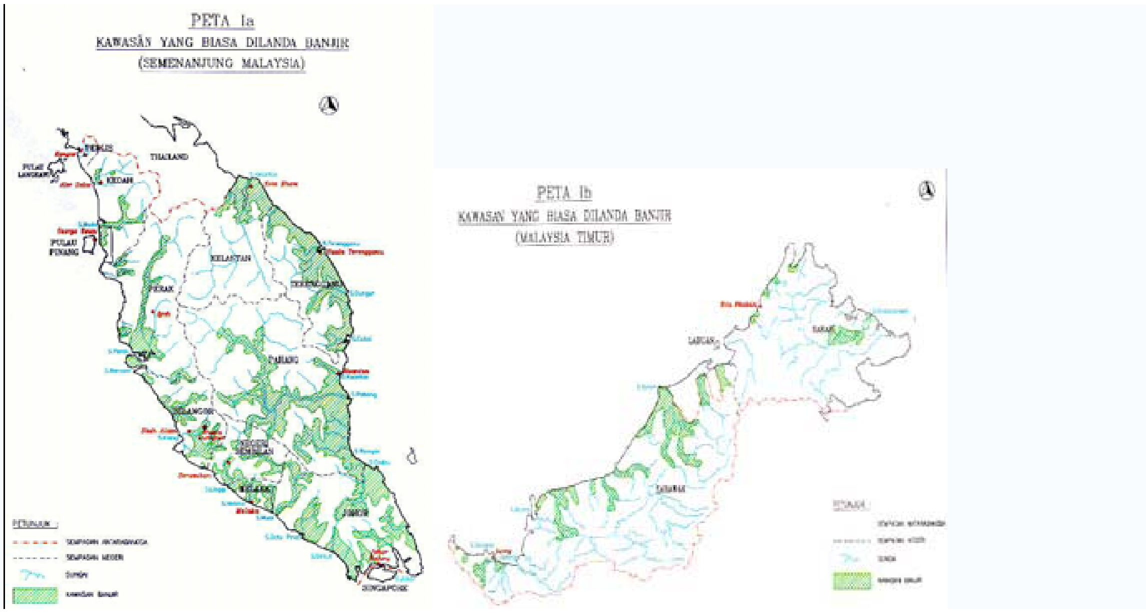


Figure 1: The flood prone areas in Malaysia.
(Source: Abd Jalil And Aminuddin)

There is no particular attempt yet in Malaysia to provide accurate flood risk maps taking into account of sediment movement along the river channel. Ab. Ghani *et. al* (1999) attemps to quantify the effects of sediment movement and corresponding cross-sectional changes in producing the flood levels. Successful applications of several sediment transport models such as HEC-6 and FLUVIAL-12 (Abu Hassan, 1998; Yahaya, 1999) indicate the possibility of extending the obtained results in mapping the flood prone areas by incorporating sediment transport bearing in mind the physical aspects of river ability to change its boundary. Sinnakaudan (1999) shows the possibilities in incorporating the river models and Geographic Information Systems (GIS) to map the spatial variation in sediment movement patterns.

There are some related studies have been conducted to highlight on various flood issues in Malaysia. These are among others, Ab. Ghani *et. al* (1999), Abu Hassan, (1998); Yahaya, (1999), CTI Engineering International CO., LTD,(1999), DID.(1994), DID. (1999), MPSP(a) (1999), MPSP(b) (1999) and Sinnakaudan, S. (1999).

(http://www1.eng.usm.my/redac/html/IRPA/floodrisk/Research%20Background.htm)

At present, the development of flood risk map is still very slow process and insufficient to be used for the analysis and the information in the flood plain i.e. ground data and the infrastructure are not readily available.

Mitigation is the cornerstone of emergency management. It is the ongoing effort to lessen the impact of disasters on people and property. The non-structural methods of mitigation of flood hazards are less expensive as compared to structural ones (dams and dikes). Among non-structural methods, modern flood forecasting and real-time data collection systems have grown favor in countries prone to flood hazards. However, flood mitigation and control in Malaysia are still disintegrated and still no Flood Decision

Support System available to be used for flood monitoring, mitigation and control. The development of Decision Support System for flood risk assessment is vital in flood forecasting and warning for administrative machinery involved in rescue and evacuation work. The importance of the flood forecasting and warning is widely recognized as a vital non-structural measures to aid the mitigating- the loss of life, crops and property caused by the annual flood occurrence.

Preparedness provides leadership, training, readiness and exercise support, and technical and financial assistance to strengthen citizens, communities, State and local governments, and professional emergency workers as they prepare for disasters, mitigate the effects of disasters, respond to community needs after a disaster, and launch effective recovery efforts (Venkata and Rajiv).

The development of Decision Support System for flood plain mapping and risk assessment requires a proper planning in flood database design and developments. This is the major role of GIS to be used as a tool for flood modeling and analysis on various issues related to flood hazard.

4.0 GIS Application for Floodplain mapping and Analysis for Segamat

Nowadays GIS is emerging as a powerful tool for the assessment of risk and management of Natural Hazards. Due to these techniques, natural hazard mapping can be prepared now to delineate flood prone areas on the map. Such kind of maps will help the civil authorities for quick assessment of potential impact of a natural hazard and initiation of appropriate measures for reducing the impact. Such data will help the planners and decision-makers to take positive and in time steps during pre disaster situation. It will also help them during post disaster activities for the assessment of damages and losses occur due to flooding. Moreover, GIS provides a broad range of tool for determining areas affected by floods or forecasting areas likely to be flooded due to high discharge of the river.

A Geographic Information System (GIS) is a tool that can assist floodplain managers in identifying flood prone areas in our community. With a GIS, geographical information is stored in a database that can be queried and graphically displayed for analysis. By overlaying or intersecting different geographical layers, flood prone areas can be identified and targeted for mitigation or stricter floodplain management practices.

For the analysis and generating floodplain maps, the district of Segamat, northern part of Johor state is selected for the study area (Refer to Figure 2). Total study area is 287,000 hactres. Data used in this study originally produced by Directorate of National Mapping Malaysia (JUPEM) as topographic maps series L7030 at scale of 1:50 000 with 20 metres contour intervals. Other data such as geological structure, utilities and landuse are taken from Johor Structure Plan studies 2002. Other data such as buildings, precipitation and hydrologic data were not available at this time and this will be used in future study provided the data is readily available. Two different software were used in this study, Autocad Map 2004 and ArcView 3.1. Data preparation, processing and editing were made using Autocad and then converted to GIS format (*.shp) for database development and perform GIS analysis using ArcView.

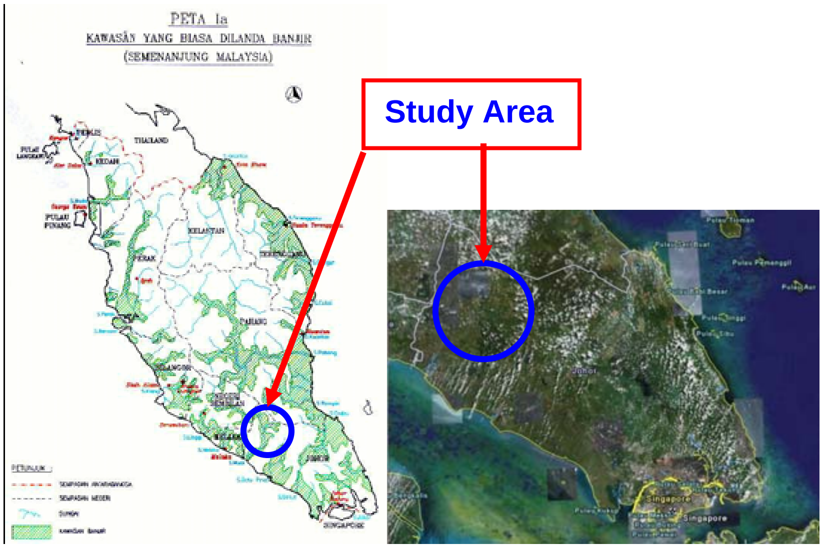


Figure 2: Study Area – Segamat, Johor

5.0 Results and Analysis

The results obtained from this study are illustrated in Figure 3 – Figure 12. The results indicated that the low lying areas along two main rivers running north-south and the other from east- west are exposed to flooding. This is known as floodplain. Total Floodplain area = 90 054 hactres and Total District area = 287 281.340 hactres. Thus, total floodplain area is about 31% of the whole area of Segamat District. Rivers flowing east-west came from the catchment area on the east side of Segamat District at height of about 760 metres to flooplain area where the height is less than 20 metres at distance of 26 km (Refer to Figure 4). This may cause severe flooding during heavy rain since the water carrying capacity will reach the floodplain area in short time.

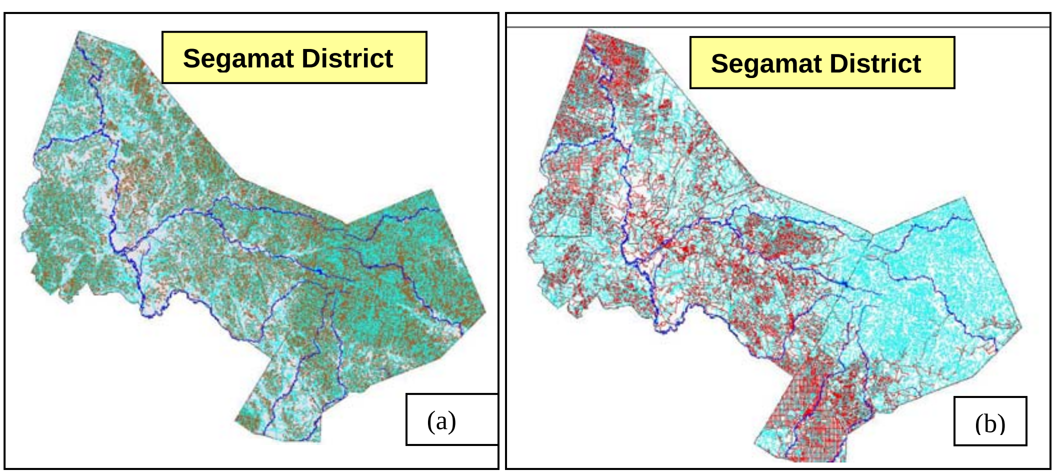


Figure 3: Segamat district. Data consist of (a) district boundaries, main rivers and contour lines (b) Rivers and roads netwoks

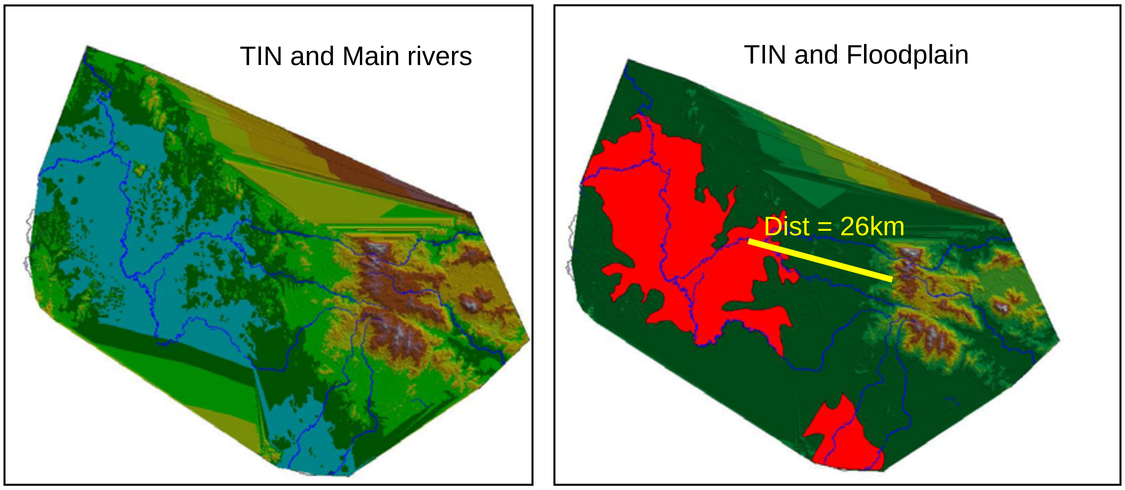


Figure 4: Results of Triangular Irrigular Network (TIN) combined with main rivers and flood plain zone

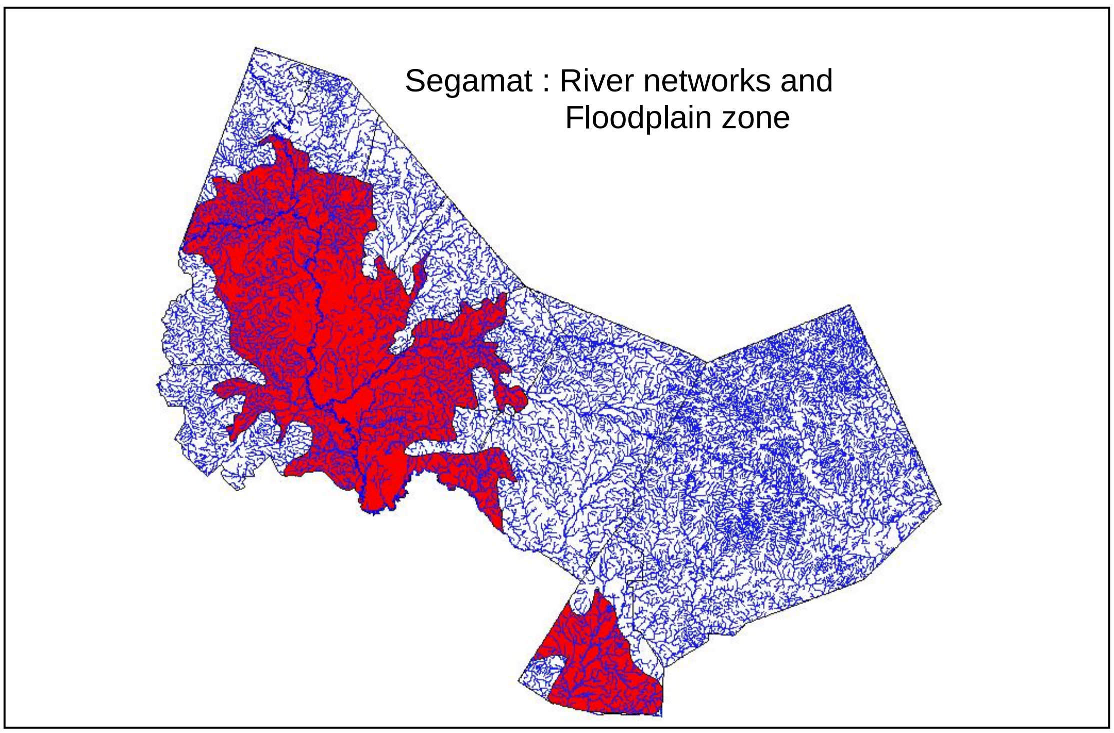


Figure 5: Illustrates river networks in Segamat District contributed to flooding

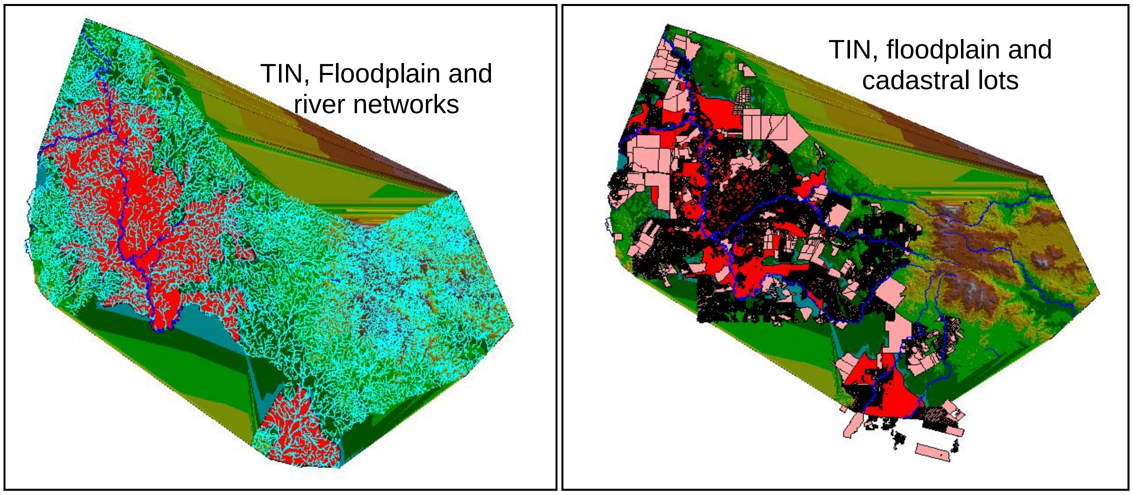


Figure 6 : Results of overlay several layers : floodplain, river networks and cadastral lots on TIN.

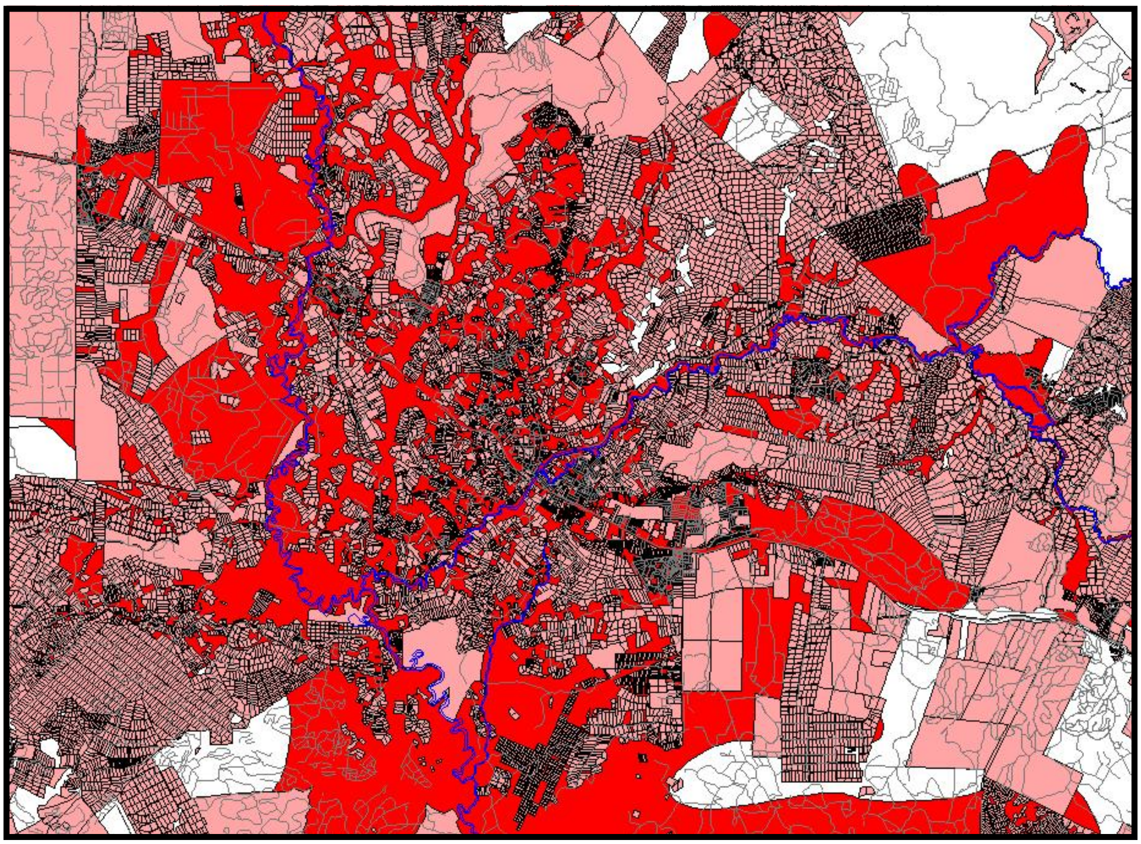


Figure 7 : Segamat Town area (cadastral lots) situated on the floodplain zone (red)

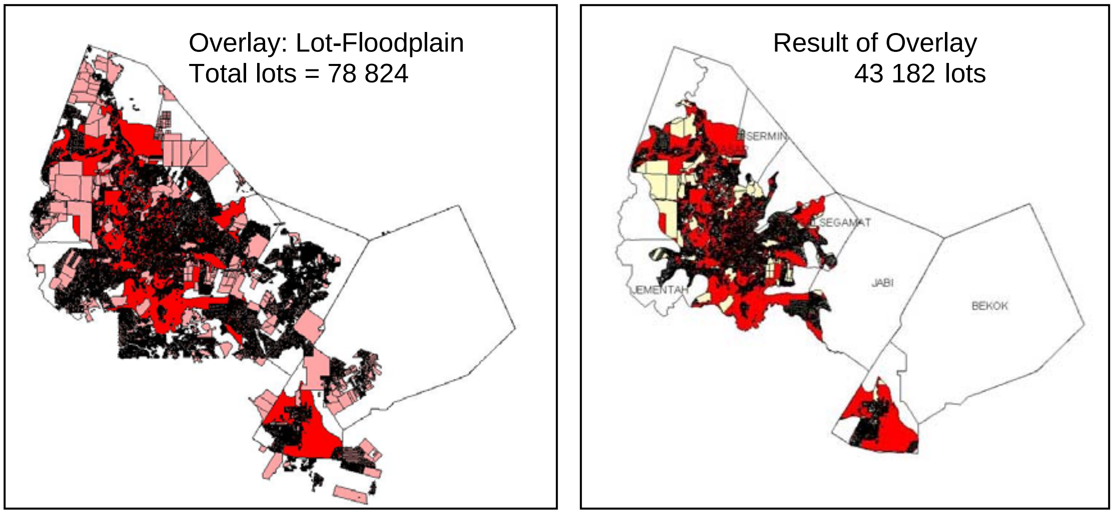


Figure 8 : Illustrates (43 182 lots out of total lots of 78 824) about 55 % cadastral lots are exposed to flooding

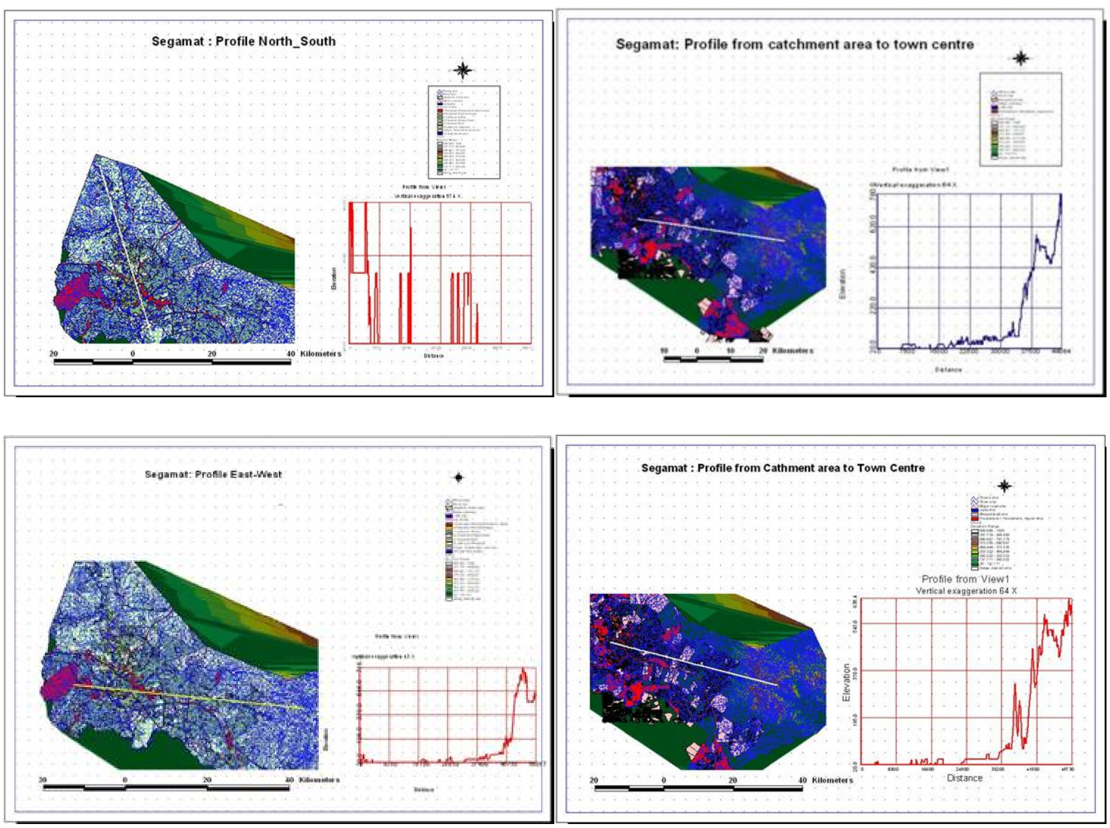


Figure 9 : Results of analysis on the profile (North-South and East-West) of study area.

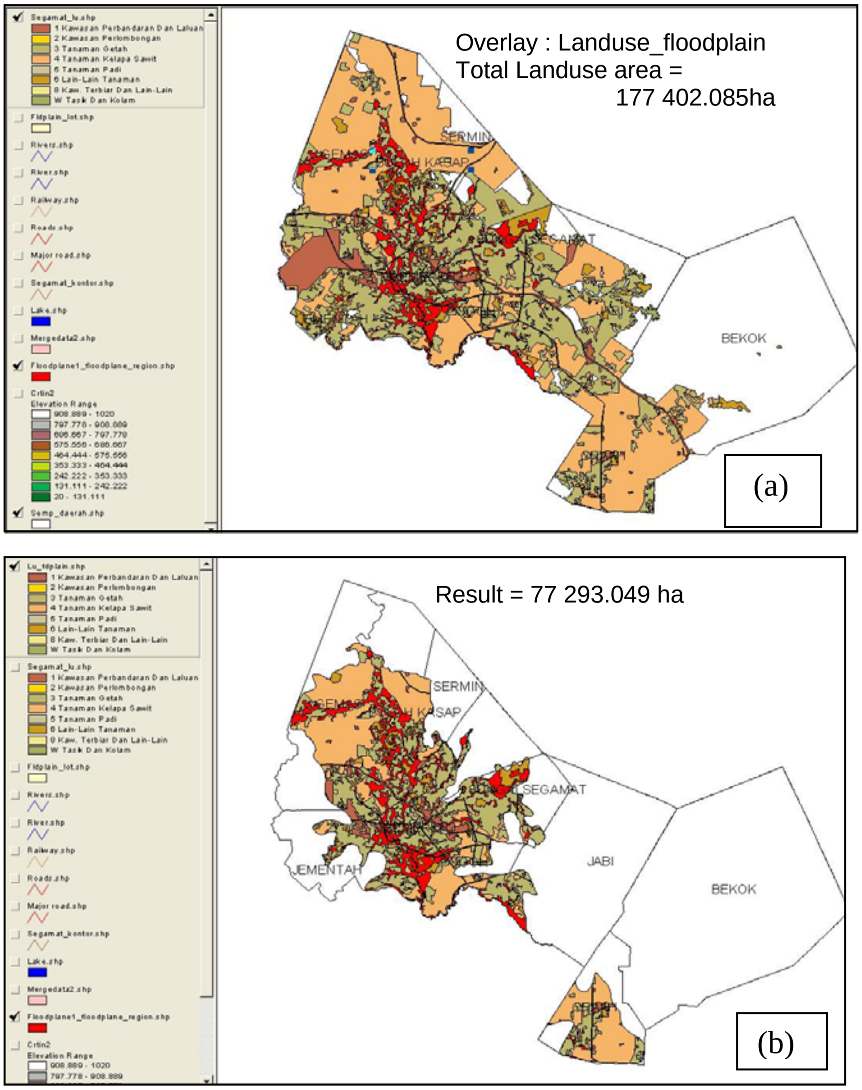


Figure 10 : Results show that about 44% of the landuse area is exposed to flooding

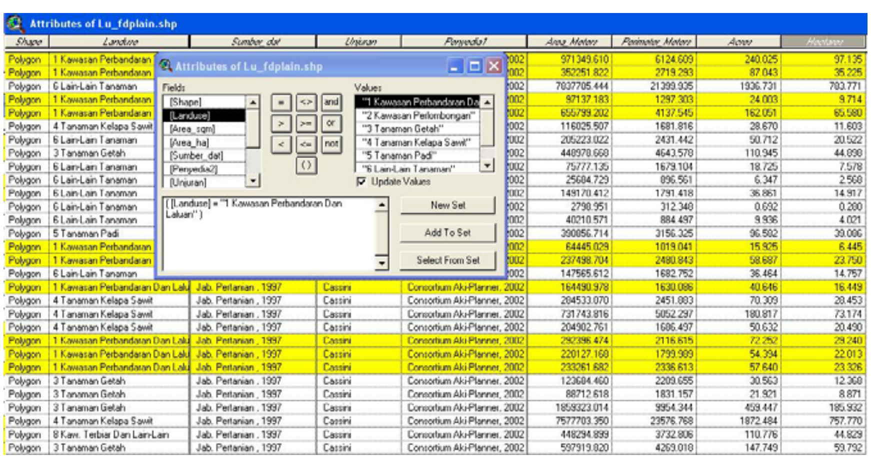
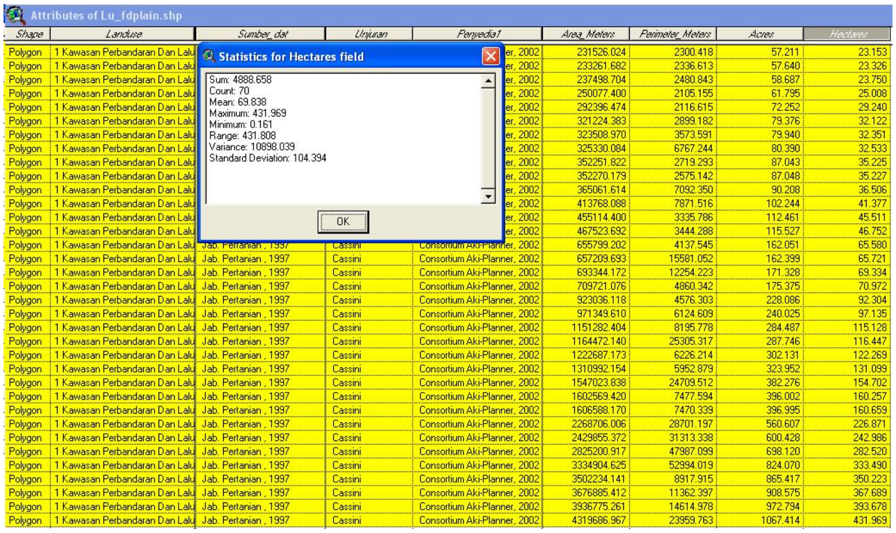


Figure 11 : Query of Landuse type for (urban) town area and statistical calculation



Shape	Landuse	Sumber_dat	Unjuran	Penyedia1	Area_Meters	Perimeter_Meters	Acres	Hectares
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	231526.024	2300.418	57.211	23.153
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	233261.682	2336.613	57.640	23.326
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	237498.704	2480.843	58.687	23.750
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	250077.400	2105.155	61.795	25.008
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	292396.474	2116.615	72.252	29.240
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	321224.383	2899.182	79.376	32.122
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	323508.970	3573.591	79.940	32.351
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	325330.084	6767.244	80.390	32.533
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	352251.822	2719.293	87.043	35.225
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	352270.179	2575.142	87.048	35.227
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	365061.614	7092.350	90.208	36.506
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	413768.088	7871.516	102.244	41.377
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	455114.400	3335.786	112.461	45.511
Polygon	1 Kawasan Perbandaran Dan Lalu			er, 2002	467523.692	3444.288	115.527	46.752
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	655799.202	4137.545	162.051	65.580
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	657209.693	15581.052	162.399	65.721
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	693344.172	12254.223	171.328	69.334
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	709721.076	4860.342	175.375	70.972
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	923036.118	4576.303	228.086	92.304
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	971349.610	6124.609	240.025	97.135
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	1151282.404	8195.778	284.487	115.128
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	1164472.140	25305.317	287.746	116.447
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	1222687.173	6226.214	302.131	122.269
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	1310992.154	5952.879	323.952	131.099
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	1547023.838	24709.512	382.276	154.702
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	1602569.420	7477.594	396.002	160.257
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	1606588.170	7470.339	396.995	160.659
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	2268706.006	28701.197	560.607	226.871
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	2429855.372	31313.338	600.428	242.986
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	2825200.917	47987.099	698.120	282.520
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	3334904.625	52994.019	824.070	333.490
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	3502234.141	8917.915	865.417	350.223
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	3676885.412	11362.397	908.575	367.689
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	3936775.261	14614.978	972.794	393.678
Polygon	1 Kawasan Perbandaran Dan Lalu	Jab. Pertanian , 1997	Cassini	Consortium Aki-Planner, 2002	4319686.967	23959.763	1067.414	431.969

Figure 12 : Statistical calculation for rubber and Oil Palm Plantation (Agriculture Landuse type)

The results of GIS analysis on landuse types lying on the floodplain can be summarized as follows :

Town Area	=	4 888.650 ha (about 6.3% of the total landuse on floodplain)
Rubber Plantation	=	32 702.144 ha (about 42.3% of the total landuse on floodplain)
Oil Palm Plantation	=	33 571.902 ha (about 43.4% of the total landuse on floodplain)

This will be useful information for the management of the Local Authority, to plan for flood preparedness, mitigation and control as well as to estimate the damage before or after the flooding. Further studies would be focused on the analysis of erosion and deposition as well as for environmental control especially for water and air pollution studies.

6.0 Conclusion

GIS techniques and analysis proven to be a valuable tool for various analysis and application. This has been used for quite sometimes in mapping, modeling and analysis of variety of applications in natural hazard or disaster at various levels and scales. This study highlights the potential use of GIS techniques and analysis for floodplain mapping for Segamat area. The results and analysis of this study to some extent will help the Segamat Local Authority to evaluate the potential damage of the properties and can be used for flood mitigation, control and management. However, this is not a comprehensive study, since the data layers are limited to topographic and landuse only. In order to carry out a thorough GIS analysis the data layers should be collected and added to the present GIS database. Data should be collected from all drainage and flood defence organisations in the State Planning Authorites area regarding historic flood events. The data should include:

The date and time of the flood event.
The climatic conditions at the time of the event (e.g catchment conditions, intensity of rainfall, flood flows, tide level, wave height).
The climatic conditions leading up to the event.
Estimated storm return period.
Extent of flood envelope and depth of flooding
Local unique factors which may have affected the shape of the flood envelope (e.g blocked weed screens, obstructions in watercourses, failed pump etc).
The impact of the event – properties affected, damage and disruption caused.
The duration of the flood (e.g how long to seal breach, clear floodwater etc).

The data layers to be considered and incorporate into GIS database may include:

Planning area boundaries, typically defined by the 100-year frequency floodplain
Topography, soils, geology, and mineral resources

Hydrology, including surface drainage patterns, channel morphology, and geohydrology

Biological resources, including fisheries and wildlife, forest, vegetation and habitat

Water resources, including water quality, watershed hydrology, and groundwater systems

Land use, including forestry, recreation, agriculture, aquaculture, and residential, commercial, and industrial uses

Descriptions of current land use, zoning, and projected development trends

Population, current and projected trends

Transportation and utility systems, including navigation characteristics

Scenic, aesthetic, and historic/cultural resources.

In conjunction to the response of people to disasters whether it is volcano, earthquake or flood, there are generally four options for human response to disasters:

- to protect (prevent and modify disasters);
- to accommodate (change human use system to suit disasters);
- to retreat (resettlement, forbid development in disaster zones, migration); and
- to do nothing

The first two options are proactive and are usually first considered for effective disaster management while the last two options are passive responses usually taken as an attitude of resignation that little can be done about disasters

As a conclusion, GIS can be a useful tool for floodplain mapping, management and planning. CAMA-GIS Group is continuously finding new uses for GIS and hopes to add additional data layers and expand its capabilities in the future especially for flood damage assessment on properties.

7.0 References

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