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Bathymetric Survey Investigation for Lagos Lagoon Seabed Topographical Changes

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Abstract Bathymetry is the study of under water depth of lake and ocean floors and accurate data for production of nautical chart is the main objective of bathymetric survey. This research work was conducted to investigate changes in the topography of the northern part of Lagos lagoon (Ikorodu route) and thereby updating the existing chart. Data acquisition was done using satellite imagery, tidal observation and reduction, depth sounding with echo sounder and GPS. Initial processing performed on observed bathymetric data includes spike removal, tidal correction on instantaneous depth and sorting with HYPACK 2008 software. Further processing was done using ArcGIS 10.0 Software. The processed depths were analyzed and presented in form of graphs and charts. A surface descriptor of sediment region for accretion and dredged region was developed using depth differential of two dataset and their sediment volumes were ascertained. From the analysis conducted, there is an indication that accreted sediment volume is greater than Dredged volume and perhaps could have being influenced by the adjoining tributaries of the lagoon water. For further studies, needs for investigating the source of accreted mass through integrated coastal management plan is recommended.

Keywords: *bathymetric survey, investigation, Lagos Lagoon, seabed, topographical changes*

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1. Introduction

Bathymetry is the study of under water depth of lake and ocean floors [9]. In bathymetric survey, charts are produced to support safety of surface or sub-surface navigations which usually shows seafloor relief or terrain as contour lines (depth contours), and such chart provides surface navigational information [6,11]. The survey sets for best description of the submarine topographical features that may include sound velocity and slope corrections that are more accurate but eliminate the safety bias [10].

Bathymetric surveys are important for many purposes; such includes sedimentation purposes to check for accretion or erosion, pre and post dredging bathymetry, that is to determine the existing status of the water body or to ascertain the dredged volume. It can also be done prior to pipeline and cable (laying) positioning, fishing and other geophysical exploration exercise.

Updating of bathymetric chart is a daunting task and cannot be over passed due to its importance in estimating or determining temporal changes in an ocean floor which in effect; provides accurate information for public usage, [7] in terms of planning, engineering design, construction, operation, maintenance, and regulation of navigation, flood control, river engineering, charting, and coastal engineering projects.

Resurvey policy especially that of bathymetry gives bounds for reliability of identified sea erosion and accretion areas, determination of sediment transport pathways, magnitude of sediment transport estimates, and validity of sediment budget estimates [11]. Comparison of digital bathymetric data for the same region but different time periods provides a method for estimating or calculating net movement of sediment into (accretion) and out of (erosion) a study area.

Producing a bathymetric chart; tidal observation and reduction is a must [3] to reduce sounding depth to chart datum. Tidal observation is conducted prior to and concurrently with sounding operations period and can be done on established gauge or a temporarily on any selected position where water level hardly goes below the zero reading of the measuring device (Temporary gauge).

The reduction applicable to sounding depth is done based on the rise and fall differential subtraction for gauge data using an instantaneous timing interval for each sounding point. Further processes have to do with spike removal, HYPACK matrix generation and possibly preparation of schema for ideal data structuring; then production of bathymetric chart.

A proper environmental impact assessment needs to be done in order to assess the level of impact caused by man and nature, especially as it concerns coastal waters. Bathymetric survey of Ikorodu is important for production of up-to-date bathymetric chart, due to mining exercises opined by local miners and licensed dredging companies.

In absence of mining exercise, there is need to investigate and account for sediment deposit or eroded, so that proper planning responses can be implemented. It is therefore necessary to update the bathymetric chart covering the northern part of Lagos lagoon which would be compared with the earlier bathymetric survey; for investigating sediments (Accretion and Erosion) and dredged region area.

Therefore, this paper aimed at investigating topographical changes for Northern part Lagos Lagoon seabed using two epoch data which reveals morphological changes, determines and quantifies the mass of dredged material, accretion and their spatial locations and fast track planning and engineering services.

2. Methodology

2.1. Reconnaissance

Reconnaissance was conducted in office and field to ascertain the condition of equipments, available maps, previous data and suitable location for tide gauge installation for the area under investigation. The collected data include carved out portion of 2008 Lagos bathymetric survey dataset and map covering Ijebu-lekki and major equipments used were SDE-28S south single frequency echo sounder and 62sc Garmin hand held GPS labeled by the manufacturer as most accurate and reliable GPS tested so far; best used for boating, mountaineering and hunting services. SDE-28Secho sounder run on Windows XP operating system, user-friendly interface,
integrated with both computer and echo sounder at industr ial level, with low power consumption. Measurement accuracy and operation range might vary due to atmospheric conditions, signal multipath, obstructions, observation time, temperature, signal geometry and number of tracked satellites. However, the below is its measurement specification[12].

Frequency 200 kHz
Beam Angle 7°
Depth Resolution 0.1ft/0.01m
Accuracy ±1cm±0.1%D (0.1% of depth value)
Ping Rate 14Hz, Maximum 30Hz
Sound Velocity 1300-1700m/s, resolution is 1m/s
Depth Range 0.3-300m/900ft
Draft 0-9.9 m

on the other hand,

a. Hand Held GPS Receivers (GPSmap 62s Garmin GPS)
b. South 28SD Digital Echo sounder
c. Hydrographic Boat
d Surveyor's band and tapes (30 m, 50 m and 100 m)
e. AO and A4 Scanners
f. AO and A4 Printers
g. Communication Equipment
h. Leveling staff for tidal observation

2.2. Map Conversion, Establishment of Tide gauge and Observations

All maps were converted to digital format using Arcmap ArcGIS 10.0 and all the available data were referenced to WGS 84 datum. A temporary tide gauge was established at a point where water level hardly goes below the zero mark of a leveling staff supported by two poles laid vertically to one another and tidal observation commenced seven day consecutively before the Depth sounding. The boat was deployed inn into the water and its accessories installed. Having fixed the boat engine however, the boat was tested before all other equipments were transferred inn; with the aid of the metal support, the transducer was anchored at one side of the boat. The depth of the transducer below waterline was measured and fed inn during the initial settings. It was ensured that ten (10) to eleven (11) satellites were visible on the sky point for better geometry and 95% clear visibility with a Position Dilution of Precision (PDOP) within 0.8 to 1.0 was ensured. To ensure best fit vertical positioning, depth measurements were taken at a mini second time interval along navigational routes and reliable depth measurement was achieved. The Global Positioning System receiver is interfaced with HYPACK navigation software to compute vessel positions.

A test on the instrument was performed by taking redundant observations of water depth in comparison with bar check measurement. The result of the test was in conformity to IHO standard for all depth measurement acquired. Subsequently data acquired during reconnaissance was set on display unit of the echo sounder and cruise was set to tour round the study site to ensure that all the equipments are in good working condition and properly integrated. Sounding (depth measurement) of points were done more on a zigzag strip on navigable areas of the lagoon due to water levels' depth and some water obstructions.

Snapshot of research instruments at the lagoon water front

Figure 2.2. Site photos

3. Results and Analysis of Results

3.1. Results

Results presented are in form of tables, charts, and graph of relevance which depicts processed dataset aiding analysis takes. The results for this study were carved out portion from Lagos bathymetric survey dataset for 2008 bathymetric survey project and 2013 bathymetric dataset covering the same area. These results are shown in figures 3.1a to 3.1c. Table 3.1a shows the coordinate listing of the carved out portion of 2008 Lagos bathymetric survey and the 2013 bathymetric project; see detail in [5].

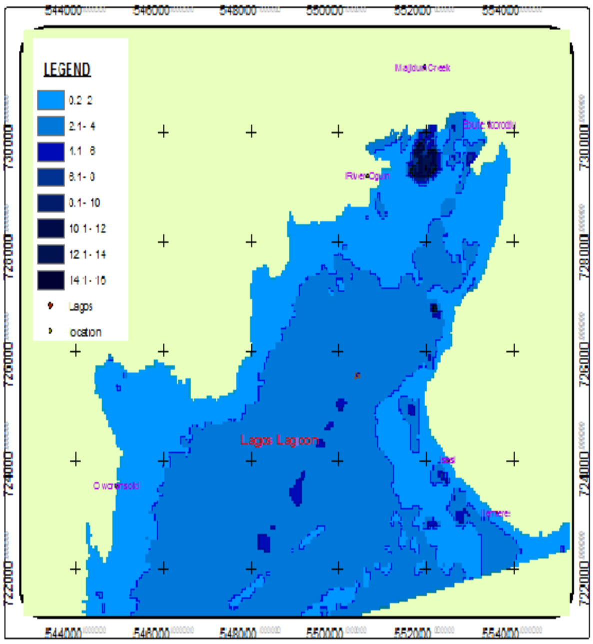


Figure 3.1a. processed Bathymetric dataset for 2008 survey

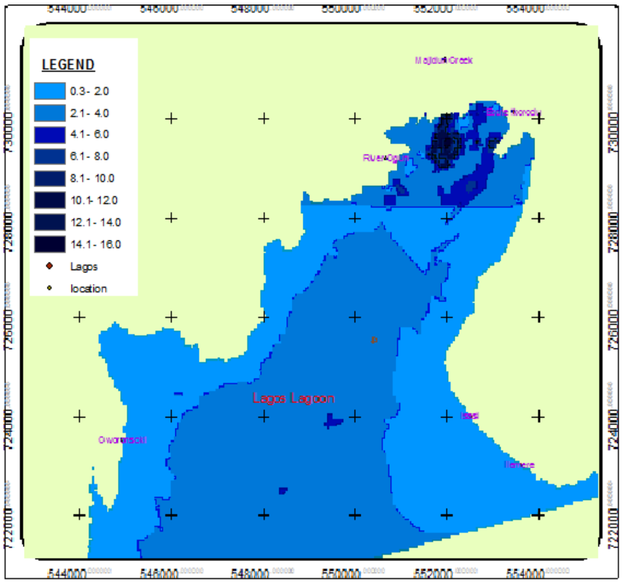


Figure 3.1b. processed Bathymetric dataset for 2013 survey

Table 3.1. Corrdinate listing for 2008 and 2013 bathymetric dataset

	M.Sc. 2013 Bathymetric Data for Lagos Lagoon			2008 Lagos Bathymetric Survey Data for Project Area		
S/NO	EASTING	NORTHERN	DEPTH	EASTING	NORTHING	DEPTH
1	544353.140000	720513.830000	0.300000	556719.27000	719346.34000	2.63000
2	544564.650000	720371.480000	0.380000	545493.74000	719346.38000	2.48000
3	544599.850000	720335.970000	0.300000	553698.92000	719346.58000	3.44000
4	544635.050000	720300.460000	0.300000	550678.57000	719346.81000	3.45000
5	544670.250000	720264.960000	0.300000	547658.22000	719347.04000	2.90000
6	544705.450000	720229.450000	0.300000	555863.41000	719347.24000	3.06000
7	544740.650000	720193.940000	0.300000	544637.88000	719347.28000	1.47000
8	544775.850000	720158.430000	0.400000	552843.06000	719347.47000	3.71000
9	544388.960000	720619.740000	0.300000	549822.71000	719347.70000	3.59000
10	544424.160000	720584.230000	0.300000	546802.36000	719347.94000	0.22000
11	544494.560000	720513.210000	0.300000	555007.54000	719348.13000	3.12000
12	544529.760000	720477.700000	0.580000	551987.20000	719348.36000	3.88000
13	544564.960000	720442.190000	0.690000	348966.85000	719348.60000	2.98000
14	544600.160000	720406.630000	0.700000	557172.03000	719348.79000	2.83000
15	544635.360000	720371.170000	0.660000	545946.50000	719348.83000	2.5SOOO
16	544670.560000	720335.670000	0.620000	554151.68000	719349.02000	3.57000
17	544705.760000	720300.160000	0.530000	551131.33000	719349.26000	3.19000
18	544740.960000	720264.650000	0.520000	548110.99000	719349.49000	2.89000
19	544776.160000	720229.140000	0.590000	556316.17000	719349.68000	3.44000
20	544811.360000	720193.630000	0.500000	545090.64000	719349.72000	1.61000
21	544846.560000	720158.120000	0.390000	553295.82000	719349.92000	3.18000
22	544354.060000	720725.960000	0.300000	550275.47000	719350.15000	3.82000
23	544389.260000	720690.450000	0.350000	547255.12000	719350.38000	2.17000

3.2 Data Statistics

In order to investigate (morphological changes) dredging and accretion taken place on the topography of the lagoon were examined in order to quantify sediment deposit/ sediment reduction for the time difference; we used histogram in classification of depth range and determining the change in depth distribution. The results have indication that there is population growth for depth between 0-4 m; and were shown in figure 3.2a and 3.2b. Conversely, to detect depth change over time on the lagoon topography, three routes were designed and the depth values for the two dataset were plotted against distances drawn along a given profile at an interval of 200 m. The plotted graphs showed morphological changes using data dataset shown on table 3.1. The three graphs were taken at interval of 200 m on a profile along the three routes; line 1, line 2 and line 3 respectively as shown in appendix 1. The three route profiles graphs had shown that the sea bed had changes between 2008 and 2013; with this therefore, a comprehensive search is inevitable. appendix 2 had shown spatial distribution of dredged area and accretion area; however, we are concerned about quantity, and source of sediment dredged or settled on the lagoon topography. Performing spatial queries on the processed raster theme got through use of field calculator, the volumes distribution for dredged material and accretion zone area is quantified; as in appendix 3 *and ref [3]*

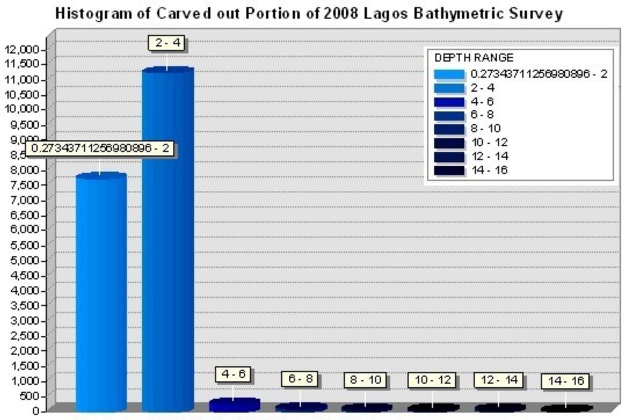
3.3. Determination of Mass Volumes

The data for this computation was initially stored in grid raster format having arrays of square cells structures. For any given depth difference input, the volumes for dredged mass and accretion on the topography can be determined. The cells in the image were scaled using an orderly manner in assigning value; from the upper-right corner, a sequential value is given to each unique edge-connected area of accretion, dredged, or no change. Determining the volume, the area was first calculated. This is simply the number of cells in the region (Count) multiplied by the cell size of the raster.

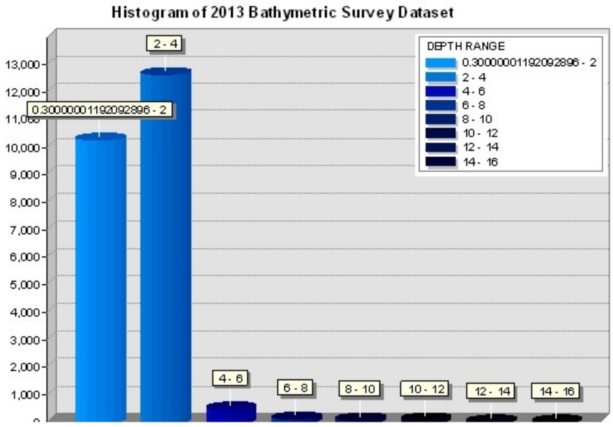
Having calculated the area, the volume was calculated using the below representation.

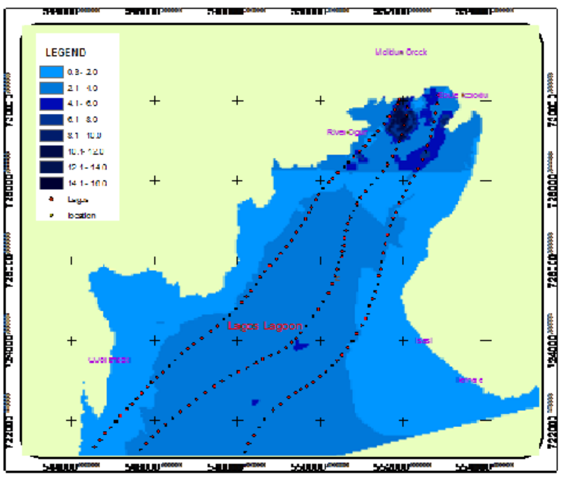
$$Vol = (cell\_area) * \Delta Z \ where: \Delta Z = Z_{2008} - Z_{2013}$$

From the formula, areas where dredging occurred, the volume is positive whereas, accretion places, the volume is negative. Areas in red shows dredged portion while blue areas shows accretion area. See appendix 3 for the volume distribution.



Depth range Distribution for 2008 Bathymetric Dataset





3.4 Querry using GIS as a tool

GIS, a veritable tool which offers the capability of extracting meaningful information; through querying of feature class data, through use of spatial analyst for extraction of useful information relating to spatial distributed data. Spatial analyst uses image statistics to estimate volume from image data, the two images were initially converted to Raster format in the same bit, so the partitioning was uniquely done; as in getting the area. The brightness value is a function of depth and the difference from the two images in use, gives the change in depth which can be used in determine the volume through mathematical multiplication.

Queries for accretion and its statistical distribution indicates that the total volume of deposited sediment is the sum of component volume shown in the statistical portion; and it was calculated as 20715513.306339m^3

Figure 4.2b and 4.2b1 had also shown querying for dredged volumes and its statistical distribution. The total dredged volume is the sum of component volume shown in the statistical portion; and was shown as 13323440.263648m^3

3.5. Conversion of Volumes to Metric Ton

From section 3.4, volumes for accretion and dredged material were respectively calculated as **20715513.306339**m^3 and **13323440.263648**m^3.

From the calculated volumes, it simply means that sediment deposited volume is greater than the mass material dredged from the lagoon. Converting these volumes to weight, we have Density (D)= Mass/ Volume

The density for wet sand is 1922 kg/cu.m

Mass (kg)= Density*Volume= **20715513.306339m^3* 1922 kg/cu.m**

Sediment mass=39815216574.7836kg For Dredged mass (kg) = 25607652186.7315kg

Determining the number of tons; we have 1000kg as an equivalent of 1 metric ton

Therefore, the mass (tons) for both dredged material and sediment materials are as below;

Sediment mass (Metric Ton)=39,815,216.5747836 Metric tons

For Dredged mass (Metric Ton) = 25,607,652.1867315 Metric tons

From the above estimates; there is an indication that more than average of the above metric tons of sand is being dredged or deposited to this portion of lagoon; due to the reason that some portion of the accreted area might have been dredged and there is no proper method of quantifying the mass sediments that has been dredged and subsequently accretion replacement. Perhaps, questioning for the source of this sediment volume in the lagoon topography, needs investigation on the entire coast; though this accretion volume estimate is in confirmation with the study conducted by one of cited in [1]; suspecting mass erosion at Eko Atlantic beach; as been investigated by one of cited literature.

A proper assessment of impact of dredging to the environment need to be done, an Environmental Sensitivity Index can be derived for proper analysis and evaluation.

4. Conclusion and Recommendation

4.1. Conclusion

The paper investigates Lagoon seabed topographical changes and possibly the cause. The stages of this exercise includes; planning, data acquisition, processing analysis and documentation. However, spatial changes were confirmed to have taken place in the study area within the time frame. Compared to previous study of carved out portion of 2008 Lagos bathymetric survey project, a dramatic change had occurred; which was in two folds, areas of sediment deposits and areas of dredging influx. The volume of the two has indication that mass sediment is greater than mass dredged and need for further investigation on the remaining part of lagoon is of great importance in determining the source of mass deposit to the lagoon. The study has also demonstrated the unlimited use of GIS in bathymetric survey processing; from its acquisition stage to production of chart.

4.2. Recommendation

i. An integrated coastal management plan needs to be embraced, by which the activities of the dredgers would be monitored, environmental impact analysis would be strictly adhered to, and legislation fully enforced.

ii. Adopting a good Coastal management policy; coastal education will be a useful tool in educating the involved communities on their impact on coastal waters and the consequences in terms of flooding, disease spread and use of contaminated water in focus.

iii. The study should be extended to the entire lagoon and a validation study should also be extended to suspected beach erosion acclaimed by some literature.

iv. This study is money demanding and effort should be made in financing a research of this capacity by government agencies and capable individuals; as financing hinders the success of many research of this capacity.

v. The study has shown effective use of GIS as a tool for bathymetric survey and coastal management in general; researchers are recommended to enjoy the benefit it offers from start to finish, and also a central open source should be developed to bring researchers close, in term of data needs.

vi Tidal correction is compulsory for reduction of sounding depth and its observation process laborious, therefore government should intensify effort in establishing automatic tide gauge for her coastal waters; this will encourage researchers in extending their study to other part of the country as we are currently witnessing flooding in many states of the country.

vii. However, this paper document is prepared through careful observation, processing and logically drawn to conclusion using scientific method and therefore serves as a good reference material for decision and policy formulation relating to coastal management.

Acknowledgement

I am grateful to those who assisted me during data collection, processing and those who read my manuscript; for the standard of this work is dependable on your contribution.

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[12] http://en.southinstrument.com/products/pro_info.asp?id=234

APPENDIX 1

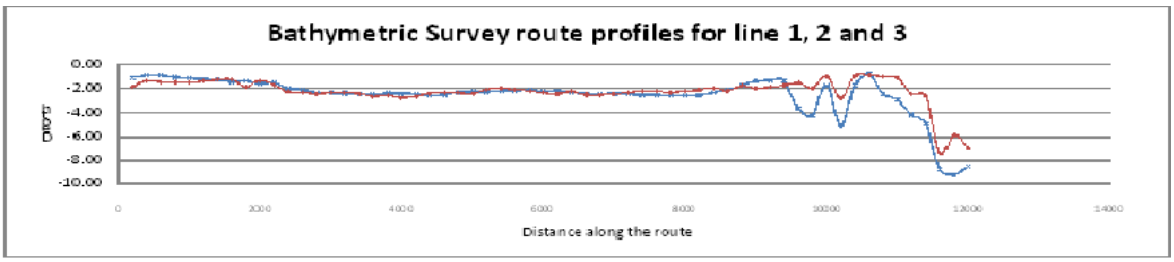


Figure 4.2a. Left flank of Unilag Front to lkorodu Route

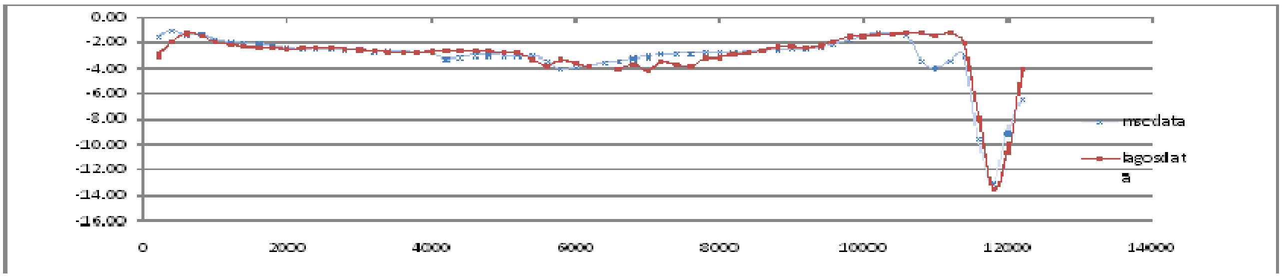


Figure 4.2b. Central flank of Unilag Front to lkorodu Route

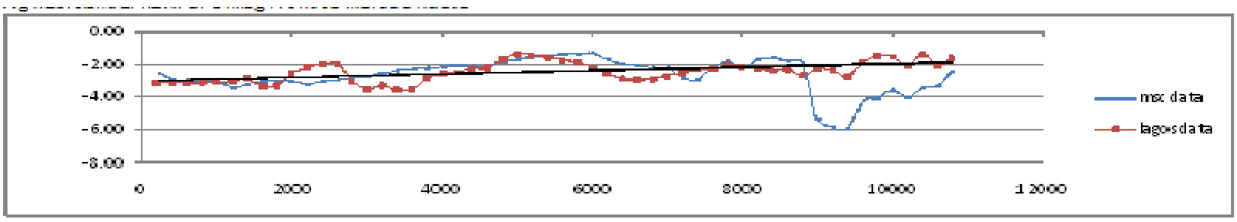


Figure 4.2c. Right flank of Unilag Front to lkorodu Route

Graph showing Depth Changes over time
source [5]

APPENDIX 2

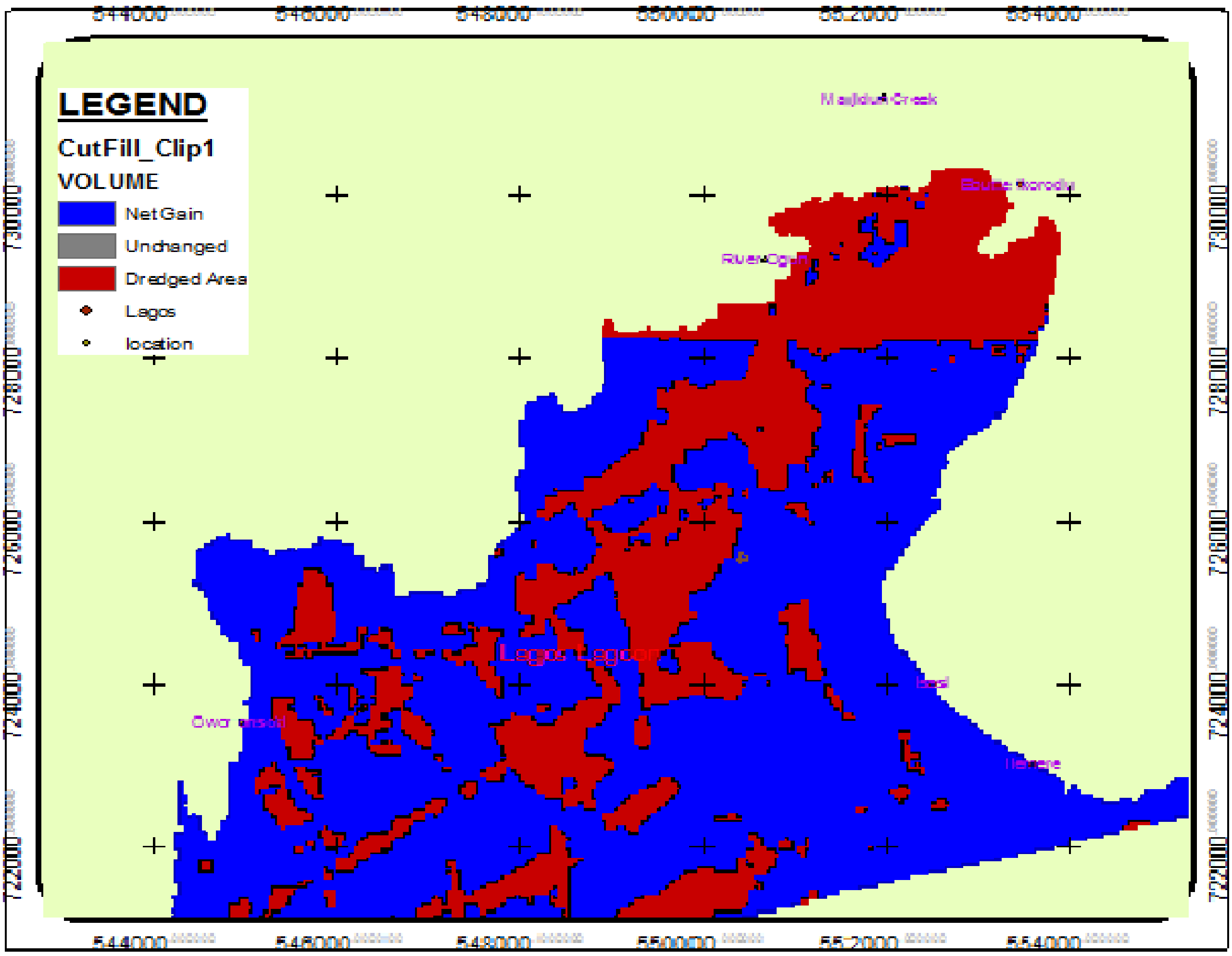
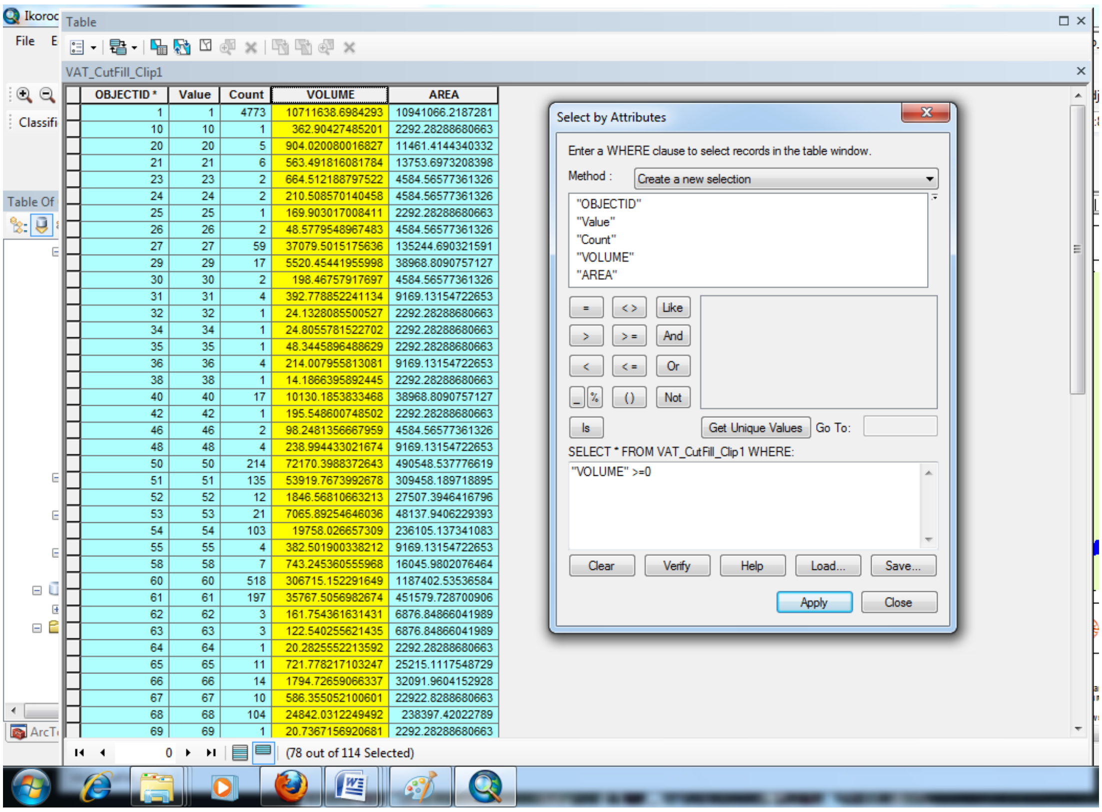


Figure 3.2c. Spatial Changes between 2008 to 2013

APPENDIX 3a



VAT_CutFill_Clip1

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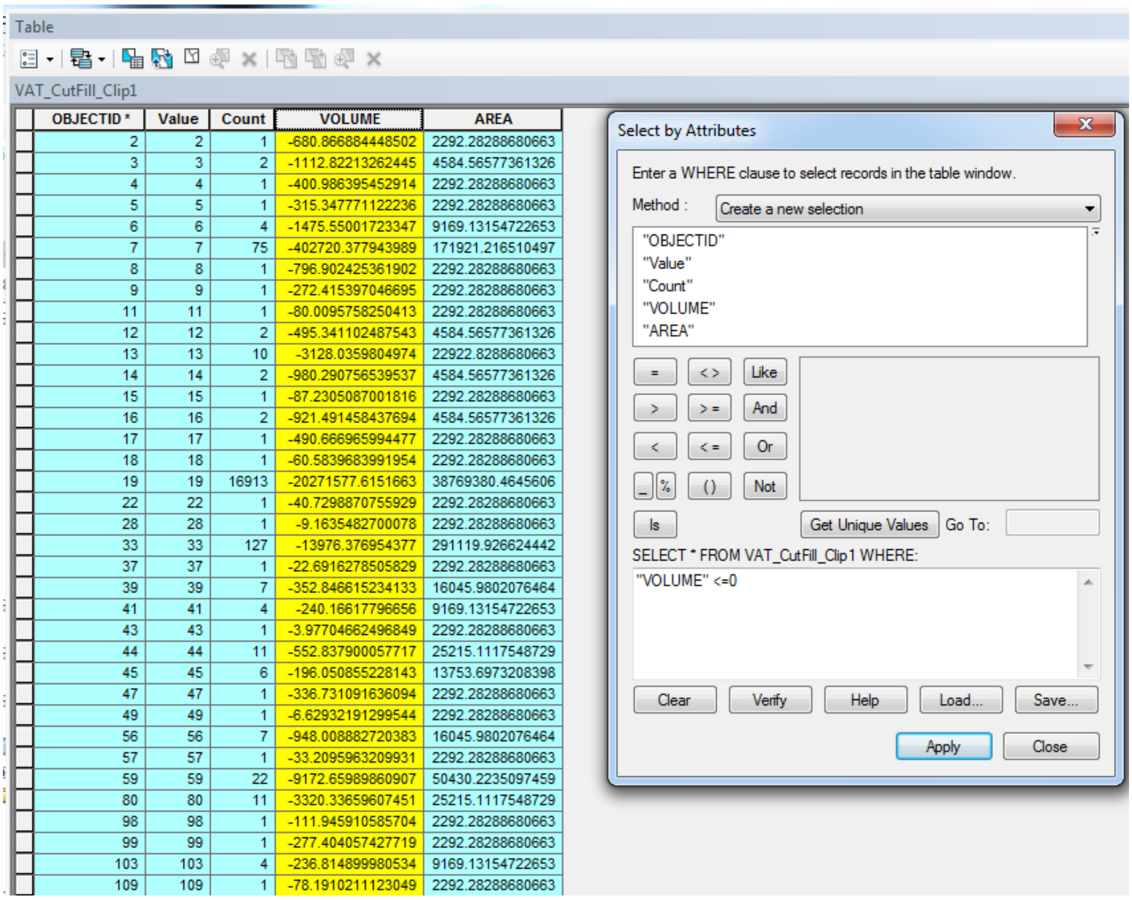
23	23	2	664.512188797522	4584.56577361326
24	24	2	210.508570140458	4584.56577361326
25	25	1	169.903017008411	2292.28288680663
26	26	2	48.5779548967483	4584.56577361326
27	27	59	37079.5015175636	135244.690321591
29	29	17	5520.45441955998	38968.8090757127
30	30	2	198.46757917697	4584.56577361326
31	31	4	392.778852241134	9169.13154722653
32	32	1	24.1328085500527	2292.28288680663
34	34	1	24.8055781522702	2292.28288680663
35	35	1	48.3445896488629	2292.28288680663
36	36	4	214.007955813081	9169.13154722653
38	38	1	14.1866395892445	2292.28288680663
40	40	17	10130.1853833468	38968.8090757127
42	42	1	195.548600748502	2292.28288680663
46	46	2	98.2481356667959	4584.56577361326
48	48	4	238.994433021674	9169.13154722653
50	50	214	72170.3988372643	490548.537776619
51	51	135	53919.7673992678	309458.189718895
52	52	12	1846.56810663213	27507.3946416796
53	53	21	7065.89254646036	48137.9406229393
54	54	103	19758.026657309	236105.137341083
55	55	4	382.501900338212	9169.13154722653
58	58	7	743.245360555968	16045.9802076464
60	60	518	306715.152291649	1187402.53536584
61	61	197	35767.5056982674	451579.728700906
62	62	3	161.754361631431	6876.84866041989
63	63	3	122.540255621435	6876.84866041989
64	64	1	20.2825552213592	2292.28288680663
65	65	11	721.778217103247	25215.1117548729
66	66	14	1794.72659066337	32091.9604152928
67	67	10	586.355052100601	22922.8288680663
68	68	104	24842.0312249492	238397.42022789
69	69	1	20.7367156920681	2292.28288680663

(78 out of 114 Selected)

APPENDIX 3b

Table 4.2b. Accretion volumes distribution



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4	4	1	-400.986395452914	2292.28288680663
5	5	1	-315.347771122236	2292.28288680663
6	6	4	-1475.55001723347	9169.13154722653
7	7	75	-402720.377943989	171921.216510497
8	8	1	-796.902425361902	2292.28288680663
9	9	1	-272.415397046695	2292.28288680663
11	11	1	-80.0095758250413	2292.28288680663
12	12	2	-495.341102487543	4584.56577361326
13	13	10	-3128.0359804974	22922.8288680663
14	14	2	-980.290756539537	4584.56577361326
15	15	1	-87.2305087001816	2292.28288680663
16	16	2	-921.491458437694	4584.56577361326
17	17	1	-490.666965994477	2292.28288680663
18	18	1	-60.5839683991954	2292.28288680663
19	19	16913	-20271577.6151663	38769380.4645606
22	22	1	-40.7298870755929	2292.28288680663
28	28	1	-9.1635482700078	2292.28288680663
33	33	127	-13976.376954377	291119.926624442
37	37	1	-22.6916278505829	2292.28288680663
39	39	7	-352.846615234133	16045.9802076464
41	41	4	-240.16617796656	9169.13154722653
43	43	1	-3.97704662496849	2292.28288680663
44	44	11	-552.837900057717	25215.1117548729
45	45	6	-196.050855228143	13753.6973208398
47	47	1	-336.731091636094	2292.28288680663
49	49	1	-6.62932191299544	2292.28288680663
56	56	7	-948.008882720383	16045.9802076464
57	57	1	-33.2095963209931	2292.28288680663
59	59	22	-9172.65989860907	50430.2235097459
80	80	11	-3320.33659607451	25215.1117548729
98	98	1	-111.945910585704	2292.28288680663
99	99	1	-277.404057427719	2292.28288680663
103	103	4	-236.814899980534	9169.13154722653
109	109	1	-78.1910211123049	2292.28288680663