The Remaining Storage and Rate of Siltation of Mairuwa Dam, Funtua, Katsina State, North-western Nigeria

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Abstract
Mairuwa impounded reservoir (Dam) which was constructed in 1970, had an initial installed capacity of 5.5 million cubic meters and it is the main source of piped water supply to Funtua and its environs for the purpose of irrigation farming and potable water supply. The volume of rainfall in the drainage basin is 102,259,006m^3. Runoff coefficient of the area is 0.23. Volume of total runoff is 23,519,571m^3. Total volume of material eroded from the drainage basin is 4,703m^3/a. After 50 years of impoundment, continuous siltation caused by sediment being deposited annually is affecting its usefulness to the people. In order to determine the remaining storage of the reservoir, there is need to study the reservoir's bathymetry using boat, satellite navigator and metric tape with a heavy stone attached to it. Results of this measurement show that as at 2020, the remaining storage of the reservoir is 1,944,000m^3 representing 35% of the installed capacity. The rate of siltation is 349,920m^3/y and loss in volume is 3,556,000m^3 representing 65% of the total storage. The rate of erosion in the drainage basin of 102 km^2 is calculated to be 0.45mm/a. This is far higher than the world average of 0.088mm/a. The reservoir will be completely silted up if preventive measures are not taken. This will result to inadequate supply of piped water to Funtua and Environs.

Keywords: Dam, Impounding Reservoir, Siltation, Rate of Erosion.

1.0 INTRODUCTION

Impounded reservoirs are pivotal to the growth of any economy; they play a major role in the generation of electricity, irrigation farming, potable water supply, flood control and recreational purposes. Water supply to Funtua and its environs which is mostly dependent on supply from the Mairuwa Dam has been grossly inadequate. The amount of water pumped is insufficient to meet the increasing water demand. The residents of Funtua town rely mostly on hand dug wells, boreholes and rain harvesting. Yields from irrigated farms are often poor as a result of inadequate water supply.

At the United Nations Environment Programme International conference on fresh water ((UNEP, 2001), it was reported that many of the world's reservoirs upon which billions of people depends for drinking water and food production, are suffering significant reductions in storage capacity as a result of sedimentation. These sediments are composed of eroded materials of different shapes and sizes carried by streams or rivers (Ritter, 2006). Sediments generated within a catchment area of a river are subsequently moved from a drainage basin to be deposited in flood plains; in storage reservoirs (Oyegun, 1980). Globally, impounded reservoirs are being threatened by erosion within its drainage basin.

Reports from Graf (1984); Fan and Morris, (1992): In Althaus and De Cesare, (2006), sediment deposition in reservoirs leads to loss of water storage. According to White (2000), the global rate of erosion is 0.088 mm/year with the global distribution of the rate of loss of storage varying considerably. China and India are losing 2.3% and 0.5% respectively of storage capacity annually because of the low forest cover and high erosion, but the annual loss rates in Japan and Southeast Asia are only 0.15% and 0.3% respectively due to high forest cover and relatively low sediment yield.

Igiusi (1997) did an earlier assessment on the level of sedimentation in the Kubani Dam. According to A.B.U committee on Protection of the Kubanni Drainage Basin, (2008), there is high rate of siltation of the Kubanni Reservoir which supplies water to Ahmadu Bello University and its environs. They further stated that if necessary actions are not taken, water rationing within the University campus, caused by progressive siltation of the Kubanni impounding reservoir, could possibly begin in 2022 with a complete siltation of the reservoir in year 2059. Baba *et al*, (2009) also reported the high rate of siltation of the Ahmadu Bello University Farm Lake at Zaria which was constructed in 1966 with original storage capacity of 636,300m^2. They gave the remaining storage capacity of the reservoir as 349,911m^2 and calculated rate of siltation between year 1966 to 2009 as 6,600m^3/a, and the rate of erosion in the drainage basin in the same period as 0.559mm/a. Kudamnya *et al,* (2013) also carried out an evaluation of the remaining storage of the Zaria impounded reservoir and rate of erosion in its drainage basin.

According to Ofoezie (2002) and Etosa (2006) after updating the number of dams in Nigeria, reported that out of 323 dams been constructed nationally, 106 are large dams while 192 are small dams. The Mairuwa Dam is one of these large dams, having a catchment area of 120km^2, with a crest length of 457m and maximum height of 12m. Therefore, this study is aimed at determining the rate of siltation of Mairuwa Dam with the view to ascertain the remaining storage of the dam, to improved piped water supply to Funtua and its environs.

2.0 THE STUDY AREA

Mairuwa Dam is located within the crystalline hydrogeological province of northern Nigeria, within the Guinea Savannah belt. It is located at 11^0 30' to 11^0 38'N, and 7^0 13' to 7^0 21'E, sheet 78 (FUNTUA), Federal Surveys of Nigeria 1: 50,000 (1986). Geological and mineral resources map of Katsina State, Nigeria on scale 1: 500,000 shows that the study area is overlay by granite gneiss and silicified sheared rock of Crystalline Basement Complex, Precambrian to Cambrian in age Nigerian Geological Survey Agency (2006) Figure 1. The study area is accessible through a trunk a road from Zaria through Funtua to Gusau. The dam is about 10km north-west of Funtua. The geology of the Mairuwa Dam is mainly igneous and metamorphic (Migmatite Gneiss Complex). The area is underlain by granite gneiss and silicified sheared of Precambrian to Cambrian.

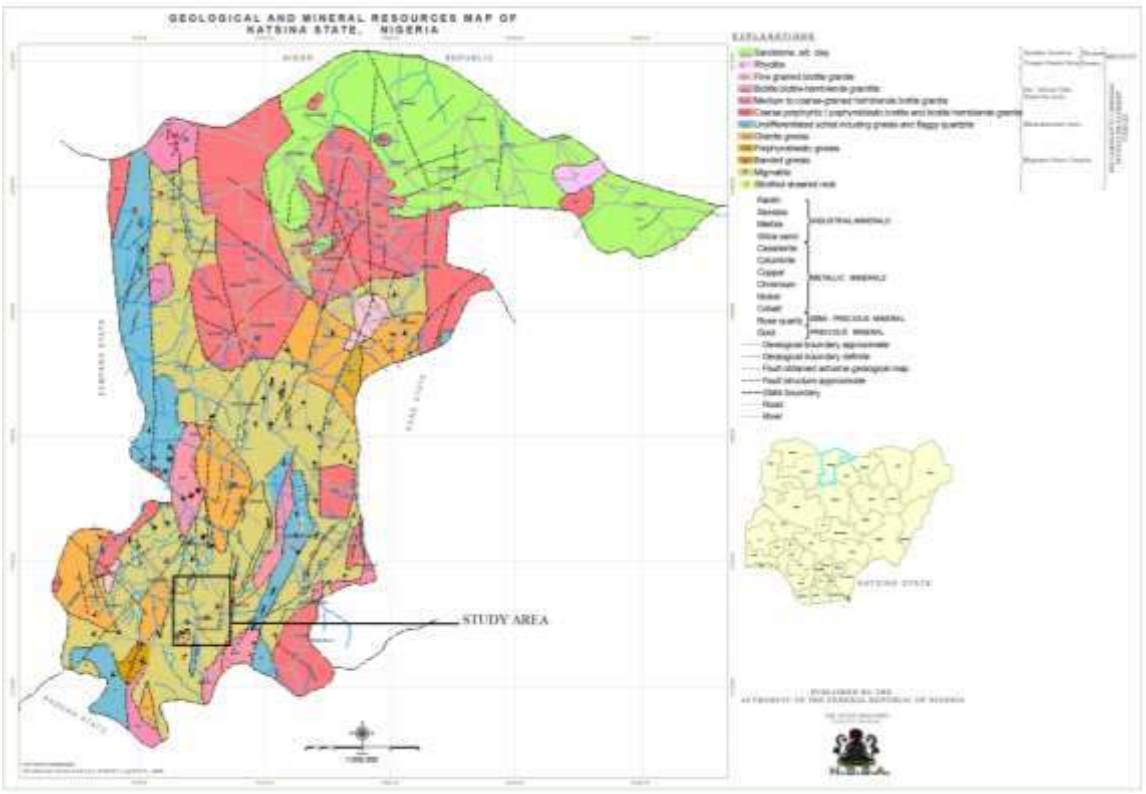

Figure 1: Geological and Mineral Resources Map of Katsina State, Nigeria. Source: Nigerian Geological Survey Agency (2006)

3.0 METHODOLOGY

Measurement of the depth to water table was done during the rainy season at the time the storage reservoir has a maximum capacity, it was measured in meters from a fishing boat with metric tape having a heavy object tied to its end. Points of measurement were located with a Garmin Oregon 550T satellite navigator, with a horizontal accuracy of 3m. Delineation of the edge of the surface water table was located with the Global Positional System (GPS) satellite navigator on the same day with the spillway flowing. The edges of the open water – table was located in the field also. The measurement of the depth in meters for irregular network of points carried out represents the remaining depth of the Mairuwa Dam at a selected sampling point. This procedure was repeatedly applied to all randomly sampling points to determine the depth of the dam at each given point. Depths measured at each of the station points are annotated on the base map on a scale 1:57,500 from which Isobaths were produced based on interpolations between the various depth points. From the bathymetric map produced, the least square method was used to calculate the area of the open water table of the Mairuwa Dam. A graph paper was superimposed on the bathymetric map; the small squares were counted as well as the big squares. Using the average depth, the volume of the remaining storage of the Dam was calculated.

From the base map on a scale of 1:57,500, the watershed was demarcated. A graph paper was thereby imposed and the extent of the drainage basin was drawn from which the area of the

drainage basin was calculated. Using the result of the area of the drainage basin and the depth of annual rainfall around Funtua, the area of the drainage basin was multiplied by the depth of rainfall to get the volume of rainfall in the Drainage Basin.

4.0 RESULT OF MEASUREMENTS OF DEPTH OF STORAGE IN MAIRUWA DAM

Table 1, shows the results of water depth measurements. Table 2, shows the results of location of edge of surface water table. Figure 2, is the Google Earth Image which were used in the demarcation of surface water from dry land. These results were used to plot the map of remaining storage of the Mairuwa Dam as shown in Figure 3. The boundary of the reservoir was located with satellite navigator while the spillway was overflowing. The reservoir boundaries were not easily accessible as they were often separated from the dry land by a few meters wide swampy belt from where water was seeping to the lake. A Satellite map was used to locate all details of the water edge. The results of reservoir boundary location area using graph paper least square method are presented in Table 3.

Figure 2: Satellite image showing Mairuwa Dam (Source: Google Earth, 2012)

Table 1: Results of Measurement of Remaining Storage. Instruments used are Satellite Navigator, Metric Tape and Paddle Canoe measured

Location	Latitude (N)	Longitude (E)	Elevation of Water (Masl)	Depth Below Level of Spillway (M)
01	11^0 35' 10.7"	07^0 14' 13.5"	640	0.17
02	11^0 35' 12.8"	07^0 14' 15.4"	640	0.69
03	11^0 35' 11.2"	07^0 14' 16.2"	641	0.83
04	11^0 35' 09.8"	07^0 14' 16.5"	640	0.68
05	11^0 35' 08.0"	07^0 14' 17.6"	641	1.32
06	11^0 35' 07.3"	07^0 14' 18.0"	642	0.89
07	11^0 35' 08.5"	07^0 14' 20.0"	641	1.36
08	11^0 35' 11.3"	07^0 14' 19.5"	640	4.80
09	11^0 35' 13.8"	07^0 14' 19.2"	639	5.10
10	11^0 35' 15.8"	07^0 14' 19.1"	640	6.17
11	11^0 35' 17.6"	07^0 14' 18.1"	640	3.50
12	11^0 35' 15.5"	07^0 14' 20.1"	641	0.98
13	11^0 35' 15.8"	07^0 14' 22.9"	641	1.62
14	11^0 35' 16.4"	07^0 14' 23.4"	642	5.34
15	11^0 35' 13.0"	07^0 14' 22.5"	641	6.45
16	11^0 35' 09.4"	07^0 14' 24.4"	641	4.15
17	11^0 35' 06.3"	07^0 14' 24.4"	640	0.56
18	11^0 35' 04.6"	07^0 14' 25.2"	642	0.53
19	11^0 35' 01.2"	07^0 14' 26.2"	642	08.7
20	11^0 35' 01.3"	07^0 14' 30.2"	641	0.89
21	11^0 35' 05.0"	07^0 14' 31.7"	640	5.50
22	11^0 35' 06.4"	07^0 14' 33.6"	640	5.40
23	11^0 35' 10.9"	07^0 14' 28.2"	641	6.12
24	11^0 35' 10.6"	07^0 14' 32.3"	642	5.93
25	11^0 35' 12.7"	07^0 14' 31.2"	641	5.85
26	11^0 35' 15.8"	07^0 14' 32.7"	639	5.39
27	11^0 35' 18.4"	07^0 14' 29.5"	640	5.41
28	11^0 35' 20.5"	07^0 14' 27.6"	641	4.83
29	11^0 35' 20.5"	07^0 14' 20.4"	641	0.68
30	11^0 35' 23.4"	07^0 14' 26.3"	642	4.44
31	11^0 35' 22.0"	07^0 14' 25.5"	641	0.83
32	11^0 35' 23.2"	07^0 14' 29.0"	641	3.66
33	11^0 35' 21.4"	07^0 14' 27.6"	641	2.51
34	11^0 35' 23.9"	07^0 14' 30.9"	641	3.12
35	11^0 35' 27.0"	11^0 14' 32.8"	642	2.42
36	11^0 35' 23.1"	07^0 14' 31.5"	641	4.72
37	11^0 35' 27.1"	07^0 14' 28.4"	641	0.93
38	11^0 35' 31.6"	07^0 14' 31.0"	641	1.49
39	11^0 35' 31.3"	07^0 14' 35.4"	640	3,43
40	11^0 35' 39.4"	07^0 35' 37.4"	641	0.68
41	11^0 35' 38.9"	07^0 14' 41.5"	642	2.11
42	11^0 35' 41.4"	07^0 14' 43.3"	639	1.59
43	11^0 35' 40.8"	07^0 14' 45.4"	641	2.05
44	11^0 35' 44.5"	07^0 14' 45.3"	641	1.36
45	11^0 35' 44.4"	07^0 14' 47.4"	639	0.88
46	11^0 35' 42.3"	07^0 14' 49.0"	640	1.53
47	11^0 35' 40.9"	07^0 14' 49.0"	640	0.62
48	11^0 35' 40.5"	07^0 14' 47.1"	642	1,92
49	11^0 35' 39.7"	07^0 14' 45.8"	641	1.91
50	11^0 35' 37.4"	07^0 14' 37.4"	640	0.71
51	11^0 35' 34.4"	07^0 14' 46.8"	641	0.39

52	11⁰ 35’ 35.5”	07⁰ 14’ 32.5”	640	0.56
53	11⁰ 35’ 35.9”	07⁰ 14’ 44.4”	640	1.72
54	11⁰ 35’ 35.0”	07⁰ 14’ 41.0”	641	2.74
55	11⁰ 35’ 34.1”	07⁰ 14’ 39.8”	641	2.87
56	11⁰ 35’ 33.1”	07⁰ 14’ 41.4”	640	2.87
57	11⁰ 35’ 31.2”	07⁰ 14’ 43.1”	640	1.56
58	11⁰ 35’ 30.6”	07⁰ 14’ 41.2”	640	3.53
59	11⁰ 35’ 29.8”	07⁰ 14’ 39.3”	641	3.81
60	11⁰ 35’ 27.6”	07⁰ 14’ 38.7”	642	4.14
61	11⁰ 35’ 29.0”	07⁰ 14’43.9”	641	0.45
62	11⁰ 35’ 26.7”	07⁰ 14’ 42.0”	640	3.88
63	11⁰ 35’ 25.9”	07⁰ 14’ 44.3”	640	1.54
64	11⁰ 35’ 24.3”	07⁰ 14’ 42.0”	643	1.53
65	11⁰ 35’ 23.0”	07⁰ 14’ 42.9”	642	1.36
66	11⁰ 35’ 23.8”	07⁰ 14’ 40.9”	640	1.46
67	11⁰ 35’ 21.4”	07⁰ 14’ 43.0 ”	640	0.44
68	11⁰ 35’ 22.6”	07⁰ 14’ 40.4”	641	0.30
69	11⁰ 35’ 24.5”	07⁰ 14’ 43.9”	641	0.51
70	11⁰ 35’ 23.4”	07⁰ 14’ 37.5”	640	4.50
71	11⁰ 35’ 22.5”	07⁰ 14’ 35.1”	639	5.00
72	11⁰ 35’ 19.5”	07⁰ 14’ 34.7”	639	5.17
73	11⁰ 35’ 18.8”	07⁰ 14’ 38.8”	639	4.55
74	11⁰ 35’ 17.0”	07⁰ 14’ 42.0”	640	0.47
75	11⁰ 35’ 15.3”	07⁰ 14’ 42.4”	640	1.67
76	11⁰ 35’ 13.0”	07⁰ 14’ 40.6”	639	3.16
77	11⁰ 35’ 09.2”	07⁰ 14’ 40.0”	639	5.76
78	11⁰ 35’ 07.0”	07⁰ 14’ 39.7”	640	4.99
79	11⁰ 35’ 06.6”	07⁰ 14’ 41.2”	641	5.18
80	11⁰ 35’ 08.1”	07⁰ 14’ 42.0”	640	5.16
81	11⁰ 35’ 11.0”	07⁰ 14’ 42.6”	641	5.17
82	11⁰ 35’ 14.6”	07⁰ 14’ 43.3”	640	0.17
83	11⁰ 35’ 12.9”	07⁰ 14’ 45.6”	640	3.57
84	11⁰ 35’ 12.3”	07⁰ 14’ 47.4”	640	3.98
85	11⁰ 35’ 15.5”	07⁰ 14’ 49.2”	639	0.74
86	11⁰ 35’ 15.1”	07⁰ 14’ 51.8”	639	1.44
87	11⁰ 35’ 13.3”	07⁰ 14’ 54.7”	640	1.45
88	11⁰ 35’ 15.1”	07⁰ 14’ 54.0”	640	0.33
89	11⁰ 35’ 11.3”	07⁰ 14’ 56.7”	640	0.25
90	11⁰ 35’ 11.2”	07⁰ 14’ 54.3”	642	3.19
91	11⁰ 35’ 07.3”	07⁰ 14’ 51.4”	641	4.09
92	11⁰ 35’ 04.4”	07⁰ 14’ 53.0”	641	4.45
93	11⁰ 35’ 04.0”	07⁰ 14’ 59.0”	643	1.43
94	11⁰ 35’ 06.3”	07⁰ 14’ 59.0”	641	0.36
95	11⁰ 35’ 01.4”	07⁰ 14’ 59.7”	642	3.64
96	11⁰ 34’ 59.0”	07⁰ 15’ 00.0”	642	3.61
97	11⁰ 35’ 01.6”	07⁰ 15’ 02.1”	641	3.37
98	11⁰ 35’ 06.0”	07⁰ 15’ 04.6”	640	0.67
99	11⁰ 35’ 10.7”	07⁰ 15’ 00.9”	641	0.21
100	11⁰ 35’ 03.3”	07⁰ 15’ 07.5”	641	1.62
102	11⁰ 35’ 02.3”	07⁰ 15’ 12.1”	642	0.53
103	11⁰ 35’ 01.2”	07⁰ 15’ 01.3”	640	2.87
105	11⁰ 34’ 58.4”	07⁰ 15’ 06.6”	641	3.07
106	11⁰ 34’ 54.8”	07⁰ 15’ 10.6”	641	2.70
107	11⁰ 34’ 53.7”	07⁰ 15’ 14.4”	640	1.38
108	11⁰ 34’ 50.3”	07⁰ 15’ 14.0”	639	2.15
109	11⁰ 34’ 49.8”	07⁰ 15’ 16.9”	640	2.15

110	11^0 34’ 52.3”	07^0 15’ 17.6”	641	1.93
111	11^0 34’ 55.1”	07^0 15’ 17.6”	641	1.93
112	11^0 34’ 57.4”	07^0`15’ 18.8”	640	1,54
113	11^0 34’ 57.6”	07^0 15’ 20.6”	640	1.51
114	11^0 34’ 54.3”	07^0 15’ 21.7”	641	1.55
115	11^0 34’ 51.9”	07^0 15’ 23.8”	642	0.52
116	11^0 34’ 49.3”	07^0 15’ 19.1”	641	1.52
117	11^0 34’ 46.4”	07^0 15’ 21.8”	641	05.1
118	11^0 34’ 47.0”	07^0 15’ 27.1”	640	0.66
119	11^0 34’ 50.2”	07^0 15’ 31.2”	640	0.49
120	11^0 34’ 48.5”	07^0 15’ 32.0”	639	0.62
121	11^0 34’ 54.5”	07^0 15’ 27.1”	639	0.53
122	11^0 34’ 52.5”	07^0 15’ 31.2”	640	0.51
123	11^0 34’ 58.8”	07^0 15’ 25.4”	640	0.53
124	11^0 34’ 57.0”	07^0 15’ 16.5”	641	0.51
125	11^0 34’ 49.1”	07^0 15’ 17.4”	641	1.81
126	11^0 34’ 46.6”	07^0 15’ 15.9”	641	1.55
127	11^0 34’ 44.1”	07^0 15’ 16.1”	642	0.57
126	11^0 34’ 47.7”	07^0 15’ 14.2”	641	1.72
127	11^0 34’ 45.4”	07^0 15’ 12.9”	640	1.90
128	11^0 34’ 45.6”	07^0 15’ 09.0”	640	0.40
129	11^0 34’ 47.7”	07^0 15’ 10.1”	639	2.16
130	11^0 34’ 46.8”	07^0 15’ 06.2”	639	1.85
131	11^0 34’ 49.0”	07^0 15’ 04.5”	641	1.99
132	11^0 34’ 49.2”	07^0 15’ 02.2”	641	0.31
133	11^0 34’ 52.0”	07^0 15’ 05.3”	642	2.12
134	11^0 34’ 52.9”	07^0 15’ 06.4”	642	2.63
135	11^0 34’ 54.1”	07^0 15’ 05.7”	641	2.71
136	11^0 34’ 53.7”	07^0 15’ 03.9”	641	1.08
137	11^0 34’ 52.2”	07^0 15’ 03.0”	642	2.93
138	11^0 34’ 53.6”	07^0 15’ 00.0”	641	1.05
139	11^0 34’ 55.7”	07^0 14’ 56.6”	642	0.95
140	11^0 34’ 57.4”	07^0 14’ 56.4”	642	2.68
141	11^0 34’ 59.4”	07^0 14’ 55.4”	640	3.65
142	11^0 35’ 00.0”	07^0 14’ 54.3”	640	2.93
143	11^0 34’ 58.7”	07^0 14’ 52.2”	642	2.60
144	11^0 34’ 57.5”	07^0 14’ 50.3”	640	0.61
145	11^0 35’ 00.0”	07^0 14’ 51.1”	641	2.73
146	11^0 35’ 04.1”	07^0 14’ 50.5”	641	4.82
147	11^0 35’ 05.8”	07^0 14’ 49.4”	642	5.08
148	11^0 35’ 04.6”	07^0 14’ 47.6”	642	4.04
149	11^0 35’ 03.5”	07^0 14’ 46.4”	641	1.24
150	11^0 35’ 03.5”	07^0 14’ 44.8”	640	1.65
151	11^0 35’ 05.0”	07^0 14’ 44.3”	643	0.63
152	11^0 35’ 04.7”	07^0 14’ 43.5”	642	4.93
153	11^0 35’ 06.6”	07^0 14’ 42.1”	641	5.31
154	11^0 35’ 07.3”	07^0 14’ 41.2”	640	5.10
155	11^0 35’ 04.2”	07^0 14’ 40.3”	641	4.54
156	11^0 35’ 00.4”	07^0 14’ 39.7”	641	2.43
157	11^0 34’ 59.0”	07^0 14’ 38.8”	642	1.19
158	11^0 34’ 59.6”	07^0 14’ 34.9”	641	0.86
159	11^0 34’ 59.6”	07^0 14’ 35.0”	641	0.34
160	11^0 35’ 01.4”	07^0 14’ 34.8”	642	4.40
161	11^0 35’ 03.5”	07^0 14’ 34.3”	642	5.49
162	11^0 35’ 04.4”	07^0 14’ 32.9”	642	5.25

Table 2: Results of Location of Surface Water Table Boundary of Mairuwa Dam. Instruments used are Satellite Navigator Measured

S/No	Date of Measurement	Cordinates In Satellite Navigator Latitude	Longitude	Elevation (M Asl)
1	18/07/2011	11^0 35’ 13.1”N	07^0 14’ 14.7”E	671
2	18/07/2011	11^0 35’ 14.5”N	07^0 14’ 15.2”E	668
3	18/07/2011	11^0 35’ 18.0”N	07^0 14’ 16.7”E	651
4	18/07/2011	11^0 35’ 21.8”N	07^0 14’ 20.3”E	668
5	18/07/2011	11^0 35’ 21.1”N	07^0 14’ 20.7”E	666
6	18/07/2011	11^0 35’ 20.5”N	07^0 14’ 22.7”E	666
7	18/07/2011	11^0 35’ 20.22N	07^0 14’ 24.2”E	667
8	18/07/2011	11^0 35’ 21.2”N	07^0 14’ 24.9”E	668
9	18/07/2011	11^0 35’ 24.4”N	07^0 14’ 27.4”E	669
10	18/07/2011	11^0 35’ 26.0”N	07^0 14’ 27.3”E	664
11	18/07/2011	11^0 35’ 28.8”N	07^0 14’ 28.4”E	665
12	18/07/2011	11^0 35’ 20.8”N	07^0 14’ 30.4”E	663
13	18/07/2011	11^0 35’ 32.4”N	07^0 14’ 30.4”E	658
14	18/07/2011	11^0 35’ 34.8”N	07^0 14’ 34.8”E	660
15	18/07/2011	11^0 35’ 39.8”N	07^0 14’ 37.4”E	662
16	18/07/2011	11^0 35’ 42.8”N	07^0 14’ 38.9”E	661
17	18/07/2011	11^0 35’ 43.6”N	07^0 14’ 40.9”E	664
18	18/07/2011	11^0 35’ 43.1”N	07^0 14’ 42.8”E	666
19	18/07/2011	11^0 35’ 44.5”N	07^0 14’ 42.4”E	667
20	18/07/2011	11^0 35’ 42.3”N	07^0 14’ 51.4”E	666
21	18/07/2011	11^0 35’ 41.5”N	07^0 14’ 44.5”E	668
22	18/07/2011	11^0 35’ 39.2”N	07^0 14’ 50.4”E	670
23	18/07/2011	11^0 35’ 38.0”N	07^0 14’ 44.3”E	659
24	18/07/2011	11^0 35’ 36.6”N	07^0 14’ 46.3”E	664
25	18/07/2011	11^0 35’ 35.2”N	07^0 14’ 45.0”E	669
26	18/07/2011	11^0 35’ 34.0”N	07^0 14’ 44.0”E	668
27	18/07/2011	11^0 35’ 32.2”N	07^0 14’ 43.6”E	664
28	18/07/2011	11^0 35’ 30.6”N	07^0 14’ 43.7”E	667
29	18/07/2011	11^0 35’ 27.2”N	07^0 14’ 44.5”E	664
30	18/07/2011	11^0 35’ 23.7”N	07^0 14’ 43.1”E	666
31	18/07/2011	11^0 35’ 24.4”N	07^0 14’ 44.3”E	655
32	18/07/2011	11^0 35’ 22.1”N	07^0 14’ 22.1”E	658
33	18/07/2011	11^0 35’ 22.9”N	07^0 14’ 40.9”E	659
34	18/07/2011	11^0 35’ 20.7”N	07^0 14’ 41.1”E	666
35	18/07/2011	11^0 35’ 21.4”N	07^0 14’ 41.9”E	668
36	18/07/2011	11^0 35’ 22.0”N	07^0 14’ 43.7”E	669
37	18/07/2011	11^0 35’ 21.5”N	07^0 14’ 44.7”E	664
38	18/07/2011	11^0 35’ 20.3”N	07^0 14’ 43.7”E	663
39	18/07/2011	11^0 35’ 18.7”N	07^0 14’ 43.1”E	662
40	18/07/2011	11^0 35’ 17.0”N	07^0 14’ 44.3”E	667
41	18/07/2011	11^0 35’ 16.0”N	07^0 14’ 46.1”E	668
42	18/07/2011	11^0 35’ 16.2”N	07^0 14’ 49.0”E	665
43	18/07/2011	11^0 35’ 15.4”N	07^0 14’ 53.0”E	666
44	18/07/2011	11^0 35’ 14.9”N	07^0 14’ 54.9”E	665
45	18/07/2011	11^0 35’ 12.0”N	07^0 14’ 57.8”E	669
46	18/07/2011	11^0 35’ 09.1”N	07^0 14’ 57.4”E	670
47	18/07/2011	11^0 35’ 05.3”N	07^0 14’ 59.2”E	664
48	18/07/2011	11^0 35’ 06.5”N	07^0 15’ 02.1”E	665
49	18/07/2011	11^0 35’ 06.7”N	07^0 15’ 06.7”E	666
50	18/07/2011	11^0 35’ 03.9”N	07^0 15’ 09.5”E	667

51	18/07/2011	11^0 35’ 02.9”N	07^0 15’ 14.0”E	661
52	18/07/2011	11^0 35’ 00.8”N	07^0 15’ 15.1“E	662
53	18/07/2011	11^0 35’ 00.0”N	07^0 15’ 19.1”E	664
54	18/07/2011	11^0 34’ 59.0”N	07^0 15’ 18.7”E	668
55	18/07/2011	11^0 34’ 58.8”N	07^0 15’ 16.7”E	666
56	18/07/2011	11^0 34’ 58.2”N	07^0 15’ 15.3”E	665
57	18/07/2011	11^0 34’ 56.8”N	07^0 15’ 15.8”E	667
58	18/07/2011	11^0 34’ 58.5”N	07^0 15’ 17.7”E	668
59	18/07/2011	11^0 34’ 58.5”N	07^0 15’ 20.0”E	669
60	18/07/2011	11^0 34’ 59.9”N	07^0 15’ 20.0”E	665
61	18/07/2011	11^0 35’ 00.4”N	07^0 15’ 23.0”E	667
62	18/07/2011	11^0 34’ 59.9”N	07^0 15’ 25.7”E	665
63	18/07/2011	11^0 34’ 54.3”N	07^0 15’ 30.4”E	666
64	18/07/2011	11^0 34’ 51.8”N	07^0 15’ 37.1”E	669
65	18/07/2011	11^0 34’ 50.7”N	07^0 15’ 35.3”E	665
66	18/07/2011	11^0 35’ 10.5”N	07^0 14’ 13.2”E	668
67	18/07/2011	11^0 35’ 10.3”N	07^0 14’ 14.0”E	667
68	19/07/2011	11^0 35’ 10.3”N	07^0 14’ 15.9”E	664
69	19/07/2011	11^0 35’ 10.5”N	07^0 14’ 16.5”E	665
70	19/07/2011	11^0 35’ 09.8”N	07^0 14’ 16.6”E	668
71	19/07/2011	11^0 35’ 08.1”N	07^0 14’ 16.4”E	669
72	19/07/2011	11^0 35’ 06.8”N	07^0 14’ 16.9”E	664
73	19/07/2011	11^0 35’ 05.8”N	07^0 14’ 17.5”E	665
74	19/07/2011	11^0 35’ 05.0”N	07^0 14’ 17.9”E	667
75	19/07/2011	11^0 35’ 00.6”N	07^0 14’ 25.7”E	664
76	19/07/2011	11^0 35’ 00.6”N	07^0 14’ 26.3”E	665
77	19/07/2011	11^0 35’ 00.2”N	07^0 14’ 27.7”E	667
78	19/07/2011	11^0 35’ 00.6”N	07^0 14’ 29.0”E	665
79	19/07/2011	11^0 35’ 00.4”N	07^0 14’ 31.3”E	666
80	19/07/2011	11^0 35’ 00.1”N	07^0 14’ 31.4”E	668
81	19/07/2011	11^0 34’ 59.4”N	07^0 14’ 34.2”E	663
82	19/07/2011	11^0 34’ 59.2”N	07^0 14’ 34.4”E	662
83	19/07/2011	11^0 34’ 58.2”N	07^0 14’ 34.9”E	665
84	19/07/2011	11^0 34’ 57.5”N	07^0 14’ 35.8”E	663
85	19/07/2011	11^0 34’ 58.1”N	07^0 14’ 36.5”E	668
86	19/07/2011	11 ^{0}34’ 58.2”N	07^0 14’ 37.6”E	664
87	19/07/2011	11^{0}34 ‘57.7”N	07^0 14’ 39.6”E	663
88	19/07/2011	11^0 34’ 57.4”N	07^0 14’ 40.3”E	660
89	19/07/2011	11^0 34’ 55.7”N	07^0 14’ 42.1”E	662
90	19/07/2011	11^0 34’ 55.1”N	07^0 34’ 42.4”E	666
91	19/07/2011	11^0 34’ 54.8”N	07^0 34’ 52.3”E	665
92	19/07/2011	11^0 34’ 54.5”N	07^0 34’ 54.9”E	664
93	19/07/2011	11^0 34’ 54.5”N	07^0 14’ 56.5”E	668
95	19/07/2011	11^0 34’ 53.7”N	07^0 14’ 57.5”E	667
96	19/07/2011	11^0 34’ 52.5”N	07^0 14’ 59.2”E	665
97	19/07/2011	11^0 34’ 51.0”N	07^0 15’ 01.8”E	659
98	19/07/2011	11^0 34’ 49.2”N	07^0 15’ 01.6”E	660
99	19/07/2011	11^P 34’ 47.2”N	07^0 15’ 04.3”E	664
100	19/07/2011	11^0 34’ 46.7”N	07^0 15’ 04.5”E	668
101	19/07/2011	11^0 34’ 45.7”N	07^0 15’ 05.7”E	667
102	19/07/2011	11^0 34’ 45.8”N	07^0 15’ 06.2”E	665
103	19/07/2011	11^0 34’ 45.6”N	07^0 15’ 08.0”E	667
104	19/07/2011	11^0 34’ 45.0”N	07^0 15’ 09.5”E	666
105	19/07/2011	11^0 34’ 45.0”N	07^0 15’ 10.0”E	665
106	19/07/2011	11^0 34’ 44.7”N	07^0 15’ 10.7”E	669

107	19/07/2011	11^0 34' 44.2"N	07^0 15' 10.9"E	662
108	19/07/2011	11^0 34' 41.9"N	07^0 15' 14.9"E	663
109	19/07/2011	11^0 34' 43.2"N	07^0 15' 17.6"E	665
110	19/07/2011	11^0 34' 44.1"N	07^0 15' 21.7"E	668
111	19/07/2011	11^0 34' 44.3"N	07^0 15' 22.9"E	669
112	19/07/2011	11^0 34' 44.3"N	07^0 15' 23.7"E	670
113	19/07/2011	11^0 34' 04.7"N	07^0 15' 26.0"E	665
114	19/07/2011	11^0 34' 45.9"N	07^0 15' 27.1"E	660
115	19/07/2011	11^0 34' 45.9"N	07^0 15' 28.1"E	667
116	19/07/2011	11^0 34' 46.9"N	07^0 15' 28.9"E	664
117	19/07/2011	11^0 34' 46.5"N	07^0 15' 29.8"E	661
118	19/07/2011	11^0 34' 45.2"N	07^0 15' 30.3"E	667

Table 3: Determination of Reservoir Area by Least Square Method Using Graph Paper.

Intervals(m)	No of small boxes counted	Area
0 – 1	1,401	409,764
1 – 2	847	247,731
2 – 3	874	255,628
3 – 4	710	207,661
4 – 5	546	159,694
5 – 6	708	207,076
6 >	58	16,964

Correction for expansion or contraction of graph paper

Horizontally:

81 small square boxes = 17 cm = 170 mm

One small square box = 170/81 = 2.0988 mm

Vertically:

78 small square boxes = 17 cm = 170 mm

For one small square box = 170/78 = 2.1795

Area of one small box = 2.0988 x 2.1795 = 4.5743 mm^2 = 4.57 mm^2

From the map of scale 1: 8,000

One millimeter on paper represents 8m on the ground

For 1mm^2 = 64mm^2 on ground

Hence area of one small square box = 4.57 mm^2 on paper = 4.57 x 64 m^2/ 1m^2 on ground

One small square box = 292.48 m^2 on ground.

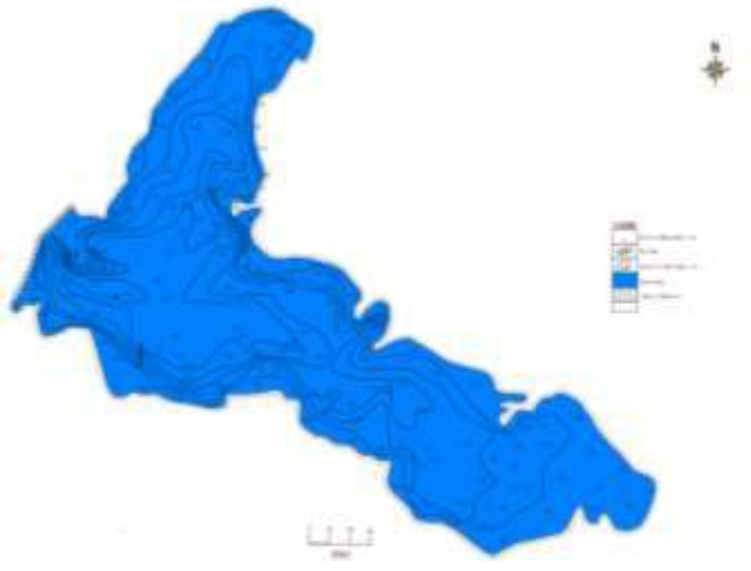

Figure 3: The Bathymetric Map of Mairuwa Dam Kastina State of Nigeria

Table 4: Calculation for the Remaining Storage of Mairuwa Impounding Reservoir

INTERVAL (m)	AREA (m^2)	AVERAGE DEPTH (m)	VOLUME (m^3)
0-1	409,764	0.50	204,882
1-2	247,731	1.50	371,597
2-3	255,628	2.50	639,070
3-4	207,661	3.50	726,814
4-5	159,694	4.50	718,623
5-6	207,076	5.50	1,138,918
>6	16,964	6.25	106,025
TOTAL	1,504,518	2.60	3,905,929

From Table 4, the calculated remaining storage of the Mairuwa Dam is **3,905,929m^3** as at 2011.

4.1 Calculating the Rate of Siltation of Mairuwa Dam

Loss in volume due to siltation from the date of construction of Mairuwa Dam results from the subtraction of the calculated remaining storage of 3,905,929m^3 (Table 4) as at 2011 from the original installed capacity of the dam of 5.5 million cubic meters (5.5 x 10^6) is determined as. Loss in volume equals subtracting the calculated remaining storage from the original storage (5.5 x 10^6 – 3,905,929) is determined as 1,594,071m^3. The dam was constructed in 1970 and has a drainage basin area of 102km. Its area of open water table is calculated as 1,504,518m^2 (Table 4). The loss in volume by the number of years spent as at 2011 reveals the actual rate of siltation (1,594,071m^3/41years) to be 38,880m^3/year. In comparison with the 100% installed capacity of the dam at the time of construction, the dam has lost 29% of its total storage, which translates to 0.71% loss in storage per annum. Loss in volume in 2020 (after 50 years) is (38,880m^3/year x 50years) 1,944,000m^3/year subtract from installed capacity (5.5 x 10^6 – 1,944,000m^3) is 3,556,000m^3 (65%) which gives an increase in loss in volume from 2011 to 2020 as 1,961,929m^3 (36%). The rate of siltation in 2020 (rate of siltation per annum x number of years) 38,880m^3/year x 9years is 349,920m^3/year. The loss in storage of 1,594,071m^3 in the dam from 1970 to 2011 was 29% and the loss from 1970 to 2020 is 3,556,000m^3 which is 65% of the installed capacity since the dam construction means increment of 1,961,929m^3 in the loss of storage of 36% from 2011 to 2020. Therefore, the present loss in volume in 50 years is 3,556,000m^3, remaining storage is 1,944,00m^3 and the rate of siltation from 349,920m^3/y.

4.2 Calculations for the Rate of Erosion in the Drainage Basin

4.2.1 Calculation of the Area of Drainage Basin:

Scale of the map on which calculation is done is 1:57,500.

1mm^2 on scale 1: 57,500 is 57.5 m x 57.5 m = 3,306.25 m^2

Graph paper was used, there are 9,546 small boxes covering the drainage basin.

Area of one small box = 1.8 mm x 1.8 mm = 3.24 mm^2

For the area of drainage basin on graph paper is 9,564 x 3.24m^2 = 30,929 mm^2.

The same area of the drainage basin expressed in square meter on the ground is 30,929 mm^2 x 3,306.25 m^2/mm^2 = 102,259,006 m^2

Area of drainage basin = **102,259,006 m^2**

4.2.2 Volume of Rainfall in the Drainage Basin:

Given that the depth of rainfall for Funtua area is 1000mm/a (Figure 4)

1000 mm/a = 1.0 m/a

For the volume of rainfall in the drainage basin will be

Area of the drainage basin x depth of rainfall in the drainage basin

102,259,006 m^2 x 1.0 m = **102,259,006 m^3**

4.2.3 Volume of Total Runoff:

Given that the run-off coefficient for the area is equal to 0.23 (Schoeneich *et al*, 2001)

Therefore 1.0 m/a x 0.23 = 0.23 m/a = Depth of Total Runoff.

Volume of total run-off is Area of drainage basin x depth of total run-of is

102,259,006 m^2 x 0.23 m/a = 23,519,571 m^3

23,519,571 m^3 = Volume of total runoff.

4.2.4 Volume of Suspended Solids Removed from the Drainage Basin:

Given that turbidity = 50 NTU = 0.5 g/l of suspended solid = 500 g/l = 0.5 kg/m^3.

Assuming that the turbidity is formed by silty and clayey particles and its density after drying in 105 ^{0}C temperature is 2.0 g/cm^2. For each gram is 0.5 cm^3 of dry substance.

In every cubic meter, there is 500 g of suspended solids, after drying up, 250 cm^3 of dry clayey and silty substance. 250 cm^3 = 0.00025m^3.

Since the total run-off from the drainage basin is 23,519,571m^3/a, and each cubic meter of water carries 250cm^3 of dried up suspended solids, therefore total volume of dried suspended solids received from the drainage basin is 23,519,571 m^3/a x 0.00025m^3 = **5,880 m^3/a**. of dry state suspended solids washed out from the drainage basin.

4.2.5 Volume of Dissolved Solid Removed from the Drainage Basin:

The average mineralization of water within the Crystalline Hydrological Province of Nigeria according to Schoeneich and Garba (2010) is 60 mg/l = 0.06 mg/cm^3.

Therefore, the weight of dissolved substance in one cubic meter of water is 60 g.

Assuming that density of the dissolved solids in dry state is 1.5g/cm^3.

Then 60 g/m^3:1.5 g/cm^3 = 40 cm^3/m^3.

40 cm^3/m^3 of dried dissolved solid = 0.00004 m^3/m^3.

Therefore, the total volume of the dissolved solid washed out from the drainage basin is

(23,579,571 m^3 x 0.00004) is **943 m^3/a**.

Table 5: Total Volume of Material Eroded from the drainage basin:

Material	Volume (m^3/a)
Bottom load	38,880
Suspended load	5,880
Dissolved load	943
TOTAL	45,703

Total volume load eroded from the drainage basin is **45,703 m^3/a.**

Then rate of erosion in the drainage basin is 45,703 m^3/a: 102,259,006 m^2 =

0.00045 m^3/a = 0.45 mm^3 = the rate of erosion in the drainage basin is therefore, **0.45 mm/a.**

5.0 CONCLUSION

Area of Mairuwa Dam drainage basin is 102,259,006m^2. Volume of rainfall is 1.0m/a. The volume of rainfall in the drainage basin is 102,259,006m^3. Runoff coefficient of the area is 0.23. Volume of total runoff is 23,519,571m^3. Total volume of material eroded from the drainage basin is 4,703m^3/a. The impounding reservoir was constructed in 1970, for the purpose of water supply and irrigation farming to the people of Funtua and its environs with an initial storage capacity of 5,500,000 m^3 (5.5 x 10^6). This study reveals that; in 2011, the remaining storage of the dam was 3,905,929 m^3, the surface open water table was 1,504,518m^3, loss in volume 1,594,071m^3 (29%) which is 0.71% loss in storage per annum. In 2020 nine years later, the remaining storage is 1,944,000 m^3(35%), loss in volume is 3,556,000m^3 (65%). The dam has lost 65% of its total storage after 50 years of its construction. With this rate of siltation, the dam will be completely silted up totally in a few years if no action is taken to stop or reduce the rate of siltation of the dam. The rate of erosion in the Mairuwa drainage basin is 0.45mm/a, this is far more than the world average of 0.088mm/a. It is necessary to slow down the processes of erosion in the drainage basin and reduce drastically the rate of siltation. It is very important to employ sediment management strategy which is the construction of sediment traps upstream of the reservoir to prevent sediments from entering the reservoir, elevating crest of the dam, dredging, hydraulic flushing, and afforestation of the drainage basin.

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