Pipeline taking water from the Pandan reservoir, Singapore

Pipeline going through Johor state in the Kota Tinggi region of Malaysia

Causeway between Johor state and Singapore

Upper Seletar reservoir, Singapore

Building site in Punggol, Singapore

River splash in Bishan Park, Singapore

Architecture of Territory
ETH Zurich
FCL Future Cities Laboratory

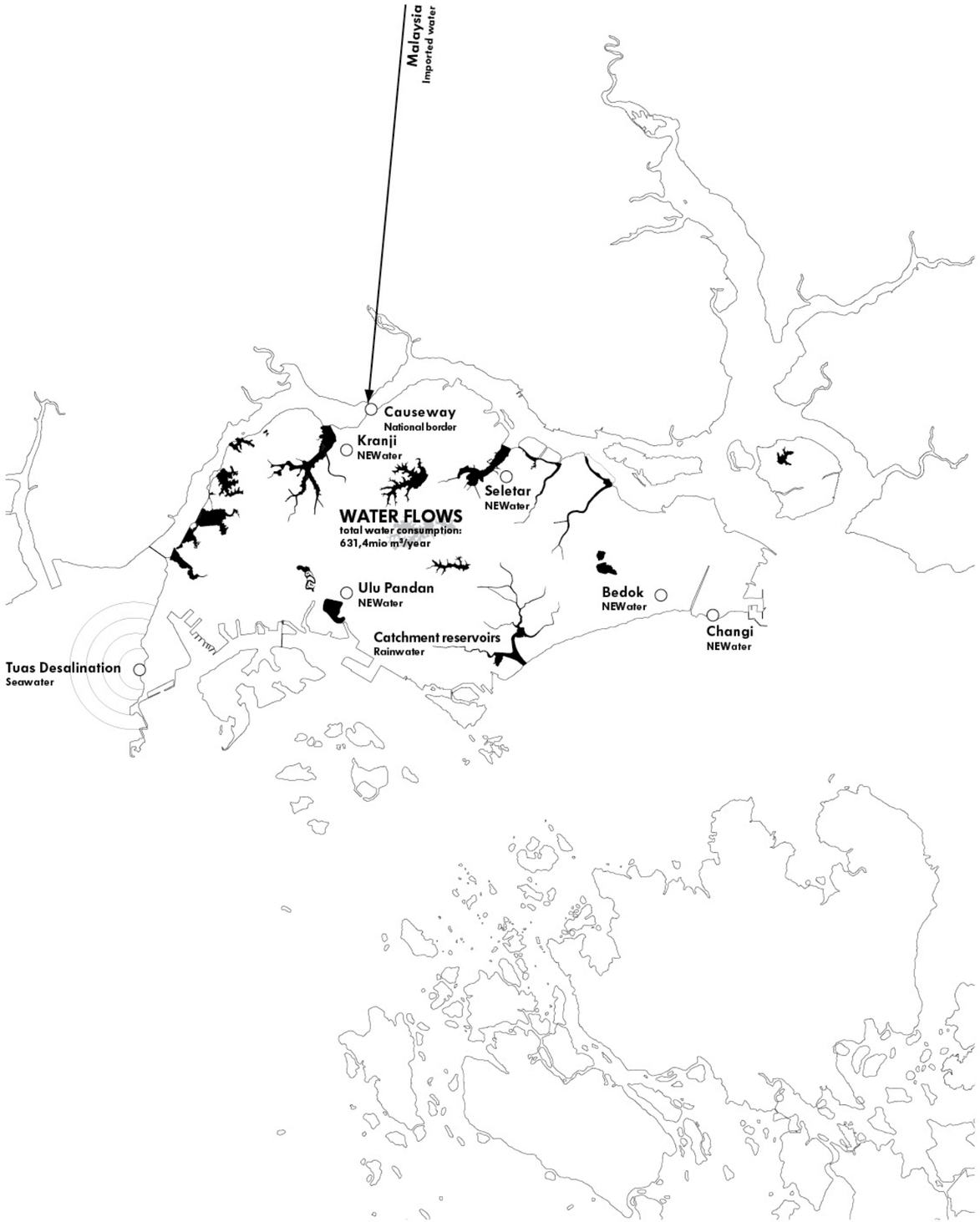
Hinterland
Singapore, Indonesia, Malaysia
Project 1, part 2

Asst. Prof. Milica Topalovic
Martin Knüsel
Marcel Jäggi

WATER SCARCE

A Record of Dependencies

by
Pascal Deschenaux
Simon Zemp



Water is omnipresent on the island state of Singapore. As this resource is present in insufficient amounts, islanders are required to save as much of the precious liquid as possible and keep the channels clean.
Water resources are subject to economic, geopolitical and everyday life preoccupations in Singapore. Although the country strives for independence, between thirty to fifty percent of Singapore's water continues to be imported from Malaysia.
Singapore’s rainwater is being collected and stored in a variety of reservoirs where it is valued differently depending on its location. To be able to manage such a complex water system, an incredibly efficient and opaque authority has unilateral choice on all the issues concerning this resource.

Bilateral Relationships

Singapore is a first world country that lies in between transitional economies striving through their industrial sectors. Singapore's strong economy grants access to technological strategies that remain out of reach to its neighbours. The management of the country's water system is a strong example of the advantage that Singapore holds over Indonesia and Malaysia.
Drinkable water comes from four different sources, the so-called 'four taps': rain catchment, treated sewage water, desalinated water and imports from Malaysia. Because of its high population compared to its small surface (5.35M inhabitants on 714 km2 in 2012), the amount of fresh water needed each day is considerably more than what is available locally. On the other hand, locally available resources in Malaysia and Indonesia are enough to meet the need of these countries' respective populations.

1.
Johor river, one of the main water source for Johor state

2.
River with fresh water in the natural reserve of Gunung Pulai

3.
Boats for firefly sightseeing on the Johor river

4.
Water intake from the Johor river for the Kotta Tinggi treatment plant

5.
Pipelines coming out of the Kotta Tinggi treatment plant

1.

Johor State, Malaysia

The state of Johor is economically dependent on the plantations of palm trees to produce oil. This type of agriculture requires a tropical climate and a high amount of water. Coming from the mountain regions in the North, water flows through the territory mostly by rivers where the palm farmers directly take water free of charge.

With its economical growth in the last thirty years, Johor state has been able to upgrade its water treatment to potable standards, making tap water drinkable.

Although the quality of water has improved due to treatment technologies, water resources remain underappreciated: rivers and lakes are polluted by garbage and human waste. In Johor Bahru, the capital of the state of Johor, the river that flows through the center of the city has been covered by a parking lot in the 1960s.

2.

3.

4.

5.

1.
Dam at the Muka Kuning reservoir

2.
Hole in a fence protecting the reservoir where people pass through to reach the body of water

3.
Child jumping from the dam

4.
Children in the reservoir's water

5.
Locals fishing on the shores of Batam's reservoir water

1.

Muka Kuning Reservoir Batam, Indonesia

Contrasting to its northern neighbours of Singapore and Malaysia, Indonesia's economical condition does not allow it to acquire a potable water network. Households need to boil tap water before drinking it to avoid contamination. Rivers and streams are still commonly used as a sewage system.

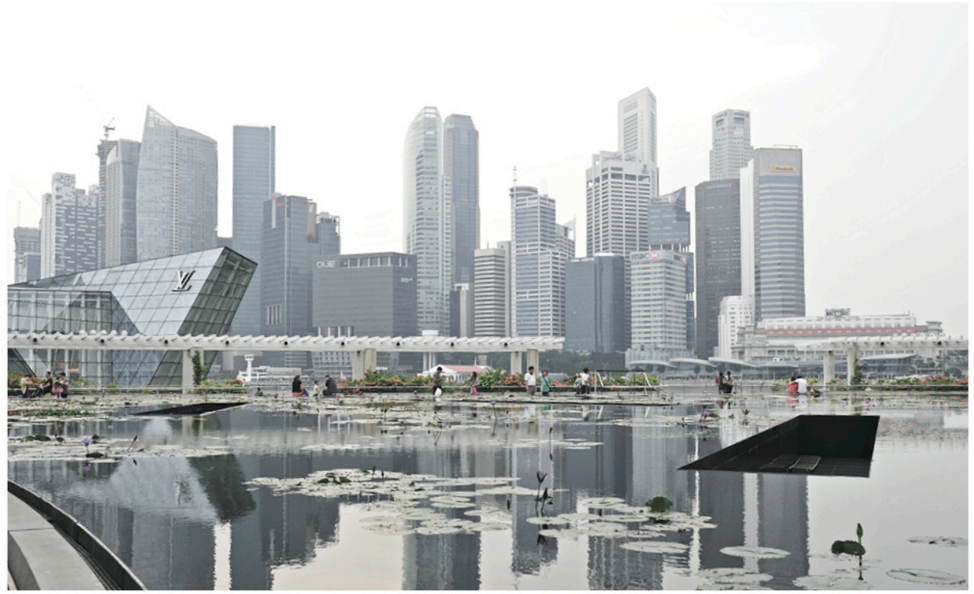
Batam's reservoirs provide enough tap water for its region. Although these structures are supposed to be protected, the neighbouring population uses them informally for swimming, fishing and weekend strolls.

2.

3.

4.

5.



1.
Singapore's skyline surrounding the Marina Bay reservoir

2.
NEWater plant near Kranji reservoir

3.
Channel restricted to the public near Kranji reservoir

4.
Water flowing out of a gutter with Pearl's hill restricted service reservoir in the background

5.
Public PUB sign mentioning bans and sanctions

Singapore

Singapore administers its water management in a way that differs from its neighbours. Its world ranking water management facilities are strictly off access to the general public. Water reservoirs, channels and gutters are a defining characteristic of the city-state's landscape.

The country teaches its population to save water through an education program given to every child in primary school. If somebody is caught polluting the water system in any way, costly fines are imposed. Singapore's water technologies have become world famous and it is now a world leader in the water industry.

2.

1.

3.

4.

5.

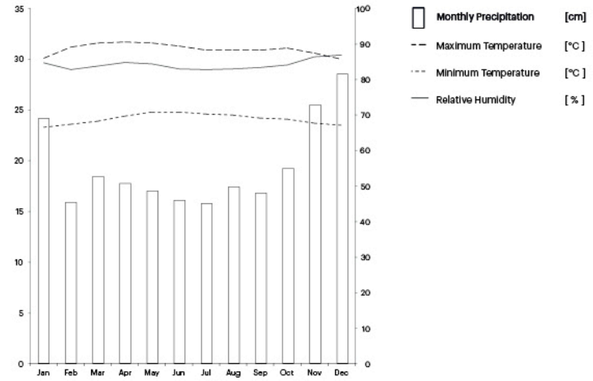
A Geographical Paradox

Although Singapore is situated in a tropical region where rain precipitations are far over the world average, it does not possess enough natural water for its own population.

This phenomenon is due to the high density of population. This puts Singapore in a similar condition of water scarcity to Qatar or Dubai.

The only solutions to solve water scarcity are through new technologies (treatment of sewage water and desalination of seawater) or importing water from other countries.

Until recently, Singapore was mostly dependent on Malaysia. In the last thirty years, Singapore has also been investing a considerable amount of money into research and futuristic infrastructures in an attempt to lower its dependency on foreign sources.



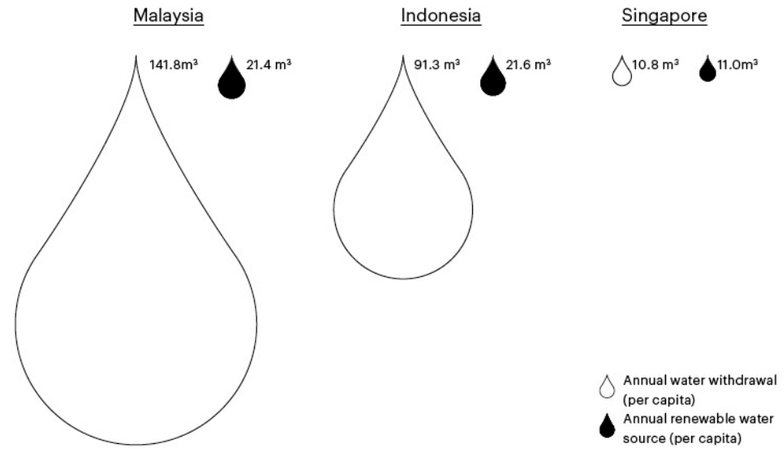
Relation in Water: Mesures Usage and Renewable Sources

The total renewable water resources represent how much water a country can gather and is calculated as the sum of surface run-off water and groundwater.

Indonesia and Malaysia have large amounts of water available due to their extensive land area. Singapore by contrast can not satisfy its needs with natural resources due to its small surface.

The comparaison also shows that the withdrawl per capita is much higher in the neigbouring countries than in Singapore. This is mainly due to the prevalent agriculture sector which takes 81% of the water withdrawl in Indonesia and 22% in Malaysia.

source: Aquastat (FAO)



Water Politics

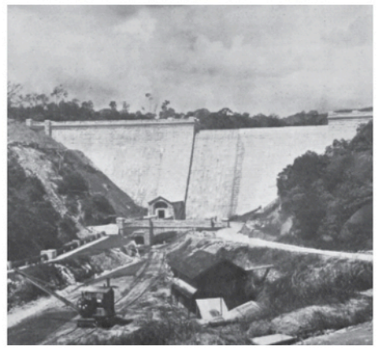
Water became a political issue at the beginning of the twentieth century when Singapore turned into one of the central trading ports in Southeast Asia. Basic rain catchment reservoirs were formerly sufficient to supply local needs. With its rapid growth, Singapore needed to sign an agreement with the neighbouring state of Johor to allow the import water for consumption. At the time of the contract in 1927, both regions were under British rule, making the bilateral implications insignificant. Water was imported without charge and the amounts were unregulated.

In 1942, British troops fleeing Singapore from Japanese invasion blew up the causeway linking the island to Johor state, which lead to a dramatic water shortage during the Japanese occupation. Only then did Singaporeans realise the implication of their dependence on foreign resources.

In 1961 and 1962, Singapore signed two major contracts with Johor stipulating the quantity limits and prices of water imports. At that point, Singapore was going to become part of Malaysia, making the process relatively easy. Only when Singapore declared independence from Malaysia three years later did the contracts become a source of tensions. Even though the UN approved the agreements, Singapore still feared its complete dependence on another country. This granted upon Malaysia a tactical advantage and negotiation leverage, which it maintains to this day.

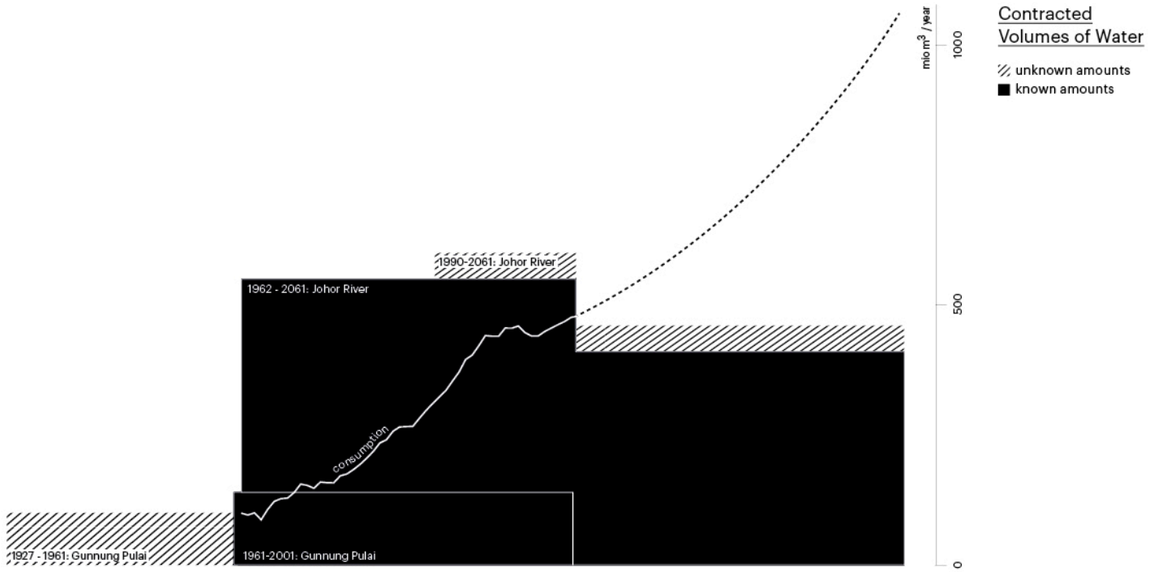
Ever since its independence, Singapore has tried to develop new technologies allowing it to become less dependent on its neighbour.

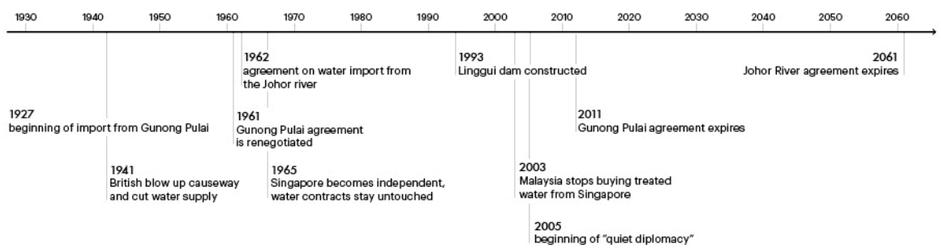
Tensions amplified by the media and the government of each country became so high that both governments agreed to decide on all water-related issues under 'quiet diplomacy' at the beginning of the 2000s. From then on, information regarding water agreements became out of reach to the public. Basic information and geographical knowledge has been lacking ever since.



Left:
Geographical map of the 1961 and 1962 agreements between Malaysia and Singapore

Right:
Newly built dam of the Gunung Pulai reservoir





Locating the Agreements

Placing the different water agreements on a map makes the geographical implications of politics visible.

Singapore used to take water from three different rivers: the Scudai, the Tebrau and the Johor river. It then treated the water and gave back part of it to Malaysia at a higher price.

In 1990, pipeline technology and new negotiations allowed Singapore to build a new reservoir in Pahang state, north of Johor in the middle of the jungle.

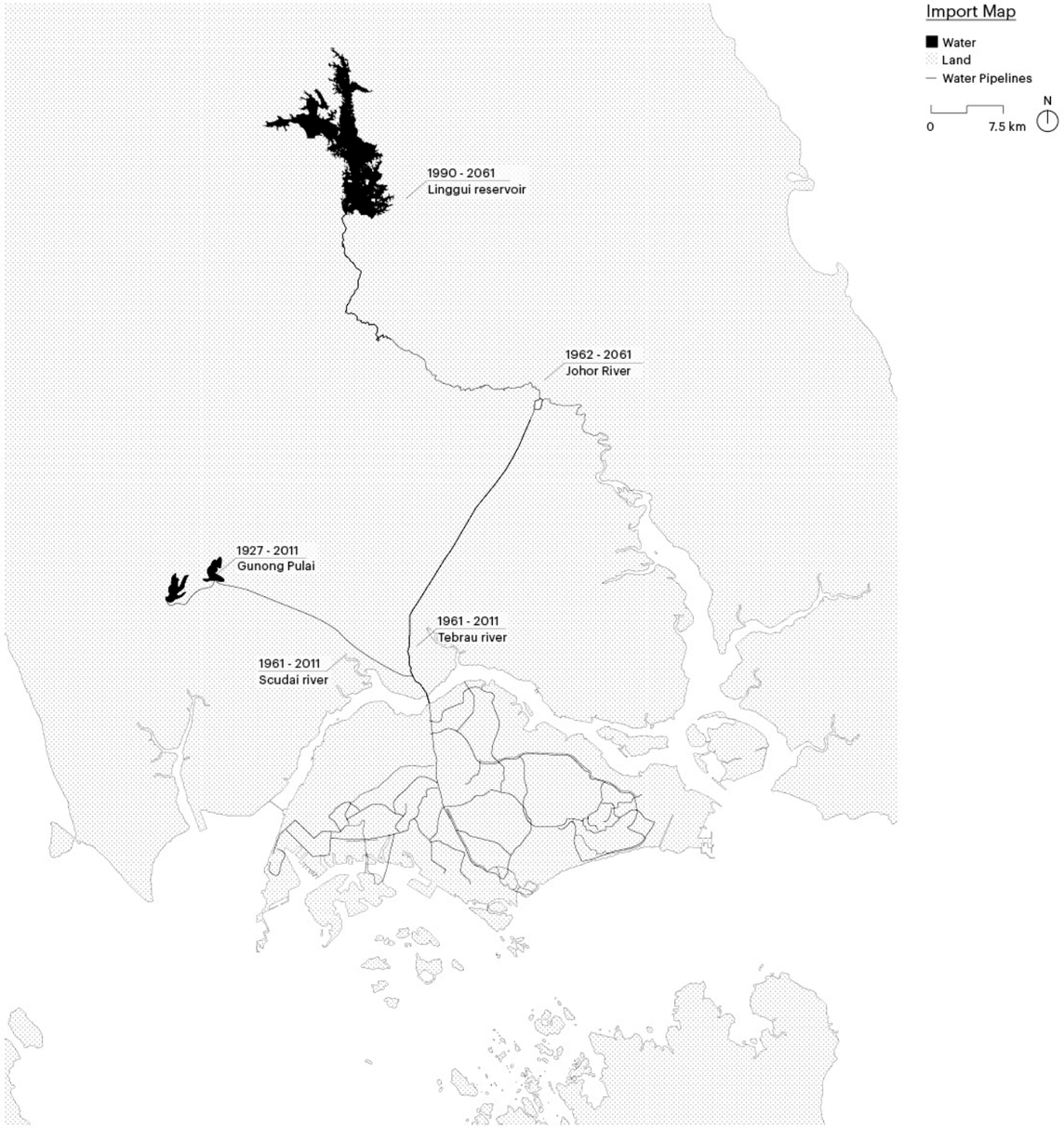
At the end of 2011, the 1961 agreement allowing Singapore to take water from Gunong Pulai ended, marking the end of a chapter in the bilateral relationship.

1961 - 2011 Tebrau and Scudai Rivers
The 1927 agreement was declared void when the British empire signed a new contract with independent Malaysia. This contract gave Singapore the right to take up to 390'000 m^3/day from the Gunong Pulai reservoir, Tebrau river and Scudai river. The contract ended after fifty years in 2011 and the installations were handed over to Johor state.

1927 - 2011 Gunong Pulai
The first agreement between the Singapore state and Sultan Ibrahim of Johor state allowed Singapore to rent an area of 8.5 km2 and to collect and withdraw the rainwater in the newly constructed reservoir. Together with a dam the first pipeline to Singapore was built.

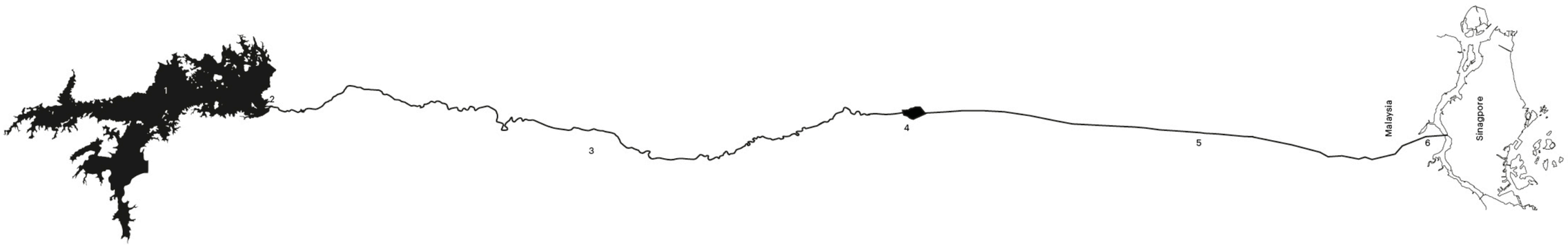
1962 - 2061 Johor River
Valid for 99 years, this agreement allowed Singapore to take up to 1.14 mio. m3/day of water from the Johor river to Singapore. In exchange, Singapore had to give back up to 2% of treated water from the total amount of water it imported.

1990 - 2061 Linggui Reservoir
A complementary contract was signed between both governments in 1990. This gave Singapore the right to build the Linggui reservoir and dam, allowing the island state to import more volume. The precise amounts were not given. Singapore must pay a monthly rent and assume the cost of maintenance.



Flowing through Territories

Singapore's water supply flows through different territories and installations which each have their own rules and security levels. Starting far up in Pandang state, water is stocked in a gigantic reservoir inaccessible to the public, located in the middle of a rain forest. After being released at the Linggui dam, fishermen and farmers use the water of the river for sustenance and leisure. The water then gets pumped into a high-security treatment plant in the Kota Tinggi area where it is processed and brought to drinking standards. The water is then released into three pipelines buried underground that cut through Johor state.It finally crosses the boarder on the causeway linking Malaysia to Singapore to be redistributed in the island's water system. This infrastructure represents a physical manifestation of Singapore's relation with its hinterlands.



PUB facility protected by Malaysian military | River freely accessible | PUB facility protected by Malaysian military | Pipelines freely accessible | Causeway - Singapore border guards

1. Linggui Reservoir

The reservoir exists since the agreement of 1990. It is fenced and restricted to the public despite its gigantic surface. A rich wildlife exists along its shores. Twenty Malaysian soldiers constantly guard the reservoir.

2. Linggui Dam

The dam creates the artificial lake and allows control on the stream flowing out of it. It is highly guarded and twelve PUB workers tend to the installations.

3. Johor River

The water of the river is freely accessible and used by farmers to water palm forests and orchid farms. Tourists appreciate the fireflies sightseeing at night whilst fishers use the water for sustenance.

4. Kota Tinggi Water Treatment Plant

The PUB's Kotta Tinggi plant is highly guarded by Malaysian army. The fact that a Singaporean facility is guarded by a Malaysian authority is surprising knowing the tense relationship between both countries.

5. Pipelines

The pipelines coming out of the treatment plant are mostly buried underground but the land covering them stays untouched by constructions or farmland, like a green scar in the middle of a palm forest landscape. They are freely accessible.

6. Causeway

The pipelines reappear out of the ground when crossing the boarder, placed next to the bridge. The whole causeway is guarded by both Singaporean and Malaysian border guards.

1.
The Linggui dam

2.
Rocky road leading to the dam

3.
Securised arrival to the facilities' checkpoint

4.
Malaysian soliders guarding the dam

Heart of the Island

The Linggui reservoir and its dam are highly restricted areas placed in an uninhabited region of Johor state. A single rocky and unmaintained road leads to the facilities where armed soldiers guard the dam against unwelcomed visitors. The dam is controlled by the Public Utility board, Singapore's water agency. The fact that the area is concealed from the public eye has been explained by a PUB official as an "insurance against Malaysians frustration".

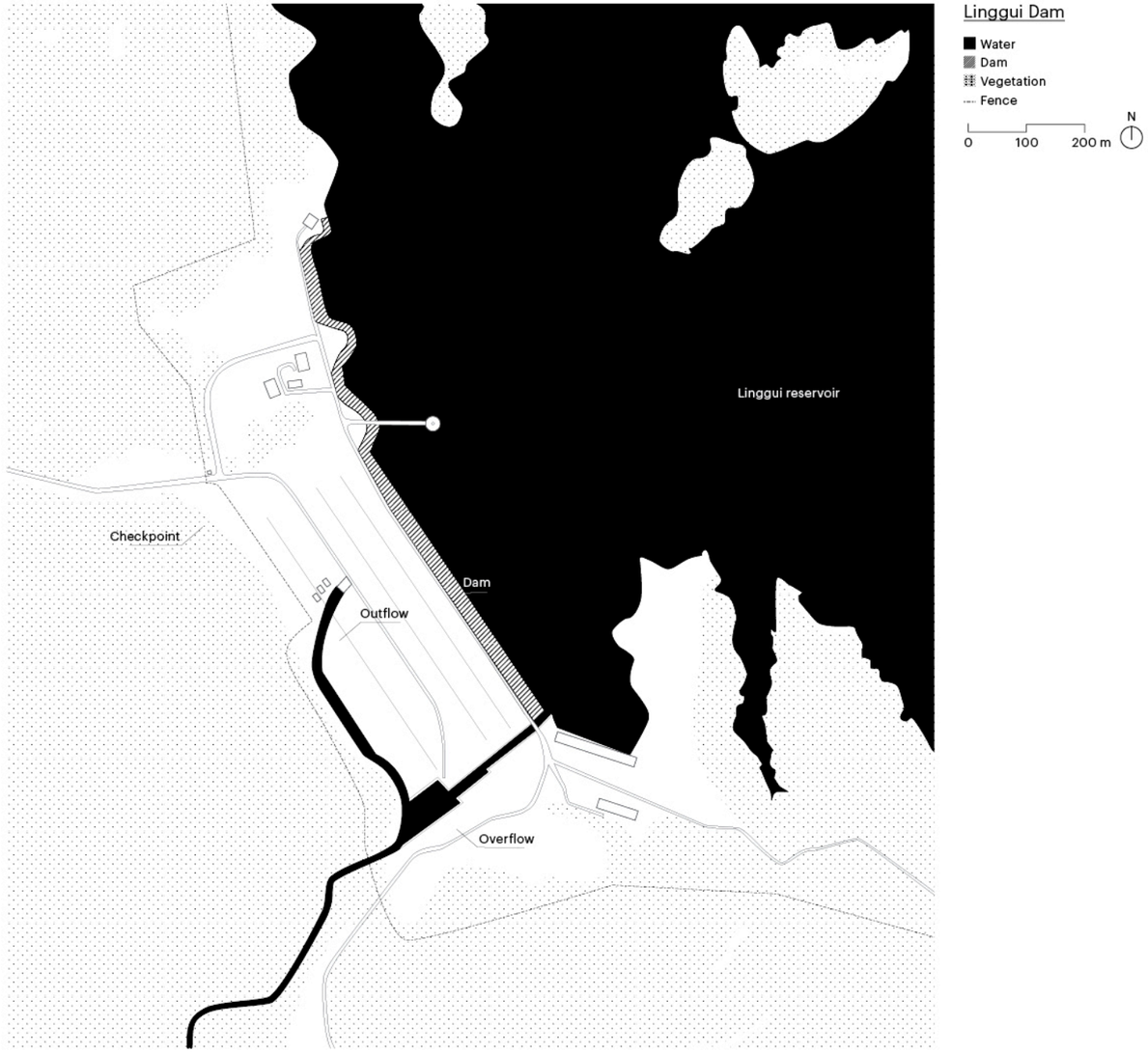
Singapore's water is released from this artificial lake and into the country's water infrastructure system, making it the heart of the island.

1.

2.

3.

4.

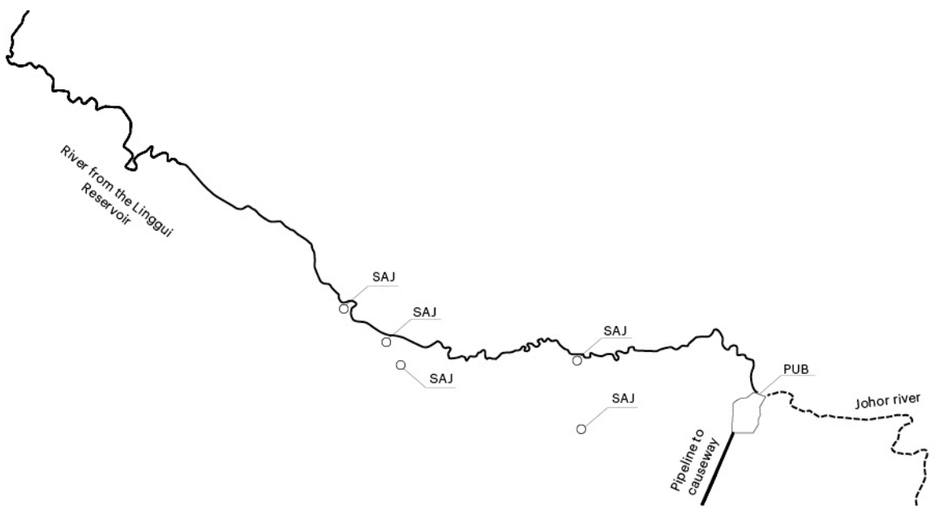


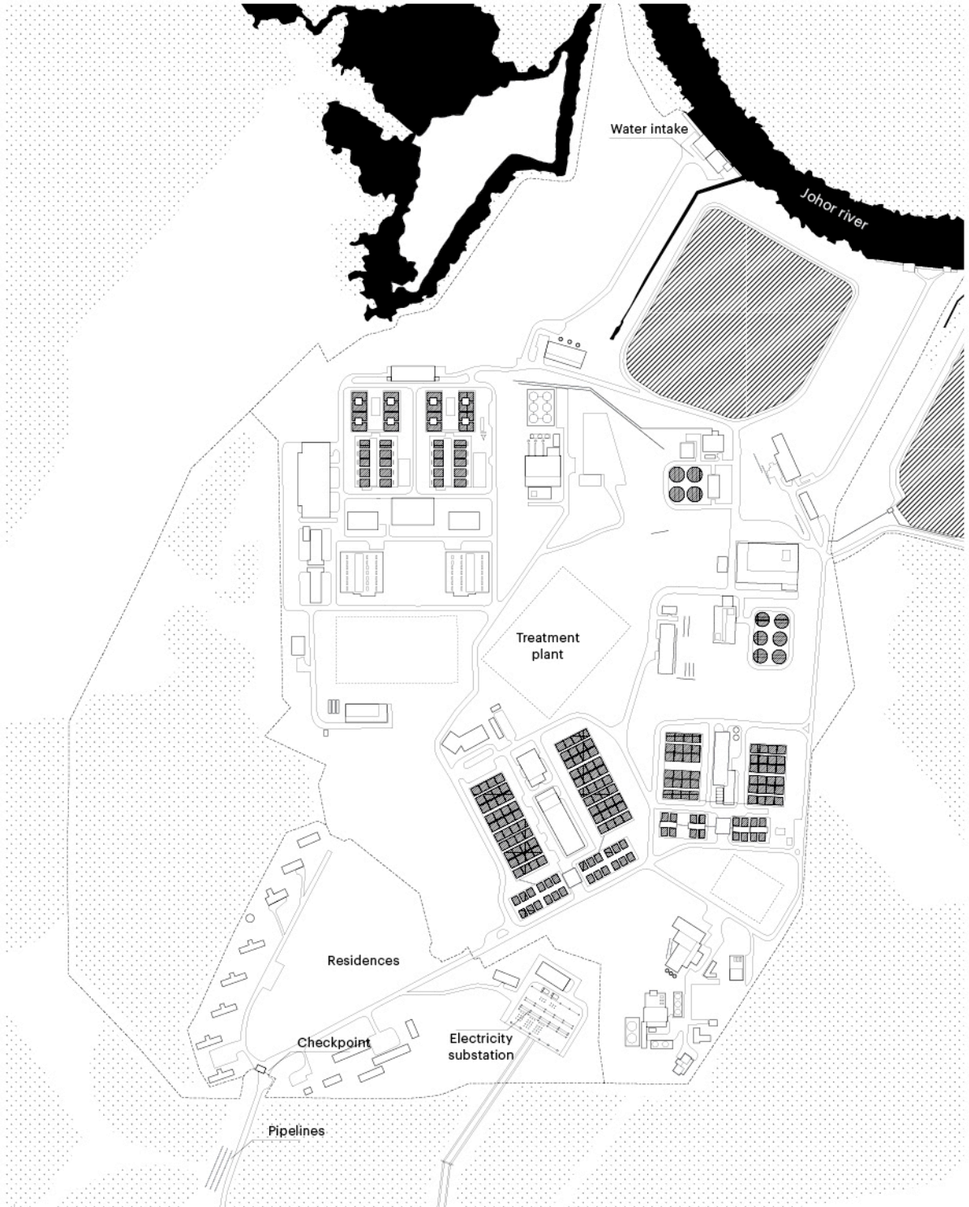
Kota Tinggi treatment plant's checkpoint with pipelines heading to Singapore

Negotiating Control

To keep control on Singapore's water supply, the SAJ (Johor's water agency) has first take on the river's water coming from the Linggui dam. There are ten SAJ plants located along the river shores before Singapore's Kotta Tinggi plant.

The plant is built like a small town; a part of "contemporary Singapore" in "industrial Johor". A residential and office area is built at the south of the actual treatment plant. An electricity substation finds itself at the southern tip of the facilities, providing enough energy for the whole installation. Like many other water infrastructure facilities, the area is heavily guarded by Malaysian soldiers.





Water Treatment Plant Kota Tinggi

Water
Dam
Vegetation
Fence

N

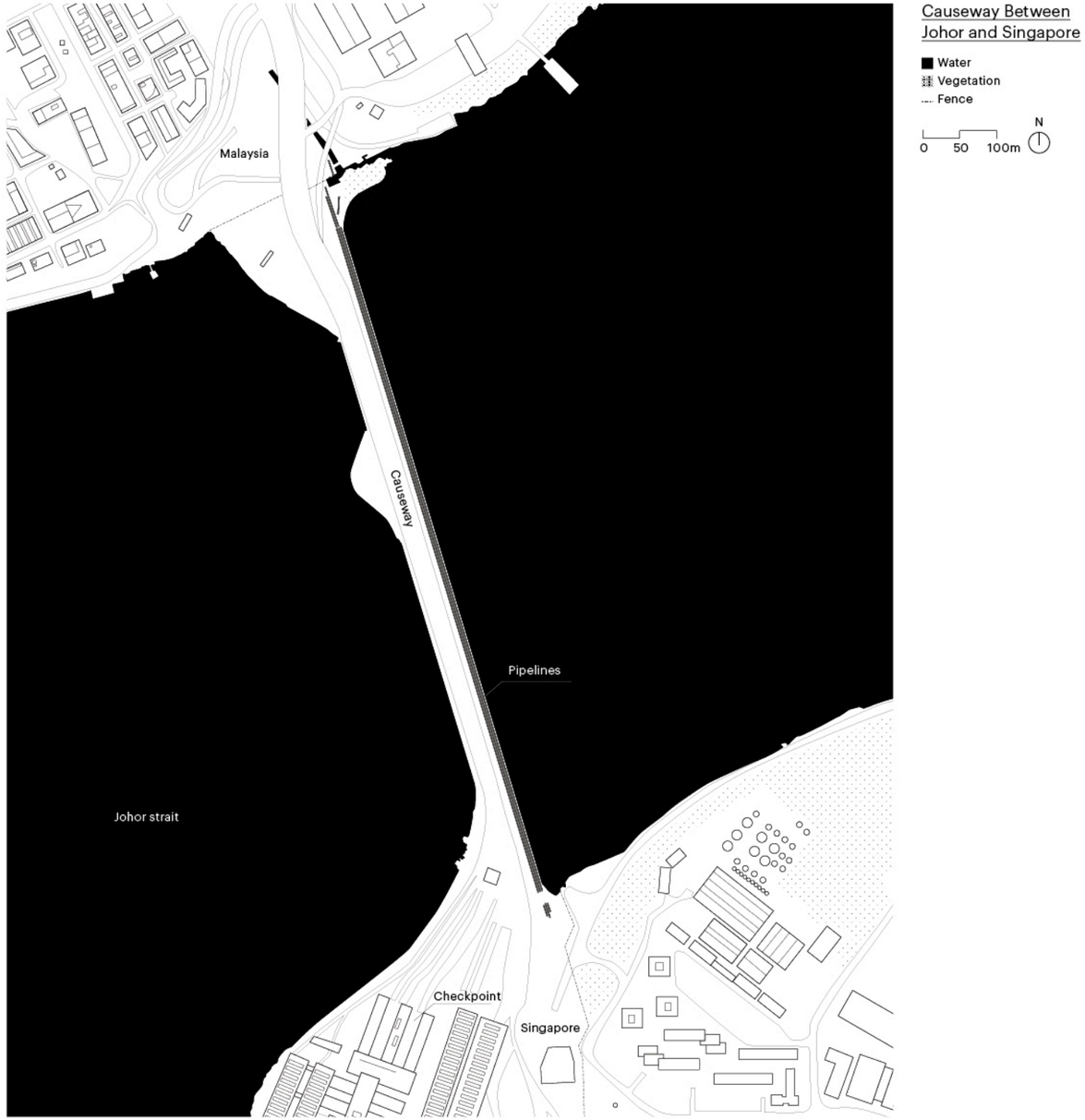
0 50 100m

Left:
Pipelines crossing the causeway

Bottom:
Japanes soldiers imprisoning British troops in 1942

Water Gate

Pipelines spring out of the ground when they cross over bodies of water to connect with Singapore. They are linked to the causeway. The causeway can be seen as the physical incarnation of Singapore's fear; an artery feeding the island. Since the British made it explode whilst facing the Japanese invasion, it has always been highly guarded.



Mechanics of Control

Being a scarce and precious resource, water stocks are managed with efficiency and preciseness in Singapore. The whole territory is planned for water catchment and protection against pollution through a network of infrastructures. Although some parts of the island's surface still look untouched – mainly the natural parks – even these apparently natural territories have been rebuilt to collect rain water. Together with reservoirs, treatment plants, service reservoirs and flood control facilities, the cycle of water is artificially managed. The public utilities board oversees all water operations in a exceptionally competent but also opaque approach. Moreover, they have the monopoly over the water resources in Singapore.
By depending on Malaysian water import, the resource became a topic of national security. Because of this, information about water management has been considered sensitive. Reliable information for topics such as the capacity of treatment plants and basic information about water imports remains inaccessible.

Tide control facility at the dam of the Kranji reservoir

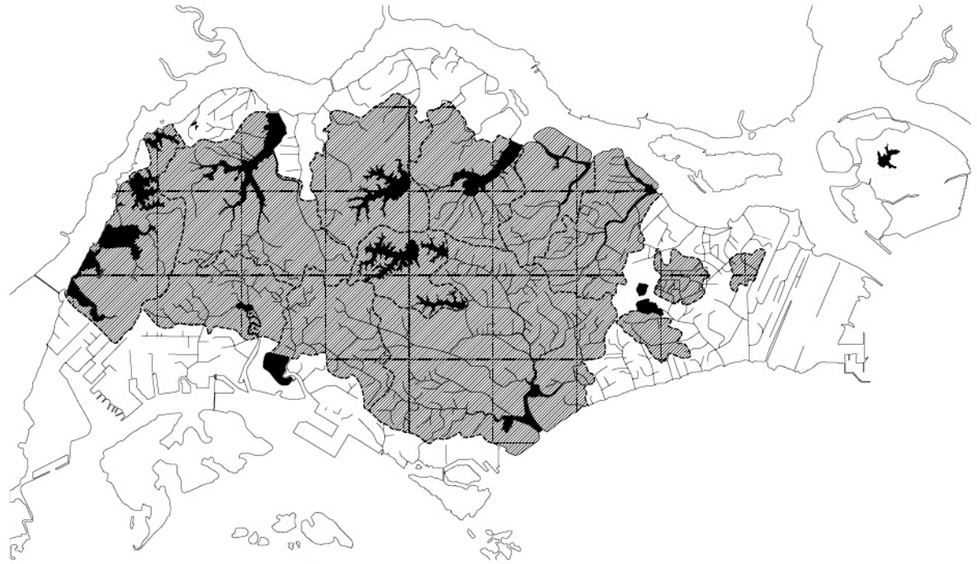
Engineered Territory

Singapore's water shortage and excess at precipitation peaks is managed through a vast network of channels and drains. Its territory is engineered to catch water on sixty six percent of its surface, which represents a technological prowess. This area includes different kinds of territories, from natural environments to highly dense residential and business districts.

Annual Average Rainfall (mm)

History

Singapore started to use catchment technology ever since it became a trading port at the turn of the last century; a time when the country stored water in reservoirs to cope with draughts. It only started to shape its territory for catchment purposes in the 1970s. Existing reservoirs were enlarged in order to store more water and new ones were created by damming rivers from the sea. In the future, Singapore intends to collect water on up to ninety percent of its terrain by also damming smaller streams.

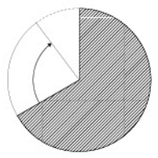


Water Catchment Area

Reservoirs
Catchment Area

0 2.5 5 km

N



Infrastructure of Control

Beside the channel network, operating buildings are also a part of Singapore's water harvesting machine. Their uncommon architecture enriches the otherwise monotonous Singaporean landscape.

Service Reservoir - Asmara

Service reservoirs can be found all over the island. After the treatment process, potable water is stored in these structures to supply large amounts of water during peak hours. The specific shape of the Asmara service reservoir is due to static considerations and can be found in Singapore's older water constructions.

Flood Control - Pandan

Flash floods remain a considerable problem in tropical environments. Singapore also experiences water flow problems when precipitations are too high. The drainage network that was developed over the last decades allowed to decrease the flood prone areas from 3'200 ha in 1960 to 48 ha in 2012.

Water Towers - Tampines

These specific water towers stock NEWater, distributing it to high-tech industries. NEWater is sent into a different system of pipes specially built for this ultra-clean ressource.

Tide Control - Kranji

Estuary reservoirs were rivers that have been dammed where they rejoined the sea. During high tide, powerful pumps are needed to prevent floodings in the interior of the country and not contaminate the fresh water with salt.

NEWater Plant - Changi

At the moment, four NEWater plants clean sewage water to ultra-clean water used mostly in high-tech industries and airconditioning. Only a minor part of its production is redistributed into reservoirs.

Residential Area as Catchment Area

Buildings
Roads
Vegetation

0 20 40 m N

Singapore's dense residential areas have all become catchment areas.

Drainage System

Sungei Ulu Pandan
Drains

0 20 40 m N

The drainage network splits up into the smallest of drains, redrawing the built environment with a new water layer.

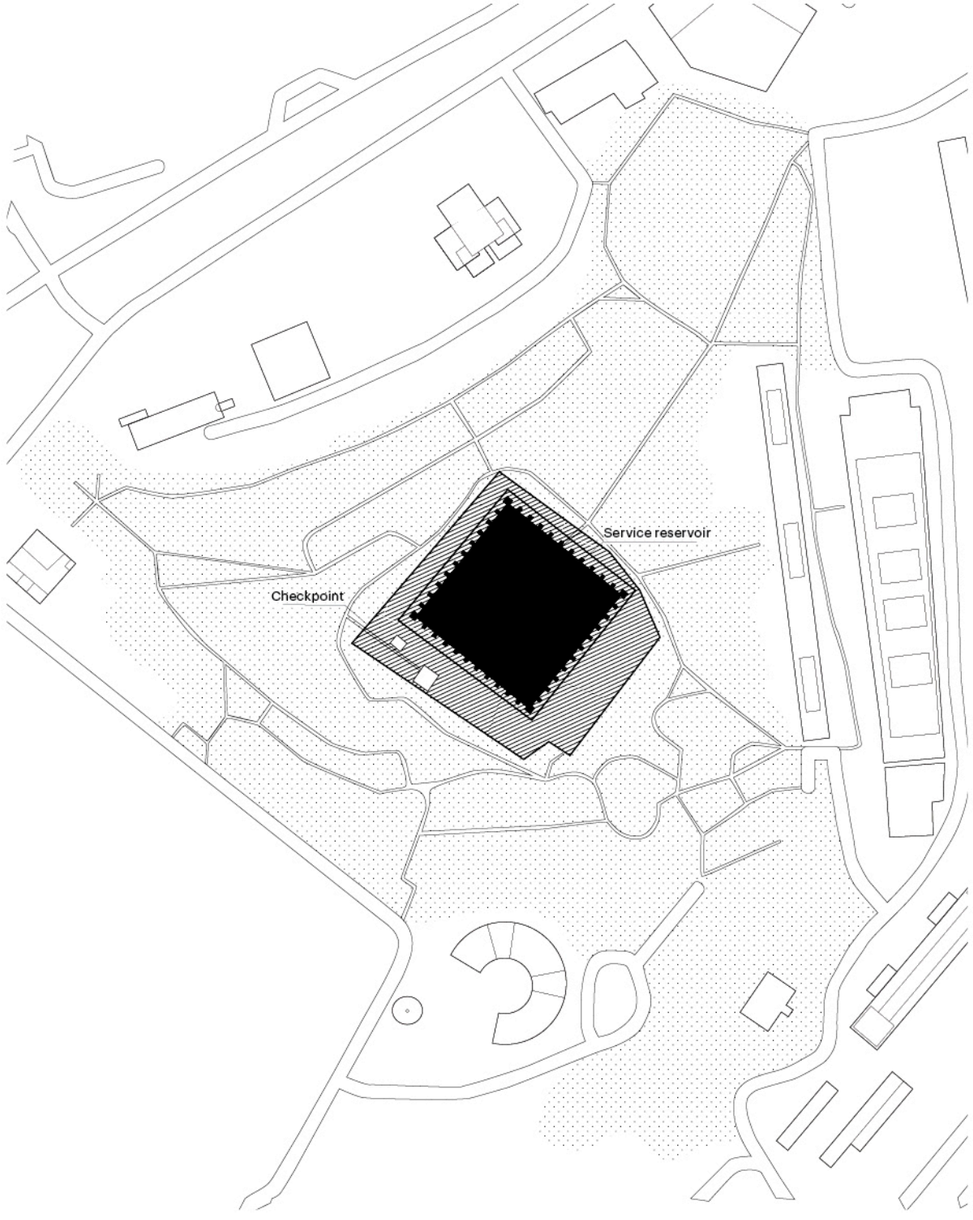
Top:
The double fence in front of Pearl's Hill's reservoir

Botton:
Aerial view of Pearl's Hill'a reservoir

Fortress in CBD:
Pearl's Hill Service Reservoir

Service reservoirs are highly protected because they contain the water that is directly piped to the fresh water network. For the same reasons, they are often located close to residential areas or within the city centre.

The proximity of parks and residential areas to a double fenced security facility creates an uncommon visual clash in the urban landscape. Pearl's hill is a radical example of a military protected zone set in the middle of a park.



Pearl's Hill Service Reservoir

Service Reservoir
Restricted Zone
Vegetation
Fence

0 30 60 m
N

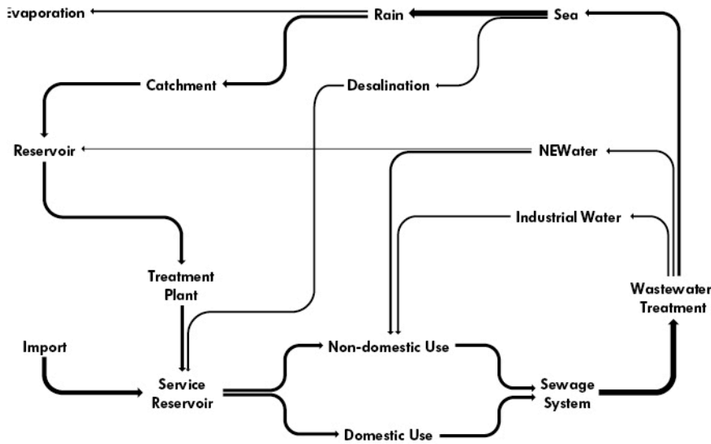
Pearl's Hill Reservoir lies in the middle of Singapore's downtown, with residential areas in the north and bustling Chinatown to the south.

Centralised Power

Founded in 1963 as the agency responsible for gas, electricity and water affairs, the influential Public Utilities Board only focuses on water. Over time, all water issues were integrated to the Board, from import relationships to public education.

The widespread catchment network, the sophisticated new technologies or the successful decrease of domestic water use demonstrate the power and determination of the Board as well as the Singaporean government.

In 2004, the PUB started a new strategy that would broaden its authority even more. Under the concept of 3P (people, private, public), the Board started to include semi-private companies into the water cycle: competitions for NEWater and desalination plants were held and the lowest priced submissions were selected. The two most known participants are the Hylfux group and the Keppel Corporation, both are Singaporean companies with strong ties to the government. By dominating both public and private sectors and supervising all water affairs, the PUB has become an impressive machine of control: a centralised power.

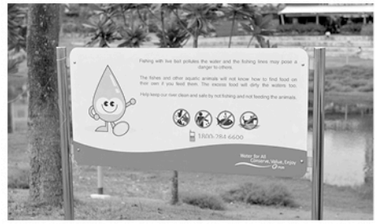


PUB's Water Cycle

The Public Utilities Board is directly in charge of all elements of the water cycle. Potable water is produced and supplied by four different sources: imported water from Malaysia, rain catchment, treated sewage water ("NEWater") and desalinated water.

The two first ones are still the most important supplies of potable water. Industrial water and "NEWater" are mainly used in industries to satisfy their special needs. Yet a small part of "NEWater" (3.5% of Singaporeans' daily consumption of drinkable water) is introduced into the potable water cycle by releasing it into reservoirs.

Desalination plays a small role in 2012 (only producing 10% of the total daily consumption) but it will increase its capacity with the opening of the Tuaspring seawater plant in 2013.



Education

The PUB has established an efficient education program. Using cartoons (notably Bobo the water saving elephant or Wally the friendly drop), children focus on the problematic of water and learn how to save it. Other notable events are the Singapore water week or water shortage days to prepare against a possible water crisis.

Collection

Though Singapore is in a tropical zone and receives twice the world average rainfall on its territory, it remains one of the most water scarce country in the world because of its high population density. Through an ingenious catchment system that covers 66 percent of its territory, it is able to stock a large part of its rain into reservoirs.

Production

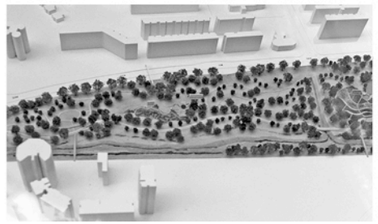
Singapore produces drinkable water for its population from rainwater. It also uses two major new technologies: "NEWater", that is recycled waste water, the purest form of water available in Singapore and desalinated water which still is a costly and a highly energy consuming production method.

Import

The PUB imports between thirty to fifty percent (depending on different sources) of its drinkable water from Malaysia. It possesses reservoirs out of its own territory and is always searching for new possibilities to import water from foreign ground. At the end of the 1990s, it signed an important water contract with Riau (Indonesia), allowing Singapore to import up to 4.5 M m3/day for one century starting from 2005. This contract was never put into practise due to technical difficulties and insufficient amounts of water on the archipelago.

Reclamation

After potable water is used, an ingenious new system of pipes brings back wastewater to be treated. Most of it is then poured in the sea after having been partly cleaned. The other part is used for the production of "NEWater" or industrial water, a non-drinkable water used for cooling.



Planning

The PUB is in charge of planning for every issue concerning water: it distributes it, takes it back, cleans it, but also makes urban plans. The new ABC model for reservoirs and waterways has been put in place by the Board.

MARINA
barrage

HOMEPAGE
internet

INFORMATION
vulgarised

MARINA
barrage

NEWATER
visitor centre

2061
goals

EDUCATION
policy

ABC
policy

ANNUAL
report

WATER
wally

10 YEARS
10 liters

SUPPLY
quantities

FINANCE
detailed

CAPACITY
of the different taps

MAPS
of water facilities

ENTRY
to facilites

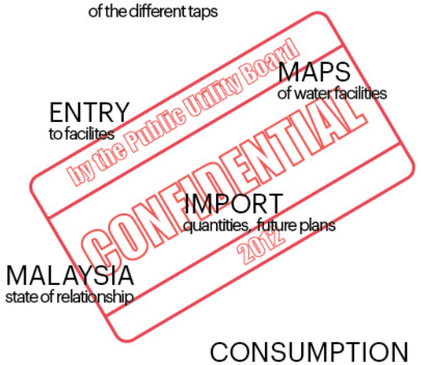
IMPORT
quantities, future plans

MALAYSIA
state of relationship

CONSUMPTION
precise numbers

TECHNOLOGIES
how they work

INDONESIA
future import plans



Information Firewall

PUB's Public Relations is twofold. On the one hand it advertises the ideal of Singapore as a blue city that presents itself with nice river shores and fantastic technologies. With enormous promotional expenditure and labels like "ABC" (active, beautiful and clean) or the "3P" approach, people shall be brought closer to the water to enjoy, value and save the resource.

On the other hand, there is a reluctance to share precise information about water resources and the technologies it promotes. Numbers, locations and prices are considered strategically sensitive and are not shared with the public.

Left:
Restricted service reservoir in Fort Canning Park

Bottom:
Picture from the PUB's annual report of 2011 promoting interaction with waterbodies

Public Image

Part of the PUB's public relations strategy is to promote Singapore's water bodies as places of recreation. This is part of the new "ABC" strategy where new star projects have been successfully implemented and used as objects for marketing purposes. However most of the existing facilities defy this image as reservoirs are seldom used and the direct contact with water is prohibited and penalised.

Miscellaneous Interactions

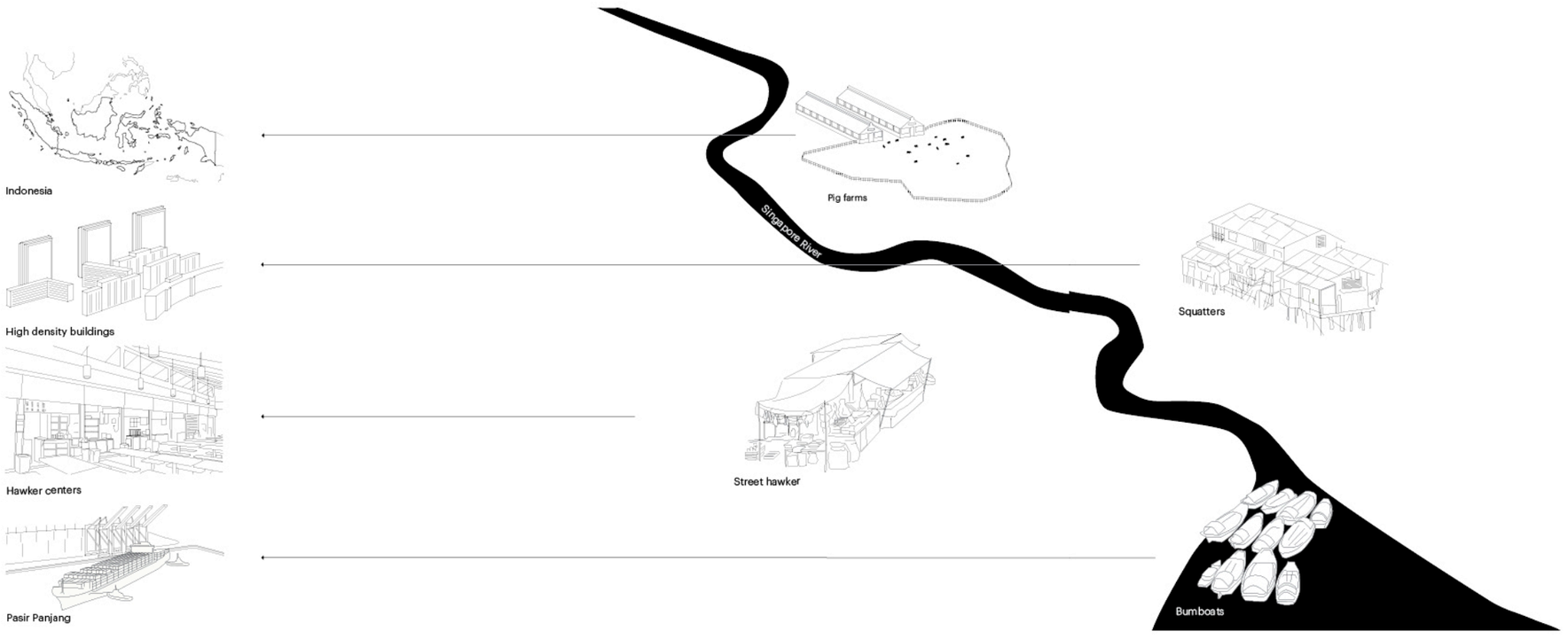
Water infrastructures are present throughout the territory, from small gutters along the roads to lake reservoirs, channels and parks. At present, Singapore's water can be found in between two different government planning strategies; two periods in time that now contradict themselves. The newly implemented strategy is trying to create water-friendly interactions whilst the effect of the ulterior one established a complete separation from water with the rest of the city, making it inaccessible and unattractive. By describing these different strategies through case studies, a broad overview over a complex multiplicity of urban interactions with waterscapes can be achieved.

Marina bay reservoir with the construction of the stadium in the background and kayaks in the foreground

A Change in Value

During the last fifty years, Singapore's urban landscape changed dramatically. The economic boom turned the island from a low-income economy into a metropolitan city and financial hub. This change can be demonstrated by contrasting the way people perceived and dealt with water bodies before and today.

In the first half of the 20th century people used to live with and around the water. Life and economy were organised along its shores, inducing its pollution. After realising the strategic importance of water, the Singaporean government decided that water was no longer a natural resource that everyone should have access to but a precious good that had to be protected. In the 1980s, the authorities restructured a whole area of the city going from Singapore river to the Kallang basins, relocating and reorganising all sources of pollution. The same process also took place less intensely all over the island. The positive results of this catharsis became tangible immediately but at the same time prevented any direct interaction with water. This downside still remains today although attempts are made to re-stimulate interconnection between the city and its water fabric.



Cleaning the River

A major source of pollution was generated by pig and duck farming further upstream. Their high water demand reinforced the decision to abandon animal farming in Singapore and rely on imports. For instance, Pulau Bulau, better known as "pig island", now exports 1'100 pigs every day exclusively for Singapore.

Before the cleaning of the river took place, Boat quay was a bustling dock where boats shipped goods and people. The harbour trade with its shipyards and bumboats were relocated to Pasir Panjang, on seawater, where soiling was less of an issue.

Hawker Centers and HDBs

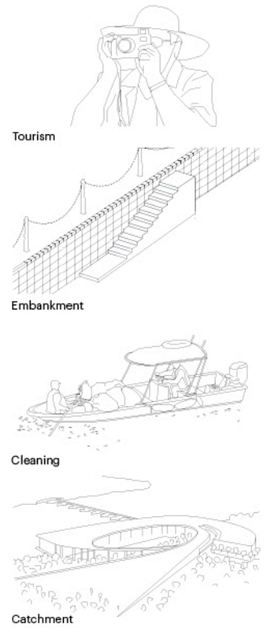
Informal settlements along the riverbanks remained a concern because of lacking basic sanitation infrastructures. Sewage was directly discharged into the river. Unauthorised market-stands generated the same problems as unsold food would be thrown into the water.

The government decided to relocate squat residents into "High Density Buildings" which were firstly built in the 1960s and now characterise the city's architectural landscape. Food stalls were transferred to hawker centres where basic infrastructures are provided.

The New Wave of Tourism

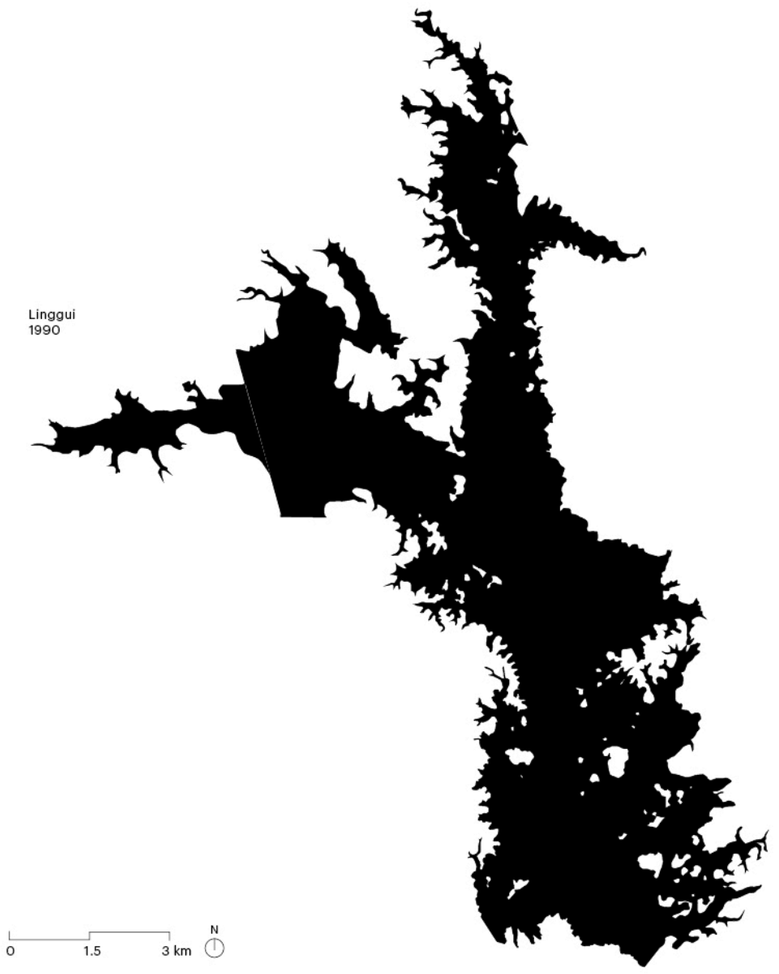
After restructuring the city area, the riversides were converted into touristic hotspots. Boat Quay, once a murky port, became one of the most coveted neighbourhoods for clubs and restaurants.

Water is now regularly cleaned and tourist boats allow sightseeing for Singapore's tourists.

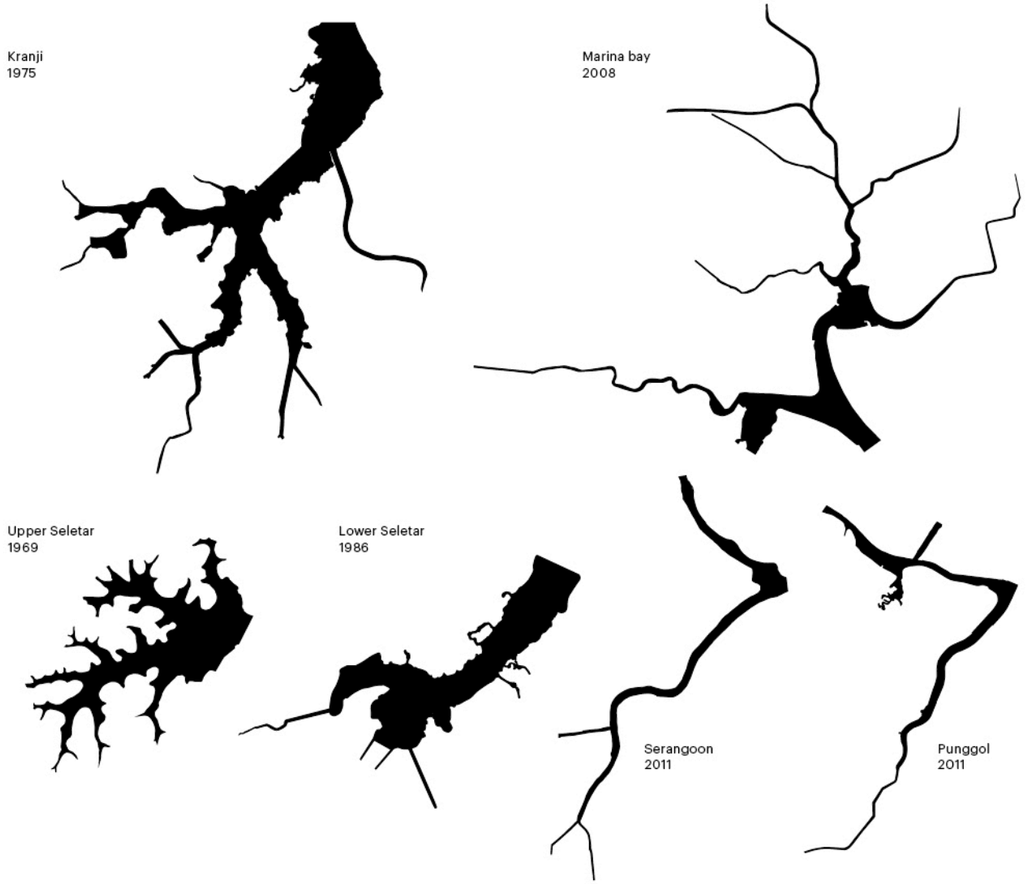


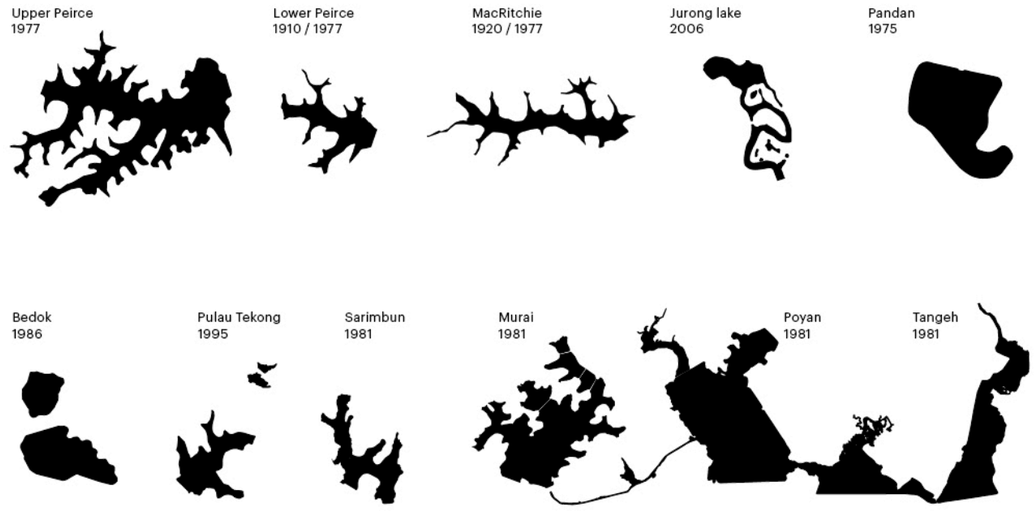
Reservoir Typologies

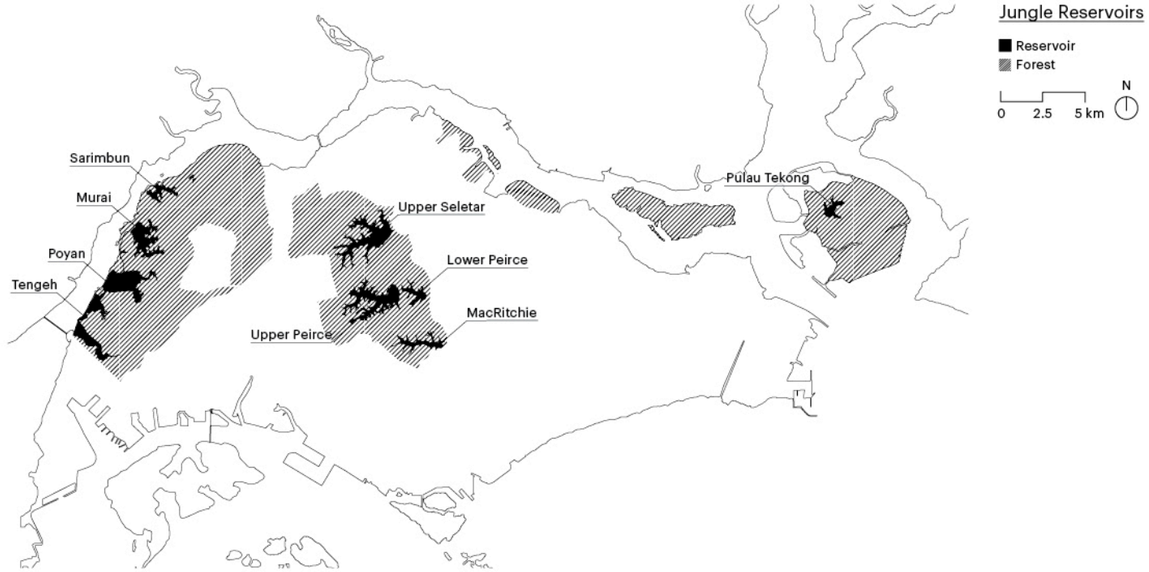
Singapore reservoirs differ not only by function, but also by form. Some are clearly rivers that have been dammed whilst others are lakes that have been upsized. This morphological diversity brings richness to the landscape of the island. Unfortunately Singapore's authorities are very slow to exploit this grandeur. Most of them continue to be seen as mere reservoirs instead of urban artefacts.



Singapore's Reservoirs
The Linggui Reservoir in Malaysia (this side) covers a surface double the size of all national reservoirs of Singapore (right side).







Forgotten in the Jungle

When water became a concern, Singapore started stocking it in reservoirs it placed in the middle of the forest. With the MacRitchie reservoir built in the middle of the eighteenth century, the island was able to provide enough water for its port and the numerous boats that stopped there. This phenomenon continued with the Lower Peirce reservoir, the Upper Seletar reservoir and the Upper Peirce reservoir. In those times, water was not considered as an urban artefact but more as a commodity. Thus the access to these geographical spaces was not seen as a necessity.

When Singapore experienced a surge in its population growth in the 1970s, a new generation of reservoirs was built. Exploiting the last space in the jungle, the reservoirs were built in military zones, making them absolutely inaccessible to the island's population. In 2013, this type of water reservoirs remains essentially closed to the public even though an evolution in the PUB's mentality created a more interactive future for these waterscapes.

1.

1.
Upper Peirce reservoir

2.
Military zone next to the reservoir

3.
A small part of the shore close to the dam makes an picnic area.

Upper Peirce

Except for a golf course on one of its sides and a few picnickers on Sundays, the Upper Peirce reservoir remains hardly used by the Singaporean population. It is unconnected to the public transport system and can only be reached by car. Water treatment plants and storage facilities as well as military zones can be found along the shoreline. A few remote paths leading through the jungle allows users to appreciate the rich wildlife still present on the island, free from human interference.

2.

3.

A tourist boat that transports zoo visitors around the facility

The Zoo Reservoir

The Upper Seletar reservoir is another example of a body of water difficult to access. The only exception is its dam and the Singapore zoo that is situated on a part of the reservoir. There, people use the view to take souvenir photos and feel as though they landed in the middle of primary nature, while actually being in an artificially recreated landscape. A single boat is allowed on the lake: a tourist attraction offered by the zoo.

Apparent Wilderness

One could think that these jungle reservoirs are the last remains of Singapore's natural landscape. The truth is very different: although the nature is primarily rainforest, its ground is engineered to catch every drop, leading the water to the reservoirs.

The reservoirs were upsized in the 1970s to store as much water as possible. Because no fisherman are allowed, the fishes there are especially large.

"In-Between" Reservoirs

Reservoir
Forest
Urban Footprint

0 2.5 5 km N

In-Between Zones

In the 1970s, a new generation of reservoirs appeared. Located outside the city to prevent the pollution of its water, these reservoirs remain difficult to access. A common character of these reservoirs is expressed through the multiplicity of different land use around its shores: military grounds, industrial zones, forests, parks and golf courses. They are also set far away from residential zones to prevent interaction.

Although these reservoirs are underused and located outside urban centres, they could be reintegrated if the city continues to expand around them.

1.
Pandan's industrial surroundings

2.
Flood control building

3.
Industries on the shores of the reservoir

4.
Pipeline pumping water out of the reservoir

1.

Jurong's Shores

The Pandan reservoir is set in one of Singapore's industrial zones in the south of Jurong. Although residential areas are not in direct proximity to its waters, the reservoir became more user-friendly when a rowing club and a park were established on its shores. In spite of this evolution, the surrounding environment remains morose with industries and containers making a clear contrast to more integrated reservoirs like Marina Bay or Punggol.

"In-between" reservoirs stay largely undefined spaces due to a lack of a clear vision and the heterogeneous areas around them.

2.

3.

4.

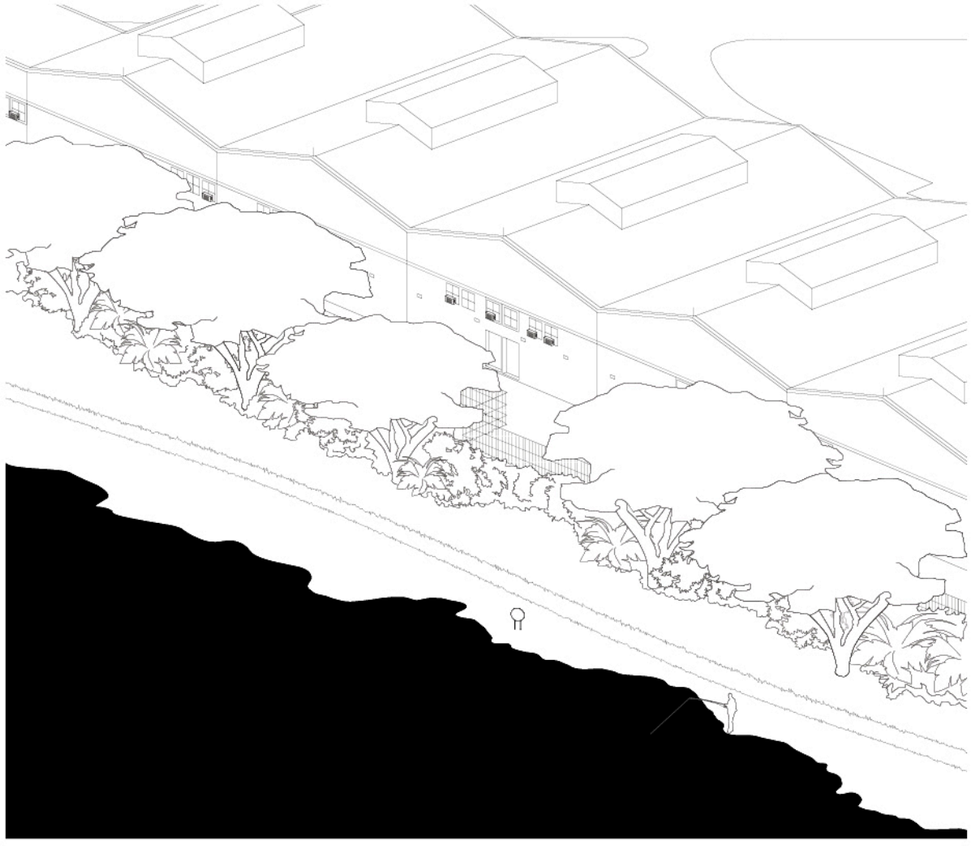
Left:
The reservoir seen from the dam

Bottom:
Illegal fishing on Kranji's shores

An Industrial Paradox

Industries as well as military zones and nature reserves encircle the shores of the Kranji reservoir. A few people fish near the dam, far from the control of the Public Utility Board. Fishermen risk a fine up to five hundred Singapore dollars if they get caught.

This attitude of forbidding direct contact with water is meant as an extra safety against water pollution: no fishing, no swimming, no dogs. In contradiction with these bans, the fact that numerous middle-sized industries are in close proximity to the water does not seem to be a problem.



Beautified Shore

The industries set along Kranji reservoir's shores are seperated by a green belt made out of trees and bushes. This is meant as a reservoir beautification as well as a buffer against possible pollution.

Urban Reservoirs

Reservoir
Urban Footprint

0 2.5 5 km N

Urban Integration

In around 2005, the Public Utility Board realised that waterscapes and channels could actually serve the city more than by just stocking water as a basic resource. It created a new policy called "ABC" (active, beautiful and clean) and started integrating water infrastructures to the city.

With this, water came to be seen as multifunctional in the newly built reservoirs and other selected sites were carefully picked for renovation and re-naturalisation. In this new policy, carefully selected activities are permitted in certain locations. For example, the Punggol reservoir has a defined area where the population can go kayaking.

Although this evolution allows more interactions, it is only focused on certain areas of water infrastructures. Thus most of the city stays in the old system where the infrastructures are completely separated from the island's population. Only a few "ABC" projects have already been built. The location choices for such redevelopment favour new residential areas and touristic hotspots.

1.
Chinese gardens at Jurong lake

2.
ABC aims to promote reservoirs for pedestrians and bird watchers

3.
View of the landscaping of Jurong lake

4.
Jurong lake at dusk

1.

"ABC": A New Policy

When one talks about interactions, one expects to actually be able to touch the water. The "ABC" policy however does not allow any direct contact. It is more meant as a dialogue between land and water - people jogging and sitting at its sides, view towers and bridges, kayaking and bird watching. In this manner a more distant relationship is created: an indirect interaction.

The official explanation for the ban of direct interaction is related to concerns with pollution. However, given the fact that high-tech cleaning processes remove contamination created by roads and industrial areas after the water has passed through reservoirs, the ratio of pollution created through direct human contact is rather negligible.

2.

3.

4.

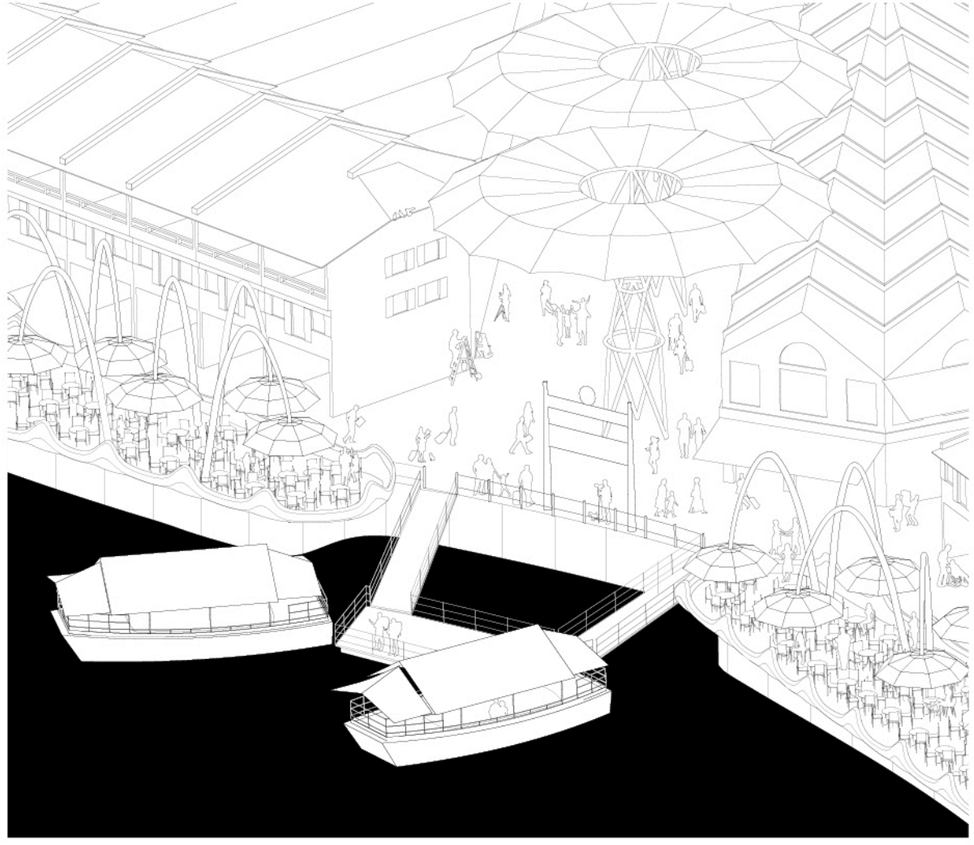
Left:
Singapore's iconic Marina Bay Sands on the shore of the Marina reservoir

Bottom:
Jogger on the Marina barrage

CBD's Luxury

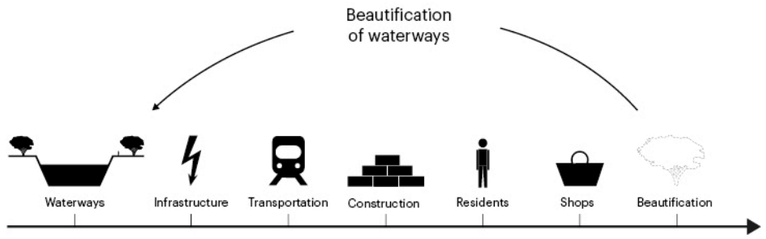
Marina bay differs from all other reservoirs by the sheer density of the city around it: from the towers of downtown to the nightclub neighbourhood of Clarke quay, from the harbour front of Marina Bay Sands to the highways passing over it. This proximity to water enriches the landscape, attracting tourists and business. Hence the reservoir is in perfect contradiction to Singapore's old policy of protecting and shutting off its waters.

A new phenomenon establishes itself in these new urban reservoirs: the trade off between the limited surface and the shortage of water. This leads to stronger interconnectivity between the city and the water. It also creates new problems, such as higher water pollution levels due to urban surroundings.



A Tourist Attraction

Whereas almost all direct interaction with water is prohibited, tourist boats provide an exception to allow tourists to admire the skyline. Cleaning boats patrol the channels.



A City in the Making

More than a million new citizens have been added to Singapore's population in the last ten years and this number is expected to rise even more reaching a total of six million people in 2017. To meet the rising demand of living space, new residential areas are being developed. Watertown, a new residential project situated in Punggol in the Northeast region of the island adds five thousand new living unites to try to satisfy demand pressure.

The centrepiece of the urban plan consists of a waterway connecting Punggol and Serangoon reservoirs. PUB's new interaction strategy permitted to build an attractive waterway, referred to as the "Venice of Punggol", instead of a cost effective pipeline.

The newly acquired significance attached to the waterway as an attraction for investors and residents can be shown chronologically; the waterway, instead of being reshaped when the city would already exist around it, was beautified when only roads and basic infrastructures were being built.

This shows that a new purpose has been added to Singapore's water system besides the one of being functional. It is now used as an urban artefact capable of generating a more attractive neighbourhood with higher rents.

1.

2.

3.

4.

1.
Bare field in wait of investors

2.-4.
City in construction with the green belt already built in the foreground

Lines through the Island

Singapore's channels spread all over the island, like a highway for water. Their presence in the city landscape cannot be overseen and their appearance could not be more diverse. The vast majority of channels are designed as mono-functional infrastructure elements made out of concrete. Their features were designed in order to receive large amounts of water, assure a constant flow and keep the precious good free from pollution. This type of channel is inaccessible, each side being closed by railings. Despite their unattractive appearance, people are found using the paths along the ducts for strolls and jogging.

But channels are now being renovated as integrated urban artefacts. Some projects simply try to beautify the existing infrastructure with vegetation to make it more user-friendly. Others are entirely rebuilt, creating spaces for people to enjoy and interact.

Primary Drainage Network

Reservoirs
Urban footprint
— Channels

0 2.5 5 km N

1.

1.
Channel in the Ang Mo Kio neighbourhood

2.
Channel near the Pandan reservoir

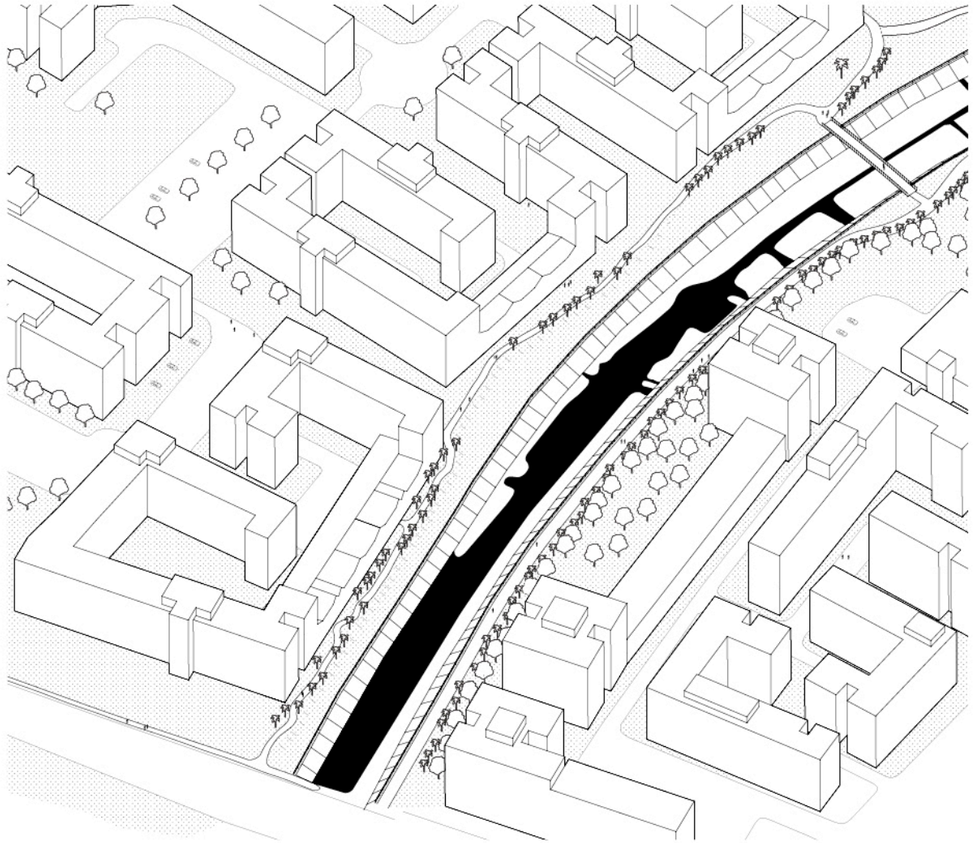
3.
"River plains" in Bishan Park

Scars and Connectors

Similar to roads, the majority of channels create boundaries between different urban parcels. A few star projects show how park landscapes can be combined with channels to create neighbourhood centres instead.

2.

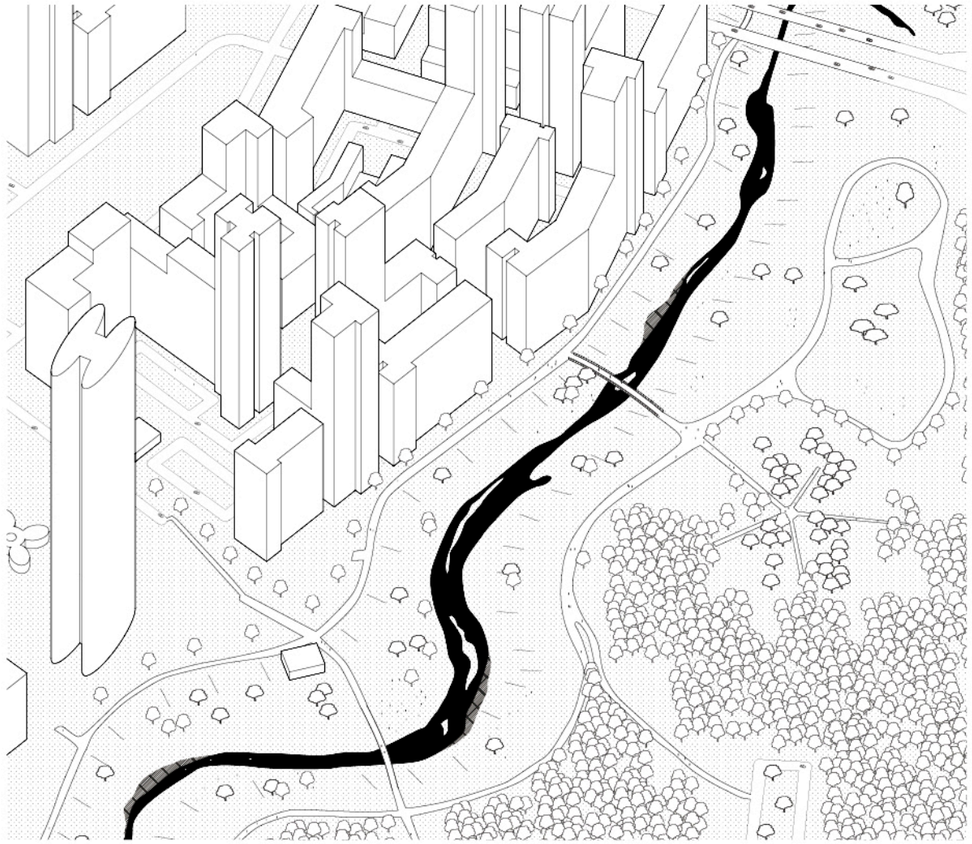
3.



Pasir Ris channel separating neighbourhoods

1970-80s - Engineered Channel

In those years, urban planning was dominated by direct functionality, with each urban artefact having a precise function. Hence channels were only meant to direct water from one part of the island to another. Basic security and anti-pollution rules fenced the channels from their surroundings. The downside of this approach is the separation of territory into different areas.



Bishan Park connecting neighbourhoods

2010s - Renaturalisation

With its new "ABC" policy, the PUB is not only making waterways friendlier but also having an effect on the island's connectivity. Instead of separating neighbourhoods, it creates new urban centres, making the city's environment livelier. Although these new waterways seem to be part of nature at first sight, they are in fact a highly controlled apparatus of water regulation, designed vegetation and flood warning systems.

Kallang River

Water
Urban footprint

Following Kalang

Channels cannot be classified by type seeing that they pass through diverse urban areas and change their appearance accordingly.

1 - 3: Kallang river begins as an overflow outlet at the Lower Peirce reservoir, constructed during British occupation and originally know as Kallang reservoir.

4 - 6: Further downstream the channel enters Bishan park where it flows into a re-naturalised shape, one of the "ABC" policy's star projects.

7 - 8: The park is followed by the old design of channels. The water is lead by wide concrete basins towards its destination.

10 - 12: After six kilometres the channel transforms itself into a river, becoming part of the Marina reservoir.

13 - 15: The water goes through residential areas, separating the neighbourhoods.

16 - 18: The water arrives into the Kallang basin. There it is blocked from entering the sea by the Marina barrage and will instead be pumped and processed into drinkable standards.


1


2


3


4


5


6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8


9


10


11


12


13


14


15


16


17


18

1.-4.
Different types of drains

1.

Capillary Veins

Upstream, channels split up into infrastructures that create a network of pipes and drains, some not larger than 30 cm. Water is collected from every surface, therefore the system is created like capillary veins bringing rainfall to the reservoirs.

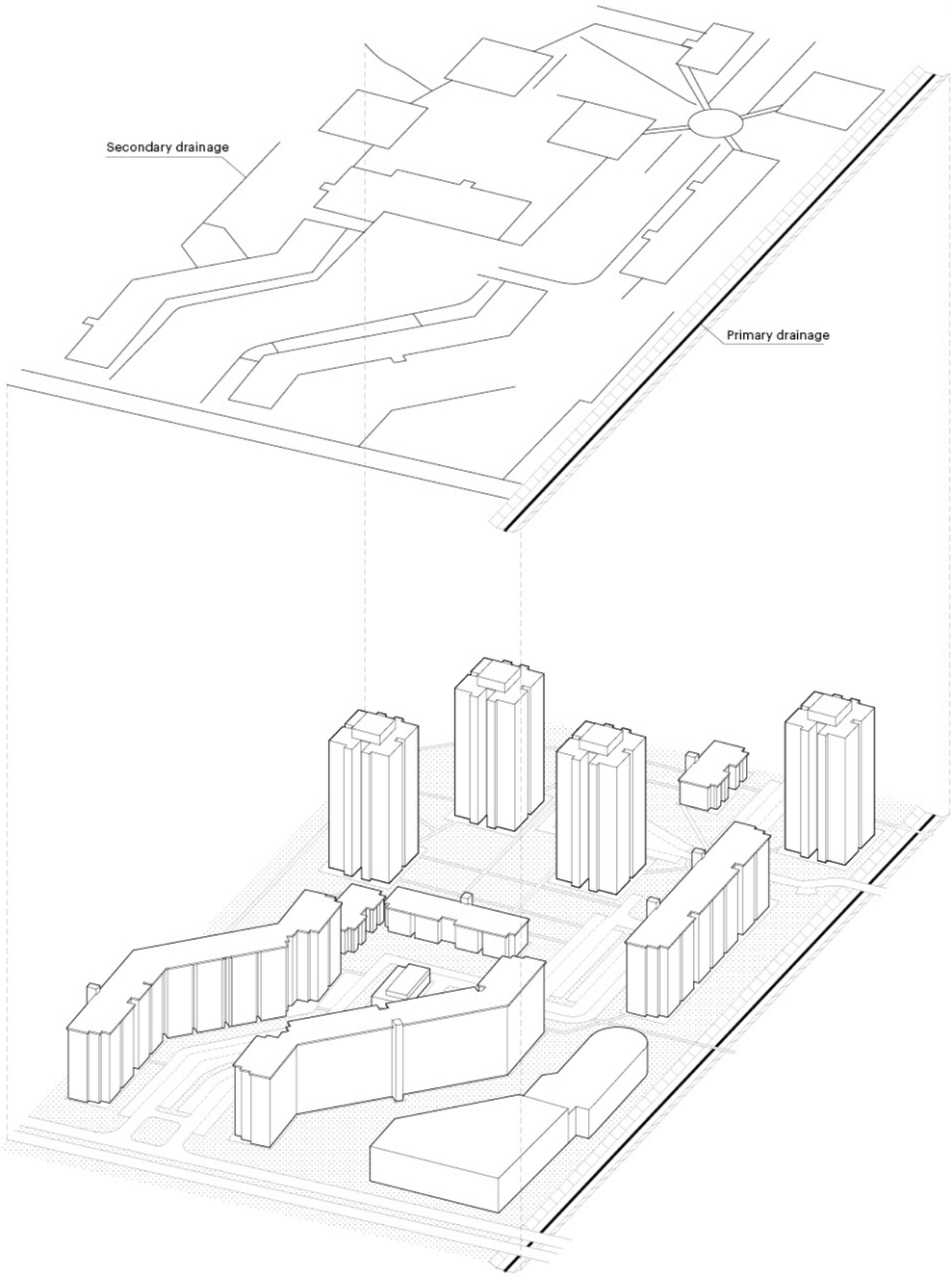
During heavy precipitations, drains instantly get filled up but during dry spells they appear oversized. Except for the newest development projects, these drains are uncovered and hence are part of the Singaporean landscape.

2.

3.

4.

Neighbourhood Clementi
West Street 1



A Driving Fear

Since the very beginning of the Republic of Singapore in 1965, water was a vulnerable issue and a topic of national security. The fear of being at the mercy of Malaysia led to an unprecedented struggle for resource independence. Only with this historical background can Singapore's water strategies be understood. After more than half a century of fear, Singapore claims today to be able to satisfy its daily needs with domestic water productions. It also presents itself as a leader in water management and water production technologies.

June 1988, Singapore's and Malaysia's prime ministers sign the agreement to build the Linggui dam

Water Scarce

Singapore realised early that water scarcity would lead to some significant problems. Since as early as 1824, it has been trying to keep up providing enough water to its growing population and industries. Even with imported water from Johor, draughts still affected the vulnerable city-state. In 1963, the situation became so bad it had to cut supply for periods of twelve hours to be able to make the whole nation survive. Water became a matter of life and death.

Singapore's Fear

Singapore's dependence on Malaysian goodwill became tangible the moment it declared independence. After Malaysian Prime Minister Tunku Abdul Rahman threatend to cut the water supply if the young nation's foreign policy would interfere with Malaysia, tensions between both countries reached a new high.

Singapore also feared shortages like in 1963 due to draughts or war like in 1942 during the Japanese occupation.

Reforming the Territory

After deciding to become more water self-sufficient, the first step was to increase the domestic catchment capacity. The three existing reservoirs were heavily enlarged and complemented by eleven new ones, increasing the storage capacities within 20 years by a factor of eighteen. The catchment territory was first enlarged to 50 percent of the territory and reaches now over sixty six percent.

Turn of the Century

From the beginning on, Singapore knew that it could not solve its water supply problem only with rainfall, its own territory not being big enough to catch as much water as demand required. Therefore the government invested large amounts in researching new technologies. After the turn of the millennium, lower prices allowed to introduce NEWater (2003) and desalination (2005) plants into the water cycle. The only limit to these new technologies was their cost.

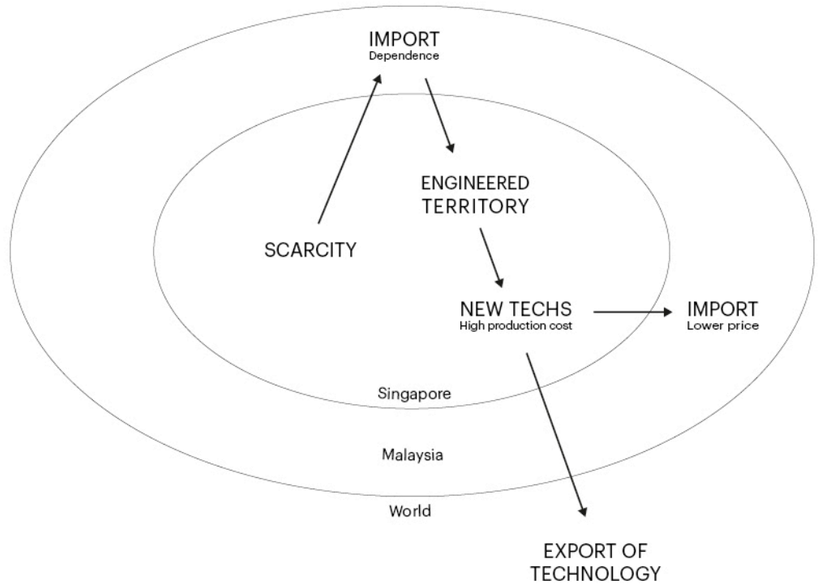
From Dependence to Chance

On the 30th of July 2012, PUB's chief executive Chew Men Leong declared: “If you’re asking me this question about when will we ever get self-sufficiency, I will put it this way that we can be self-sufficient if need be”.

Whilst the 1962 import agreement with Malaysia stays the same, Singapore's position in negotiations changed completely. Import remains the first choice because of price more than need.

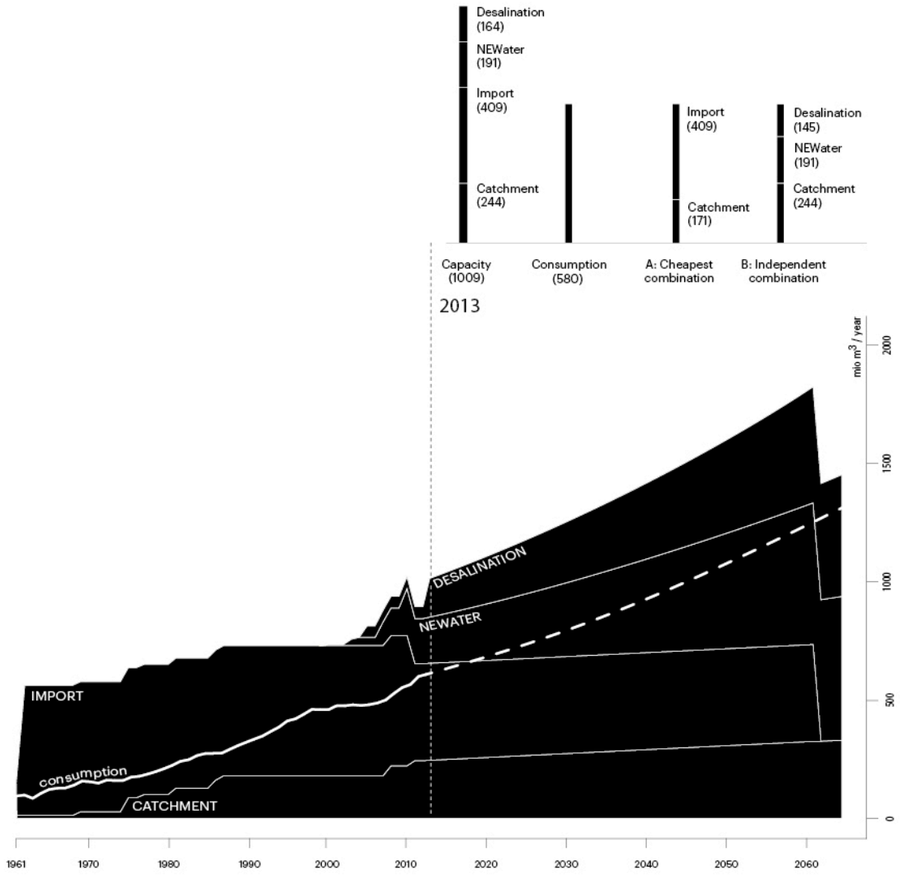
Exporting Know-How

Research is still a big element of expenditure for Singapore's government and its companies gather profit from past investments. In 2013, the Singaporean water industry counts more than 100 companies and is estimated to be worth 9 billion Singapore dollars.



A Chronological Strategy

In the last decades Singapore introduced different strategies to solve the problem of water scarcity in bilateral contracts and within its own territory.



The Possibility of Choice

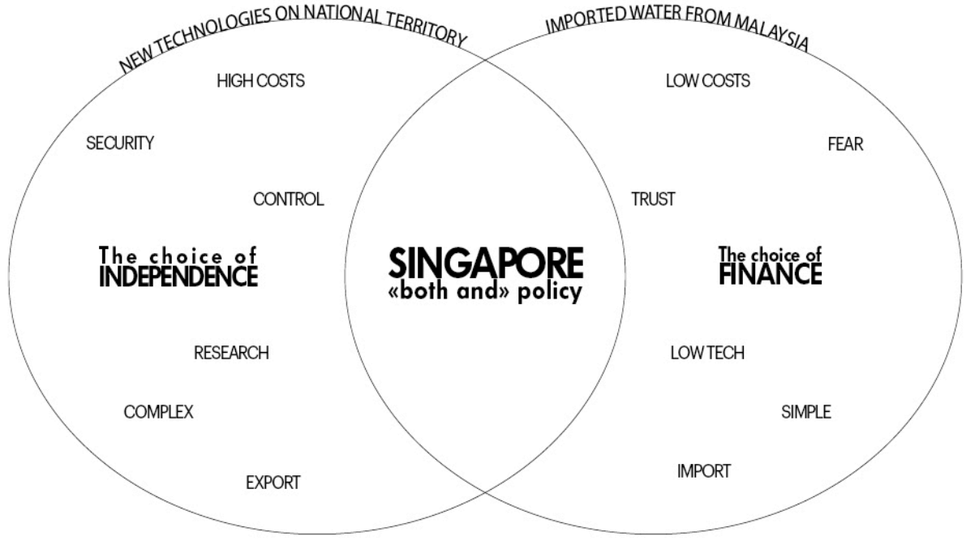
Singapore aims to be self-sufficient in the year 2061 when the second import contract with Malaysia will expire. But by comparing the maximal capacity of new technologies to the national consumption, it becomes apparent that Singapore already has the capacity to produce enough water.

Importing water from Malaysia remains the cheapest solution, followed by rainfall catchment, NEWater and desalination. The last became more accessible in recent years but the costs of production are still double the ones of imported water from Johor.

Meeting the Demand throughout Time

Development of demand and supply over 100 years: Since 1965 Singapore tried to become less dependent on water imports by increasing the catchment areas in the 1970s and 1980s and by introducing new technologies in more recent years.

The situation in 2013 (numbers in M m^3/year): The combined capacity of natural sources, water factories and international contracts results in an oversupply. Variation A and B show possible combinations based on financial and political interests.



"Both and" Strategy

Given the fact that the island state is now able to be water independent, it can continue to import cheap water from Johor without fearing to be at the mercy of the Malaysian government. Instead of taking a clear position, one of total independence or one of financial necessity, it chooses a "both and" strategy, benefiting of the advantages offered by both sides.

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