PRESERVATION STRATEGY OF IRRIGATION PONDS IN URBAN DISTRICT : HISTORICAL DEVELOPMENT, PRESENT STATUS, AND FUTURE PERSPECTIVES

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Abstract: Hyogo prefecture prides itself for having the most Irrigation Ponds. The Higashi Harima region was selected as one of the 180 cultural sceneries for its vast collection of Irrigation Ponds. However, as a result of urbanization and ageing farmers, appropriate management of Irrigation Ponds has become difficult, thus causing advancing dilapidation. Also, the inflow of household effluents causes eutrophication leading to the forming of a microorganism known as 'waterbloom' that emits foul odor. The introduction of invasive species is also one of the causes of environmental problems in many Irrigation Ponds. On the other hand, these Irrigation Ponds play the vital role of biotope habitats for endangered species and also as recreation parks in the city
In this paper, with Eigashima Dish Pond* [1] as an example of a typical Irrigation Pond in an urban area, we investigated the cause of eutrophication using hearing investigation, bibliographical survey, and concentration assessment of water samples. The traditional ways of utilizing the Irrigation Pond and current management methods are used as reference for the Irrigation Pond's management in the future. In addition, current approach in the purification of water quality would be reported in this paper.

Keywords: irrigation pond, purification of water quality, nutrient salt, urbanization, biotope

1. Introduction

In Hyogo Prefecture, historical irrigation heritages which include irrigation ponds, irrigation channels, flood control facilities as well as material resources, which include living things around the water area and sceneries, immaterial resources such as local culture and life are being passed down through Inami Museum of Irrigation Ponds as historical and cultural assets. However, irrigation ponds in urban areas sport growth of waterbloom caused by eutrophication, and the decaying odor of the waterbloom emits cause much inconvenience to local residents. In addition, the site has been polluted by illegal dumping and what used to be a clean irrigation pond which was used as playground of kids as well as a place to wash dishes.
In this paper, as outlined in Fig. 1 with Eigashima Dish Pond* [1] as an example of a

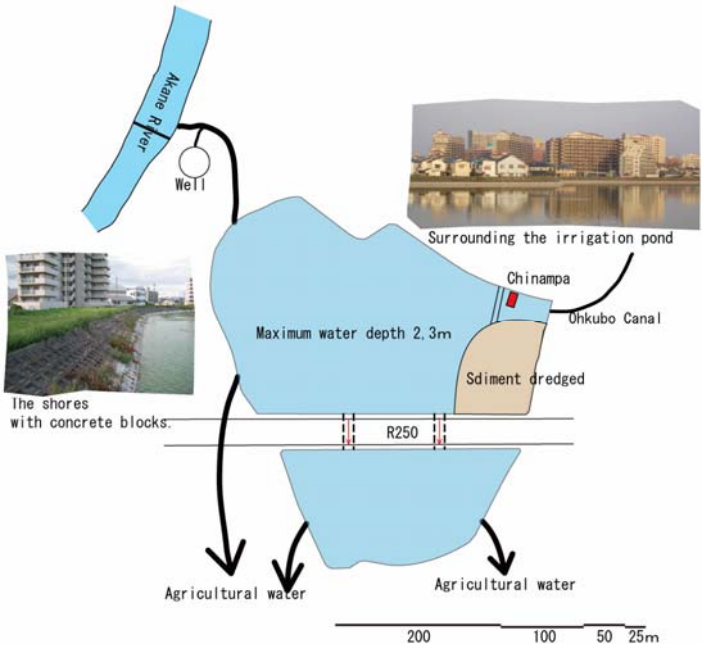

Fig1. Outline of Eigashima Dish Pond

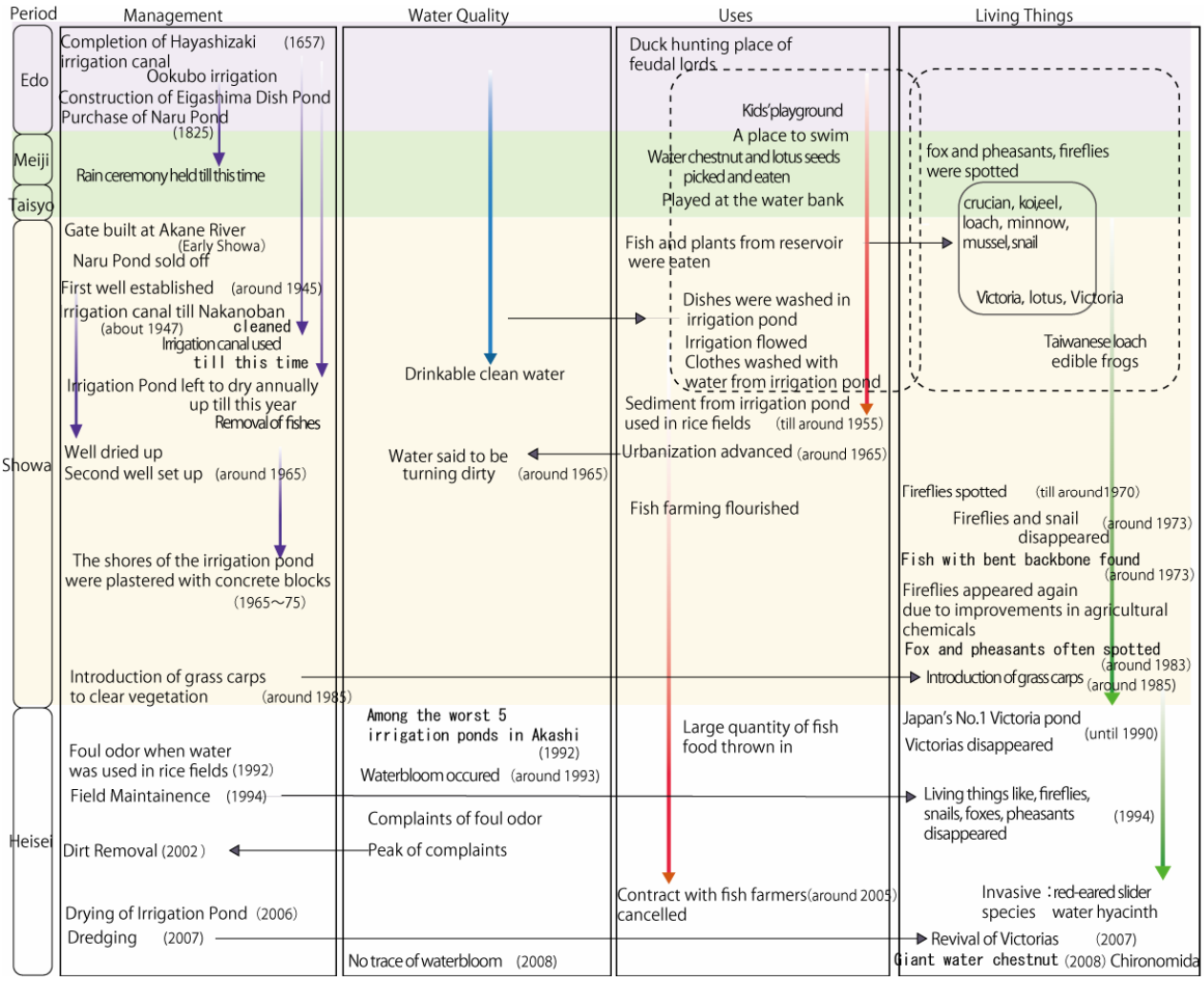

Fig.2 History of Eigashima Dish Pond

typical irrigation pond in an urban area, we investigated the cause of eutrophication using hearing investigation, bibliographical survey, and concentration assessment of water samples. The traditional ways of utilizing the irrigation pond and current management methods are used as reference in future management of the irrigation ponds. In addition, current approach in the purification of water quality would be reported and a suggestion would be placed on the management methods in the future.

2. History of Eigashima Dish Pond

Higashi Harima's area is located at "Inami Plateau" in between Kakogawa River and Akashi River, and receives little rain because of Inland Sea Weather. Thus, it is a difficult land to secure irrigation for rice farming. During Edo period (1603-1867) irrigation canals and irrigation ponds were built to sustain water for agricultural purposes, enabling development of rice fields. The subject of study in this paper, Eigashima Dish Pond's irrigation system- Hayashizaki Canal, (excavation records in 1657), and the purchase of Naru Pond in 1825 to overcome lack of water, shows that the irrigation pond have been built during Edo period. Also, it is said to be the hunting ground of the feudal lord of Akashi at that time. Eigashima Dish Pond's management methods, water quality, uses of irrigation pond and changes of the living things based on hearing investigations and documentary records are shown in Fig. 2. Until the 1930s, when a dam was built in Akane River and water was pumped up from the river, it was said that ceremonies were held to pray for rain. Hence, we can infer that there was a lot of hardship undergone in order to secure water. Subsequently, around 1945, the first well

(20-30m in depth) was dug and underground water was pumped into the irrigation pond. But during the economic growth period, (1955-1974) factories mushroomed in the surrounding areas of the irrigation pond and as underground water was pumped up for industrial uses, the first well slowly dried up. In 1965, a second well (70-100m in depth) was dug and this is the one still currently in use. Up till 1955, after the rice planting season ended, water was channeled out of the irrigation pond and the irrigation pond was left to dry. During this time, fishes were a food source and the sediment left at the base of the irrigation pond was used as fertilizer and returned to the rice fields. According to hearing investigations, around 1955, the water was said to be so clean that it was used to wash dishes, and was even drinkable. But, 10 years later around 1965, people began to feel that the water became dirty.

Some of the factors of eutrophication that caused deterioration in water quality during this period are listed as below:

1. The introduction of chemical fertilizers, the stop in using sediment from the Irrigation Pond's as fertilizers, caused an accumulation of sediment and increase in nutrient salt eluted.
2. As a result of the stop in eating fishes from the Irrigation Pond, the amount of fish increased and the feces discharged added to the increase of nutrient salt.
3. Due to the discontinuation in drying the Irrigation Pond, the concentration of nutrient salt overcame that of the previous year.
4. As underground water was increasingly pumped up for industrial uses, clean spring water slowly reduced and this caused quality deterioration in water supplied.

After that, from 1965 till 1975, as the irrigation channels were converted into three surfaces of concrete, the shores of the irrigation pond were plastered with concrete blocks. As a result, plants became lesser and natural purification abilities decreased. Besides that, fish farming began in the irrigation pond and fish food is also found to be linked to eutrophication. Nonetheless, throughout this time, a genus of giant water lilies called Victoria that specially adapted to this irrigation pond, spread so quickly that it covered to the whole surface of it. Because Victorias have thorns that cause problems such as getting the sluice gate jammed, grass carps were released into the irrigation pond to get rid of the plants. The grass carps ate up the aquatic plants and waterbloom occurred in 1992 when vegetation disappeared. As a result of the foul odor emitted by waterbloom, many complaints were received from residents living in neighboring areas and in 2002, the complaints reached its peak.

The factors of eutrophication after the year 1965 are summarized as below:

1. Purification abilities decrease because of irrigation and breakwater implementation
2. Increase of inflow from household effluents as a result of urbanization
3. Insertion of fish food from fish farming activities
4. Disappearance of vegetation because of the release of grass carps

Historically, eutrophication progressed along the process as stated above.

3.Current situation of Eigashima Dish Pond

As described in the preceding text, the water quality of Eigashima Dish Pond was so low that waterbloom occurred in summer and caused odor. From water investigations in September 2007, the following data was obtained- COD 98mg/L、TN 10.5 mg/L、TP 0.36 mg/L. This has far exceeded environmental standards of for agricultural used water COD 5mg/L, TN 1mg/L、TP 0.1g/L as defined by the Ministry of Environment.

The irrigation pond lost the beautiful scenery it once had as a result of the bad odor emitted, decrease in aquatic plants and animals, as well as illegal disposal of garbage..

3.1. Waterbloom's growth and odor

After waterbloom generated extensively over summer, odor was emitted when it decomposes. Because of the irrigation pond's close location to a residential area, many complaints had been received. Three-point comparison method was used to determine the odor concentration from the irrigation pond's water. For this experiment, sample water obtained from the irrigation pond on September 19 was measured on the day itself by a 9-man panel. The temperature of the laboratory was 32.1□, humidity 64%. The sample water's data is as follows: COD- 79mg/L, chlorophyll concentration- 84μg/L.

3.2. Experiment to calculate odor concentration

The sample water collected from the irrigation pond is diluted with soft drinking water 1/2, 1/4.1/8 and so on. The sample water is put into PET bottles. To prevent the panel from judging from the sample's color etc, a covered sample, as well as a blank sample is given to the panel as shown in Photo.1. Next, the panel would open the lid of the PET bottle and compress it before smelling the odor filled inside and choosing the bottle with odor. When the odor becomes thin to an undeterminable level, it is considered as inaccurate. When samples of the same concentration become inaccurate twice, the experiment ends.

Photo 1 How to smell odor

The odor threshold from every panel is calculated as common logarithm according to Weber-Fechner's law.

Example: panel *a*,

$$Xa = \frac{\log M_{1a} + \log M_{0a}}{2} \qquad \cdots\cdots(1)$$

Xa : The odor threshold related to dilution multiplied odor levels of panel i.

M_{1a} : The maximum dilution multiple when panel a's response is correct.

M_{0a} : Dilution multiple when Panel a's response is incorrect.

Based on this, the average from the median value of the whole panel becomes threshold limit value (X) of the whole panel.

The value as calculated in (1) is converted into the formulae below and the odor concentration is calculated.

$$Y = 10^{x} \qquad \cdots\cdots(2)$$

X : Threshold limit value of the whole panel

Y : Odor concentration

The result from the 9-man panel is shown in Table 1.

The result of the threshold limit value's average calculated from the experiment

$$X = \frac{2.56 + 2.26 + 2.26 + 2.56 + 1.66 + 2.26 + 1.96 + 3.16 + 3.16}{9}$$

$$= 2.43$$

This value is next substituted with (2) and odor concentration is calculated as follows:

$$Y = 10^{2.43} = 269$$

Table 1. Results of each panel

Panel	dilution multiple							odor threshold Xi
	32	64	128	256	512	1024	2048	
a		○	○	○	×			2.56
b		○	○	×				2.26
c		○	○	×				2.26
d		○	○	○	×			2.56
e		○	○	×				2.26
f		○	×					1.96
g		○	○	○	○	○	×	3.16
h		○	○	○	○	○	×	3.16
i	○	×						1.66

Thus, the Irrigation Pond's odor concentration is 269. From the experiment, it shows that even after diluting the water from the irrigation pond 269 times, odor can still be perceived faintly.

4. Water purification measures

With water purification as the main purpose, these measures had been carried out- drying of irrigation pond, sediment dredging, insertion of adsorbent in the irrigation channel, well water use, and a relatively higher water quality supply from Akane River. As these measures showed effectiveness in whole, it is hard to determine the effectiveness of each measure. According to water quality data on July 2008- TN 3.0 mg/L, TP 0.13 mg/L, concentrations of nitrogen and phosphorus have reduced to one third that of 2007's and there was no sightings of waterbloom. However, this concentration is very close to the limit waterbloom could not occur where plants cover the whole of the irrigation pond. If water purification measures is neglected after 2009, there's a high possibility for waterbloom to occur again. Each of the measures that had been taken is as explained below:

4.1. Dredging

Up till 1955, from autumn to winter, water had been drawn out, fish were considered a food source, and sediment was used as fertilizer. But, after entering the economic growth period, dietary life became richer and residents stopped eating fishes from the irrigation pond, and the use of chemical fertilizer caused a stop in utilizing sediment. There is report[2)] that the elution of nitrogen and phosphorus from sediment was more than 40% of the amount of nutrition. It is assumable that sediment accumulated and the amount of nutrient salt eluted has increased even at Eigashima Dish Pond. During the winter of 2007, as much as 12,672 m^3 of accumulated sediment had been dredged.

4.2. Drying of irrigation pond

From October 2007 till March 2008, along with dredging sediment, water was channeled out and the irrigation pond was left to dry. The quantity of nutrient salt elution from sediment decreased as a result from drying of sediment. According to investigations from Hanazato[3)] , the decrease of nutrient salt elution is the result of drying of the irrigation pond that in turn causes a drop in the amount of fish feces, which if left naturally adds to the quantity of nutrient salt in water.

4.3. Adsorbent

The inflow into Eigashima Dish Pond includes Ookubo's irrigation canal, Akane River, and well water. Household effluents are found in the Ookubo's irrigation canal with nutrient salt content as high as TN 3.57 mg/L, TP 0.38 mg/L. Therefore, the 3.3 m^3 adsorbent made of coal ash was inserted at the end of the Ookubo's irrigation canal.

4.4. Well water

When there was a shortage of water from Akane River, water from a well of 70-100m deep can be pumped up. The well water in the area has 10mg/L amount of iron. When well water is inserted into irrigation pond, the iron functions as an adsorbent and affects the deposition of nutrient salt. However, as this area is close to the sea, there is a possibility that when well water is pumped up water salinity may increase, reducing the purification abilities.

4.5. Dilution by water from Akane River

The concentration of nutrient salt of Akane River- TN 0.5 mg/L, TP 0.15mg/L is lower than that of the irrigation canal. As the water is sourced out for the rice fields, water level falls and moisture evaporates in summer when temperature rises causing the nutrient salt to condense. When water level falls during summer, nutrient salt concentration is lowered using the water supplied from Akane River.

5. Irrigation pond in urban area- New Roles and Future

Until the economic growth period, the irrigation pond served not only as a source of agricultural water supply but also as a living space though after that period, it has been managed catering only to the usage of agricultural water supply. But an irrigation pond whose goal is not only as source of agricultural water supply is much needed, amidst changes in condition such as, deterioration of water quality, aging farmers and urbanization in areas surrounding the irrigation pond. There are new roles of the Irrigation Pond that should be recognized like the four roles stated below:

1. Biotope to sustain biological diversity including rare species
2. Precious open space in an urban area for the residents' rest area
3. A place for interchange between local residents and farmers
4. Flood regulator to a downstream urban area

These roles do not just cater to the farmers but also the residents as well. Along with the aging farmers, the local residents, the co-operation of companies and various groups are needed for managing the irrigation pond as well. Because of financial difficulties, energy saving methods are needed, it is effective to use ecotechnology and appropriate technology as management methods of for the irrigation pond.

The authors made a Chinampa[*2] as trial, as seen in Fig.3 using sediment and plant residue to create a structure of biological diversity for water purification and as a habitat for living things. The materials are thinning timber from neighboring area, and bamboos which helped the maintenance of *Satoyama*[*3]. Although currently surrounded by concrete blocks which make vegetation growth difficult, a water edge structure with more diversity could be made, and nutrient salt could be absorbed with the increase of plants. At the same time, dredged sediment and plant residue are inserted into the Chinampa thus completing the whole role of dredging.

Hereafter, with measures taken against eutrophication of inflow from household effluent as a result of the city structure, necessary measures must be taken in the irrigation pond. The changes in aquatic life, such as aquatic plants, fishes, plankton have a huge effect on water quality. While observing the changes in the irrigation pond, we need to revise the pond's management methods in compliance with the changes in the ecosystem.

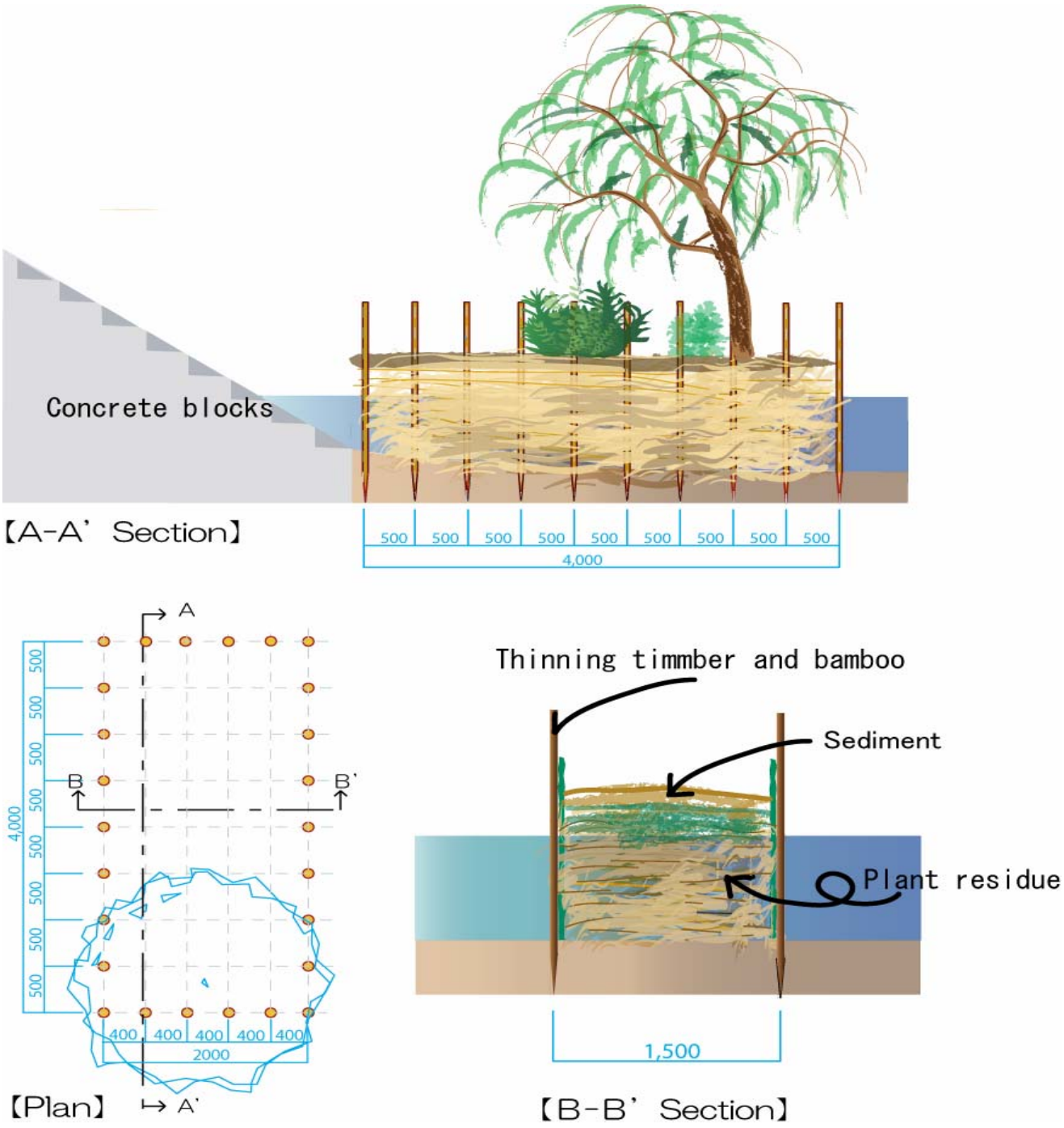

Fig3 Outline of Chinampa in Eigashima Dish Pond

Notes

*1: Dish Pond(*Sara-ike)* is an area surrounded by banks and is used to store water. It is also shallow and wide just like a dish (*sara*). The Eigashima Dish Pond is a typical *sara-ike*.

*2: An agricultural method utilizing sediment from lake beds and is created by layering water plants turning it into a floating island. This method started from areas around Tenochtitlán, the capital of ancient Aztec civilization.

*3: *Satoyama* is Japanese term apply to the border area among the foot of mountain and arable flat land, literary *Sato* is home land, and *yama* is mountain. Satoyama has been developed from centuries of small scale of agricultural and forestry use, also presents biodiversity if property maintained by human activities.

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