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DESIGN OF PUMPING STATION FOR A TIDAL FISH FARM IN THE NIGER DELTA, NIGERIA.

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ABSTRACT
The design of pumping station for submersible FLYGT pump 3102 version LL to redress the water supply problem of some ponds in the tidal fish farm of African Regional Aquaculture Centre (ARAC) located in Omuihuechi, Aluu, Rivers State, Nigeria was carried out. Prior to the design baseline study was carried out for the proper sitting of the pumping station. The topographic survey of the area indicated gentle sloping woodland, with the highest and lowest elevations of 11.00 m and 1.00 m respectively. The mean peak heights of water in the supply canal during spring and neap tides ranged from 0.95 to 1.45 m and 0.38 to 0.86 m respectively. The flood tide and ebb tide velocities of supply canal water flow varied from 0.40 to 0.75 m/s and 0.75 to 0.92 m/s respectively. Soil particle size analysis indicated loamy clay and clay soils. The results of pumping station design were 1.80 m (length),1.30 m (width), 3.60 m (height),0.15 m (thickness), 1 (cement) : 2 (sand) : 4 (gravel) (concrete mixture ratio) and 12 mm (reinforcement bar). Results of pump characteristic calculation were 0.069 m^3/s (discharge) ,4.02 m/s (pumping velocity), 5.73 m (total dynamic head), 0.82 m (minimum submergence depth), 5.04 KW (pump power) and 0.40 and 0.30 m (clearances from floor and wall respectively). The results obtained were considered adequate for the purpose of construction of the pumping station for the pump and the procedures adopted will assist in similar design tasks in the development of fish farms in the Niger Delta Region of Nigeria and beyond.
Key words: Design, Pumping station, Fish farm, Niger Delta.

INTRODUCTION
Some of the fish ponds making up the 81 hectare fish farm (Ajayi, 1991) of the African Regional Aquaculture Centre (ARAC) have been having water shortage problem. The farm has largely been operating without adequate water for the ponds. The ponds are usually dry during the dry season (November to March), thus exposing the ponds' bottom soils to repeated cycle of drying and wetting, which destroys the structure of pond bottom soils (Kovari, 1984). Baseline study to redress the water supply problem by designing water supply facilities (inundation canal, impounding reservoir, sluice gate, and pumping station) have been carried out (Leton and Uzukwu, 2011, Uzukwu and Leton, 2011; Uzukwu *et al.*, 2010). Pumping stations are facilities including pumps and equipment for pumping fluids from one place to another, such as the supply of water to canals or fish farms, the drainage of low-lying land, and the removal of sewage to processing sites(Arcadia and Gregoria,2002; Wikipedia,2012). It is important in the proper running of fish farms whose ground elevations are higher than the water supply source. The design and construction of the pumping station and installation of the FLYGT submersible pump (model 3102 version LL) of capacity 5,500m^3/day for the farm will ensure adequate water supply for the affected 25 ponds which require approximately 25,000m^3 of water daily. This paper presents notes on site selection studies, and design of a pumping station for the fish farm. It is hoped that this will assist in similar design tasks in Nigeria and elsewhere.

MATERIALS AND METHODS
The Study Area:The study area is the 81 hectare fish farm (Ajayi, 1991) of the African Regional Aquaculture Centre (ARAC) located at Omuihuechi, Aluu, Rivers State,. Nigeria. It lies between $6^0 53^1$ and $7^0 00^1$ N latitudes and $4^0 54^1$ and $4^0 56^1$ E longitudes. The farm is situated 350 m inland from the New Calabar river, which is located on the eastern flank of the Niger Delta River System. The New Calabar river is a black water type (RPI, 1985), and empties into some creeks and lagoon bordering the Atlantic Ocean. At Omiuhuechi, Aluu where ARAC fish farm is located, the river is fresh and tidal whereas at a little distance down stream (Choba and Ogbogoro) it is brackish. The study area is low lying and is constantly inundated by tidal waters during floodtides. The climate is tropical with a dry season during November to March and wet season during April to October. The vegetation is thick swampy forest with gentle sloping topography. The New Calabar river basin is identified with the annual rainfall of 254mm (Erondu and Chindah, 1991).

Measurement of flow velocity in supply canal:The velocity of tidal water flow in the supply canal was measured at the canal water surface using the float method and the values obtained were multiplied by a factor of 0.85 to obtain mean values (Coche and Van der Wal, 1981).

Topographic map of the site:The topographic map of the project area was obtained from Apapa (1995). The map is considered adequate for the purpose of this work.

Determination of the soil quality of the site:Undisturbed representative soil samples were taken with pothole digger at a depth of 1.0 m in labelled black polythene bags. The samples were air-dried and analysed for particle size using the pipette method (Mckeague, 1980; Uzukwu, 2010). The textural class of the soil samples was determined using the textural triangular diagram (Dureza, 1982).

Measurement of water quality parameters:Selected water quality parameters (pH, transparency, dissolved oxygen, total hardness, and temperature) of the supply canal water were taken during high tides twice a month. Dissolved oxygen (DO) was measured using Winkler's method (Boyd, 1990); temperature was measured using Celsius thermometer; pH was recorded with a pH meter model 191. Transparency was measured with Secchi disk of diameter 12 cm while total hardness was measured using Ethylene diamine tetra acetic acid (EDTA) titration (APHA, 1995). Dissolved oxygen deficit was computed by subtracting ambient DO values from saturation DO values.

Pumping Station Design:A reinforced concrete sump foundation was designed to carry the weight of the pump and prime mover. With respect to the layout and elevation of pump and prime mover, the following were considered :Suction lift limitation,Tidal water level and Accessibility, economy and security.

Sump Design:A sump refers to a basin or well provided at the foot of the pump column suction end. The plan and elevation of the sump are shown in figures 2 and 3 respectively. Its design considered the following:Minimum submergence depth, Clearances from floor and wall, andStrainers and trash rack.

Minimum Submergence Depth:The difference between the lowest possible water level in the sump and the inlet part of the suction pipe is the minimum submergence depth (Hm) which is given by: $Hm \geq V^2/2g$.

Clearances:Floor and wall clearances of 0.40 m and 0.30 m respectively were specified for the sump. These were considered adequate since they are nearly equal to the bell diameter.

Screening:The sump was provided with strainers and trash rack consisting of a grid of 30 mm mesh at the mouth of the pump sump to remove obstacles to the operation of the pump such as branches, sand, pebbles, and other hard objects.

Basic Calculations

Pumping Velocity:From pump manual, the minimum submergence depth = 0.82 m

Minimum submergence depth (Hm) is given by: $Hm > V^2/2g$

Where Hm = minimum submergence depth (m), V = velocity of flow (m/s), g = gravitational acceleration (m/s^2)

$$V=\sqrt{(Hm)(2)(g)} = \sqrt{(0.82)(2)(9.81)} = 4.02 \text{ m/s}$$

Total Dynamic Head (TDH).

The total head of a pump comprises the geodetic level difference between the inlet –side and the delivery –side water levels and the pressure affecting them as well as the various hydraulic losses during lifting (Kepenyes, 1984, 2012). TDH is given by:

$$H = h_g + h_o + h_1 + h_2 + h_3 + h_4 + h_5 + h_6 + h_7 + (P_s - P_d/p.g).$$

Where: TDH=total dynamic head, h_g=geodetic head(m),h_o=entrance loss(m),h_1=resistance of the filter(m), h_2=resistance of the foot valve(m),h_3=loss by pipe friction,h_4=loss from increase in cross section(m),h_5= loss from reduction in cross section(m),h_6=loss from valves(m), h_7=loss from inversion(m),p=density of water 1000 kg/m^3,g=gravitational acceleration(9.81m/s^2).

If atmospheric pressure affects the water levels of both inlet and delivery sides the last item: ($P_s-P_d/p.g$) = 0.

For simplicity sake TDH FLYGT pump was calculated as follows:

From pump manual, the discharge = 0.069 m^3/s

Suction head = 3 m

Discharge head = 1 m

Friction head in 8m discharge pipe of 6 inch diameter

$$8 \text{ m} \times \frac{3.281 \text{ ft}}{\text{m}} \times \frac{6.17 \text{ ft}}{100 \text{ ft}} \times \frac{0.3048 \text{ m}}{\text{ft}}$$

Friction head in fittings equivalent length of three (3) angle elbows

$$3 \times 7.5 \text{ ft} \times \frac{6.17 \text{ ft}}{100\text{ft}} \times \frac{0.3048 \text{ m}}{\text{ft}} = 0.42 \text{ m}$$

$$\text{Velocity head} = \frac{V^2}{2g} = \frac{(4.02 \text{ m/s})^2}{2(9.81 \text{ m/s}^2)} = 0.82 \text{ m}$$

TOTAL = 5.73 m

Pump Power

Pump power is given by: P (KW) = $\frac{YQH_T}{102 \times n_p \times n_m}$

Where: Y =	unit weight of water	=	1000 kg/m^3
H_T =	Total dynamic head (m)	=	5.73 m
n_p =	pump efficiency	=	0.81
n_m =	Motor efficiency	=	0.95
Q =	Discharged of pump	=	0.069m^3/s

$$P\ (kw) = \frac{1000\ kg \times 0.069\ m^3/s \times 5.73\ m}{102 \times 0.81 \times 0.95} = 5.04KW$$

RESULTS and DISCUSSION

Baseline Studies: The lowest value of water level in supply canal (0.38 m) was recorded in March, that is, peak dry season. The water level values recorded during high tides indicate that there will be enough water in the sump to operate the submersible pump to be installed The textural class of soil in and around the site which ranged from loamy sand to clay will not promote subsidence and uneven settlement. The site was therefore considered adequate for the purpose of siting the pumping station. Besides, the reinforced concrete raft foundation specified for the sump will guarantee safe operation. The flood tide and ebb tide velocity values which ranged from 0.40 to 0.65 m/s and 0.72 to 0.92 m/s respectively are within safe limits for the clay/ loamy soil types found in the site (Table 1). Ansa *et al.* (2011) stated that the values of ebb tide and flood tide velocities in the supply canal are within the normal ranges for tidal flows which encourage silt deposition both in the canal and reservoir. However, the pumping velocity of the FLYGT pump (4.02 m/s) to be installed would not encourage silt deposition in the sump but in the canal and reservoir. Silt removal in the canal and reservoir will be carried out annually as part of routine maintenance of the system. The topographic map of the site (figure 1) together with the supply canal, the sluice gate and the reservoir, all of which are to work in conjunction with the FLYGT submersible pump to be installed in the pumping station as the water supply system for the farm is considered adequate. Results of the water quality parameters analysis are presented are also considered adequate except mean pH values which ranged from 5.80 to 6.97. The mean pH values which were slightly acidic could promote corrosion of the pump. It is believed that this problem must have been taken care of by the manufacturer of the pump.

Pumping Station Design: The plan and elevation of the pump sump (figures 2 and 3 respectively) were considered adequate. The reinforced concrete foundation design to carry the pump and prime mover (electric motor) also good. The suction head and minimum submergence depth specified as 3.00 m and 0.82 m respectively are within the manufacturer's recommendation. The suction head and minimum submergence depth specified as 3.00 m and 0.82 m respectively are within the manufacturer's recommendation. Clearances of the pump from sump floor and wall were specified as 0.40 m and 0.30 m respectively is good. Kenpenyes (2012) stated that if the centre line of the pump's bell mouth entry is fairly close to the opposite wall of the inlet chamber there would be no whirling. The difference between the critical minimum water level in reservoir/sump and the minimum submergence depth specified as 1.98 m was adequate. The suction head and discharged head specified as 3.0m and 1.0 m respectively as well as the total dynamic head of 5.73 m are considered okay since they are within safe limits in the pump manual . The pump power which was computed as 2.98 KW using pump and motor efficiencies of 0.81 and 0.95 respectively is correct. Strainers and trash rack was provided at the mouth of the pump sump to protect the pump from damage due to objects while burglar proof was provided at the top of the sump to prevent burglary and vandalism. A circular reinforced concrete retaining wall of 0.12 m thickness and 2.20 m diameter was provided for the sump to protect nearby installations such as surface pumps station and pond dykes. An existing surface pump, with 20% delivery, serves as the operational reserve or back-up in case of failure. The FLYGT submersible pump of capacity 5,500m^3/day selected for the pumping station is considered adequate for the water needs of the farm estimated at 25,000 m^3/day. This is because it adequately satisfies the requirement of being able to fill the ponds in the farm within 7 days (Coche and Van der wal, 1981).The sump raft foundation thickness of 0.15 m and the concrete mixture design of 1:2:4 (cement: sand: gravel), with 12 mm high yield reinforcement bar for the floor and walls is considered adequate. The FLYGT pump minimum submergence depth of 0.82 m in relation to the critical minimum water level of 2.80 m in reservoir during high tides in dry season is quite permissible. The overall height of 3.60 m of the sump, viewed against the fact that FLYGT pump 3102 version LL to be installed was a submersible pump with requirement for adequate clearance from sump floor, was good .The results of water quality parameters indicated that the metal parts of the pump may be subject to corrosion since the water is black (RPI, 1981).However, there was no cause for alarm since the manufactuers have assured that the pump is rugged and can be used for reclamation operations. For routine maintenance or replacement Kepenyes (2012) advised that there is a need to include in the cost estimates for installation a pump house for the switchgears and the electronic controllers as well as equipment to lift up the pump from the sump. The cost of installation of the pump is given in Table 4

CONCLUSION

The results obtained in this work were considered adequate for the purpose of construction of the pumping station to solve the water supply challenges for the affected fish ponds in ARAC and the procedures adopted will assist in similar design tasks in the development of fish farms in the Niger Delta Region of Nigeria and beyond.

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Table 1: Soil textural analysis of soil samples around the pumping station.

Sample	Textural class
A	Silty loam
B	Clay
C	Siltyclay

Table 2: Flood tide and ebb tide velocities of the supply canal water flow.

Months	Floodtide velocity(m/s)	Ebbtide velocity(m/s)
October	0.65	0.92
November	0.75	0.75
December	0.45	0.72
January	0.50	0.78
February	0.40	0.73
Mean ± SD	0.55 ± 0.13	0.78 ± 0.07

Table 3. Mean values of water physicochemical parameters of New Calabar river

Months	pH	Transparency (cm)	DO (mg/)	Total hardness ($mgCaCO_3/l$)	Temperature (^0C)	DOD(mg/l)
Aug	6.00	12.00	6.00	14.20	26.20	2.00
Sept	6.50	10.80	6.20	14.50	24.50	2.30
Oct	6.20	11.70	5.90	13.90	24.00	2.60
Nov	6.70	13.30	6.30	14.30	25.70	1.90
Dec	6.80	14.80	6.50	14.20	26.10	1.70
Jan	6.95	18.50	6.80	14.60	25.10	1.50
Feb	6.97	16,70	5.50	28.50	27.50	1.50
Mar	6.50	19.00	6.90	49.60	28.90	1.00
April	5.90	16.50	7.40	50.20	29.90	0.20
May	6.80	14.50	6.90	24.20	28.20	1.10
June	6.05	13.00	6.20	14.10	26.50	2.00
July	6.08	13.00	6.00	15.80	24.80	2.30
Aug	6.20	11.00	5.80	14.40	25.10	2.50
Sep	6.10	10.50	5.80	13.20	24.50	2.50
Oct	6.15	9.50	6.20	13.00	25.60	2.00
Nov	6.40	12.00	5.90	12.90	26.20	2.30
Dec	6.55	13.50	6.30	13.60	23.50	2.40
Mean ± SD	6.40 ± 0.34	13.55 ± 2.70	6.26 ± 0.48	19.72 ± 11.74	26.02 ± 1.70	1.87 ± 0.63

Table 4: Financial Implication for Installation of FLYGT Pump at ARAC

Description of items and activities	Quantity	Rate	Amount
Cost of FLYGT Pump 3102 version LL	1	40,000	40,000.00
Serving of FLYGT pump and test run	L/S	-	5,000.00
Construction of canal linking New Calabar River (earth work)	$900m^3$	600	540,000.00
Construction of sluice gate across canal	L/S	-	150,000.00
Expansion of reservoir to 100m x 50m x 2m (earth work)	$1333.3m^3$	600	800,000.00
Construction of concrete training wall and sump 0.12m thickness, 2.2m diameter and 4m height	L/S	-	400,000.00
Cleaning of distribution channels	L/s	-	200,000.00
Contingency (10%)	-	-	213,500.00
Total			2,348,500

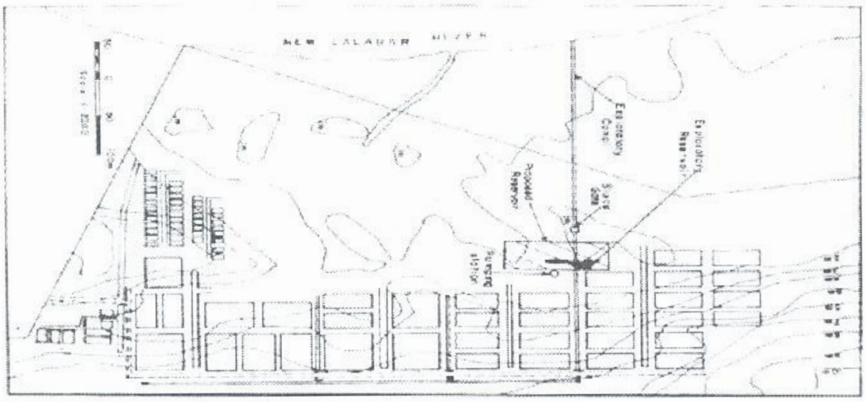

Fig. 1: Topographic Map of ARAC Fish Farm, Aluu, (Modified after Apapa, 1995)

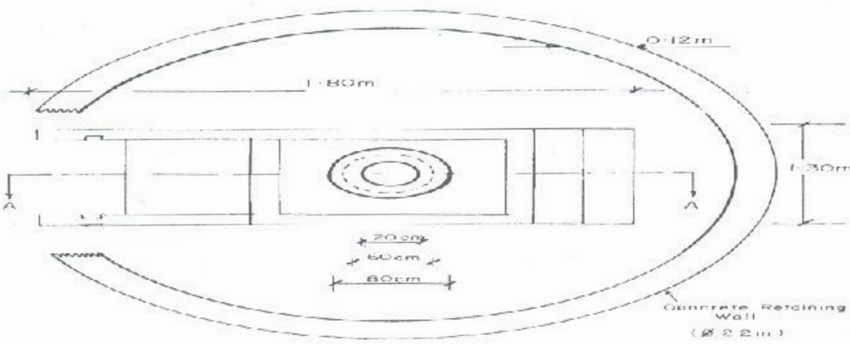

Fig. 2: Plan of Pumping station

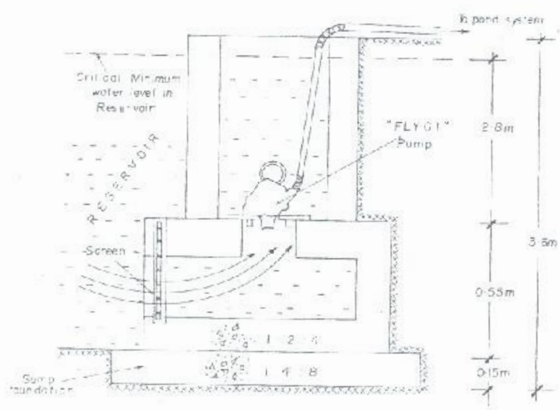

Fig. 3: Pump Sump Design (Elevation)

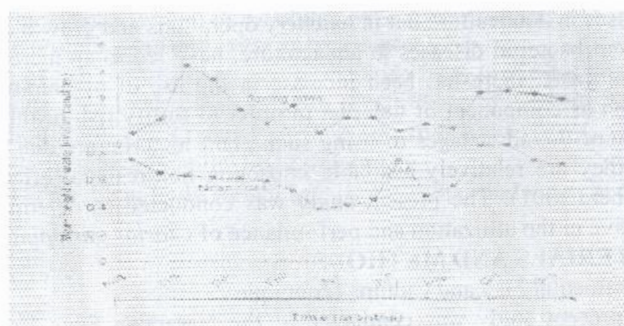

Fig. 4: Mean maximum water heights in supply canal during spring and neap tides