Effect of Large Dams on Groundwater Sources Down Stream of Dadinkowa and Balanga Dams, Gombe State Nigeria

***Malum J. Flayin[1], Udochukwu, M. Okechukwu[1], Akpen, G.Delian[2], Onoja, S. Baba[1]**
[1]Department of Agricultural and Environmental Engineering, Joseph Sarwuan Tarka University, Makurdi, Nigeria. [2] Department of Civil Engineering, Joseph Sarwuan Tarka University, Makurdi, Nigeria
*Corresponding Author: jf.malum@uam.edu.ng jmflayin@gmail.com

D.O.I: 10.56201/ijaes.v9.no1.2023.pg39.53

ABSTRACT
In Gombe State, Nigeria, two concrete dams were constructed in Balanga and Dadinkowa and completed in 1987 and 1988 respectively. Balanga dam with a capacity of 63 mcm, and Dadinkowa dam, 1,770 mcm, were to be both used for irrigation and provision of hydroelectric power supply. Since the completion of the two dams, they have not been commissioned for the intended use. The effects of these large dams on water table rise downstream of Dadinkowa and Balanga dams were determined using various groundwater potentials study methods. Ten wells from earlier sources of water before the construction of the dams down streams were selected and subjected to wells depth to water level measurement during the peaks of dry season (March and April) and rainy season (August and September). In Dadinkowa wells (W1-W10), water depth to ground level ranged from 1.39 - 4.12 m in the dry season, with a mean water depth range from 1.42 - 3.91m. In the peak of rainy season, water depth to ground level ranged from 2.45 - 5.96 m. In Balanga dam area, the water depth during dry season ranged from 2.15 - 2.87 m and a mean depth range from 2.16 - 2.81 m, in the rainy season, water depths ranged from 2.65 - 4.32 m and mean depths ranged from 2.96 - 4.85 m. During dry season, water depths in Dadinkowa wells entire site mean (E.S.M) was 2.46 m, and 4.28 m, in the rainy season. In Balanga, the E.S.M for dry season was 2.44 m and 3.80 m during rainy season. By comparison, the depth to water levels of the entire seasonal mean in Dadinkowa wells during dry season which is 2.46 m, to that of rainy season, 4.28 m, indicated that the level of water table increase due to rainfall influence was just by 1.82 m; while E.S.M for Balanga in the dry season (2.44 m) and rainy season (3.80 m) had rainfall infiltration influence by 1.36 m depth only. This means the hand dug wells maintenance of a steady depth to water level rise throughout the dry season comes from the replenishment of the groundwater from the dams after many years of construction.

KEY WORDS: *Dam, Groundwater, Downstream, Well depth, Irrigation, Dadinkowa, Balanga*

1. INTRODUCTION

A large dam is defined by the dam industry as one higher than 15 metres (taller than a four-story building). Amanda (2016) defined large dam as being 15-20 meters while major dams are those of 150 - 250 metres.

Large dams store larger volume of water for needs of the growing urban and industrial centres, generation of hydropower or for agricultural support and control flooding (ICID,2000; Tahmiscioğlu *et al.*, 2016 and ICOLD, 2017).

In ancient times, dams were built for the single purpose of water supply or irrigation. Presently, dams are constructed for specific purpose such as water supply, flood control, irrigation, navigation, sedimentation control, and hydropower. A multipurpose dam is a very important project for developing countries, because the population receives domestic and economic benefits from a single investment and this has led developing countries and international agencies such as the World Bank to undertake major investments in large dams construction, with over 45,000 large dams built worldwide, (WCD, 2000; 2002; ICOLD, 2016; Alberta, 2016; NHDES, 2016;).

According to World Register of Dams, most dams are single-purpose dams while others are multipurpose dams, where; 48 % are for irrigation, 17% for hydropower (production of electricity), 13% for water supply, 10% for flood control, 5% for recreation and less than 5% for navigation and fish farming (ICOLD, 2016, Tahmiscioğlu *et al.*, 2016).

Presently, there are 291 dams in Nigeria,(Okoye and Achakpa, 2007; FMWR, 2019). Federal government owned 210, States government 34, 20 owned by private organizations and 27 earth dams by both Federal and States governments(FMWR, 2020) (Figure 1). The Federal government dams are regionally rationed and left under the management of the twelve (12) River Basins(Upper Benue, Lower Benue, Chad Basin, Benin-Owena, Sokoto-Rima, Hadejia-Jema'are, Cross River, Ogun-Osun, Anambra-Imo, Niger-Delta, Upper Niger and Lower Niger), to facilitate the effective management and utilization for the purpose of which the dams are built, most dams are sited in the Northern part of the country(Figure 1) (Bazin *et al, 2016.*

Out of the 31 large dams in Nigeria, 22 are either constructed for irrigation water supply, irrigation and water supply, or for irrigation /water supply/ hydropower, but none has been officially commission for irrigation. (Table 1) (Okoye and Achakpa, 2007; FMWR, 2019).

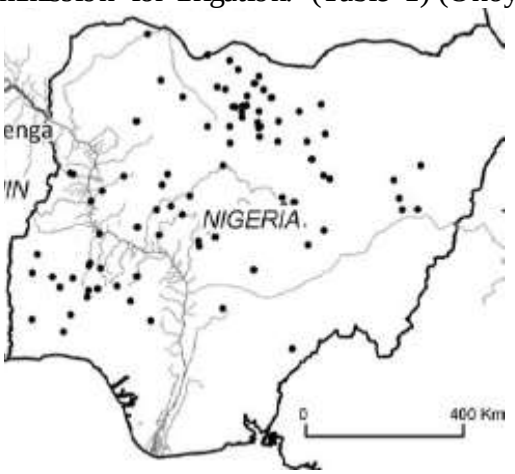


Figure 1: Dams construction across Nigeria

In Gombe State (Nigeria), two concrete dams were constructed (Balanga and Dadinkowa) and completed in 1987 and 1988 respectively. Balanga dam with a height of 41m, and a capacity of 63 million cubic metres (mcm), covering a surface area of 15,000 hectares (ha) was constructed to be used for hydroelectric power supply and irrigation (MWRGS),2017), while Dadinkowa dam, 42 m in height, with a capacity of 1,770 million cubic metres (1,770 million m^3) and covering a surface area of 29,000 hectares was also for both irrigation and provision of

hydroelectric power supply. Since the completion of the two dams, they have not been commissioned for the intended uses,(GS, 2014).

Preliminary survey around the vicinity of the two dams showed that, farmers utilize penstock releases of water from the dam through the downstream water course, dig shallow wells within the flood plains to obtain water for domestic use and to irrigate dry season rice, onions and vegetables.

Table 1: Large Dams in Nigeria

H.A	Dam	Active Capacity (mcm)	Dam Height (m)	Objective	Completed Year
1	Zibiya	121	21.5	Irri/W.S	1990
1	Zobe	170	18.9	Irri/W.S	1983
1	Bakolori	403	48.0	Irri/W.P	1982
1	Goronyo	833	20.0	Irri/W.S	1984
1	Kainji	11,500	65.5	H.P	1968
1	Kubli	62	23.0	Irri	1992
2	Kontagora	200	32.0	Irri	U.C
2	Asa	344	27.0	W.S	?
2	Kagara	39	31.0	W.S	U.C
2	Jebba	1,000	40.0	H.P	1983
2	Omi	220	43.0	Irri	U.C
2	Zaria	29.8	15.0	W.S	1974
2	Kangimi	59.3	19.2	Irri/W.S	1975
2	Shiroro	6,050	105.0	H.P	1989
2	Suleja	48.5	27.8	W.S	?
2	Usuma	100	45.0	W.S	1984
3	Balanga	63	41.0	Irri	1987
3	Dadin Kowa	1,770	42.0	Irri/H.P	1988
3	Kiri	325	37.0	Irri	1982
4	Doma	28.5	15.7	Irri	1988
6	Ikere Gorge	565	47.5	Irri/W.S/H.P	U.C
6	Oyan	254	30.4	Irri/W.S/H.P	1983
8	Erinle	92.5	27.0	W.S	1989
8	Gari	203	22.0	Irri	1980
8	Challawa	900	38.0	Irri/W.S	1992
8	Watari	92.7	19.8	Irri	1980
8	Tiga	1,845	47.2	Irri/W.S	1975
8	KafinZaki	2,500	40.0	Irri	U.C
8	Tomas	56.6	13.7	Irri	1976
8	Jakar	54.5	14.3	Irri	1976
8	Alau	106	9.5	Irri/W.S	1972

Key: Irri: Irrigation, W.S : Water supply, H.P : Hydropower, U.C : Under Construction, H.A : Hydrological Area

2. MATERIALS AND METHODS

2.1 The Study Area

Gombe State is located in the Sudan savannah region of North-eastern part of Nigeria, bordering with Adamawa, Bauchi, Borno and Yobe States. The approximate altitude of Gombe ranges from 400-500m above mean sea level. Topography is mainly mountainous, undulating and hilly to the southeast and open plains in the central north east, west and northwest (Yahaya and Adamu, 2016).

2.1.1 The climate of Gombe state

Gombe State is located between latitude 9° 30' and 12°30' N and longitudes 8° 45' and 11°45'E of the Greenwich Meridian. It lies within the North east region of Nigeria, within the coordinates of 10°15′N and 11°10′E, and occupies a total land area of about 20,265 sq km and a population of about 1.8 million (Ikusemoran, *et al*, 2018; GS, 2014).

The climate of Gombe is characterized by dry season of six months, alternating with a six months of rainy season. As in other parts of the Nigerian Savanna precipitation distribution is mainly triggered by a seasonal shift of the Inter -Tropical Convergence Zone (ITCZ)(GMS, 2014 and WWOL, 2020). Rainy season starts around April or May but heavy rainfall may occur from June or July to middle September. By October, the amounts of rainfall begin to decrease (Yahaya, 2015). The mean annual temperature tends to be very hot between November and March with average high temperature reaching 33^0C or more (WS,2021).

The harmattan wind from around February makes the temperature cooler, although with dusty conditions, whereas relative humidity reaches its peak of about 90% in August and dropping to less than 10% during the harmattan period (Yahaya and Adamu, 2016).

2.2 Dadinkowa and Balanga Dams

2.2.1 Dadinkowa dam

Dadinkowa dam is a multipurpose dam(Table 1), located in Yamaltu / Deba L.G.A, (Figure 2) Gombe state, (Maigari *et al* (2016). It has a reservoir capacity of 2.8109 m^3, live storage 1.77109 m^3, made of earth rock-fill embankment, crest length about 520m, maximum height of 47m, Ogee Crested Spillway equipped with radial gates and Hydro Electrical Power (H.E.P) house.

The H.E.P has a design installed capacity of 34MW,(Abubakar, 2011). Soils in this area are shallow to deep loamy, sandy clay, loam and vertisols with cracking clays that have weathered from shales. Dadinkowa dam has an irrigation capacity of 44000 ha of fertile land for the production of maize, rice and groundnuts twice a year; and vegetables almost all year round. Presently only 100 ha are under irrigation, using abstraction water from the irrigable lands downstream,(Abubakar, 2011). It has the capacity to produce an estimated 20,000 tonnes of fresh fish from the reservoir when fully harnessed. It is now the major source of water supply to Gombe town and villages downstream,(Maigari *et al.*, 2016).

2.2.2 Balanga dam

Balanga dam is a double purpose dam, located in Balanga LGA (Table 1)(North East) of Dadinkowa dam - about 50 km apart,. Construction started in 1982 and completed in 1987. It has a height of 41m, and a capacity of 63 million cubic metres (63 mcm) of water, covering a surface area 15,000 hectares, was purposely constructed to be used for irrigation and hydroelectricity generation (MWRGS, 2017). The dam has also not been put to use after completion in 1987.

Sources of Water in study areas before the dams construction

Preliminary investigations indicated that before the dams were constructed the peoples main sources of water in Dadinkowa town and Balanga area downstream were predominantly from hand dug wells. Ten (10) hand dug wells were randomly selected, from Dadinkowa and Balanga

dams downstream in identified locations. Each well's year of construction, well depth, and depth to water table for both dry and rainy seasons studied, in March - April (dry season) and August-September (rainy season). The measurements were done using the materials/equipment shown in Table 2(Figure 3) (Cephas, 2017).

3. RESULTS AND DISCUSSION

3.1 Water from Hand Dug Wells before Construction of Dams

The depths to water level in hand-dug wells were measured during the peak of dry season (April 2020) and at the peak of rainy season (September 2020). The detail results of ten (10) hand dug wells each from Dadinkowa and Balanga dams downstream, were randomly selected indicating site locations and elevations Above Sea Level(asl), latitude, longitude and distance from dams in kilometers(Km) (Table 3). Years of construction, well depth, depth to water table at peaks of dry and rainy seasons (March- April and August – September) and their respective means, are shown in Tables 4-6.

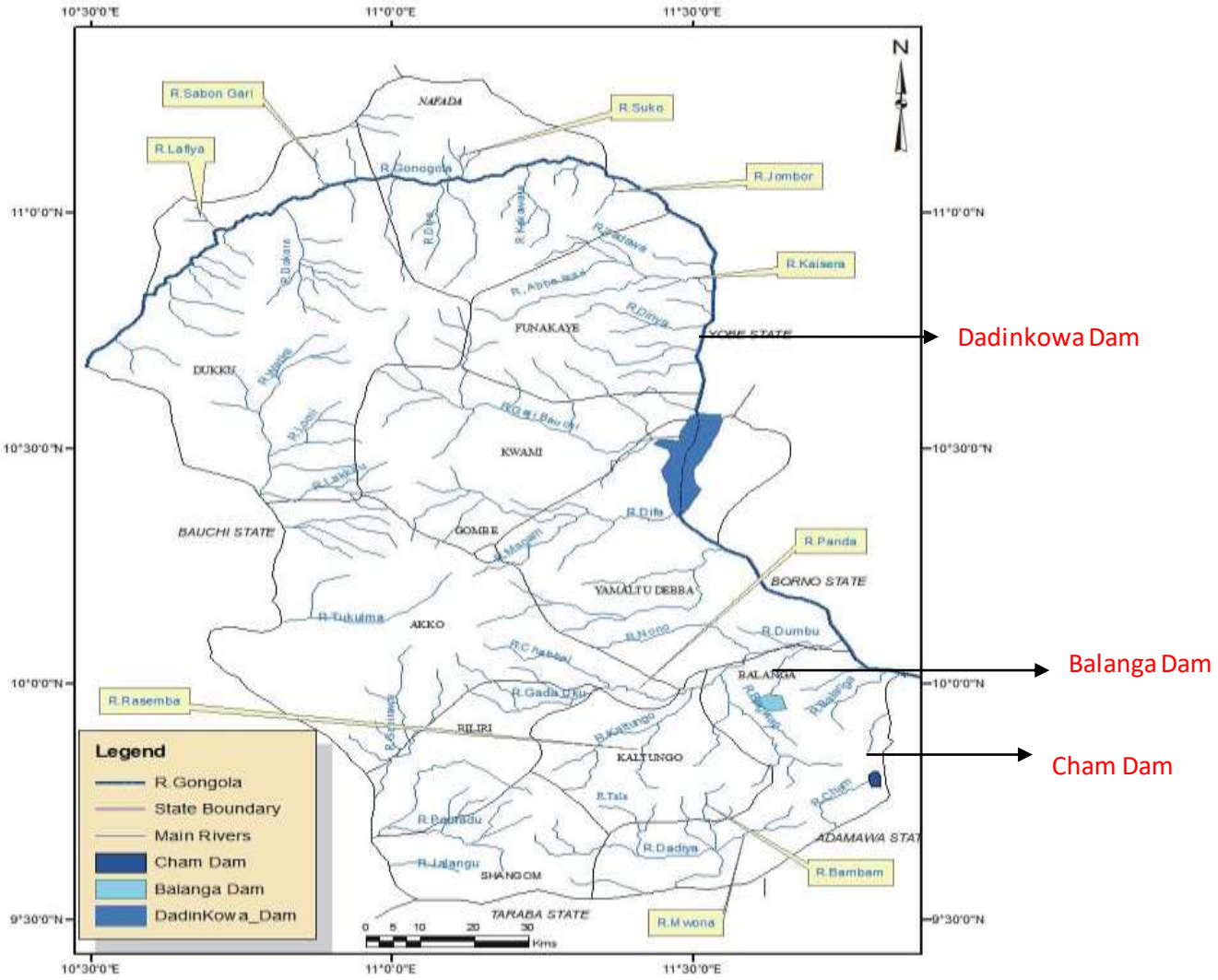


Figure 2: Location of Dadinkowa and Balanga Dams in Gombe State Drainage Map

3.2.2 Effect on Dadinkowa dam downstream

During peak of dry season ((March and April)(Table 7), the initial water levels taken in first week of March ranged from 1.54 – 4.12 m, while the second measurement at the end of March ranged from 1.49 – 3.97 m. The mean depth to water level of each well (W1- W10) for the month of March ranged from 1.52 – 4.05 m. For the month of April, initial depth to water level ranged from 1.45 – 3.91m and end of month measurement ranged from 1.39 – 2.87, with a monthly mean of the wells ranged from 1.42 – 3.39 m (Table 7).

Table 2: Materials/ Equipments used in Assessing Depth to Water Levels in Wells

S/N	Materials/Equipment	Uses
1	Measuring tape	Used to measure the diametre of sample wells
2	Geographical positioning system (GPS) device	Used to provide information on location and elevation of the sample sites
3	Steel tape water level meter	Used in taking water level measurement in wells (The equipment was constructed and calibrated according to engineering standard)(Figure 19 and 20).
4	Record Note book/pen	This was used to record the values of measured data.

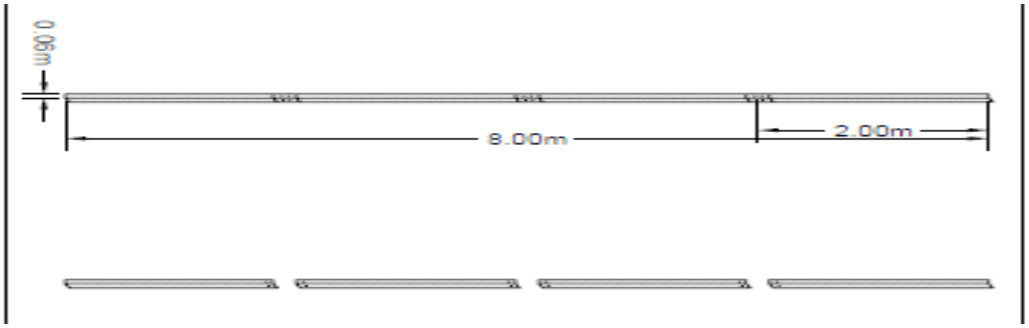
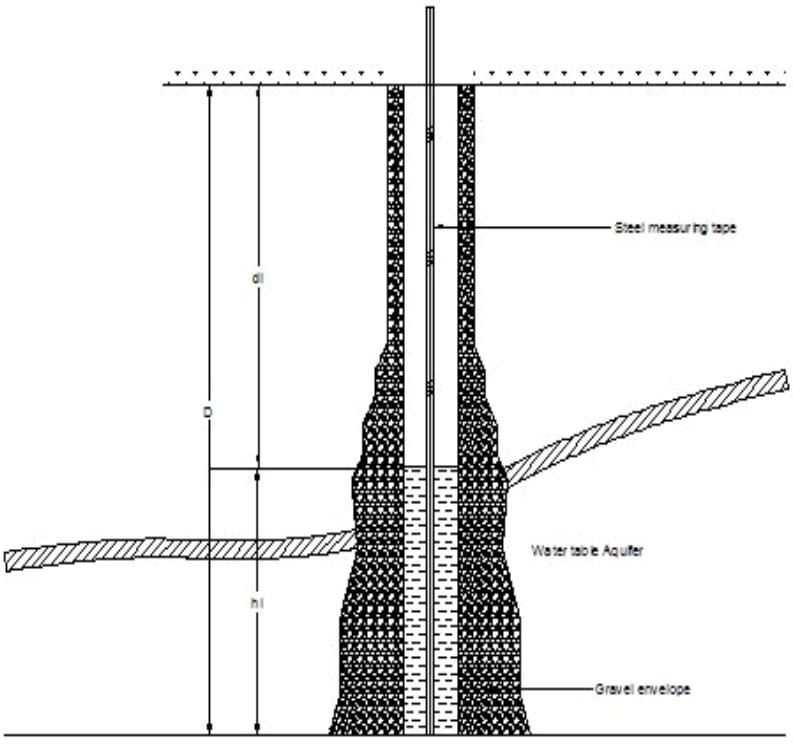


Figure 3a: Water Level Meter (calibrated to Engineering Standard)



Where, d_1 = depth of water table from ground surface
h_1 = depth to water level from the bottom
D = Total depth of well
$d_1 = D - h_1$

Figure 3b: Sketch illustrating Measurement of Depth of Water Table using Water Level Metre.

Table 3: Location of Water Sources before Construction of Dams

Dadinkowa Dam Downstream					
Well (W) No	**Location**	**Elevation(m) Above Sea Level**	**Latitude ^{0}N**	**Longitude ^{0}E**	**Distance fro Dam (km)**
W1	Gada	211	$10^0$19’19.7544”	$11^0$28’54.0984”	6
W2	Dakum	227	$10^0$17’43.6344”	$11^0$30’42.0552”	6
W3	Bolawa	219	$10^0$18’22.8816”	$11^0$30’18.9504”	6
W4	Kasuwa	208	$10^0$17’35.4552”	$11^0$30’14.2776”	6.5
W5	Tike	212	$10^0$17’28.1436”	$11^0$30’8.4636”	6.5
W6	Kerme	218	$10^0$17’41.0964”	$11^0$38’0.0844”	7
W7	Kota	203	$10^0$18’24.0120”	$11^0$30’09.7272”	7
W8	Zarma	210	$10^0$18’25.0560”	$11^0$30’20.117”	7
W9	Galadima	199	$10^0$18’30.7332.”	$11^0$30’25.8948”	7
W10	Tunga	215	$10^0$17’10.0752”	$11^0$29’55.3272”	7
Balanga Dam Downstream					

W1	Sulawagn	336	$9^0$53’57.8436”	$11^0$33’14.7024”	7
W2	Urshalima	348	$9^0$53’53.6604”	$11^0$33’11.898”	7
W3	Lungure 1	330	$9^0$54’17.3880”	$11^0$33’24. 8184”	5
W4	Lungure 2	326	$9^0$54’19.9584”	$11^0$33’17.8164”	5
W5	Kitushe	330	$9^0$54’21.0672”	$11^0$33’16. 4988”	8
W6	Jalingo	329	$9^0$54’25.7112”	$11^0$33’24.4800”	6
W7	J/Dorawa	326	$9^0$54’27.3096”	$11^0$33’23.4000”	6
W8	J/kasuwa	331	$9^0$54’26.9388”	$11^0$33’27.0144”	6
W9	Yelwa 1	323	$9^0$54’30.276”	$11^0$33’34. 5852”	4.5
W10	Y/stream 2	326	$9^0$54’33.246”	$11^0$33’32.4824”	4.5

Table 4: Water Sources before the Construction of Dams

Dadinkowa Dam Downstream					
Well (W) No	**Location (*Anguwa*)**	**Year Well Constructed**	**Year We Rehabilitated**	**Well depth (m)**	**Use of well**
W1	Gada	1980	*	4.35	Abandoned
W2	Dakum	1977	-	5.67	Abandoned
W3	Bolawa	1975	-	5.43	Laundry
W4	Kasuwa	1991	-	6.23	Laundry
W5	Tike	1985	-	6.10	Laundry
W6	Kerme	2000	-	7.74	Abandoned
W7	Kota	1970	-	7.11	Domestic
W8	Zarma	1890	1970	7.82	Domestic
W9	Galadima	1895	1990	12.64	Domestic
W10	Tunga	1987	-	6.13	Domestic
Balanga Dam Downstream					
W1	Sulawagn	1951	*	6.34	Domestic
W2	Urshalima	1955	-	6.67	Abandoned
W3	Lungure 1	1938	-	6.23	Abandoned
W4	Lungure 2	1949	-	5.74	Abandoned
W5	Kitushe	1958	-	6.05	Abandoned
W6	Jalingo	1948	1991	5.67	Domestic
W7	Dorawa	1980	-	5.12	Domestic
W8	J/kasuwa	1986	-	4.32	Domestic
W9	Yelwa 1	1937	-	5.54	Domestic
W10	Yelwa 2	1992	-	3.05	Domestic

* - Not Rehabilitated

Table 5: Water Sources after over 30 years of Construction of the Dams

Dadinkowa Dam Downstream					
Site(S) No	**Site Name**	**Type of Water source**	**Year Constructed**	**Well Depth (m)**	**Use of Water/ Remarks**

S1	Gada	Tap water	2005	*NA	Domestic, from treatment plant
S2	Dakum	Tap water	2005	NA	Domestic, from treatment plant
S3	Bolawa	Tap water	2005	NA	Domestic, from treatment plant
S4	Zarma	Well	1890	7.82	Domestic: Does not dry during dry season. Tap water not extended to the 2 areas.
S5	Galadima	Well	1895	8.64	
Balanga Dam Downstream					
S1	Lungure	Borehole	2013	4.25	Domestic
S2	Kitushe	Borehole	2013	4.12	Domestic
S3	Jalingo	Borehole	2013	4.03	Domestic
S4	Dorawa	Gouge well	2011	0.73	Domestic/Spring water
S5	Yelwa	Gouge well	2009	1.02	Domestic/Spring water

*NA = Not Applicable

Table 6: Water Sources after over 30 Years of Construction of Dams by Abstraction

Dadinkowa Dam Downstream						
No (Site)	**Location**	**Year Abstraction started**	**Depth (m)**	**Depth to Water (m) (Dry season**	**Depth to Water (m) (Rainy season**	**Water Source/Use**
1		2010	3.9	*-	*-	- Shallow boreholes
2	Proposed	2011	3.6	-	-	
3	irrigation	2015	3.4	-	-	- Dry season irrigatic
4	Site	2017	4.2	-	-	farming using portab
5		2018	4.7	-	-	irrigation pumps
	Villages			**Balanga Dam Downstream**		
1	Sulawagn	2010	0.89	0.86	Brimful	Gouge / Springwater
2	Betikwanti	2015	1.27	1.25	Brimful	
3	Jalingo 1	2013	0.61	0.58	Brimful	- Domestic uses
4	Jalingo 2	2012	0.64	0.62	Brimful	
5	Yelwa	2010	1.15	1.05	Brimful	

* Unable to measure due lack of equipment

During the peak of raining season (August and September), depth to water level of same tenwells for first week of August ranged from 2.45 – 4.26 m; end of month measurement ranged from3.20 - 4.54 m and a monthly mean from 2.83 – 4.37m. In September, first week measurement ranged from 3.60 – 5.96 m, while end of month records ranged from 4.18 – 6.67 m and the monthly mean ranged from 3.91 – 6.32 m (Table 7).

Thus, the general depth to water level fluctuates down ward from month of March to April (peak of dry season) in all the wells, but there was no well that dry completely. During the peak of rainy season (August and September), wells number, 1,2,3,4 and 10 almost got full to the brim, although the wells have different depths and diametres. The inhabitants testified that before the construction of the dam, wells number 1,2,4, 6,7, and 10 used to dry up completely, but the lowest depth to water level of 1.39 m was recorded in April from Well 7. This proves that there is water table rise in groundwater after so many years of the dam's construction.

The trend in all the observation wells appears similar with little deviation from the general trend irrespective of their various diameter and total depth of wells from the ground level. This is because the groundwater table at the observation wells shows that the mean minimum depth to

Table 7: Depth to Water Levels from the Observation Wells during Peaks of Dry and Rainy Seasons

Dadinkowa Dam Downstream (2020)													
Month:		**March**			**April**			**August**			**September**		
Well (W)	**Well Depth (m)**	**S1 (m)**	**S2 (m)**	**Mean (m)**	**S1 (m)**	**S2 (m)**	**Mean (m)**	**S3 (m)**	**S4 (m)**	**Mean (m)**	**S3 (m)**	**S4 (m)**	**Mean (m)**
W1	4.35	2.11	2.09	**2.51**	2.07	2.04	**2.05**	3.05	3.45	**3.20**	3.60	4.21	**3.91**
W2	5.67	2.64	2.62	**2.63**	2.58	2.46	**2.52**	3.37	3.75	**3.56**	4.25	4.54	**4.40**
W3	5.43	1.97	1.94	**1.96**	1.92	1.89	**1.91**	2.76	3.87	**3.32**	4.35	4.67	**4.51**
W4	6.23	3.10	3.07	**3.09**	3.04	2.98	**3.01**	3.45	4.34	**3.90**	4.68	5.21	**4.95**
W5	6.10	2.84	2.79	**2.82**	2.77	2.73	**2.75**	3.07	3.54	**3.31**	3.98	4.18	**4.08**
W6	7.74	2.67	2.64	**2.66**	2.63	2.62	**2.63**	4.26	4.48	**4.37**	4.98	5.54	**5.26**
W7	7.11	1.54	1.49	**1.52**	1.45	1.39	**1.42**	4.12	4.54	**4.33**	5.11	5.70	**5.41**
W8	7.82	2.35	2.26	**2.31**	2.21	2.17	**2.19**	3.37	3.97	**3.67**	4.64	5.26	**4.95**
W9	9.64	4.12	3.97	**4.05**	3.91	2.87	**3.39**	4.22	4.53	**4.28**	5.96	6.67	**6.32**
W10	6.13	2.05	1.87	**1.96**	1.82	1.78	**1.80**	2.45	3.20	**2.83**	4.45	5.36	**4.91**
E.M.M				**2.55**			**2.37**			**3.68**			**4.87**
E.S.M					**2.46**			**4.28**					
Balanga Dam Downstream													
W1	6.34	2.20	2.18	**2.19**	2.16	2.15	**2.16**	2.89	3.32	**3.11**	3.86	4.67	**4.27**
W2	6.67	2.82	2.73	**2.78**	2.68	2.66	**2.67**	3.28	3.78	**3.53**	4.12	4.85	**4.49**
W3	6.23	2.86	2.75	**2.81**	2.73	2.72	**2.73**	3.32	3.62	**3.47**	4.18	4.97	**4.58**
W4	5.74	2.54	2.47	**2.51**	2.43	2.41	**2.42**	2.87	3.42	**3.15**	3.84	4.54	**4.19**
W5	6.05	2.23	2.17	**2.20**	2.17	2.15	**2.16**	2.65	3.25	**2.95**	3.75	4.65	**4.20**
W6	5.67	2.43	2.39	**2.41**	2.34	2.30	**2.32**	2.97	3.34	**3.16**	4.02	4.70	**4.36**
W7	5.12	2.87	2.68	**2.78**	2.65	2.63	**2.64**	3.26	3.84	**3.55**	4.26	5.12	**4.69**
W8	4.32	2.56	2.45	**2.51**	2.43	2.43	**2.43**	3.50	4.12	**3.81**	4.32	4.32	**4.32**
W9	5.54	2.47	2.35	**2.41**	2.31	2.28	**2.30**	2.89	3.42	**3.16**	4.25	5.45	**4.85**
W10	3.05	2.21	2.19	**2.20**	2.18	2.16	**2.17**	2.87	3.05	**2.96**	3.05	3.05	**3.05**
E.M.M (m)				**2.48**			**2.40**			**3.29**			**4.30**
E.S.M (m)					**2.44**			**3.80**					

Notes
S1 = Water depth at beginning of Month; S2 = Water depth at end of Month
E.M.M = Entire monthly mean; E.S.M = Entire site mean.

water level was recorded in April with an entire monthly mean(E.M.M) of 2.37 m and maximum mean depth to water level for September with E.M.M of 4.87m.
The results by entire seasonal mean(E.S.M) in the dry season (2.46 m), to that of rainy season (4.28 m) showed rainfall influence on groundwater table rise in the observation wells compared with that of peak of dry season, rise up by just 1.82 m difference (Table 7) and as seen in the plot of mean values(Table 8) of the water levels fluctuations during the peaks of dry and rainy

seasons, (Figure 4).This could be due to over saturation of the soil by the rain in August that recharged the groundwater table in September, because the peak of rainfall for the past 16 years in Gombe has been in the month of August(GMS, 2018), although with climate change, higher rainfall is being recorded up to the end of October in Gombe with general increase in rainfall (Abashiya *et al*, 2017; WWOL,2020). The research showed a steady fluctuation and replenishment of groundwater as shown inTable 8 (Figure4). This steady replenishment is attributed to long period of groundwater recharge through seepage, release of reservoir excess water and penstock releases.

Out of the 10 wells,3 (W1,W2and W6) had water but were abandoned (out of use for both domestic and laundry services),another 3(W3-W5) are used for laundry purposes only, while the

Table 8: Mean Depth to Water Levels from the Observation Wells during Dry and Rainy Seasons

Well (W) No	Location	Well Depth (m)	Dry Season Water Level Mean (m)		Rainy Season Water Level Mean (m)		Remarks
			March	April	August	September	
Dadinkowa Dam Downstream							
W1	Gada	4.35	2.51	2.05	3.20	3.91	- Well nos.W1,2,4,6,7 used to
W2	Dakum	5.67	2.63	2.52	3.56	4.40	dry up completely during
W3	Bolawa	5.43	1.96	1.91	3.32	4.51	dry season.
W4	Kasuwa	6.23	3.09	3.01	3.90	4.95	- Nos.3and5 used to dry
W5	Tike	6.10	2.82	2.75	3.31	4.08	subject to daily use.
W6	Kerme	7.74	2.66	2.63	4.37	5.26	- Nos. 8 and 9 does not dry
W7	Kota	7.11	1.52	1.42	4.33	5.41	but water reaches ground
W8	Zarma	7.82	2.31	2.19	3.67	4.95	level during dry season.
W9	Galadima	12.64	4.05	3.39	4.28	6.32	**But many years after da**
W10	Tunga	6.13	1.96	1.80	2.83	4.91	**construct, all the wells yields water throughout the year.**
	Balanga Dam Downstream						
W1	Sulawagn	6.34	2.19	2.16	3.11	4.27	- Well nos.W1, 6-8 used to
W2	Urshalima	6.67	2.78	2.67	3.53	4.49	dry due to Excessive daily
W3	Lungure 1	6.23	2.81	2.73	3.47	4.58	use.
W4	Lungure 2	5.74	2.51	2.42	3.15	4.19	
W5	Kitushe	6.05	2.20	2.16	2.95	4.20	- W2-5 used to dry in peak of
W6	Jalingo	5.67	2.41	2.32	3.16	4.36	dry season.
W7	J/Dorawa	5.12	2.78	2.64	3.55	4.69	
W8	J/kasuwa	4.32	2.51	2.43	3.81	4.32	- W9 and 10 water reaches
W9	Yelwa	5.54	2.41	2.30	3.16	4.85	bottom level at peak of dry
W10	Y/stream	3.05	2.20	2.17	2.96	3.05	Season.
							Presently, all the wells yields water throughout the year.

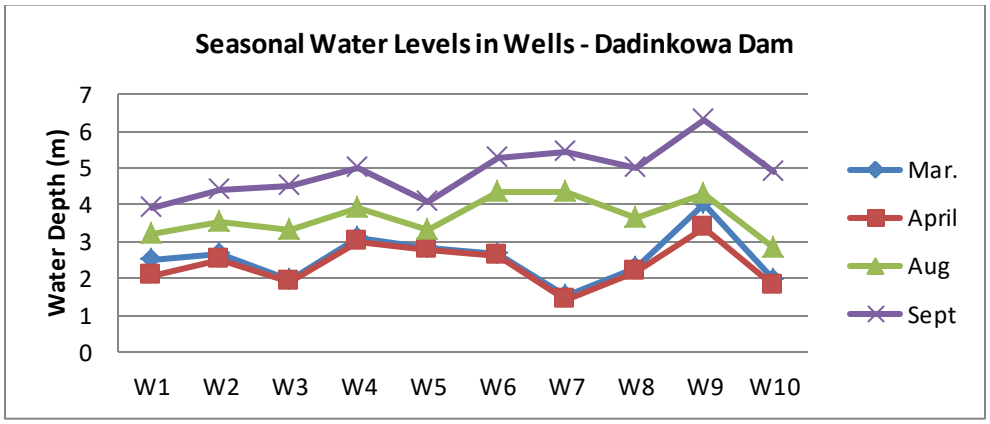


Figure 4: Water levels fluctuations during peaks of dry and rainy seasons in Dadinkowa Vicinity

remaining 4(W7-W10) are used for domestic purposes (Table 4).The choice of well use was necessitated by better alternative sources of water, provided by the presence of the dam after years of construction.

3.2.3 Water sources downstream before the Balanga dam construction

In Balanga dam downstream, earlier water sources for the inhabitants before the construction of the dam were equally hand dug wells; ten were randomly selected at different locations with their elevations. Their distances from the dam ranged between 4.5 – 8 km (Table 3).The wells were constructed between the year 1937 and 1992. The well depths ranged from 3.05 – 6.67 m and only one was rehabilitated in 1991(Well number 6) at Jalingo ward (constructed in 1948) (Table 4).

Before the construction of Balanga dam, wells number W2- W5 used to go dry into the dry season and does not yield water completely by peak of dry season. Wells number W1, W6 - W8 used to dry due to excessive water daily use and replenishes when left for several hours without draw down. Wells number W9 and W10 does not dry but depth to water levels used to remain at bottom levels of the wells during peak of dry season. Research indicates that after many years of the dam's construction, most of the wells (both abandoned and functional) were noticed to have maintained steady availability of water throughout the year.

3.2.4 Influence of dam water on earlier groundwater sources downstream of Balanga

Study into the depth to water level measurement after 33 years of the dam's construction was also done during the peak of dry season (March and April) and peak of rainy season(August and September) (Table 7).

The initial water levels taken in first week of March from the ten observation wells(W1- W10) ranged from 2.20 – 2.87m, while the second measurement at the end of March ranged from 2.17 – 2.75. The mean depth to water level of each well for the month of March ranged from 2.19 – 2.81m. In April, the initial depth to water level ranged from 2.16 – 2.73 m and end of month measurement ranged from 2.15 – 2.72, with a monthly mean of the wells from 2.16 – 2.73 m (Table 8).

During the peak of raining season (August and September), depth to water level of the ten wells for first week of August ranged from 2.65 – 3.50 m; end of month measurement ranged from 3.05- 4.12 m and a monthly mean from 2.96 – 3.81 m. For September, first week measurement

ranged from 3.05 – 4. 32 m, while end of month records ranged from 3.05 – 4.85 m and the monthly mean ranged from 3.05 – 4. 85 m(Table 8).

From the results, depth to water level fluctuation reduces down ward from month of March to April (peak of dry season) in the entire wells. None of the wells dried during peak of dry season. Well numbers W2- W5 (Table 4) that were abandoned in the early years after the construction of the dam because they dried up completely, now yields water (though still out of use due to other available sources of water). Depths to water levels in all the wells were above 2 m throughout the peak of dry season (Table 7).

During the peak of rainy season (August and September), depth to water levels increased in all the wells due to rainfall infiltrations,(Figure 5). Wells number, 1- 7 and 9 were more than 80% ful, while wells number 8 and 10 were brimful though the emphasis is not on their different depths and diametres. By comparison, the depth to water levels of the entire seasonal mean(E.S.M) in the dry season which is 2.44 m, to that of rainy season (3.80 m)(Table 7), showed that the level of water table increase due to rainfall influence was just by 1.36 m. Therefore, since the hand dug wells maintained a steady depth to water level throughout the dry season, the continues water level rise in the wells comes from the recharge and replenishment of the groundwater from the dam after many years of construction.

The construction of the dam in the area also affected the use of the earlier sources of the water. Wells numbers W2- W5 were abandoned for both domestic and laundry services, because there are other suitable water sources while the remaining 6 (W1, W6 – W10), are still use for domestic purposes (Table 4).

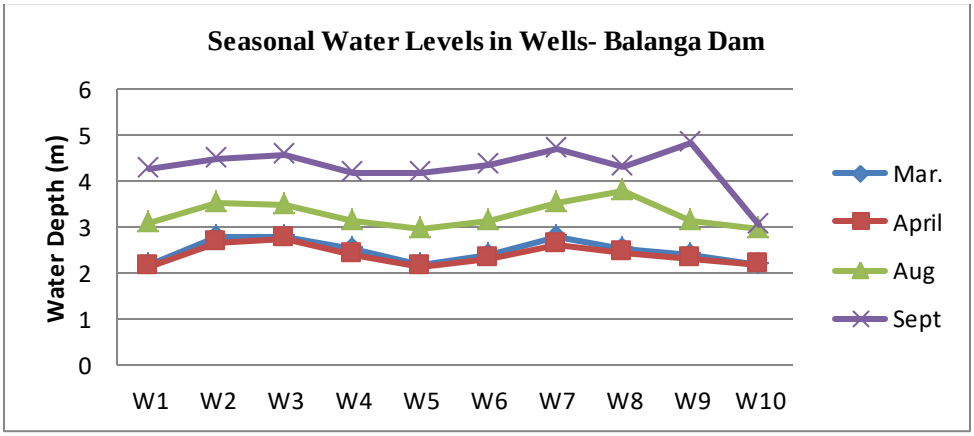


Figure 5: Water levels fluctuations during peaks of dry and rainy seasons in Balanga Vicinity

4. CONCLUSION

Before the construction of the two dams, all the wells that were used as sources of water were not yielding water throughout the year. Some used to dry up during peak of dry season, some yield water at the ground level (bottom) of the well during peak of dry season and only few yielded water both in the dry and rainy season. Now, all the observation wells selected for this study in both Dadinkowa and Balanga dam vicinities yields water throughout the year. This is an indication that there is water table rise after many years of the dams construction.

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