# Measurements and Documentation for Flood and Erosion Monitoring and Control in the Niger Delta States of Nigeria

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**Key words:** Gully erosion, rill Erosion, GPS, Remote sensing, GIS

**SUMMARY**

Flooding and erosion are serious ecological problems in Nigeria. National and state governments have tried to give the problems the attention they deserve because of the serious negative impact they have on agricultural productivity, lives and properties in both urban and rural environments. These impacts assume greater dimensions in urban areas and regions with limited land areas such as the Niger Delta region of Nigeria.

In general, any human activity that modifies the land is a potential catalyst for soil erosion and flooding. Such human induced impacts are of great concern in environmentally sensitive areas and in regions with scarce land resources as exemplified by the Niger Delta region.

As a result of the above, the Niger Delta Development Commission NDDC recently commissioned research consultants to carry out research profile on flood and erosion in the region. Measurements carried out by the authors for monitoring and control of flooding and erosion in some Niger delta states are discussed in this paper. These included using satellite imageries a long with GPS and total station instruments for watershed, flood basins and erosion gullies sites to determine their spatial extent, acquisition of baseline data for monitoring of bank slumping and sliding in erosion gullies and hill slopes. The results of the measurements in combination with meteorological data,. Hydrology, hydrogeology, geology, geomorphology, soils, etc were used for erosion and flood risk sensitivity and vulnerability analysis. They also form a data base for severity ratings of the flood and erosion sites for mitigation and management purposes.

# Measurements and Documentation for Flood and Erosion Monitoring and Control in the Niger Delta States of Nigeria

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## 1. INTRODUCTION

Flooding and erosion are serious ecological problems worldwide. In Nigeria, the federal and state governments have attempted to give both problems some attention even though inadequate. The twin problems of flooding and erosion have serious negative impact on both agricultural productivity, lives and properties in both urban and rural environments. These impacts assume greater dimensions in urban areas and regions with scarce land resources such as the Niger delta region of Nigeria where as a result of exploration and exploitation of oil and gas, a large proportion of the land area have been degraded and therefore unsuitable for farming. In general, any human activity that modifies the land is a potential catalyst for soil erosion and flooding.

Flooding is one of the water related environmental problems the magnitude of which is very much dependent on land use practices in the watershed of each river or stream. Riverine floods occur when the amount of run-off originating in a watershed exceeds the carrying capacity of natural constructed drainage system (Khalequzzama 1999).

Documentation of flood in form of flood depth, area affected, damage to crops, damage to infrastructure, number of people affected and overall monetary damages need to be quantified. Long-term factors contributing to inertia frequency and duration of flood need to be studies. Once the causes of the problem are determined then preventive measures can be taken to reduce future damages caused by flood.

Soil erosion on the other hand is mainly affected by vegetation cover, topographic features, climatic variables and soil characteristics. Human activities and large scale developments alter vegetation cover. Surface run-off can easily wash away the top soil from cultivated lands. This surface erosion reduces land elevation which in turn increases flood intensity in an area (Dregne 1987, Thapa and Weber 1991). Unwise land use practice results in increased rates of soil erosion and sediment discharge to rivers.

Rapid population growth creates extra pressure on lands in urban areas, agricultural lands give way to housing development and roads without adequate drainage facilities give rise to flooding and erosion problems (Ehiorobo et al 2010) The amount of soil erosion is in the main affected by vegetation cover, topography, climatic variables and soil characteristics (Suresh 2007, Yuksel et al 2008)

Human activities give rise to removal of vegetation cover then leading to increase in the rate of soil erosion. Topographic features such as ground slope, length and shape affect rill erosion.

Erosivity which consists of amount of rainfall and precipitation intensity are most important climatic factors affecting the amount and rate of soil erosion:

The intensity and amount of rainfall in recent times has resulted in some of the most significant flooding and erosion experienced within the Niger Delta region in the last years. With climate change, heavy and damaging storms will continue to increase in frequency.

Temperature also has an effect on vegetative materials which are used as mulching to control erosion.

Soil erodibility is a factor of physical characteristics of soil and land management practices.

The physical characteristics of the soil include; soil texture, structure, organic content (Suresh 2007). Gully erosion is a highly noticeable form of soil erosion and can affect soil productivity and impair roads and water ways (Worrell 2007). Many erosion gullies start as narrow rills with a down slope orientation and with time as a result of increased run-off undergo progressive widening and deepening. Most of the above type of gullies tend to occur on bare soil surfaces, created by human and animal foot traffic and wheeled traffic in off-road locations and also by the grading of the soil along the sides of roads (Suresh 2006).

Within the Niger Delta region, erosion gullies are formed primarily by surface run-off from high intensity rainfall events on the fine-to coarse grained sand of the Benin formation. The gully forming process yield a degraded terrain in which deep and wide gullies are formed within some states such as Edo, Delta and Cross River states.

Within the region, the gullies originate as rills with a down-slope orientation which undergo progressive widening and deepening with successive rainfall events. This is typical with most of the erosion gullies in Edo and Cross River States, the study areas.

Rainfall intensities exceeding design capacity of drainage systems results in surcharging in urban areas such as Benin City, Calabar, Auchi, etc. Assessing the soil erosion rate is essential for the development of adequate erosion prevention measures for sustainable management of our scarce land resources within the Niger Delta region. A flood and erosion management system in general will require a meteorological model to forecast the rainfall, a hydrological model to convert rainfall to a run-off, a hydraulic model to route the flow through the stream network and to predict timing and severity of the flooding, a decision support model to convert results to an early warning system and take necessary action, and socio-economic assessment model to evaluate damage caused by flooding and erosion and take necessary action (Koussen et al 2003, Cesur 2007,Adebe and Price 2005)

GIS technology is a valuable tool in developing environmental models and they include space and time as a common denominator and also possess advanced features for data storage, management analysis and display. Geoinformation technology aside from being used to integrate various models also enable us to acquire information about the environment. Remote sensing technology provide land use and land cover images which when combined with ground survey data by GPS and Total station instrument enable us to model soil erosion and other environmental hazards. The integration of these various Geoinformation technologies do not only enable us to estimate soil loss but they provide the spatial distribution of the flood and erosion sites. Accurate erosion risks and sensitivity index maps can be generated by the system (Ehiorobo et al 2010, Yuksel et al 2008)

### 1.1 The Study Area

The Niger Delta region of Nigeria is situated within the Gulf of Guinea and covers an area of approximately 80,000sq kilometers representing about 8% of Nigeria's land mass. The estimated population of the region is twenty-eight million and the people are predominantly farmers and fishermen The states that make up the region include Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo and Rivers.(Fig 1)

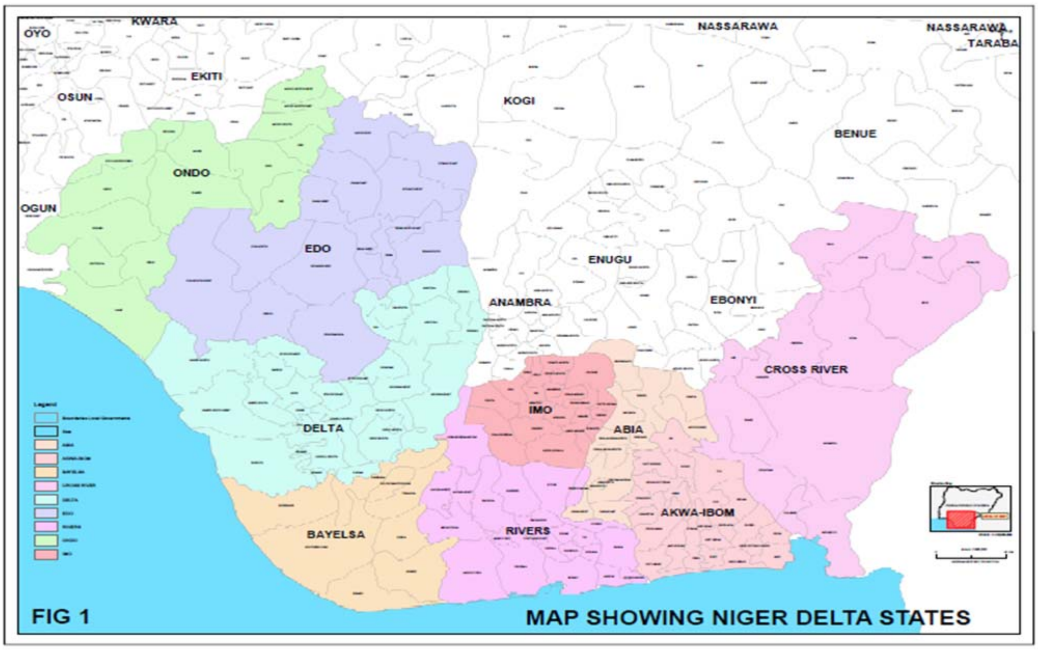


Fig 1: Map Showing Niger Delta States.

Nigerian economy depends mainly on oil and gas and the country's crude oil production within the Niger Delta region averages 2,118 million barrels per day and 90 – 95% of the export revenue is derived from the oil and gas.

In this region, flooding and erosion is prevalent mostly as a result of human intervention or a combination of human impact and natural events. Due to oil exploration and exploitation activities, construction of export pipelines, tank farms, canals, etc a lot of farm lands are lost and flooding and erosion set in. The activities of the oil companies, unplanned construction activities, stripping of land surfaces has placed the zone as among the most prone to the effect of flooding and erosion in Nigeria. In Cross River State alone for instance, it is estimated that there are over 300 active flood and erosion sites in the state (Ehiorobo et al 2010).

In the urban areas many of the flooding problems are the result of a lack of coordinated land Use planning and control of property development for over 30 years. This is why the Niger delta Development commission (NDDC) recently commissioned consultants to carry out multidisciplinary research on flood and erosion profile in some selected states within the Niger Delta region as a pilot project.

The authors are currently carrying out research work on flood and erosion profile in Edo and Cross River states. Edo state which was created in 1991 out of the old Bendel state is one of the Niger Delta states and has a population of about 3.2 million. The state lies between latitude 05° 44' to 07° 34'N and longitude 05° 04' and 06° 45' E and covers a land mass of about 19,635sqKm (Fig 2). The land mass has relatively flat terrain in the southern part with dissecting plateau and hills in the Northern part of the state. Slopes of varying gradients exists and this contributes to the problem of gully erosion in the state. The state lies within the rain forest belt in the southern and central district and Guinea Savanna vegetation in the North. There is relatively high rainfall, the average annual rainfall ranges from 1400mm in the northern extremity to 2,000 mm in the south. There are two seasons; the dry and the wet season. The wet season lasts from April to October while the dry season lasts from mid October to March.

The geology of this area consists of the crystalline basement rocks in the hilly and dissected zone in the north followed southwards by residual lateritic soils of the well drained dry lands at Auchi, Agbede and Afuze. Further south is the continental deposits of the Benin formation. The flood plains further inland are composed of medium-coarse point bar sands and clayed back swamp deposit.
The growing menace of flooding and gully erosion can be traced to particularly the geology and topography of the region. Gullying which is rapidly developing in many areas due mainly to the urbanization has been identified mostly in terrain covered by friable and highly erodible soil deposits such as the gully site in University of Benin, Queen Ede, in Edo South, Ibore and Emu in Edo Central, Orle-Oshiobugie and Ikabigbo in Edo North. (Fig. 2)

### 1.2 Aims And Objectives

The aims of the project are to identify the mechanics and dynamics and the factors responsible for flood and erosion with a view to prescribing appropriate management plan to address current problems and the measures against future occurrence and spread.
The objectives include:

- To locate and verify flood and erosion prone areas
- Carry out flood and erosion vulnerability assessment of the study area
- Acquire meteorological, hydrological, geological, geotechnical and other data on flooding and erosion prone areas
- Carry out modeling of flood and erosion phenomena
- Carry out modeling and simulation of climatic change induced flooding and erosion
- Create a data base model for flood and erosion management and control
- Identify areas where activities need continuous monitoring
- Recommend structural and non-structural flooding and erosion control measures for implementation by government.

## 2. METHODS

Satellite remote sensing and other space based systems provide the information needed in the space, time and frequency domain for flood and erosion monitoring.

Remote sensing offers a synoptic view of the spatial distribution and dynamic of hydrological phenomenon such as flood and erosion. They are used to measure and monitor the extent of flooded areas, provide a quantifiable estimate of the land area and infrastructure affected by flooding and erosion.

In order to plan for appropriate flood and erosion control, it is necessary to acquire timely and reliable geospatial information about the flooded areas, water sheds, river and streams configuration prior to, during and after flood events. The use of conventional survey methods alone are quite inadequate in providing such information.

Various earth observation satellites provide comprehensive synoptic and multispectral coverage of large areas in real time. The use of high resolution satellite imagery contribute greatly to the understanding of various parameters relevant to rainfall run-off analysis, flood forecasting and flood zone mapping including flood drainage assessment.(Khana et al 2001). Soil erosion prediction technologies are mathematical procedures that estimate rates of erosion, sediment delivery and sediment characteristics for specific sites as a function of weather, soils, topography and Land use (Foster 2001).

Geoinformation technology combines space based sensors and ground based earth observation systems to generate spatial models for current and future analysis of flooding and erosion events. Incooporation of remotely sensed data into a GIS allows for quick calculation and assessment of flood levels, damages and areas facing potential flood and erosion risk.

In order to achieve the set objectives in this study a preliminary survey was carried out to identify the major flood and erosion sites in the state. This was done using Google imagery and 1:50,000 topographical maps, covering the state. The locations were then geo reference with the aid of GPS receivers. The GPS derived coordinates were converted to NTM coordinates using GEOMATRIX software and exported into a base map covering the state (Fig 2) .Using severity rating based on length, depth and width of erosion gullies and area of flood basins, some of the sites were selected for detailed studies.

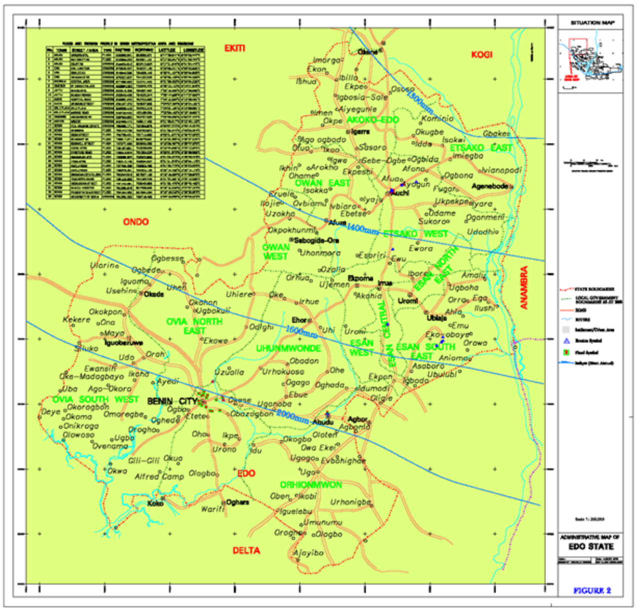


Figure 2: Map of Edo State

The gullies selected included university of Benin and Queen Ede Gully sites in Edo south (fig 3a), Emu and Iboren gully sites in Edo central district, (fig. 3b) Ikabigbo and Oshiobugie Gully sites in Edo North (fig. 3c) ,flooded area in Benin City(fig.4). Preliminary attribute data acquire included metrological data fron Benin airport metrological state, river discharge data from Benin-Owenna river basin development authority.

**Figure 3(a): University of Benin and Queen Ede Gully sites.**

**Figure 3(b):Emu and Ibore Erosion Gully sites.**

**Figure 3(c ): Orle Oshiobugie and Ikabigbo Erosion Gully sites**

**Figure 4: Flooded area by Teachers House in Benin City**

The first phase of field surveys was completed in December 2010. This included detailed topographical surveys of the erosion gullies using Leica Total station instrument, location and assessment of spatial coverage of flood basins from Google imagery. The imageries for the University of Benin and Queen Ede Gully sites are presented in figure 5a and 5b. XYZ coordinates generated from the total station measurement were stored in Microsoft excel file format. They were thereafter imported into the ArcGIS environment using the Add XY menu. The project coordinates system were then specified in (Nigeria West Belt) and then exported into personal Geo data base as shape files for each of the erosion sites. The shape files containing the elevation data were then added and a Triangulated Irregular Network (TIN) created using the Z coordinates. The DEM (Digital Elevation Models) were generated by converting the TIN into Raster. Contours lines were generated using the created TIN to interpolate for the contour with the aid of 3D analyst extension. ArcScene was then used for the visualization of the 3D model generated from the TIN.

The Edo state Government recently commission a construction company to develop drainage master plan based on satellite imagery contours. The mapping of the project area by means of Lidar survey is planned. The survey is to be flown at a low altitude to counter the cloud cover present over Benin City.

Control points have been established and referenced by GPS method and these are to be used as reference for the Lidar survey. The anticipated accuracy of the Digital Elevation model is expected to be 10-15cm (High-tech Benin City 2010). The results from this survey will be used to prepare flood inundation maps which will be used to:

- Define spatial extent of flood inundation within the city.
- Identify likely worst flood affected areas during storms.
- Evaluate impact of flooding on infrastructure and utilities within the city.

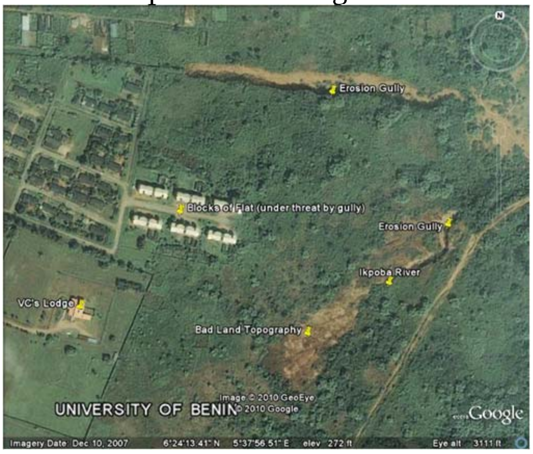


**Figure 5(a): Satellite Imagery of University of Benin Erosion Gully Site I**


**Figure 5(b): Satellite Imagery of Queen Ede Erosion Gully Site I**

## 3. RESULTS AND THEIR DISCUSSION

In Edo state, thirty five flood and erosion sites were identified from Spot imageries. Of the 35 sites identified in the state, six erosion gully sites and four flood sites were selected for detailed studies based on severity rating. The selected sites are presented in Table II below. The table gives the location, area affected by flooding and size of gullies, as obtained from the satellite imageries and general ground surveys

**TABLE I: Selected Flooding and Erosion Sites for Detailed studies**

| S/N | Description of location | Type of problem | coordinates | | Area Flooded (hec) | Gully length (km) | Remark |
|---|---|---|---|---|---|---|---|
| | | | X | Y | | | |
| 1 | **University of Benin** | Erosion | 266062.513 | 356179.253 | 300 | 1.8 | |
| 2 | **Queen Ede area Benin City** | Erosion | 259469.751 | 361342.934 | 250 | 2.4 | |
| 3 | **Use/Siluko Road** | Flood | 261545.004 | 350900.371 | 150 | - | |
| 4 | **Ighomo/Ahile/Uwasota Benin City** | Flood | 263486.004 | 352214.607 | 180 | - | |
| 5 | **Uwelu Road area** | Flood | 261041.608 | 352530.164 | 150 | - | |
| 6 | **Emu town** | Erosion | 281724.328 | 444692.147 | 280 | - | |
| 7 | **Ibore** | Erosion | 307927.000 | 430839.000 | 450 | 4.5 | |
| 8 | **Oshiobugie** | Erosion | 339475.810 | 424947.464 | 480 | 1.5 | |
| 9 | **Ikabigbo** | Erosion | 342794.065 | 434407.197 | 130 | 1.3 | |
| 10 | **Ilushi** | Flood | 318137.428 | 464109.870 | 350 | - | |

In order to understand the phenomenon giving rise to the above environmental hazards site analysis was carried out using a combination of satellite imageries obtained from SPOT and field survey data. Based on these data various maps were produced. (Fig 6a and b) show the location map for the university of Benin and Queen Ede erosion sites, the spot height and contoured maps of the sites are shown in figure 7 and 8 respectively. Triangulate irregular network Tin was used to provide 3D models of the same sites fig. 9 gives a triangulation Irregular Network (TIN) model for the sites

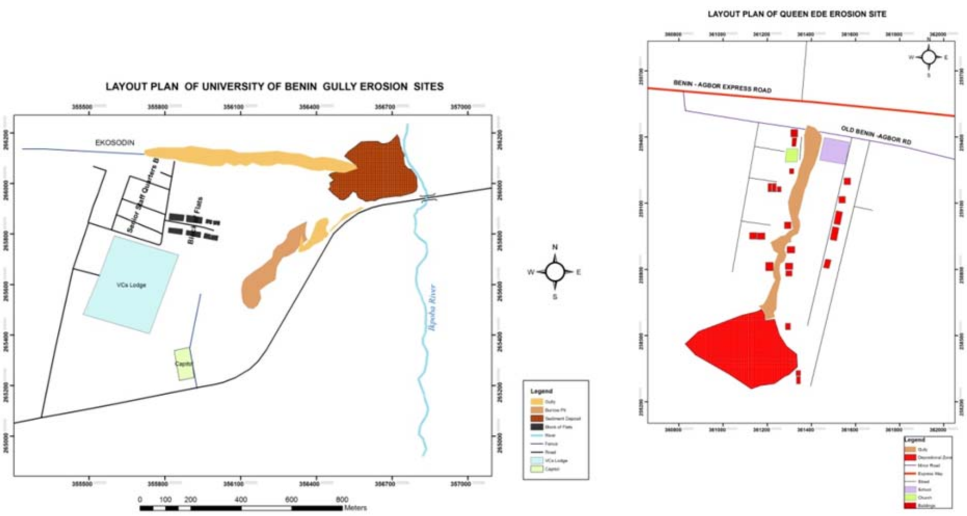

**Figure 6: Layout of University of Benin and Queen Ede Gully Erosion Sites**

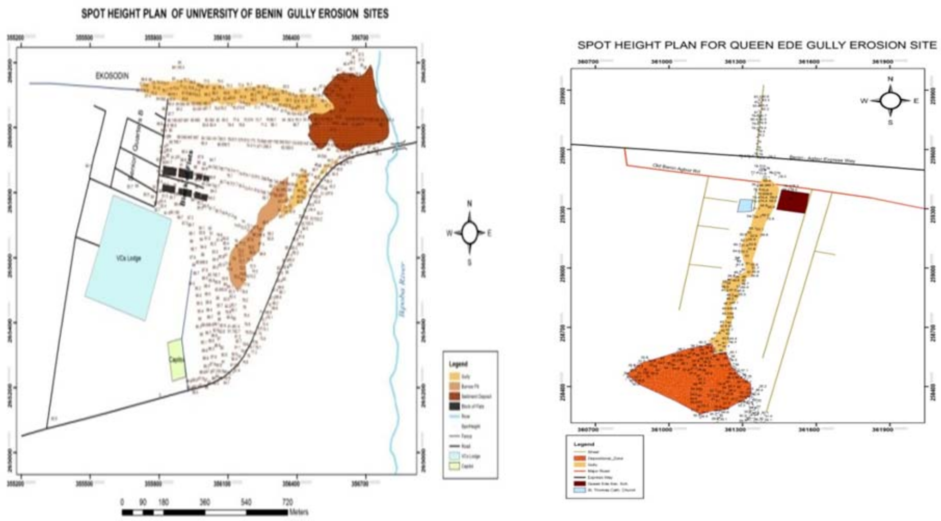


**FIGURE 7: SPOT HEIGHT PLAN OF UNIVERSITY OF BENIN AND QUEEN EDE GULLY EROSION SITES**

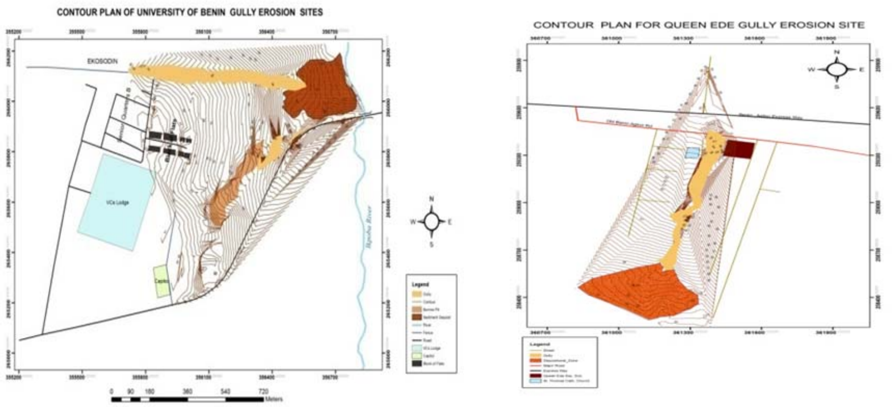


**Figure 8: CONTOUR PLAN OF UNIVERSITY OF BENIN GULLY AND QUEEN EDE EROSION SITES**

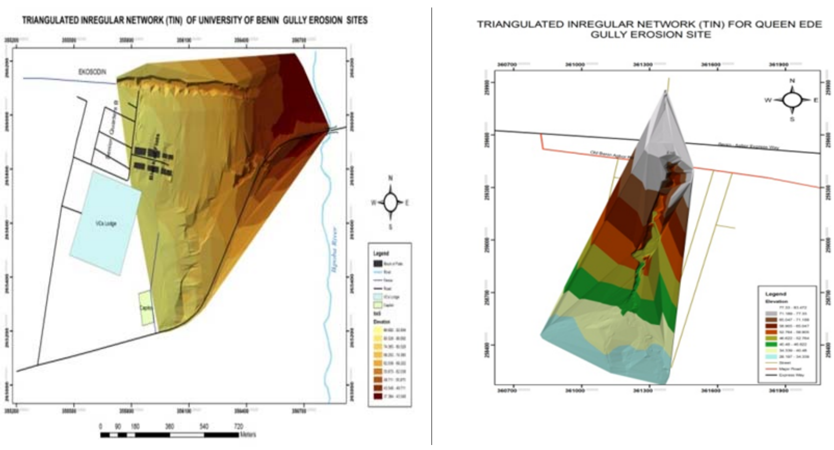

**FIGURE 9: TRIANGULATED IRREGULAR NETWORK (TIN) OF UNIVERSITY OF BENIN AND QUEEN EDE GULLY**

In order to be able to model the phenonmenon giving rise to the environmental problem further field surveys are ongoing. Metrological stations have been established in all the local Government headquarters of the state. River discharges are measured in all the streams and rivers in the state.

Incorporation of all these data into a GIS will enable us generate spatial models for current and future analysis of flooding and erosion events in the state.

Table I present details of the six erosion gully sites and four flood basins being studied. While the erosion gully sites are evenly distributed across the state, flooding is more prevalent in Benin City, the state capital. This has been found to be as a result of inappropriate land use and as the landscape of Benin is relatively flat, pluvial flooding is common. During the period of heavy storm most of the flood water as a result of lack of outlet settle in residential areas, and properties worth millions of Naira are destroyed. Of the six gully sites, Oshiobugie has the highest flood basin occupying an area of about 480 Hectares. This is follow by Ibore with a land area of 450 hectares and the university of Benin-gully site with a land area of 300 Hectares. The largest flood basin is at Ilushi. This is accounted for by the fact that Ilushi is located by the bank of the river Niger. During peak discharge, the river overflows its bank and most of the low-lying land around Ilushi is flooded.

## 4. CONCLUSION

In this study Remote sensing, GPS and total station survey along with GIS, were used for generating the geospatial information needed for flood and erosion modeling and assessment.

Satellite remote sensing and GIS are essential both for flood management. GIS will assist flood managers in identifying flood prone areas in the Niger Delta states. With GIS, spatial data can be stored in a data base that can be querried and graphically displayed for analysis by overlaying different geographic layers. Flood prone areas can be identified and targeted for mitigation and management. GIS was used in this study to model the 1m interval contours for the university of Benin and Queen Ede erosion site. The contours were then used in generating a digital Elevation model for the gully sites within the flood basin. The DTM were valuable for analyzing the terrain in term of this research work is ongoing. It is anticipated that with extensive use of remote sensing and GIS a long term database will be created for flood and erosion monitoring, risk assessment and mitigation management within the Niger delta region of Nigeria.

Integration of remote sensing data, ground survey and GIS will serve as an interface for hydrologic modeling of flood and erosion events

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