MONITORING GULLY FORMATION AND DEVELOPMENT FOR EFFECTIVE REMEDIATION AND CONTROL

Jacob Odeh EHIOROBO and Osadolor Christopher IZINYON (Nigeria)

GPS, Gully Erosion, DEM, Morphology, Land Reclamation

SUMMARY

Gully erosion is one of the most environmental degradation processes. Gully processes are difficult to study and difficult to control.

In this study, two field surveys were carried out on the Queen Ede Gully Site, the first in December 2010 and the second in November 2011.

The field surveys included the mapping of the catchment basin and detailed morphological surveys of the gully itself.

Morphological data including gully width, depth, cross sectional area and volume of soil loss were computed for each monitoring epoch. Satellite imagery was acquired and used for land use classification and to determine the catchment area.

Based on the topographical data from the 2010 and 2011 measurements, short term erosion rates and the average soil loss per unit surface area for the measurement period were estimated. The result of the study revealed that the gully is U shaped and the run off contributing catchment is large. Additionally, slumping and widening of gully cross sections occurs only in the section where flood water discharge are in appropriately terminated

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1.0 INTRODUCTION

Shumun et al 1984, Stabulloughlu, Tarbolin and pack 2003 defined gullies as unstable channels formed at or close to valley heads, sides and floor. Poesen et al 2003 on the other hand defined gully erosion as the process whereby run off water accumulates and also receives in narrow channels and over short periods removes the soil from this narrow area to considerable depth. Gullies have three dimensional nature affected by varied factors and processes including surface hydrology, soils, topography, land use e.t.c
Many gullies grow initially rapidly to large dimensions (Thoma et al 2004, Valentin, Poesen and Li 2005) making effective control technically difficult or prohibitively expensive.

Gully processes has for sometimes been neglected because gully processes are difficult to study and difficult to control. This is why studies in gully processes (Gomez et al 2003) and their modeling (siderchuk 2005) are scarce.

Recent research and field studies have shown that gully erosion is one of the most soil degradation processes in most states of the South East and South South zones of Nigeria as it causes considerable soil loss and produces larger volume of sediment. Field measurements have shown that the development of gullies increases sediment delivery to low lands and water courses. Many causes of damages to water courses, and properties by run off relate to the occurrence of gully erosion as evidenced in the lower reaches of the Queen Ede gully site in Benin City.

One of the main causes of gully erosion in the study area, Edo State includes road construction with inappropriately terminated drainage network. While damages, by surface run off to the road may be limited, off site effects can be severe as withnessed in the study area (Ehiorobo and Izinyon 2011).

The road is said to induce a concentration of surface run off to other catchments and an increase in catchment size enhances gully development after road construction. Changes in drainage pattern associated with urbanization also results in gullying particularly where illegal settlements without urban infrastructure exist such as along the moat in Benin City.

Although gullies are visually striking, their small spatial extent generally renders them undetectable in most generally available topographical maps and low resolution satellite imageries.

As a result, it is necessary to carryout ground monitoring and modeling of the gully erosion phenomenon in order to predict their environmental impact and take remedial measures.

In time past, both ground based and airborne sensors have been used to assess gully erosion rates at a time scale. Short term monitoring of gully head or gully wall retreat has been conducted by measuring the change in distance between the edge of the gully head or wall and bench mark points installed on the gully walls (Vandekerekhova et al 2001). Some other researchers have used aerial photographic methods to determine the volume of soil loss by concentrated flow erosion (Thomas et al 1986, Ries and Marzolf 2003).

The most important factor to note is that monitoring and experimental studies of the initiation and development of gullies at various temporal and spatial scales need to be carried out. The critical threshold for the initiation, development and filling of gullies in different environment in terms of flow hydraulics, rainfall, topography soils and land use need to be identified. Once these are done adequate remediation measures can be undertaken. Preventing gully formation is much easier and more economical than treating the already formed gully (Pathak et al 2005). It is therefore very important to identify the causes and extent of gully development in order to carryout effective remediation and control of their spread.

This study involves the integration of GPS with Total Stations, remote sensing and GIS for the monitoring and experimental studies of gully morphology for the planning of land reclamation and control of the gully in order to prevent further land degredation.

2.0 THE STUDY AREAS

The study area is located in Benin City, the capital of Edo State of Nigeria.

It lies within UTM Zone 31, to the North Eastern part of the city.

The gully area is bounded by UTM coordinates 700800mN to 702500mN and 795800mE to 79600mE. The gully runs in a south – easternly direction down to Ikpoba river. The elevation of the study area ranges from 16m to 110m above sea level (fig1). The average temperature in this area is 280c. The raining season commences usually from April to October with a break during the month of August commonly referred to as August break. Maximum recorded rainfall 2001–2011 was 439mm with a minimum of 3.75mm. There is however a sharp deviation this year 2012, probably as a result of climate change, as heavy rains have been experienced from January to date. Humidity is generally high about 98% for most of the year. The area lies within the tropical rain forest zone of Nigeria.

Fig 1: Queen Ede Catchment Area

2.1 BACKGROUND TO THE PROBLEM AND PREVIOUS EFFORTS AT REHABILITATION

The Queen Ede problem is said to have started sometime in the 1990's as a result of abrupt termination of the drainage channel along the Benin-Asaba road in front of the current location of the gully.

Another major factor contribution to the gullying is the fact that on the opposite side of the highways most of the roads slope towards Igunbor Street which receives the runoff from Pogha, Edobor and partly Agbonlahor street.

A gully of length 200m and 2m wide and almost 5m deep run along Edobor street to join another gully of the same width and depth and about 400m long along Pogha road. This gully continues for about 60m along Igunbor street carrying along its part sediment and waste, which are dumped along Ogunbor street. As the run off in this area continue towards the highway with very high velocity it joins the storm generated along the Benin Asaba highway, crosses the highway at almost a right angle and with increase velocity of flow, continue down slope to cause more devastating damage around the Queen Ede secondary school.

Efforts made in recent years to address the situation by both State and Federal Government have not been successful probably due to the fact that not adequate studies was carried out before remediation and control measures were undertaken.

There are four 900mm diameter culverts constructed to carry the storm discharge from Igunbor street at the right hand side of Benin-Asaba road from Asaba end. Both of these culverts and the drain were constructed to carry the storm runoff to the opposite side of the road into two catchpits from where they are to be conveyed by a rectangular drain through the gully into Ikpoba River (Fig 2)

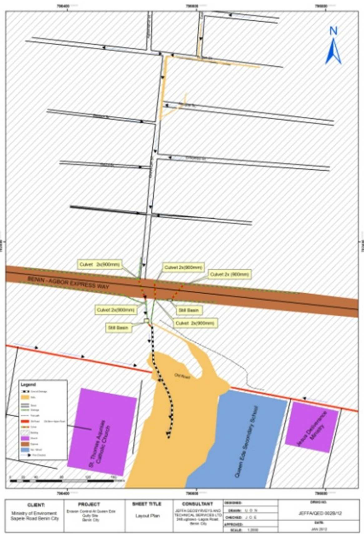


Fig 2:Layout of Existing Drainage Infrastructure

An assessment of these catchpits indicated that they are in adequate in size compared to the volume of storm runoff they receive at a time. They cannot therefore serve the purpose for which they were constructed.

Storm discharge from both sides of the old Benin-Asaba road are not properly terminated at the gully head, thus creating under cutting of the gully head in both directions leading to slumping and widening of the gully in this section.

Another drainage channel at the end of St. Thomas Aquinas Catholic church also carry runoff into this part of the gully creating under cutting of the gully wall with the consequences of the collapse of the wall in this section and widening of the gully.

In order to adequately address the problem of the area, the dynamics of flood water within the catchment basin must be adequately studied. The volume of run off from the western, northern and southern catchments must be known so that appropriate structural and non structural measures can be taken to address the problem.

In 2010, the Niger Delta Development Commission (NDDC) appointed consultants to carry out research profiles on flood and erosion in the Niger Delta region. The studies involved generating and creating a database for the flood and erosion problem in the region in order to carryout control and remediative measures.

Since 2011, the Federal Government with assistance from the World bank initiated the National Erosion and Water-Shed Management Project (NEWMAP). Part of Newmap initiative is the Gully Rapid Action and Slope Stabilization (GRASS) (Jeffa 2012).

The Queen Ede Gully Erosion discussed in this paper is part of the WORLD BANK GRASS initiative in Edo State.

2.2 FIELD MEASUREMENTS

The surveys carried out for gully control and remediation included:

- Mapping of catchment basin and location of rills and secondary gullies contributing run off to the main gully
- Detailed surveys of existing control infrastructure including gutters, culverts, catch pits, drainage channels e.t.c
- Longitudinal bed profile from head to outlet of the main gully.
- Planimetric survey of the gully head at large scale
- Cross sectional surveys of the gully to determine the nature of the stage of gully development i.e whether V or U shaped.

In order to carry out the above surveys three 2^{nd} order control points QED1 – QED 3 were established around the gully head by method of differential GPS using a BEM pillar along the old Benin – Asaba road as a reference station. Based on the above controls, two field observation sessions were carried out within the gully area, the first in December 2010 and the second in November 2011.

Each observation session consisted of detailed topographical surveys of the gully site with the associated catchment basins using a LEICA TS 700 total station instrument. The total station instrument was used to capture XY and Z coordinates covering the entire gully site at about 10m interval as well as other points of significant changes in slope along the bank, gully walls and gully floor.

During the topographical surveys, the average point density in some areas such as the gully head, gully floor and terraces were more intense than in other parts of the gully. The total station measurements in each epoch were collected at centimeter level resolution to capture break in slope and other topographic features necessary for producing accurate Digital Elevation Model (DEM).

Levels was run from the BM control points to the three GPS points to control the vertical components of the coordinates.

The gully cross sections along with topographical profile of the gully bed from head to outlet was carried out using Automatic level with Telescopic staff.

Ikono imagery was acquired to measure and monitor the extent of the eroded area as well as providing a quantifiable estimate of the landed area and in the analysis of physical structures that have been affected or endangered by the gully (See Fig 3).

Fig 3: Ikonos Imagery of Queen Ede Gully Site

2.3 DATA PROCESSING

Using the morphological data, cross sections were plotted in order to determine the shape of the gully formed. From the contours, slopes were generated as necessary. The pixel size of the DEM was 1m.

The morphological data and cross sectional data were used to determine the cross sectional areas and the volume of soil loss in each case.

The eroded volume of each gully segment was calculated using the cross sectional area and the distance between cross section as:

$$V = \sum L_i A_i \quad (1)$$

Where L is length of gully section in meters

A_i is crossectional area in m^2

The computation of the morphological data along with the cross sectional area and volume of soil loss was carried out using AUTODESK Land Development Software

Short term erosion rates ($t\ ha^{-1}\ yr^{-1}$) (E_S) were calculated in order to determine the rate of erosion over the period of study using the equation given as (Nyssen et al 2006).

$$E_s = \frac{(V_{2010} - V_{2011})\rho_d}{T.A} \quad (2)$$

Where E_s - Erosion rate

ρ_d - Bulk density of soil occurring in the contributing area

T – Period of gully development in years.

A – Watershed area in hectares

Erosion per unit gully surface ($t.m^{-2}$) was estimated using the equation

$$E_p = \frac{V\rho_d}{A_p} \quad (3)$$

Where V – Current volume of soil loss in the gully

A_p - Plan area of gully (m^2)

E_p - Erosion per unit gully surface

ρ_d - Bulk density

3.0 RESULTS AND DISCUSSIONS

Typical cross section of the gully are shown in Fig 4 below.

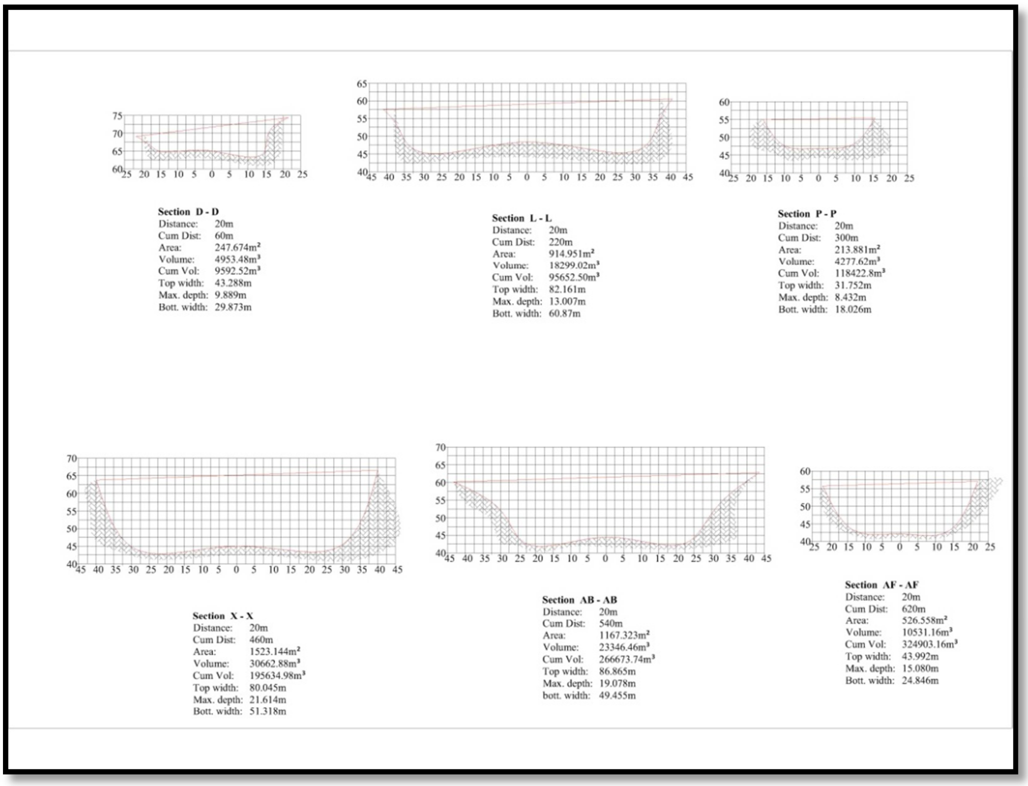


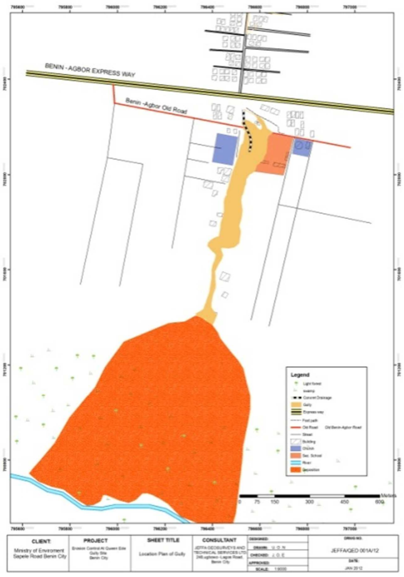
Fig 4: Typical Cross sections of Queen Ede gully

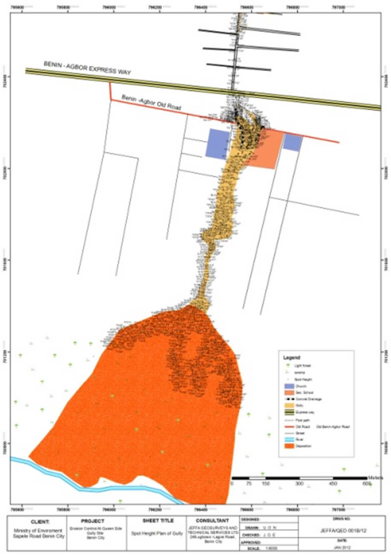
From the cross section, it can be seen that the gully is U – shaped, thus;

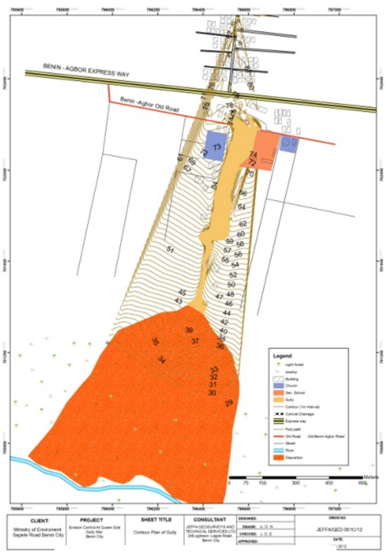
- The run-off contributing catchment area is large and therefore the discharge passing through the gully is also large
- The longitudinal slope of the gully bottom is parallel to the land slope
- The run off enters the gully from the head and from the sides at points where adjacent land is slightly lower than the surrounding. (See Fig. 2)
- The gully have been formed by under cutting and collapse of the bank walls

- The gully continue to expand towards the head as active erosion action occurs mainly from side walls near the head as a result of under cutting of the base and walls

Using the field survey data, various maps including location maps, spot height, contoured and 3-D model of the gully sites were produced using Arc GIS 9.3 software. The different maps produced are shown in Fig 5a – 5d







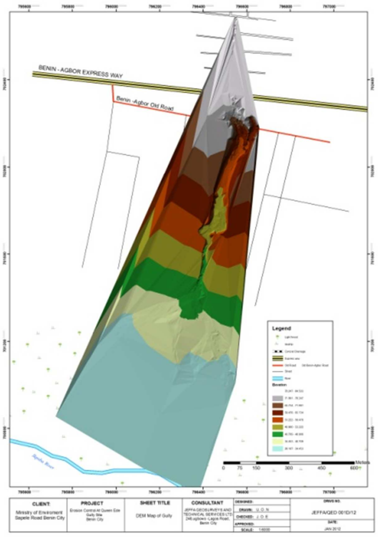


Fig 5a: Location Map of Queen Ede Gully

Fig 5b: Spot Height Map of Queen Ede Gully Site.

The longitudinal profile of the gully bed from head to the outlet at Ikpoba river is shown in Fig 6 while a planimetric survey plan of the gully head at large scale is shown in Fig 7.

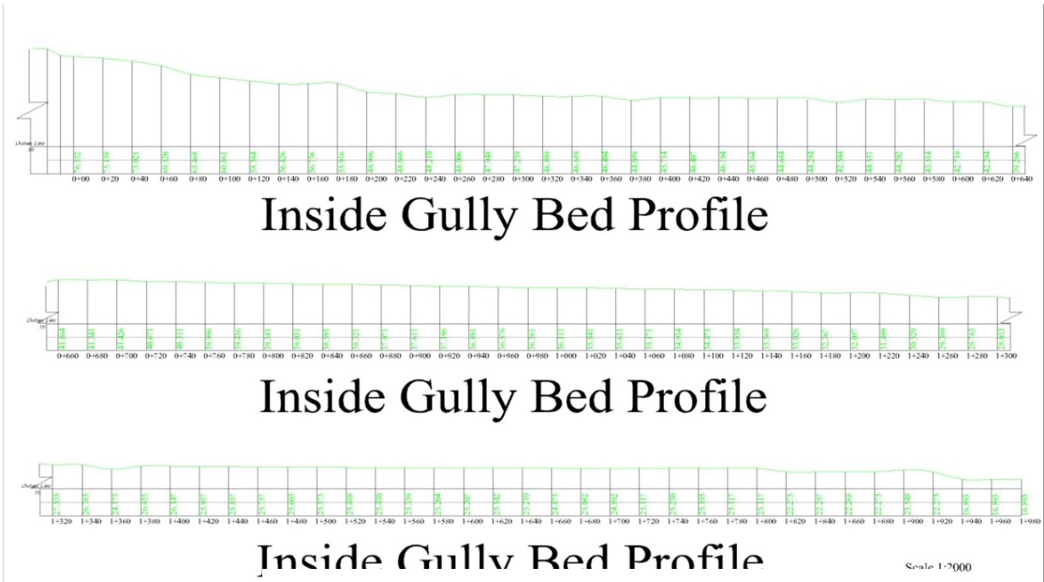


Fig 6:Bed Profile of Queen Ede Gully as at Nov. 2011

The morphological parameters of the gully from ch 00+00 to ch 00+960 including the cross sectional areas and computed volume of soil loss between the monitoring period December 2010 and November 2011 is shown Table I below.

Satellite imagery delineation and field measurement of the gully growth indicated that the planimetric area of the gully has increased from 9.48 Hectares to 10.44 Hectares. From Table I, it can be shown that the value of soil loss increased from 375,322m^3 in 2010 to 393070m^3 in 2011.

Short term erosion rates was calculated using equation (2), to be 0.541 t ha^{-1} yr^{-1}
The average was based on measured gully volume and the average soil bulk density.
This indicate the severity of soil loss due to gully erosion in the Queen ede catchment basin
During the period of observation, the top and bottom width of the gully experienced increased between ch 00+40 – ch 00 +100, between ch00+220 – ch00+280 and between ch00+940 and 00+980 respectively (See Table I)

The increase in the first two section was as a result of storm run off from both sides of the old Benin-Asaba road which created under cutting and slumping of the gully wall in this area. The increase in width at the end of the gully was due to the fact that at the gully entrance the run off volume is higher. In all the other parts of the gully, the rate of widening was negligible.

As can be seen from Table I, no appreciate change in depth of the gully bed took place during the period 2010 – 2011

It is however expected that with heavy rain start in Benin city since January 2012, series of gully will slump in various part of the gully will occur as a result of ground water exerting pressure on the overlaying saturated soil profile. This in turn will cause the soil to loose its stability and consequently causing the slumping of gully walls with consequent further widening of the gully and deposition of higher volume of sediment at the down stream of the gully. This will create further environmental degradation and loss of valuable properties and land resources.

S/N	CHAINAGES	TOP WIDTH			BOTTOM WIDTH			DEPTH			CROSS SECTION AREA			VOLUME			CUMULATIVE VOLUME OF SOIL LOSS		
		2010	2011	DFFERENCE	2010	2011	DIFFERENCE	2010	2011	DIFFERENCE	2010	2011	DIFFERENCE	2010	2011	DIFFERNCE	2010	2011	DIFFERENCE
1	00+00	15.604	15.604	0.000	10.000	10.000	0.000	0.374	0.374	0.000	3.510	3.510	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	00+20	36.993	36.993	0.000	13.466	13.466	0.000	3.478	3.478	0.000	55.172	55.172	0.000	1103.440	1103.440	0.000	1103.440	1103.440	0.000
3	00+40	62.702	68.582	5.880	28.556	28.920	0.364	4.751	4.751	0.000	173.467	176.780	3.313	3469.340	3535.600	66.260	4572.780	4639.040	66.260
4	00+60	39.300	43.288	3.988	29.873	30.002	0.129	9.889	9.889	0.000	242.322	247.670	5.348	4846.440	4953.480	107.040	9419.220	9592.520	173.300
5	00+80	61.687	61.687	0.000	17.500	17.500	0.000	7.846	7.846	0.000	316.256	316.256	0.000	6325.120	6325.120	0.000	15744.340	15917.640	173.300
6	00+100	99.454	101.218	1.764	81.556	82.877	1.321	9.155	9.155	0.000	429.739	431.335	1.596	8594.780	8626.700	31.920	24339.120	24544.340	205.220
7	00+120	76.554	76.554	0.000	65.996	65.996	0.000	6.988	6.988	0.000	328.321	328.321	0.000	6566.420	6566.420	0.000	30905.540	31110.760	205.220
8	00+140	80.297	80.297	0.000	66.556	66.556	0.000	13.788	13.788	0.000	726.142	726.142	0.000	14522.840	14522.840	0.000	45428.380	45633.600	205.220
9	00+160	81.627	81.627	0.000	69.246	69.246	0.000	10.585	10.585	0.000	593.031	593.031	0.000	11860.620	11860.620	0.000	57289.000	57494.220	205.220
10	00+180	76.533	76.533	0.000	71.784	71.784	0.000	7.112	7.112	0.000	283.207	283.207	0.000	5664.140	5664.140	0.000	62953.140	63158.360	205.220
11	00+200	74.184	74.184	0.000	60.000	60.000	0.000	12.394	12.394	0.000	709.756	709.756	0.000	14195.120	14195.120	0.000	77148.260	77353.480	205.220
12	00+220	75.820	82.161	6.341	60.870	60.000	-0.870	13.007	13.007	0.000	897.077	914.951	17.874	17941.540	18299.020	357.480	95089.800	95652.500	562.700
13	00+240	40.418	50.173	9.755	32.232	32.232	0.000	10.727	10.727	0.000	357.197	386.809	29.612	7143.940	7736.180	592.240	102233.740	103388.680	1154.940
14	00+260	41.971	54.266	12.295	37.500	38.060	0.560	7.492	7.492	0.000	288.332	313.481	25.149	5766.640	6269.620	502.980	108000.380	109658.300	1657.920
15	00+280	36.292	49.53	13.238	22.500	22.500	0.000	7.208	7.208	0.000	204.210	224.344	20.134	4084.200	4486.880	402.680	112084.580	114145.180	2060.600
16	00+300	31.752	31.752	0.000	18.026	18.026	0.000	8.432	8.432	0.000	213.881	213.881	0.000	4277.620	4277.620	0.000	116362.600	118422.800	2060.200
17	00+320	32.290	32.290	0.000	22.098	22.098	0.000	8.855	8.855	0.000	220.372	220.372	0.000	4407.440	4407.440	0.000	120769.600	122830.240	2060.640
18	00+340	30.000	30.000	0.000	23.894	23.894	0.000	7.975	7.975	0.000	218.855	218.855	0.000	4377.100	4377.100	0.000	125146.740	127207.340	2060.600
19	00+360	31.780	31.780	0.000	19.505	19.505	0.000	7.046	7.046	0.000	179.625	179.625	0.000	3592.500	3592.500	0.000	128739.240	130799.840	2060.600
20	00+380	41.297	41.297	0.000	30.705	30.705	0.000	8.737	8.737	0.000	283.715	283.715	0.000	5674.300	5674.300	0.000	134413.540	136474.140	2060.600
21	00+400	56.205	56.205	0.000	40.841	40.841	0.000	8.981	8.981	0.000	391.768	391.768	0.000	7835.360	7835.360	0.000	142248.900	144309.500	2060.600
22	00+420	62.090	62.090	0.000	46.441	46.441	0.000	10.306	10.306	0.000	499.879	499.879	0.000	9997.580	9997.580	0.000	152246.480	154307.080	2060.600
23	00+440	62.348	62.348	0.000	47.829	47.829	0.000	11.046	11.046	0.000	533.251	533.251	0.000	10665.020	10665.020	0.000	162911.500	164972.100	2060.600
24	00+460	80.045	80.045	0.000	51.318	51.318	0.000	21.614	21.614	0.000	1523.144	1523.144	0.000	30662.880	30662.880	0.000	193574.380	195634.980	2060.600
25	00+480	69.267	69.267	0.000	51.288	51.288	0.000	16.874	16.874	0.000	774.903	774.903	0.000	15498.060	15498.060	0.000	209052.440	211133.040	2080.600
26	00+500	70.000	70.000	0.000	54.260	54.260	0.000	16.378	16.378	0.000	841.278	841.278	0.000	16825.560	16825.560	0.000	225598.040	227958.600	2360.560
27	00+520	69.477	69.477	0.000	52.584	52.584	0.000	16.125	16.125	0.000	768.434	768.434	0.000	15368.680	15368.680	0.000	241266.680	243327.280	2060.600
28	00+540	86.865	86.865	0.000	49.455	49.455	0.000	19.078	19.078	0.000	1167.323	1167.323	0.000	23346.460	23346.460	0.000	264613.140	266673.740	2060.600
29	00+560	85.458	85.458	0.000	55.914	55.914	0.000	9.362	9.362	0.000	445.352	445.352	0.000	8907.040	8907.040	0.000	273520.180	275580.780	2060.600
30	00+580	111.139	111.139	0.000	65.229	65.229	0.000	12.857	12.857	0.000	969.522	969.522	0.000	19390.440	19390.440	0.000	292910.620	294971.220	2060.600
31	00+600	112.000	112.000	0.000	59.430	59.430	0.000	13.409	13.409	0.000	970.039	970.039	0.000	19400.780	19400.780	0.000	312311.400	314372.000	2060.600
32	00+620	43.992	43.992	0.000	24.806	24.806	0.000	15.080	15.080	0.000	526.558	526.558	0.000	10531.160	10531.160	0.000	322342.500	324903.160	2560.660
33	00+640	31.865	31.865	0.000	20.279	20.279	0.000	11.392	11.392	0.000	286.565	286.565	0.000	5731.300	5731.300	0.000	328573.800	330634.460	2060.660
34	00+660	32.077	32.077	0.000	23.008	23.008	0.000	13.889	13.889	0.000	372.530	372.530	0.000	7450.600	7450.600	0.000	336024.460	338085.060	2060.600
35	00+680	23.191	23.191	0.000	15.000	15.000	0.000	11.000	11.000	0.000	180.686	180.686	0.000	3613.720	3613.720	0.000	339638.180	341698.780	2060.600
36	00+700	17.363	17.363	0.000	14.300	14.300	0.000	9.854	9.854	0.000	128.751	128.751	0.000	2575.020	2575.020	0.000	342213.200	344273.800	2060.600
37	00+720	15.000	15.000	0.000	11.379	11.379	0.000	9.586	9.586	0.000	105.702	105.702	0.000	2114.040	2114.040	0.000	344327.240	346387.840	2060.600
38	00+740	16.790	16.790	0.000	11.090	11.090	0.000	8.496	8.496	0.000	103.483	103.483	0.000	2069.660	2069.660	0.000	346396.900	348457.500	2060.600
39	00+760	12.312	12.312	0.000	9.461	9.461	0.000	4.393	4.393	0.000	46.675	46.675	0.000	933.500	933.500	0.000	347330.410	349391.000	2060.590
40	00+780	22.282	22.282	0.000	13.941	13.941	0.000	8.877	8.877	0.000	149.781	149.781	0.000	2995.620	2995.620	0.000	350326.020	352386.620	2060.600
41	00+800	19.363	19.363	0.000	13.948	13.948	0.000	7.780	7.780	0.000	127.897	127.897	0.000	2557.940	2557.940	0.000	352883.960	354944.560	2060.600
42	00+820	21.557	21.557	0.000	16.248	16.248	0.000	7.202	7.202	0.000	133.749	133.749	0.000	2674.980	2674.980	0.000	355558.940	357619.540	2060.600
43	00+840	24.080	24.080	0.000	18.115	18.115	0.000	6.422	6.422	0.000	124.698	124.698	0.000	2493.960	2493.960	0.000	358052.900	360113.500	2060.600
44	00+860	31.696	31.696	0.000	20.000	20.000	0.000	5.361	5.361	0.000	128.396	128.396	0.000	2567.920	2567.920	0.000	360620.820	362681.420	2060.600
45	00+880	42.771	42.771	0.000	25.000	25.000	0.000	3.771	3.771	0.000	118.461	118.461	0.000	2369.220	2369.220	0.000	362990.040	365050.640	2060.600
46	00+900	77.226	77.226	0.000	32.500	32.500	0.000	3.890	3.890	0.000	196.260	196.260	0.000	3925.000	3925.000	0.000	366915.040	368975.640	2060.600

47	00+920	119.049	119.049	0.000	100.000	100.000	0.000	5.458	5.458	0.000	298.924	298.924	0.000	5978.480	5978.480	0.000	372893.520	374954.120	2060.600
48	00+940	22.401	29.604	7.203	7.500	7.500	0.000	5.126	5.126	0.000	70.761	82.052	11.291	1415.220	16410.04	14994.820	374308.740	391364.160	17055.420
49	00+960	18.367	40.815	22.448	7.890	7.890	0.000	4.480	4.48	0.000	50.656	85.271	34.615	1013.000	1705.42	692.420	375321.740	393069.580	17747.840

TABLE 1: MOPHOLOGICAL PARAMETERS OF GULLY INCLUDING CROSS SECTIONAL AREAS AND VOLUME OF SOIL LOSS IN 2010 AND 2011 MONITORING PERIOD

4.0 CONCLUSIONS

This paper examines the use of GPS, Total Station Instrument, Remote Sensing and GIS in monitoring Gully formation and development. Results of the topographical surveys of the catchment basin revealed that the gully is at a low point which serves as a receptor for all the run off coming from the entire catchment basin.

The cross sectional surveys revealed that the Gully is U shaped which show that the run off contributing catchment area is large and therefore the discharge passing through the gully is also large.

The recent increase in the growth and expansion of the gully can be attributed to the change in rainfall pattern in the region caused by climatic change.

The use of high resolution satellite imagery in combination with ground survey methods using GPS and Total station enables us to produce different types of maps and develop models, and accurately design structures needed to control the gully process.

The Geo information provided, will enable the Engineer carryout control measures including redesign and upgrading of existing drainage infrastructure, provision of gully control measures at the head region and other remediation measures necessary for healing of the gully and its prevention from further expansion to protect the environment from further degredation

REFERENCE

1. Ehiorobo J.O and Izinyon O.C (2011) "Monitoring of Soil loss and Erosion Using Geoinformation and Geotechnical Engineering methods"
2. Gomez B, Banburg K, Marden M, Trustum N A, Peacock D.H, and Hoskin P.J (2003) "Gully Erosion and Sediment production" TC Weraroa Strem, New Zealand. Water Resources Vol 39(7) pp 1187.
3. Istanbulluoglu,E., Tarboton, D.G, and Robert T.P, "A sediment transport model for incision of gullies on steep topography" Water Resources Research Vol. 39(4) pp 1103.
4. JEFFA Geosurveys and Technical Services Ltd (2011) "Queen Ede Gully Erosion Site, Showing Report" submitted to Edo state Ministry of Environment Under the National Erosion and Water shed management Project (NEWMAP). December 2011.
5. Nyssen J, Poesen, Jr, Veyret-picot,M., Moeyersion,J.,Haile,M,Deckers,J.,Dewit,J., Naudts,J., Teka,K. and Govers,G(2006) "Assessment of gully erosion rates through Interviews and Measurment: a Case study from northern Ethiopia" Earth Surface processes and Land Forms Vol 31 (2) pp 167 – 187.
6. Pathak,P., Wani,Sp.,and Sudi,R (2005) "Gully Control in SAT Water sheeds" Global Tewe on Agro eco system Report No 15, Patancharu, 50 2324, Andhra Pradesh, India: International Crops research institute for the semi- Arid tropics.
7. Peosen J, Ngehtergaele J, Verstraeten G and Valentin C (2003) "Gully Erosion and Environmental change, importance and Research needs" Catena, Vol 50 pp 91 – 133.
8. Ries J.B and Marzolff H.L. (2003) "Monitoring of Gully Erosion in the Central Ebro Basin by Large Scale Aerial Photographs taken from a Remotely Controlled Blimp" Catena, Vol 50 pp 309 – 328.
9. SCLUMM S,A., Harvey, M.D., and Watson C.C., (1984) "Incised channels: Morphology Dynamics and control" Water Resources Publ, Highlands ranch, Colorada 200pp.
10. Siderchuk A (2005)" Stochestic Component in the Gully Erosion Modelling" Catena, Vol 63 Vol 63 pp 299 – 317.
11. Thomas J,T, Iverson N.R, Burkest M.R, Kramer. L.A (2004) "Long Term Growth of a valley – both Gully" Western Iowa. Earth Surface Processed and Land Forms Vol 2a pp 995 – 1009.
12. Vandakerckhava, L., Muys, B., Poesen,J., Deweardo, B., and Coppe O., (2001) "A method for Dendrochromological assessment of medium term gully erosion rates" Catena vol 45 (2) pp 123 - 161
13. Valentin C, Poesen J. and Young Li (2005) " Gully Erosion: Impacts, Factors and Control" Catena, Vol 63 pp 132 – 153.
14. Yongui wa and Hong Cherg (2005) Monitoring of gully erosion on the Loess plateau of China using a Global Positioning system" Catena vol 63 (2) pp 154 – 166.

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