Water Quality Study for Supporting an Advanced Aquaculture Technology in Sei Teras Fishpond Irrigation Area, Central Kalimantan

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ABSTRACT

This study aims to determine the distribution of water quality in the canal network and Sei Teras fishpond under tidal cycle conditions for aquaculture technology. The previous study focused on the water quality upstream of the canals. The result shows that the degree of acidity (pH) met the criteria for advanced aquaculture, while the salinity and total dissolved solids need improvement. This study measured water quality and hydraulic parameters during spring and neap tide conditions. To conduct a calibration process for an optimal roughness coefficient and collect boundary condition data, selected locations of observation points are upstream and downstream of the primary canals, secondary canals, and fishpond. The difference in amplitude in neap and spring tide influenced the flow distribution pattern in the canal. During the spring tide in march 2022, the distribution of water quality was almost evenly distributed along the primary canals with a salinity range of 22.9 – 25.2 ppt, a pH range of 6.89 – 7.02, and a temperature range of 27.9 – 28.3°C. However, during the neap tide, the distribution of water quality was uneven due to low tidal energy. The salinity concentrations in secondary canals and fishponds ranged from 9.8 – 12.1 ppt, pH ranged from 7.03 -8.34, and temperature ranged from 31.3 – 33.6°C. The improvement of advanced cultivation technology could be applied. The salinity parameter meets the criteria to be improved for semi-intensive farming of vannamei shrimp or tiger prawn. Meanwhile, pH and temperature parameters meet the criteria for super-intensive improvement. Good management and the development requirement of intensive farming, such as fishpond preparation, were indispensable to achieving that goal.

Keywords: *Water quality, salinity, pond, aquaculture*

1. INTRODUCTION

Food self-sufficiency is the goal of the Indonesian nation to prosper its people and also the success indicator of development. Therefore, the government always strives to achieve food self-sufficiency by creating a concept of food estate. Food estate is an idea of integrated food development based on horticulture, plantation, livestock, and food plant in an area [1]. This food estate will be one of the 2020-2024 National Strategic Programs and an excellent strategy for food self-sufficiency during the pandemic [2].

Central Kalimantan's food estate area is in the previous peatland project (PLG) area. The peatland project area consists of several irrigation units developed during 1970s. The irrigation units, currently, are still being used for agriculture and fisheries. One of the development areas in the food estate program is brackish water fishery in irrigation area of Sei Teras fishpond. The cultivation technology used, currently, is still simple: the availability of feed and seeds still depends on nature [3], the management is simple and uncomplicated; the production is low, that is between 50-500 kg/ha/planting season [4].

Several cultivation technologies from traditional to the intensive one have been applied in Indonesia as an effort to develop and improve irrigation area of Sei Teras fishpond. The difference in technology lies in land handling methods, feeding, and stocking density patterns.

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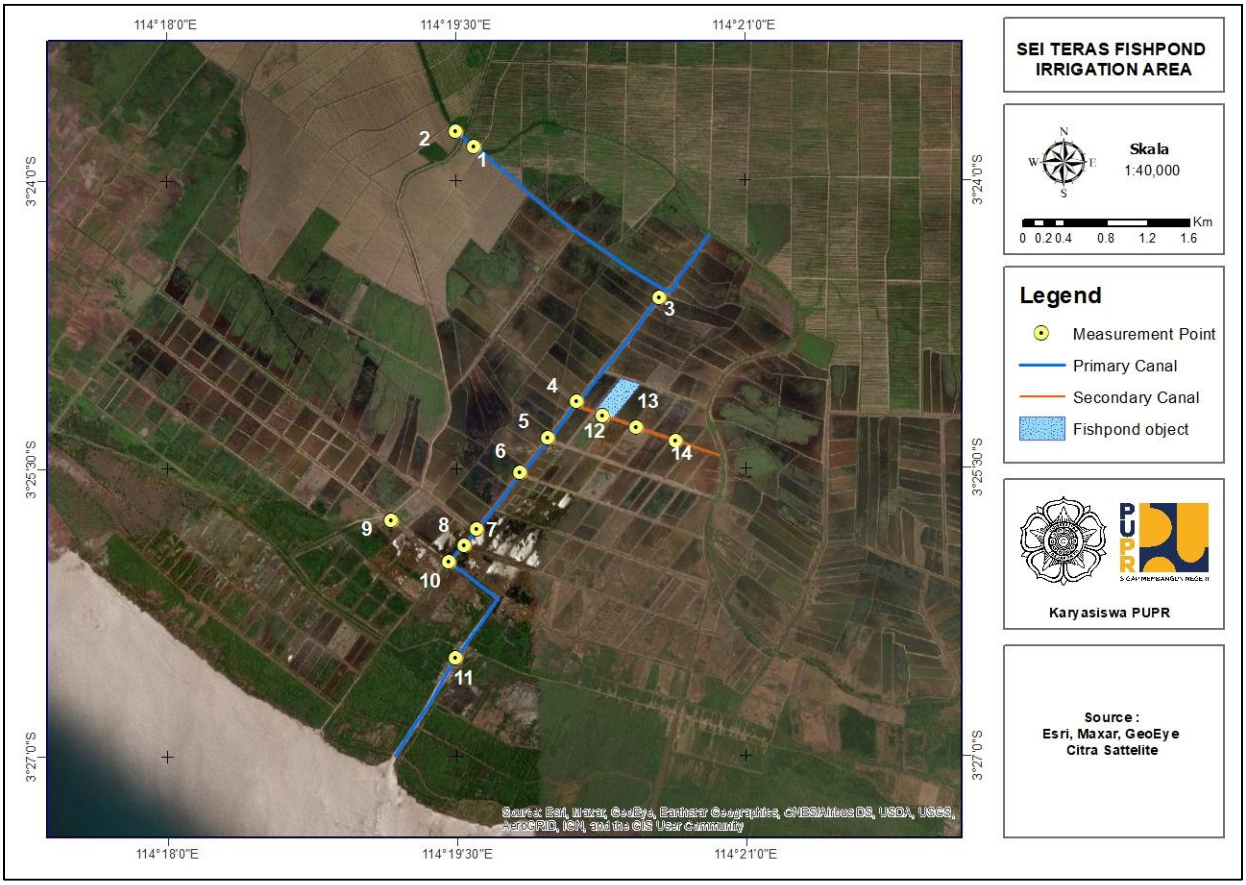

Figure 1 Location of Study Area (source: Modification of ArcGis World Imagery)

The classification of fishponds technology used for cultivation is as follows: the extensive system, semi-intensive system, intensive system, and super-intensive system [4][5]. Efforts to develop the irrigation area of Sei Teras fishpond by applying this technology are closely related to the land's carrying capacity. The technology cannot be applied by neglecting the potential carrying capacity of the land. One of the lands carrying capacities meant water quality. Water quality is one of the crucial factors in the development of brackish water aquaculture. The availability of good nutrients also depends on water quality parameters. The indicators that are commonly used to determine water quality are salinity (salt content), temperature, pH (acidity degree), and dissolved oxygen content [6]. In this study, salinity, pH, and temperature measurements were conducted except dissolved oxygen due to the apparatuses' unavailability.

Sei Teras fishpond is located near the coast, which is affected by tidal cycles. The tidal cycle will certainly affect the dynamics of water quality. The current water system is open. It means that the source of seawater enters through the primary canal and then the secondary canal and directly enters the pond through the door. The primary canal was connected to the Teras river as a source of fresh water, affecting water quality.

Some cultured organisms have specific boundary condition values that must be maintained. Salinity, temperature, and pH requirements will be different for each species. For example, vannamei shrimps need a salinity range of about 10-30 ppt to grow well and in the range of 15-25 ppt to grow ideally. Regarding temperatures, vannamei shrimps need a temperature range of about 24 -34 °C to grow well in the range of 28-34°C to grow ideally [4]. The significant change in the dynamic of water quality will adversely affect the development of organisms at each level of maintenance [6]. The previous studies revealed the water quality condition in the canal but did not reach the condition in the pond. However, this study aims to determine the dynamics of changes in water quality from the source, primary canal, secondary canal, to the fishpond. Determining the condition of water quality as a support for the development of brackish water aquaculture is very important so that the development activities of the irrigation area of Sei Teras fishpond can be implemented sustainably. Hopefully, by knowing the pattern of change and distribution of water quality, this research can provide an overview and recommendations to stakeholders in making development policies.

2. MATERIALS AND METHODS

2.1 Location of the Study

Sei Teras Fishpond Irrigation Area is located in Sei Teras Village, Kuala Kapuas Regency, Central Kalimantan Province, Indonesia. It is a coastal area between Barito river mouth and Kapuas Murung river mouth. Aside from being a fishpond, the land used in the research location is agricultural fields, oil palm plantations, and residential areas. The location map is shown in figure 1

2.2 Data Collection and Measurement

The primary data was obtained directly in the field in March 2022, while the secondary data was obtained from scientific publication information and data from government agencies, that as the River Management Authority of Kalimantan Region II, in the final report on the planning of the SID Rehabilitation and Improvement of the Swamp Irrigation Network for the working area of Block D (Package 4). Tidal measurements were simultaneously carried out at two observation points. The first observation point was at the mouth of the primary canal and the second observation point was at the upstream reach of the canal. The measurement of tidal water level was carried out for 27 hours with a measurement interval of 1 hour using a wooden tidal gauge scale.

The measurement and water sampling were carried out in primary canals, secondary canals, and fishponds. The measurement points were located using a handheld GPS based on a satellite-based map. The water quality samplings were conducted once at each measurement point (grab sampling). The total number of measurement points were 11 on the primary canal (marked with a label of observation point 1 to observation point 11), 3 on the secondary canal (marked with a label of observation point 12 to observation point 14), and the other 5 on the fishpond (marked with a label of observation point 15 to observation point 19). All the samples were obtained in instantaneous conditions. The simultaneous observations of water samples were carried out at the two water level observation points. The water quality parameters that were measured in the field were salinity, temperature, and acidity level (pH). The measurement was conducted in the rainy season using the COM600 saltwater meter at the canal water surface. No measurement for dissolved oxygen. In addition, at two measurement points (observation point 3 and observation point 11), water samplings were carried out at three depth of 0.2D, 0.6D, and 0.8D, where D is the channel. Water samplings were done using a water sample apparatus as shown in Figure 2 that was created by the Swamp Technical Center, the Ministry of Public Works and Housing located in Banjarmasin city. The secondary data are obtained in the

Figure 2 The Modified Water Sample apparatus provided by the Swamp Technical Centre, Banjarmasin

Table 1. Classification of Shrimp Farming Technology [6]

Technology	Land Handling	Feeding	Stocking Density (shrimp/m2)
Extensive	No fishpond preparation	Organic feed from nature	Seeds entered when filling pond water
Semi - Intensive	Pond preparation, aeration with waterwheel	Inorganic feed in the form of pellets, given 2-3 times a day	15-30 (tiger shrimp), 25-40 (vannamei shrimp)
Intensive	Pond preparation, aeration with waterwheel, addition of water tank and filter tanks	Inorganic feed in the form of pellets, given 4-6 times a day	30-50 (tiger shrimp), 40-100 (vannamei shrimp)
Super Intensive	Pond preparation, use of advanced technology, waste management, quality control by laboratory experts	Feeding based on the feeding program Feeding tool is usually called an *automatic feeder*	>50 (tiger shrimp), >100 (vannamei shrimp)

form of tidal and water quality data of October 2021 and canal topography data [3].

2.3 Aquaculture Technology

Aquaculture in the Sei Teras area began in 2006. The primary commodities developed in this area are white shrimp *(Penaeus merguiensis)*, milkfish *(Chanos chanos)*, and some mangrove crabs *(Scylla paramamosain)*. Currently, the technology used is still simple, so the production is still low [3]. Aquaculture technology developed in Indonesia can be classified into extensive and intensive methods. The intensity of aquaculture is carried out step by step according to the level [7]. The shrimp farming technology is classified into four categories, and those are extensive, semi-intensive, intensive, and super-intensive farming systems [5]. The difference in technology lies in land handling methods, feeding, and stocking density patterns [6], as shown in Table.1

Pond preparation is an essential activity to support the advanced cultivation methods. Its includes drying, plowing or tillage, liming, and fertilizing [4]. Good pond preparation will determine the yield of the developed commodity. Furthermore, the condition of the pond subgrade is related to the quality of the water above it. The chemical processes in the subgrade will also affect water quality conditions [6]. Therefore, the relevance and success of subgrade management is one of the success keys in water quality management.

2.4 Quality of Water

The success of aquaculture is also influenced by the water quality. Therefore, an understanding of water quality is vital for farmers. The types of organisms that are cultivated indeed have boundary conditions or tolerances for physical and chemical changes. In terms of physical, water is a place of life that provides space for shrimp or fish cultivated. Meanwhile, regarding chemistry, water was a carrier of nutrients, minerals, vitamins, dissolved gases, and others [8]. Vannamei shrimp need a good water quality for an optimal growth. The management of water quality parameters is mentioned in the guidebook for better management practice of vannamei shrimp culture issued by the non-governmental organization of World wide Fund for Nature (WWF) as shown in Table 2. For example, regarding saltwater conditions, vannamei shrimp has a boundary condition of around 15-25ppt, which must be maintained for an optimal growth. Then, the temperature must be maintained in the range of 28°C - 32°C [9]. Therefore, the water quality in each cultivation level has its own criteria values. These criteria were set in the regulation of the Minister of Maritime Affairs and Fisheries of the Republic of Indonesia. The difference between the guideline of an optimal growth and regulation of cultivation level is at the level of parameter concentrations. The higher cultivation level needs a limited concentration but is still in the range value of optimal growth.

Table 2. The Optimal Parameter of Water Quality for Vannamei Shrimp Growth [9]

Parameter	Unit	Optimum	Tolerance
DO	ppm	> 4	> 3
Temperature	°C	28 -32	26 -35
Salinity	Ppt	15 - 25	0 - 35
pH		7.5 - 8	7 - 8
NH_3	ppm	0	0.1 – 0.5
NO_{2-}	ppm	0	0.1 - 1
H_2S	ppm	0	0.001
Alkalinity	ppm	100 - 120	> 100
Brightness	cm	25 - 40	
Pesticides/ Insecticides	ppb	0	
Watercolor		Brownish Green	

The understanding of the optimal values of water quality parameters and how to achieve that values are required for the farmers. Water management in the pond system will have an impact on the aquaculture environment for vannamei shrimp. This impact involves the development of pond organisms especially that of vannamei shrimp that are cultivated. Therefore, it is important to maintain the suitable environmental condition for optimal aquaculture production.

2.5 Data Analysis

This study used descriptive analysis to determine the distribution pattern of water quality parameters in the primary canals, secondary canals, and fishponds. The water quality parameters analyzed were salinity, pH, and temperature and were limited to dissolved oxygen parameters.

Analysis of the distribution pattern in the canal is executed by observing the trend of series of instantaneous measurement values from the upstream to the downstream the primary canal. The trends of water quality data series during spring and neap tide conditions were compared. For water quality data values of the pond, two data collected closes to the gate (point no. 16 and 17 in Figure 3) were compared to the others three data collected at the other sides of the pond far away from the inlet (point no. 15, no. 18 to 19 in Figure 3).

Data analysis of the results of the simultaneous measurements was conducted by comparing the values of water quality parameters and water level associated with the occurrence of rain. The results of all of the above

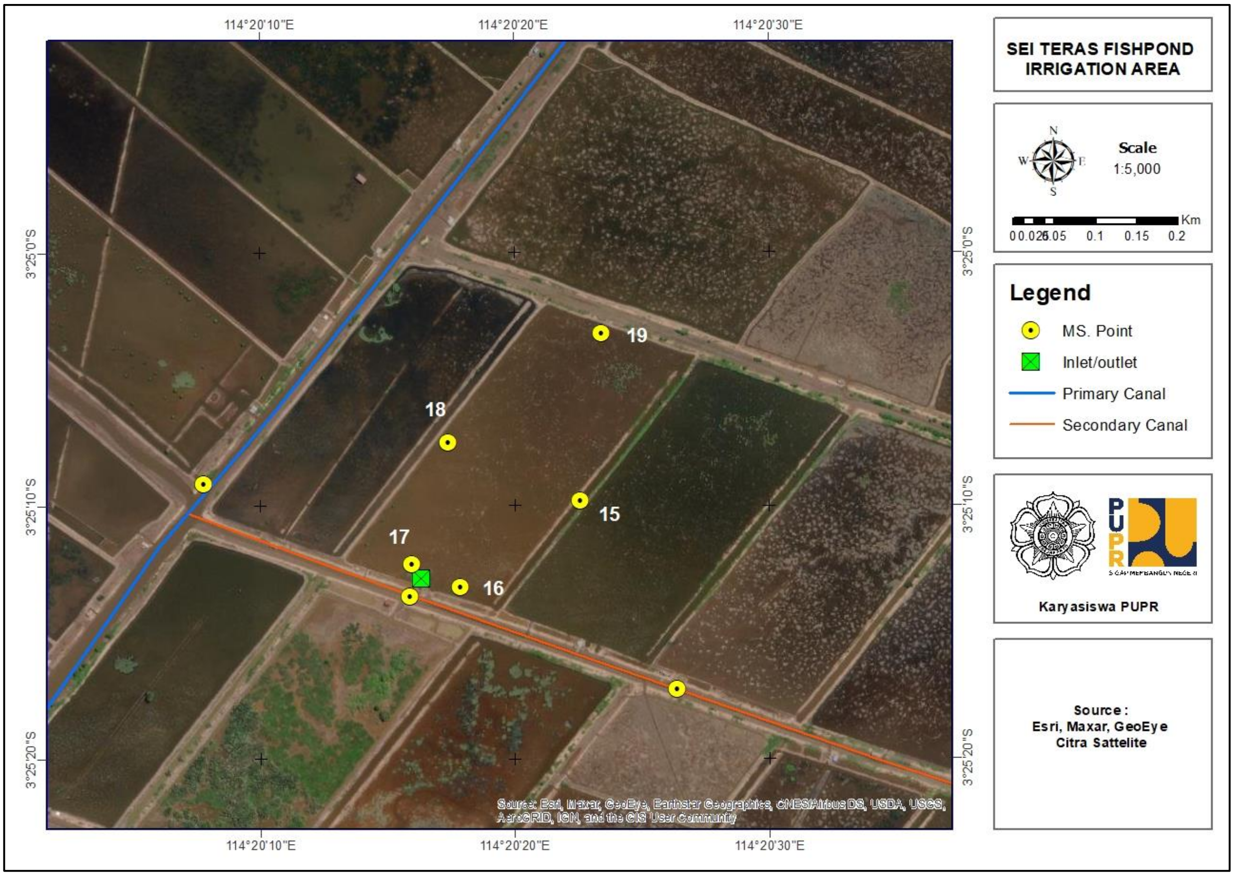

Figure 3 Location of pond measurement point (source: Modification of ArcGis World Imagery)

measurements were presented in Tables 3 to Table 4 and Figure 4 to Figure 6.

3. RESULT AND DISCUSSION

3.1 Existing Condition of Water Quality

The organism cultivated in The Sei Teras fishpond area is brackish water cultivation. Fresh water sources come from rain through the sei teras river, and saline water comes from the java sea. The place where fresh and saltwater are mixed is in the primary canal. The Sei Teras primary canal, which is connected to the secondary canals, supplies the mixed water into fishpond through secondary canals.

The measurements on the primary canal were carried out on March 6-7, 2022, during the neap tide period, and on March 13-14, 2022, during the spring tide period. The point measurement locations are shown on the Figure 1 above. Water quality samples were salinity, pH, and temperature. The results of salinity, pH, and temperature measurements are shown in Figure 3.

The salinity ranged from 4.7 – 9.3 ppt during neap tide and ranged from 9.3 – 25.2 ppt during spring tide. The difference occurs due to the tide. The tide amplitude is higher at spring than at neap tide, affecting the salinity conditions, so that the average salinity at spring tide is higher. The salinity measurement results indicated that the salinity is less than the requirement for the optimum growth of the shrimp, quite low. The shift of the salinity affects the growth rate of fish. The low salt content is

Table 3. The Result of Vertically Measurement of Water Quality on the Upstream and Downstream Primary Canal

Loc.	Indicator	Unit	0,2D	0,6D	0,8D
Measurement Point 3 (water level = 1,9 m)	Salinity	ppt	22.25	22.23	22.22
	pH		7.74	7.74	7.75
	Temp.	°C	31.26	31.22	31.2
Measurement Point 11 (water level = 2,4 m)	Salinity	ppt	22.57	22.85	22.81
	pH		7.64	7.72	7.75
	Temp.	°C	30.62	30.69	30.69

better when compared to high salt content. The environment with low salt concentration allows the transport of more energy for the flesh formation process of the shrimp and less energy is used for osmoregulation to maintain a balance of body fluid pressure with the environment [10]. Based on the measurements, salinity distribution is quite good and evenly distributed upstream of the canal. Observation point 2 is the location of the freshwater source from the Teras river. The measurement results show that the salt concentration tends to be low.

The measurement result of the degree of acidity (pH) in two tidal periods did not show a significant difference. The maximum pH value in the primary canal is 7.02, and the lowest is 6.74. Several environmental factors affect the pH concentration. One of the negative impacts is the survival rate of shrimp. A pH concentration that is too alkaline or too acidic can harm shrimp [11]. However, in brackish water, the pH is influenced by the attachment and balance of carbon dioxide, carbonic acid, carbonate, and bicarbonate ions so that the pH of the water does not fall beyond 6.5 or increase above 9 [12]. This is evidenced by the results of pH measurements in the primary canal. By looking at the measurement results, the pH distribution in the canal can be said to be well distributed throughout the canal.

The temperature results in the primary canal ranged from 27.9 – 28.3°C in the spring tide period. This temperature value is higher in the neap tide period, which is 29.4 – 30.9°C. At neap tide, the water level is lower than at spring tide, where the volume of water becomes less in the canal. This allows the sun's rays to reach the bottom of the canal, affecting the overall temperature in the water. In terms of fish growth rate, it is influenced by internal and external factors. The internal factors are gender, age, heredity, and disease resistance, while the external factors are feed availability and temperature [10]. The temperature is closely related to dissolved oxygen (DO) and the rate of consumption of aquatic animals. Temperature is inversely proportional to the saturated concentration of dissolved oxygen (DO) but directly proportional to the oxygen consumption rate of aquatic animals and the rate of chemical reactions in water [10].

The water sampling was conducted on March 14, 2022, at spring tide conditions, in the primary canal at a depth of 0.2D – 0.6D – 0.8D. The measurements are upstream of the canal (observation point 3) and downstream canal of Sei Teras (observation point 11) based on Figure 1 above. The results are presented in Table 3. From the results of vertical measurements at observation point 3, there is no significant change in the salinity concentration in depth. The salinity at the surface and bottom of the canal has the same value. The degree of acidity (pH) and temperature are likewise. The measured water quality indicators are evenly distributed in vertical canals. Observation point 11 shows the same distribution dynamics. There was no significant difference in the concentration of salinity on the surface and bottom of the canal, followed by the value of the degree of acidity (pH) and temperature. The average difference between the measurement results is 0.49%. The correlation between the two observation points shows that the effect of tides on the estuary by bringing the concentration of salinity and acidity (pH) ions upstream is quite good. The spring tide period with high tide could bring the concentration of these water quality parameters. Based on the measurement results and some information from the literature review, the water type in

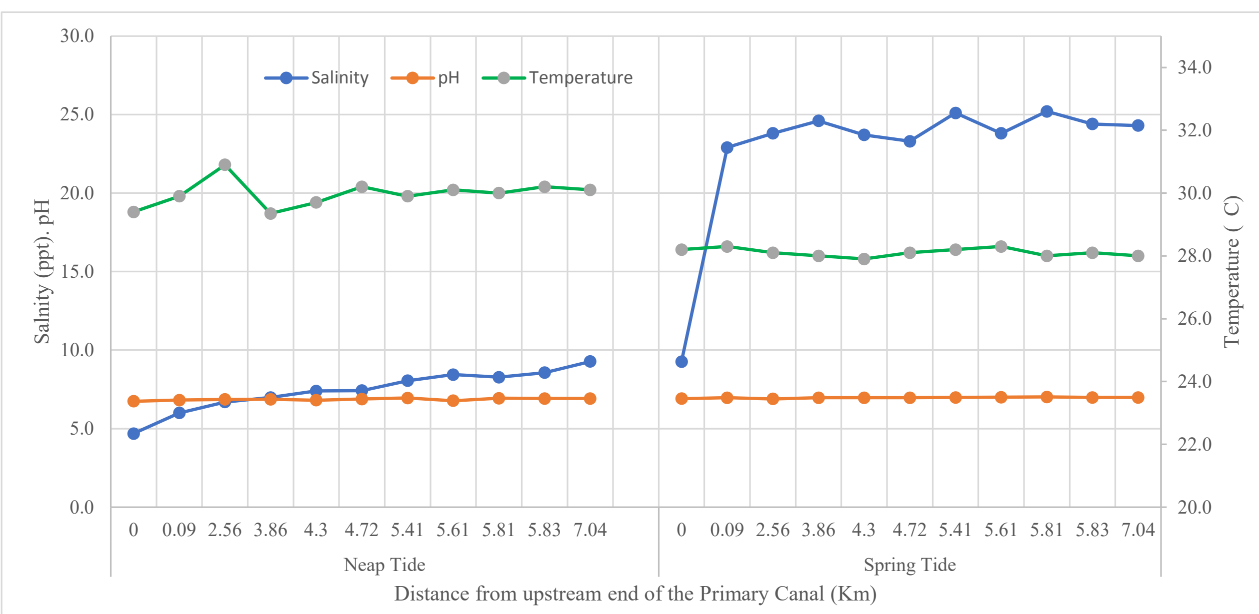

Figure 4 The Result of Instantaneous Measurement at Primary Canal

the estuary of Sei Teras is classified as a well-mixed estuary. This type is characterized by a clear boundary between fresh water and salt water [13]. The waters and primary canals of Sei Terraces have strong vertical agitation at the time of spring tide resulting in the waters being vertically homogeneous.

The instantaneous sampling in the secondary canal and fishpond was carried out on March 27, 2022. The object for observing the secondary canal is 1,550 m long, where point 12 is downstream of the canal, point 13 is in the middle, and point 14 is upstream of the canal. The point measurement location is based on figure 1 above. The pond area that becomes the object of observation is 5-7 ha. Observation points 15 is on the east side of the fishpond. Observation point 16 and 17 are on the south side of the pond near the inlet water source. Observation point 18 is on the west side, and observation point 19 is on the north side and is the furthest from the inlet water source. The measurement results are presented in Table 4.

Table 4. The Result of Instantaneous Measurement at Secondary Canal and Fishpond

Loc.	Ms. Point	Salinity (ppt)	pH	Temp. (°C)
Secondary canal	12	9.8	7.92	33.6
	13	10.4	7.03	33.4
	14	11.6	7.50	33.6
Fishpond	15	11.4	7.29	31.6
	16	11.4	7.29	31.8
	17	11.6	7.22	31.3
	18	12.1	8.34	32.4
	19	11.7	8.34	33.0

The range of measured salinity for improving the cultivation can be increased to semi-intensive cultivation. However, upgrading to an intensive technique is not feasible. It is based on the measurement and the distribution of salinity with a review point in the canal and fishpond. In terms of shrimp growth, the salinity range is still within the tolerance range (0-35ppt), but shrimp will not grow optimally (15-25 ppt) [9]. At the same time, good salinity for shrimp farming is 12-20 ppt. Shrimp will die when the salinities are greater than 50 ppt. Pigment metabolism will be disturbed and susceptible to disease if the salinity is less than 12 ppt [14]. In ponds, the salinity range is well distributed in terms of distribution patterns. There is no significant difference between those closest to the inlet water source and those that are farthest away.

The acidity degree (pH) of water in fishponds is not good. It is not evenly distributed throughout the fishpond. The west side (observation point 18) and the north side of the pond (observation point 19) are a bit too alkaline. From the results of visual observations, this area has experienced silting and deposition of klekap moss. Cultivation techniques can be improved to super-intensive technology based on the measured pH range. However, keeping the required pH range within the limit takes effort. The measurement results are still within tolerance for shrimp growth but are not optimal. The water environment that is less than 7 is acidic and will be less productive for shrimp. This condition will cause dissolved oxygen (DO), resulting in the increased respiratory activity of shrimp and decreased appetite [14]. An increase in pH can also increase the concentration of ammonia (NH_3), and a decrease in pH can also increase the concentration of H_2S [11]. An increase in these two chemical compounds will increase the toxicity and be harmful to shrimp. Surface temperatures in fishponds are quite variable. Similar to the results of pH measurements, the temperature distribution is not evenly distributed in the pond. The temperature on the west side (observation point 18) and the north side of the pond (observation point 19) is too high for shrimp. From these results, technological improvements can only be limited to extensive or traditional. However, increasing the level of super-intensive technology is still very possible. From the results of visual observations, the average pond depth is about ±30 cm. The depth is only about ±10 cm on the west and north sides. This depth is due to siltation and deposition. The sun ray can directly go through the bottom of the pond so that the water temperature becomes high. If the depth of the pond can be reached by digging according to the requirements of the cultivation technique, then the temperature limit requirements can be achieved. Based on the results, the temperature range is still quite good for shrimp growth but needs further management. Shrimp will grow optimally in the range of 28 -32 ° C and still live in the range of 26 -35 ° C [9]. A Shrimp can properly carry out the digestive process in the optimal temperature range, producing good shrimp growth.

3.2 Tidal Dynamics With Water Quality

The irrigation area of Sei Teras is located in Kalimantan Island, precisely in the province of Central Kalimantan. Unlike the island of Java in general, the climate zone in Kalimantan Island is classified as a wet tropical climate type. It has the characteristics of very high rainfall intensity ranging from 1,500 mm to 4500 mm per year. The cultivation businesses in open nature, such as ponds, of course, depend on the physical conditions of the environment. External factors such as rain can affect productivity. Moreover, the Sei Teras aquaculture is located in an area influenced by tides. The correlation between tides and rain is shown in Figure 4.

The hourly rain data is obtained from the Jaxa Global Rainfall Watch satellite. In Figure 4, it is shown that the intensity of rain is high. The high intensity of rainfall started at 03:00 on March 7, 2022, affects tidal conditions in the canal. These anomalies occur from 07:00 to 15:00 upstream and downstream of the canal. During this period, there is an irregular up and down movement. The result of the observation shows that high rainfall could suppress effect of tides from the sea. Sei Teras fishpond area is included in zone I, which is influenced by daily tides in the form of overflowing brackish water [15]. This area is like a large pond with only one outlet to release water to the estuary, so it can be assumed to have the same function as a tide reservoir. The concept of a tide reservoir is to control the flow. So, a tidal reservoir in one low tide cycle can push the water further without a pond [16]. Therefore, if a high intensity of rain falls in that area, the energy receding towards the estuary will be greater than the tide from the sea.

The occurrence of rain and tides will certainly affect the condition of water quality. The correlation between rain, tides, and water quality is shown in Figure 5. Based on the graphic, the salinity is decreased due to rain. The characteristics of Salinity in Sei Teras aquaculture are influenced by tides. When there is a tidal anomaly due to the rain, the trend of salinity decreases, followed by the high intensity and long duration of the rain. At 06:00 on March 7, 2022, the salinity tends to decrease when the water level rises due to high tides. This phenomenon occurs upstream and downstream of the canal. So, rain is very influential in the decrease of salinity concentration. The pH condition is relatively stable in the range of ±7 without the influence of rain. The buffer zone of brackish water can support pH conditions under stable conditions [12].

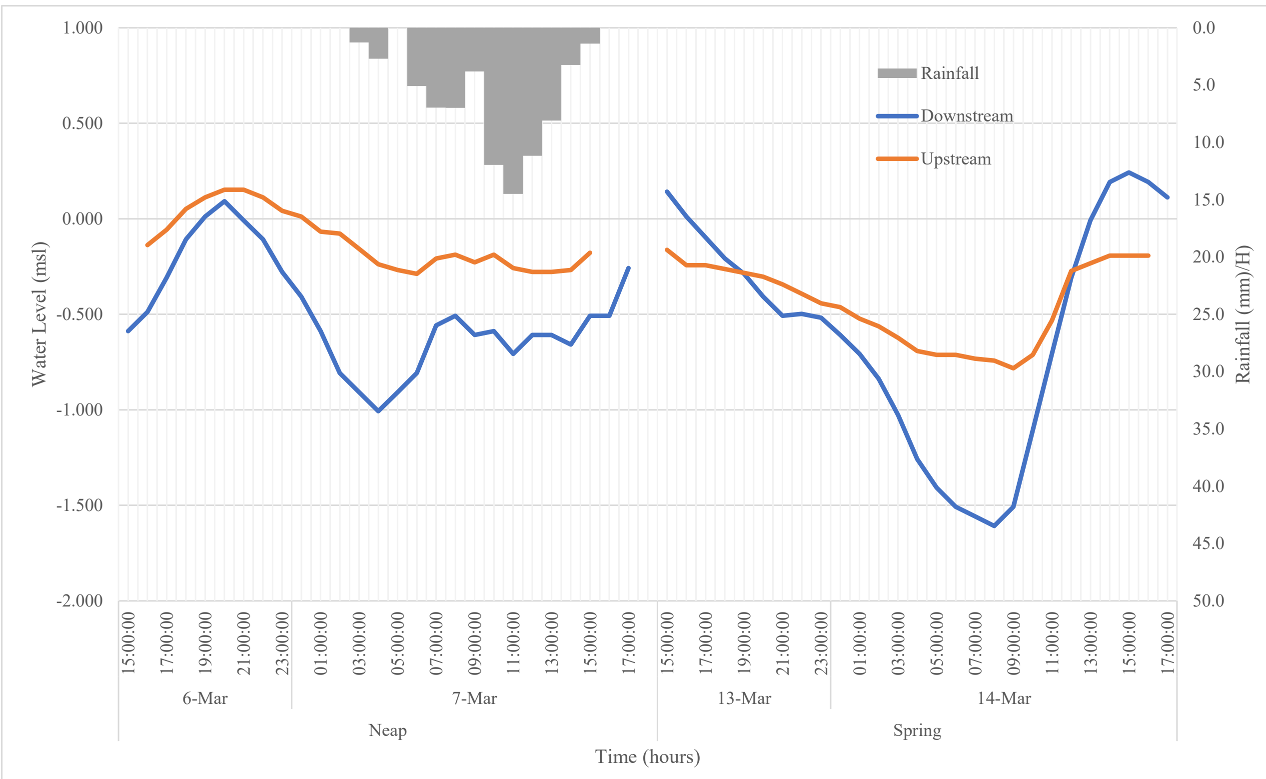

Figure 5 Rainfall and water level

4. CONCLUSIONS AND SUGGESTIONS

4.1 Conclusions

The analysis results explain that the distribution of water quality has been influenced by the tidal cycle. The difference in tide amplitude at the neap tide and spring tide impacts the distribution pattern in the canal. During spring tide, the distribution of water quality is almost evenly distributed along the primary canal with a salinity range of 22.9 – 25.2 ppt, a pH range of 6.89 – 7.02, and a temperature range of 27.9 – 28.3°C. On the contrary, during the neap tide, the distribution of water quality was uneven due to low tidal energy. The salinity concentrations in secondary canals and ponds ranged from 9.8 – 12.1 ppt, pH ranged from 7.03 -8.34, and temperature ranged from 31.3 – 33.6°C. In fishponds, the salinity is well distributed. No significant difference exists between those closest to the inlet water source and those farthest away. However, in contrast to the salinity, pH and temperature were not evenly distributed due to the pond's silting and deposition of klekap moss.

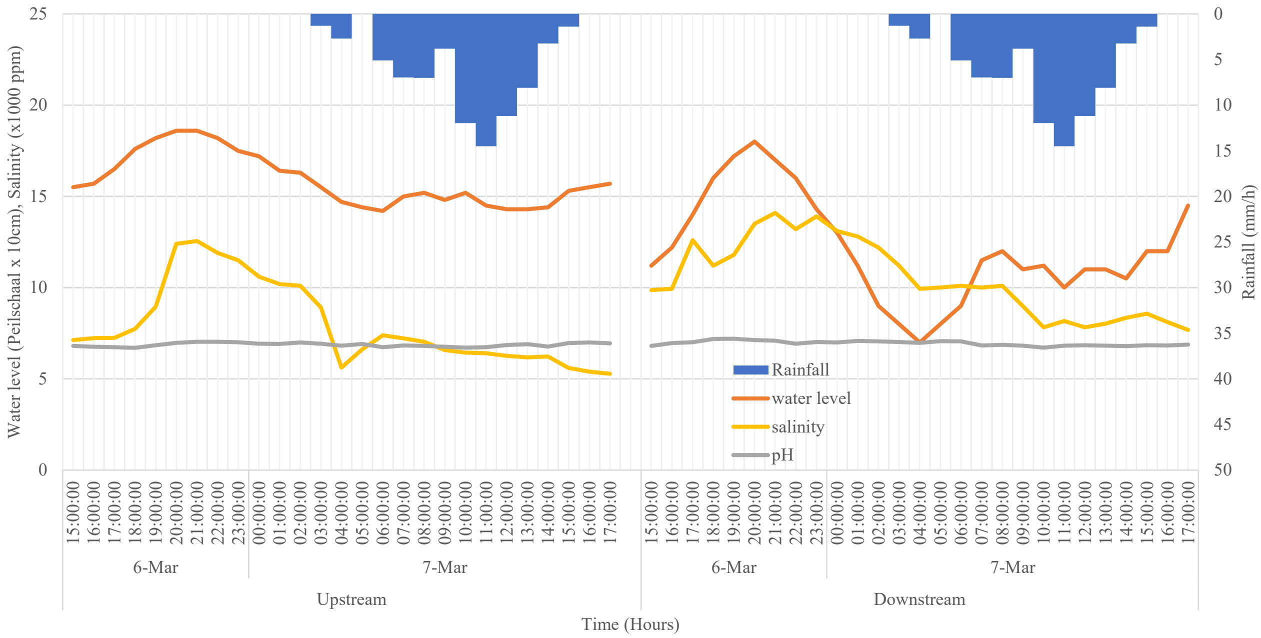

Figure 6 Recorded Water Level, Salinity, pH and Rainfall at upstream canal (observation point 3) and downstream canal (observation point 11)

Therefore, technology improvements for advanced aquaculture can be applied. The salinity parameter meets the criteria to be upgraded to semi-intensive cultivation of vanammei shrimp or tiger prawns. The degree of acidity (pH) and temperature parameters meet the criteria for super-intensive improvement. However, good management and development requirements of intensive farming, such as fishpond preparation, were indispensable to achieve that goal. Tidal fluctuation influence strongly the environment for growing the shrimp. The rain that falls on the Sei Teras fishponds affects the water level in the canals. The results of the observations show that high rainfall could suppress the effect of tides from the sea. The salinity concentration decreased due to the presence of rain but this gives no significant impact to the degree of acidity (pH). The vertical distribution of water quality was relatively homogeneous.

AUTHORS' CONTRIBUTIONS

Hanny Adityanta Hermawanto conducted the field measurement, data collection, interpretation, analysis and manuscript writing. Adam Pamudji Raharjo and Budi Kamulyan as supervisors who assisted in data analysis and interpretation, manuscript writing procedures and conclusions.

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