Journal of Geography and Regional Planning Vol. 4(7), pp. 392-400, July, 2011
Available online at http://www.academicjournals.org/JGRP
ISSN 2070-1845 ©2011 Academic Journals

Full Length Research Paper

Municipal water supply planning in Oyo metropolis, Oyo State, South Western Nigeria

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Accepted 10 May, 2011

The study attempted a municipal water supply planning in Oyo metropolis using a land based approach to prepare a long range forecast of water supply demand for Oyo metropolis with the aim of providing effective planning, development and operation of water supply and distribution networks which is one of the most essential compounds of urban infrastructure. The problem of water sector in Oyo metropolis was reviewed and the challenges which may result from the capacities of the facilities of the provision in Oyo metropolis was taken care of through the designs of facilities that will ensure adequate planning for, till the projected year. The study delineated the areas within the metropolis that are unserved or underserved by the water corporation. Geographic information system (GIS) was applied to existing distribution maps of the water corporation to present a graphic detail of the current state of facilities frame work for taking management of new facilities was given. Large scale facility maps that will serve as source of information for vital application for the Erelu water corporation in carrying out its daily function were produced. Such maps in digital forms are extremely vital and are useful to integrate collateral data, that is, available within the corporation.

Key words: Water supply, Oyo metropolis, Geographic Information System (GIS).

INTRODUCTION

The socio-economic life of man can never be completed in the absence of water; as a result of this, man has been struggling to make sure water is never out of his reach. As population increases, more pressure will be put on the available water resources. So, many methods are adopted by man to analyse the problems of water supply in order to have water within his reach by conservation and storage of rain water in some areas for their daily activities (Ajibade, 2005; Chaudhery, 2005; Ufoegbune, 2009).

With man's persistence in the search for continuous availability of water, many land-owners in Oyo metropolis had to dig wells around them (Ayoade, 1988). 3.46% of the total population in the metropolis according to Census (2006) data depend on well water for all activities, 8.06 and 1.25% depend on inside pipe-borne and outside pipe-borne water respectively; 5.11% depend on tanker/vendor supply, 2.37% depend on borehole, 8.99% on rainwater, 19.8% on nearby rivers, 1.14% on dam and 3.79% of the people on other sources like subsurface water as springs.

The plan of water supply in Oyo town has become ineffective because fewer numbers of people in Oyo metropolis have access to water supply (Oyebande, 2005). So, there is need for proper planning which entails: Proper abstraction, treatment and distribution in the right amount needed.

The objective of this study is to provide effective planning needed for the supply of potable water across all parts or areas of the metropolis.

Oyo town is located in the North of Ibadan, the capital city of Oyo State situated in the south western part of Nigeria and lies between latitude 7º.8'33"N and 7º.9'33"N and longitude 3º.8'67"E and 4º.0'00"E. The state, Oyo, was reduced in size when Osun State was created out of its eastern portion in 1991. Oyo is bounded by the states of Kwara on the north, Osun on the east, and Ogun on the south and by the Republic Of Benin on the west (Figure 1). Oyo State is traversed by the Yoruba hills in the north. The state has some tropical rain-forest in the south around Ibadan, the state capital, but the remaining parts of the state are covered by Derived Savanah (Ayoade, 1983).

Erelu Dam is one of the dams built by Water Corporation

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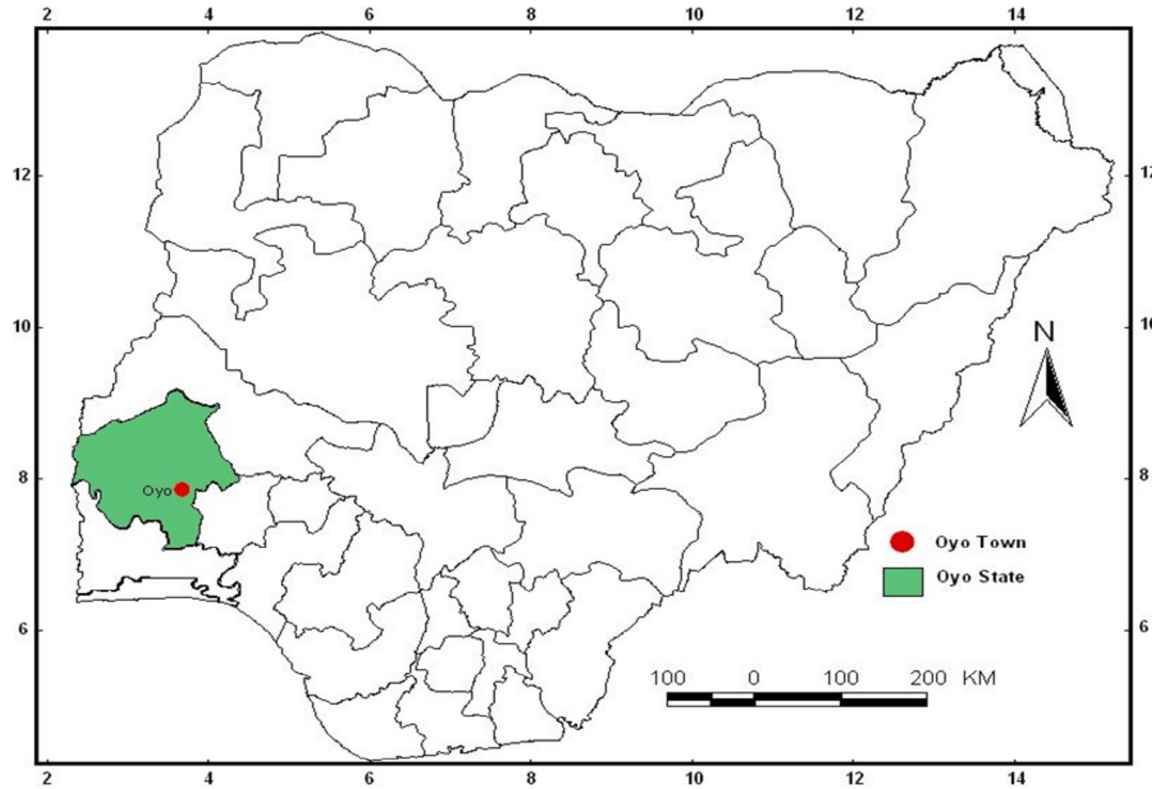

Figure 1. Map of Nigeria showing Oyo State and Oyo town.

of Oyo State. The dam was built in Oyo town in 1961 on Awon River along Oyo/Iseyin to supply potable water to the town and its environs. The water scheme was commissioned in 1963.

The impoundment area of the dam is 161.07 ha, and the catchment area is 243.36 km. Erelu dam is about 6.4 km from the heart of Oyo town. Oyo town is located in the North of Ibadan, the capital city of Oyo State. This appears to be the major source of water supply to Oyo and its environs Figure 2.

The water scheme treatment plant is a conventional type with an output of 7.5 million liters per day and reservoir capacity of 10 cm^3. The project was set up when the population of Oyo was 112,349.

Materials used for the study included map of existing facilities of the metropolis, showing distribution pipelines, pumping station, future and present population statistics of the area, information on WHO and other standards for daily water requirement per person per day and GIS software (Arcview 3.2a with spatial analyst extension).

Water demand forecast are usually based on population which requires accurate population forecasts. For the purpose of this project, a growth rate of 2.5% shall be adopted for Oyo. The compound growth rate is given as:

$$P_n = P_0\left(1 + \frac{r}{100}\right)^n$$

where P_n = projected population for nth year, P_0 = initial population figure = 2006 NPC Figure (428,798), r = growth rate = 2.5%, n = numbers of years from 2006, P_{2010} = 428,798 $(1+ 2.5/100)^4$, P_{2015} = 428,798 $(1 + 2.5/100)^9$, P_{2020} = 428,798 $(1 + 2.5/100)^{14}$, P_{2025} = 428,798 $(1+ 2.5/100)^{19}$, P_{2030} = 428,798 $(1+ 2.95/100)^{24}$.

The consumption was given as a product of population, per capita consumptions of 160 L/day and a safety factor of 1.6.

Design of intake conduit was done assuming a maximum daily demand of 2.585 m^3/s and a self cleansing velocity of 1.8 m/s adopting:

$$Q = AV$$

where Q = pipe discharge / intake (m^3/s); V = velocity of flow (m/s), and A = cross sectional area of pipe (m^2)

$$A = \frac{Q}{V}$$

$$A = \frac{\pi d^2}{4}$$

where A = cross sectional area of pipe (m^2), and d = diameter of pipe (m).

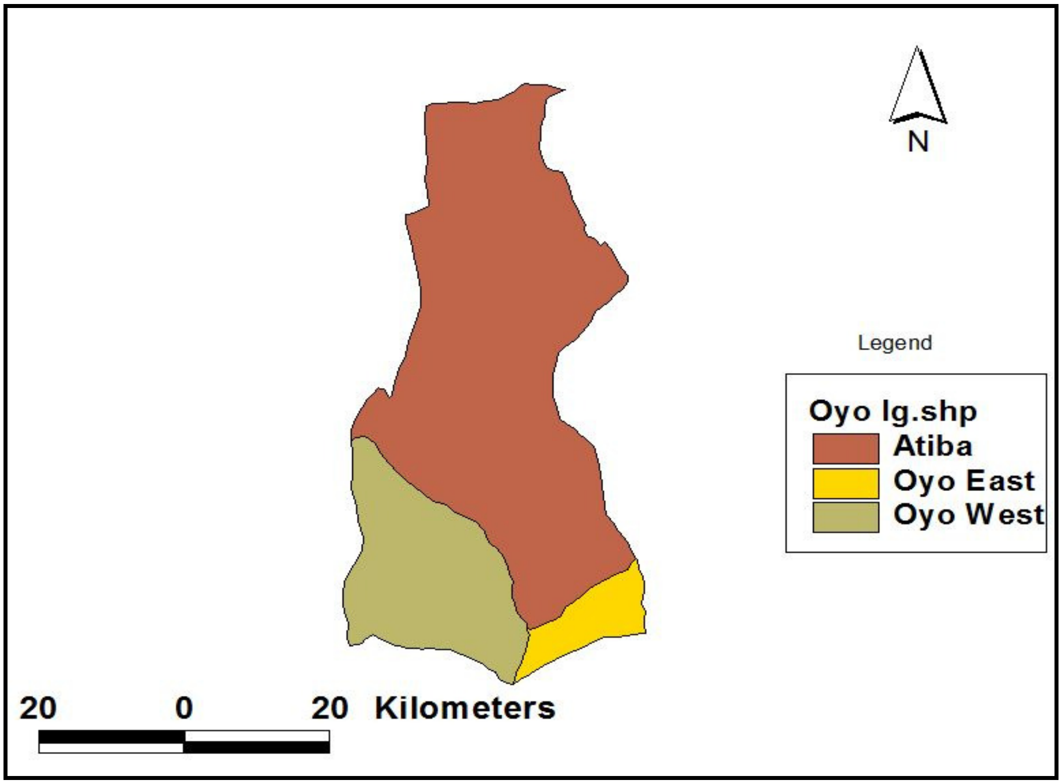

Figure 2. Oyo showing local government areas.

For the purpose of this study, two intake pipes will be adopted; each approximately 0.7 m in diameter. In the selection of low lift pump, the following factors must be taken into consideration. The factors are the average rate of consumption, the requirement of the mixing tank, the low water level in the reservoir, losses in the delivery and suction and the total head.

According to Ajibade (2005), the effective head which the pump must provide is equal to the total lift plus the friction loss and as well as the kinetic energy of the fluid at discharge.

In summary:

$$H_e = H_s + H_d + H_{fs} + H_{ds} + {}^{V2d}/_{2g}$$

where, He = effective head which the pump must provide, H_s = suction lift, H_d = delivery lift, H_{fs} = loss of head in the suction pipe, H_{ds}= loss of head in delivery pipe, $V^2d/2g$ = velocity head in delivery pipe, H_s is a head factor highly dependent on the water level / depth distance to the pump in the low lift pump house, H_d is a factor of head; that is water level in the treatment plant, H_f = Head loss in pipe = (2.5 - 3.0), H_m = water losses in the pipe = (0.8 - 1 cm), Total head for pump $H = H_s + H_d + H_f + H_m$

For the purpose of this study, H is adopted and stipulated at 30 m. The efficiency of centrifugal pump lies between 0.40 and 0.85

If the pumping efficient is put at 75% putting discharge Q, which is the maximum daily requirement at 2.585 m^3/s>BHP = $\frac{QWH}{PE}$

For this purpose; selection of 2 stand-by pump of 7000 HP each is required.

Design of aerator was done with a detection time of 2 min and a depth of tank of 2 m

Note that: The quantity of water required = $115.11 m^3/min$

The rectangular chamber spraying water will have the capacity of length = 15 m, breath = 1 m

Therefore volume of aerator tank = $115.11\ m^3/min \times 2$ min

Making assumptions for two aerator tank, therefore volume of $115.11\ m^3$,

Surface area = v/d = $\frac{115.113\ m^3}{2m}$

The cross-sectional area of rectangular chamber spraying water = L × B

Therefore, total surface area required for one (1) aerator tank will be $(57.55 + 15)\ m^2$ and adopted surface area of 16.5 m length and 4.5 m breadth.

METHODOLOGY

Design of solution tank

Aluminum compound shall be used as the coagulant for flocculation process in this project. The dosing for turbidity ranges from 70 to 120 ppm according to Barnes et al. (1981).

90 ppm shall be adopted for this study.
Consumption = 160 l.c.d
Maximum daily consumption = 186,138.7 m^3/day
Dosing for turbidity = 90 ppm
Maximum weight of coagulant used daily (20 h)
= 90 (gm/m^3) × 186,138.7 (m^3/day)
= 16,752,483 gm/day
= 16,752 kg

If the coagulation will be used in form of solution with 20%.

Therefore volume required = $\frac{16752 \times 100}{20}$

Volume of tank approximately = 85 m^3

Discharge of solution = $\frac{85000}{20 \times 60 \times 60}$

Design of flash mixer

Assume the detention period of 2 min, maximum water demand of 115.11 m^3/min, volume of flash mixer of water demand × 2 min given 115.11m^3/min × 2 min with an assumed depth of 1.5 m. This will be as area divided by 1.5 m and gives 230.22 m^3

Design of a clarriflocculator

Assume detention time of 40 min
Assume the depth of 5 m
Quantity of water required = 115.11 m^3/min
Volume = (115.11 × 40) (m^3/min × min)
Assuming 4 units of the tank
Volume of one (1) unit = $\frac{4604.4m^3}{4}$

Area = $\frac{volume}{Depth} = \frac{1151.1}{5}$

Area = $\frac{230.22m^2}{4}$ πd^2

$d^2 = \frac{920.88}{3.142}$

Let the diameter of the flocculation = 17.12 m

Design of clarifier (settling tank)

Detention time = 4 h
Depth of tank = 6 m

According to Barnes et al. (1981), depth of sedimentation tank is usually 0.6 to 1.2 m more than flocculation tank.

Quantity of water required = 9306.94 m^3/h Volume required = (9306.94 × 4) m^3
Assume units of this tank are 8 (eight)

Volume of 1 unit = $\frac{36,147.76}{8}$

Surface area = $\frac{4518.47m^3}{6m}$

For circular shape type clarifier

Area = $\frac{\pi d^2}{4}$

To optimize the use of land area flocculation unit is usually constructed in the middle of the clarifier.
Volume of the tanks unit each = 4518.47 m^3 + 1151.1 m^3
Assume a depth of 6 m for the unit

Therefore surface area = $\frac{5669.57m^3}{6m}$

Therefore adopted diameter for clarriflocculator unit = 35 m

Design of filter tank

Operation rate according to Helthes et al. (1986) slow filter are usually designed for normal operation at a rate of 0.1 m^3/m^2/h. However, a pilot studies have shown that higher rates of 0.2 m^3/m^2/h or even 0.3 m^3/m^2/h may be used without deterioration to fill water quantity.

Quantity of water required = 9306.94 m^3/h

Assume operation rate = 0.3 m^3/m^2/h
Total filter bed area = $\frac{9306.94m^3/hr}{0.3m^3/m^2/hr}$

Assume 20 units of this;

$\frac{31,023.13\ m^2}{20}$

Adopt size 45 × 35 m
If the depth of filter bed = 0.7 m
If the depth of sub grade = 0.85 m
Assume freeboard = 0.4 m
Depth of under rain = 0.5 m
Total depth = 4.45m ≈ 4.5 m

Design of clear water tank

Maximum daily consumption = 9306.94 m^3/h
Detention period = 4 h
Total volume of tank = (9306.94 × 4)m^3
For easy management select 4 number of tanks

Volume of 1 tank = $\frac{37227.76m^3}{4}$

Assume the depth of tank = 8 m

Surface area = $\frac{9306.94m^3}{8m}$

Adopt size of 30 m (breadth), 40 m (length) and 8 m (depth)

Transmission works

Design of high lift pump

According to Ajibade (2005), the break horse power (BHP) of the high lift pump to be used is very important. It will be recommended.

Assume a total head (H) = 80 m
Maximum water requirement Q = 2.585 m^3/s
Pumping efficiency = 75%
Efficiency of pump = 0.75
Pumping is usually done in two shifts in a day 24 h, that is, morning and evening.

BHP = $\frac{QWH}{75E}$

= $\frac{2.585x\ 1000x80}{75x0.75}$

Design of rinsing main

Rinsing main conveys water from clear water tank to service reservoir.
Take velocity = 1.5 m/s
Maximum water requirement = 2.585 m^3/s

$$Q = AV$$

$$\frac{2.585m^3/s}{1.5\,m/s}$$

Area = $\frac{\pi d^2}{4}$

Design of service reservoir

The service reservoir is normally designed to store 20 to 50% of maximum daily water.
Maximum hourly demand of water for projected population for the year 2030
Projected population = 775,578.5
Recommended per capital per day = 160 L
Recommended factor of safety = 1.5
Maximum daily consumption = 775,578.5 ×160 × 1.5
Maximum hourly demand per hour

$$= \left(\frac{185{,}138{,}720}{24x60x60x1000}\right) m^3/s$$

Maximum daily demand = 7754.4 × 24
If 50% of maximum daily demand is allowed for capacity volume require = 93,052.8 m^3.
Making use of 12 reservoirs well spread all over the city.
Capacity of one reservoir = 7754.33 m

If the depth of tank = 10 m

Surface area = $\frac{7754.33}{10}$

For circular tank Area = $\frac{\pi d^2}{4}$

Therefore use 12 numbers 32 m diameter, 10 m depth circular reservoir each.

Design of gravity mains

Maximum water consumption = 2.585 m^3/s
Assuming flow velocity in pipe = 2 m/s

$$Q = AV$$

A = $\frac{2.585}{2}$

Area = $\frac{\pi d^2}{4}$

Distribution works

In water supply system, water is transported under pressure through a distribution network of buried pipes. Smaller pipes, called house service lines, are attached to the main water lines to bring water from the distribution network to houses. In water supply systems, water pressure is provided by pumping water up into storage tanks that store water at higher elevations than the houses they serve Figures 3 and 4. The force of gravity then "pushes" the water into homes when tap is opened. A pump brings the water out of the ground and into a small tank within the home, where the water is stored under pressure.

Areas that are not properly served by potable water supply is identified by superimposing of the existing pipeline distribution plan on the topographical map of the area (Oyo N. E.) which shows the total area cover of the metropolis Figure 5.

RESULTS AND DISCUSSION

The projected population is given in Table 1. The projected population of Oyo metropolis using National Population Census (NPC) 2006 figure at 2.5% growth, showed that population of the metropolis will continue to increase immensely and provision of social amenities to cater for the needs of the increasing population must be planned to ensure availability throughout the design period.

In planning for water sustainability and sufficiency, maximum water per capital demand was generated to determine the maximum amount of potable water to be supplied by multiplying the projected population figure for the year with recommended per capital per daily consumption and with the recommended safety factor. Results are shown in Table 2.

The results of the design of facilities will foster the effectiveness of potable water supply in the metropolis are shown in Tables 3 to 5.

Collection works include the intake conduit and the low

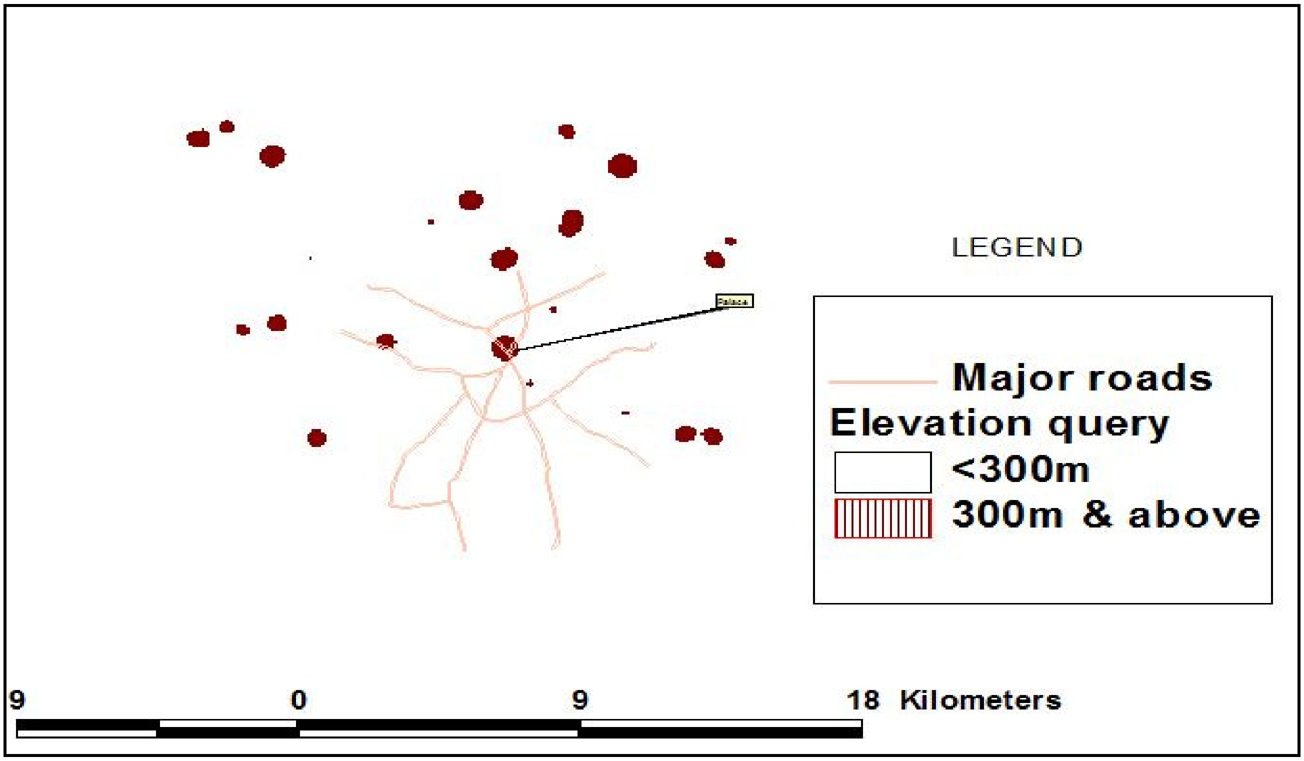

Figure 4. Map showing elevation query.

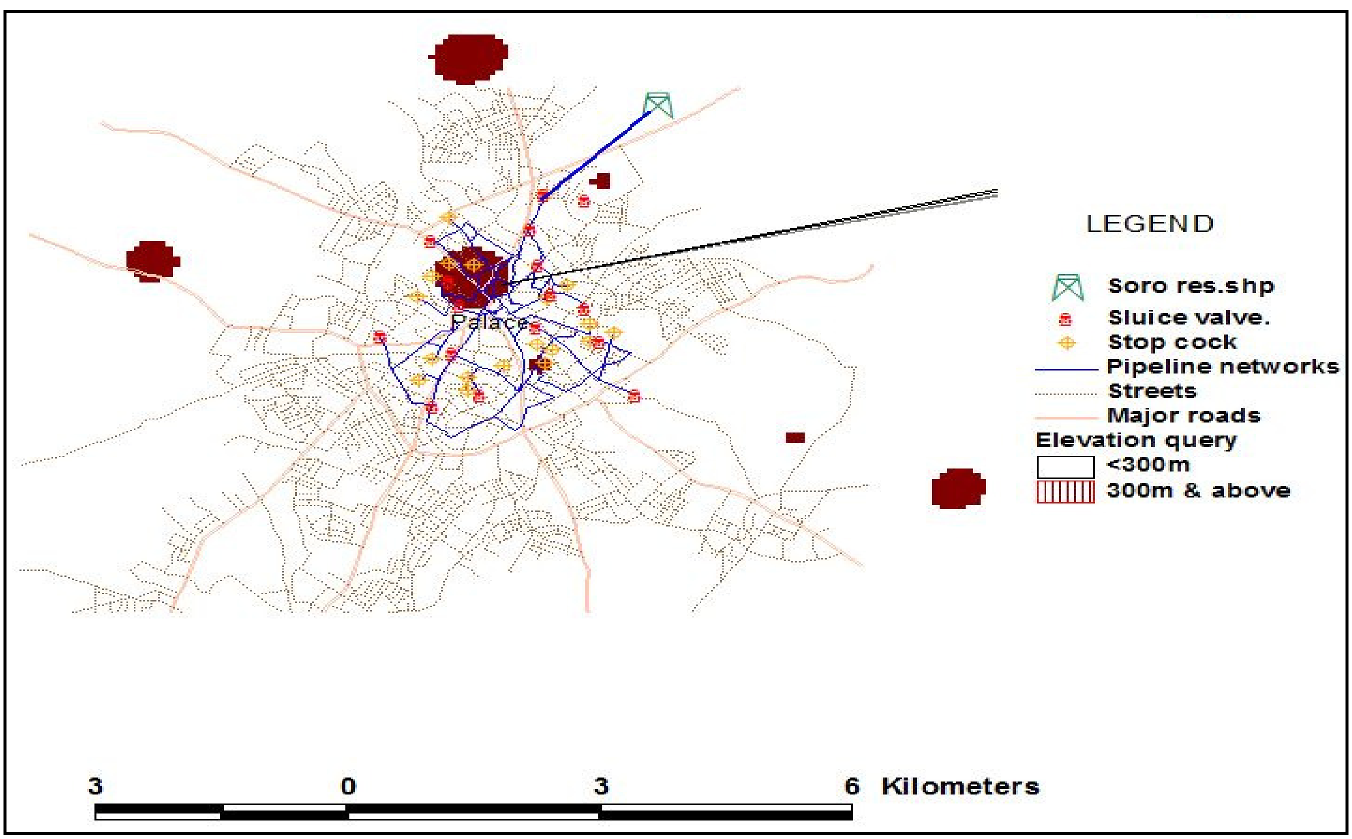

Figure 5. Map showing the existing pipeline on the present land area over of the metropolis.

Table 1. Projected population.

Year	Population projection
2010	473,312
2015	535,509
2020	605,878
2025	685,496
2030	775,577

Table 2. Water demand for the year 2010 and 2030.

Water demand	Liters/day	m^3/h	m^3/min	m^3/s
2010	113,594,880	5680.08	94.67	1.577
2030	186,138,720	9306.94	115.11	2.585

Table 3. Showing collection works design.

Collection work	Diameter of pipe	Number
Intake conduit	1.35	2
Low-lift pump	-	2

Table 4. Showing design parameters of purification works.

Purification/ Treatment work	Area (m^2)	Volume of tank (m^3)	Discharge (l/s)	No of tank needed	Depth (m)	Diameter (m)	Adopt size (m)×(m)
Aerator	72.56	230.2	-	-	-	-	-
Solution tank	-	85	1.180	-	-	-	-
Flash mixer	153.48	230.22	-	-	-	-	-
Clarriflocculation	-	115.11	-	4	-	17.12	-
Clarifier	753.07	4518.47	-	8	-	31	-
Filter tank	31,023		-	20	4.5	-	45 × 35
Clear water tank	1163.36	9306.94	-	4		-	30 ×40

Table 5. Showing transmission works.

Transmission work	Diameter of pipe (m)	Velocity (m/s)	Number	Volume (m^3)	Depth (m)	Surface area (m^2)
High - lift pump	-	-	3	-	-	-
Rinsing main	0.74	1.5	2	-	-	-
Serviceable reservoir	32		12	7754.3	10	775.43
Gravity main	-	-	-	-	-	-

lift pump station that helps in abstraction of raw water from the dam. Result of water demand per person per day gives consideration to the quantity of water that must be abstracted to meet to meet the demand.

Table 3 shows the result of the design of the collection works. Two intake conduit pipe of diameter 0.7 m must be adopted and two stand-by pumps of 700 hp each is required.

The result of the designed parameters of purification/ treatment works are shown in the Table 4 showing different planning requirements for various facilities used in the treatment work.

The result of the transmission works (Table 5) showed that 3 high lift pumps of 1300 hp each will be required to fit in with the requirements of water demand. Twelve reservoirs are needed to cater for the needs of the

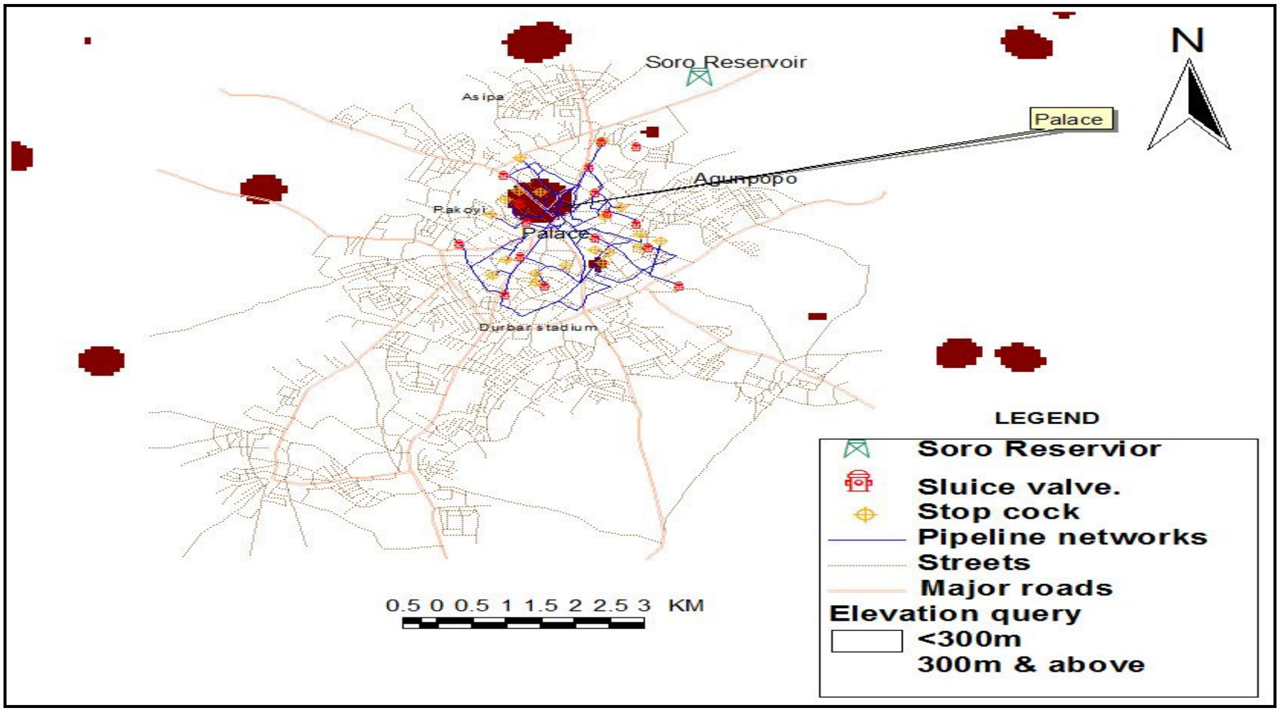

Figure 6. The combination of the generated map.

metropolis within the design period of 20 years; reservoir must be well allocated within the catchment area of Oyo metropolis. 5 reservoirs must be allocated to Atiba Local Government Area of the metropolis.

3 reservoirs allocated to Oyo East Local Government Area of the metropolis and 4 reservoirs to Oyo west Local Government Area of the metropolis. Since, Atiba Local Government area has 39.23% population of the total population of the metropolis, Oyo East has 28.94% and Oyo West has 31.82%.

The elevation query of the map distinguished between areas of elevation below 300 m and elevation at 300 m and above. Areas of 300 m elevation and above are areas suggested for the citing of reservoirs that will ensure proper distribution of potable water with or without being incorporated by a booster station, with the use of sluice valves that helps in diversion. The points are the red dot box on the map so reservoirs can be distributed as designed for the metropolis based on population density of the area.

Figure 5 shows the facilities of existing facilities of the Erelu water corporation. There is need for the pipe network to cover all areas more effectively for new development areas to be adequately catered for. The plan of the existing facilities of the water corporation include one reservoir of 900,000 gallons/ 4091.4m^3 capacity located at Sooro Hill (Figure 6) and some pressure control valves along the pipeline that allows maximum diversion of water from cannot meet the demand and requirement of the metropolis.

Conclusion

To satisfy the water requirement of the people of Oyo for domestic and other uses from 2010 to 2030, the expansion of the dam must be made to impound water at its maximum capacity that will ensure regular abstraction to meet peoples demand after undergoing the required treatment units. This situation agrees with the previous work done in Abeokuta Metropolis (Ufoegbune et al., 2009). The plan for municipal water supply made for Oyo town will far outweigh the present works in the city. Since, Oyo a large town has suffered shortage of potable water in the last two decades. Though the ancient town plays host to four tertiary institutions and a federal government girls' college, it is still grappling with water scarcity. For upward of 2 decades, residents have relied on the Erelu water works for it supply of tap water through the capacity of the dam is grossly inadequate for the increasing population of the town. For a town consisting of mainly civil servants, farmers and artisans; a borehole is largely a luxury so there is need for the government to expand the dam to be able to impound more water that can serve the entire population adequately well both satisfactorily in quality and quantity. It should also be noted that plans are made on the ultimate water requirement, which is year 2030 water requirement. Thus, plants may not be used to its fullest capacity until year 2030. Extensions of pipe lines need to be provided to cater for the water requirement of the people both now and in future. The citing of reservoirs on the generated highest contour elevation must be well distributed and be selected in such to fulfill its purpose. The scheme planned for in the project, when adopted and executed will bring a worked improvement in the standard of living of the people. More time will be committed to human, nature and material enhancing activities than water hunting. The general level of sanitation, cleanliness, healthy living will thus, rise (Warner, 1995).

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