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REQUISITE CONDITIONS FOR DESIGNING INUNDATION CANALS FOR TIDAL FISH FARMS USING TABLES

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ABSTRACT
This paper reviews environmental data requirements and procedure for designing inundation canals using design tables for tidal fish farms in brackish water environments. It summarizes baseline data that should be available prior to design process such as topographic map of the area, ground profile of canal right of way, tidal range, water level records, soil type and properties, as well as the underlying principles governing design specification of canal such as bed slopes, side slopes, carrying capacity, hydraulic radius and coefficient of roughness. It is hoped that this review paper will complement existing body of knowledge to simplify the task of designing inundation canals, as part of larger efforts at seeking sustainable fish production and human development in Nigeria and beyond.

KEYWORDS: Inundation canals, data needs, Design tables,

INTRODUCTION

Nigeria has a coastline of approximately 853km (Ajao *et al.*, 1996) bordering the Gulf of Guinea, with over 1.5 million hectares of unused coastal swamps, which can be put to profitable aquaculture production. Her territorial sea of 30 nautical miles (nm) and an Exclusive Economic Zone (FEZ) of 200nm cover 210,900km2 (World Resources, 1990). Fish is a good source of protein, sulphur and essential amino acids (Kent, 1984; Tobor, 1990). According to Tobor (1990), the annual fish yield potential in Nigerian inland, coastal and marine waters above 200m depth is 512,360mt while the demand for fish is over 1 million metric tons (mt). With a population of more than 140 million and a total current domestic production of less than 450,000mt, Nigeria has a serious problem of bridging the gap between her fish demand and supply (Tobor, 1993; Ezenwa *et al*., 1994).

Fisheries experts agree that African fishing industry including Nigeria has many challenges (Daily Sun, 2005), one of them being that fish catches have fallen sharply across the continent in recent years, resulting in a significant decline in consumption. Scientific bodies believe that small-scale fish farming is the answer to building up fish stocks particularly in sub-Saharan Africa (Daily Sun, 2005), One of the measures adopted to increase fish supply, in Nigeria over the years, is through the development of aquaculture which has a current annual production level of only 50-60,000mt (Anyanwu, 2006). The potentials of aquaculture are yet to be fully tapped, and inadequate infrastructural development particularly in the area of water supply is believed to be one of the major limiting factors, According to Sivalingam (1974), an adequate supply of water is essential for fish farming. In fact without adequate water supply there cannot be profitable fish farming (Kovari, l984). Coastal and brackish water fish farming depend on tidal water supply. However, to be able to supply the ponds, one requires the construction of inundation canals to link the pond with the estuary. The principles underlying the design, selection of sites and technical baseline data necessary for the design of open canals for small and medium scale coastal fish farms have been reported (UNEP, 1983; dela Cruz, 1983; Veroli, 1985; Coche and Muir, 1992; Hanco, 1984; Uzukwu, 2010).

This paper reviews environmental data requirements and procedure for designing inundation canals for coastal fish farms using design tables.

INUNDATION CANALS

The task of designing an inundation canal for a tidal fish farm involves taking decisions as to the type, shape and dimensions of the canal including the bed slopes, side slopes, carrying capacity and roughness coefficient based on data on the natural characteristics of the project site and the size of the farm.

Types of Canals in aquaculture
A canal is a man-made (artificial) water way for navigation, drainage, irrigation or transport of water. Different types of open water canals are used in fish farming operations to transport water, usually by tidal energy, and to drain water by gravity for five main purposes: (a) inundation canals are used to supply water from a tidal river, lagoon or estuary to a fish pond reservoir by tidal energy, (b) feeder canals are used to supply water from the main water intake (reservoir) to the fish ponds. In a large farm with several pond units, there is usually a main feeder canal (Elekes, 1984) branching into secondary and even tertiary feeder canals, (c) drainage canals are used to evacuate water by means of gravitational energy from the fish ponds, for example towards an existing channel, (d) diversion canals to divert excess runoff away from barrage ponds, (e) protection canal to divert water away from the fish ponds. This paper deals essentially with the first type, but the principles discussed can be applied to the other types.

Shape of Canals
Water canals can have various shapes. In theory the most efficient shape is a semi-circle, but this is not practicable for earthen canals. It is, therefore, generally used for precast concrete flumes or plastic flume only. For unlined canals, however, it is very common to have a trapezoidal cross-section defined by: (i) the width (b) of its horizontal bottom; (ii) the slope ratio (Z:I) of its angled sides; (iii) the maximum water depth (h); and (iv) the freeboard (f) to protect against overflowing. Water canals lined with bricks or concrete may also have a rectangular shape. Unlined earthen canals with rectangular shape will have unstable side walls (Uzukwu, 2010).

Design of Canals
All canals should be well designed to have the required water carrying capacity which is related to the size of the farm. The canals are designed using formulas that relate the carrying capacity of the canal to its shape, its effective gradient or head loss, and the roughness of the canal sides. The most commonly used formula incorporating all these factors is the manning equation: $V = \frac{1}{n} R^{\frac{2}{3}} S^{\frac{1}{2}}$

Where: V = water velocity in the canal;
n = roughness coefficient of the canal sides;
R = hydraulic radius of the canal;
S = effective bed slope

Selecting the Bed Slope for a Canal
The longitudinal bottom slope of earthen canals determines the magnitude of risk of damage by erosion. The longitudinal bed slope can be nil (horizontal canals) or at the most kept to minimum value of 0.05 percent or 5cm per l00m; in steeper areas, the bed slope should be limited to 0.1 to 0.2 percent (10 to 20cm per 100m) to avoid water flowing too fast along the canals and eroding them.

UNEP (1983) stated that the slope of the canals is less than that of the river, so that water can be supplied to the reservoir by gravity and tidal energy. If this is the case, the results is that the velocity of water in the canal is less than that in the river and silt carried by the flood water gets deposited in the initial length of the canal. It is common to see that the bed level of canal has risen at the end of the flooding (rainy) season due to the phenomenon of siltation (Leton and Uzukwu, 2011) Uzukwu and Leton 2011. A canal regulator (sluice gate) is often necessary to controI flow in the canal and is usually provided at 5 to 6m from the river.

Silt removal is an annual necessity (UNEP, and Ansa et al. (2011) stated that for sustainable management inundation canals, 1983). In lined canals, like those built of bricks or concrete, the bed slope may be greater than 0.2 percent as there is less risk of damage by erosion.

It is usual to assume, in simple cases, that the bed of the canal will slope downstream. Water normally will flow in canals as long as the level is higher at the upstream end than the downstream end. If a canal has a horizontal floor, the gradient can be taken as the difference in head between upstream and down stream. The greater the slope, the greater the flow. Table 1 can be used to select canal bed slopes for various water depths, flow velocities and soil types.

Selecting the Side Slope for a Trapezoidal Canal
The slope of the sides of a trapezoidal canal is usually expressed as a ratio, for example 2:1. This ratio is defined as the change in horizontal distance per metre of vertical distance. The side slope can also be expressed in terms of the angle it makes with vertical, in degrees and minutes.

The slope of the sides to be selected for an earthen trapezoidal canal is related to the type of soil in which canal is constructed (Coche and Muir, 1992). 'The more stable the soil materials, the steeper the slope of the sides can be. According to Dela Cruz (1983) if the canal is lined, the slope of the sides varies according to the types of lining materials used e.g. 1:1 for stone; 0.5:1 for tough hardpan. The selection of side slope is also made with rc1rcnce to the canal bed width and depth (Table 2 and 3).

Velocity of Canal Flow
In open canals, water velocity varies with depth and with distance from the sides of the canal. Close to the bottom and next to the edges, the water flows less rapidly. According to Dela Cruz (1983) the velocity of water in canals should be designed properly to avoid soil erosion and siltation of the canal bed Usually the average velocity of water across the entire cross- section is used for design purposes (Coche and Muir, I 992). They further stated that the velocity of canal flow selected should he related to the type of soil (Tables 4 and 5) and that in, most soils, design velocity of canal flow 9hld not be lower than O.3m/sec. to avoid sitting. The usual velocities of f1ow in a canal are within 0.5 to 0.7m/sec (Dela Cruz, l983; Uzukwu, 2010).

The Hydraulic Radius
The hydraulic radius, R (m) is the ratio of the wetted cross-section area A (m^2) to the wetted perimeter, P (m). It is often used to define the shape of the canal. Knowing the bottom width, b (m) of the canal, the maximum water depth, h (m) and the side ratio (Z:1), the hydraulic radius is easily computed. The wetted perimeter is the length of the perimeter of the cross-section actually in contact with water, not including the water top wêidth, B which is the distance across the water surface.

Coefficient of Roughness
The coefficient of roughness, n expresses the resistance to water flow created by the canal sides and the bottom substrates. The greater the value of n, the greater the roughness of the canal walls, and the more difficult it is for water to flow through the canal.

The values of the coefficient of roughness under various conditions have been summarized by Coche and Muir (1992). The value of 0.0225 is often used for new earthen canals (Veroli, 1985). Table 6 can be used to select appropriate values of n for various conditions of earthen canals.

Carrying Capacity of Open Canals
The carrying capacity of any open water canal with a uniform steady flow may be calculated using the manning equation in the form:

$$Q, \frac{A}{n} R^{\frac{2}{3}} S^{\frac{1}{2}} m^3 / S$$

Where: A = wetted cross-section area of the canal, m^2
R = hydraulic radius, m;
S = longitudinal slope of canal
n = roughness coefficient

According to Veroli (1985), the solution of manning equation introduces a "K" values as: $Q = \frac{K}{n} xh^{\frac{8}{3}} xs^{\frac{1}{2}}$

Where: K = discharge factor, and for trapezoidal canals,

$$K = \frac{\left(\frac{1}{X} + Z\right)^{5/3}}{\left(\frac{1}{X} + Z + Z^2\right)^{2/3}}$$

Where: X = h/b, ratio of depth of water to bottom width of canal
Z = the horizontal value of canal side slope.

Values of K corresponding to b/h values for common side slopes used in practice are presented in Table 7. Manning's formula indicates that the cross section of greatest hydraulic efficiency is the one that fir a given shape and area, has the maximum carrying capacity, Q and therefore the shortest wetted perimeter. For a trapezoidal cross section, the bed width, h can be computed using the following formula:

$$b = 2h\left[\left(1+Z^2\right)^{\frac{1}{2}} - Z\right]$$

However, Table 3 gives the values of bed width, b corresponding to depth h, and horizontal value of side slope, Z for common canals.

ENVIRONMENTAL DATA REQUIREMENTS

Before attempting to design a canal, data on the natural characteristics of the project site should be available. Such data include:

I. The topographic map of the affected area. This is needed to determine the natural gradient (slope) of the site towards the river or valley.
2. The ground profile of the proposed canal centre line. This is required to compute the amount of earthwork for the canal.
3. Tidal water levels in spring and neap tides during rainy and dry seasons. This is needed to determine the critical water level during the peak dry season, thus ensuring that the canal supplies adequately during the critical period.
4. Tidal range of the river. This information is necessary to ensure that the elevation of canal bed is higher than the minimum water level in river during ebbtides. This in turn ensures that canal is completely drained during low water slacks. Otherwise canal and ponds can only be partially drained.
5. Soil type and properties. This is needed to spcci1' the canal side slopes and bed slopes that would minimize canal wall instability, erosion and siltation.
6. Records of river flow velocity. These data give an idea for specifying the canal bed slopes that will minimize scouring and siltation phenomena in the canal. Silt removal in canals is already known to be an annual necessity (UNEP, 1983).
7. Water quality parameters of the river. This establishes baseline data for conventional and critical pollutants in the river, such as clay and silt loading (Ansa *et al.,* 2011; Leton and Uzukwu, 2011).

PROCEDURE FOR DESIGNING TRAPEZOIDAL CANALS USING TABLES

1. Determine the desired discharge, Q (m3/s). This is based on water supply needs for filling the ponds initially and to meet water losses due to evaporation, seepage, leakage and management (draining and filling).
2. Determine the desired water depth, in the canal from Table 3.
3. Take the canal side slope from table 2, and the value of the bed width, b from Table 3, Note that b should be equal or more than the width of the main control sluice gate.
4. Compute the ratio b to h and pick up the k values from Table 7 corresponding to b/h and the canal bed slopes.
5. Determine the bed slope, S from Table I for the desired velocity, V depending on soil type as determined by table 5.
6. Determine the coefficient of roughness, n from Table 6
7. Calculate the discharge, Q using the formula:

$$Q = \frac{K}{n} h^{\frac{8}{3}} S^{\frac{1}{2}} (m^3/s).$$

8. Compare result of (7) with Q value in 1. If there is a significant difference, review the process using iteration until both values converge.

SUMMARY
It summarizes environmental data requirements, procedure, for design and design tables pertinent for designing inundation canals.

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Table 1 Values of bed slope, S of canals

Depth, h (m)	Velocity (m/s)			
	Fine sand	Silt	Loam	Clay
0.50	V = 0.76	0.91	1.06	1.52
0.75	0.001242	0.001780	0.002515	0.002415
1.00	0.00722	0.001036	0.001405	0.002891
1.25	0.000492	0.000706	0.000958	0.001971
1.50	0.000366	0.000525	0.000712	0.001465
1.75	0.000287	0.000412	0.000559	0.001150
2.00	0.000234	0.000335	0.000455	0.000937
2.25	0.000196	0.00281	0.00381	0.00784
2.75	0.00128	0.000209	0.000283	0.000582
3.00	0.000128	0.000184	0.000249	0.000513
	0.000114	0.000163	0.000222	0.000457

Source: Veroli (1985).

Table 2: Side Slopes For trapezoidal Canals in various Soils

Types of soil or lining material	Side slopes	
Fine-grained silt	3:1	$18^{o}20^{1}$
Silty clay	2:1	$26^{o}30^{1}$
Sand, gravel and clay	1.5:1	$33^{o}40^{1}$
Stiff clay or stone lining	1:1 to 1.5:1	45^{o} to $33^{o}40^{1}$
Rock	1:2	$63^{o}30^{1}$
Tough hard pan	0.5:1	$63^{o}30^{1}$

Source: Coche and Muir (1992).

Table 3: Values of Bed Width, b of Cabals

Depth of Water, h (m)	SIDE SLOPE			
	1:1	1.75:1	1.5:1	2:1
0.05	0.414	0.265	0.302	0.236
0.75	0.621	0.397	0.453	0.354
1.00	0.828	0.530	0.604	0.472
1.25	1.035	0.622	0.755	0.590
1.50	1.242	0.795	0.906	0.708
1.75	1.449	0.927	1.057	0.826
2.00	1.656	1.060	1.208	0.944
2.25	1.863	1.192	1.359	2.062
2.50	2.070	1.325	1.510	1.180
2.75	2.277	1.457	2.661	1.298
3.00	2.484	1.590	1.812	1.416

Source: Veroli (1985)

Table 4: Maximum Permissible Average Velocities of Water in Canals and Flumes

TYPE OF SOIL OR LINING	MAX. PERMISSIBLE AVERAGE VELOCITY (M/S)
UNLINED CANALS	
Soft clay or very fine clay	0.2
Very fine or very light pure sand	0.3
Very light loose sand or silt	0.4
Coarse sand or light sandy soil	0.5
Average sandy or good loam	0.7
Sandy loam, small gravel	0.8
Average loam or alluvial soil	0.9
Firm loam, clay loam	1.0
Firm gravel or clay	1.1
Stiff clay soil, ordinary gravel soil, or clay and gravel	
Broken stone clay	1.4
Coarse gravel, cobbles, shale	1.5
Conglomerates, cemented gravel, soft slate	1.8
Soft rock, rocks in layer, tough hard pan	2.0
Hard rock	2.4
	4.0
LINED CANALS	
Cast-in-place cement concrete	2.5
Precast cement concrete	2.0
Stones	1.6 – 1.8
Cement Blocks	1.6
Bricks	1.4 – 1.6
Buried plastic membrane	0.6 – 0.9
FLUMES	
Concrete or smooth metal	1.5 – 2.0
Corrugated metal	1.2 – 1.8
Wood	0.9 – 1.5

Source: Coche and Muir (1992).

Table 5: Permissible Canal Velocities for Different Soil Types (SUMMARIZED)

SOIL TYPE	VELOCITY (m/s)
Fine sand	0.46 – 0.76
Silt	0.61 – 0.91
Loam	0.76 – 1.06
Clay	1.4 – 1.25

Source: Veroli (1985)

Table 6: Coefficient of Roughness (Manning) for Open Canals and Flumes

CONDITIONS OF WATER FLOW	n	$1/n$
EARTHEN CANAL, UNLINED		
Clean and smooth earth, recently completed	0.017	58.82
Little curving, in solid loam or clay, with silt deposits, free from growth, in average condition	0.025	40.00
Short grass, few weeds	0.024	41.67
Dense weeds in deep water	0.032	31.25
Irregular soil with stones	0.035	28.57
Badly maintained, dense weeds through flow depth	0.040	25.00
Clean bottom, brush on-side	0.070	14.29
LINED CANALS	0.020	50.00
Concrete bricks	0.015	66.67
Concrete, cast, unfinished, rough	0.013	76.92
Concrete, trowel finished, smooth	0.015	66.67
Brick, carefully built walls	0.013	76.92
Boards, with algae/moss growth	0.015	66.67
Boards, quite straight, no growth	0.013	76.91
Boards, well planed and fitted	0.011	90.91
Plastic buried membrane	0.027	37.04
FLUMES/GUTTERS/AQUEDUCTS		
Concrete	0.012	83.33
Metal, smooth	0.015	66.67
Metal, corrugated	0.021	47.62
Wood an bamboo (smooth	0.014	71.43

Source: Coche and Muir (1992).

Table 7: K values (Discharge factor)

(b/h) Ratio	SIDE SLOPES		
	1:1	1.5:1	2:1
0.20	5.026	5.390	5.720
0.21	4.798	5.161	5.491
0.22	4.589	4.952	5.282
0.23	4.401	4.764	5.094
0.24	4.226	4.589	4.925
0.25	4.064	4.427	4.764
0.26	3.916	4.286	4.623
0.27	3.781	4.152	4.488
0.28	3.654	4.024	4.360
0.29	3.532	3.090	4.246
0.30	3.425	3.694	4.138
0.31	3.324	3.694	4.037
0.32	3.230	3.600	3.943
0.33	3.142	3.512	3.855
0.34	3.055	3.425	3.768
0.35	2.981	3.351	3.694
0.36	2.907	3.277	3.620
0.37	2.833	3.203	3.546
0.38	2.765	3.135	3.479
0.39	2.705	3.075	3.418
0.40	2.644	3.014	3.358
0.41	2.590	3.960	3.304
0.42	2.537	2.907	3.250
0.43	2.483	2.853	3.196

			Contd...
0.44	2.424	2.806	3.149
0.45	2.388	2.759	3.103
0.46	2.341	2.718	3.061
0.47	2.301	2.671	3.021
0.48	2.261	2.631	2.974
0.49	2.220	2.592	2.942
0.50	2.187	2.550	3.021
0.51	2.146	2.523	2.974
0.52	2.113	2.489	2.940
0.53	2.076	2.456	2.900
0.54	2.052	2.422	2.866
0.55	2.081	2.388	2.833
0.56	1.991	2.362	2.799
0.57	1.958	2.335	2.765
0.58	1.931	2.308	2.738
0.59	1.904	2.281	2.705
0.60	1.884	2.254	2.678

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