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Sedimentary Characteristics of Shallow Aquifers and Suitability to Irrigation in the Drought Season: The Case of the Fruit Tree Area in Ben Tre Province, Mekong River Delta

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Abstract: In Ben Tre province, shallow groundwater found at a depth of 8 to 60 m is exploited for domestic use and for irrigation of crops in rural areas. The water wells have different depths and are usually moderately to high contaminated with iron alum, moreover the saline- brackish water is at different depths and locations. In recent years, due to the effects of climate change and drought, the problem of drinking water and irrigation for planting is an urgent need. The study determined the distribution characteristics of aquifers, the environment for forming sediments and analyzed some chemical indicators of water for crop irrigation. This study shows that shallow groundwater is clarified and consisting of the Holocene (qh) and upper Pleistocene (qp3) aquifers from 8 to 60 m in depth. The Holocene aquifer consists of fresh water commonly found at of 8.5-17.5 m in depth, and saline- brackish water appearing by layers and lenticular are commonly found at about 25- 35 m in depth. Fresh water is usually found in the fluvial flat, channel and estuary facies, and saline - brackish water is in the tidal flat, delta front and pro-delta facies belong to the subaqueous delta plain. It suggests that sedimentary facies in boreholes and geological cross-sections play an important role in determining distribution characteristics and water quality, clarifying the distribution of fresh and saline water in Holocene sediments in the study area. This result can be referenced for research in the Mekong River Delta and other regions. Shallow aquifers have not great thickness, uneven water quality, cannot provide concentrated water. However, the water source has an important meaning in providing water for agricultural irrigation in the drought season, especially in the fruit tree area in Ben Tre Province.

Keywords: Shallow Aquifer, Groundwater, Sedimentary Facies, Saltwater Intrusion, Drought, Irrigation, Ben Tre Province

1. Introduction

Groundwater is a precious resource exploited for daily life, contributing to socio-economic development, and improving people's living standards in urban and rural areas. However, due to widespread groundwater exploitation, lack of planning and management by local authorities, some negative impacts frequently occur such as lowering of groundwater level, pollution of aquifers, land subsidence [1] The extraction of groundwater exceeds the natural capacity of replenishment and serious land subsidence has occurred in urban areas such as Tokyo, Shanghai and Bangkok [2]; in rural areas in Bangladesh and India, where groundwater has been used for agricultural cultivation [3, 4]. Therefore, solutions to artificially add to groundwater to limit land subsidence and/or increase groundwater reserves to ensure sustainable exploitation of water resources are being researched and applied in Soc Trang and Ca Mau provinces in the Mekong Delta [5, 6]. In addition, coastal areas and surface water are contaminated with salt due to tidal influence bringing sea water into rivers and canals, especially in the dry season and prolonged

drought, so the solution to artificially supplement groundwater, limit land subsidence, serving agricultural production has received much research attention [1, 7]. Along with the replenishment well system, the water level and groundwater quality are collected on the existing well system, the results show that the rainwater replenishment for shallow groundwater is effective, increasing the amount of groundwater to serve agricultural production and people's livelihood [8]. Due to the effects of climate change, drought and saline intrusion, groundwater in the dune system is severely deficient in the dry season in the coastal area of Ba Tri district, Ben Tre province [9]. Exploiting a large amount of water in the sand dunes for crop irrigation causes depletion and saline water in the sand dunes. The study assesses the impact of groundwater depletion on agricultural production and proposes solutions to overcome it in Vinh Chau, Soc Trang province [10].

Issue of using clean water for daily life in rural areas is more difficult than in urban areas in Ben Tre province as well as in the Mekong Delta, the proportion of rural population with clean water supply is only about 30-35%. People mostly use rain water, ponds, canals, canals, rivers or water from drilled wells, which are often contaminated with iron, alum, and micro-organisms, so their health is significantly affected. Along with the socio-economic development, the demand for water for domestic purposes is increasing and the problem of water pollution is becoming more and more serious. Fresh water sources from surface water and groundwater for daily life and production are currently being significantly reduced and will be severely lacking in the near future, especially in the context of climate change, sea level rise [Figure 1].

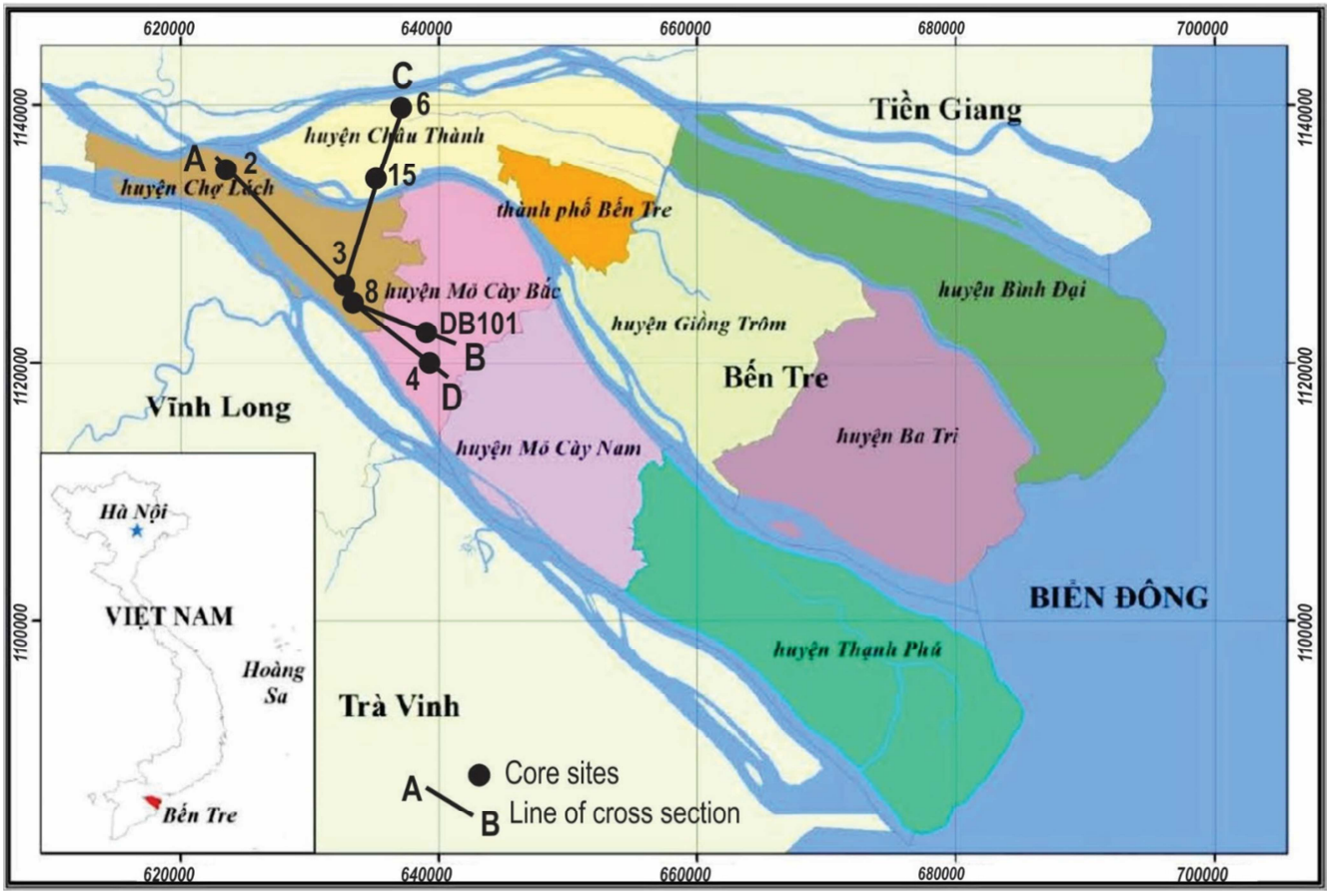

Figure 1. *Study area and locations of boring cores and line of cross section.*

Regarding agricultural development, the agricultural sector has been invested and developed quite comprehensively with the project on restructuring the agricultural sector associated with value chain development and sustainable development linkages obtained initial results. The fisheries sector continues to receive investment and affirms its important role, accounting for an increasing proportion of agricultural production value (about 53.5%); Clean farming and application of science and technology in aquaculture have increased significantly. Combined with the program of building a new rural development, it has contributed to making people's life and rural appearance continue to prosper. Agricultural production focuses on solutions to transform production models to adapt to climate change and drought. Exploiting and using from the sea into the field, including the coastal saline- brackish water areas, to develop shrimp and aquatic products; fresh- brackish water areas for rice, rice-shrimp, coconut trees, livestock; fresh water for orchards, seedlings, ornamental flowers. And the problem of finding fresh water sources to irrigate orchards, seedlings and ornamental flowers in the northwest region of Ben Tre province in Chau Thanh, Cho Lach and northwest Mo Cay

districts. Therefore, shallow groundwater resources are investigated and evaluated because deep freshwater aquifers are used for production, living and industry.

On the base of characteristics of depth, distribution, exploitation and use of groundwater use can be distinguished into 3 parts:

(1) Holocene aquifer is mostly exposed above ground at depths of 10.0 m and 40.5 m, averaging 24.0 m. The thickness of the layer of fine sand and alluvium containing water ranges from 0.0 to 39.9m, with an average of 16.3 m. The aquifer tends to sink to the west of the province.

(2) Middle - Upper Pleistocene aquifer reaches to over 120 m deep, widely distributed throughout the province. The aquifer with depth of 15 - 60 m is often contaminated with alum, some places are brackish- saline water. The aquifer of 60-120 m deep has limited distribution and is exploited for daily rural living.

(3) The aquifers are 120-395 m deep (belonging to the complex of lower Pleistocene aquifers, Middle Pliocene, Lower Pliocene and Upper Miocene) have good quality [6, 11], they are valuable water resource for exploitation using for daily life and industrial services.

This study evaluates the shallow aquifer from 0 to 60 m, exploited and used for agricultural development. Thus, it focuses on analyzing and identifying sedimentary environments in geological boreholes, establishing geological cross-sections to assess distribution characteristics and potential of groundwater for exploiting shallow groundwater in the northwest area of Ben Tre province.

2. Method

On the base of the available research results, the study conducted 6 geological drilling holes 2, 3, 4, 5, 6, 8 with a depth of 40 m at each hole [Figure 1]. Analysis and determination of sedimentary environment, characteristics of distribution of shallow aquifers. Analyzing the chemical parameters of groundwater in terms of Cl^-, total Fe, SO_4^{2-}, total As and Coliform to determine the quality of water supplied for domestic use and water for crop irrigation.

3. Results and Discussion

3.1. Saltwater Intrusion and Its Impacts to Agriculture

Saltwater intrusion is a phenomenon in which salt water with a salinity concentration above 4‰ (salinity standards of water used for agricultural cultivation in Vietnam) penetrates deep into the field during high tides, sea level rise and/ or depletion of fresh water coming from the upstream (Ministry of Agriculture and Rural Development, 2016).

Since the end of 2014, El Nino has affected the Mekong Delta, caused high temperature and lack of rainfall, which is the main cause of drought and saltwater intrusion. The impact of water replenishment or groundwater extraction leads to the displacement of the interface between fresh water and salt water from one location to another. That displacement can cause water levels to rise or fall depending on whether the fresh water entering the aquifer increases or decreases. This situation will increase faster if groundwater replenishment is reduced. Climate change-induced changes such as rainfall and temperature changes and land-use changes can also significantly alter the quantity of groundwater replenished to aquifer systems affecting the process of saltwater intrusion.

The 2015-2016 El Nino was the strongest and longest lasting in about 60 years. Rainfall from the end of 2015 to April 2016 was at 20%-40% lower than the average of many years, the rainy season ended earlier than the average of many years. In the period of 2015-2016, salinity of 4‰ on the main rivers entered into 45-65 km, 1‰ salinity entered into 50-70 km from the coast. It is the time of saltwater intrusion reached a record. Therefore, saline water affects early and gets more into the field causing damage to agricultural production and people's daily life. According to statistics, the total area of winter-spring rice in 2015-2016 has been damaged over 10,000 hectares, mostly in Ba Tri and Giong Trom districts, in addition, hundreds of fruit trees areas in districts such as Cho Lach, Giong Trom and Chau Thanh … have been severely reduced in productivity due to lack of irrigation fresh water.

In the period of 2019-2020, according to the General Department of Natural Disaster Prevention and Control (2020), the 2019 rainy season in the Mekong River basin appears late, the rainy season duration is short, the total annual flow is only medium - low. The flow to the delta from the beginning of the dry season to present has decreased rapidly and is at a very low level in comparison to the multi-year average from 1980 to 2020. The two important upstream factors that dominate water source, saline intrusion in the 2019-2020 dry season in the Mekong Delta are the storage in Tonle Sap and the flow to Kratie (the beginning of the Mekong Delta). The flow to the Mekong Delta is seriously deficient, lower than the whole year 2015-2016. This is the main cause of early and prolonged saltwater intrusion in the 2019 - 2020 dry season. Saltwater intrusion has appeared at a sudden high level from December 12 to 15, 2019, the farthest salinity contour of 4‰ in the Mekong estuaries was about 57 km (Ham Luong river) from the coast, which was further than the annual average 24 km, further than the 2015 salinity contour of 17 km. In January 2020, saline intrusion increased sharply in the period from January 6 to 13, 2020 with the 4‰ salinity contour at the Mekong estuaries about 45 - 66 km from the coast, further than the 2016 saline contour from 06 - 17 km.

The impact of saltwater intrusion in recent times has also been recorded. In recent years, the situation of saltwater intrusion in Ben Tre province has become more and more intense, irregular, difficult to predict. Previously, salinity usually peaked and remained in March then gradually decreased, but in 2019, the salinity was at a very high level since December and continued to remain for about 5 months. In addition, the irrigation system is not yet complete due to the blocked flow by hydroelectric projects on the Mekong River upstream as well as the progress of climate change, sea level rise which make saline intrusion encroach far inland through river mouths. Therefore, Ben Tre province needs agricultural

farming solutions to adapt to saltwater intrusion both in the short term and long term. In which, the solution to transform agricultural production models adapting to climate change is prioritized and is being implemented in Ben Tre province, especially there is a big transformation in coastal districts: Thanh Phu, Binh Dai and Ba Tri districts. Currently, saltwater intrusion spreads far into the field that causes many negative impacts on agricultural production. In Ben Tre province, it is estimated that about 5,200 hectares of rice in two districts of Ba Tri and Giong Trom which are likely to be lost due to lack of irrigation water. In addition, it is noticed that about 20,000 hectares of fruit trees, more than 72 thousand hectares of coconuts, nearly 1,500 ha of vegetables, more than 100,000 seedlings and ornamental flowers are also at risk of being affected by saline intrusion. This leds to a reduction of 10 thousand hectares of rice cultivation area to switch to aquaculture in saline areas, to plant other crops of higher economic value such as: coconuts, fruit trees, vegetables, grass for farming livestock and non-agricultural land; Coconut area from 68 thousand ha reached to 72 thousand ha; the area of fruit trees increased from 27,000 ha to more than 28,000 ha. Thereby, transformation of agricultural production models adapting to climate change contributes to restructure agricultural production in the direction of value enhancement and sustainable development. The above results show that agricultural production models adapting to climate change in Ben Tre province are shrimp, aquatic products, rice-shrimp in coastal districts Thanh Phu, Ba Tri, Binh Dai; 2-crop rice and coconut trees in the districts of Mo Cay Nam, Mo Cay Bac, Giong Trom, northwest of Binh Dai district and southeast of Chau Thanh district. The area of fruit trees, seedlings and ornamental flowers in Chau Thanh, Cho Lach districts and the northwest of Mo Cay Bac district needs fresh water from shallow aquifer for irrigation especially in dry and drought season when salt water intrudes into this area.

3.2. Characteristics of Sedimentary Facies

Sedimentary characteristics are determined based on detailed analysis of the sedimentary environment of 6 new boreholes, stratigraphic relations of the boreholes, two cross-sections to clarify sedimentary facies and characteristics of the shallow aquifers. In addition, borehole data and previous research documents are also aggregated to update and compare enriching the research results.

3.2.1. Holocene Sedimentary Characteristics

On the base of borehole sediment characteristics, the results of analysis of grain size parameter, sedimentary structure and diatom species, sedimentary environments of boreholes are determined. The column sections represent the characteristics of the sediment of boreholes 2, 3, 4, 6, 8, 15 [*Figure 2*]. They can be divided into four sedimentary units from the surface to 40 m deep as follows:

1) Unit 1 (0.0 to 5.5m deep) is mainly composed of gray, grayish brown silty and sandy silt containing organic matter and a little shell fragment. It is 4.5 - 5.5 m in thickness and found in 2, 3, 4, 6, 8 and 15 cores. Sandy silt and fine sand usually appear with thing laminae of about 2- 4 mm thick in the 2, 6 and 15 cores, but they are not found in 3, 4 and 8 cores instead of the common occurrence of silty clay is rich in browns, and dark browns organic. Mud content ranges from 61- 68%, and sand is 29.5- 37.8%. This unit is characterized by discontinuous parallel lamination in the lower part of this unit. The diatom assemblage is composed of by 52.6- 60.4% fresh water, 21.7 – 27.5% fresh- brackish water and 14.5- 18.2% brackish water diatom species. Diatom species is dominated by *Cymbella* spp., *Gomphonema* sp., *Pinnularia* spp., and *Aulacoseira granulata. Cyclotella caspia, Cyclotella styrolum* and *Coscinodiscus* spp. are common. It indicates a fresh and fresh- brackish water environments, sediment is formed in the back swamp environment, flood plain belonging to subaerial delta plain, typical environment on the lower delta plain [Figures 3, 4]. Sediment distribution and depositional processes along the fluvial to marine transition zone in both recent Mekong rivers and boreholes. The process regime, salinity, morphological, and sedimentary characteristics are clarified and comparing to sedimentary facies along the fluvial to marine transition zone of the mixed-energy MRD [12, 13].
2) Unit 2 (5.5 to 9.4 m deep) is characterized by grayish, greenish silt, silty sand and fine containing organic matter and shell. Sandy silt and fine sand usually appear with thing laminae of about 2- 4 mm thick in the 2, 6 and 15 cores. Sedimentary structure is characterized by parallel lamination, discontinuous parallel lamination, interbedded parallel and tidal rhythm. Mud content is of 52-64%, and 32-41% sand. The diatom assemblage is composed of by 42.6 -56.2% fresh water, 15.4- 18.2% brackish water, 12.5- 18.8% marine -brackish benthic and 10.3- 16.2.% fresh- brackish water diatom species. Diatom species is dominated by *Cymbella* spp., *Gomphonema* sp., *Pinnularia* spp., and *Aulacoseira granulata. Cyclotella caspia, Cyclotella styrolum* are common, and *Achnanthes brevipes, Cocconeis sublittolaris, Diploneis bombus, Navicula* spp., occur with low frequency. This sediment is formed in fluvial mudflat, tidal flat and estuary environments.
3) Unit 3 is mainly composed of grayish and pale gray fine-medium sand, fine sand, characterized by discontinuous parallel lamination, interbedded parallel, bidirection and current rhythm. This unit is of 3.8 - 6.5 m thick found from 8.5 to 17.5 m in depth from the 2, 3, 4, and 8 cores. The sand content is of 52-67% and silt of 29-45%. The results of analysis of the diatom species composition in the fine-grained sediments show that although it is not abundant, it is valuable for determining the ecological environment. The diatom assemblage is common of by 54.8 -62.4% fresh water, 12.6- 15.4% in each brackish and fresh- brackish water the freshwater diatom species, and 9 - 10% marine-brackish benthic water diatom species. The representatives of *Diploneis* spp., *Grammatophora* sp., *Navicula* spp and *Cymbella* spp., *Gomphonema* spp., *Pinnularia* spp. It compares with diatom assemblages in a late

Pleistocene-Holocene incised-valley sequence from MRD [14, 15]. This sediment is formed in fluvial mudflat, channel, estuary and tidal flat.

4) Unit 4 is divided into 2 parts as follows:
   a. The upper part is about 5.5 - 9.0 m thick, mainly composed of grayish green silt interbedded with sandy silt lenticulars, about 1.8- 2.0 m thickness. The mud content is of 56-67% and sand of 29-39%, parallel and discontinuous parallel laminations are common in this part of the unit.
   b. The lower part is about 10-16 m thick, characterized by grayish green fine sand, silty sand interbedded silty and silty sand layers and rich in organic matter and shell fragments. It is of 2.5 to 32.0 m deep in the 2, 3, 4, 6, 8 and 15 cores with average thickness of 12-18 m. The maximum thickness is of 25 m in the DB101, characterized by interbedded of fine sand and sandy silt. Sand content is of 47-56% and mud of 36-48%, the sedimentary structure is characterized by discontinuous parallel lamination.

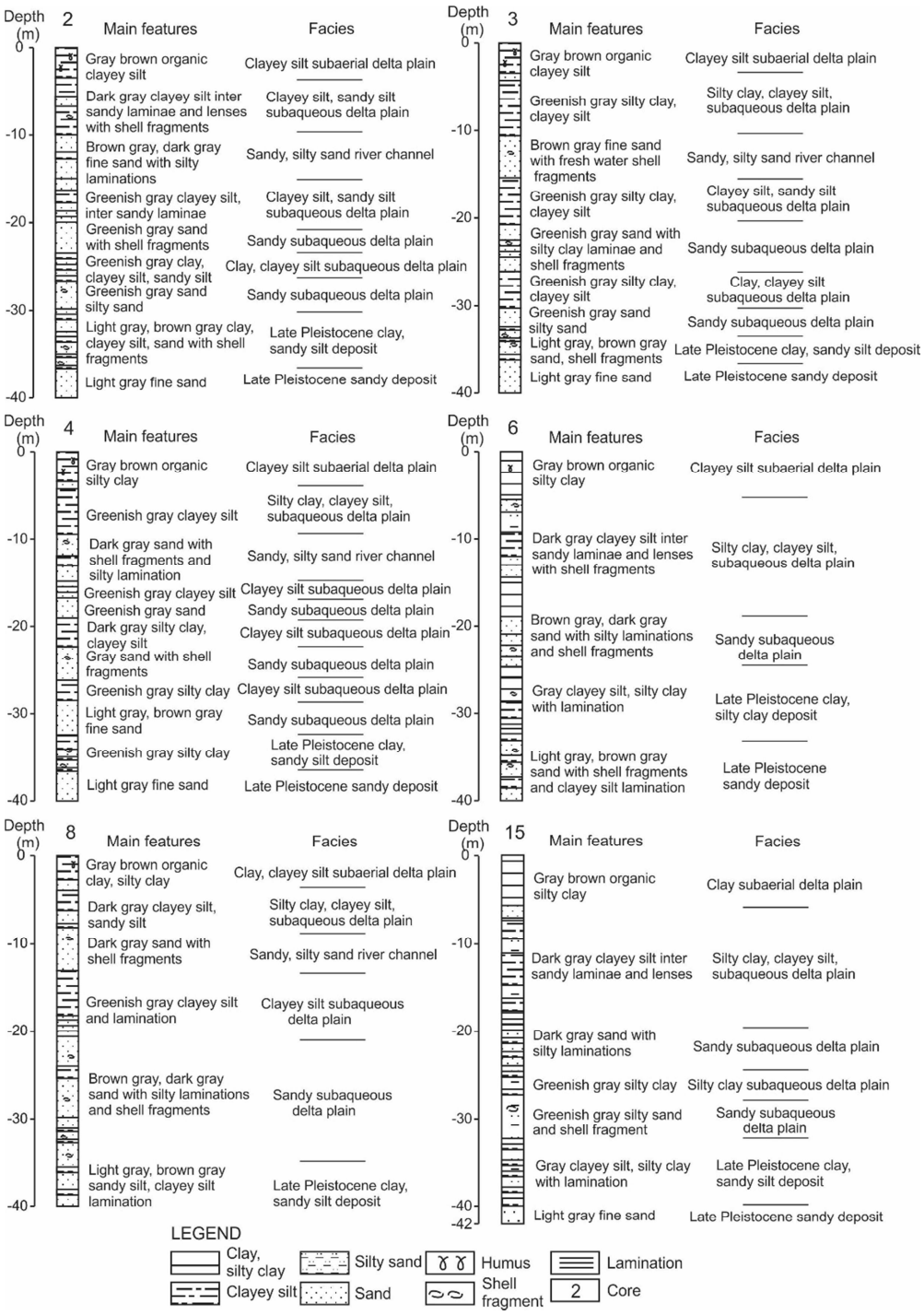

Figure 2. *Colum sections of boring cores indicating characteristic of sediments (see locations at Figure 1).*

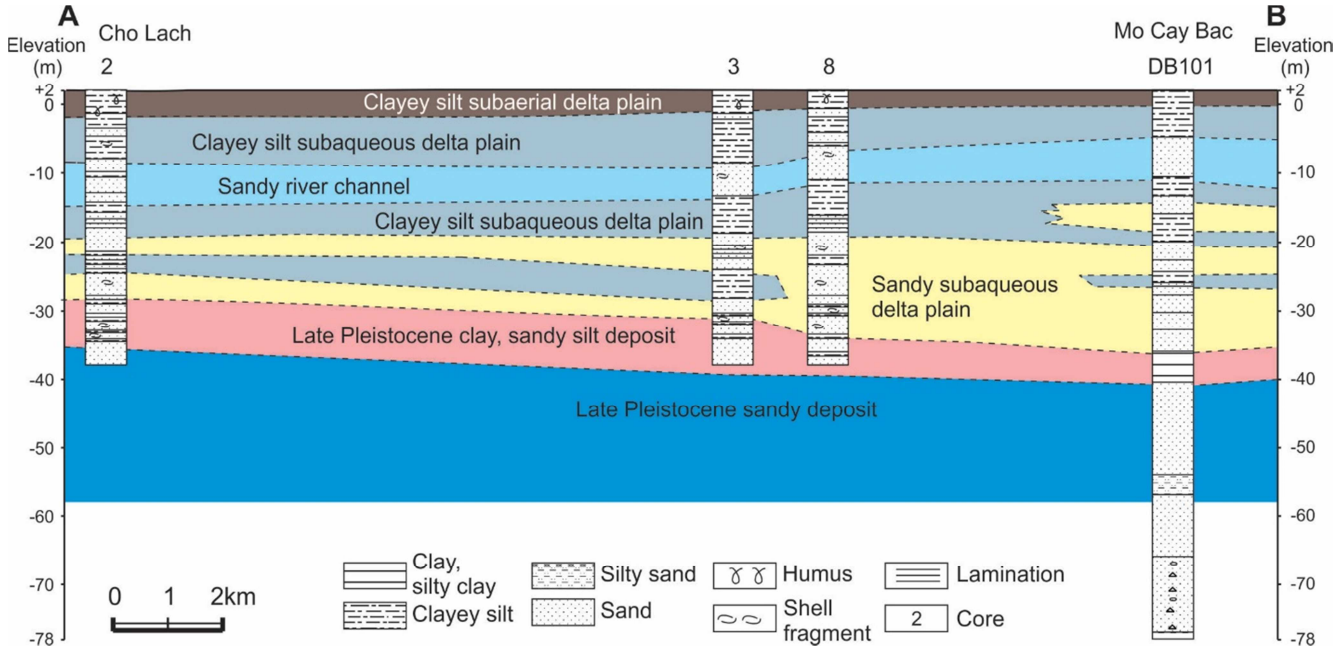

Figure 3. *AB cross section showing shallow Holocene and Late Pleistocene aquifers.*

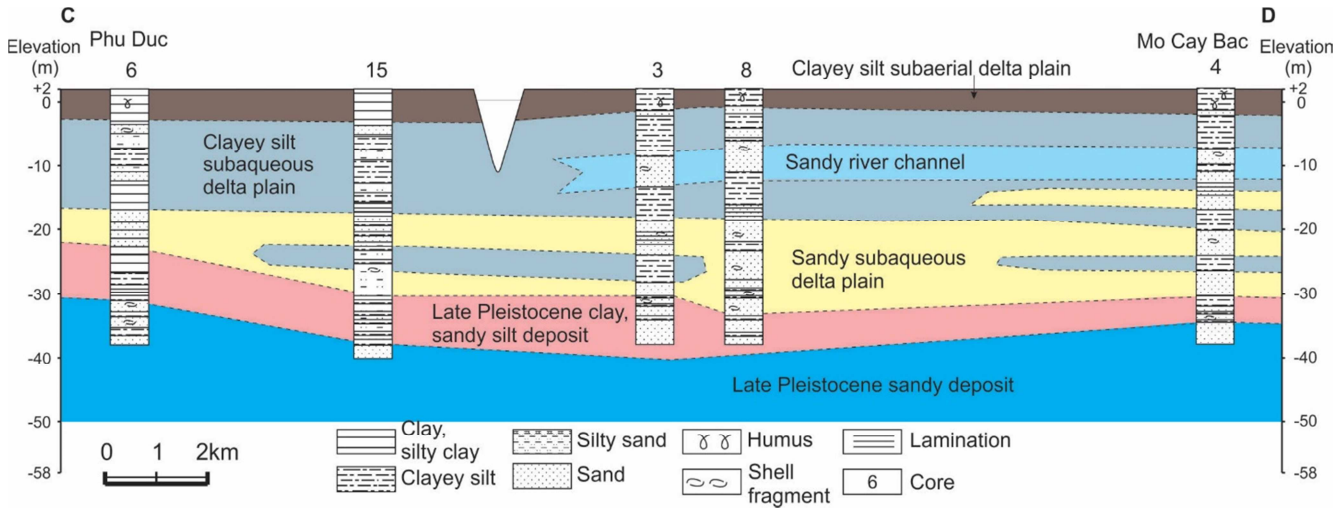

Figure 4. *CD cross section showing shallow Holocene and Late Pleistocene aquifers.*

The diatom assemblage is common of by 20.6 -28.5% marine brackish benthic, 18.7 -26.4% marine planktonic, 12.5-15.7% brackish water, 9.2-12.5% fresh- brackish water and 25.6- 28.3% fresh water diatom species. The representatives of *Coscinodiscus radiatus, C. nodulife, Thalassiosira eccentrica, Thalassionema sp. Achnanthes brevipes, Cocconeis sublittolaris, Diploneis bombus, Grammatophora oceanica, Navicula* spp., *Nitzschia sigma; Aulacoseira granulate, Cymbella* spp., *Diploneis ovalis, Gomphonema* spp., *Pinnularia* spp. The results show the ecological environment of saltwater- brackish water, and the delta front, pro-delta sedimentary environment. This sediment is formed in subaqueous delta plain such as intertidal flat, delta front and pro-delta. These results consistent with the changes of sedimentary facies and delta progradation in the last 5000 years in Ben Tre province [16].

3.2.2. Pleistocene Sediments

The Pleistocene sediments are divided into 2 parts, the upper part is of 29.5 to 37.5 m in depths and characterized by mainly pale greenish gray and pale gray and red-yellow silty sand with containing iron nodules. This sediment has light consolidated hence easily distinguishable from the overlying soft Holocene sediment. The lower part is mainly composed of gray to brownish gray medium-fine sand of gray with a thickness of about 12-26 m (Figures 3, 4).

3.3. Characteristics of Groundwater Distribution in Shallow Aquifers

On the base of analyzing and synthesizing collected documents on geological characteristics, geomorphology, hydrogeology and new data from 6 boring cores (Figure 2), characteristics of sedimentary facies are clarified from ground

surface to 40 m in depth. Distribution of subaerial to subaqueous delta plain indicate sedimentary processes that contribute significantly to the characterization of shallow aquifers.

The results of collecting groundwater samples of boreholes from this study and local people's wells for water extraction suggest the distribution of shallow aquifers and poor water aquifers are up to 60 m deep and freshwater and brackish-saline aquifers are detected.

Shallow groundwater belongs to the Holocene (qh) and upper Pleistocene (qp3) aquifers, distributed at depths from 8 to 60m, consistent with previous studies [10]. The AB and CD cross sections specifically show the uneven distribution of shallow aquifers at depths of 12-14 and 40-60 m in Cho Lach, Mo Cay Bac and Chau Thanh districts (Figures 3, 4). These shallow aquifers are quite abundant and are exploited to irrigate fruit gardens and ornamental plants most commonly in Ben Tre province.

3.3.1. Holocene Aquifer (qh)

The Holocene pore aquifer is formed by coarse-grained sediments of different origins, including fluvial mudflat, channel, tidal sand flat and delta front facies, mostly exposed on the ground or covered with a subaerial delta plain of 8–10 m thick, distributed mainly in the northern area of Ben Tre province, including Cho Lach, Mo Cay Bac and Mo Cay districts. The bottom of this aquifer is of 10.0 to 40.5m in depth, with an average of 24.0 m. The average aquifer thickness is from 0.0 to 16.3m, tends to sink to the west of the province. The main composition is fine sand, powder, clay mud, alternating layers of saturated silty clay, aquifers tend to be sunken in the west of the province. This underground aquifer has water levels ranging from rich, moderate to poor. The results of the study identified freshwater and brackish aquifers as follows:

(1) Fresh water aquifer corresponding to unit 3, characterized by fine-medium sand, fine sand and sandy silt, usually found at of 8.5-17.5 m in depth, with an average thickness of 3.8-6.5 m. The sedimentary environment is fluvial flat, channel and estuary, thus abundant water is found in the fluvial flat and channel, however brackish water is found in the estuary and/or intertidal environment.

(2) The brackish- saline aquifer corresponds to the unit 4, usually found at a depth of 12.5- 32.0 m with an average thickness of 12-18 m. This aquifer occurs of layers and lenticulars found at a depth of 25- 35 m, characterized by green to greenish gray fine sand, silty sand interbedded with thick layers of silty clay and sandy silt, about 10- 16 m in thickness. The sedimentary environments are tidal flat, delta front and pro-delta facies belong to the subaqueous delta plain, hence it contains brackish-salt water.

The results show that the Holocene aquifer consists of (1) fresh water commonly found at of 8.5-17.5 m in depth, and (2) brackish- saline water is in the layers and lenticular with water-poor strata are commonly found at 25- 35 m in depth. It coincides with stratigraphy and the change of Holocene sedimentary facies in the MRD [16, 17].

Exploiting flow of small wells is from 0.01 to 2.22 l/s, average 0.25 l/s, Static water level changes seasonally from 0.30m to 3.00m, average 1.19 m and tidal fluctuations of rivers and seas [10]. In the dry season, the water level fluctuates less, tends to decrease gradually and reaches a minimum at the end of the season around May to June. In the rainy season, the water level changes strongly and fluctuates with many extremes and reaches the maximum value in the end of rainy season in October because the aquifer receives its supply directly from rainwater. The number and amplitude of water level fluctuations depend on the intensity and duration of the rains. According to monitoring results, the highest water level is -0.70m, the lowest -2.25m. The annual amplitude fluctuates from 0.87m to 1.36m; average 1.11m, and the water level tends to rise gradually over time.

Result of chemical analysis of ground water in 12- 15 m deep showing as follows:

Chloride (Cl^-): 30- 883 mg/l, Sulphate (SO_4^{2-}): 41 - 266 mg/l; total Fe (Fe): 0 - 53.40 mg/l, total As: 0.0- 0.05 mg/l; Coliform CFU/100ml: 0 – 240.

The Holocene shallow aquifer has a small thickness, mostly poor water, uneven water quality, and is unable to provide concentrated water. However, the water source is significant in the supply of household water, for daily life and eating in areas with limited freshwater such as Ben Tre province.

3.3.2. Upper Pleistocene Aquifer (qp3)

This aquifer is made up of upper Pleistocene sediments, composed mainly of fine to medium-grained sand and little gravel. This aquifer is distributed almost throughout Ben Tre province, not exposed on the ground. The aquifer roof was detected at a depth of 25.0 to 62.5m, with an average of 42.8m; The bottom of the aquifer is at depths from 31.0 to 115.0m, with an average of 86.7m. The aquifer thickness varies from 0.0 to 72.0m, with an average of 38.9m. The aquifer tends to sink to the east and southeast and covers the middle and upper Pleistocene formations, which are very poor in water. The aquifer capacity of aquifers varies from rich to poor, in which rich aquifers occupy a small area in the eastern part of the province with a total area of about 34.40km^2. The static water level of this layer varies from 1.71 to 4.80m, with an average of 3.76m. The monthly mean value of water level ranges from -3.47m to -5.61m. The annual amplitude is from 0.29 to 0.91m [11].

The AB and CD sections (Figures 3, 4) show that the Pleistocene sediments are divided into 2 parts, the upper part is of 3.5 - 8.5 m in thickness, found at a depth of 29.5 - 37.5 m, characterized by mainly greenish-gray and red-yellow silty clay, silty sand and fine sand containing iron concrets. This sediment is weak consolidation, thus easily distinguishing to soft overlaying Holocene sediment. The lower part is composed mainly of light gray, brownish gray medium-fine sand with 12- 26 m in thickness. The results show that brackish- saline water was found in the 3 and 8 boreholes in Cho Lach district. The results of chemical analysis of

underground water at a depth of 40 m showed the following: Chloride (Cl^-): 30-268 mg/l, Sulfate (SO_4^{2-}): 16 - 41 mg/l; total Fe (Fe): 0- 4.24 mg/l, total As: 0.0- 0.05 mg/l; Coliform CFU/100ml: 0- 23. In Generally the Upper Pleistocene aquifer has a wide distribution area, quite large thickness and medium water capacity.

4. Conclusion

Transforming agricultural production models to adapt to climate change contributes to restructuring agricultural production towards rational use of water resources in Ben Tre province. From the coast to the inland, production models of shrimp- mangroves, aquatic products, two-crop rice, and coconuts are exploited appropriately using brackish and fresh water from rivers and canals. However, the northwest area of Ben Tre province where grows fruit trees, seedlings, ornamental flowers need fresh water from the shallow aquifer for irrigation, especially in the dry season.

The shallow groundwater is clarified and consisting of the Holocene (qh) and upper Pleistocene (qp3) aquifers from 8 to 60 m in depth. The Holocene aquifer consists of fresh water commonly found at of 8.5-17.5 m in depth, and saline- brackish aquifers appearing by layers and lenticular are commonly found at about 25- 35 m in depth. Fresh water is usually found in the fluvial flat, channel and estuary facies, and saline - brackish water is in the tidal flat, delta front and pro-delta facies belong to the subaqueous delta plain. It suggests that sedimentary facies in boreholes and geological cross-sections play an important role in determining distribution characteristics and water quality, clarifying the distribution of fresh and saline water in Holocene sediments in the study area. This result can be referenced for researches in the Mekong River Delta and other regions.

Holocene shallow aquifer has not much thickness, mainly poor water, uneven water quality, cannot provide concentrated water. However, water sources have an important meaning in providing water for daily life and irrigation orchards in rural areas. The upper Pleistocene aquifer, at a depth of 38-40 to 50 m, contain fresh water with medium- high iron alum contamination found in Chau Thanh, Cho Lach and Mo Cay Bac districts. The shallow aquifers including Holocene and Pleistocene aquifers are exploited and treated with iron alum for irrigating orchards, seedlings and ornamental flowers in Chau Thanh and Cho Lach districts in dry season.

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