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Hydrolink

COASTAL RESERVOIRS IN CHINA

BY PENGZHI LIN, ZHIGUO HE, ZELIN GONG & JINQUAN WU

Modern river basin management treats flooding not only as a threat, but also as a precious water resource. In inland areas, dams are built to impound water in reservoirs. In coastal regions, however, building reservoirs does not seem to be an obvious choice, at least at first glance. How to develop more freshwater for coastal cities becomes a challenging issue. For coastal regions with abundant precipitation and/or river outflow, the key to solving water shortage problem is to find a suitable place to store freshwater, especially during the flood season.

River mouth reservoir – the early form of coastal reservoir

In China, the first downstream reservoir appeared at the time of the Tang Dynasty, and was made possible by the Tuoshan Weir, one of the four famous hydraulic projects in ancient China. The Tuoshan Weir was constructed in 833 B.C. downstream on the Yin River near Ningbo (Figure 1 and Figure 2). The weir was about 134 m long and 3 m high, and was originally built to prevent seawater intrusion. Naturally it impounded freshwater upstream and created a reservoir in the river channel that helped to irrigate over 6,000 hectares of cropland.

In the past decades, many sluice gates were built on river mouths along the coastline of China, protecting inland areas from saltwater intrusion and storing freshwater for irrigation purpose. Examples include the Haihe Tide Gate in Tianjin and the Sheyang Tide Gate in Jiangsu Province, both of which were constructed in the 1950s. In the 1970s, more such river mouth reservoirs were constructed. Examples are the Datang Harbor Reservoir and Huchen Harbor Reservoir in Sanmen Bay, Zhejiang Province (Figure 3). The Datang Harbor Reservoir was built in 1973 with an area of 4.79 km^2 and a capacity of 46.75 million m^3 (Figure 4). The Huchen Harbor Reservoir was built in 1973 as well, with a total capacity of 81.73 million m^3 (Figure 5). Sluice gates in river mouths continue to be used effectively and new ones are added such as the Cao'e River sluice gates constructed between 2005 to 2007 in Hangzhou Bay.

Sluice gates in river mouths are easy to construct and can effectively prevent seawater intrusion. The gates, on the other hand, block sediment transport and result in river channel siltation. In addition, considering that the river channel is normally narrow, the freshwater stored in the reservoir can be limited.
To increase reservoir capacity, we need to extend our view to bay and coastal areas.

Bay reservoir - the modern form of coastal reservoir

In the 1960s, Hong Kong's economy development soared with the fast increase of population thirsty for more drinking water. Mr. T.O. Morgan, the former director of Hong Kong's Water Supplies Department, suggested converting the bay of Plover Cove into a

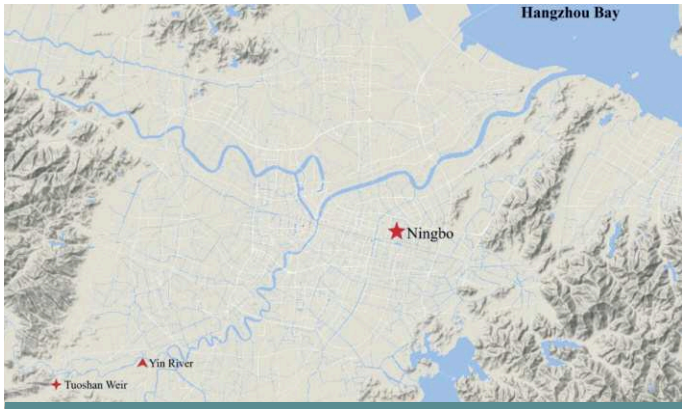

Figure 1. The Tuoshan Weir in Yin River


Figure 2. The Tuoshan Weir today

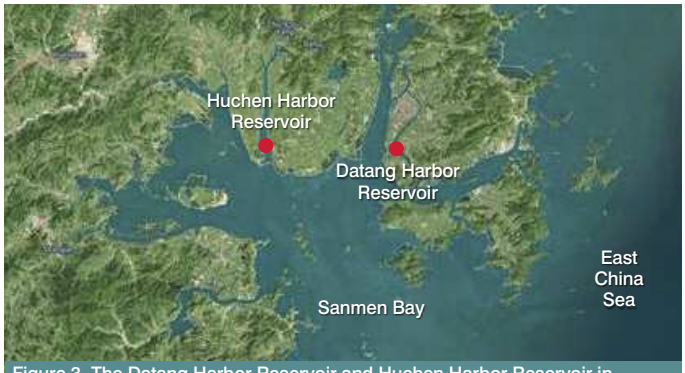

Figure 3. The Datang Harbor Reservoir and Huchen Harbor Reservoir in Sanmen Bay

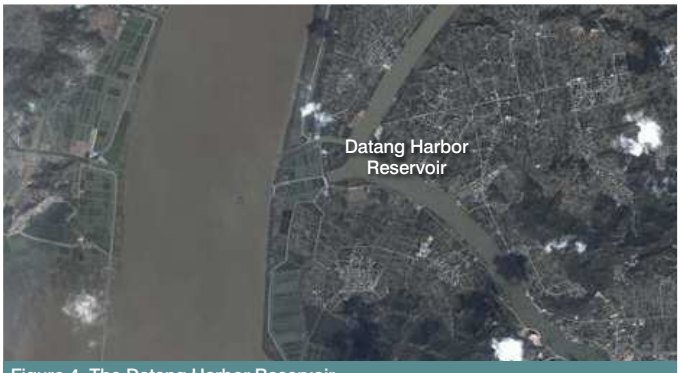

Figure 4. The Datang Harbor Reservoir

Figure 5. The Huchen Harbor Reservoir

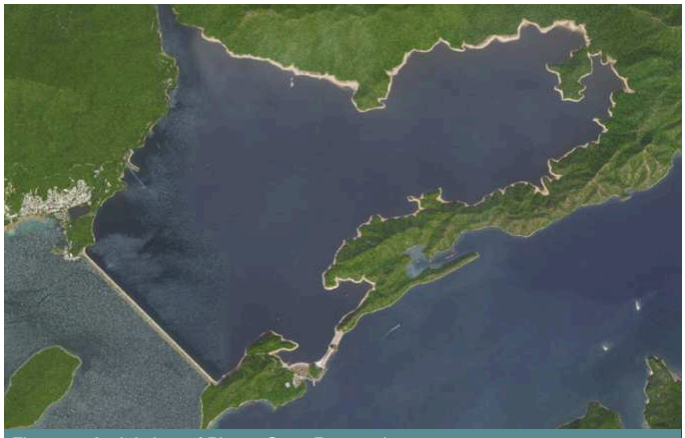
Figure 6. Aerial view of Plover Cove Reservoir

Figure 7. Location of Hangzhou city and Shanhusha Reservoir in Qiantang River

Figure 8. Shanhusha Reservoir in Qiantang River

reservoir, making use of existing islands and connecting them with dams. Construction work on this project started in 1960 and was completed in 1968, providing a capacity of 170 million m^3 (Figure 6). The dams were later raised from 1970 to 1973, increasing the reservoir capacity to 230 million m^3. Although the reservoir was later abandoned due to Hong Kong's successful contract with mainland China for trading freshwater, Hong Kong was the very first city in the world to construct a bay reservoir. As a pioneer in coastal reservoirs, the Hong Kong government showed great vision for the future of water supply.

Interestingly, almost at the same time, a similar idea of using the bay space for coastal reservoirs was also proposed and implemented in mainland China, although at a much smaller scale compared to that of the Plover Cove Reservoir. The Shanhusha Reservoir located by Qiantang River of Hangzhou Bay was built in August 1979 (Figure 7). Different from the river mouth reservoirs, the Shanhusha Reservoir was constructed inside the tide-dominated estuary (Figure 8) and has a very small capacity of nearly 1.9 million m^3. However, it is one of the most important water supply sources for Hangzhou in case of emergency. It could store freshwater from Qiantang River during the ebb tide by two inlets with a capacity of 500 thousand m^3/d and 1 million m^3/d, respectively, and provide water supply to the city with two outlets with a capacity of 450 thousand m^3/d and 880 thousand m^3/d, respectively.

Shanghai - the showcase of modern coastal reservoirs

Shanghai is located by the Yangtze River Estuary. It is the largest city in China with a total population of 24 million. According to the Revision of the Shanghai Urban Master Plan in 2005, the freshwater shortage in the city will reach 6 million m^3/d by 2020. To meet the increasing demand of freshwater, Shanghai took a bold step to construct a series of coastal reservoirs (Figure 9). Nowadays, three main coastal reservoirs, i.e., Chenhang Reservoir, Qingcaosha Reservoir, and Dongfengxisha Reservoir, meet over 70% of the water needs of Shanghai.

The history of coastal reservoirs in Shanghai can be traced back to the 1980s. To meet the water demand for iron and steel manufacturing, the Baogang Reservoir was built in the early 1980s. With an area of 1.64 million m^2, the reservoir has a total storage capacity of 12 million m^3. The Chenhang Reservoir, next to the Baogang Reservoir, started construction in the late 1980s and was completed in 1992 (Figure 10). The area of the reservoir is nearly 1.35 million m^2 with a capacity of 9.56 million m^3 after potential-tapping engineering works in 2008. Its average daily water supply capacity is 1.6 million m^3. Both the Baogang Reservoir and the Chenhang Reservoir are typical coastline reservoirs as they are constructed along the coastline, from which they further extend to sea.

The construction of the Qingcaosha Reservoir, the largest coastal reservoir in China, was started in June 2007 on the Changxin Island in the Yangtze River Estuary (Figure 11 and Figure 12). The area of the reservoir is nearly 70 km^2 with the total length of the surrounding dike being 48.41 km. The design capacity of the reservoir is 527 million m^3, while its effective capacity is 438 million m^3 when the water level is at 7 m. Its water supply capacity is 7.19 million m^3/d. At present, 50% of the drinking water in Shanghai is provided by the Qingcaosha reservoir, changing its history of depending on the Huangpu River as its major water source.

The construction of the Dongfengxisha Reservoir (Figure 13) started in November 2011 on the Chongming Island, the third largest island of China, and was completed in January 2014. Its total storage capacity is 9.76 million m^3 Its short-term water supply capacity is 215 thousand m^3/d, and its long-term water supply capacity is 400 thousand m^3/d. It mainly provides water supply for the residents of the Chongming Island.

The completion of these reservoirs has changed the water supply patterns for this large city, guaranteeing a safe and reliable freshwater supply in good and stable quality in all seasons. While the Baogang Reservoir and the Chenhang Reservoir were built along the coastline, Qingcaosha and Dongfengxisha Reservoirs were extensions of the islands, further into sea of the estuarine region. Shanghai created coastline reservoirs and island reservoirs, introducing new types of coastal reservoirs. This makes Shanghai a very proud showcase of modern coastal reservoirs to the world.

Vision of the future

Unlike inland reservoirs, coastal reservoirs face different technical challenges due to their special environmental surroundings. Problems such as saltwater intrusion, pollution, algal blooms, sediment accumulation, structural instability and ecosystem imbalance are important considerations for the design, construction and operation of coastal reservoirs. Finding solutions to all these problems requires the collaboration of researchers and engineers in different fields of hydraulic engineering, coastal engineering, environmental science and technology, structural engineering, geotechnical engineering, coastal oceanography, etc. The success of coastal reservoirs also requires the collaboration of different stakeholders.

In many circumstances, the construction of a coastal reservoir is similar to the construction of a harbor, except that the reservoir needs to be closed by gates for freshwater intake and storage. Thus, many technologies developed for harbor construction can be readily extended for coastal reservoir construction. First Harbor Consultants (FHC) has successfully designed and implemented a large number of marine engineering projects in various complex meteorological, hydrodynamic, and geological conditions. Their engineering practices cover design and construction of ports, waterways, ship locks, artificial islands, etc.

Nevertheless, there are many new challenges, and thus opportunities, open to engineers and researchers for coastal reservoir development. For example, new materials such as flexible curtains could be used to separate freshwater from salt water, considering the small pressure difference across the curtain. More careful treatments may be needed to minimize salt water intrusion into coastal reservoirs from both the bottom through seepage and the top by wave overtopping. Meanwhile, the degradation of water quality, harmful algal blooms, and reservoir siltation can become difficult problems for long-term reservoir operation.

There is no doubt that coastal reservoirs provide a new option to coastal societies for developing

Figure 9. The distribution of coastal reservoirs in Shanghai


Figure 11. Aerial view of Qingcaosha Reservoir

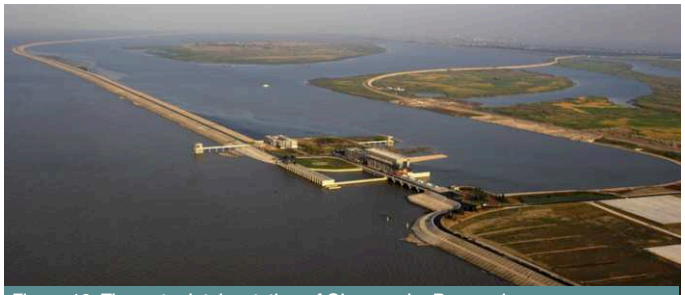
Figure 12. The water intake station of Qingcaosha Reservoir

Figure 10. Aerial view of Baogang Reservoir and Chenhang Reservoir


Figure 13. Aerial view of Dongfengxisha Reservoir

freshwater resources. On a longer time scale, it will inevitably change the pattern of water resources distribution in inland areas, forcing us to re-assess previous water distribution plans. With the spread of coastal reservoirs to many coastal regions, there is a chance that they will be multi-connected and further extended into the deeper ocean. New technologies would be developed along the way. We expect that coastal reservoirs will stimulate a new wave of ocean resources development.

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