

# Singapore's barrage boosts reserves: the new Marina Barrage

● Twenty years in the making, Singapore's new Marina Barrage captures river flow to the sea, creating a new reservoir to boost available resources.

**BRENDAN HARLEY** and **YAP KHENG GUAN** look at what is the latest project to progress Singapore's integrated view of water resources.

**Water is vital to urban sustainability – improving the quality of life, enhancing the urban environment, reducing dependencies, providing the ability to remain competitive in the new global arena and creating vibrant economic opportunities. These and other pressing concerns are top of mind for today's government officials, city planners, engineers, community leaders and businesses the world over, as they increasingly focus on balancing urban infrastructure and urban ecology, growth and livability, and engineered and natural systems.**

Urban sustainability depends on the availability of clean water. And, because water is a vital part of urban infrastructure, sound water management contributes directly to a healthy and sustainable urban environment. From Dublin to Shanghai, and Los Angeles to Singapore, today's 'cities of the future' are emphasising fresh, proactive, people-focused approaches to urban growth and revitalisation – approaches that place water in a central role for planning and development.

In Singapore, PUB, the national water agency, has adopted a leadership role in leveraging the benefits of water to promote sustainable growth, boost economic development and enhance urban quality of life by ensuring the water supply, controlling flooding, and providing water-related recreational and cultural opportunities.

Nationwide, water management is being integrated with transportation, land use and urban development. Linear parks are being designed with drainage facilities, reservoirs are opening up for recreation, and the public is being invited to enjoy water resources through a series of linked projects that establish Singapore's lead in effective water management and urban planning.

## An integrated, water-centric approach

PUB's vision, 'Water for all: Conserve, Value, Enjoy', encompasses two strategic initiatives in managing water resources. The first aims to ensure a diversified and sustainable water supply through local catchment water, imported water, NEWater (highly treated reclaimed water) and desalinated water. These are Singapore's 'Four National Taps'. The second initiative focuses on engaging the people, public and private sectors in conserving and taking ownership of water resources.

Both are evident in Singapore's approach to urban planning and water management, which includes:

- integration across public infrastructure services to provide multi-benefit approaches and create a more collaborative, efficient atmosphere for planning
- innovations in traditional engineering that take a holistic and creative approach by creating multi-functional solutions that also provide community benefits
- enrichment of urban centres by connecting or reconnecting natural assets to the urban landscape

PUB's approach to water management reflects an innovative and integrated view. In the past, cities imported water supplies from far away, discharged wastewater into receiving waters and diverted stormwater away from the city into receiving waters. Each was a separately managed function. Instead, PUB is reusing wastewater, finding ways to beneficially reuse stormwater and reducing the need for importing water supplies – ultimately becoming more self-sufficient (see box for more information).

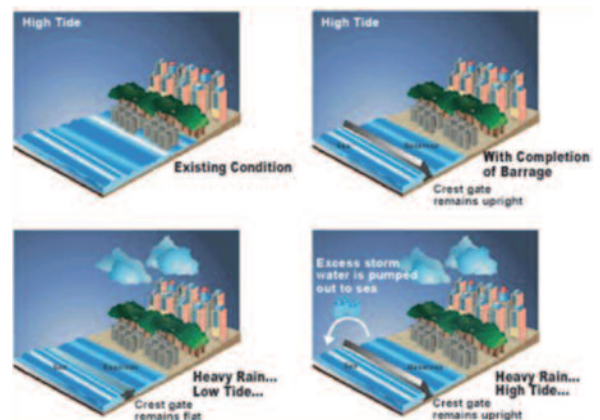
## Innovative water projects

Singapore receives 245cm of rain per year, which poses tremendous water



management challenges as well as opportunities. Throughout its history, the country has sought ways to leverage these despite its land limitations.

In the late 1970s, for instance, PUB conceived the Bedok-Seletar scheme, which represents one of the world's first urban water harvesting projects, to provide drainage systems that would support planned construction of large developments in eastern Singapore.



**Figure 1 Marina Barrage operation.**  
Credit: PUB Singapore

The scheme allows for runoff from about 5000ha to be captured both indirectly – where it is intercepted at a series of diversion points, stored in small urban ponds, then pumped to a reservoir – and directly, where runoff drains straight into the reservoir. Since start-up in 1985, the scheme has captured runoff from highly urbanised areas as a good quality source of raw water.

The Bukit-Timah project, completed in 1988, had a related purpose: to control frequent and serious urban flooding. By creating a trans-basin diversion and reconstructing the main canal, the flooding and traffic disruptions along this busy canal have become a thing of the past.

Likewise, the Marina Barrage (discussed in detail below) had flood control as one of its three objectives, along with providing a water supply

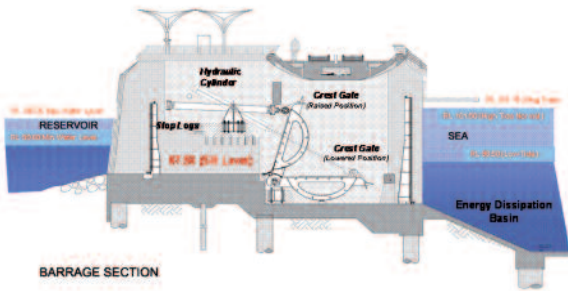
## PUB Singapore's Marina Barrage and reservoir

### Key facts

Engineer: Camp Dresser & McKee (CDM)  
 Contractor: Koh Brothers Building and Civil Engineering Contractor Pte  
 Architect: AT3, Singapore  
 Cost: S\$226 million (\$166.5 million)  
 Completion: June 2008

### Technical and construction details

- the Marina Basin measures 240ha and serves a 10,000ha catchment basin that represents one-sixth of Singapore's area. The newly created Marina reservoir will be the fifteenth in Singapore
- five waterways drain into the Marina reservoir
- saltwater will be flushed out so that the new reservoir becomes fresh water within one to two years
- the 350m long barrage includes nine 30m long and 5m high hydraulically-operated steel crest gates (see Figure 2); each gate weighs 70 tonnes
- seven drainage pumps (six main pumps and one standby) feature 3.2m diameter impellers that turn at 120 revolutions per minute; each pump is 7.5m tall
- the pumping station can pump a total of 240m<sup>3</sup> per second, with one pump in reserve – the equivalent of almost 1 billion US gallons per day per pump
- the 70t gates and 500t precast bridge segments were installed using floating cranes with lifting capacities of up to 3200t.
- precision engineering has been required as the tolerance level for error is only  $\pm 2$  mm for the centreline of the nine pivot pins of each crest gate
- the electrical building receives 22kV utility power and steps down to 6.6kV, 400V and lower voltages; this is augmented by three 4.3MW engine generators – capable of powering all loads in the event of a loss of utility power
- atop the electrical building, a 70kW peak DC solar park on the roof provides supplemental power for lighting and general power at the visitor centre, SCADA control room and common area
- a 3m diameter intake extends 200m into the reservoir, conveying water to a 5m<sup>3</sup>/sec (114MGD) pumping station that transfers raw water via a 14km pipeline to Upper Pierce reservoir
- construction involved placement of some 850 large (up to 1.5m diameter) bored piles, up to 74m deep – more than 60km in total length
- the barrage site has used to date about 140,000m<sup>3</sup> of concrete (which translates into about 20,000 truck loads) and 325km of sheet piling (each about 42m long)
- a boat hoist allows transit of small boats (up to 70t weight, 20m length and 6m width) across the barrage
- the visitor centre includes almost 2000m<sup>2</sup> of space in six galleries
- a service bridge linking Marina East and the Marina Barrage visitor centre provides public access to cross Marina channel. There are eight sheltered look-out points along the bridge where the public can take a rest and enjoy a panoramic view of the city and an endless expanse of sea



**Figure 2**  
**Cross-section**  
**of the system.**  
**Credit: PUB**  
**Singapore**

and an important lifestyle attraction. Twenty years in the making, the barrage was conceived at the same time as the Bukit-Timah project to eliminate flooding along low-lying reaches of the Singapore, Kallang and Geylang rivers.

PUB's newest programme, Active Beautiful Clean Waters (ABC Waters), integrates these and other water management schemes and serves as the centrepiece of an integrated, country-wide approach aimed at transforming all of Singapore's water bodies into a key feature of the landscape.

The programme is designed to, among other goals, bring residents closer to water, encouraging its protection and appreciation of its value. Under the ABC Waters programme, watershed managers will oversee waterways and reservoirs in three sectors, while engaging other partners from the public, private and community sectors to enhance these resources. PUB has completed its pilot project, which includes enhancing a 200m stretch of river with pathways, boardwalks, floating decks and other interactive features for recreation. Two other projects are underway at its reservoirs.

### Marina Barrage overview

Singapore's boldest water undertaking to date is the Marina Barrage. A dam built across the Marina channel, it acts as a tidal barrier that prevents high tides from flooding inland low-lying areas while creating a freshwater reservoir behind it. The programme provides three main benefits:

- water supply: isolating a river outlet to impound an additional source of drinking water from urban stormwater runoff
- flood control: alleviating flooding in the low-lying city areas of Singapore
- a new lifestyle attraction: linking the central business district with the recreational and visual attraction of the Marina basin, which is surrounded by tropical gardens

While Singapore's collection and reuse of urban runoff is already advanced, the Marina Barrage takes the practice to new levels of ingenuity. The

**Aerial photograph**  
**of the**  
**Marina Barrage**  
**construction site.**  
**Credit: PUB**  
**Singapore**





Artist's impression of the visitor centre façade. Credit: PUB Singapore

programme has multiple elements, including the actual barrage, a massive pumping station, a visitor centre and a park within which these other elements are integrated.

The 350m long barrage itself includes nine hydraulically operated steel crest gates, each 5m high. Under normal conditions, the crest gates will remain closed to isolate the reservoir from the ocean. During extreme storm events, when the tide is low, they will operate in harmony to release excess flows from the marina. When the tide is high, a pumping station housing seven vertical shaft drainage pumps will operate. Thus, in response to a range of storm flows and tide levels, the barrage and pumping station will work in tandem to maintain stable water levels in the reservoir (see Figure 1).

With the barrage in place, the Marina basin will turn into a body of fresh water through natural flushing in one to two years, and water from the new Marina reservoir will be conveyed to Singapore's water system.

Landside, the centrepiece of the facility, is a state-of-the-art structure marked by two concentric ramps that swirl toward each other before appearing to reach out over the sea. The facility houses the pump station, a 13MW electrical building and a two-story visitor centre complete with a circular theatre surrounded by glass walls and 360-degree views.

The barrage makes possible a new 101ha 'Gardens by the Bay' urban parkland of tropical horticultural excellence, which extends from downtown and along both arms of the Marina basin to the barrage. The new

parkland, now under development, will feature plant-based 'edutainment', horticultural displays, garden craftsmanship and floral artistry, and is intended to enhance Singapore's reputation as a tropical waterfront garden city through sustainable green infrastructure.

Within its setting at the head of the Gardens by the Bay, the Marina Barrage facilities will be accessible and especially inviting to the public. The 'green' turf-covered roof of the pumping station, visitor centre and electrical building – the equivalent of four football pitches in area – will be accessible to the public via two concentric helical ramps.

The state-of-the-art visitor centre will showcase Singapore's environmental accomplishments, offering films, interactive exhibits and refreshments – as well as abundant use of active and passive water displays in keeping with the facilities' theme and underlying purpose. Other major features of the park include an amphitheatre for events, internal water courtyard and function room.

When completed, the new reservoir will be the site of international water sport competitions, cultural performances and recreational activities such as boating, sailing, water skiing and wind surfing. Concurrent with the Marina Barrage effort is an exciting redevelopment project known as Downtown at Marina Bay, which includes integrated live-work-play communities, shops and restaurants, dramatic lighting for 24-hour enjoyment of the city, the new waterfront and beautiful parks. In addition to using

water resources to enhance quality of life, the Marina Barrage is playing a key role in attracting world-class businesses and promoting further economic growth.

### A model programme

A true city of the future, Singapore has successfully incorporated a number of interdependent elements to realise its vision. The Marina Barrage is a world-class example of how vision, technical excellence and ingenuity can be used to develop innovative, multi-benefit solutions that improve the liveability, economic health and sustainability of cities.

The programme is a centrepiece of the nation's plans to manage its water resources for enhanced supply, public enjoyment and sustainable economic development – and a model for other urban areas. Within the next few years, fully two-thirds of Singapore will be water catchments, and runoff from 80% of Singapore's area will be captured and treated as water supply.

Singapore's experience has demonstrated how good water management and technology can help overcome water challenges for a city-state with limited resources. It is timely that Singapore will be hosting the Singapore International Water Week for the first time this year. The Water Week is a global platform for water solutions and aims to bring policymakers, industry leaders, experts and practitioners together to address challenges, showcase technologies, discover opportunities and celebrate achievements in the water world.

The theme for the Water Week this year, 'Sustainable water solutions for cities', is tied to the issues of the day, including the world's rapidly-growing urban populations. According to the UN Population Fund, more than 3.3 billion people will live in an urban environment by 2008, a figure projected to rise to 5 billion in 2030. The urban population in Asia alone will double to 2.6 billion between 2000 and 2030. The Water Week will focus on best practices, successful case studies and the practical delivery of water solutions and technologies, which will be welcomed by urban communities worldwide. ●

Visitor centre pump station under construction. Credit: PUB Singapore



### About the authors

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