ENGINEERING ASPECTS OF OPERATIONAL FRESHWATER FISH FARMS OF RAIGAD, MAHARASHTRA

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(Maharashtra State, India)

DECEMBER, 2018

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THESIS

Submitted to the

Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli

in partial fulfilment of the requirements

for the degree of

MASTER OF FISHERIES SCIENCE

IN

FISHERIES ENGINEERING AND TECHNOLOGY

BY

GURUDEV BUDHYA CHIBHADE
B. F. Sc.

Under the guidance of

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Assistance Professor,
Department of Fisheries Engineering,
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With regard to the thesis entitled, **'Engineering aspects of operational freshwater fish farms of Raigad, Maharashtra'** submitted by **Mr. Gurudev Budhya Chibhade** for the degree of this university**.**

I certify that :

1. He has carried out the research work under my direct supervision and guidance during the academic year 2017-2018 and that the manuscript of the dissertation has been scrutinized by me.

2. The entire thesis comprises the candidate's own work and it is his own achievement. It has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of recognition.

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4. He has completed his research work to my entire satisfaction.

5. The final typed copy of the thesis, which is being submitted to the University office, has been carefully read by me for its material and languages and it is to my entire satisfaction.

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Date:

Place: Ratnagiri.

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part of thereof has not been submitted by me or other person to any other University or Institute for a Degree or Diploma.

Date:
Place: Ratnagiri. **(GURUDEV BUDHYA CHIBHADE)**

Dedicated

To My

Parents, Brothers, Sister, Friends

And

Teachers

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(Gurudev B. Chibhade)

LIST OF ABBREVIATIONS

ABBREVIATIONS	FULL NAME
APHA	: American Public Health Association
AWWA	: American Water Works Association
ATMA	: Agricultural Technology Management Agency
BFDAs	: Brackish water Fish Farms Development Agencies
BIS	: Bureau of Indian Standards
CAA	: Coastal Aquaculture Authority
CIFA	: Central Institute of Freshwater Aquaculture
DO	: Dissolved Oxygen
EC	: Electric Conductivity
FFDAs	: Freshwater Fish Farmers Development Agencies
FRP	: Fibre-reinforced plastic
GOC	: Ground-nut Oil Cake
H : V	: Horizontal : Vertical
HDPE	: High Density Polyethylene
HP	: Hours Power
ID	: Inner diameter
IS	: Indian Standards
ISSCFG	: International Standard Statistical Classification of Fishing Gear
KVKs	: Krishi Vigyan Kendras
MPEDA	: Marine Product Export Development Authority
MSEB	: Maharashtra State Electricity Board
NABARD	: National Bank for Agriculture and Rural Development
NACA	: Network of Aquaculture Centres in Asia
NBFGR	: National Bureau of Fish Genetic Resources
NFDB	: National Fisheries Development Board

NSPFS	: National Special Programme for Food Security
PA	: Polyamide
PP	: Polypropylene
PVC	: Poly-vinyl Chloride
RCC	: Reinforce Cement Concrete
SAE	: Standard Aerator Efficiency
SIFT	: State Institute of Fishery Technology
SOTR	: Standard Oxygen Transfer rate
SSP	: Single Super Phosphate
VRL	: Very High Rainfall Lateritic soil zone
VRNL	: Very High Rainfall Non Lateritic soil zone
WPCF	: Water Pollution Control Federation

ABSTRACT

Present study was undertaken to investigate the engineering aspect of operational freshwater fish farms of Raigad district, Maharashtra, India. For this study, Raigad district was divided into three Regions namely North, Central and South. Various type of aquaculture systems, types of pond and engineering aspect of aquafarm were studied. In Raigad district, twenty-eight freshwater fish farms were observed to be operational during the study period, comprising of 18 small farms, 6 medium farms and 4 large size farms. In North Raigad Region, medium size farms and South Raigad Region, large size farms were not reported during study period.

It was observed that operational freshwater fish farms were located near the leading canal, open well, tube well, reservoir, dam, and rivers with good water source. Topography of observed farms was plain, marginally slope and hilly areas. The recorded shape of the ponds was rectangular, square and even irregular. Water supply system was constructed with various materials such as PVC, HDPE, Rubber, HDPE Flexible and Galvanized iron. Wood and RCC structure was adapted for construction of the pond sluice and main sluice gates of the farm. Cast net used for sampling/partial harvesting and dragnet was used for complete harvesting of the pond. HDPE lining was recorded on two fish farms to prevent seepage loss. Basic equipment like weighing balance was used for weighing lime, feed, ingredients, fishes etc. on all farms. Essential electric power supply was availed for all farms from MSEB around the Raigad district. For source of alternating power supply Diesel generator was adapted in the three regions, while use of solar power system were observed in addition to generator on one farm from North Raigad Region. Approach road and farm stead facility was observed on 27 farms. Fish processing facility only

reported in North Raigad Region. Pump aeration system was erected on single farm from Central Raigad Region.

Raigad district operational freshwater fish farms area and water spread area was ranged from 0.10 to 22.25 ha and 0.05 to 4.30 ha; respectively. Top width of leading canal was observed to be range of 1 to 6 m, bottom width 1 to 4 m and depth 1 to 2 m. The length, width and water depth of the ponds was observed from 8 to 143 m, 4 to 91 m and 1 to 5 m; respectively. The range of pond area, water spread area of cultured ponds and bottom slope was observed from 0.001 to 6.84 ha, 0.001 to 3.61 ha and 1000:0.6 to 1000:5; respectively. The top width, side slope, free board and total height of peripheral dike was ranged from 0.3 to 5 m, 2:0.6 to 10:5 m, 0.3 to 1.2 m and 1.3 to 6 m; respectively. The top width of partition dike ranged from 0.3 to 5 m, side slope 2:0.6 to 10:5 m, free board 0.3 to 1.2 m and total height of partition dike ranged from 1.3 to 6 m. The dimensions of drainage canal were recorded; top width, bottom width, depth and bottom slope ranged from 1.5 to 2 m, 0.8 to 1.2 m, 0.9 to 1.5 m and 1000:1; respectively. Top width of the drainage canal dike and free board was ranges from 0.3 to 0.5 m and 1 to 1.3 m; respectively. The length of catwalk was ranged from 1.5 to 15 m, width 0.4 to 0.5 m, height from pond bottom of the catwalk was 2 to 3.5 m; respectively. The demand feeder length 0.3 m, width 0.3 m, height 0.45 m; respectively. The dimensions of the feeder canal top width, bottom width and depth were ranged from 0.5 to 1.5 m, 0.3 to 0.8 m and 0.5 to 1 m; respectively. Length of sluice gate was 2 to 5 m, height 1 to 2 m and width 1 m. The sluice gate of the ponds width was 1 m, and height 1 to 3 m. For water supply system, pipes dimeter and wall thickness were ranged from 16.15 to 140.45 mm and 2.15 to 5 mm; respectively.

The range of soil parameters recorded from Raigad district were, pH 6.1 to 8, water holding capacity 50.53 to 72.03 %, conductivity 1.25 to 3.55 dS/m, moisture 9 to 16 %, bulk density 1.2 to 1.29 g/cm^3 and water parameters namely salinity 3 to 6 PSU, temperature 27 to 30^0C, pH 7.4 to 8, dissolved oxygen 4 to 5.6 mg/l, ammonia 0.02 mg/l, total alkalinity 100 to 140 mg/l, total hardness 70 to 140 mg/l and transparency were found from 30 to 45 cm. Minor seepage rate of 2 to 7 cm/day was noticed during sampled freshwater fish farms.

It was concluded that, in Raigad district majority of the farms are semi-intensive types and most of the parameters like site selection, design and engineering aspects as well as soil and water parameters were found within the ideal limit described by many researchers across the India, with some minor variations. All these fish farms form an important asset for excellent future development of sustainable aquaculture in the studied region, thus forming a backbone, contributing to the livelihood of fish farmers.

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EC	: Electric Conductivity
FFDAs	: Freshwater Fish Farmers Development Agencies
FRP	: Fibre-reinforced plastic
GOC	: Ground-nut Oil Cake
H : V	: Horizontal : Vertical
HDPE	: High Density Polyethylene
HP	: Hours Power
ID	: Inner diameter
IS	: Indian Standards
ISSCFG	: International Standard Statistical Classification of Fishing Gear
KVKs	: Krishi Vigyan Kendras
MPEDA	: Marine Product Export Development Authority
MSEB	: Maharashtra State Electricity Board

NABARD	: National Bank for Agriculture and Rural Development
NACA	: Network of Aquaculture Centres in Asia
NBFGR	: National Bureau of Fish Genetic Resources
NFDB	: National Fisheries Development Board
NSPFS	: National Special Programme for Food Security
PA	: Polyamide
PP	: Polypropylene
PVC	: Poly-vinyl Chloride
RCC	: Reinforce Cement Concrete
S	: Small size farms
M	: Medium size farms
L	: Large size farms
SAE	: Standard Aerator Efficiency
SIFT	: State Institute of Fishery Technology
SOTR	: Standard Oxygen Transfer rate
SSP	: Single Super Phosphate
VRL	: Very High Rainfall Lateritic soil zone
VRNL	: Very High Rainfall Non Lateritic soil zone

1.0 INTRODUCTION

Aquaculture engineering is the application of engineering principles and procedures to fisheries and to the culture of aquatic organisms with evolved a wide range of engineering technologies in aquaculture. It deals with the important content to modernise or improve aquaculture for augmenting its production effectively by proper survey, location of suitable sites, design of aquaculture farm, water intake system, construction and maintenance of fish farm selection and design of major equipment such as pumps, aerators, feeders cannel, feed plant, effluent treatment plant and other mechanical and electrical equipment and to update modern technique available or applicable in the field of aquaculture and aquaculture engineering (MPEDA, 1997).

Aquaculture engineering programmes require integration of aquaculture science with the engineering aspects like civil, chemical and mechanical. A wide range of engineering technologies now find application in aquaculture. Application of civil engineering techniques could improve the designs of many aquaculture facilities and such engineering techniques require to be documented and propagated.

The demand for aquaculture has increased tremendously in recent years. Aquaculture engineering is concerned with the design and development of effective aquaculture systems for marine and freshwater fish culture. Aquaculture engineering are one of the most technically important subject matter for designing effective fish ponds. Ponds are now serving a variety of purposes, including fish culture, shrimp culture, crab culture, aquaponics and concern hatchery to increase fish production to strengthen the fisheries field. Aquaculture is concerned with propagation and rearing of aquatic organisms under complete human control. Now aquaculture production is increasing worldwide and it is expected from new fish farm designs and that activities

will be expanding significantly in the near future as practices are further improved and diversified. Aquafarming is the fastest growing animal-based food producing sector particularly in India. Aquaculture engineering is an industry in its early development stages for fish culture showing that the continent has not utilized its immense fish farming potential. It continues to grow at a rapid pace with understanding the engineering behind aquatic production facilities is of increasing importance for all those working in the industry. It requires knowledge of the many general aspects of engineering such as material technology, building design and construction, mechanical engineering, and environmental engineering.

The application of engineering in aquaculture starts right from the initial stage of selection of sites for construction of aquaculture facilities, design and construction, water management, maintenance of the facilities and goes up to the end of the activities of the aquaculture industry, i.e., harvesting, transportation and marketing including the postharvest technology. Aquaculture engineering programmes require integration of aquaculture science with the engineering disciplines such as civil, chemical, mechanical and agricultural engineering and naval architecture. Aquaculture engineering deals with the engineering principles related to aquaculture, economical layout and design, use of modern equipment such as high discharge pumps, aerators, water testing kits, blowers, etc. have been worked out by the Aquaculture Engineering (Mukharjee, 2003).

In India various water resources are available rivers, canals, reservoirs, lakes, swamp area and other water bodies which is immense various scopes for development of fisheries to strengthen the food security, which create employment opportunities to earn foreign exchange. The Government of India declaring the centrally sponsored scheme for building a new fish farm in every new plan of government for

“Development of Inland Fisheries and Aquaculture” underneath macro-management approach in States and Union Territories. The components approved under the scheme are development of freshwater aquaculture, development of brackish water aquaculture, cold water fisheries and aquaculture, development of waterlogged areas, productive utilization of inland saline and alkaline soils for aquaculture, integrated development of inland capture resources i.e reservoirs/rivers and this major component are to be implemented by various agency FFDAs, BFDAs, NFDB and fisheries department of the States and Union Territories. The schemes are available for self-help Groups, Women Groups and Fisheries Co-operative Societies, etc.

Some of the fisheries related departments, authority, institution and private limited fish feed companies have also played a major role for the development of Inland fisheries and Aquaculture Industry such as State Fisheries Department, CIFA, CIFRI, National Research Centre on Cold Water Fisheries, CAA, MPEDA, NBFGR, SIFT, NABARD, KVKs and ATMA also doing major role to develop fisheries sector.

Raigad district is one of the coastal districts situated along the west coast of the State Maharashtra and is located between North latitude 17°51’00” and 19°08’00” and East longitudes 72°50’00” and 73°40’00”. The district covers geographical area is 7152 sq. km and cultivable area is 3286 sq. km has been divided into four revenue division’s viz., Alibag, Panvel, Mahad and Mangaon which are further divided into fourteen talukas viz., Alibag, Panvel, Uran, Karjat, Khalapur, Pen, Sudhagad, Mahad, Roha, Mangaon, Poladpur, Mahasala, Shriwardhan and Murud. Freshwater resource available for Raigad district from Ulhas, Panvel and Patalganga are the three main rivers in northern part. Main river in central part Kundalika river whereas Savitri river is the southern part of the main river. (Gupta, 2013).

The success of the business is depending on the selection of a good site for aquafarm, layout and the adopted farm management practice. In the world major part of fish culture production depends on the use of freshwater ponds which hold and exchange water, receive fertilizer or feed, and allow for holding, rearing and harvesting of fish. The proper preparation and construction of such ponds and their associated structures are essential for successful fish farming. Good ponds should be inexpensive to construct, easy to maintain and efficient in allowing good water and fish management. Physical, chemical and good characteristics of soil is one of the most important factor which must be considered for successful freshwater fish culture. Soil that is needed for the construction of ponds, a water supply, canals, reservoirs, barrages, small dams, and for the efficient management of fish ponds.

Freshwater fish farm requires some essential equipment and facilities which are used for various purposes. On the fish farm machineries, gear and techniques may be used for maintenance and repairs, harvesting the crop, monitoring and maintaining of water quality, excluding predators and pests, and other miscellaneous facilities for maximizing the use of various inputs.

Freshwater aquaculture surveys are essential to determine natural accessibility to site and to determine the type of services available, especially power and water supply as these factors should also be taken into consideration in selection of sites suitable for development of aquaculture facilities. The success of fishpond operations depends not only on the general site suitability for fish production as well as various engineering inputs of the aquafarm. Site selection not only involves the determination of desirable physical, chemical and biological factors but also important in providing valuable information in the preparation of the overall design and layout of the facility, engineering modifications to be made and the choice of management practices

appropriate for the given site. Hydrological studies are carried out for selected major streams within the site to determine the magnitude of flows. Hydrological events and the effects of high and low flows will be essential for the assessment of water quality.

Proper selection of a site is probably the most important factor in the success of a fish farm. The quality of soil influences both productivity and water quality in a pond. However, it must also be suitable for dike construction (Carballo *et al.*, 2008).

Considering the importance of all the above mentioned aspects the present study was undertaken with the following objectives: -

1) To study the layout, design and engineering aspects of operational freshwater fish farms of Raigad district of Maharashtra.

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2.0 REVIEW OF LITERATURE

2.1 Engineering Aspects:

This chapter is a review of current and past engineering status of various freshwater aquafarms at national and international level. It describes layout, design and various engineering aspects adopted by freshwater aquafarmers. Previous work on adaptation of farms w.r.t. economic consideration different types of farms extensive, semi-intensive and intensive along with their results are also reviewed. The selection of a suitable site is great importance to fish pond development. Basic data is required on vegetation, topography, rainfall, occurrence of floods, weather condition, availability of farm inputs, type and characteristics of soil and water supply etc. for getting successful production. Freshwater farms production depends on the systems of aquaculture and various types of ponds, design and layout of farms.

The present investigation aims to study the layout, design and engineering aspects of operational freshwater fish farms of Raigad district, Maharashtra which helps to generate base line data for the soil and water 'Health Cards' of freshwater fish farms of Raigad district Maharashtra.

Kepenyes (1984) studied the design of pumping stations, the pump well for the inlet pipe should be furnished with a grid of 20 mm mesh in case of smaller pumps and with a grid of 20 to 50 mm mesh in case of pumps with capacity higher than 1 000 l/sec. Characters of pump setting w.r.t permanently and mobile, permanently set pump station should be used if, pumping delivery is extremely high, annual utilization of the pump station is high (close to 600 hrs), high operational safety is needed. Mobile pump station should be used if pump is occasional and the utilization is less than 200 hrs annually, the location of pumping is not permanent.

Upadhyay (1994) reported that the pumping station or other intake structure of aquafarm. Usually PVC or HDPE pipe network is used when flow is under pressure and in that condition flow is regulated by means of valve. Use of water network is however, limited to small farms. In case of large farms where high flow rate is required, the cheapest way to convey the water is through gravity. Open channels are therefore used as feeder channels for supply of water into the ponds of a large farms. Feeder cannel free board ranged from 0.05 to 0.25 m and depth of water approximately ranged from 0.2 to 0.8 m are the suitable values for feeder canal. The bottom slope of channel mainly depends upon the topography and energy head required for the flow of water. Drainage canal side slopes are determined by the soil texture and stability recommended side slope accordance with concrete lining ½: 1 to 1:1, earth with stone lining 1:1, firm clay $1^{1/2}$:1, loose sandy earth 2;1, sandy loam 3:1. For smaller drainage canal of bottom width of 1.2 m or less. Main gate size of each opening being usually 1 to 1.2 m in width for easy handling. Grooves are made for fixing screen, flash board of the main supply gate are provided with 4 grooves and 2 at each sides. Catwalks or walking platforms are provided between the two side walls and its made of RCC slabs or wooden planks. Screen made of high density polyethylene or nylon meshes are attached to a wooden rectangular frame which fits into the two outer grooves of the gate-one at channel side and the other towards the water source. Wooden plank of size 5 cm thick and 30 cm wide inserted into the remaining two grooves of the main gate. The size for a 1 ha pond inlet gate should not be less than 30 cm of the pipe diameter. Monk sluices are made of RCC walls and hume pipe. Monk type sluice gate constructed in various shapes such as T-shape, Y-shape, Square shape, U-shape, and V-shaped. The size of hume pipe in the pond outlet

gate should not be less than 50 to 60 cm for a 1 ha pond. Simple and cheapest design of pond outlet structure made in PVC pipes and fittings.

Coche and Muir (1995) classified the various type of ponds such as spring-water ponds, seepage ponds, rain water source ponds, fed directly, fed indirectly, pump-fed ponds, undrainable ponds, drainable ponds, pump-drained ponds, earthen ponds, walled ponds, stone pitching ponds, lining ponds, excavated ponds, embankment ponds, contour pond, spawning ponds, nursery ponds, grow-out pond, brood ponds, storage ponds, fattening ponds, drying season ponds, wintering ponds, sunken pond, barrage ponds, diversion ponds, square shaped ponds, rectangle shaped ponds and irregular shaped ponds.

Coche and Muir (1996) said that the mechanical aerators efficiency is expressed as kilogram (kg) of oxygen transferred per kilowatt-hour (kWh) of energy applied. Capacity is usually expressed as kg of oxygen transferred per hour. It varies with the size and power of mechanical aerator and its range from 0.5 to 5 kg/h. Mechanical aerators capacity is expressed at least 5 kg/h per hectare of pond, corresponding to an increase of DO concentration of about 0.5 mg/l per hour. At a typical efficiency of 1 kg/kWh, this increase would require 5kW (about 6.7 HP) of applied power per hectare. Paddle-wheel aerators are a float-mounted motor drives a horizontal axle on which is fitted at each end a vertical paddle-wheel, set about one-fourth to one-third of its diameter down into the water. The blades of the paddle-wheel are usually slightly scooped or angled and are perforated. The paddle-wheels rotate in the water, scooping, lifting and splashing the water out across the surface. They are typically 0.5 to 2 kW in size. Paddle- wheel aerators can also be set up using power from a tractor, via a propeller shaft.

Chandrakant (2003) specified engineering standards required a top width in between 4 m to 4.5 m high. Dikes range from 4.5 to 6 m require a minimum top width of 3.7 m. A minimum free board of 0.6 m is required for peripheral dike whereas a minimum of 0.3 m free board is required for partition dikes. For fishes 1.2 m to 1.5 m water depth required whereas ideal rectangular ponds the ratio of length and breadth should be ranged from 1.5: 1 to 2: 1 (L: B). NSPFS (2005) stated that the harvesting of fish can be started as soon as fish reach table size or when the water in the pond falls below 0.5 m. can always harvest for family consumption or at one time for marketing, preferably during festival period and by partial cropping 2 to 3 time (75 to 100 kg) of fish could be harvested from a 500 m^2 period in 5 to 6 months.

Pillay and Kutty (2005) reported that selection of suitable sites will depend on the culture system to be adopted, they are some which affect all systems, such as agro climatic conditions, access to markets, suitable communications, protection from natural disasters, availability of skilled and unskilled labour, public utilities security, etc. All available meteorological and hydrological information about the area. Such as range and mean monthly air temperature, rainfall, evaporation, sunshine, speed and direction of winds, floods, water table, etc., have to be examined to assess their suitability. In land-based aquaculture, the most commonly used installations are pond farms and hatcheries. Since most such farms have earthen ponds, soil characteristics, the quality and quantity of available water and the ease of filling and drainage, especially by gravity. For fresh-water pond farms land available consists mainly of swamps, unproductive agricultural land, valleys, stream and river beds exposed due to changes of water flow, etc. Sandy clay to clayey loam soils are considered suitable for pond construction.

Ayyapan (2006) suggested nursery face refer to rearing of 3 to 4 days old prawn (5 to 6 mm) in nursery pond for 15 to 20 days till they grow to fry stage. Smaller seasonal ponds ranged from 0.02 to 0.1 ha with average water depth ranged from 1.0 to 1.5 m are preferred for carp nursery and easy to manage. Concrete tank of 50 to 100 m^2 provided with a soil base ranged from 15 to 20 cm are found effective for rising multiple crops with minimum management. The water pH ranged from 6.5 to 7.0 is considered productive. Fry of carp measuring ranged from 20 to 25 mm are rear further fore 2 to 3 months to fingerlings in relatively larger ponds ranged from 0.05 to 0.2 ha with 1.2 to 1.5 m water depth. In earthen rearing ponds, usual stocking density followed ranged from 0.2 to 0.3 million fry/ha. The evaporation and seepage losses in pond are periodically compensated so as to maintain water depth ranged from 1.2 to 1.5 m gro-out culture of carp carried out in earthen ponds ranging from 0.04 to 10.0 ha and 1 to 4 min depth in different regions of the country and ponds ranged from 0.4 to 1.0 ha size with water depth of 2 to 3 m are considered ideal.

Carballo *et al.* (2008) recommended square and rectangular shaped ponds are best and easiest to build. An area of 0.03 ha is a good size for a family pond, which you can build without the use of machinery putting a fence around the pond will protect children from falling into the pond and it can help to keep out thieves and predatory animals. To make a low cost and sturdy fence, plant a thick hedge around the edge of the pond or build a fence using poles and thorn branches.

Anon (2008) indicated the standard classification of farmer categories based on the total land holding in hectares. The categories are small farmer (≤ 2 ha), medium farmer (> 2 ha and ≤ 5 ha) and large farmer (> 5 ha). ISSCFG (1980) stated that international standard statistical classification of fishing gear such as seine nets

(SX), cast nets (FCN), miscellaneous gear (MIS), gear not know or not specified (NK).

Gitte *et al.* (2013) studied the nursery rearing of carp seed a successful venture by a farmer of Roha village at Raigad district and reported production of major carp is carried out in small earthen ponds of 0.02 to 0.10 ha with depth of 1.0 to 1.5m and also area used up to 0.5 ha for large scale fry production. The total area of the farm was 0.85 ha with soil pH range from 6.5 to 7.0.

Raman and Gajera (2014) reported that the total land area 0.25% (64.22 ha) of Pune city are optimum aqua sites with availability of market and better network connections. Pune has fresh water sources that leads to vast production of fishes and will also contribute profits for aqua farmers. Rivers channels and road networks analysis is the two important factors for selecting the aqua sites. For finding suitable sites for the aquaculture we consider certain standard parameters i.e. Pond shape and size, water resources nearby aquaculture site, best suited road networking from aquaculture site to market, good soil (Clay soil) and suitable water quality that more appropriate to sustain and better yields.

Broaddus (2015) recorded slope stability results are dependent upon the results of the seepage model, therefore, it will be necessary to improve seepage model prior to developing a slope stability model. In SLOPE/W models, the major component that must be considered when analyzing the results is the lowest factor of safety computed for slope stability. Typically, a factor of safety of 1.5 is an acceptable value for stability application. A computed factor of safety of 1.5 can be acceptable for certain cases, however, that depends on how well the soil and seepage conditions are understood. If you do not have a good understanding of soil and seepage conditions,

factors of safety in the range from 2.5 to 5 is more appropriate to account for uncertainty.

Mishra and Dora (2015) stated that various systems of aquaculture such as, a. Systems of Aquaculture based on habitat in freshwater, brackish water, mari-culture. b. Based on economic consideration - extensive, semi-intensive, intensive. c. Based on sex and especially adaptive fishes- monoculture, polyculture, monosex culture, integrated farming, d. Based on climatic conditions- warm water culture and cold water culture. RCC, bricks and FRP material use for Eco- carp hatchery.

Reddy *et al.* (2017) explained on design of wave generator and pumping aerator in order to provide the farmers with cost-efficient technology. These aerators enhance the water with more dissolved oxygen in an economically feasible methodology. A pump is a machine that moves fluids (liquids or gases) or sometimes slurries, by mechanical action. Pumps operate by some mechanism (typically reciprocating or rotary) and consume energy to perform mechanical work by moving the fluid.

2.2 Design:

Elekes (1984) discussed that the small fry is reared from the age of 4 to 5 days to 3 to 4 weeks in the fry rearing ponds and basins. These should be arranged in places sheltered from wind, on impervious soil and close to the hatching house and road. The preferable size of the fry rearing ponds ranges from 100 to 1000 m^2. The pond size should therefore be adjusted to the capacity of the hatching house. Circular basins are made with diameters from 4 to 6 m and about 1 m depth. Rectangular basins should have a ratio of short to long sides ranged from 1:2 to 1:4. The fry reared in the fry ponds are transferred for further growing into the nursery ponds at the rate of about 100000 species per hectare. The optimum size of the nursery ponds ranges

from 1 to 10 ha, but the maximum size should not surpass 30 ha. The water depth should be ranged from 1.0 to 1.5 m. The nursery ponds should be arranged in the vicinity of the fry ponds preferably in a manner to permit direct transfer of the fry to the nursery pond together with the water from the fry rearing ponds. The ponds vary from 20 to 100 ha in size, but the largest pond size should be determined by taking the total fish production envisaged into consideration, so that the total fish production in a single pond should not surpass 100 t. For holding purposes small 0.05 to 0.2 ha basins or ponds of 0.2 to 10 ha area should be provided. Under climatic conditions similar to those of Hungary, the basins are termed "wintering" ponds or basins. The average depth of the holding ponds should be from 1.8 to 2.2 m. Water depth for fish ponds should be ranged from 0.5 to 3.0 m and freeboard height for various depth of pond water was 0.40 to 0.60 m recommended by Kovari (1984).

NACA (1985) stated that the general practice size of growth pond ranges from 5 to 10 mu with depth from 3 to 3.5 m (water depth 2.5 to 3 m); fingerling pond size ranged from 2 to 5 mu with depth 2 to 2.5 m (water depth 1.5 to 2 m); nursery pond 1 to 2 mu with depth ranged from 1.5 to 2 m (water depth 1 to 1.5 m). The brooder pond equals to the grow out pond. The ratio of pond length and width should be ranged from 2:1 or 3:2. The design of outflow canal is almost the same as the inflow canal, but the bottom of the canal is 0.3 m lower than the pond bottom. The gradient of dyke slope of loam soil should be 1:1 to 1:1.5 while the one of poor soil or grow out pond dyke should be greater, that is, 1:2.5 to 1:3 under the water surface and 1:1 to 1:1.5 above the water surface. In grow-out pond 0.5 to 1 m wide path along the inner slopes should be provided for the sake of pulling nets and avoiding erosion by waves. The common width of pond bank ranges from 2 to 5 meters. It often creates excessive water turbulence and turbidity in earthen ponds less than 0.1 ha to 0.15 ha in area.

Attempts to produce small, highly efficient paddle wheel aerators using design features provided by Ahmad and Boyd (1988) for larger aerators have not been very useful. Electric paddle wheel aerators are widely used in pond aquaculture.

Upadhyay (1994) said that the intensive and semi-intensive farming, regular flat bottom pond bed with uniform slope is preferred. Pond bottom slope provided with 1000:1 to 1000:5 to words the drain to facilitate the water flow during harvest and pond drainage. Coastal aquaculture pond is normal designed for a water depth of 1 to 1.5 m depends upon the species to be culture. For main dike/peripheral dike required minimum free board 0.6 m are necessary but 0.6 m to 1.0 m suitable for main dike. Outer slope and inner slope of dike depends upon soil texture and prevailing site conditions. Side slope (horizontal to vertical) clayey soil ratio of 1:1, loamy soil 1.5:1, sand soil 2:1. Engineering standards required a minimum top width of 2.4 m for all dike ranged from 3 to 4.5 m high but in actual practice main dike of fish aqua farms are built with a top width ranged from 1.5 to 2.5 m. Whereas, partition dike or secondary dike required free board of 0.3 m for smaller pond size and for larger pond size it should be minimum 0.5 m. Top width of partition dike is usually between 1 to 2 m.

Coche and Muir (1995) stated freshwater fish ponds differentiate by according to the source of water, means of drainage, material and method used for construction, use of the pond for a specific purpose and they also described three basic pond types such as sunken, barrage and diversion ponds. The freeboard is the upper part of dike and should be under water. It varies from 0.25 m for small diversion ponds to 1 m for barrage ponds.

Boyd and Ahmad (1997); Moore and Boyd (1992) highlighted that aquaculture research is often conducted in small ponds of 0.05 to 0.5 ha in area and

small ponds are also used in some types of commercial aquaculture. Aerators of 0.25 to 2 HP are often used in smaller ponds. Small paddle wheel aerators (1 and 2 HP) are Taiwan make and sold worldwide for use in small ponds.

Chandrakant (2003) recommended pond size for effective management of nursery pond ranged from 0.05 to 0.20 ha, brood stock or grow-out ponds should be ranged from 0.25 to 10.00 ha, spawning ponds should be ranged from 0.01 to 0.05 ha, intensive culture ponds 1.0 to 5.0 ha. The size of pond considered good for management is ranged from 1 to 2 ha. For major carp essential pond water pond depth is ranged from 1.5 to 2.0 m. Copley *et al.* (2005) said that size of nursery pond should be ranged from 0.02 to 0.04 ha in size and water depth should be ranged from1 to 1.5 m.

Pillay and Kutty (2005) said for a fish pond average depth 1.5 m required. Depending on the harvesting system to be adopted, there may also be a need for market ponds for holding the harvests before marketing. It is possible to use some of the ponds mentioned above for more than one purpose, depending on the seasonality of operations. The size of ponds would vary according to the intensity of culture operations, but ranges of 0.05 to 2.00 ha for nursery ponds and 0.25 to 10.00 ha for production or stock ponds have been suggested. There appears to be a greater preference for rectangular-shaped ponds in fresh-water farms. From the point of view of cost of construction, square-shaped ponds are considered preferable. The conventional classification of fish pond design into barrage ponds, contour ponds and paddy ponds are also generally located near a stream, canal, river or reservoir and in a valley, the bottom having a slightly sloping contour. Paddy ponds are constructed on relatively flat areas surrounded by a dike. A minimum of 3 m top width will be required for embankments to be used by vehicles. Sandy loam and sandy clay type of

soil inside slope range of 1: 2 to 1: 3 and 1: 1.5 sandy loam and sandy clay. Top width of dike 0.50 to 1.00 m and freeboard 0.40 to 0.50 m. A range of average water depth of 0.4 to 1.5 m for nursery ponds and 0.8 to 3.0 m for production or stocking ponds have been recorded. In fresh-water fish culture, spawning ponds may have an average depth of 0.4 to 1m and holding or market ponds 1.2 to 2.0m. The water area of nursery ponds varies between 0.05 and 2 ha and of production or stocking ponds between 0.25 and 10.0 ha. Spawning ponds are smaller, ranging from 0.01 to 0.5 ha and holding or market ponds size from 0.10 to 1.0 ha.

NSPFS (2005) reported the pond may dig into the ground, they may be partly above and partly in the ground or they may be below original ground elevation; slop and bottom should be well packed during construction to prevent erosion and seepage; soil should contain a minimum 25% of clay. Roack, grass, branches and undesirable should be eliminated from the dikes. Dipper pond may be required in northern regions where the threat of winter-kill below deep ice cover exit. Best shapes for pond is rectangle and square. Pond should be 0.5 m at sallow end and 1 m at the drain end. ideal shape for ponds is rectangular and square. Construct pond with 2:1 to 3:1 slopes on all sides (each meter of height needed 2 or 3 m of horizontal distance). They differentiated various types of diversion pond such as embankment, excavated, partially excavated pond and barrage pond (are made by building a dike across a natural stream). The water inlet consists of a canal to bring in the water a silt catchment basin, and a pipe to carry water into the pond. Water inlet pipe fitted above the water level 15 cm so the incoming water splashes down into the pond. It also helps to mix air (oxygen) into the water. The inlet pipe is screened at the edge which is outside the pond to stop wild fish and things like branches and leaves from entering. The outlet is screened inside the pond to stop fish escaping. If liming is necessary the

following rate are recommended quicklime/slaked lime (20 to 50 gm/m^2), agriculture lime (50 to 200 gm/m^2). Quicklime is most commonly used at 200 kg/ha. Maintain a reasonable freeboard (minimum 0.15 to 0.2 m) and avoid filling pond water to same level as top of pond walls. Recommended stocking rates of sub-adult fish species (3 to 15 cm sized) vary from 1 to 5 fish/m^2.

Ayyapan (2006) mentioned that typical traditional method of aerating a pond is by pumping same pond-water in to a series of bamboo basket fitted vertically one below the other from a common vertical pole. Paddle wheel-aerator, aspirator aerator and air diffuser are commonly mechanical means of aeration in intensive ponds. Paddle wheel-aerator agitate surface water and may be ideal for water depth range from 1.0 to 1.5 m the other 2 are more effective in deeper ponds due of their high capacity of injecting air bubbles into water.

Carballo *et al.* (2008) described the different methods of fish farms such as extensive fish farming, semi-intensive fish farming, intensive fish farming and recommended side slopes is 2:1 or 3:1 (each meters of height needs 2 or 3 meters of horizontal distance), which allows easy access to the pond and reduces the risk of erosion problems. Minimum depth should be ranged from 0.5 to 1.0 m at shallow end, sloping ranged from 1.5 to 2.0 m at the drain end.

Standard specification of pipe suggested by BIS (2010) inner diameter should be ranged from 40 to 315 mm and wall thickness should be from 1.8 to 8.7 mm. BIS (2000) announced that the various standard specification for pipes diameter ranged from 20 to 630 mm and wall thickness was 1.3 to 49.2 mm.

Rath (2011) said that the spawn of 3 days old larvae reared in nursery and rearing ponds. Nursery and rearing ponds is the fry 2 to 3 cm length, time 11 to 30 days, nursery pond ideal size of fry pond is 0.04 ha and their number vary in

accordance to target production with water depth of 1 to 1.5 m. The number of stocking ponds vary according to the targeted fish production. The stocking pond area having 1 acer to 1.5 acer consider for freshwater fish culture with water depth of 2.5 to 3 m culture period 8 to 10 months. The slop of the embankment in horizontal to vertical axis should be 2:1 in good quality clay soil. Stocking density in nursery, rearing and stocking pond are 6 million spawn/ha, 0.3 million fry/ha and 5000 fingerlings /ha respectively. Nursery pond depending on the ponds productivity the stocking density of spawn is determine from 2.5 million to 10 million/ha. However, in rearing ponds multispecies rearing is practiced to make use of different natural food niches. The stocking density varies from 0.1 to 0.3 million/ha in 1:1:1 ratio of catla, rohu, and mrigal depending on the pond productivity. Finger lings Stocking density 0.4 to 0.6 million/ha. The increase in water volume per unit area create a favourable condition for poly-culture of different varieties of fish at high density. Optimum water depth ranged from 2.0 to 2.5 m all the year round.

Mishra and Dora (2015) explained the nursery ponds of 0.02 to 0.06 ha size with a depth of 0.7 to 1 m are suitable. Side slope of the pond dikes should be 1.5:1(horizontal: vertical). Free board should be 0.3 m. Tope width of the dike should be 1 m. Rearing of ponds should be ranged from 0.06 to 0.1 ha size with a depth of 1 m. Stocking pond size should be ranged from 0.2 to 2.0 ha, Brood stock ponds varies from 0.2 to 0.50 ha with a depth of 2 m and marketing pond should be ranged from 0.2 to 0.4 ha this are optimum size for different types of pond. Eco-carp hatchery outer chamber diameter of 3 to 4 m and inner chamber diameter of 1 m with a water depth of 1 m, free board 0.2 m and total depth 1.2 m.

Azhar *et al.* (2016) study was carried on engineering aspect of aquafarms at South Ratnagiri Region of Maharashtra. The partition dike of aquafarm top width was

ranged from 1.4 to 2.0 m, slope was 1.4:1 to 2:1, free board was 0.3 to 0.5 m. The aquafarm drainage canal dike top width was ranged from 1.2 to 1.8 m, free board height was 0.8 to 1.0 m, check tray scaffolding / catwalk material was wooden/cemented, length was 5.6 to 8.0 m, width was 0.5 to 1.0 m, height from pond bottom was 2.0 to 2.5 m. Feeder canal width was 9 m, and depth 3 m. Main Sluice Gate of the aquafarm construction material was RCC/ Wooden, length was 1.0 to 2.0 m, width was 0.8 to 1.2 m, ponds sluice gate width was 1.0 to 2.1 m, height was 2.4 to 2.8 m, number of planks 6 to 10 were used.

Omofunmi *et al.* (2016) studied the importance and functions of aeration were examined and prototype paddle wheel aerator was developed. Electric motor was used for paddle wheel aerator mover of one horse power capacity. Paddle hubs with six paddles all mounted on a shaft made of stainless steel and brass materials and performance test carried out showed that the overall oxygen transfers co-efficient (KLa) was observed to be as high as 8.19 hr-1 and SOTR and SAE ranged from 1.1 to 1.2 kg$O_2$$hr^{-1}$ and 1.1 to 1.3 kg $O_2$$KW^{-1}$ hr-1respectively.

Azhar *et al.* (2017) reported the operational aspect of aquafarms at North Ratnagiri, Maharashtra. The partition dike top width was 1.3 m, slope was 1.3:1, free board 0.6 m and stone used for pitching. Check tray scaffolding / cat walk length was 2.8 m, width 1.5 m and height from pond bottom 1.8 m.

Azhar and Mohite (2017) had measured the dimensions of the aquafarms at Central Ratnagiri of Maharashtra. Drainage canal top width was ranged from 2 to 10 m, bottom width was 1.4 to 3.6 m, depth was 1 to 3 m, and slope 1:1000 to 1:2000. Drainage canal dike top width was ranged from1.2 to 2.0 m, free board height 0.4 to 1.2 m and stone pitching materials was used. Feeder canal width was ranged from

4.40 to 13 m and depth was 1 to 1.2 m. Sluice gate of ponds width was1 m, height 2 m and number of planks was 4 to 10 were used.

Anon (2018) stated the basic use of a cast net is a part of sampling designed to either provide a representative sample of the local fish community or to target individual species for specific purposes. As use of a cast net alone may not fulfil these objectives, users should consider using a cast net as one component of a suite of different fishing gear types.

2.3 Layout:

Varadi (1984) stated that equipment is connected with fish feeding can be divided into three major groups, 1. feed storage facilities, 2. feed transporting equipment and feed distributors. In case of feed distributors, the fish feeders can be divided into two major groups, first stationary feeding equipment- a. without supplied energy; demand feeders. b. with supplied energy; automatic feeders (electric, pneumatic, hydraulic). Second, mobile feeding equipment-a. feeding carts. b. feeding boats. Demand feeders are controlled by the fish themselves according to their appetite. These feeders are easy to install and operate. The level of the feed in the container is a good indication of the condition of the fish. Demand feeders can be divided into two main groups, namely bait-rod or pendulum-type feeders and submerged plate-type feeders.

Shang (1984) discussed cost of construction affecting by various factors that is size, depth, shape of ponds and the construction methods. Large size of ponds is less productive as compare to small size fish ponds because of large ponds cannot be drained well and take more time to drainage, feed cannot be distributed fully in large size of pond area. Depth of fish ponds depends on the species to be cultured and weather conditions. Ponds can be construct in any shape but rectangular type of shape

suitable for feeding and harvesting of culture pond. A system of water supply used different material like, PVC piping or by canal, pipes can be made with bamboo, plastic, cement. The sluice gate prepared using wooden or concrete material and water tanks fabric made or concrete. The most essential work for construction of new fish farm mainly land clearing, earthwork, layout, design, water system, sluice gates, buildings. Construction of sluice gates and water system affecting by cost on the basis of unit cost, materials used and labour per days required. On a new fish farm equipment should be needed usually holding tank, truck, pump, oxygen meter and pH meter, etc. The number of equipment needed on farm but it's mainly depends on the size of the farm.

Toth (1984) said that the mechanization of maintenance and reconstruction in pond fish farms is needed both because of the decreasing level of labor supply and the increasing level of technical development. Maintenance and reconstruction of the pond bottom, dikes, water supply canals and drainage canals, water control structures and their surroundings during the first years of operation fish ponds need the most maintenance. The unexpected subsidence and settlement of dikes and the more serious erosion on the surface of dikes and excavations occur. Maintenance must be carried out continuously from the first year of operation. One can expect the following troubles with dikes: slope failure, soil slip, notch, slight erosion of the slope, etc. mechanized reconstruction is carried out through reconstruction of crown of dikes, replacement of eroded slopes, elimination of unevenness of pond bottom, partial removal of mud in order to ensure harvest ability and drainage, removal of water weeds, reconstruction of dike protection.

Coche (1986) stated that a good understanding of soil and its characteristics is one of the most important of the many factors which must be considered for

successful freshwater fish culture. Soil that is needed for the construction of ponds, a water supply, canals, reservoirs, barrages, small dam, and for the efficient management of fish ponds. Baluyut (1989) the layout of the pond system depends on the species for culture and on the size and shape of the area, which in turn determines the number and sizes of ponds and the position of the water canals and gates.

Upadhyay (1994) stated that the lay out of the farm mainly depends upon the topography and shape of the area. The water distribution system should be straight and short as possible. Layout of channel and dike should be fitted as closely as technically possible existing land slopes and undulation. Farm discharge outlet should be located at downstream of the river intake system. Deep well for freshwater supply to the farm should be located at reasonable distance from the sea to avoid risk of intrusions of sea water due to pumping of large water. The pond size from 1 to 5 ha for extensive farming, 0.25 to 1.0 ha for semi-intensive and 0.025 to 0.25 ha for intensive farming. For intensive farming, smaller size pond is constructed in different shapes such as circular, square, rectangular, triangular. Circular and square shape of pond commonly used for intensive farming. The large ponds on the other hand are usually constructed in rectangular shape as it facilitates the pond management and culture operation.

Coche and Muir (1998) suggested about fish farm planning and carrying out a daily routine and this daily routine is shaped by weekly, monthly and seasonal patterns as well as by climate, work requirements and crop cycles. For the fish farmer management involves choosing and stocking small fish, ensuring good water conditions, providing the fish with adequate food, harvesting and marketing the fish produced. Size and complexity of a fish farm increases, sound management based on engineering technological knowledge becomes increasingly important that are fish

pond management of aqua pond. Ebrahim (2003) suggested the pond area should be fenced with at least 4 feet web wire and two strands of barbed wire at the top. Chandrakant (2003) said that layout of an aquafarm mainly depends upon the topography and shape of the farm area.

NSPFS (2005) since neutral gravity is used to fill and drain the ponds no pump is needed. Water source for fish ponds such as rainfall ("sky" ponds rely on rainfall only to supply water), run-off (pond can be filled when water from the surrounding land area runs into them) natural water (ca be diverted and brought in from stream, river or lake) spring (water under the ground that has found a way to get out and it is good for fish ponds because it is usually clean), well (wells are place where ground water is pumped up). Farming may range systems can be distinguished in terms of input levels such as extensive, semi-intensive and intensive fish farming.

Mishra and Dora (2015) mentioned that rain water along with well water is most suitable for aquaculture. Important part of the culture system prevailing in India is the pond which may be classified into three main type: nursery, rearing, and stocking pond. Fore ideal rectangle pond, the ratio of length and breadth should be 2:1. Ponds shallower than 1.0 m depth of water often gets over heated during summer and water depths greater than 4.0 m are less productive. Generally, fish culture up to 2.0 to 3.0 m depth is sufficient.

2.4 Soil quality:

2.4.1 Soil Texture and pH

Coche (1986) good water retention such as clay or sandy clay soils. Good pond fertility such as clay loam or silty clay loams. The best soils for fish culture are the sandy clay, silty clay loam or clay loam soils. Sandy clay soil good for dike construction. Soil pH should be in the range of 6.5 to 8.5. Soils with a pH value lower

than 5.5 are to acid and soils with a pH value greater than 9.5 are too alkaline. Manjulekshmi *et al.* (2014) stated soil pH ranged from 7.5 to 8.5 good for fresh water fish culture and recommended, if soil pH is ranged from 4.0 to 4.5 the nature of soil is highly acidic and required lime doses is 1000 kg/ha, 4.5 to 5.5 the nature of soil is medium acidic and required lime doses is 700 kg/ha, 5.5 to 6.5-the nature of soil is slightly acidic and required lime doses is 500 kg/ha, 6.5 to 7.5 the nature of soil is near acidic and required lime doses is 200 kg/ha, 7.5 to 8.5 the nature of soil is alkaline and lime doses is not required to rise the pH of soil. Patil *et al.* (2016) studied soil texture class were, sandy-clay-loam of various villages in Konkan region and pH was ranged from 5.60 to 6.80.

2.4.2 Water holding capacity and seepage Rate

Viji and Prasanna (2012) estimated value of water holding capacity at Lalgudi Taluk of Tiruchirappalli district area and showed a highest of 30.69%, whereas high clay content. Coche and Wal (1981) stated the rate of seepage losses in millimeters per day from various soil types (in the natural state) needed to calculate pond seepage losses over a period of time. Seepage of natural soil type sand 25.00 to 250 mm/day, sandy loam 13.0 to 76 mm/day, loam 8.0 to 20 mm/day, clayey loam 2.50 to 15 mm/day, loamy clay 0.25 to 5 mm/day, clay 1.25 to 10 mm/day.

2.4.3 Bulk density and Moisture

Coche (1986) said that the optimum moisture content for various types of soils is clayey sands, sand-clay mix with optimum moisture content for compaction range 11 to 10 %, sand-silt-clay mix with plastic, silt clay fraction 15 to 11 %, inorganic silt, clayey silt with 24 to 12 %, inorganic clay 24 to 12 %, organic silt 33 to 21 %, inorganic clay, highly plastic 36 to 19 %, organic clay 45 to 21 %. Garretson (1999) given an expected range for bulk density i.e 1.0 g/cm^3 for clay soils to 1 .8

g/cm^3 for sandy or compacted soils. Patil *et al.* (2016) studied that coastal soils of Maharashtra. There was bulk density ranged from 1.29 to 1.26 g cc-1 and moisture 13.62 to 17.93 %.

2.4.4 Electric conductivity

Study was conducted by Gul *et al.* (2015) to detect some physiochemical properties and metals concentration in soil sample of circuit house Sibi pond, District Sibi of the province Balochistan. Pond soil samples were collected from the fish pond of district Sibi. Electrical conductivity of soil sample was ranged between 2.89 to 2.90 dS/m with average value 2.90 dS/m. These values of pond soil sample were in the ideal range.

2.5 Water Quality:

2.5.1 Temperature and pH

NSPFS (2005) recommended water quality monitoring and maintenance desirable level of pH 6.5 to 9.0, maintain the water depth at 1 to 1.5 m. Tolerable water temperature ranged from 20 to 30^{0}C. Carballo *et al.* (2008) stated that water temperature ranged from 20 °C and 30 °C is generally good for fish farming. Water suitable pH-value for fish farming range between 6.7 and 8.6.

2.5.2 Dissolved oxygen (DO) and Transparency

Rajyalakshmi *et al.* (1988) observed that the transparency ranging from 14 to 36 cm in the farm ponds of Chilka lake fringe area. Santhosh and Singh (2007) said that the transparency 30 to 40 cm good for fish culture. Chakraborty and Banerjee (2010) studied that turbidity (cm) 30.1 ± 1.0 good for culture ponds. DO levels of less than 3 ppm will kill warm water fish and levels less than 5 ppm will kill cold water fish stated by (Sallenave, 2012).

2.5.3 Alkalinity and Hardness

Wurts and Durborow (1992) stated that the required water quality parameter for fish culture such as total alkalinity (50 - 150 mg/l) total hardness (75 - 200 mg/l). Manjulekshmi *et al.* (2014) recommended the total alkalinity ranged from 20 to 150 ppm and total hardness 20 to 200 ppm.

2.5.4 Ammonia and Salinity

Garg (1996) studied fish culture in inland saline water from India for the culture of common carp as well as the Indian major carps, since these fish species are stenohaline and he mentioned that Common carp and Indian Major Carps perform well up to 7.5 ppt salinity. According to Santhosh and Singh (2007) ammonia in fish ponds should not more than 0.1 mg/l. Patil *et al.* (2016) studied that Coastal Saline Soils of Maharashtra and they locally called as Khar or Khajan soils. The coastal saline soils occur in these districts due to periodical inundation of cultivable land by creek/sea water during high tides. Northern part of Raigad district where the soils are derived from the basalt parent material, while VRL soil zone covers the southern portion of Raigad district. It reached the average salinity of groundwater ranged from 29 dSm-1 in the month of July to 75 dSm-1 in the month of May.

2.6 Hydro-meteorological parameters

Gupta (2013) reported, the climate of Raigad district and said that typical of west coast and characterized with plentiful and regular seasonal rainfall, oppressive weather in summer and high humidity throughout the year. The mean minimum temperature is 17.7°C and mean maximum temperature is 31.8°C. The analysis of long term rainfall data indicates that normal annual rainfall over the district ranges from 2200 mm to more than 3000 mm in the plains and it is above 5000 mm in the

hills. The minimum rainfall is in the northwest around Uran (2197 mm) and maximum around Mahad (3360 mm).

3.0 MATERIALS AND METHODS

In the present study general characteristics and other relevant information of the operational freshwater fish farms were collected by the interview-cum-data-collection schedule (Annexure-I). The data pertaining to the technical specifications was recorded after examining the operational freshwater fish farms. Layout, design and engineering aspects of operational freshwater fish farms were studied.

3.1 Study Area

Raigad district is one of the district of Maharashtra which has rich potential resources for inland fisheries and aquaculture (Map.3.1). There are in all five rivers, i.e. Ulhas, Panvel and Patalganga rivers in the northern part, Kundalika in central and Savitri in the Southern part of the Raigad district. In all, 28 operational freshwater fish farms of Raigad district of Maharashtra state were studied. Their location is represented in Map 3.2.

In this investigation Raigad district was divided into three Regions, namely 'North Raigad Region' covering the areas of Panvel, Karjat, Uran, Pen and Khalapur Talukas; 'Central Raigad Region' covering areas of Roha, Alibag, Murud, Tala and Sudhagad talukas; and the 'South Raigad Region' covering the areas of Mangoan, Shriwardhan, Mhasala, Poladpur and Mahad talukas.

3.1.1 Site Selection

Information with respect to the operational freshwater fish farms of the three regions of Raigad district where obtained from private farm input dealers and the same was crosschecked with the list given by Department of Fisheries, Government of Maharashtra Raigad, FFDAs, MPEDA, KVKs and a survey was undertaken to study them. Prior to the exploration, a pilot survey was done to identify the operational freshwater fish farms. Raigad district comprises of a total 15 Talukas out

of which freshwater fish farming activity was carried out in 4 Talukas of North Raigad Region (viz. Panvel, Karjat, Uran and Pen), 3 Talukas of Central Raigad Region (viz. Alibag, Roha, and Murud) and in only 2 Talukas of South Raigad Region (viz. Mangoan and Mahad). These 9 Talukas of Raigad had a total of 41 freshwater fish farms of which 28 were in operational condition during the study period and all the operational farms were studied. The freshwater farms were further categorized as Small farms (below 2.0 ha), Medium farms (2.0 to 5.0 ha) and Large farms (above 5 ha) (Anon, 2008).

3.1.1.1 North Raigad Region

North Raigad region, covering the areas of Panvel, Karjat, Khalapur, Pen and Uran talukas shown in Map 3.3. The survey of twelve operational freshwater fish farms was undertaken (Map 3.4). Details with respect to their location, cultured species etc. of the freshwater fish farms are given in Table 3.1.

3.1.1.2 Central Raigad Region

In Central Raigad Region, covering the areas of Alibag, Sudhagad, Roha, Murud and Tala taluka shown in Map 3.5. The survey of eleven operational freshwater fish farms was undertaken (Map 3.6). Details are given in Table 3.2.

3.1.1.3 South Raigad Region

South Raigad Region covers the areas of Mangoan, Mahad Mhasala, Shriwardhan and Poladpur Talukas shown in Map 3.7. In South Raigad region five operational fish farms were observed (Map 3.8). Details are given in Table 3.3.

3.2 Sampling Units

Twenty-eight operational freshwater fish farms from the three regions of Raigad district were taken for sampling for the present study. The detail information regarding the general characteristics and technical inputs of the farm were obtained by

interviewing the farm owners in the study area. Design, layout and engineering aspects was collected by physical sampling of the units. Data was collected in two phases as the duration of the farming of one crop was seven to eight months; in first phase, general and technical information was collected and in second phase, the information regarding engineering aspects was collected. Similarly, the information related to constraints faced by the farmers was collected simultaneously.

3.3 Interview Schedule, Data Collection, Documentation and Analysis

The handbook of aqua farming published by Marine Products Export Development Authority (MPEDA, 1997) and Coastal Aquaculture Authority (CAA, 2005) of India were used as a base line for compilation of the interview-cum-data-collection schedule. Further, the surveyed freshwater fish ponds and farms were classified as per (Coche and Muir, 1995; Mishra and Dora, 2015). The prepared schedule was tested on three operational freshwater fish farms to check its validity and to find lacunas, if any. The final draft of the interview-cum-data-collection schedule was prepared after eliminating all the drawbacks (Annexure I).

The interview-cum-data collection schedule comprised of three sections. The first section dealt with the particulars of farm owner, the second section dealt with the design, layout and technical specifications which were physically collected while the third section dealt with the engineering aspect.

3.4 Evaluate Engineering, Design and Layout Aspects

Measurement of the ponds e.g. length, width and depth and other aspects like canal top width, bottom width, slope, dike width, freeboard height, pond bottom slope, formulation of layout etc. were taken in to account for the present study.

3.5 Soil Quality

Soil samples were collected from operational freshwater fish farms and evaluated for various parameters like, moisture, pH, electrical conductivity, water holding capacity, bulk density, seepage rate, and texture by standard methods (Boyd, 1995).

3.6 Water Quality Parameters

Water samples were collected from all operational farms and were analyzed for important water quality parameters namely, salinity, temperature, pH, dissolved oxygen, ammonia, total alkalinity, total hardness and transparency following standard methods (APHA, 1998).

3.7 Statistical Analysis

Data collected was analyzed with the appropriate statistical procedures wherever required (Snedecor and Cochran, 1967).

4.0 RESULTS

As per information and data collected from the freshwater fish farmers the operational freshwater fish farms of Raigad district were classified into three different Regions which are North, Central and South. The operational freshwater fish farms were categorized as small size farm (below 2.0 ha), medium size farms (2.0 to 5.0 ha) and large size farms (above 5.0 ha). Detail information was collected from freshwater fish farms based on selection of site, engineering aspects, design and layout, water qualities parameters and soil quality parameters with basic characteristics and advanced technological specifications were observed, recorded and analyzed.

Raigad district comprises with total 15 talukas out of which freshwater fish farming activity was carried out at 4 talukas of North Raigad Region (viz. Panvel, Karjat, Pen, Uran). Three talukas of Central Raigad Region (viz. Alibag, Roha, Murud) and only 2 talukas of South Raigad Region (viz. Mangoan and Mahad). These nine talukas of Raigad had a total of 28 numbers of operational freshwater fish farms which were studied and are presented in this chapter. The locations of operational freshwater fish farms have been depicted in Map 3.2.

4.1 General information of the operational freshwater fish farms of Raigad district

In North Raigad Region, for small size farms, the total area of the farms, total water spread area of farms, total pond area, water spread area of single ponds ranged from 0.34 to 1.88 ha, 0.11 to 1.24 ha, 0.017 to 0.84 ha, 0.01 to 0.68 ha; respectively. Medium size operational farm was not observed in North Raigad Region. In North Raigad Region large size farm, the total area of the farm, total water spread area of farms, total pond area, water spread area of single ponds ranged from 12.16 to 22.25 ha, 0.8 to 1.33 ha, 0.02 to 6.84 ha, 0.01 to 3.61 ha; respectively. For seepage control

measures plastic lining was observed to be adapted on one large size farm. For these farms accessibility was by road. Distance between farms and agricultural field were more than 500 m. No mangroves were observed around these farms in the North Raigad Region.

In Central Raigad Region, for small size farms, the total area of the farms, total water spread area of farms, single pond area, water spread area of single ponds ranged from 0.1 to 1.91 ha, 0.05 to 0.98 ha, 0.05 to 0.66 ha, 0.03 to 0.62 ha; respectively. In the Central Raigad Region medium size farm, total area of the farm, total water spread area of farms, single pond area, water spread area of single ponds ranged from 2.02 to 2.94 ha, 1.21 to 1.95 ha, 0.001 to 1.74 ha, 0.001 to 1.35 ha; respectively. In the Central Raigad Region large size farms, the total area of the farm, total water spread area of farms, single pond area, water spread area of single ponds was 20.04 ha, 0.27 ha, 0.17 to 0.18 ha, 0.12 to 0.15 ha; respectively. HDEP plastic lining was observed to be adapted as seepage control measures on one small size fish farm. For farms mode of accessibility was by road. Distance between farms and agricultural field were above than 500 m. No mangroves were observed around there Central Raigad Region.

In South Raigad Region small size farm, total area of the farms, total water spread area of farms, single pond area, water spread area of single ponds ranged from 0.75 to 0.9 ha, 0.24 to 0.55 ha, 0.05 to 0.72 ha, 0.03 to 0.03 ha; respectively. In the South Raigad Region medium size farms, the total area of the farms, total water spread area of farms, single pond area, water spread area of single ponds ranged from 2.1 to 4.00 ha, 0.6 to 0.86 ha, 0.05 to 0.55 ha, 0.03 to 0.5 ha; respectively. Stone pitching was observed to be adapted on single small size farm. For farm mode of

accessibility was by road. Distance between farms and agricultural field were more than 500 m. No mangroves were observed around their South Raigad Region.

General Information of operational freshwater fish farms of North, Central and South Raigad Region details are given in Table 4.1.

4.2 Site selection criteria of the operational freshwater fish farms of Raigad district

The site selection criteria of the operational freshwater fish farms of Raigad Region stated in Table 4.2. The topography of the farms of three different Region of Raigad was plain, slightly sloping around hilly area with good water source from the rivers, irrigation dams, reservoirs, tube wells. Seepage ground water resource was observed to be available on one small size fish farm of the Center Raigad Region. The seepage rate ranged from 2 to 7 cm per day in all three different Regions of Raigad. The wind direction of North Raigad Region was 'North to East' whereas in Central and South Raigad Region wind direction were recorded 'West to South'. Cyclones and drastic climatic changes were not observed during the time of sampling. The average temperature was recorded to range from 26^0 to 32^0 C and relative humidity was observed to be 75 to 81 %. Nutritious artificial feed was supplied by various private companies through dealers. Seed was procured from Fisheries Research Station in North Raigad Region whereas in Central Raigad Region seed was procured from the nearest fish seed suppliers and from states like Andhra Pradesh, West Bengal. The average annual rainfall of North Raigad Region was 2654 to 3976 mm whereas 2722.5 to 3598.1 mm rainfall was recorded for Center and South Raigad Region. Electric power supply was provided by MSEB to all three Regions of Raigad. Infrastructure facilities such as mobile, telephone and approach road to all farms were available. The required equipment's and machineries for North, Central and South

Raigad regions were procured from local market of nearest cities as well as some were imported from other countries. Fish farmers availed financial assistance from various agencies such as ATMA, MPEDA and FFDA. The pre-processing and processing facilities were observed only in North Raigad Region. The required human resource/labors were brought from nearby states like Karnataka, Andhra Pradesh etc. in North Raigad Region and Central Raigad Region. But in South Raigad Region all farms were operated by local workers. The site particulars of operational freshwater fish farms of Raigad Region are given in Table 4.2.

4.3 Classification of operational freshwater fish farms of North Raigad Region

The warm water aquafarms of North Raigad Region were classified on the basis of economic consideration as extensive, semi-intensive and intensive. Further on the basis of sex and especially adaptive fishes they are divided as monoculture, polyculture, monosex culture and warm water culture farms. Out of the total 9 small size freshwater farms of North Raigad Region, all farms were observed to follow semi-intensive culture practice. Out of the 9 small size farms, 8 farms polyculture was observed while as 1 farm monosex culture was observed to be practice during the study period. Out of the total 3 large size freshwater farms of North Raigad Region, all farms were observed to follow semi-intensive culture practice of the 3 large size farms on 2 farms polyculture was observed while as 1 farm monosex culture was observed to be practice during the study period.

Out of the total 9 small size farms studied in North Raigad Region and sub-classified in to basic pond types as 16 sunken ponds and 2 diversion ponds. According to use of the ground water source only one pond was spring-water source pond and 18 were rain water source ponds. The use of pump for top of water level of pond as 3 pump-fed ponds. According to the drainage system of pond 7 undrainable ponds and

11 pump-drained ponds reported in North Raigad Region. According to the construction materials 18 earthen ponds observed in in North Raigad Region. According to the construction method 18 dug-out ponds observed in North Raigad Region. Use of pond for specific purpose as 2 nursery ponds, 16 ponds used for grow-out ponds and 18 ponds dry season ponds were reported in North Raigad Region. The shapes of the ponds also observed as 13 number of ponds was rectangle shaped and 5 number of ponds was irregular shaped ponds in North Raigad Region.

Similarly, out of the total 3 large size farms observed and sub-classified into basic pond types as 14 sunken pond and 15 diversion ponds whereas only one pond was barrage pond in North Raigad Region. According to use of the ground water source 2 ponds was spring-water source ponds, and 30 rain water source ponds was observed in North Raigad Region. Other water body resources of pond were 2 numbers of ponds water supply directly from barrage ponds. According to the drainage system of pond 25 numbers of ponds was undrainable, 3 drainable ponds and 2 pump-drained ponds observed in North Raigad Region. According to the construction materials 28 earthen ponds, 2 ponds adapted to be plastic liner. According to the construction method 26 ponds was dug-out and 4 ponds was cut-and-fill / counter ponds. According to use of ponds for specific purpose 26 ponds was nursery, 4 ponds was grow-out, 31 ponds was drying season whereas only one pond of brood pond, storage pond (marketing) and fattening pond was reported in North Raigad Region. The shapes of the pond in North Raigad Region were 7 numbers of square shape ponds, 21 numbers of rectangle shape ponds and 2 numbers of irregular shape ponds observed.

Classification of operational freshwater fish farms of North Raigad Region details are given in Table 4.3.

4.4 Design and engineering aspects of operational freshwater fish farm of North Raigad Region

Small size farms were studied from North Raigad Region and its area ranged from 0.34 to 1.88 ha (0.89 ± 0.76). Whereas farm water spread area ranged from 0.11 to 1.24 ha (0.54 ± 0.56) and on each farm the numbers of ponds ranged from 1 to 3 (1.88 ± 1).

Medium size farms were not reported from North Raigad Region.

For the area of large size farm ranged from 7.05 to 22.25 ha (13.82 ± 7.60), water spread area of the farm was ranged from 0.81 to 4.3 ha (2.15 ± 1.74). Numbers of pond on each farm were observed from 2 to 25 (10 ± 11.5). all the fish farms where observed to be constructed with earthen soil, whereas one large size fish farm was fitted with plastic liners.

Design and engineering aspects of small and large size operational freshwater fish farms of North Raigad Region are stated in Table 4.4 and depicted in layout 4.1, 4.2, 4.3 and photo 4.1, 4.2; respectively.

4.4.1 Leading canal

The leading canal was absent for all small, medium, large size of fish farms of North Raigad Region.

4.4.2 Specifications of pond

The length of the small size farm ponds ranged from 13 to 118 m (65.87 ± 52.5), and width of the ponds were observed to be ranged from 8 to 73.81 m (40.85 ± 32.90). The water depth of pond was ranged from 1 to 2.1 m (1.55 ± 0.55), the area of the single pond was ranged from 0.01 to 0.84 ha (0.33 ± 0.41), water spread area of the single pond was ranged from 0.01 to 0.68 ha (0.26 ± 0.33) in North Raigad Region.

The length of the large size farm ponds was ranged from 16.16 to 68 m (34.56 ± 25.92), width of the ponds was ranged from 12.6 to 55.6 m (23.3 ± 21.5). The water depth was ranged from 1 to 5 m (1.63 ± 2). The single pond area was ranged from 0.02 to 6.84 ha (0.31 ± 3.40), water spread area of single pond ranged from 0.01 to 3.61 ha (0.18 ± 1.80). The slope of pond bottom was ranged from 1000:0.3 to 1000:5 (1.86 ± 1.56) towards drainage side in North Raigad Region.

4.4.3 Dikes

4.4.3.1 Peripheral dike

The peripheral dike acts as protective dike for entire farm against flood, cyclone and top area can also use as road around the farm for transportation. The top width of the small size farm ponds peripheral dike ranged from 1 to 2 m (1.72 ± 0.5) in North Raigad Region. The side slope was ranged from 2:0 to 8:0 (3.25 ± 0), range of free board was ranged from 0.4 to 1.2 m (0.7 ± 0.4), total height ranged from 1.6 to 3 m (2.25 ± 0.7). No stone pitching/ plastic lining were recorded on peripheral dikes of all small size farm ponds.

In North Raigad Region, the top width of the large size farm ponds of peripheral dike was ranged from 1.5 to 5 m (2.07 ± 1.75). The side slope was ranged from 2:0.3 to 10:5 (3.33 ± 4), free board was ranged from 0.3 to 1 m (0.76 ± 0.35), total height ranged from 1.4 to 6 m (2.44 ± 2.3). Stone pitching was absent on all peripheral dike of large size farms whereas on one farm reported plastic liner on peripheral dike.

4.4.3.2 Partition/Internal dike

An internal dike separates two successive culture ponds. Top width of the small size farm ponds partition dike ranged from 1 to 3 m (1.54 ± 1). The side slope ranged from 2:0 to 8:0 (3.25 ± 0), free board was ranged from 0.4 to 1.2 m (0.7 ± 0.4),

total height was ranged from 1.6 to 3 m (2.25 ± 0.7). Stones pitching was not reported on all partition dike of small size farms in North Raigad Region.

The top width of the large size farm ponds of partition dike ranged from 1 to 2.75 m (1.29 ± 0.87). The side slope was ranged from 2:0.3 to 10:5 (3.33 ± 4), free board was ranged from 0.3 to 1 m (0.76 ± 0.35) and total height was ranged from 1.4 to 6 m (2.44 ± 2.3). No stone pitching was reported on all partition dike of the large size farm ponds.

4.4.4 Drainage canal

The drainage canal facility observed only one small size farm. The dimension of drainage canal of small size farm ponds top width was 1.5 m (1.5 ± 0), bottom width was 1 m (1 ± 0), water depth was 1 m (1 ± 0), slope 1000:1 (1 ± 0).

Dike of the drainage canal recorded top width, free board height, 1 m, 0.3 m; respectively. The average of top width and free board height was 1 ± 0, 0.3 ± 0; respectively. Earthen soil was used for construction of drainage canal. On the medium and large size farm drainage canal was not reported.

4.4.5 Check tray scaffolding /Catwalk

At North Raigad Region use of check trays and catwalk/scaffolding was no observed. But for distribution of for feed galvanized demand feeder was utilized on large size farm to provide feed. The dimensions of the demand feeder length, width and height was 0.3 m, 0.3 m and 0.45 m; respectively. Average was 0.3± 0, 0.3± 0, 0.45 ± 0; respectively. Hanging height of the demand feeder from pond bottom was recorded 1.3 m with water depth 1.5 m.

4.4.6 Water supply system

4.4.6.1 Feeder canal

The distribution of water through feeder cannel was recorded on one large size farm at North Raigad Region. The dimensions of the feeder canal; top width was 1 m (1 ± 0), bottom width was 0.8 m (0.8 ± 0), depth was 1 m (1±0).

4.4.6.2 Pipe

Pipe line used to supply water to various pond by using pumps. On small size farms ID of the pipes was observed to be ranged from 40.20 to 63.20 mm (51.7 ± 11.5) and wall thickness was ranged from 3.25 to 4.12 mm (3.68 ± 0.43) in North Raigad Region. PVC, Cornaflex, High Density Poly-vinyl Chloride, HDPE materials were selected for construction of water supply system. Ball valve are fitted at the end to controlling the flow of water.

On large size farms, ID of the pipes was observed to be ranged from 40.20 to 140.45 mm (90.32 ± 50.12) and wall thickness was ranged from 3.25 to 5 mm (4.12 ± 0.87).

4.4.7 Lining

HDPE lining was adapted on single large size farm to prevent the seepage. The thickness of the HDPE material was 0.5 mm and average was observed 0.5 ± 0 in North Raigad Region.

4.4.8 Main sluice gate

In North Raigad Region, the main sluice gate was observed on single small size farm and it was constructed by RCC material. This sluice gate was only used for intake of water. The dimensions; length 2 m (2 ± 0), height 2 m (2 ± 0) and width of the main sluice gate was 1 m (1 ± 0). Only one farm reported main sluice gate for freshwater farm in North Raigad Region.

4.4.9 Sluice gate of the ponds

Only one sluice gate of the ponds was reported on small size fish farm in North Raigad Region. The length, height and width of sluice gate of the pond were 2 m (2 ± 0), 2 m (2 ± 0) and 1 m (1 ± 0); respectively. Sluice gate comprised with three slots (grooves), dimensions of the screen was 2.5 × 1 m, mesh size of the screen was 60 microns. Four planks were used for each sluice gate.

4.4.10 Instruments and equipments

4.4.10.1 Hume pipes

Use of hume pipe was reported on small size farm for drainage purpose. The diameter, of hume pipe was 0.8 m (0.8 ± 0) and length 5.7 m (5.7 ± 0); respectively in North Raigad Region.

4.4.10.2 Pumps

The Kirloskar make centrifugal type of pump was installed on small size farms. Diesel operated pump with capacity ranged from 1.5 to 5 HP was installed for intake of water. Each farm reported only one number of pump for operation in North Raigad Region. No stand by pump was recorded.

For large size farms Kirloskar make, centrifugal type diesel pump was recorded with the capacity ranged from 3 to 5 HP were installed. Each farm reported only one pump used for operation of farm. No stand by pump was recorded.

4.4.10.3 Aerators

Because of less stocking density no aerators were adapted on small size farms from North Raigad Region.

Whereas aerators were adapted on two large size farms at North Raigad Region. The details of the aerators make Suyog Pvt. Ltd., type paddle wheel aerators, capacity 2 HP. One to two aerators were installed in each pond. Installed aerator were

used for aeration of water, recirculation of water, to generate flow inner the pond to gather fecal matter at the center.

4.4.10.4 Check trays

Check trays not reported in North Raigad Region.

4.4.10.5 Other equipments

Basic equipments such as Refractometer, DO meter, Secchi disc, pH meter, were not observed in North Raigad Region. Weighing balance with capacity of 10 to 50 kg was used for weighing feed and other ingredients on farm in North Raigad Region.

4.4.10.6 Other infrastructure

The basic infrastructure was studied from various farms of North Raigad Region was observed on various farms. It was observed that the approach tar roads were observed for all farms. Each farm was equipped with farms shed and space was utilized for multipurpose activities of farmers such as storage of feed, holding of small equipments, harvesting materials, temporary accommodation etc. The distribution of electrical energy recorded threw electric transformer, electric meter, control panel, electrical appliances. One small farms reported Autobat solar power system capacity was ranged from 12 V to 24 V used for providing light during night time for vigilance purpose. Freshwater fish hatchery and diesel generator was not observed throughout the North Raigad Region.

Other equipments and infrastructure details of operational freshwater fish farms of North Raigad Region has been given in Table 4.5.

4.5 Soil and water quality parameters of operational freshwater fish farms of North Raigad Region

Soil quality parameters of small size operational freshwater fish farms of North Raigad Region were analyzed. The ranges of soil parameters, such as moisture was ranged from 10 to 15 % (12.11 ± 2.5), pH was ranged from 6.6 to 7.5 (7.07 ± 0.45), electric conductivity was ranged from 1.95 to 3.55 dS/m (2.71 ± 0.79), water holding capacity was ranged from 58 to 72 % (66.45 ± 7), bulk density was ranged from 1.24 to 1.29 g/cm^3 (1.26 ± 0.02), seepage rate was ranged from 2 to 6 cm/day (3.36 ± 2) and soil texture was sandy clay loam shown in Table 4.6. The water quality parameters, such as salinity was ranged from 4 PSU (4 ± 0), temperature was ranged from 27 to 30^{0}C (28.33 ± 1.5), pH was ranged from 7.4 to 8 (7.73 ± 0.3), dissolve oxygen was ranged from 4 to 5.6 mg/l (4.56 ± 0.8), ammonia was ranged from 0 to 0.02 mg/l (0.02 ± 0), total alkalinity was ranged from 100 to 130 mg/l (117.77 ± 15), total hardness was ranged from 70 to 130 mg/l (102.22 ± 30), transparency was ranged from 30 to 40 cm (34.44 ± 5) were evaluated and the shown in Table 4.7.

Soil quality parameters of large size operational freshwater fish farms of North Raigad Region were analyzed. The ranges of soil parameters, such as moisture was ranged from 11 to 16 % (13 ± 2.5), pH was ranged from 6.1 to 7.0 (6.66 ± 0.5), electric conductivity 2.32 to 3.56 dS/m (2.94 ± 0.61), water holding capacity was ranged from 54.85 to 61.57 % (57.14 ± 3.35), bulk density was ranged from 1.24 to 1.27 g/cm^3 (1.25 ± 0.01), seepage rate was ranged from 3 to 4 cm/day (3.5 ± 0.5) and soil texture sandy clay loam shown in the Table 4.6. Water quality parameters such as salinity was ranged from 5 PSU (5 ± 0), temperature was ranged from 28 to 29^{0}C (28.66 ± 0.5), pH was ranged from 7.5 to 7.7 (7.6 ± 0.1), dissolve oxygen was ranged from 4.5 to 4.7 mg/l (4.6 ± 0.1), ammonia was ranged from 0 to 0.01 mg/l (0.01 ± 0),

total alkalinity was ranged from 110 to 120 mg/l (113.33 ± 5), total hardness was ranged from 100 to 110 mg/l (106.66 ± 5), transparency was ranged from 30 to 35 cm (33.33 ± 2.5) were evaluated and resulted in Table 4.7.

Soil and water quality parameters of small, medium and large size operational freshwater fish farms of North Raigad Region details are given in table 4.6 and 4.7.

4.6 Classification of operational freshwater fish farms of Central Raigad Region

Out of the 7 small size farms observed in Central Raigad Region and classified the system of aquaculture on the basis of fish habitat were all farms was freshwater. further on the basis of economic consideration 6 farms were observed to be follow semi-intensive culture practices whereas one farm was extensive fish farm in Central Raigad Region. Based on sex and especially adaptive fishes 5 farms was polyculture technique adapted in Central Raigad Region. In Central Raigad Region farms classified based on sex and especially adaptive fishes as 2 farms were monosex culture practice and all farms climatic conditions was warm. Out of the 3 medium size farms observed in Central Raigad Region and classified the system of aquaculture on the basis of fish habitat were all farms was freshwater. Further on the basis of economic consideration 3 farms were observed to be follow semi-intensive. Based on sex and especially adaptive fishes as 2 farms was polyculture whereas one farms were monosex culture and all farms climatic conditions was warm in Central Raigad Region. The large size farms observed in Central Raigad Region and its classified into aquaculture system on the basis of fish habitat, economic consideration, sex and especially adaptive fishes whereas one farm classified in each system of aquafarming such as freshwater, semi-intensive, polyculture, warm water climatic conditions observed in Central Raigad Region. Details are given in table 4.8.

In Central Raigad Region, out of the total 7 small size farms were classified in to basis pond types as 12 sunken ponds and 2 diversion ponds whereas only one pond was barrage pond. According to use of the ground water source 3 ponds was spring water source, 4 was seepage ponds, 14 ponds was rain water source and 3 ponds was pump-fed. According to the drainage system of pond 5 ponds was undrainable, 8 drainable ponds and 3 number of ponds was pump-drained. According to the construction materials 14 ponds was earthen whereas only one pond was adapted to be plastic liner in Central Raigad Region. According to the construction method as 12 numbers of pond was dug-out ponds, 3 cut-and-fill ponds/ counter ponds was observed in Central Raigad Region. According to use of the ponds as 15 grow-out ponds, and 15 drying season ponds in Central Raigad Region. The shapes of the pond in North Raigad Region was 6 square shaped ponds, 7 was rectangle shaped ponds and 2 irregular shaped ponds was observed.

Out of the 3 medium size farms were classified in to basis pond types as 26 numbers of sunken ponds and 2 diversion ponds observed in Central Raigad Region. According to use of the ground water source as 30 was rain water source ponds, 16 was pump-fed ponds. According to the drainage system of pond as 9 was undrainable ponds, 21 was drainable ponds. According to the construction materials as 28 number of ponds was earthen and 2 ponds was walled ponds was observed in Central Raigad Region. According to the construction method as 28 dug-out ponds and 2 embankment ponds was observed. According to use of the ponds as 19 nursery ponds, 11 grow-out pond, 30 numbers was drying season ponds was observed in Central Raigad Region. The shapes of the pond in Central Raigad Region was 3 square shaped ponds, 26 ponds were rectangle shaped whereas only one pond was irregular.

Out of only one large size farms were classified in to basis pond types as 2 ponds was sunken ponds was observed in Central Raigad Region. According to use of the ground water source were observed to be as 2 rain water source. According to the drainage system of pond as 2 number of ponds were undrainable. According to the construction materials as 2 ponds were earthen. According to the construction method as 2 dug-out ponds ponds observed. According to use of the pond as 2 number of ponds were used for nursery and 2 number of ponds was drying season ponds observed in Central Raigad Region. Only two numbers of square shape types ponds observed in Central Raigad Region.

Classification of small, medium and large size operational freshwater fish farms of Central Raigad Region, details are given in Table 4.8.

4.7 Design and engineering aspects of operational freshwater fish farms of Central Raigad Region

The ranges of small size farms area in Central Raigad Region were evaluated and it was ranged from 0.10 to 1.91 ha (0.88 ± 0.90), water spread area of farm was ranged from 0.05 to 0.98 ha (0.37 ± 0.46), number of ponds were ranged from 1 to 4 (2.14 ± 1.5).

The ranges of medium size farms of Central Raigad Region were evaluated and it was ranged from 2.02 to 2.94 ha (2.46 ± 0.46), water spread area of farm ranged from 1.21 to 1.95 ha (1.69 ± 0.36), number of ponds were ranged from 5 to 16 (9 ± 5.5).

Only one large size farms reported in Central Raigad Region and it was evaluated farm area of 20.04 ha (20.04 ± 0), water spread area of farm was 0.28 ha (0.28 ± 0) and 2 (2 ± 0) numbers of ponds were reported.

Design and Engineering aspects of small, medium and large size operational freshwater fish farms of Center Raigad Region are stated in Table 4.9 and their layout depicted in 4.4, 4.5, 4.6, 4.7 and in photographs 4.3, 4.4, 4.5; respectively.

4.7.1 Leading canal

In Central Raigad Region, no leading canal was observed because source of water available from tube well, open well and harvested rain water throughout the culture period.

4.7.2 Specifications of pond

In Central Raigad Region, the length and width of the ponds of small size farms ranged from 24.54 to 75 m (42.33 ± 25.23) and 16.48 to 62 m (32.16 ± 22.76); respectively. The water depth was found to be ranged from 1 to 2.1 m (1.63 ± 0.55). The pond area was ranged from 0.05 to 0.66 ha (0.18 ± 0.30) and water spread area of single pond was ranged from 0.03 to 0.62 ha (0.14 ± 0.29). The slope of pond bottom was observed as 1000:1 (1 ± 0) towards drainage side.

In Central Raigad Region, the length and width of the ponds under the medium size farms ranges from 8 to 143 m (45.82 ± 67.5) and 4 to 82.24 m (26.60 ± 39.12). The water depth was found to be 1 to 1.5 m (1.3 ± 0.25). The pond area was 0.001 to 1.74 ha (0.19 ± 0.87) and water spread area was 0.001 to 1.35 ha (0.13 ± 0.67).

In Central Raigad Region, the length and width of the ponds under the large size farms 43 m (42.5 ± 0.5) and 43 m (42 ± 0); respectively. The water depth was found to be 1.3 m (1.3 ± 0). The pond area was 0.18 ha (0.18 ± 0) and water spread area of single pond was ranged from 0.12 to 0.15 ha (0.13 ± 0.01). Bottom slope of pond on medium and large size farms not observed in Central Raigad Region.

4.7.3 Dikes

4.7.3.2 Peripheral dike

The peripheral dike act as protective barrier for the farm against flood and cyclone, also act as pathway for pond management. In Central Raigad Region, the top width of peripheral dike of ponds under small size farms ranged from 1 to 2 m (1.46 ± 0.5), side slope was ranged from 2:1 to 4:1(3.2 ± 1), free board was ranged from 0.3 to 1 m (0.50 ± 0.35) and total height was ranged from 1.3 to 3 m (2.14 ± 0.85). All peripheral dykes of small size farms were constructed with earthen soil. No stone pitching was adapted on all peripheral dikes of small size farms in Central Raigad Region.

In Central Raigad Region, the top width of peripheral dike of ponds under medium size farms ranged from 0.3 to 2 m (1.47 ± 0.85), side slope ranged from 2.5:0 to 3:0 (2.78 ± 0.25), free board was ranged from 0.3 to 0.7 m (0.48 ± 0.2) and total height was ranged from 1.3 to 2.2 m (1.78±0.45). All peripheral dykes of medium size farms were constructed with earthen soil. No stone pitching was adapted on all peripheral dikes of medium size farms in Central Raigad Region.

In Central Raigad Region, the top width of peripheral dike of ponds under large size farms was ranged from 1.5 to 5 m (2 ± 0), side slope was ranged from 3:0 to 3:0 (3 ± 0), free board was 0.3 m (0.3 ± 0) and total height was 1.6 m (1.6 ± 0).

4.7.3.2 Partition dike

In Central Raigad Region, the partition dikes are constructed to separate culture ponds. It was measured that the top width of partition dike of ponds under the small size farms ranged from 1 to 2 m (1.46 ± 0.5), side slope was ranged from 2:1 to 4:1 (3.2 ± 1), free board was ranged from 0.3 to 1 m (0.50 ± 0.35), total height was

ranged from 1.3 to 3 m (2.14 ± 0.85). No stone pitching recorded for partition dikes of small size farms.

In Central Raigad Region, the top width of medium size farm ponds partition dike ranged from 0.3 to 2 m (1.47 ± 0.85), side slope was ranged from 2.5:0 to 3:0 (2.78 ± 0.25), free board was ranged from 0.3 to 0.7 m (0.48 ± 0.2) and total height ranged from 1.3 to 2.2 m (1.78±0.45). No stone pitching was constructed for partition dikes of medium size farms.

In Central Raigad Region, the top width of the large size farm ponds of peripheral dike ranged from 1.5 to 5 m (2 ± 0). The side slope was 3:0 (3 ± 0), free board was 0.3 m (0.3 ± 0) and total height was 1.6 m (1.6 ± 0). Three ponds of one farm were lined with HDPE material sheet used for partition dike to prevent erosion in Central Raigad Region.

4.7.4 Drainage canal

It was noticed that the top width of the drainage canal was 1.5 m (1.5 ± 0) of medium size farms, bottom width was 1 m (1 ± 0), the depth was 1 m (1.5 ± 0) and bottom slope of drainage canal ratio was 1000:1 reported in Central Raigad Region.

Drainage canal was not observed in small and large size farms.

4.7.5 Drainage canal dike

In Central Raigad Region, the top width of the drainage canal dike under medium size farms was 1 m (1 ± 0), free board height was 0.5 m (0.5 ± 0).

4.7.6 Check tray scaffolding /Catwalk

In medium size fish farms of Central Raigad Region, catwalk was constructed with wooden material and check trays was constructed with iron rods. The length of the catwalk was ranged from 1.5 to 2.0 m (1.75 ± 0.25), width was ranged from 0.4 to 0.5 m (0.45 ± 0.05) and height was 2 m (2 ± 0).

4.7.7 Water supply system

4.7.7.1 Feeder canal

In Central Raigad Region supply of water observed threw open well, tube well and harvested rain water. Feeder canal was not observed.

4.7.7.2 Pipe

It was observed that the rain was the dominant source of water used for culture in Central Raigad Region and water was supplied through pipes. The material used for pipes HDPE, PVC, Galvanized and Cornaflex.

The inner diameter of the pipes of small size farms varies from 16.15 to 63.20 mm (39.67 ± 23.52) and wall thickness of pipe was ranged from 2.15 to 4.12 mm (3.13 ± 0.98). The water supply pipe was fitted with get valves and positioned at the beginning of the pipe.

The inner diameter of the pipes of medium size farms varies from 40.2 to 63.2 mm (51.7 ± 11.5) and wall thickness of pipes was ranged from 3.12 to 4.12 mm (3.62 ± 0.5). The water supply pipe was present with ball valves and positioned at the beginning of the pipe.

The inner diameter of the pipes of large size farms varies from 140.45 mm (average 140.45 ± 0) and wall thickness of pipes was 5 mm (5 ± 0).

4.7.8 Lining

The seepage rate was high and lining was applied on only one of the small size farms in Central Raigad Region. The thickness of the HDPE plastic liner was 0.3 mm (0.3 ± 0).

4.7.9 Main sluice gate

The main sluice gate was absent in medium size farms.

4.7.10 Sluice gate of the ponds

Sluice gate was observed on only one of the ponds under medium size farms in Central Raigad Region having 1m - width (1 ± 0), 1m - height (1 ± 0), number of grooves was 2 (2 ± 0), mesh size of the screen was 40 microns (40 ± 0), number of planks was 3 (3 ± 0) in Central Raigad Region.

4.7.11 Instruments and equipments

4.7.11.1 Hume pipe

For small size farms of Central Raigad Region, the diameter of hume pipe was 0.8 m (0.8 ± 0.0) and length of hume pipe was 5.7 m (5.7 ± 0).

On medium size farm, cemented hume pipes RCC were used in the drainage canal system containing 1.2 m diameter (1.2 ± 0) and 5.7m length (5.7 ± 0) in Central Raigad Region.

On large size farm, cemented hume pipes RCC were used in the drainage canal system containing 0.8 m - diameter (0.8 ± 0) and length was 2.5 m (2.5 ± 0) in Central Raigad Region.

4.7.11.2 Pump

Each small size farms of Central Raigad Region observed with only one pump for pumping water having capacity ranged from 1.5 to 5 HP (3 ± 2) with specifications Kirloskar make, Monoblock DF10 operated on electrical energy were as one farm reported pump operated with diesel fuel.

In Central Raigad Region, capacity of the pumps recorded from 3 to 5 HP (4 ± 1) Kirloskar make, Monoblock DF10 and three diesel pump were also used on medium size farms.

In Central Raigad Region of large size farms 10 HP (10 ± 0) capacity pump was installed. Only one pump of Kirloskar make of Monoblock DF10 were used.

4.7.11.3 Aerator

In Central Raigad Region aerator was not install on any operational fish farms because of less stocking density in ponds.

4.7.11.4 Check tray

In Central Raigad Region check tray was present on one medium size farm and square shaped check trays was used on farm. Length 1.5 m (1.5 ± 0), width 1.5 m (1.5 ± 0), mesh size of screen of check tray was 40 microns (40 ± 0) and made of iron rode.

4.7.11.5 Other equipments

Limited resource facilities such as 10 kg digital weighing balance, platform balance, spring balance were used on the farms for measurement of feed, weight of fish etc. Lack of other equipment's such as Sedgwick grafter, refractometer, secchi disc, DO meter, pH meter on Central Raigad Region.

4.7.11.6 Other infrastructure

A farms shed of average size 4 L×10W× 4H was utilized for accommodating feed, equipments, tillers, tools etc. The distribution of electrical energy was recorded threw electric transformer, electric meter, control panel, electrical appliances. Other equipment's and infrastructure of operational freshwater fish farms of Central Raigad Region depicted in table 4.10. One small size farm does not have approach road. Freshwater fish hatchery and diffuser tank facility not observed from Center Raigad Region.

4.8 Soil and water quality parameters of operational freshwater fish farms of Central Raigad Region

On small size farms soil quality parameters of operational freshwater fish farms of Central Raigad Region were analyzed. The parameters of the soil such as

moisture was ranged from 9 to 15 % (11.28 ± 3), pH ranged from 6.5 to 8 (7.04 ± 0.75), electric conductivity ranged from 1.25 to 3.32 dS/m (2.56 ± 1.03), water holding capacity ranged from 50.53 to 70.01 % (60.05 ± 9.73), bulk density ranged from 1.2 to 1.27 g/cm^3 (1.23 ± 0.03), seepage rate ranged from 2 to 7 cm/day (3.71 ± 2.5) and soil texture is sandy clay loam was analyzed and as shown in the Table 4.11. Water quality parameters such as salinity was 3 PSU (3 ± 0), temperature ranged from 27 to 29^{0}C (28.28 ± 1), pH ranged from 7.5 to 7.9 (7.65 ± 0.2), dissolve oxygen ranged from 4 to 5.5 mg/l (4.71 ± 0.75), ammonia ranged from 0 to 0.02 mg/l (0.02 ± 0), total alkalinity ranged from 100 to 140 mg/l (118.57 ± 20), total hardness ranged from 80 to 130 mg/l (108.57 ± 25), and transparency ranged from 30 to 45 cm (37.14 ± 7.5) were analyzed and resulted in the Table 4.12.

On medium size farms soil and water quality parameters of operational freshwater fish farms of Central Raigad Region were analyzed. The parameters of the cultured soil such as moisture ranged from 12 to 16 % (14 ± 2), pH ranged from 6.9 to 7.2 (7 ± 0.15), electric conductivity ranged from 2.13 to 3.52 dS/m (2.69 ± 0.69), water holding capacity ranged from 57 to 72.03 % (64.88 ± 7.51), bulk density ranged from 1.21 to 1.28 g/cm^3 (1.24 ± 0.03), seepage rate ranged from 2 to 4 cm/day (3 ± 1) and soil texture was sandy clay loam was analyzed and shown in the Table 4.11. Water quality parameters such as salinity was 6 PSU (6 ± 0), temperature ranged from 27 to 28^{0}C (27.66 ± 0.5), pH ranged from 7.5 to 7.8 (7.63 ± 0.15), dissolve oxygen ranged from 4.3 to 4.9 mg/l (4.6 ± 0.3), ammonia was 0.0 mg/l (0.00 ± 0), total alkalinity ranged from 110 to 140mg/l (130 ± 15), total hardness ranged from 70 to 140 mg/l (106.66 ± 35) and transparency ranged from 30 to 40 cm (36.66 ± 5) were analyzed.

On large size farms soil and water quality parameters of operational freshwater fish farms of Central Raigad Region were analyzed. The parameters of the soil such as moisture was 13 % (13 ± 0), pH 6.8 (6.8 ± 0), electric conductivity 2.13 dS/m (2.13 ± 0), water holding capacity 60 % (60 ± 0), bulk density 1.26 g/cm^3 (1.26 ± 0), seepage rate 3 cm/day (3±0) and soil texture was sandy clay loam was analyzed as shown in the Table 4.11. Water quality parameters such as salinity was 0 PSU (0 ± 0), temperature 29^0C (29 ± 0), pH was 7.7 (7.7 ± 0), DO 4.9 mg/l (4.9 ± 0), ammonia 0.00 mg/l (0.00 ± 0), total alkalinity 130 mg/l (130 ± 0), total hardness 130 mg/l (130 ± 0) and transparency 40 cm (40 ± 0) were analyzed.

Soil and water quality parameters of small, medium and large size operational freshwater fish farms of Central Raigad Region details are given in table 4.11 and 4.12.

4.9 Classification of operational freshwater fish farms of South Raigad Region

Out of the total 2 small size farms reported in South Raigad Region and classified the system of aquaculture on the basis of fish habitat were all farms was freshwater. further on the basis of economic consideration 2 farms were observed to be follow semi-intensive culture practices whereas on the basis of sex and especially adaptive fishes one farm was polyculture and one farm was monosex culture in South Raigad Region with warm climatic conditions. Out of the total 3 medium size farms reported in South Raigad Region and classified the system of aquaculture on the basis of fish habitat were all farms was freshwater. further on the basis of economic consideration 3 farms were observed to be follow semi-intensive culture practices and on the basis of sex and especially adaptive fishes as 3 farm was polyculture practices adapted with warm climatic conditions in South Raigad Region. Details are given in table 4.13.

In South Raigad Region, out of the total 2 small size farms were classified in to basis pond types as 7 diversion ponds was observed. According to use of the ground water source 6 numbers of seepage ponds, 7 numbers of rain water source ponds and 7 numbers of pump-fed ponds. According to the drainage system of pond 7 numbers of pond were pump-drained. According to the construction materials 14 ponds was stone pitched ponds earthen whereas only one pond was adapted to be earthen in South Raigad Region. According to the construction method as 6 numbers of pond was dug-out ponds, 1 cut-and-fill ponds/ counter ponds was observed in South Raigad Region. According to use of the ponds as 7 grow-out ponds, and 6 drying season ponds in South Raigad Region. The shapes of the pond in North Raigad Region was 6 square shaped ponds whereas only pond was rectangle shaped ponds as shown in the Table 4.13.

In South Raigad Region, out of the total 3 medium size farms were classified in to basis pond types as sunken ponds and 17 diversion ponds. According to use of the ground water source 9 ponds was rain water source, 11 ponds were indirectly supplied water by diversion ponds and 6 ponds was pump-fed. According to the drainage system of pond 3 ponds was undrainable, 11 drainable ponds and 6 number of ponds was pump-drained. According to the construction materials 20 ponds was earthen whereas only one pond was adapted to be stone pitching in South Raigad Region. According to the construction method as 20 number of pond was embankment ponds, 9 numbers of pond was dug-out ponds/, 11 cut-and-fill ponds/ counter ponds was observed in South Raigad Region. According to use of the ponds as 12 grow-out ponds,3 numbers of pond was bloodstock ponds and 20 drying season ponds in South Raigad Region. The shapes of the pond in South Raigad Region 18

numbers of pond was rectangle shaped ponds and 2 irregular shaped ponds was observed.

Large size farms were not observed throughout the area of South Raigad Region.

Classification of small and medium size operational freshwater fish farms of South Raigad Region details are given in Table 4.13.

4.10 Design and engineering aspects of operational freshwater fish farms of South Raigad Region

In South Raigad Region small size farms number of ponds ranged from 1 to 6 and one farm constructed with earthen soil and one farm constructed with stone pitching.

On medium size of farms, number ponds were ranged from 3 to 11 whereas one pond of fish farms was constructed with stone-pitching and other all pond of farms were earthen. Design and engineering aspects of small and medium size operational freshwater fish farms of South Raigad Region are as stated in Table 4.14 and their layouts are depicted in 4.8, 4.9, 4.10 and in Photographs 4.6, 4.7; respectively.

4.10.1 Leading canal

Top width of the leading canal was ranged from 1 to 6 m (3.5 ± 2.5), bottom width was ranged from 1 to 4 m (2.5 ± 1.5) whereas depth was ranged from 1 to 2 m (1.5 ± 0.5) observed in South Raigad Region of medium size farm.

4.10.2 Specifications of ponds

In South Raigad Region the length of the small size farm ponds ranged from 25 to 111 m (37.28 ± 43) and width of the ponds was ranged from 22 to 74 m (29.42 ± 26). The water depth was found to be ranged from 1.5 to 3 m (2.78 ± 0.75). The single

pond area was ranged from 0.05 to 0.72 ha (0.14 ± 0.33) and water spread area of single pond was 0.03 ha (0.03 ± 0). The pond bottom slope was provided with 1000:1 towards drainage side.

In South Raigad Region the length of the medium size farms ponds ranged from 25 to 140 m (56.68 ± 57.5) and width of the ponds was ranged from 9.27 to 91 m (26.51 ± 40.86). The water depth was found to be ranged from 1.5 to 2 m (1.62 ± 0.25). The single pond area was ranged from 0.05 to 0.55 ha (0.16 ± 0.25) and water spread area of single pond was ranged from 0.03 to 0.5 ha (0.13 ± 0.23). The pond bottom slope was provided with 1000:1 towards drainage side.

4.10.3 Dikes

4.10.3.1 Peripheral dike

The peripheral dike act as protective barrier for the farm against flood and cyclone, also act as pathway for pond management. Top width of the small size farm ponds peripheral dike ranged from 2 to 5 m (4.57 ± 1.5). The side slope ranged from 3:1 to 6:1 (5.57 ± 1.5) and free board was 1m (1 ± 0), total height was ranged from 2.5 to 4 m (3.78±0.75). Stone pitching was recorded inner areas of pond dikes of small size farms.

Top width of the medium size farm ponds peripheral dike ranged from 1.5 to 2 m (1.72 ± 0.25). The side slope ranged from 3:1 to 6:1 (3.5 ± 1.5) and free board was ranged from 0.4 to 1 m (0.66 ± 0.3), total height was ranged from 1.9 to 3 m (2.27±0.55). No stone pitching recorded for peripheral dikes of medium size farms.

4.10.3.2 Partition dike

Top width of partition dike of the small size farm ponds was 1 m (2.42 ± 1.5), side slope was ranged from 3:1 to 6:1 (5.57 ± 1.5), free board 1 m (1 ± 0) and total height was ranged from 2.5 to 4 m (3.78±0.75). One fish farm reported stone pitching

to partition dike. No plastic lining was adopted for partition dike for small fish farm of South Raigad Region.

Top width of the medium size farm ponds partition dike ranged from 1 to 2 m (1.29 ± 0.5), side slope ranged from 3:1 to 6:1 (3.5 ± 1.5) and free board was ranged from 0.4 to 1 m (0.66 ± 0.3), total height was ranged from 1.9 to 3 m (2.27±0.55). There was no stone pitching adapted for partition dike. Plastic lining for partition dike observed on one farm to prevent erosion of pond dike.

4.10.4 Drainage canal

Dimensions of the drainage canal at South Raigad Region for small size farms were: top width 1.5 m (1.5 ± 0), bottom width 1 m (1 ± 0), depth 1 m (1 ± 0), slope was 1000:1 (1 ± 0).

4.10.5 Drainage canal dike

Dimensions of drainage canal dike at South Raigad Region for small size farm were: top width 1 m (1 ± 0) and free board height 0.3 m (0.3 ± 0).

4.10.6 Check tray scaffolding /Catwalk

From small size fish farms of South Raigad Region, catwalk was constructed with wooden material and check trays was constructed with iron rods**.** The length of the catwalk was 15 m (15 ± 0), width 0.5 m (0.5 ± 0) and the height from the pond bottom was 3.5 m (3.5 ± 0).

4.10.7 Water supply system

4.10.7.1 Feeder canal

In small size fish farms of South Raigad Region, the top width was 0.5 m (0.5 ± 0), bottom width was 0.5 m (0.5 ± 0) and depth was 1 m (1 ± 0).

From medium size fish farms of South Raigad Region, the top width was ranged from 0.5 to 1.5 m (1 ± 0. 5), bottom width was ranged from ranged from 0.3 to 0.5 m (0.4 ± 0.1) and depth was 0.5 m (0.5 ± 0).

4.10.7.2 Pipe

Various materials such as PVC/HDPE/Cornaflex pipes used for pumps for small size farms from South Raigad Region. The ID of the pipe was ranged from 40.20 to 140.45 mm (90.32 ± 50.12) and wall thickness was ranged from 3.25 to 5 mm (4.12 ± 0.87). Gate valve was provided for each line for controlling flow of water toward pond.

For medium size farms of South Raigad Region, similar material PVC/Cornaflex/HDPE flexible was used. The ID of the pipe was ranged from 50.20 to 140.45 mm (95.32 ± 45.12) and wall thickness was ranged from 3.7 to 5.6 mm (4.65 ± 0.95). Gate valve was provided for each line for controlling flow of water toward pond.

4.10.8 Lining

No any lining was adopted for all freshwater farms of South Raigad Region.

4.10.9 Main sluice gate

Two small size farms were recorded from South Raigad Region, out of one fish farms was equipped with main sluice gate. Iron metal plate was utilized for opening and closing of main sluice gate to distribute water threw feeder canal system. The dimensions of sluice gate were length 3 m (3 ± 0), height 1m (1 ± 0) and width 1 m (1 ± 0).

Three medium size farms were observed from South Raigad Region. One fish farm was equipped with two main sluice gate for one feeder canal. Sluice gate constructed with iron sheet to distribute water threw feeder canal system. The

dimensions of sluice gate were length 5 m (5 ± 0), height 1 m (1 ± 0), and width 1 m (1 ± 0).

4.10.10 Sluice gate of the ponds

No sluice gate for individual culture ponds were observed from South Raigad Region.

4.10.11 Instruments and equipments

4.10.11.1 Hume pipe

One small size farm from South Raigad Region constructed with hume pipe for drainage purpose. The dimensions of hume pipe were diameter 1.2 m (1.2 ± 0) and length was 5.7 m (5.7 ± 0).

For drainage purpose hume pipe was adopted on one medium size farm. The dimensions were recorded diameter 0.8 m (0.8 ± 0) and length of 2.5 m (2.5 ± 0).

4.10.11.2 Pump

In South Raigad Region for small size farms capacity of the pump was ranged from 3 to 5 HP (3 ± 1) and number of pumps were ranged from 1 to 2 (1.5 ± 0.5) electric pump Kirloskar make of Monoblock DF10 and diesel pump were used.

In South Raigad Region for medium size farms pump capacity were observed ranged from 5 to 10 HP (7.51 ± 2.5) and number of pumps was 2 (2 ± 0) of Kirloskar make of Monoblock DF10 and diesel pump were used.

4.10.11.3 Aerator

Aerator was not used for aeration in rearing and cultured ponds from operational fish farms from South Raigad Region.

4.10.11.4 Check tray

In South Raigad Region feed was broadcasted threw pond dykes. No any check tray was reported on any operational fish farms of South Raigad Region.

4.10.11.5 Other equipments

Weighing with 10 kg capacity commonly utilized on all operational farms and recorded other equipment are shown in the Table 4.15. Lack of other equipments such as secchi disc, refractometer, DO meter, Sedgwick grafter, pH meter was observed from all farms South Raigad Region.

4.10.11.6 Other infrastructure

One medium size farm observed with Eco-carp hatchery unit and diffuser tank from South Raigad Region. The details of Eco-carp hatchery unit such as outer chamber diameter 3.6 m (3.6 ± 0), inner chamber diameter 1.6 m (0.8 ± 0), water height 1 m (1 ± 0), free board height 0.2 m (0.2 ± 0), total height 1.2 m (1.2 ± 0). The basic infrastructure on site of South Raigad Region was observed on various farms. Tar roads were available for all farms to connect ourbon areas. Each farm was equipped with farms shed and space was utilized for multipurpose such as storage of feed, holding of small equipment's, harvesting materials, temporary accommodation etc. The distribution of electrical energy recorded threw electric transformer, electric meter, control panel, electrical appliances.

Other equipment's and infrastructure of operational freshwater fish farms of South Raigad Region depicted in table 4.15.

4.11 Soil and water quality parameters of operational freshwater fish farms of South Raigad Region

The soil quality parameters of operational freshwater fish farms of the small size farms from South Raigad Region were analyzed. The parameters of the soil such as moisture ranged from 10 to 12 % (11 ± 1), pH ranged from 6.8 to 7.1 (6.95 ± 0.15), electric conductivity ranged from 1.26 to 2.92 dS/m (2.09 ± 0.82), water holding capacity ranged from 52.49 to 62.3 % (57.39 ± 4.9), bulk density ranged from 1.22 to

1.27 g/cm^3 (1.24 ± 0.02), seepage rate ranged from 3 to 6 cm/day (4.5±1.5) and soil texture was sandy loam and loamy sand was analyzed as shown in the Table 4.16. Water quality parameters such as salinity was 00 PSU (0 ± 0), temperature ranged from 28 to 29^0 C (28.5 ± 0.5), pH ranged from 7.6 to 7.8 (7.7 ± 0.1), dissolve oxygen ranged from 4.1 to 4.7 mg/l (4.4 ± 0.3), ammonia was 0.00 mg/l (0.0 ± 0), total alkalinity ranged from 110 to 130 mg/l (120 ± 10), total hardness 110 mg/l (110 ± 0) and transparency ranged from 30 to 40 cm (35.5 ± 5) were analyzed and shown in the Table 4.17.

The soil quality parameters of operational freshwater fish farms of the medium size farms from South Raigad Region were analyzed. The parameters of the soil such as moisture was ranged from 11 to 13 % (12 ± 1), pH ranged from 7.2 to 7.5 (7.36 ± 0.15), electric conductivity ranged from 1.12 to 2.42 dS/m (1.88 ± 0.65), water holding capacity ranged from 55.94 to 60.8 % (57.58 ± 2.43), bulk density ranged from 1.24 to 1.26 g/cm^3(1.25 ± 0.01), seepage rate ranged from 4 to 5 cm/day (4.33 ± 0.5) and soil texture sandy loam and loamy sand were analyzed and shown in the Table 4.16. Water quality parameters such as salinity was 00 PSU (0 ± 0), temperature ranged from 28 to 29^0 C (28.66 ± 0.5), pH ranged from 7.4 to 7.7 (7.56 ± 0.15), dissolve oxygen ranged from 4 to 5 mg/l (4.66 ± 0.5), ammonia ranged from 0 to 0.01 mg/l (0.01 ± 0), total alkalinity ranged from 120 to 130 mg/l (123.33 ± 5), total hardness ranged from 90 to 130 mg/l (113.33 ± 20) and transparency ranged from 30 to 40 cm/day (33.33 ± 5) were resulted in the Table 4.17.

Soil and water quality parameters of small, medium and large size operational freshwater fish farms of South Raigad Region details are given in table 4.16 and 4.17.

4.12 Classification of operational freshwater fish farms of Raigad district

Out of the total 18 small size farms observed in Raigad district and classified the system of aquaculture on the basis of fish habitat were all farms was freshwater. Further on the basis of economic consideration 17 farms were observed to be follow semi-intensive culture practices whereas one farm was extensive fish farm in Raigad district. Based on sex and especially adaptive fishes 14 farms and 4 farms reported monosex culture practice with warm water climatic conditions was observed in Raigad district. Out of the total 6 medium size farms observed in Raigad district and classified the system of aquaculture on the basis of fish habitat were all farms was freshwater. Further on the basis of economic consideration 6 farms were observed to be follow semi-intensive. Based on sex and especially adaptive fishes as 5 farms was polyculture whereas one farms were monosex culture and all farms climatic conditions was warm in Raigad district. Out of the total 4 large size farms observed in Raigad district and classified the system of aquaculture on the basis of fish habitat were all farms was freshwater. Further on the basis of economic consideration 4 farms were observed to be follow semi-intensive. Based on sex and especially adaptive fishes as 3 farms was polyculture whereas one farms were monosex culture and all farms climatic conditions was warm in Raigad district.

In Raigad district, out of the total 18 small size farms were classified in to basis pond types as 28 sunken ponds and 11 diversion ponds whereas only one pond was barrage pond. According to use of the ground water source 4 ponds was spring water source ponds, 10 seepage ponds, 31 ponds was rain water source and 13 ponds was pump-fed. According to the drainage system of pond 12 ponds was undrainable, 8 drainable ponds and 21 number of ponds was pump-drained. According to the construction materials 33 ponds was earthen, 6 ponds was stone pitched whereas only

one pond was adapted to be plastic liner in Raigad district. According to the construction method as 36 numbers of pond was dug-out ponds, 4 cut-and-fill ponds/ counter ponds was observed in Raigad district. According to use of the ponds as 38 grow-out ponds and 39 drying season ponds in Raigad district. The shapes of the pond in Raigad district was 12 square shaped ponds, 21 was rectangle shaped ponds and 7 irregular shaped ponds was observed.

In Raigad district, out of the total 6 medium size farms were classified in to basis pond types as 29 sunken ponds and 19 diversion ponds. According to use of the ground water source 11 ponds was water supply indirectly by diversion ponds, 39 ponds was rain water source and 22 ponds water fed by pump. According to the drainage system of pond 12 ponds were undrainable, 32 drainable ponds and 6 number of ponds was pump-drained. According to the construction materials 48 ponds were earthen, 2 wall ponds whereas only one pond was stone pitched in Raigad district. According to the construction method as 37 numbers of pond was dug-out ponds, 11 cut-and-fill ponds/ counter ponds was observed in Raigad district. According to use of the ponds as 27 ponds were used for nursery, 23 for grow-out ponds, 3 pond for used for bloodstock and 50 ponds drying season ponds in Raigad district. The shapes of the pond in Raigad district was 3 square shaped ponds, 44 was rectangle shaped ponds and 3 irregular shaped ponds was observed.

In Raigad district, out of the total 4 large size farms were classified in to basis pond types as 16 sunken ponds and 15 diversion ponds whereas only one pond was barrage pond. According to use of the ground water source 2 ponds was water supply directly by barrage ponds. According to use of the ground water source as 2 spring-water source ponds, 32 ponds was rain water source and 2 ponds water fed directly by barrage pond. According to the drainage system of pond 27 ponds were undrainable, 3

drainable ponds and 2 number of ponds was pump-drained. According to the construction materials 30 ponds were earthen, 2 ponds were adapted to be plastic liner in Raigad district. According to the construction method as 28 numbers of pond was dug-out ponds, 4 cut-and-fill ponds/ counter ponds was observed in Raigad district. According to use of the ponds as 28 ponds were used for nursery, 4 grow-out ponds, 33 ponds drying season ponds whereas reported one farm was bloodstock, storage ponds(marketing) and fattening pond were observed in Raigad district. The shapes of the pond in Raigad district were 9 square shaped ponds, 21 rectangle shaped ponds and 2 irregular shaped ponds was observed in Raigad district.

Classification of small, medium and large size operational freshwater fish farms of Raigad district shown in the Table 4.18.

4.13 Design and engineering aspects of operational freshwater fish farms of Raigad district

Area of operational freshwater small size farms of Raigad district ranged from 0.10 to 1.91 ha (0.88 ± 0.90), water spread area of the farm ranged from 0.05 to 1.24 ha (0.46 ± 0.59) and number of ponds ranged from 1 to 6 (2.16 ± 2.5).

In Raigad district, the medium size operational freshwater fish farm area was ranged from 2.02 to 4.0 ha (2.83 ± 0.99), water spread area of farm was ranged from 0.6 to 1.95 ha (1.22 ± 0.67) and number of ponds ranged from 3 to 16 (7.66 ± 6.5).

In Raigad district, the large size operational freshwater fish farms area ranged from 7.05 to 22.25 ha (15.37 ± 7.60), water spread area of the farm was ranged from 0.27 to 4.30 ha (1.68 ± 2.01) and number of ponds ranged from 2 to 25 (8 ± 11.5).

Design and engineering aspects of small, medium and large size operational freshwater fish farms of Raigad district details are given in Table 4.19.

4.13.1 Leading canal

In Raigad district, medium size operational freshwater fish farms reported top width of leading canal ranged from 1 to 6 m (3.5 ± 2.5), bottom width was ranged from 1 to 4 m (2.5 ± 1.5) and depth of the leading canal was ranged from 1 to 2 m (1.5 ± 0.5).

In small and large size farms in Raigad district were leading canal not reported.

4.13.2 Specifications of pond

In Raigad district, the small size operational freshwater fish farms the length of ponds were observed ranged from 13 to 118 m (50.98 ± 52.5), width of ponds ranged from 8 to 74 m (35.17 ± 33), water depth of ponds ranged from 1 to 3 m (1.79 ± 1), pond area ranged from 0.01 to 0.84 ha (0.24 ± 0.41), water spread area of cultured ponds ranged from 0.01 to 0.68 ha (0.17 ± 0.33) and bottom slope was 1000:1 (1 ± 0).

The medium size operational freshwater fish farms of Raigad district the length of ponds was ranged from 8 to 143 m (50.25 ± 67.5), width of ponds ranged from 4 to 91 m (26.56 ± 43.5), pond water depth ranged from 1 to 2 m (1.43 ± 0.5), pond area ranged from 0.001 to 1.74 ha (0.18 ± 0.87), water spread area ranged from 0.001 to 1.35 ha (0.13 ± 0.67) and bottom slope was 1000:1 (1 ± 0).

In Raigad district, the large size operational freshwater fish farms, the length of ponds was observed ranged from 16.16 to 68 m (35.06 ± 25.92), width of ponds ranged from 12.6 to 55.6 m (24.50 ± 21.5), pond water depth ranged from 1 to 5 m (1.61 ± 2), pond area ranged from 0.02 to 6.84 ha (0.30 ± 3.40), water spread area of cultured ponds ranged from 0.01 to 3.61 ha (0.17 ± 1.80) and bottom slope was ranged from 1000:0.6 to 1000:5 (2.06 ± 4.4).

4.13.3 Peripheral dike

In Raigad district, the small size operational freshwater fish farms the top width was ranged from 1 to 5 m (2.12 ± 2), side slope was ranged from 2:1 to 8:1 m (3.64 ± 3), free board was ranged from 0.3 to 1.2 m (0.68 ± 0.45) and total height of peripheral dike ranged from 1.3 to 4 m (2.47 ± 1.35).

The medium size fish farms top width was ranged from 0.3 to 2 m (1.57 ± 0.85), side slope ranged from 2.5:1 to 6:1 m (3.08 ± 1.75), free board ranged from 0.3 to 1 m (0.50 ± 0.35) and total height of peripheral dike ranged from 1.3 to 3 m (1.98 ± 0.85) in Raigad district.

The large size fish farms top width was ranged from 1.5 to 5 m (2.06 ± 1.75), side slope ranged from 2:0.6 to 10:5 m (3.31 ± 4), free board ranged from 0.3 to 1 m (0.72 ± 0.35) and total height of peripheral dike ranged from 1.4 to 6 m (2.39 ± 2.3) in Raigad district.

4.13.4 Partition dike

In Raigad district, the small size operational freshwater fish farms top width was ranged from 1 to 5 m (1.66 ± 2), side slope ranged from 2:1 to 8:1 m (3.64 ± 3), free board ranged from 0.3 to 1.2 m (0.68 ± 0.45) and total height of partition dike ranged from 1.3 to 4 m (2.47 ± 1.35).

The medium size fish farms top width was ranged from 0.3 to 2 m (1.11 ± 0.85), side slope ranged from 2.5:1 to 6:1 m (3.08 ± 1.75), free board ranged from 0.3 to 1 m (0.50 ± 0.35) and total height of partition dike ranged from 1.3 to 3 m (1.98 ± 0.85).

The large size fish farms top width was ranged from 0.4 to 2.75 m (1.23 ± 1.17), side slope ranged from 2:0.6 to 10:5 m (3.31 ± 4), free board ranged from 0.3 to

1 m (0.72 ± 0.35) and total height of partition dike ranged from 1.4 to 6 m (2.39 ± 2.3).

4.13.5 Drainage canal

In Raigad district, the dimensions of small size operational freshwater fish farms were the top width of drainage canal ranged from 1.5 to 2 m (1.6 ± 0.1), bottom width ranged from 0.8 to 1.2 m (1.03 ± 0.23), depth ranged from 0.9 to 1.5 m (1.23 ± 0.33), slope was 1000:1 (1 ± 0).

4.13.6 Drainage canal dike

The dimensions of the drainage canal dike of small size operational freshwater fish farms were the top width ranged from 1 to 1.3 m (1.2 ± 0.2) and free board of drainage canal dike was ranged from 0.3 to 0.5 m (0.36 ± 0.06).

4.13.7 Check tray scaffolding/ Catwalk

In Raigad district, on small size farms length of catwalk was 15 m (15 ± 00), width 0.5 m (0.5 ± 0.0) and height from pond bottom of the catwalk was 3.5 m (3.5 ± 0.0).

The dimensions of medium size farms catwalk length were ranged from 1.5 to 2.0 m (1.75 ± 0.25), width ranged from 0.4 to 0.5 m (0.45 ± 0.05) and height from pond bottom of the catwalk was 2 m (2 ± 0).

4.13.8 Demand feeder

From small size farms the dimensions of demand feeder were: length 0.3 m (0.3 ± 0), width 0.3 m (0.3 ± 0) and height 0.45 m (0.45 ± 0).

4.13.9 Water supply system

4.13.9.1 Feeder canal

In Raigad district, the small size farm feeder canal top width 0.5 m (0.5 ± 0), bottom width 0.5 m (0.5 ± 0) and depth 1 m (1 ± 0).

The medium size farm feeder canal top width ranged from 0.5 to 1.5 m (1 ± 0), bottom width ranged from 0.3 to 0.5 m (0.4 ± 0.1) and depth was 0.5 m (0.5 ± 0).

Top width of the large size farm feeder canal was 1 m (1 ± 0), bottom width was 0.8 m (0.8 ± 0) and depth was 1 m (1 ± 0) in Raigad district.

4.13.9.2 Pipe

In Raigad district, the small size of farms inner diameters of pipe ranged from 16.15 to 140.45 mm (60.56 ± 62.15) and wall thickness was ranged from 2.15 to 5 mm (4 ± 1.85).

The medium size of farms inner diameters of pipe ranged from 40.2 to 140.45 mm (73.51 ± 50.12) and wall thickness was ranged from 3.12 to 5.6 mm (4.13 ± 0.01) in Raigad district.

The large size of farms inner diameters of pipe ranged from 40.2 to 140.45 mm (107.03 ± 50.12) and wall thickness 3.25 to 5 mm (4.12 ± 0.87) in Raigad district.

4.13.10 Lining

In Raigad district, for small size farms HDPE lining was applied and thickness was 0.3 mm (0.3 ± 0).

For large size farms HDPE lining was applied and thickness was 0.5 mm (0.5 ± 0) in Raigad district.

4.13.11 Main sluice gate

In Raigad district small size of farms, the number of sluice gate was 1 (1 ± 0), length ranged from 2 to 3 m (2.5 ± 0.5), height was ranged from 1 to 2 m (1.5 ± 0.5) and width of main sluice gate was 1 m (1 ± 0).

The medium size of farms, the number of sluice gate was 2 (2 ± 0), length 5 m (5 ± 0), height was 1 m (1 ± 0) and width of main sluice gate was 1 m (1 ± 0).

4.13.12 Sluice gate of the ponds

In Raigad district for small size farms, the total number of sluice gate adopted 1 (1 ± 0) and its details were: width 1 m (1 ± 0), height 3 m (3 ± 0), number of grooves 2 (2 ± 0), number of planks was 4 (4 ± 0), screen size was 2.5 m x 1 m (l × h) and mesh size of the screen 60 microns (60 ± 0).

For medium size farm, the number of sluice gate was observed 1 (1 ± 0), width 1 m (1 ± 0), height 1 m (1 ± 0), number of grooves 2 (2 ± 0), mesh size of the screen 40 microns (40 ± 0) and number of planks were 3 (3 ± 0) and dimensions of the screen was 1 Length × 1 W.

4.13.13 Instruments and equipment's

4.13.13.1 Hume pipe

For small size farms of Raigad district, the average diameter of hume pipe was 0.8 to 1.2 m (1 ± 0.2) and length of hume pipe was 5.7 m (5.7 ± 0).

The medium size farms, the diameter of hume pipe was ranged from 0.8 to 1.2 m (1 ± 0.2) and length was ranged from 2.5 to 5.7 m (4.1 ± 1.6) in Raigad district.

In Raigad district The diameter of hume pipe was 0.8 m (0.8 ± 0) and length was 2.5 m (2.5 ± 0) of hume pipe for large size farms.

4.13.13.2 Pump

In Raigad district small size farms, the pump was utilized with a capacity of 1.5 to 5 HP (3.37 ± 1.75) whereas the only one pump on each farms.

The medium size of farms, the pump was used with a capacity of 3 to 5 HP (4 ± 1) whereas the number of pump was 1 (1 ± 0) on each farms.

The large size of farms, the pump capacity was ranged from 5 to 10 HP (7.5 ± 2.5) whereas the number of pump was 1 (1 ± 0) on each farms.

4.13.13.3 Aerator

On large size of farms of Raigad district, the aerator was used with a capacity of 2 HP (2 ± 0) whereas the number of aerators was ranged from 1 to 2 (1.5 ± 0.5).

4.13.13.4 Other infrastructure

. In Raigad district only one operational freshwater fish hatchery was recorded (Eco-carp hatchery) on medium size farm during sampling period and details such as outer chamber diameter 3.6 m (3.6 ± 0), inner chamber diameter 1.6 m (1.6 ± 0), water height 1 m (1 ± 0), free board height 0.2 m (0.2 ± 0), total height 1.2 m (1.2 ± 0).

4.14 Soil and water quality parameters of operational freshwater fish farms of Raigad district

In Raigad district small size farms, soil and water quality parameters of operational freshwater fish farms were analyzed. Range of soil quality parameters and its average such as moisture were 9 to 15 % (11.66 ± 3), pH 6.5 to 8 (7.05 ± 0.75), electric conductivity 1.25 to 3.55 dS/m (2.58 ± 1.14), water holding capacity 50.53 to 72 % (62.96 ± 10.73), bulk density 1.2 to 1.29 g/cm^3 (1.24 ± 0.04), seepage rate 2 to 7 cm/day (3.61 ± 2.5) and sandy clay loam, sandy loam and loamy sand soil texture was resulted and shown in the Table 4.20. Ranges and its average of water quality parameters such as salinity 3 to 4 PSU (3.5 ± 0.5), temperature 27 to 30^{0}C (28.33 ± 1.5), pH 7.4 to 8 (7.7 ± 0.3), dissolve oxygen 4 to 5.6 mg/l (4.6 ± 0.8), ammonia 0 to 0.02 mg/l (0.02 ± 0), total alkalinity 100 to 140 mg/l (118.33 ± 20), total hardness 70 to 130 mg/l (105.55 ± 30), and transparency 30 to 45 cm (35.55 ± 7.5) were analyzed. The results are shown in the Table 4.21.

The medium size farms of Raigad district, soil and water quality parameters of operational freshwater fish farms were analyzed. The range of soil parameters and its

average such as moisture 11 to 16 % (13±2.5), pH 6.9 to 7.5 (7.18 ± 0.3), electric conductivity 1.12 to 3.52 dS/m (2.29 ± 1.19), water holding capacity 55.94 to 72.03 % (61.23 ± 8.04), bulk density 1.21 to 1.28 g/cm^3 (1.24 ± 0.03), seepage rate 2 to 5 cm/day (3.66 ± 1.5), soil texture was sandy loam and loamy sand were analyzed and depicted in the Table 4.20. Ranges of water quality parameter and its average such as salinity were 6 PSU (6 ± 0), temperature 27 to 29^{0}C (28.16 ± 1), pH 7.4 to 7.8 (7.6 ± 0.2), dissolve oxygen 4 to 5 mg/l (4.63 ± 0.5), ammonia 0 to 0.01 mg/l (0.01 ± 0), total alkalinity 110 to 140 mg/l (126.66 ± 15), total hardness 70 to 140 mg/l (110 ± 35), transparency 30 to 40 cm (35 ± 5) were analyzed. The results obtained and shown in the Table 4.21.

The large size farms of Raigad district, soil and water quality parameters of operational freshwater fish farms were analyzed. Ranges of soil parameters and its average such as moisture 11 to 16 % (13 ± 2.5), pH 6.1 to 7.1 (6.7 ± 0.5), electric conductivity 2.13 to 3.56 dS/m (2.67 ± 0.71), water holding capacity 54.85 to 61.57 % (57.85 ± 3.35), bulk density 1.24 to 1.27 g/cm^3 (1.25 ± 0.01), seepage rate 3 to 4 cm/day (3.33 ± 0.5), soil texture was clayey and sandy clay were analyzed and as shown in the Table 4.20. Range and average of water quality parameters such as salinity were 5 PSU (5 ± 0), temperature 28 to 29^{0}C (28.75 ± 0.5), pH 7.5 to 7.7 (7.62 ± 0.1), dissolve oxygen 4.5 to 4.9 mg/l (4.67 ± 0.2), ammonia 0 to 0.01 mg/l (0.01 ± 0.00), total alkalinity 110 to 130 mg/l (117.5 ± 10), total hardness 100 to 130 mg/l (112.5 ± 15), transparency 30 to 40 cm (35 ± 5) were analyzed and shown in the Table 4.20.

Soil and water quality parameters of small, medium and large size operational freshwater fish farms of Raigad district details are given in table 4.20 and 4.21.

4.15 Fish farming

The various aspects of fish farming were studied from Raigad districts such as pre-stocking management, seed stocking, feeding, sampling and harvesting were carried out from all operational freshwater fish farms of Raigad district.

4.15.1 Biosecurity

Biosecurity plans are needed to be feet for purpose and balance practicality, cost and regulatory requirements, ultimately, the propose biosecurity precise should improve the biology, operational and economic performance of your form. Good biosecurity practice should be as simple and low cost as possible to achieve the desired outcomes. Ultimately, biosecurity plan should be viewed as insurance, and as such, require both financial and intellectual investment as well as commitment.

4.15.2 Animal fencing

Animal fencing was necessary, because amphibious and terrestrial animals such as frog, crab, otter, dogs, cattle and cats can mechanically carry contamination virus from one pond to another. Preventing entry of animals and unauthorized personnel into the farming area through fencing is the only way to address this problem.

4.15.3 Bird fencing

Bird fencing was necessary, because bird negatively affect fish production by transmitting or transporting disease, weed seed and parasites from pond to pond or from one facility to another. material used for bird fencing was monofilament (nylon), Polypropylene (pp) multi filaments and plastics bags attached to rope used by fish farmers.

4.15.4 Drying and Ploughing

In pre-stocking management drying and ploughing was observed in all operational freshwater fish farms of Raigad district. The duration of the drying period ranged from 15 to 30 days and ploughing duration was observed from 5 to 12 days.

4.15.5 Liming

Liming was done before 6 days stocking of spawn/fry of fish in the pond for supply calcium which is important nutrient and liming also improve the pH of soil. Liming was done with dolomite, agricultural lime dose was given was 250 kg/ha. pond.

4.15.6 Bleaching

After pond filling with water; disinfection was carried using bleaching powder. This bleaching powder was applied with 300 to 350kg /ha.to raise the chlorine concentration up to 50 to 100 ppm.

4.15.7 Fertilization

Fertilization was done to improve natural fertility and minerals in ponds. It was carried out with the help of urea, single super phosphate (SSP), rice bran, yeast, jagerry and ground nut oil cake (GOC) in all operational freshwater fish farms of Raigad. Doses was adopted urea @ 50 kg/ha, cow dung @ 200 kg/ha, GOC @ 375 to 700 kg/ha, SSP @ 300 kg/ha.

4.15.8 Seed stocking

The seed of common carp was usually procured from Kharland Research Station, Panvel available for North Raigad Region and all over the Maharashtra, in Center Raigad Region seed was availled from Hans AquaFarms Pvt. Ltd., Kolad. In South Raigad Region seed was availed at Shramajivi Carp Hatchery, Mahad. Carp stocking density was 0.5 to 1 milions of spawn or fry was stocked. Stocking density

for Monosex tilapia (*Oriochromiss niloticus)* was observed 20000 to 25000 /ha and seed was procured from West Bengal, Orissa, Andhra Pradesh and Tripura. *Latus calcarifer* seed was procured from local areas (wild seed) of Raigad district 1000 to 2000 fry/ ha and stocked with tilapia and IMC.

4.15.9 Feeding

In Raigad district, manual method of feed broadcasting as per the body weight was undertaken two times per day. Feeding was carried by using raft which was made with FRP material, thermacol, puff and wooden planks also fabricated to form raft. Artificial feed was availed from Grovel Feeds Pvt Ltd. The average size of feed pellets was 2.5 to 4 mm with protein concentration of 24%, 28%, fat; 4% and weight of each bag was 35 kg. Godrej Agro vet Ltd. (NutriFry) the pellets feed size was recorded 1mm to 2 mm with protein concentration of 32 %, 34 %, 36 % and fat 5%, 4%. SAKTI brand feed was also reported with protein concentration 20 %, fat 3% and weight of each bag was 20 kg/Bag. Feed for all farms was applied manually as per as body weight of cultured fishes.

4.15.9.1 Feeding ring

In Raigad district, fish feeding ring was observed in square shaped and circular shaped feeding ring adapted on few farms of culture practices for feeding purposes.

4.15.10 Sampling and harvesting

Sampling was carried using cast net after the 10 to 15 days of interval time. After 2 to 4 months partial harvesting was adopted using cast net and dragnet. Complete harvesting was carried before summer season using gravity force/ pumps to drain the water.

4.15.10.1 Cast net

All over Raigad district, the diameter of cast nets was observed 3 to 12 m and mesh size was 20 to 40 mm. But farmer's also fabricating their own cast net as per their requirements.

4.15.10.2 Drag net

In all Raigad district dragnet length was 20 to 50 m and height was 3 to 5 m. Size of dragnet used for harvesting depends on culture pond area and depth of water. Many farmers were fabricating their own dragnets as per their requirements.

5.0 DISCUSSION

The whole future of success of aquaculture enterprise depends on the selection of a good site for fish farm. The layout and the management of farms will largely be influenced by the kinds of site selection of an ideal site, layout, design and construction etc. The choice of construction materials essentially depends on their suitability, their local availability and the amount of money to invest (Coche and Muir, 1995).

The main objective of the present research to study the layout, design and engineering aspects of operational freshwater fish farms of Raigad district, Maharashtra

which helps to generate standard data inputs for soil and water 'Health Cards'. The studied data of soil and water parameters will be helpful for freshwater fish farmers of Raigad district for increasing inland aquafarming. The layout, design, engineering aspects, soil and water quality parameters has been discussed in the following sessions.

5.1 Classification of operational freshwater fish farms of Raigad district

The classification of operational freshwater fish farms of Raigad district is given in Table 4.18. This study was carried out on the 28 fish farms from entire Raigad district. All freshwater farms were categorized in small, medium and large size farms. These operational fish farm were further classified on the basis of economic consideration such as extensive and semi-intensive aquafarms. On the basis of sex, they were classified into polyculture and monosex culture aquafarm. Similar classification was stated by Mishra and Dora (2015). NSPFS (2005) classified aqua farming into extensive, semi-intensive and intensive farming; while Carballo *et al.* (2008) classified them as extensive, semi-intensive and intensive fish farming.

In present study of Raigad district small, medium and large size farm ponds were classified on the basis of basic pond types such as sunken ponds, barrage ponds, diversion ponds; respectively and result are given in Table 4.18. Operational fish farm ponds were further classified on the basis of water sources such as spring-water source ponds, seepage ponds, rain water source ponds and other water body resources provided directly, indirectly or by pumps. The ponds were also classified on the basis of pond drainage system such as undrainable ponds, drainable ponds and pump-drained ponds. On the basis of construction materials, they were classified as earthen ponds, walled ponds, stone pitched ponds and lining ponds; while on the basis of construction method such as dug-out ponds, embankment ponds and cut-and-fill ponds. According to the use of the ponds theeey were refereed as nursery ponds, grow-out ponds, brood ponds, storage ponds, fattening ponds and drying season ponds. As per the shape such as square shape ponds, rectangle shape ponds and irregular shape ponds. Similar classification was stated by Coche and Muir (1995). NSPFS (2005) also differentiated various types of diversion pond like embankment, excavated, partially excavated pond and barrage ponds. Pillay and Kutty (2005) have given greater preference to the square shaped ponds with respect to the cost of construction. In this study the observed ponds were rectangular shapes, which are beneficial for fish culture practices. Similarly, rectangular shape ponds were described by Carballo *et al.* (2008) and suggested that rectangular or square shape ponds are best and easiest to build for freshwater fish farming.

5.2 Design and engineering aspects of operational freshwater fish farms of Raigad district

5.2.1 Site selection

In this study topography of various farms from three different Raigad regions were recorded such as plain, slightly sloping and hilly area with good water source from the rivers, irrigation dams, reservoirs, tube wells, open wells and seepage water resource was available. Chandrakant (2003) explained the importance of various site parameters like ground water resources (spring, stream, reservoir), surface water resource (wells, rivers) and miscellaneous resources (rain water, cycled water), marketing facilities should be nearby. Levelled ground with the gentle sloping, undulating, hilly also preferable for freshwater fish farming. Raman and Gajera (2014) said the standard parameters for finding suitable sites such as pond shape and size, water resources nearby aquaculture site, best suited road networking from aquaculture site to market, good soil (Clay soil) and suitable water quality that more appropriate to sustain and better yields.

The seepage rate ranged from 2 to 7 cm per day was recorded in all three different Regions of Raigad district. The wind directions were also studied and it was North to East for North Raigad Region, in Central and South Raigad Region wind direction was West to South. No any cyclones and drastic climatic changes were observed during the time of sampling. The average temperature recorded in between 26 to 32^0 C and relative humidity was 75 to 81 %. Similarly, the meteorological parameter such as rainfall and its distribution, evaporation rate, temperature, storm, etc. have a great role in the growth of fish food organism as well as in the design of farm elements stated by Chandrakant (2003). Gupta (2013) reported, the climate of Raigad district and said that typical of west coast and characterized with plentiful and

regular seasonal rainfall, oppressive weather in summer and high humidity throughout the year. The mean minimum temperature was 17.7°C and mean maximum temperature is 31.8°C which is correlating to the temperature of Raigad district.

5.2.2 Leading canal

In Raigad district, medium size operational freshwater fish farms, the top width of leading canal was observed from 1 to 6 m, bottom width was 1 to 4 m, depth of the leading canal was 1 to 2 m and details are given in Table 4.19. Azhar *et al.* (2016) also measured the leading canal top width and it was ranged from 10 to 40 m, bottom width was 9 to 36 m and depth of leading canal was 0.5 to 1.0 m during low tide and 1.0 to 1.4 m during high tide of operational aquafarms at Ratnagiri district. Small dimensions of leading canal in the present study because of overall small size of culture freshwater ponds.

5.2.3 Specifications of pond

In Raigad district, small, medium and large size operational freshwater fish farms were categorized and length of ponds was observed from 13 to 118 m, 8 to 143 m, 16.16 to 68 m; respectively. Whereas, the width of ponds was observed from 8 to 74 m, 4 to 91 m, 12.6 to 55.6 m; respectively. Similar study of engineering aspects of aquafarms was carried by Azhar *et al.* (2016) at South Ratnagiri district and recorded length ranged from 80 to 200 m, width 30 to 200 m. Azhar and Mohite (2017) stated the length of ponds was 46.10 to 158 m and width was 21.40 to 120 m from Central Ratnagiri district.

In present investigation of Raigad district small, medium and large size operational freshwater fish farms, the water depth of ponds was observed from 1 to 3 m, 1 to 2 m, 1 to 5 m; respectively. Elekes (1984) said water depths less than 0.6 m will result in less production. Kovari (1984) recommended various water depth for

fish ponds and ranged from 0.5 to 3.0 m. NACA (1985) stated the general practice size of growth pond water depth ranges from 2.5 to 3 m, fingerling pond water depth 1.5 to 2 m, nursery pond water depth 1 to 1.5 m. The brooder pond equals to the grow out pond. Similarly, Chandralant (2003) recommended that average water depth should be less than 1.5 m for aquatic ponds. Pillay and Kutty (2005) suggested for a fish pond average depth of 1.5 m the amount of water required. A range of average water depth of 0.4 to 1.5 m for nursery ponds and 0.8 to 3.0 m for production or stocking ponds have been recorded. Ponds may have an average depth of 0.4 to 1 m and holding or market ponds 1.2 to 2.0 m. Carballo *et al* (2008) stated the water depth should be 0.5 to 1.0 m at shallow end, sloping to 1.5 to 2.0 m at the drain end. Rath (2011) recommended, the stocking pond with water depth of 2.5 to 3 m consider for freshwater fish culture. Mishra and Dora (2015) reported the fish culture up to 2.0 to 3.0 m depth of water is sufficient. In the present study the finding of the water depth of cultured ponds meeting to the water depth studied by many researchers.

In this study of Raigad district small, medium and large size of operational freshwater fish farms, the pond size was observed from 0.01 to 0.84 ha, 0.001 to 1.74 ha, 0.02 to 6.84 ha and water area of ponds was 0.01 to 0.68 ha, 0.001 to 1.35 ha, 0.01 to 3.61 ha; respectively. Upadhyay (1994) said that the pond size between 1 to 5 ha for extensive farming, 0.25 to 1.0 ha for semi-intensive and 0.025 to 0.25 ha for intensive farming. The recorded pond area in this study is smaller than Chandrakant (2003) recommended pond size for effective management of nursery pond 0.05 to 0.20 ha, brood stock or grow-out ponds 0.25 to10.00 ha, spawning ponds 0.01 to 0.05 ha, intensive culture ponds 1.00 to 5.00 ha. Generally, pond size between 1 to 2 ha are considered good for management. Copley *et al.* (2005) recommended that nursery pond area often from 0.02 to 0.04 ha in size. Pillay and Kutty (2005) stated that water

spread area of nursery ponds varies from 0.05 and 2.0 ha and of production or stocking ponds from 0.25 and 10.0 ha. Spawning ponds are smaller, ranging from 0.01 to 0.5 ha and holding or market ponds from 0.10 to 1.0 ha.

Ayyapan (2006) suggested that the grout culture of carp is carried out in earthen ponds ranging from 0.01 to 0.5 ha and in different regions of the country ponds of 0.4 to 1.0 ha size. Rath (2011) discussed that the nursery pond ideal size of fry pond is 0.04 ha and their number vary in accordance to target production. The pond size for rearing ponds of 0.06 to 0.1 ha, stocking pond size of 0.2 to 2.0 ha, brood stock ponds size varies from 0.2 to 0.50 ha and marketing pond 0.2 to 0.4 ha this are optimum size for different types of pond recommended by Mishra and Dora (2015). Many small dimensional ponds from Raigad district are utilized for nursery and rearing while large dimensional ponds utilized for growing during the time of culture. The observed pond sizes in this study are meeting to the pond size studied by above researchers.

In Raigad district, small, medium and large size farms of operational freshwater fish farms, the bottom slope of ponds was observed from 1000:1, 1000:1, 1000:0.6 to 1000:5; respectively and it is resulted in Table 4.19. Upadhyay (1994) studied that the intensive and semi-intensive farming, regular flat bottom pond bed with uniform slope are preferred. Pond bottom slope provided with 1000:1 to 1000:5 to words the drain to facilitate the water flow during harvest and pond drainage. Chandrakant (2003) have prescribe that the slopes on either side can be 1.5:1 (H : V). Mishra and Dora (2015) said the desired pond bottom slope range from 0.5 to 1 %. 1 % slope indicates that for every change in 100 m length there is a change of 1 m in depth. Similar considerations have been mentioned by Azhar and Mohite (2017)

studied that the pond bottom slope and it was also 1000:1 to 1000:2 similar to findings of this research.

5.2.4 Peripheral dike

The small, medium and large size operational freshwater fish farms the top width of peripheral dike was ranged from 1 to 5 m, 0.3 to 2 m, 1.5 to 5 m; respectively and it is recorded in Table 4.19. NACA (1985) mentioned about the grow-out pond 0.5 to 1 m wide path along the inner slopes should be provided for the sake of pulling nets and avoiding erosion by waves. The common width of pond dike ranges from 2 to 5 m. Upadhyay (1994) given similar engineering standards required a minimum top width of 2.4 m for all dike between 3 to 4.5 m high but in actual practice main dike of fish aquafarms are built with a top width ranged from 1.5 to 2.5 m. Pillay and Kutty (2005) stated that a minimum top width required 4.5 m but in actual practice most of main dikes of aquaculture farm are built top width from 1.5 to 2.5 m and these findings are close to the observation in the present study. Mishra and Dora (2015) resulted that the tope width of the dike should be 1m. In Raigad district the pond observed with the small size peripheral dike in plan areas and large size peripheral dike observed in slightly slope and hilly areas to protect the entire farm from erosion during monsoon.

In Raigad district small, medium and large size operational freshwater fish farms side slope of peripheral dike was ranged from 2:1 to 8:1, 2.5:1 to 6:1, 2:0.6 to 10:5; respectively. NACA (1985) has given the gradient of dike slope of loam soil should be 1:1 to 1:1.5 while the one of poor soil or grow out pond dike should be greater, that is, 1:2.5 to 1:3 under the water surface and 1:1 to 1:1.5 above the water surface. Coche and Muir (1995) said that valley cross-sectional profile possible type of pond is barrage pond, sunken pond, diversion pond, paddy pond, sunken pond

slope should less than 5 %. The findings of side slopes of this research are similar to findings of many researchers. NSPFS (2005) mentioned that constructed pond with 2:1 to 3:1 slopes on all sides (each meter of height needed 2 or 3 m of horizontal distance). The recommendation of Carballo *et al.* (2008) are also on the same line for side slopes should be 2:1 or 3:1. Broaddus (2015) studied the SLOPE/W models and suggested typical factor of safety of 1.5 is an acceptable slope value for stability of dike, that depends on how well the soil and seepage conditions.

In Raigad district small, medium and large size operational freshwater fish farms free board of peripheral dike was ranged from 0.3 to 1.2 m, 0.3 to 1 m, 0.3 to 1 m; respectively. The freeboard height for various depth of pond water was 0.40 to 0.60 m recommended by Kovari (1984). Coche and Muir (1995) stated the freeboard is the upper part of dike and should be under water. It varies from 0.25 m for small diversion ponds to 1 m for barrage ponds. Similar freeboard was mentioned by Mishra and Dora (2015) that desirable free board for small pond should be 0.3 m, large pond it should be 0.5 m. The observations mentioned by above researchers are closely meeting to the findings of this research.

In Raigad district small, medium and large size operational freshwater fish farms total height of peripheral dike was ranged from 1.3 to 4 m, 1.3 to 3 m, 1.4 to 6 m; respectively. Elekes (1984) stated that the ponds should be from 1.2 to 1.8 m deep, with pond depth of 1.8 m especially in regions with elevated. On the other side similar observations total height of peripheral dike, growth pond depth ranges from 3 to 3.5 m with brooder pond equals to the growth pond, fingerling pond depth 2 to 2.5 m, nursery pond depth 1.5 to 2 m were stated by NACA (1985).

5.2.5 Partition dike

In Raigad district small, medium and large size operational freshwater fish farms top width of partition dike was ranged from 1 to 5 m, 0.3 to 2 m, 0.4 to 2.75 m; respectively. As described by Upadhyay (1994) the partition dike or secondary dike required top width of partition dike is usually between 1 to 2 m. For movement of men and material, the required range of top width of partition dike from 1.2 to 2 m is stated by Chandrakant (2003). Azhar *et al.* (2016) studied the engineering aspects of cultured farms of South Ratnagiri district and resulted top width of partition dike was 1.4 to 2 m. Same dimensions of the operational aquafarms partition dike top width were 1.3 m mentioned by Azhar *et al.* (2017).

In Raigad district, small, medium and large size operational freshwater fish farms side slope of partition dike was ranged from 2:1 to 8:1 m, 2.5:1 to 6:1 m, 2:0.6 to 10:5 m; respectively. Azhar *et al.* (2016) studied the engineering aspects of aquafarms of South Ratnagiri district, Maharashtra and resulted slope of partition dike was 1.4:1 to 2:1. Azhar *et al.* (2017) resulted that the dimensions of the operational aquafarms partition dike slope were 1.3:1.

In Raigad district small, medium and large size operational freshwater fish farms free board of partition dike was ranged from 0.3 to 1.2 m, 0.3 to 1 m and 0.3 to 1 m; respectively. Upadhyay (1994) said that the partition dike or secondary dike required free board of 0.3 m for smaller pond size and for larger pond size it should be minimum 0.5 m. The findings of this research are in agreements to study of Chandrakant (2003) resulted 0.3 m free board of partition dike. The partition dike free boards were 0.6 m represented by Azhar *et al.* (2017) in operational aquafarms.

5.2.6 Drainage canal

In Raigad district small size operational fish farms top width of drainage canal was ranged from 1.5 to 2 m. Azhar and Mohite (2017) studied the engineering considerations of cultured farms of Central Ratnagiri district, Maharashtra and reported similar drainage canal top width 2 to 10 m.

In Raigad district, small size operational freshwater fish farms bottom width of drainage canal was ranged from 0.8 to 1.2 m. Upadhyay (1994) discussed the required bottom width for smaller drainage canal was 1.2 m or less. Azhar and Mohite (2017) studied the engineering aspect of aquafarms at Central Ratnagiri district, Maharashtra and resulted drainage canal bottom width 1.4 to 3.6 m. The bottom width dimensions are in the acceptable limit according to Upadhyay (1994) and Azhar and Mohite (2017).

In Raigad district, small size operational freshwater fish farms depth of drainage canal ranged from 0.9 to 1.5 m; respectively. Same aquafarm depth of drainage canal was 1 to 3 m mentioned by Azhar and Mohite (2017). The depth of the pond recorded in this research meeting to depth of drainage canal reported by Azhar and Mohite (2017).

In Raigad district, small size operational freshwater fish farms slope of drainage canal were 1000:1. Chandrakant (2003) stated that an open drainage channel is designed and constructed with a longitudinal slope of 500:1 to 1000:1 in to discharge pond water quickly and smoothly without any soil erosion. This result is also in the agreement of Azhar and Mohite (2017) who reported drainage canal slope 1000:1 to 2000:1 during the investigation of aquafarms at Central Ratnagiri of Maharashtra.

5.2.7 Drainage canal dike

In Raigad district, small size operational freshwater fish farms drainage canal dikes, the top width was ranged from 1 to 1.3 m and free board was 0.3 to 0.5 m. These findings are in agreement to Azhar *et al.* (2016) who studied the engineering aspects of cultured farms of South Ratnagiri district, Maharashtra and similar top width was recorded 1.2 to 1.8 m of drainage canal dike and free board height was 0.8 to 1.0 m.

5.2.8 Check tray scaffolding/ Catwalk

In current study of Raigad district, small and medium size farm catwalk length was 15 m, 1.5 to 2.0 m; respectively details given in Table 4.19. Upadhyay (1994) stated the catwalks are provided between the two side walls and it is being constructed with RCC slabs or wooden planks. Similar size catwalk was studied by Azhar *et al.* (2016) during his study length of catwalk was recorded from 5.6 to 8.0 m and also resulted the length of catwalk was recorded 2.8 m and 1.5 m; respectively.

In Raigad district, small and medium size farm, width of catwalk was recorded 0.5 m, 0.4 to 0.5 m. Azhar *et al.* (2016) studied engineering aspects of aquafarms of South Ratnagiri district, Maharashtra and resulted that similar width 0.5 to 1.0 m. Azhar *et al.* (2017) stated that operational aspects of aquafarms of North Ratnagiri, Maharashtra, the width of catwalk was 1.5 m which is similar to the other researchers.

In Raigad district, small and medium size farm catwalk height from pond bottom was 3.5 m, 2 m; respectively. Azhar *et al.* (2016) studied engineering aspects of aquafarms of South Ratnagiri district, Maharashtra and resulted that height from pond bottom 2.0 to 2.5 m. Height of the catwalk 1.8 m was recorded by Azhar *et al.* (2017) during study of aquafarms of North Ratnagiri, Maharashtra which is similar to findings of this research.

5.2.9 Demand feeder

In present study of Raigad district, small size farm submerged plate-type demand feeder dimensions such as length, width, height was 0.3 m, 0.3 m, 0.45 m; respectively. Varadi (1984) reported use of demand feeders in freshwater fish farming in order to control consumption of fish feed by themselves according to their appetite. The demand feeder observed on farm was stationary and submerged plate type demand feeder.

5.2.10 Water supply system

In the present study of Raigad district, gravitational flow was utilized to fill the freshwater fish ponds. Similarly, Chandrakant (2003) suggested the gravitational flow may be used to fill the ponds and tanks which is also economical for cost of operation for culture period. Similarly, Shang (1984) discussed system of water supply used different material like, PVC piping or by canal, pipes can be made with bamboo, plastic, cement.

5.2.10.1 Feeder canal

In present study of Raigad district, small, medium and large size farm feeder canal top width was 0.5 m, 0.5 to 1.5 m, 1 m; respectively. The bottom width was 0.5 m, 0.3 to 0.5 m, 0.8 m and feeder canal depth was 1 m, 0.5 m, 1m; respectively. Upadhyay (1994) suggested the depth of water 0.2 to 0.8 m are the suitable values for feeder canal. The bottom slope of channel mostly depends upon the topography and energy head necessary for the flow of water. The study was carried by Azhar *et al.* (2016) on engineering aspects of aquafarms at South Ratnagiri district, the feeder canal width was 9 m and depth was 3 m. Azhar and Mohite (2017) studied that the feeder canal width was ranged from 4.40 to 13 m and depth was 1 to 1.2 m. The depth

of feeder canal reported 1 m, 0.5 m, 1m is similar to depth suggested by Upadhyay (1994); Azhar and Mohite (2017).

5.2.10.2 Pipe

In Raigad district, small, medium and large size of farms were studied the ID of pipe 16.15 to 140.45 mm, 40.2 to 140.45 mm, 40.2 to 140.45 mm and wall thickness of pipe was 2.15 to 5 mm, 3.12 to 5.6 mm, 3.25 to 5 mm; respectively. The dimensions are shown in Table 4.19. BIS (2000) announced that the various standard specification for pipes diameter ranged from 20 to 630 mm and wall thickness was 1.3 to 49.2 mm. Standard specification of pipe suggested by BIS (2010) inner diameter should be ranged from 40 to 315 mm and wall thickness should be from 1.8 to 8.7 mm.

5.2.11 Lining

In Raigad district, small and large size farm lining was adapted and its thickness of the HDPE material was 0.3 mm and 0.5 mm to control seepage. Similarly, Chandrakant (2003) said seepage of water along the slope of an embankments can be controlled by adapting polyethylene lining, stone pitching and cement concrete lining etc.

5.2.12 Main sluice gate

It was observed that small, medium size of farms, the length of main sluice gate was 2 to 3 m, 5 m, the height was 1 to 2 m, 1 m, the width was 1 m, 1 m; respectively. This main sluice gate was only used for intake of water. Upadhyay (1994) discussed that main sluice gate size of each opening being usually 1 to 1.2 m in width for easy handling. Grooves are made for fixing screen and flash board of the main supply gate are provided with 4 grooves, 2 at each sides. Chandrakant (2003) said that main gates size of each opening being usually 1 to 1.2 m in width for easy

handling. Azhar *et al.* (2016) reported that main sluice gate the length was 1.0 to 2.0 m and width 0.8 to 1.2 m. Size of the sluice gate recorded are similar to the finding of these researcher.

5.2.13 Sluice gate of the ponds

In Raigad district, small, medium size of farm, the width was 1 m, 1 m, the height was 2 m, 1 m; respectively. The sluice gate of pond was only used for intake of water. The number of planks for small and medium size of farm was 4, 3; respectively. Azhar *et al.* (2016) studied the sluice gate of ponds width was 1.0 to 2.1 m, height was 2.4 to 2.8 m, number of planks were 6 to 10. Azhar and Mohite (2017) resulted the engineering considerations of aquafarms of Central Ratnagiri district, Maharashtra, the sluice gate of ponds **w**idth was 1 m**,** height was 2 m and number of planks ranged from 4 to 10.

5.2.14 Hume pipe

RCC constructed ready-made hume pipe with length of 2.5 m were selected for sluice gate/drainage system. To increase the length these hume pipes were joined to each other in the grooves, as per the required length for constructions of feeder canal, drainage canal/ overflow water drainage, which length ranged from 2.5 to 5.7 m. Raigad district, small, medium, large size of farms, the diameter of hume pipe was 0.8 to 1.2 m, 0.8 to 1.2 m, 0.8 m; respectively. Anon (1971) the Indian Hume Pipe Co.Ltd., company made diameter of Hume pipe ranged from 0.1 to 2.2 m and length 2.5 m was adapted for drainage/overflow purpose in freshwater fish farms.

5.2.15 Pump

In Raigad district small, medium, large size of farms, the location of pumping was not permanent set pump (movable) was installed with a capacity of 1.5 to 5 HP, 3 to 5 HP, 5 to 10 HP. Similar study of pumps was carried by Kepenyes (1984) and

classified the pump having two main group such as permanently set pump (constructed on RCC plat form) and mobile pumps constructed on iron frame (pump installed on iron frame trolley). Mobile setup pumps were adapted in entire Raigad district for freshwater farming. Ayyapan (2006) discussed traditional method of aerating a pond is by pumping. Reddy *et al.* (2017) explained on design of wave generator and pumping aerator in order to provide the farmers with cost-efficient technology. These aerators enhance the water with more dissolved oxygen in an economically feasible methodology. A pump is a machine that moves fluids (liquids or gases) or sometimes slurries, by mechanical action. Pumps operate by some mechanism (typically reciprocating or rotary) and consume energy to perform mechanical work by moving the fluid. In present study one farm from Central Raigad Region reported same type of pump, used for aeration purpose.

5.2.16 Aerator

In present study of Raigad district only in large size of farms, the paddle wheel aerator was adapted with a capacity of 2 HP whereas the number of aerators range from 1 to 2. Ahamad and Boyd (1988) observed that the excessive water turbulence and turbidity in earthen ponds less than 0.1 ha to 0.15 ha in area. Attempt to produce small, highly efficient paddle wheel aerators using design features provided for larger aerators have not been very useful. Moor and Boyd (1992) stated that aerator of 0.25 to 2 HP are often used in smaller freshwater fish ponds. Coche and Muir (1996) said that the capacity is required at least 5 kg/h per hectare of pond, corresponding to an increase of DO concentration of about 0.5 mg/l per hour. At a typical efficiency of 1 kg/kWh, this increase would require 5kW (about 6.7 HP) of applied power per hectare. Paddle-wheel aerators are a float-mounted motor drives a horizontal axle on which is fitted at each end a vertical paddle-wheel, set about one-fourth to one-third

of its diameter down into the water. They are typically 0.5 to 2 kW in size. Paddle-wheel aerators can also be set up using power from a tractor, via a propeller shaft. In the present study the capacity of aerators was 2 HP which is similar to aerator described by above author in freshwater farming. Omofunmi *et al.* (2016) told that the electric motor was used for paddle wheel aerator mover of 1 HP capacity.

5.3 Soil quality parameters of operational freshwater fish farms of Raigad district

5.3.1 Moisture

In present study soil parameters of small, medium and large size operational fish farms of Raigad district was studied such as moisture and it ranged from 9 to 15 %, 11 to 16 %, 11 to 16 %; respectively. Li Li *et al.* (2014) also recommended that the optimum moisture content varies from 10 to 20 % from the soils of different ponds. Pitts (2016) has reported that in soil with good characteristic the moisture ranged from 5 to 10%. Patil *et al.* (2016) also studied the coastal soils of Maharashtra and recorded two zones namely VRL and VRNL which covers the Raigad district and reported soil moisture to range from 13.62 to 17.93 %. The studied percentage of soil moisture is according to moisture level reported by above researchers. In the present study, the soil moisture percentage it gates varied because of many factors such as seasons, layer of soil sampled, temperature of soil, rate of evaporation etc.

5.3.2 pH

Das *et al.* (2004) reported minimum and maximum pH from 7.21 to 8.05 of intensive carp culture. Sallenave (2012) inferred that optimum pH for fish growth and health is between 6 and 9. If pH is higher/lesser than this range, fish growth will be reduced. Mortalities will occur when pH values are less than 4.5 or greater than 10. Bhatnagar and Devi (2013) stated pH from 7 to 8.5 is ideal for biological productivity.

In present study small, medium and large size of farms, soil parameters of fish farms of Raigad district were studied pH, 6.5 to 8.0, 6.9 to 7.5, 6.1 to 7.1. are in the ideal limit prescribed by many researchers. Manjulekshmi *et al.* (2014) stated that the pH of freshwater composite culture farms of Indian Major Carp at Goa was 7.5 to 8.5.

5.3.3 Electric conductivity

Gul *et al.* (2015) stated similar findings of EC of 2.90 dS/m for the fish ponds which was within the favorable range. In this study small, medium and large size of farms, soil parameters of operational freshwater fish farms of Raigad district were studied, EC, 1.25 to 3.55 dS/m, 1.12 to 3.52 dS/m, 2.13 to 3.56 dS/m. Therefore, the results show that EC of the soils of Raigad district are suitable for the freshwater fish farming. The soil study was carried by Patil *et al.* (2016) and reported EC was 11.90 dS/m for VRL soil while for VRNL soil it was 25.40 dS/m. In soil study, EC was reported by Tapader *et al.* (2017) the electrical conductivity among new fish ponds at Noakhali, Bangladesh indicate that the EC was 3.348 dS/m and in the old ponds it was 1.306 dS/m.

5.3.4 Water holding capacity

Jayanthi *et al.* (2000) stated that the soil of Kakinada area with clay content of 35.5 % had high water retention capacity ranging from 45 to 46.5 %. However, Jayanthi (2007) reported that the water holding capacity is less 20.7 to 36.8 % in most of the farms of the Cuddalore district, Tamil Nadu because of high sand content resulting in porosity. In this study revealed the water holding capacity ranged from 50.53 to 72 %, 55.94 to 72.03 %, 54.85 to 61.57 % for small, medium and large size farms of Raigad district aquafarms which is more suitable for fish farming. Viji and Rajesh (2012) assessed water holding capacity of agriculture soil at Trichy, India which showed a water holding capacity 30.69%.

5.3.5 Bulk density

In present study small, medium and large size farms, soil parameters of Raigad district aquafarms were studied and reported bulk density, 1.2 to 1.29 g/cm^3, 1.21 to 1.28 g/cm^3, 1.24 to 1.27 g/cm^3. Garretson (1999) given an expected range for bulk density i.e 1.0 g/cm^3 for clay soils to 1 .8 g/cm^3 for sandy or compacted soils. Patil *et al.* (2016) stated that the costal saline soils of Maharashtra which had bulk density of very high rainfall non laterite soil zone and very high rainfall laterite soil zone was 1.26 and 1.29 g/cm^3; respectively. Prihutomo *et al.* (2016) reported the mineral soil bulk density was 1 to 2 g/cm^3 in Indonesia. These are likely to be higher bulk density values in intensive aquaculture systems compared to traditional systems.

5.3.6 Seepage rate

In present study small, medium and large size farms, soil parameters of Raigad district fish farm were studied and recorded seepage rate 2 to 7 cm/day, 2 to 5 cm/day, 3 to 4 cm/day. Boyd (1982) reported that seepage ranged from 1.2 to 20.3 mm/day for small ponds on the Auburn University Fisheries Research Unit. Coche (1986) recommended minimum seepage rate 4.8 cm/day. Jayanthi (2007) reported the seepage rate of 10.2 to 13.1 cm/day from various farms of Cuddalore district, Tamil Nadu due to high sand content in the soil. The seepage rate of recoded during the present research work was 2 to 7 cm/day, (Table 1) which is lesser than the seepage of the ponds recorded by other researchers, indicating Raigad district having ideal soils for aquaculture. The lesser seepage rate may because of excellent soil texture such as sandy loam and loamy sand, sandy clay loam observed throughout North, Central and South Raigad region.

5.4. Water quality parameters of operational freshwater fish farms of Raigad District

5.4.1 Salinity

In present study small, medium and large size of farms, water parameters of operational freshwater fish farms of Raigad district were studied salinity 3 to 4 PSU, 0.0 to 6 PSU, 0.0 to 5 PSU; respectively. Subrahmanyam (1973) said salinity plays important role in growth of culture organisms through osmoregulation of body minerals from that of the surrounding water. Kasim (1983) are reported upper incipient lethal salinity for freshwater fishes *Cirrhinus. mrigala* 3.54 ppt and *Cyprinus carpio* 8.13 ppt. The obtain result of salinity marginally higher because of coastal location of farms. Garg (1996) reported culture of common carp performs well up to salinity 7.5 ppt.

5.4.2 Temperature

In present study small, medium and large size of farms, water parameters of fish farms of Raigad district were studied temperature, 27 to 30^0C, 27 to 29^0 C, 28 to 29^0 C; respectively. Das *et al.* (2004) recorded variation of water temperature from 20 to 32 ^{0}C during intensive carp culture period. Ramakrishna *et al.* (2013) Indian major carp studied the various ponds at Andhra Pradesh and reported similar pond water temperature at surface, mid-column and bottom 31^0 C, 28^0 C and 26^0 C; respectively. Bhatanagar and Devi (2013) recommended optimum tolerance value of temperature 15 to 31^0C for fish culture. Water temperature varies with the season, length of the day, water depth and meteorological condition (Zafar *et al.,* 2015). Bhattacharyya and Ghosh (2018) studied physico-chemical analysis of pond water in Purba Barddhaman, West Bengal, India and reported water temperature ranges from 16°C to 31.8°C which is suitable for fish culture.

5.4.3 pH

In present study small, medium and large size of farms, water parameters of operational freshwater fish farms of Raigad district were studied pH 7.4 to 8, 7.4 to 7.8, 7.5 to 7.7; respectively. Santhosh and Singh (2007) recorded ideal pH of pond water from 7.5 to 8.5 for the growth of fishes and if it out of this range, it become stressful to the growing fishes. The best range of water pH for fish culture is 7 to 8.5 as reported by Bhatanagar and Devi (2013). Keremah *et al.* (2014) has reported pH of freshwater fish pond ranged from 6.24 to 6.68 at Bayelsa state, Nigeria. Manjulekshmi *et al.* (2014) stated that the pH of freshwater composite culture farms of Indian Major Carp at Goa was 7.5 to 8.5. The maintenance of good water quality is essential for survival, growth and production of commercial aquaculture species (Zafar *et al.*, 2015). The pH of the sampled water of operational freshwater farms of Raigad district falls within the range as prescribed by the researchers. The finding of this research pH ranged from 7.4 to 8.0 are meeting to the finding of many researchers.

5.4.4 Dissolve oxygen

In present study small, medium and large size of farms, water parameters of operational freshwater fish farms of Raigad district were studied dissolve oxygen 4 to 5.6 mg/l, 4 to 5 mg/l, 4.5 to 4.9 mg/l; respectively. The DO preferred 4 to 5 mg/l levels for common carp and tilapia by Coche and Muir (1996). Dineshkumar *et al.* (2017) expressed dissolved oxygen of Thittai panchayath village, Thanjavur district in Tamilnadu ranged from 6.5 to 7.9 mg/l. Sultana *et al.* (2017) reported DO content in the aerated fish ponds was higher 7.23 mg/l from the beginning to the end of trials. The dissolved oxygen recorded in this research 4 to 5.6 mg/l, 4 to 5 mg/l, 4.5 to 4.9

mg/l from small, medium and large size farm ponds are within the recommended optimum ranges.

5.4.5 Ammonia

In present study small, medium and large size farms of Raigad district were studied ammonia, 0 to 0.02 mg/l, 0 to 0.01 mg/l, 0 to 0.01 mg/l; respectively. According to Swann (1997) the levels below 0.02 ppm were considered safe for fish culture. The ideal limit of ammonia in operational fish pond ranged from 0.00 to 0.025 mg/l suggested by Bhatnagar and Devi (2013). The level of ammonia in the cultured ponds from Raigad district 0.0 to 0.02 mg/l was less than ideal limit of ammonia given by many researchers.

5.4.6 Alkalinity

In present study small, medium and large size water parameters of farms pond of Raigad district were studied total alkalinity, 100 to 140 mg/l, 110 to 140 mg/l, 110 to 130 mg/l. According to Wurts and Durborow (1992) suitable alkalinity from 75 to 200 mg/l, but not less than 20 mg/l is ideal in an aquaculture pond. Santhosh and Singh (2007) suggested that the alkalinity range 30 to 180 mg/l. The normal range of alkalinity observed during present study might be due to the best stocking management practices including the adequate dose of agriculture lime, dolomite, adopted by the freshwater fish farmers of Raigad district.

5.4.7 Hardness

According to Bhatnagar *et al.* (2004) hardness values less than 20 ppm causes stress, 75 to 150 ppm is optimum for fish culture and >300 ppm is lethal to fish life. Santhosh and Singh (2007) recommended hardness range of 30 to 180 mg/l for freshwater fish culture at Tripura, India. At Bijnor district (Uttar Pradesh), India

(Rana and Jain, 2017) reported hardness ranged from 100 to 450 mg/l of various freshwater ponds.

In this investigation, small, medium and large size water parameters of aquafarms of Raigad district were studied and reported total hardness, 70 to 130 mg/l, 70 to 140 mg/l, 100 to 130 mg/l which is in the agreement of above investigators.

5.4.8 Transparency

Rajyalakshmi *et al.* (1988) observed transparency ranging from 14 to 36 cm in the farm ponds of Chilka lake fringe area. Boyd and Lichtkoppler (1979) recommended 30 cm transparency in aquaculture pond. Das *et al.* (2001) suggested 17.8 cm transparency is quite useful in aquaculture ponds. In Raigad district transparency recorded 30 to 45 cm, 30 to 40 cm, 30 to 40 cm from small, medium and large size farms; respectively well within the ideal range of transparency 30 to 40 cm for freshwater ponds as stated by Santhosh and Singh (2007).

5.5 Fish farming

There are various aspects in the fish farming such as pre-stocking management, seed stocking, feeding, sampling and harvesting is carried out in all operational freshwater fish farms of Raigad district.

5.5.1 Animal fencing

In present study peripheral farm fencing was adapted to prevent land animal such as otter, dogs, cattle and cats etc. can carry the virus from one pond to another. Preventing entry of stray animals and unauthorized personnel into the farming area through fencing is the only way to address this problem. Carballo *et al.* (2008) recommended a fence around the pond will protect children from falling into the pond and it can help to keep out thieves and predatory animals. To make a low cost and

sturdy fence, plant a thick hedge around the edge of the pond or build a fence using poles and thorn branches.

5.5.2 Bird fencing

Current observation of Raigad district polyethylene rope fencing was adapted, for preventing the entry of bird because bird negatively affect fish production by transmitting or transporting disease, weed seed and parasites from pond to pond or from one facility to another. Bird fencing material was monofilament (nylon), Polypropylene (pp) multi filaments and plastics bags attached to rope used by fish farmers. Ebrahim (2003) suggested the pond area should be fenced with at least 4 feet web wire and two strands of barbed wire at the top.

5.5.3 Sampling and harvesting

In present observation of Raigad district sampling was carried using cast net after the 10 to 15 days of interval time. After 2 to 4 months partial harvesting was adopted using cast net and dragnet. Complete harvesting was carried before summer season using gravity force or pumps to drain the water. Chandrakant (2003) suggested the gravitational flow may be used to drained the ponds during pond harvesting. NSPFS (2005) told that neutral gravity is used to fill and drain the ponds no pump is needed. Anon (2018) stated the basic use of a cast net is a part of sampling designed to either provide a representative sample of the local fish community or to target individual species for specific purposes. As use of a cast net alone may not fulfil these objectives, users should consider using a cast net as one component of a suite of different fishing gear types.

Thus it can be concluded that, Raigad district which has various freshwater aquaculture systems and pond types of operational fish farms, most of the parameters like site selection, design and engineering aspects as well as soil and water parameters

were found to be correlated with the observations or recommendations documented by other researchers across India, with some minor variations. All these freshwater fish farms form an important asset for the future development of sustainable aquaculture in this region, thus forming a backbone, contributing to the livelihood of freshwater fish farmers.

6.0 SUMMARY

Recently, the rate of fish consumption is showing increasing trend. It indicates more demand for fish in local market. For this demand, supply of acceptable and large quantity of fish for increasing population is being accorded top priority by aquafarmers. The Raigad district has great potential for aquaculture through 3286 sq. km cultivable area. Abdundant freshwater resource available for this district from Ulhas, Panvel and Patalganga are the three main rivers in northern part. The main river in central part Kundalika river whereas Savitri river is the Southern part of the main river. In Raigad district, twenty-eight freshwater fish farms were observed to be operational during the study period, comprising of 18 small farms, 6 medium farms and 4 large size farms.

Each parameter of the three regions of Raigad (North, Central and South Raigad Region) of the fish farms such as selection of site, layout, design and engineering aspects, soil and water quality parameter with the technological details and general features observed and described.

6.1 Site selection

The topography of the Raigad district farms of all three regions is plain, slightly sloping and hilly areas with good quality of water source from open well, tube well, reservoir, spring water, dam and rain water. The evaporation rate was between 2 to 7 cm per day in all three regions of Raigad whereas the average temperature ranged from 26 to 32^0C. Mode of accessibility was by road to all the operational fish farms of Raigad. The above parameters such as topography, source of water, rate of evaporation, temperature indicates ideal sight for freshwater fish culture.

6.2 Site particulars of operational freshwater fish farms of Raigad district

It was observed that operational freshwater fish farms were located near the leading canal, open well, tube well, reservoir, dam, and rivers with good water source. Topography of the operational freshwater fish farms was plain, slightly slope and hilly areas. The shape of the ponds was rectangular, square and even irregular. Water supply system was by feeder canal or pipe network system (PVC, HDPE, Hose, HDPE Flexible, galvanized material). Wood and RCC was used in construction of the sluice and main sluice gates of the ponds. Cast net and dragnet was used for sampling/partial harvesting whereas complete harvesting was done by cast net and dragnet. Approach road and farm stead were observed in 27 farms and on one farm approach road was not available. Lining was installed on two operational freshwater fish farms of Raigad district. Equipment like weighing balance was present on farm. MSEB power supply was available along with diesel generator as source of alternating power supply in the three regions, whereas use of solar panel were observed in addition to generator only in one farm at North Raigad Region. Processing units were availed only in North Raigad Region. From Central Raigad Region, one farm was reported pump aeration system.

6.3 Design and engineering aspects of operational freshwater fish farm of three regions of Raigad district

Three regions of Raigad district such as North, Central and South Raigad Region aquafarms were classified on the basis of economic consideration as extensive, semi-intensive and intensive culture system. On the basis of sex and especially adaptive fishes further divided as monoculture, polyculture, monosex culture and warm climatic conditions.

The regions of Raigad district such as North, Central and South Raigad Region classified in to various type of ponds such as spring-water source ponds, seepage water source ponds, rain water source ponds, water fed directly from barge pond, water fed indirectly from diversion ponds, pump-fed ponds, undrainable ponds, drainable ponds, pump-drained ponds, earthen ponds, walled ponds, stone pitching ponds, lining ponds, excavated ponds, embankment ponds, contour pond, spawning ponds, nursery ponds, grow-out pond, brood ponds, storage ponds, fattening ponds, drying season ponds, wintering ponds, sunken pond, barrage ponds, diversion ponds, square shaped ponds, rectangle shaped ponds and irregular shaped ponds.

Area of small, medium and large operational freshwater fish farms of Raigad district was ranged from 0.10 to 1.91 ha, 2.02 to 4.0 ha and 7.05 to 22.25 ha; respectively and its water spread area of farms was ranged from 0.05 to 1.24 ha, 0.6 to 1.95 ha and 0.27 to 4.30 ha; respectively.

The dimensions of leading canal; top width, bottom width and depth was ranged from 1 to 6 m, 1 to 4 m and 1 to 2 m; respectively. No leading canal was reported to small and large size fish farms of Raigad district.

Overall length of ponds for small, medium and large size fish farms was observed from 13 to 118 m, 8 to 143 m and 16.16 to 68 m; respectively while width of ponds was ranged from 8 to 74 m, 4 to 91 m and 12.6 to 55.6 m; respectively. In Raigad district water depth of ponds for small, medium and large size fish farms was ranged from 1 to 3 m, 1 to 2 m, 1 to 5 m; respectively. The fish farms pond area from Raigad district for small, medium and large size farm was ranged from 0.01 to 0.84 ha, 0.001 to 1.74 ha, 0.02 to 6.84 ha; respectively while water spread area of cultured ponds was observed from 0.01 to 0.68 ha, 0.001 to 1.35 ha, 0.01 to 3.61 ha; respectively. The pond bottom slope was 1000:1, 1000:1, 1000:0.6 to 1000:5 for

small, medium and large size fish farms; respectively and it was in the recommended range.

The dimensions of peripheral dike; top width were ranged from 1 to 5 m, 0.3 to 2 m and 1.5 to 5 m for small, medium and large size fish farms; respectively while side slope was observed from 2:1 to 8:1 m, 2.5:1 to 6:1 m, 2:0.6 to 10:5 m; respectively. The range of free board for small, medium and large size fish farms peripheral dike was from 0.3 to 1.2 m, 0.3 to 1 m, 0.3 to 1 m; respectively and total height of peripheral dike ranged from 1.3 to 4 m, 1.3 to 3 m, 1. 4 to 6 m; respectively.

In Raigad district top width of partition dike was ranged from 1 to 5 m, 0.3 to 2 m and 0.4 to 2.75 m; side slope was observed from 2:1 to 8:1 m, 2.5:1 to 6:1 m and 2:0.6 to 10:5 m; free board was ranged from 0.3 to 1.2 m, 0.3 to 1 m and 0.3 to 1 m; total height ranged from 1.3 to 4 m, 1.3 to 3 m and 1.4 to 6 m for small, medium and large size fish farms; respectively.

The drainage canal was constructed only for small size fish farms of Raigad district with top width, bottom width, depth, bottom slope, drainage canal dike top width and free board of drainage canal dike 1.5 to 2 m, 0.8 to 1.2 m, 0.9 to 1.5 m, 1000:1,1 to 1.3 m and 0.3 to 0.5 m; respectively. In Raigad district majority of the medium and large size fish farms was seasonal hence drainage canal was not adapted.

The catwalk was adapted on small and medium size fish farms and its dimensions; length 15 m, 1.5 to 2.0 m; respectively, while width was 0.5 m, 0.4 to 0.5 m; respectively and height from pond bottom was 3.5 m, 2 m; respectively. For large size farm catwalk was not constructed. Overall fish sampling was conducted using cast net.

Advanced demand feeder was observed only on one small size fish farm of North Raigad Region with dimensions' length, width and height was 0.3 m, 0.3 m and 0.45 m; respectively while on other farms feeding was conducted manually.

Raigad district small, medium and large size fish farms feeder canal; top width was 0.5 m, 0.5 to 1.5 m, 1 m; bottom width was 0.5 m, 0.3 to 0.5 m, 0.8 m; depth was 1 m, 0.5 m, 1 m; respectively.

Inner diameter of pipe was ranged from 16.15 to 140.45 mm, 40.2 to 140.45 mm, 40.2 to 140.45 mm for small, medium and large size fish farms; respectively. Raigad district Raigad district small, medium and large size fish farms pipe wall thickness was ranged from 2.15 to 5 mm, 3.12 to 5.6 mm, 3.25 to 5 mm; respectively.

Raigad district small, medium and large size fish farms HDPE lining was applied and thickness was 0.3 mm, 0, 0.5 mm; respectively.

Raigad district small and medium size fish farms length of main sluice gate was ranged from 2 to 3 m, 5 m; height was ranged from 1 to 2 m, 1 m; width was 1 m, 1 m; respectively.

Raigad district small and medium size fish farms sluice gate of the ponds width was 1 m and 1 m; ponds height 3 m and 1 m; respectively.

Raigad district small, medium and large size fish farms average diameter of hume pipe was ranged from 0.8 to 1.2 m, 0.8 to 1.2 m, 0.8 m; respectively. Raigad district small, medium and large size fish farms length of hume pipe was 5.7 m, 2.5 to 5.7 m, 2.5 m; respectively.

Raigad district small, medium and large size fish farms pump was utilized with a capacity ranged from 1.5 to 5 HP, 3 to 5 HP, 5 to 10 HP; respectively. Aerator in Raigad district only reported on one large size fish farms with a capacity of 2 HP.

6.4 Soil quality parameters of operational freshwater fish farms of Raigad district

The small, medium and large size farm soil quality parameters of the soil such as moisture was ranged from 9 to 15 %, 11 to 16 %, 11 to 16 %; pH was ranged from 6.5 to 8, 6.9 to 7.5, 6.1 to 7.1; electric conductivity was ranged from 1.25 to 3.55 dS/m, 1.12 to 3.52 dS/m, 2.13 to 3.56 dS/m; water holding capacity was ranged from 50.53 to 72 %, 55.94 to 72.03 %, 54.85 to 61.57 %; bulk density was ranged from 1.2 to 1.29 g/cm^3 - 1.21 to 1.28 g/cm^3 - 1.24 to 1.27 g/cm^3; seepage rate was ranged from 2 to 7 cm/day, 2 to 5 cm/day, 3 to 4 cm/day; respectively. The small, medium and large size farm soil texture was sandy clay loam, sandy loam and loamy sand; respectively.

6.5 Water quality parameters of operational freshwater fish farms of Raigad district

The small, medium and large size farm water quality parameters such as salinity was ranged from 3 to 4 PSU, 6 PSU, 5 PSU; temperature was ranged from 27 to 30^{0}C, 27 to 29^{0}C, 28 to 29^{0}C; pH was ranged from 7.4 to 8, 7.4 to 7.8, 7.5 to 7.7; dissolve oxygen was ranged from 4 to 5.6 mg/l, 4 to 5 mg/l, 4.5 to 4.9 mg/l; ammonia was ranged from 0 to 0.02 mg/l, 0 to 0.01 mg/l, 0 to 0.01 mg/l; total alkalinity was ranged from 100 to 140 mg/l, 110 to 140 mg/l, 110 to 130 mg/l; total hardness was ranged from 70 to 130 mg/l, 70 to 140 mg/l, 100 to 130 mg/l; transparency was ranged from 30 to 45 cm, 30 to 40 cm 30 to 40 cm; respectively.

6.6 Biosecurity

Biosecurity plans are needed to be feet for purpose and balance practicality, cost and regulatory requirements, ultimately, the propose biosecurity precise should improve the biology, operational and economic performance of your form. Good

biosecurity practice should be as simple and low cost as possible to achieve the desired outcomes. Ultimately, biosecurity plan should be viewed as insurance, and as such, require both financial and intellectual investment as well as commitment.

The district covers geographical area is 7152 sq. km and cultivable area is 3286 sq. (Gupta, 2013). Due to good topography of land, ample amount of good quality of unpolluted water source from the rain water, open well, tube well, reservoir, dam, along with favourable soil quality; if the freshwater fish farmers adopt appropriate design, layout and engineering aspects as per the recommended standards of MPEDA, FAO and researcher's guidelines, the freshwater fish farming can be a guaranteed booming activity in the district. Soil and water parameters were found within the ideal limit described by many researchers across the India, with some minor variations and can form as a baseline data inputs for the Soil and Water 'Health Cards' for freshwater fish farms. All these study form an important asset for excellent future development of sustainable aquaculture in the studied region, thus forming a backbone, contributing to the livelihood of fish farmers.

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