

MANAGING STORMWATER FOR OUR FUTURE



Contents

Evolving Challenges in Stormwater Management	3	Stamford Canal	25
Stormwater Management Strategies	4	Kallang River	26
A Holistic Approach to Stormwater Management	8	Geylang River	27
Towards Better Flood Protection: The Code of Practice on Surface Water Drainage (COP)	12	Improvements to 2 Waterways in the Eastern Watershed	28
Action Plans to Improve Drainage	15	Bedok Canal	29
Improvements to 4 Waterways in the Western Watershed	18	Siglap Canal	30
Bukit Timah Canal (upstream section) to Bukit Timah First Diversion Canal to Sungei Ulu Pandan	19	Collaboration and Capacity Building	32
Sungei Pandan Kechil	20	Planning & Design	32
Improvements to 6 Waterways in the Central Watershed	22	Technical Guides	33
Bukit Timah Canal (midstream-downstream sections) to Rochor Canal	23	Operations & Maintenance	34
Alexandra Canal	24	Enhancing Public Preparedness	35
		PUB's Commitment to Raising Flood Protection	36
		Annex	37
		Glossary	43

Evolving Challenges in Stormwater Management



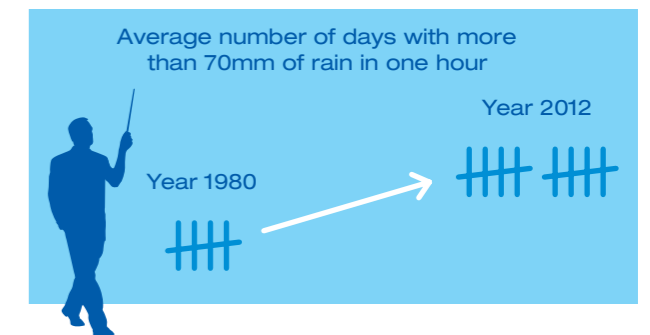
As a small but densely populated tropical island with pockets of low-lying areas and abundant rainfall, Singapore has to capture stormwater as a source of water supply and minimise flood risks at the same time. In balancing this act, national water agency PUB has taken an integrated approach to managing stormwater. In recent years, however, new challenges have emerged:

• More Intense Storms More Frequently

Historical data show that over the last three decades, Singapore has experienced more frequent bouts of intense rainfall. Rainfall intensities have also increased. These trends are expected to continue with climate change.



The maximum hourly rainfall increased at an average rate of 6.4mm per decade, or from an average of 96mm in 1980 to 117mm in 2012.



The frequency of rainfall events with more than 70mm of rain in one hour has increased at an average rate of 1.5 days per decade from 1980 to 2012.

• Continued Urban Development

The growth of urban areas has led to greater stormwater peak flows from developed areas into canals. Moreover, it is a challenge to expand Singapore's drainage systems as drains and canals often lie close to urban infrastructure such as buildings and roads.



Undeveloped areas are mostly vegetated, allowing rainwater to infiltrate into the ground.



Developed areas consist largely of paved surfaces. During a storm, more runoff is generated from developed areas.

Following recommendations from the Expert Panel on Drainage Design and Flood Protection Measures in 2012, PUB reviewed its stormwater management strategies to enhance flood protection for Singapore in light of the new challenges. It has since taken a system-wide approach to introduce flexibility and adaptability to the nation's drainage systems to cope with higher-intensity storms. This involves the significant upgrading of the drains and canals, and other revised requirements in the Code of Practice on Surface Water Drainage.

The following sections present an overview of PUB's stormwater management strategies, approach and requirements that will help prepare Singapore for the future. It will also outline plans for 12 waterways in Singapore.

Stormwater Management Strategies

1.

Getting it Right from the Start

PUB works with planning and development agencies to set aside land for drainage systems and carry out new drainage schemes before new towns or other development projects take root. For example, before the Housing & Development Board (HDB) developed the Punggol and Sengkang residential estates, PUB carried out drainage improvement works at Punggol River in the early 2000s. Other drainage schemes that will be implemented ahead of developments include those for Tampines North and Bidadari new towns.

2.

Setting out Clear Guidelines

PUB's Code of Practice (COP) on Surface Water Drainage specifies flood protection requirements for all new developments and redevelopments. These requirements include planning considerations, such as the ground level of developments (i.e. platform levels), and design considerations, such as the capacities of drainage systems.

3.

Continuous Enhancements

PUB continually upgrades Singapore's existing drainage systems, especially those in mature and highly built-up areas with rapid development and redevelopment, to meet its higher drainage design standards for flood protection.

Taking a Proactive Approach

PUB carries out periodic reviews of its drainage design standards and systems to assess the adequacy of Singapore's drainage systems and to identify solutions for increasing the capacity of the nation's drains and canals to cope with higher-intensity storms.

Going Beyond Function

PUB also introduces Active, Beautiful, Clean Waters (ABC Waters) projects, where possible, to transform utilitarian drains and canals into vibrant waterways that are focal points for the community. The ABC Waters Programme was launched in 2006 as part of PUB's efforts to transform Singapore into a City of Gardens and Water. The idea is to integrate the nation's extensive network of drains, canals and reservoirs with the surrounding environment to create beautiful community spaces that bring people closer to water. In addition, ABC Waters design features with detention/retention functions, such as bioretention basins and bioretention swales, will help to slow down peak runoff into the public drainage system. Through the ABC Waters Programme, PUB aims to improve both the quality of water and the quality of life in Singapore.

The systematic implementation of these three strategies has given Singapore an extensive blue network of about...



48 Major Waterways and their Catchments



A Holistic Approach to Stormwater Management

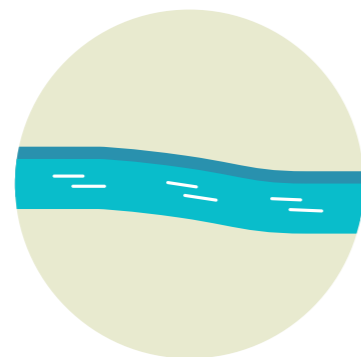
To achieve better drainage and meet new flood protection standards, PUB has adopted a “source-pathway-receptor” approach that covers Singapore’s entire drainage system, addressing flood protection not just along the drains and canals (“Pathways”) through which stormwater travels, but also in areas generating stormwater runoff (“Source”) and areas where floods may occur (“Receptors”).



Source

Areas where rainwater falls

Rainwater that falls on various surfaces either infiltrates into the soil or travels over the surface as “runoff” into drains. Areas that contribute to runoff (i.e. developed areas) are referred to as the “Source”.



Pathway

Channels that runoff flows through

The drains in the area where you live, work or play channel stormwater to canals and rivers and eventually, to the reservoirs or the sea. These drains, canals and rivers are known as “Pathways”.



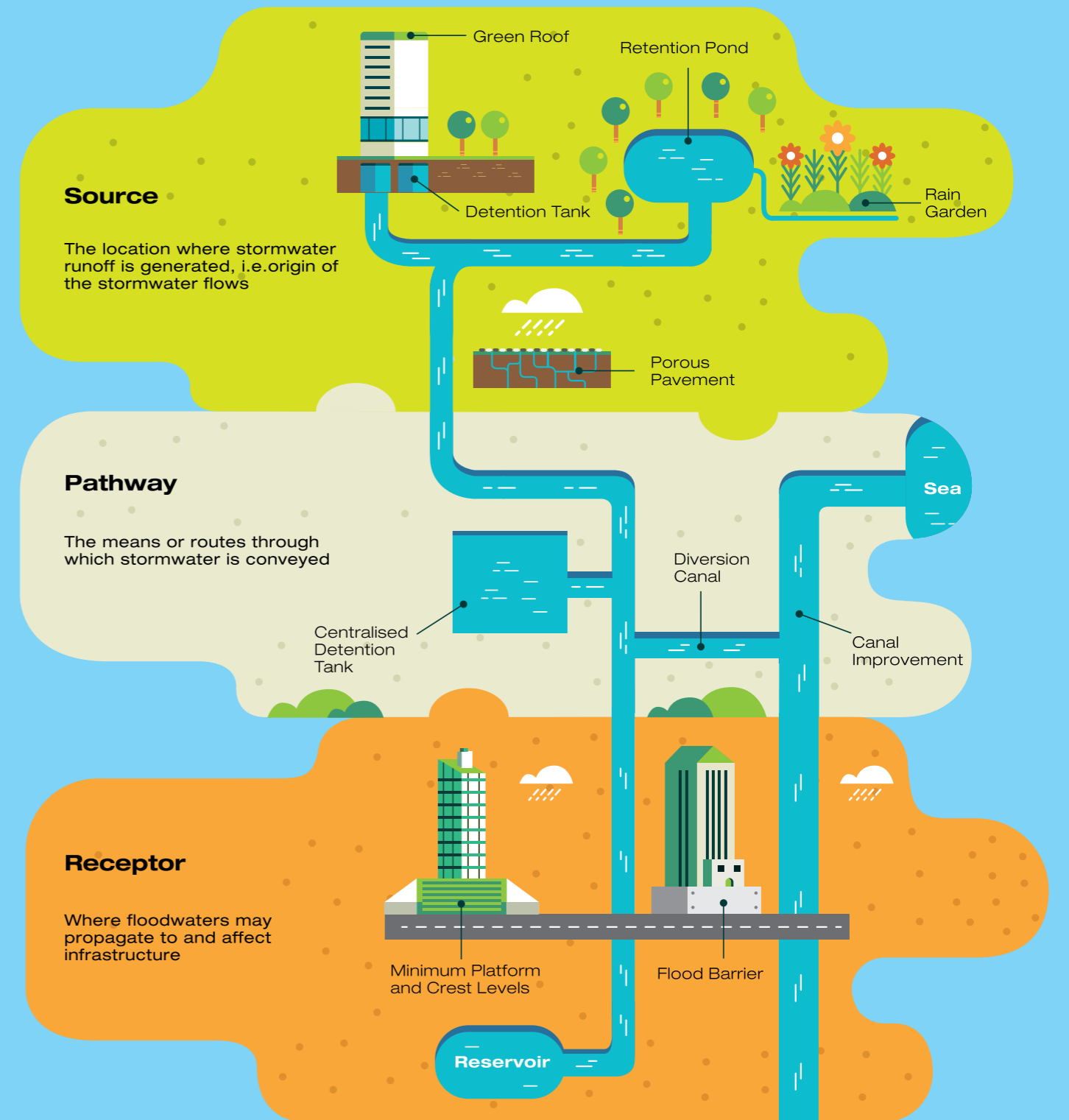
Receptor

Where floodwaters may flow to

Sometimes flash floods occur when runoff generated from the source(s) during intense rainstorms is more than what the drains and canals it flows into can hold.

Floodwaters may affect various infrastructures, such as roads, buildings, and basements. Areas that can be affected by floodwaters are called “Receptors”.

Multi-Pronged Drainage Solutions



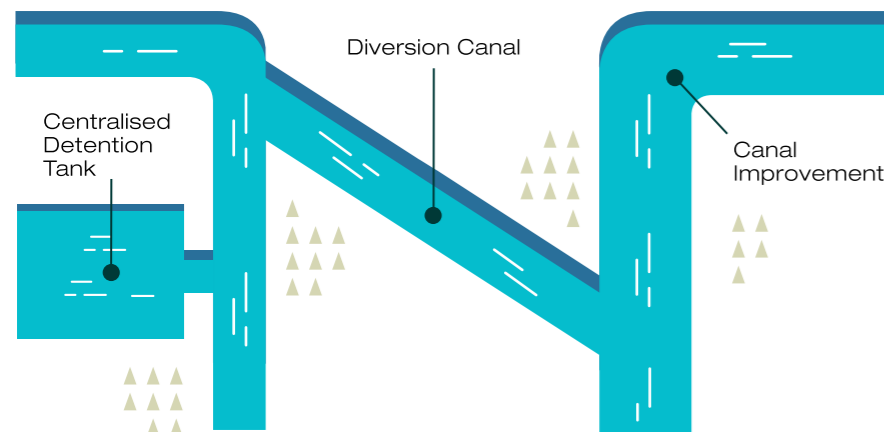
Source

Source solutions help slow down runoff from development sites into the public drainage system. They include detention tanks, bioretention basins (also known as rain gardens) and wetland ponds. Implemented by both public and private developments, source solutions complement pathway solutions to improve flood protection for the catchment.



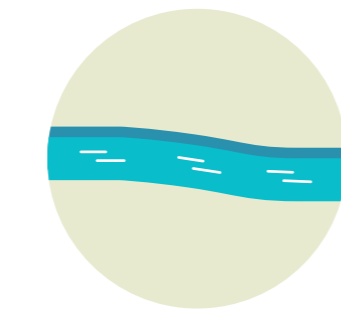
Pathway

Pathway solutions include widening or deepening existing canals, or building new canals or diversion canals. In densely built-up areas, especially where waterways are located close to roads, green verges and private property, there is limited space to widen drains and canals without causing disruption to the public. In such cases, an alternative pathway solution is to divert excess runoff from public drains or canals to a centralised detention tank or pond for temporary storage. The runoff is later released into the same canal after the storm has passed, in anticipation of the next storm.



Receptor

Receptor solutions protect infrastructure from being flooded and come in two broad categories – structural and non-structural. Structural measures include raising road levels, platform levels of developments, and entrance levels to basements and underground facilities (i.e. crest levels), and installing mechanical flood protection measures, such as flood barriers. Non-structural measures include pre-emptive flood monitoring by subscribing to heavy rain alerts and updates on water levels in Singapore's drains and canals.



Where does the drain you see lead to?

Singapore's entire drainage system is made up of internal drains serving private and public developments that lead to public roadside drains. These, in turn, flow into larger outlet drains, canals and rivers, which are connected to the nation's 17 reservoirs or the sea.



Why do flash floods happen?

Flash floods can occur due to a combination of factors, such as:

Peak runoff exceeding what the drain is designed to handle

When the intensity of the storm is higher than what the drainage system is designed to handle, the large amount of runoff within a short period of time can overwhelm the drains and overflow to adjacent areas.

Localised topographical characteristics

Localised depressions on the roads and on the ground are naturally prone to water accumulation. In low-lying areas, options to reduce flooding are sometimes limited because the deepening of drains, especially those leading to the sea, would need to tie in with downstream levels.

Clogged drainage systems

Drains can get choked with leaves, litter and other debris that get washed into them during storms.

Towards Better Flood Protection: The Code of Practice on Surface Water Drainage (COP)

PUB's Code of Practice on Surface Water Drainage (COP) specifies the minimum engineering requirements for the planning, design and construction of drainage systems. Over the years, PUB has revised the COP to raise the standards of flood protection, as well as to enhance the flexibility and adaptability of its drainage systems to cope with storms of higher intensities.

Source Solutions: Roping in the Developers

While PUB will continue to enhance the capacities of the drains and canals (i.e. pathways), developers also play an important role in mitigating the impact of urbanisation.

PUB introduced a new requirement, which took effect on 1 January 2014, for developers of new and redeveloped sites to implement on-site detention and/or retention measures to reduce peak runoff from developed areas into the public drainage system by 25 to 35 percent. These measures can be located on top of buildings, at ground level, or underground. They can also be located under amenity spaces such as playgrounds and car parks.



A landscaped green roof and rooftop garden on top of Orchard Central Mall: The rooftop vegetation captures rainwater, allowing evaporation and evapotranspiration processes to take place and reducing the amount of runoff entering downstream drainage systems.



A dry pond at Greenwood Sanctuary: During rain events, runoff from the surrounding area flows to the dry pond and infiltrates through the filter media to underground percolation tanks. During dry weather, the lawn area in the dry pond can be used for recreational activities.



A bioretention basin (or rain garden) at Balam Estate: Runoff is first filtered through densely planted surface vegetation and then through an engineered filter media layer. The filtered runoff is then collected via a perforated pipe at the bottom drainage layer and discharged to the nearby canal.

Pathway Solutions: Enhancing Singapore's Drainage Systems

To determine the capacities of drains and canals, PUB considers the size of the catchment (the area draining into the waterways), the level of future development in the area, and the rainfall intensities over the area.

In 2011, PUB raised drainage design standards to cater for more intense storms. Depending on its size, each catchment will have its drainage system upgraded in capacity by 15 to 50 percent.

Action Plans to Improve Drainage

Receptor Solutions: Raising the Minimum Levels

In 2011, PUB raised the minimum platform and crest level requirements for new developments to provide them with additional flood protection.

In addition, PUB introduced new requirements to improve flood protection for commercial and multi-unit residential buildings with basements, as well as buildings with underground linkages to Mass Rapid Transit stations.

The COP has also included provisions for flood protection measures (i.e. flood barriers) that have given developers the flexibility of using a combination of structural and mechanical measures to protect their developments from floods without compromising pedestrian connectivity.

The COP can be downloaded from www.pub.gov.sg

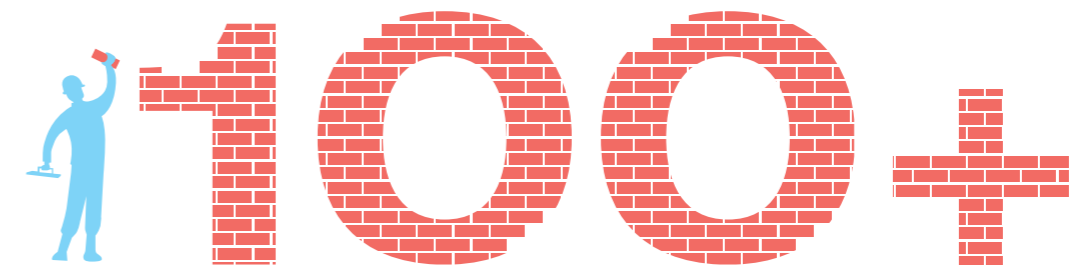


Steps and ramps are some of the ways to achieve the minimum platform levels for developments (left). Alternatively, flood barriers can be manually installed when needed (right).

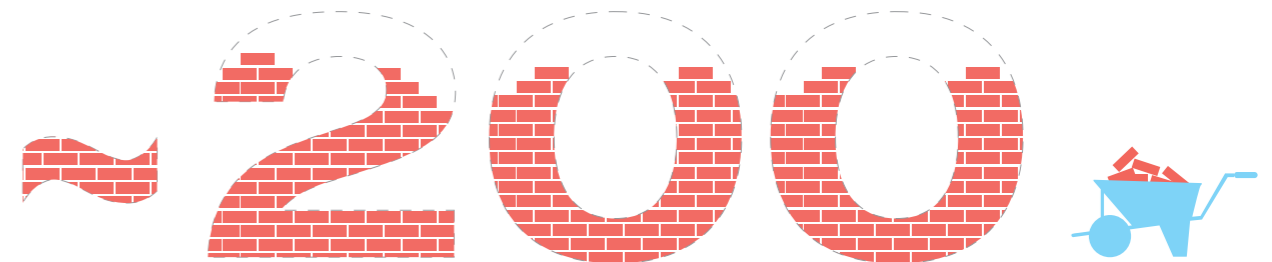


Minimum crest levels at entrances to basements can be achieved with, for example, ramps (left) or automatic flip-up flood barriers (right).

With the raised design standards for flood protection, private and public developers in Singapore must now build drains that meet the new standards. At the same time, PUB continues to work closely with various public agencies to upgrade existing drains to meet the new drainage design standards.



Drainage improvement works at more than 100 locations were completed in 2012 and 2013.



Drainage improvement works at about 200 locations are ongoing or will commence in 2014.

While some drainage improvement works take place in areas that have flooded previously, most of the drainage improvements works are being carried out either in anticipation of developments within the catchment, or to upgrade old drains to meet the raised design standards.

Most of these works will be completed by 2016, while works on some major canals, which are more complex and extensive, will be completed three to five years after the project commences. A list of ongoing and planned drainage improvement projects is provided in the Annex. As PUB continues to upgrade Singapore's drainage systems, more up-to-date information will be made available on PUB's website at www.pub.gov.sg/managingflashfloods.

PUB has also conducted reviews of major canals and rivers to identify solutions to improve flood protection for their catchments. These solutions include upgrading existing waterways, or building diversion canals and centralised detention tanks. They also include receptor measures, such as raising road and ground levels.

The subsequent chapters outline solutions identified for 12 waterways in Singapore.

Locations with Drainage Improvement Works

165 Ongoing
105 Completed in 2012 & 2013
32 Commencing in 2014



Improvements to 4 Waterways in the

Western Watershed



Bukit Timah Canal (upstream section) to Bukit Timah First Diversion Canal to Sungei Ulu Pandan



The Catchment:

The upstream section of the Bukit Timah Canal lies mainly between the busy Bukit Timah and Dunearn Roads, and is separated from the downstream section by a floodgate at Maple Avenue. It serves the Upper Bukit Timah and Bukit Timah areas, which are largely made up of residential developments and some commercial developments.

Earlier Improvements:

Over the last few decades, many residential developments have been built in the area, resulting in increased runoff into the drainage system. Because of this, plans to alleviate flood risks in the catchment were implemented, starting as early as the late 1960s.

With the completion of the Bukit Timah First Diversion Canal in the early 1970s, stormwater from the upstream part of the Bukit Timah catchment was diverted towards Sungei Ulu Pandan.

Current-day and Future Upgrades:

With higher drainage design standards, more work needs to be done to protect the catchment against higher-intensity storms.

In 2013, a section of the Bukit Timah Canal, from Jalan Kampong Chantek to Maple Avenue, was widened and deepened to meet the new design standards.

Bukit Timah Canal



Before upgrading



After upgrading

Bukit Timah First Diversion Canal



Upgrading works in progress

Current improvement works for the Bukit Timah First Diversion Canal across Ulu Pandan Road and from Bukit Timah Road to Holland Green will be completed in 2016, and the rest of the Bukit Timah First Diversion Canal will be enhanced subsequently. The remaining sections of the Bukit Timah Canal will also be enhanced in the next 5 years. PUB also has plans to upgrade Sungei Ulu Pandan. When completed, flood risks along Bukit Timah Road and the vicinity of the Clementi Road-Ulu Pandan Road junction will be reduced.

Since the Bukit Timah Canal and the Bukit Timah First Diversion Canal serve a large residential area, including the upcoming Holland Plain development, ABC Waters features will also be incorporated into the design to enhance the built environment for existing and future residents in the area.

Sungei Pandan Kechil



The Catchment:

Sungei Pandan Kechil is a 3km long concrete canal running from the Ayer Rajah Expressway (near the campus of National University of Singapore) to the sea. It serves a catchment area of around 350 hectares, comprising public and private residential estates as well as industrial and educational premises.

Current-day and Future Upgrades:

The depressed section of the Ayer Rajah Expressway (AYE) (towards East Coast Parkway) is prone to flooding when heavy rainfall coincides with high tide. To address this, PUB plans to improve Sungei Pandan Kechil to increase flood protection for the AYE. In the interim, minor drainage improvements to enhance the flow of stormwater in the canal have been implemented.



Locations with drainage improvement works

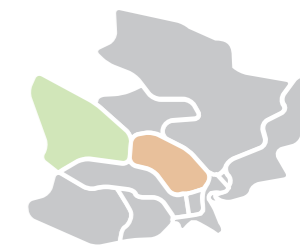


Improvements to 6 Waterways in the

Central Watershed



Bukit Timah Canal (midstream-downstream sections) to Rochor Canal



The Catchment:

The Bukit Timah Canal, downstream of Maple Avenue, connects to the Rochor Canal at Serangoon Road and flows through an area largely made up of residential and commercial developments and educational institutions, before reaching the Marina Reservoir.

Earlier Improvements:

In the late 1980s, improvements were made to the Bukit Timah Canal, including the construction of the Bukit Timah Second Diversion Canal that diverts stormwater from the middle section of the Bukit Timah Canal to the Kallang River.

Current-day and Future Upgrades:

Current improvements to the Rochor Canal from Jalan Besar to Crawford Street will be completed in 2014. Under the ABC Waters Programme, the Rochor Canal will be transformed into a river with a promenade that will be integrated with adjacent developments to create a more enjoyable experience for pedestrians walking along the river. There are also current improvements upstream, from Hampshire Road to Jalan Besar, which will be completed within the next two years. Future plans to further enhance drainage capacity include widening and deepening the remaining sections of Bukit Timah Canal.

Rochor Canal



Before upgrading

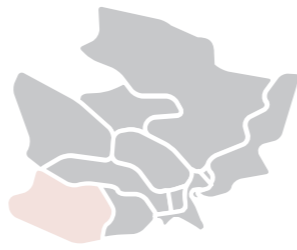


During upgrading



After upgrading (Artist's impression)

Alexandra Canal



The Catchment:

The Alexandra Canal starts at Queensway, joins the Singapore River at Kim Seng Road, and drains into the Marina Reservoir. These waterways serve the Queenstown, River Valley, Chinatown, and Boat Quay areas.

Earlier Improvements:

Drainage improvement works along Alexandra Canal were carried out in the early 2000s to increase its drainage capacity.

Current-day and Future Upgrades:

Today, the section of the Alexandra Canal between Zion Road and Kim Seng Road is undergoing reconstruction to help alleviate flooding at low-lying areas nearby (such as the area between Jervois Road and Prince Charles Crescent). Drainage improvement works on this canal will be finished in 2014, completing all the upgrading works for the Alexandra Canal to handle flows generated by storms of higher intensity.

Alexandra Canal



Before upgrading

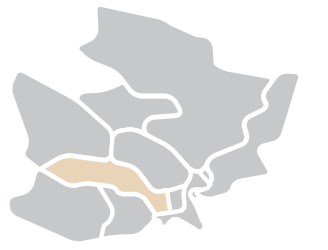


During upgrading



After upgrading (Artist's impression)

Stamford Canal



The Catchment:

The Stamford Canal serves the Holland Road, Tanglin Road, Orchard Road and downtown areas. While the upstream areas of the catchment are mostly made up of low-density residential developments, the mid and downstream part of the catchment consists of dense commercial developments.

Earlier Improvements:

The Stamford Canal was deepened and widened in phases in the 1970s and 1980s. However, with its mid and downstream sections located in densely built-up areas, further expansion is extremely challenging.

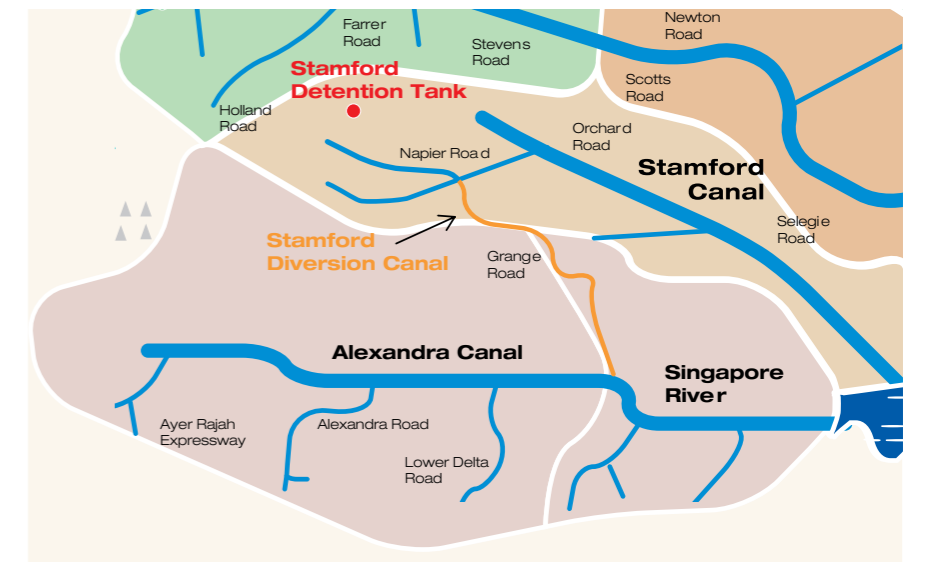
Current-day and Future Upgrades:

To minimise disruption to the public and business owners, PUB identified alternative solutions to enhance flood protection for the Stamford Canal catchment. These include a centralised detention tank and a diversion canal to channel part of the flow to the Singapore River.

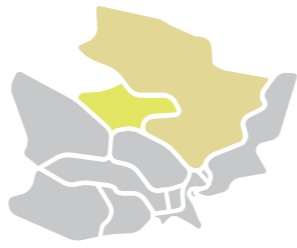
The Stamford Detention Tank is a centralised detention tank that stores excess stormwater from the drains along Holland Road. After the storm has passed, the stored runoff will be pumped back to the drains to free up storage capacity for the next storm.

The Stamford Diversion Canal diverts stormwater from the upstream portion of the Stamford Canal Catchment, which makes up about one-third of the total Stamford Canal catchment, to the Singapore River.

These two measures will divert the flow of runoff in the upstream catchment away from the mid-section of the Stamford Canal which runs through the Orchard Road shopping belt, thereby reducing flood risks in this area. Work on the detention tank and diversion canal will be completed in 2016 and 2017 respectively.



Kallang River



The Catchment:

The Kallang River, which is almost 10km long, is Singapore's longest river. It connects Lower Peirce Reservoir to Marina Reservoir.

Earlier Improvements:

In the 1990s, the mid to downstream stretch of Kallang River, from Braddell Road to Sir Arthur's Bridge, was deepened and widened. More recently, in 2012, the upstream portion between Upper Thomson Road and Bishan Road was reconstructed into a "naturalised river" with ABC Waters features and integrated with the Bishan-Ang Mo Kio Park for the enjoyment of residents in the area.

Current-day and Future Upgrades:

Plans to upgrade the Kallang River to meet new design standards include widening and deepening downstream sections, beginning with the stretch of the Kallang River downstream of the Bishan-Ang Mo Kio Park. The design of the expanded canal will also include naturalising a portion of it and creating beautiful spaces for the community to enjoy.

Kallang River



Kallang River @ Bishan-Ang Mo Kio Park, before (left) and after (right) improvement works.



The "naturalised" stretch of the Kallang River has brought people closer to water and is a popular destination for families.

Geylang River



The Catchment:

The Geylang River is about 4.2km long and serves a catchment of about 1,000 hectares, made up of residential, commercial and industrial developments, and educational institutions.

Earlier Improvements:

The Geylang River was first constructed in the 1960s and certain stretches have been deepened and widened under various development projects over the years. In 2013, a 850m stretch of the Geylang River, between Guillemard Road and Dunman Road, was upgraded and revitalised under the ABC Waters Programme.

Current-day and Future Upgrades:

The ongoing upgrading of the upstream section of the Geylang River, between Geylang Road and Paya Lebar Way, will be completed in 2015. Due to the inherently low-lying nature of some areas in the Geylang River catchment, it will be necessary to implement measures that go beyond expanding the waterway. To better protect the catchment, PUB will be encouraging the implementation of source and/or receptor measures in these areas.

Geylang River



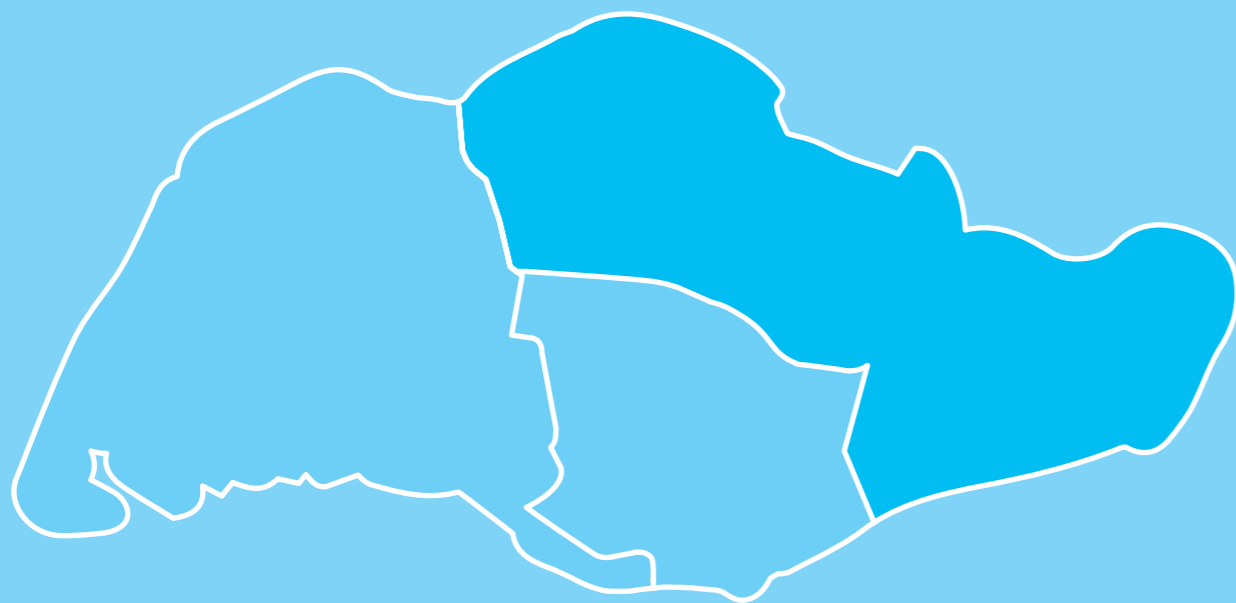
Before upgrading



After upgrading

Improvements to 2 Waterways in the

Eastern Watershed



Bedok Canal



The Catchment:

About 7km long, the Bedok Canal runs from Tampines Avenue 10 to the sea. It serves a largely developed catchment of over 2,000 hectares, comprising public and private residential estates, as well as commercial and industrial premises.

Earlier Improvements:

The upstream 1.6km section of the Bedok Canal, between Tampines Avenue 10 and Bedok Reservoir Road, was last deepened and widened in the 1990s, while the section downstream of Bedok Reservoir Road was last upgraded in the 1970s and 1980s.

Current-day and Future Upgrades:

PUB plans to expand and deepen the downstream section of the Bedok Canal further to meet the higher design standards. ABC Waters features will also be introduced at appropriate nodes to revitalise the Bedok Canal.

Improvement works at Bedok Canal will be carried out in phases, starting with the downstream sections of the Canal from Upper Changi Road East to Bedok Junction, and from East Coast Parkway to the sea. The remaining sections will be upgraded in phases over the longer term.

Bedok Canal



Existing condition of the stretch of Bedok Canal to be upgraded.

Siglap Canal



The Catchment:

The Siglap Canal is a 3.2km long concrete canal running between the Pan Island Expressway (PIE) and the sea. It serves a catchment of over 500 hectares, made up of public and private residential estates, as well as commercial and educational developments. Some parts of the catchment are relatively low-lying and remain vulnerable to flooding when heavy rain coincides with high tides. Flood risks in these low-lying areas can be mitigated when ground levels are raised during redevelopment.

Earlier Improvements:

The upstream 1.1km section of the Siglap Canal, between PIE and Changi Road, was upgraded in the 1980s while the downstream 2.1km section between Changi Road and the sea was built in the 1970s and early 1980s.

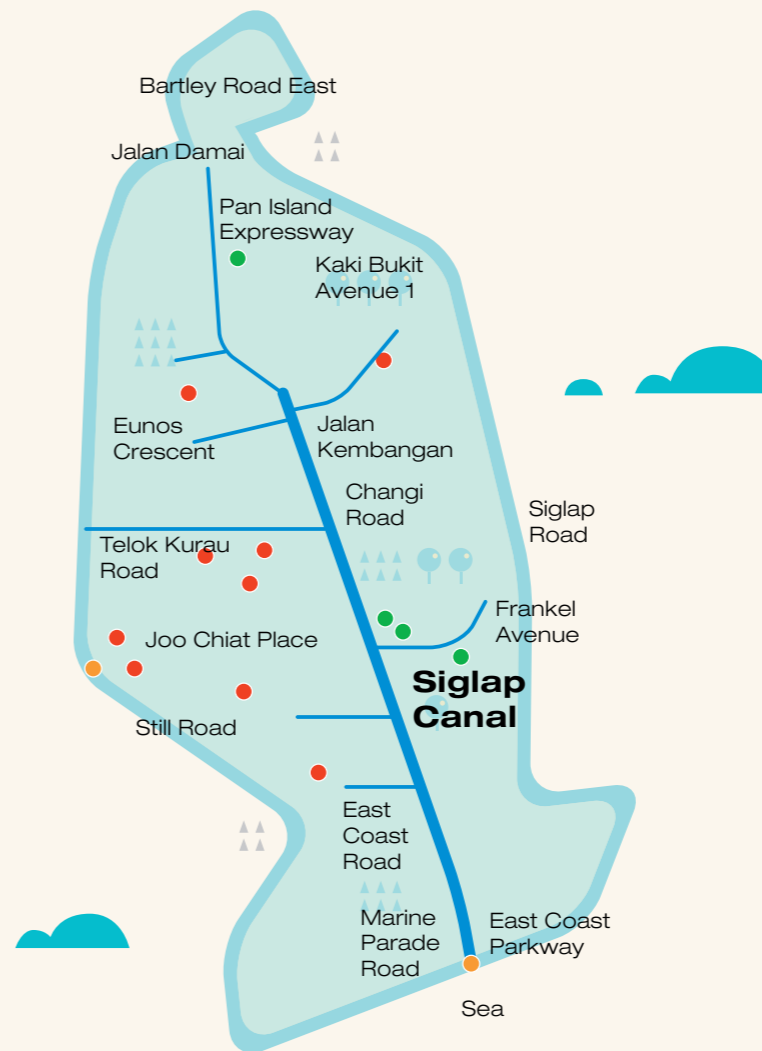
Current-day and Future Upgrades:

The Siglap Canal will be deepened and widened in phases from downstream to upstream. The first phase, involving the section between East Coast Parkway and the sea, will be implemented from 2014 to 2016 together with an ABC Waters project to provide communal spaces for East Coast Park users. Subsequent improvements, involving the rest of the Siglap Canal, will be carried out in phases thereafter, taking into consideration the rate of development in the catchment, as well as the structural conditions of the canal.

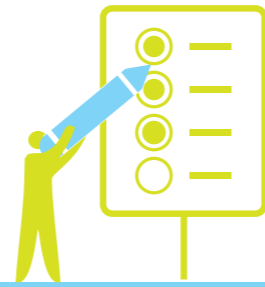
Siglap Canal



Existing condition of the stretch of Siglap Canal to be upgraded from 2014 to 2016.



Collaboration and Capacity Building



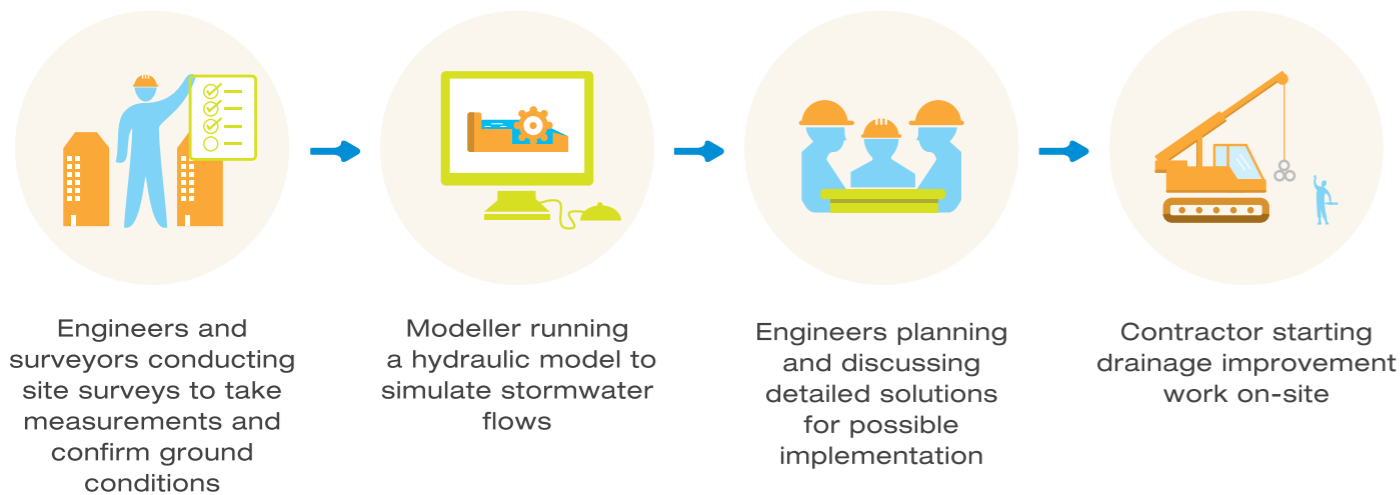
Planning & Design

Identifying drainage solutions requires detailed scientific analysis. It involves setting up hydrological and hydraulic models describing land uses in the catchment, the terrain, and the complex drainage networks. It also requires running simulations of rainfall scenarios to understand how storms affect water levels in Singapore's waterways, and flood risks on land surfaces.

Once problem areas are identified, solutions can be developed and simulated to determine their effectiveness in reducing flood risks. After the optimal solution is selected, the estimated costs, appropriate construction methods and design will be worked out before the project is implemented. Designing and implementing drainage solutions require close collaboration among planners, modellers and engineers from PUB, consultants, contractors, and other public and private stakeholders.

While PUB continues to upgrade Singapore's pathways to meet the new drainage standards, private and public developers can play their part in stormwater management too. They can do so by implementing source measures to manage peak discharge of runoff from their sites to the public drainage system, and receptor measures to protect their developments from floods.

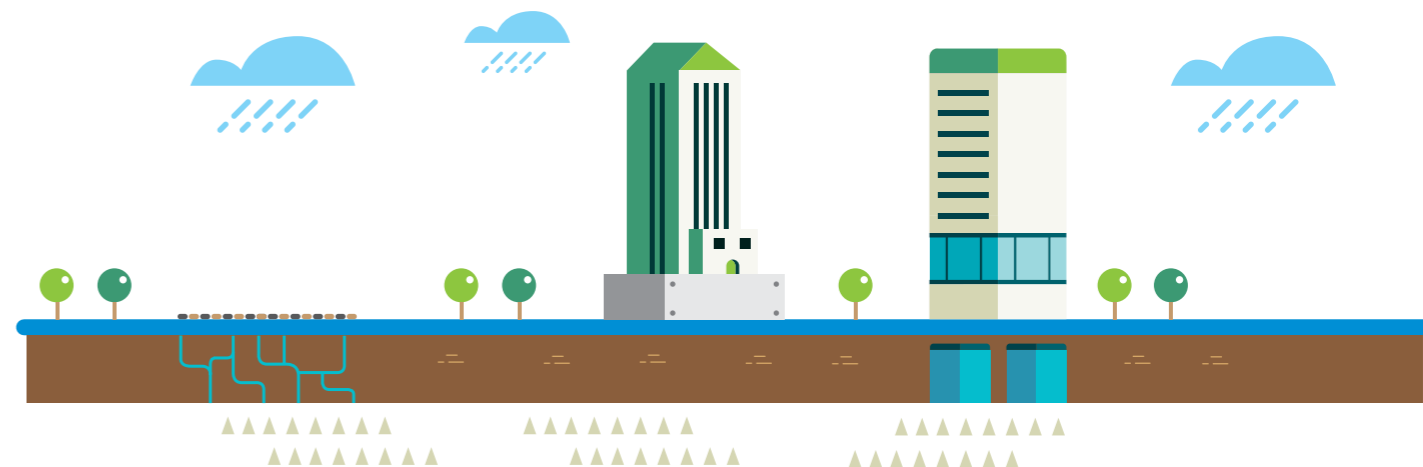
Qualified Persons (architects and engineers) and ABC Waters Professionals thus need to be equipped with the right skills to develop on-site solutions to meet these objectives. To this end, PUB works closely with organisations, such as the Institution of Engineers, Singapore (IES), the Association of Consulting Engineers, Singapore (ACES), the Singapore Institute of Architects (SIA) and the Singapore Institute of Landscape Architects (SILA), as well as public agencies, to publish handbooks and conduct seminars and training to build up the capabilities of the development community in designing stormwater drainage systems.



Technical Guides

In May 2013, PUB and IES jointly published a Handbook on Managing Urban Runoff that highlights applicable concepts and implementation strategies to facilitate the design of effective stormwater drainage systems and flood protection measures that meet the targeted needs of private developments, and the requirements specified in the COP.

In December 2013, PUB launched a Technical Guide on On-site Stormwater Detention Tank Systems to provide more in-depth and effective guidance to the industry and other agencies on the planning, design, and implementation of stormwater detention tank systems within developments.



Operations & Maintenance

While planning and design are important, proper operation and maintenance of stormwater drainage systems are just as necessary to ensure that drainage systems continue to function as designed.

PUB works closely with the Department of Public Cleanliness, set up within the National Environment Agency (NEA), on the cleaning of public drains. PUB also pays attention to preventive maintenance by carrying out functional and structural inspections on the conditions of drains, as well as conducting hydrographic surveys to determine the level of siltation within Singapore's major drains. Findings from these surveys and inspections are then acted upon to improve the conditions of all drains, canals and rivers in Singapore.

To improve drainage on roads, drop-inlet chambers are installed at regular intervals along roads to reduce the amount of debris which could clog the drains.

At the same time, private homeowners, Management Corporation Strata Titles (MCST), and managing agents must also ensure that their private drainage systems are well maintained as blockages in the internal drainage system, or failures in their pumped drainage systems, can result in flooding within developments. Developments with flood barrier systems also need to ensure their barrier systems are ready to be used and are operable at all times.

Inspecting the condition of our drains

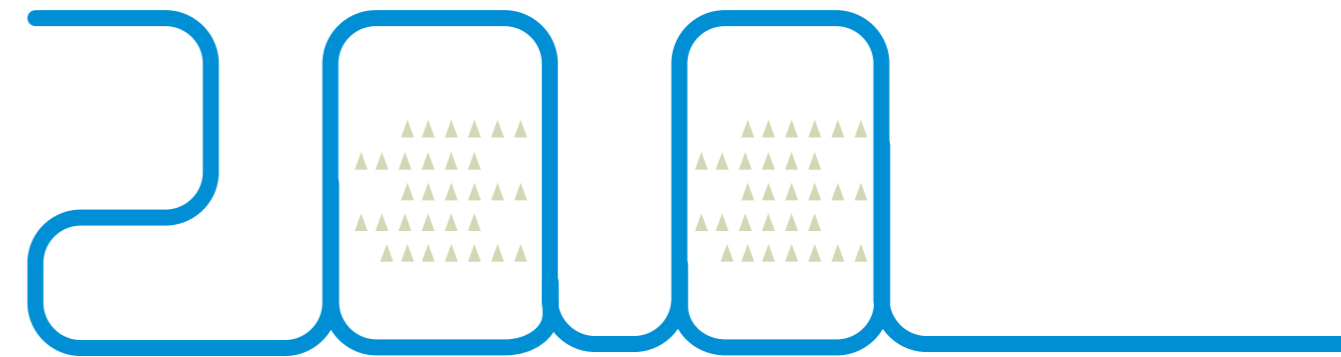


Enhancing Public Preparedness

Since 2010, PUB and NEA have developed an SMS alert system to provide early warnings of heavy rains and rising water levels in drains and canals during heavy storms. PUB will be increasing the number of water level sensors from 163 to about 200 by the end of 2014. PUB also has in place a network of 142 closed circuit television (CCTV) camera feeds for real-time monitoring of road conditions, out of which 49 CCTV feeds are available for public viewing. The public can get timely updates through PUB's website, social media platforms such as Facebook and Twitter, or via PUB's free mobile app, "MyWaters". PUB also works with the Land Transport Authority (LTA) during heavy storms to monitor road conditions, and, through electronic road signages, notify motorists of flooded roads to avoid.



The public can view information from a network of more than



water level sensors and CCTVs.

PUB's Commitment to Raising Flood Protection

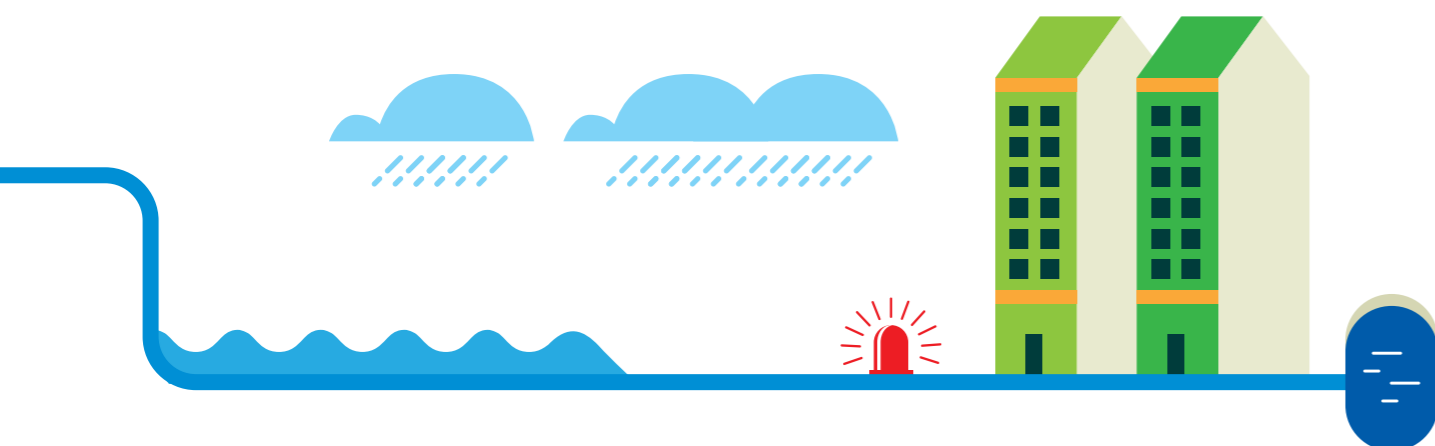
Managing flash floods in Singapore is subject to complex and dynamic factors, such as intense rainfall due to our tropical climate, the inherent low-lying nature of some areas, and the critical need to balance land needed for flood protection and for supporting the various needs of our growing population. Climate change adds further complexity to this issue as no one can say with absolute certainty how much rainfall intensities will increase and sea levels will rise.

Nevertheless, PUB has already taken measures to raise its flood protection standards in the COP in 2011 and is committed to improving flood protection for Singapore through its holistic "source-pathway-receptor" approach.

It will carry out its plans to upgrade Singapore's stormwater pathways progressively, and accelerate projects where possible. PUB will also work closely with private and public developers to implement drainage projects in anticipation of future developments. Together with the progressive catchment-wide implementation of source measures to reduce runoff from new developments and redevelopments, the entire drainage system will be able to cope better with more intense storms. Developers will also need to implement receptor solutions so that their developments will be better protected against floods.

PUB has also commissioned studies to identify and develop climate change adaptation measures to enhance flood protection. It will continue to work with public agencies and experts to identify longer-term options and innovative alternatives that will help Singapore to achieve a higher level of flood protection for the future.

With the combined efforts of PUB, its partners and the public, Singapore will be able to protect and prepare itself against future flood risks.



Annex

Locations with Drainage Improvement Works Completed in 2012 & 2013

1. Development of Kallang River @ Bishan-Ang Mo Kio Park
2. Road Raising and Drainage Works at Ah Hood Road
3. Road Raising and Drainage Works at Balmoral Road
4. Road Raising and Drainage Works at Bedok Lane
5. Road Raising and Drainage Works at Bedok Garden
6. Road Raising and Drainage Works at Lewis Road
7. Drainage Works at Ang Mo Kio Avenue 3
8. Drainage Works at Tembeling Road
9. Drainage Works at Ewe Boon Road Area
10. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Jalan Bunga Rampai
11. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Phoenix
12. Drainage Works at Mandalay Road
13. Drainage Works at Lorong 102 to 106 Changi Road
14. Drainage Works at Everitt Road North
15. Road Raising Work at Frankel Walk, Frankel Drive & Frankel Street
16. Road Raising Work at Hartley Grove
17. Drainage Works at Jalan Ma'mor
18. Drainage Works at Outram Road
19. Drainage Works at Dunearn Road/Hillcrest Road Junction
20. Drainage Works at Dorset Road/Owen Road
21. Drainage Works at Derbyshire Road
22. Drainage Works at Hillcrest Road
23. Improvement to Drains in Benoi Sector Area
24. Improvement to Bukit Timah Canal (between Jalan Kampong Chantek and Maple Avenue)
25. Drainage Works at Lengkong Dua/Lengkong Empat
26. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Gerald Drive
27. Drainage Works at Jalan Kilang Barat
28. Drainage Works at Admiralty Road West
29. Drainage Works at Dakota Crescent
30. Drainage Works at Old Airport Road
31. Drainage Works at Stadium Crescent
32. Drainage Works at Neo Pee Teck Road
33. Drainage Works at Jalan Benaan Kapal
34. Drainage Works at Indus Road
35. Drainage Works at Bishan Street 21
36. Drainage Works at West Coast Road
37. Drainage Works at Sallim Road
38. Drainage Works at Amber Road/Amber Gardens
39. Drainage Works at Stone Avenue
40. Drainage Works at Bee San Avenue
41. Drainage Works at Sago Street
42. Drainage Works at Admiralty Road
43. Drainage Works at Sembawang Road/Canberra Link
44. Drainage Works at Upper Paya Lebar Road/Lorong Ong Lye
45. Drainage Works at Queen Astrid Park
46. Drainage Works at Jalan Pari Dedap
47. Drainage Works at Clementi Avenue 4
48. Drainage Works at Raeburn Park
49. Improvement to Happy Avenue Outlet Drain
50. Drainage Works at Clementi Avenue 5
51. Drainage Works at Faber Terrace
52. Drainage Works at Pasir Ris Farmway 2
53. Drainage Works at Sungei Tengah Road
54. Drainage Works at Jalan Buroh
55. Drainage Works at Aviation Drive
56. Drainage Works at Upper Changi Road East
57. Drainage Works at Changi North Crescent
58. Drainage Works at Grove Drive
59. Drainage Works at Lorong Semangka
60. Drainage Works at Arthur Road
61. Drainage Works at Tanah Merah Besar
62. Drainage Works at King's Road
63. Drainage Works at Goodman Road
64. Drainage Works at Boscombe Road
65. Drainage Works at Broadrick Road
66. Drainage Works at Wilkinson Road
67. Drainage Works at MacPherson Road
68. Drainage Works at Jalan Wangi
69. Drainage Works at Mulberry Avenue
70. Drainage Works at Clementi Avenue 1
71. Drainage Works at Coronation Road West
72. Drainage Works at Zion Road
73. Drainage Works at Bedok South Road
74. Drainage Works at First to Sixth Lok Yang Road
75. Drainage Works at Plantation Avenue
76. Improvement to Geylang River (between Guillemard Road and Dunman Road)

77. Drainage Works at Leedon Park
78. Drainage Works at Jalan Turi
79. Drainage Works at Queen Street
80. Drainage Works at Tanjong Katong Road
81. Drainage Works at Ipoh Lane
82. Drainage Works at Sixth Avenue/Bukit Timah Road
83. Drainage Works at Benoi Road
84. Drainage Works at Gul Drive
85. Drainage Works at Clementi Avenue 2
86. Drainage Works at MacPherson Road/Jalan Belangkas
87. Drainage Works at Mayflower Way
88. Drainage Works at Hougang Street 31
89. Road Raising Works at Changi North Way
90. Drainage Works at Dunbar Walk
91. Drainage Works at Lok Yang Way
92. Drainage Works at Cardiff Grove
93. Drainage Works at Yio Chu Kang Road
94. Drainage Works at Carisbrooke Grove
95. Drainage Works at Colchester Grove
96. Drainage Works at South Bridge Road near Erskine Road
97. Drainage Works at Spottiswoode Park Road
98. Drainage Works at Chin Bee Road/International Road
99. Drainage Works at Shipyard Road
100. Drainage Works at Kay Poh Road
101. Drainage Works at Kim Tian Road
102. Drainage Works at Commonwealth Crescent
103. Drainage Works at Dover Crescent
104. Drainage Works at Chiku Road
105. Road Raising Works at Slip Road of Clementi Road/Ulu Pandan Road

Locations with Ongoing Drainage Improvement Works (in 2014)

- **Major Canals and Outlet Drains**
 1. Improvements to Outlet Drain and Culvert at Sin Ming Road and Marymount Road
 2. Improvement to Aljunied Road Outlet Drain
 3. Improvement to Alexandra Canal (between Zion Road and Kim Seng Road)
 4. Improvement to Rochor Canal (between Jalan Besar and Crawford Street)
 5. Improvement to Geylang River (between Geylang Road and Paya Lebar Way)
 6. Improvement to Bukit Timah First Diversion Canal Contract 1 (across Ulu Pandan Road)
 7. Improvement to Tanglin Halt Outlet Drain
 8. Construction of Stamford Detention Tank
 9. Improvement to Bukit Timah First Diversion Canal Contract 2 (between Bukit Timah Road and Holland Green)
 10. Improvement to Farnborough Road Outlet Drain
 11. Improvement to Sungei Pandan Kechil (between AYE and West Coast Road)
- **Estate Upgrading Programme**
 12. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Charlton Park
 13. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Sembawang Springs
 14. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Kebun Bahru Villas
 15. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Seletar
 16. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Windsor Park
 17. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Lorong Melayu
 18. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Thomson Ridge
 19. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Jalan Mata Ayer
 20. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Lucky Heights (Eastern Sector)
 21. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Lucky Heights (Western Sector)
 22. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Cambridge
 23. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Beng Wan
- 24. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – Moonstone
- 25. Improvement to Roadside Drains In Estate Upgrading Programme (EUP) – St Michael's
- **Roadside Drains**
 26. Drainage Works at Thomson View and Jalan Senang
 27. Drainage Works at Arab Street
 28. Drainage Works at Boon Lay Way/Jalan Boon Lay
 29. Drainage Works at Wan Lee Road
 30. Drainage Works at Fan Yoong Road
 31. Drainage Works at Enterprise Road
 32. Drainage Works at Tiong Bahru Road
 33. Drainage Works at Yong Siak Street
 34. Drainage Works at Nee Soon Road
 35. Drainage Works at Toh Tuck Road
 36. Drainage Works at Dunearn Road
 37. Drainage Works at Hua Guan Avenue
 38. Drainage Works at Sian Tuan Avenue
 39. Drainage Works at Binjai Park
 40. Drainage Works at Jalan Jambu Ayer
 41. Drainage Works at Upper Pickering Street
 42. Improvement to Drains in Syed Alwi Road Area
 43. Drainage Works at International Road
 44. Drainage Works at MacKenzie Road
 45. Drainage Works at Tembeling Road/Ceylon Road
 46. Drainage Works at Jalan Todak
 47. Drainage Works at Kampong Kayu Road
 48. Drainage Works at Ang Mo Kio Industrial Park 2
 49. Drainage Works at Kampong Arang Road
 50. Drainage Works at Blair Road
 51. Drainage Works at Everton Road
 52. Drainage Works at Neil Road
 53. Drainage Works at Cantonment Road
 54. Drainage Works at Amoy Street
 55. Drainage Works at McCallum Street
 56. Drainage Works at Havelock Road
 57. Drainage Works at Kranji Way
 58. Drainage Works at Jalan Lembah Kallang
 59. Drainage Works at How Sun Gardens
 60. Drainage Works at How Sun Drive
 61. Drainage Works at How Sun Avenue
 62. Drainage Works at How Sun Close

- 63. Drainage Works at How Sun Road
- 64. Drainage Works at Lorong How Sun
- 65. Drainage Works at Jalan Kesoma
- 66. Drainage Works at Upper Paya Lebar Road
- 67. Drainage Works at Jalan Seaview
- 68. Drainage Works at Bendemeer Road
- 69. Drainage Works at Haig Road
- 70. Drainage Works at Lavender Street
- 71. Drainage Works at Telok Kurau Areas
- 72. Drainage Works at Jalan Tari Zapin
- 73. Drainage Works at Dyson Road
- 74. Drainage Works at Robin Road
- 75. Drainage Works at Ang Mo Kio Avenue 5 (Tech Place II)
- 76. Drainage Works at Tay Lian Teck Road
- 77. Drainage Works at Craig Road
- 78. Drainage Works at Jalan Nuri
- 79. Drainage Works at Crescent Road
- 80. Drainage Works at Tanjong Katong Road
- 81. Drainage Works at Meyer Road/Amber Road
- 82. Drainage Works at Quemoy Road
- 83. Drainage Works at Tampines Road
- 84. Drainage Works at Chai Chee Road/Upper Changi Road Junction
- 85. Drainage Works at Guillemard Road/Guillemard Lane
- 86. Drainage Works at Lorong 1 Geylang
- 87. Drainage Works at Lorong 3 Geylang
- 88. Drainage Works at Sims Avenue
- 89. Drainage Works at Ang Mo Kio Street 22/Ang Mo Kio Street 23
- 90. Drainage Works at Eng Kong Crescent
- 91. Drainage Works at Eng Kong Place
- 92. Drainage Works at Lorong Kismis
- 93. Drainage Works at Jln Kemboja
- 94. Drainage Works at Cashew Road
- 95. Drainage Works at Commonwealth Avenue
- 96. Drainage Works at Chestnut Drive
- 97. Drainage Works at Lorong Bunga
- 98. Drainage Works at Lorong Kembang
- 99. Drainage Works at Angsana Avenue
- 100. Drainage Works at Hua Guan Crescent
- 101. Drainage Works at Geylang Area
- 102. Drainage Works at Sunset Drive

- 103. Drainage Works at Lorong 1 to Lorong 7 Realty Park
- 104. Drainage Works at Lorong N Telok Kurau
- 105. Drainage Works at St Patrick's Road
- 106. Drainage Works at Lorong Ah Soo
- 107. Drainage Works at Sims Place
- 108. Drainage Works at Mount Elizabeth
- 109. Drainage Works at Margate Road/Meyer Road
- 110. Drainage Works at Ang Mo Kio Avenue 5 (between Avenue 2 and Avenue 4)
- 111. Drainage Works at Lorong 2 Toa Payoh/Toa Payoh Central
- 112. Drainage Works at Thomson Road
- 113. Drainage Works at Stevens Close
- 114. Drainage Works at Changi Sailing Club
- 115. Drainage Works at Telok Kurau Lorong G
- 116. Drainage Works at Telok Kurau Lorong H
- 117. Drainage Works at Lorong 110 Changi
- 118. Drainage Works at Jalan Wakaff
- 119. Drainage Works at Ang Mo Kio Avenue 5 (near Ang Mo Kio Industrial Park 2)
- 120. Drainage Works at Ang Mo Kio Avenue 3/Ang Mo Kio Avenue 8 Junction
- 121. Drainage Works at Dalvey Road
- 122. Drainage Works at Linden Drive
- 123. Drainage Works at Barker Road/Dunearn Road
- 124. Drainage Works at Kingsmead Road
- 125. Drainage Works at Coronation Road
- 126. Drainage Works at Chatsworth Road
- 127. Drainage Works at Tanglin Road
- 128. Drainage Works at Lower Delta Road
- 129. Drainage Works at Jalan Bukit Merah
- 130. Drainage Works at Synagogue Street
- 131. Drainage Works at Shenton Way
- 132. Drainage Works at Hoy Fatt Road
- 133. Drainage Works at Stirling Road
- 134. Drainage Works at Mosque Street
- 135. Drainage Works at Temple Street
- 136. Drainage Works at Alexandra Road
- 137. Drainage Works at Joo Chiat Terrace
- 138. Drainage Works at Joo Chiat Place
- 139. Drainage Works at Joo Chiat Lane
- 140. Drainage Works at Mangis Road
- 141. Drainage Works at Rambutan Road
- 142. Drainage Works at Koon Seng Road

- 143. Drainage Works at Teng Tong Road
- 144. Drainage Works at Lorong Nangka
- 145. Drainage Works at Duku Road
- 146. Drainage Works at Duku Lane
- 147. Drainage Works at Duku Place
- 148. Drainage Works at Rambai Road
- 149. Drainage Works at Pulasan Road
- 150. Drainage Works at Lorong Stangee
- 151. Drainage Works at Stangee Place/Stangee Close
- 152. Drainage Works at Everitt Road
- 153. Drainage Works at Lorong 105 Changi
- 154. Drainage Works at Bukit Timah Road
- 155. Drainage Works at Chancery Lane
- 156. Drainage Works at Jalan Bukit Merah/Lower Delta Road
- 157. Drainage Works at Sunset Lane
- 158. Drainage Works at Lavender Street/Kempas Road
- 159. Drainage Works at Kee Choe Avenue
- 160. Drainage Works at Thomson Road, Norfolk Road and Keng Lee Road
- 161. Drainage Works at Lorong 2 Toa Payoh & Lorong 3 Toa Payoh
- 162. Drainage Works at Jalan Arif
- 163. Drainage Works at Poh Huat Road
- 164. Drainage Works at Upper Serangoon Road
- 165. Drainage Works at McNair Road

GLOSSARY

Locations with Drainage Improvement Works Commencing in 2014

● Major Canals and Outlet Drains

1. Construction of Stamford Diversion Canal
2. Improvement to Alexandra Canal Subsidiary Drain "F" (between Tiong Bahru Road and Havelock Road)
3. Improvement to Siglap Canal (between ECP and the sea)
4. Construction of Changi Collector Drain II
5. Improvement to Sunset Way Outlet Drain (between PIE and Sungei Ulu Pandan)
6. Improvement to Tampines Canal (between Upper Serangoon Road and Sungei Serangoon)
7. Improvement to Pioneer Sector Outlet Drain (between Gul Road and the sea)
8. Improvement to Bayshore Park Outlet Drain (between Upper East Coast Road and the sea)

● Roadside Drains

9. Drainage Works at Hillview Avenue/Jalan Remaja Junction
10. Drainage Works at Lorong 107 & 108 Changi/Langsat Road/Mangis Road
11. Drainage Works at Balestier Road/Boon Teck Road
12. Drainage Works at Novena Rise/Thomson Road
13. Drainage Works at Jalan Teliti
14. Drainage Works at Arumugam Road/Ubi Avenue 2
15. Drainage Works at Harvey Road/MacPherson Road
16. Drainage Works at Yishun Avenue 2/Yishun Avenue 5
17. Drainage Works at Nassim Road
18. Drainage Works at Somerset Road
19. Drainage Works at Clover Crescent
20. Drainage Works at Hillview Avenue (near Meralodge Condominium)
21. Drainage Works at Lermite Road/Cluny Road
22. Drainage Works at Woodlands Road/Mandai Road
23. Drainage Works at Leng Kee Road
24. Drainage Works at Telok Blangah Rise
25. Drainage Works at King's Road
26. Drainage works at Ettrick Terrace/Burnfoot Terrace/East Coast Road
27. Drainage Works at Boon Lay Way/Corporation Road
28. Drainage Works at River Valley Road/Oxley Road
29. Drainage Works at Clementi Avenue 2/Clementi Avenue 4
30. Drainage Works at Tampines Avenue 4
31. Improvement to Roadside Drains In Batch 8 of the Estate Upgrading Programme (EUP)
32. Drainage Works at Clementi Road

Active, Beautiful, Clean Waters (ABC Waters) Programme

PUB's programme that aims to improve the quality of water and life by harnessing the full potential of our waterbodies.

Active, Beautiful, Clean Waters (ABC Waters) design features

Environmentally-friendly features that detain and treat stormwater runoff using natural elements such as plants and soil. The features also enhance the surroundings with biodiversity and aesthetic value.

Bioretention basins

Vegetated land depressions designed to detain and treat stormwater runoff.

Blue network

Singapore's network of about 8,000 km of drains, canals, and rivers running across the island.

Catchment

Area draining into a waterway or reservoir.

Crest level

The bottom level of any opening (including ventilation and services openings) or summit level of a ramp or access way leading into or away from an underground or basement structure or facility, including the summit level of any exits of the underground facilities.

Detention tanks

A tank that temporarily stores stormwater to control the flow of runoff in the drains.

Development sites

The entire area of land which is slated for development.

Drop-inlet chambers

Stormwater drainage inlets into which runoff flows before flowing to the roadside drain via a connecting pipe.

Flash floods

Localised floods that typically subside within a short period of time.

Green verge

An area within the road reserve which is provided for planting greenery.

Pathways

Drains and canals through which runoff travels.

Platform level

The general ground level of a proposed development.

Receptors

Areas that can be affected by floodwaters.

Runoff

The rainwater that is not absorbed into the ground but instead flows off surfaces.

Source

Areas contributing to runoff.

Tributary

A drain, canal, or river channel that flows into a larger canal, a larger river, or a reservoir.

About PUB, Singapore's national water agency:

PUB is the water agency that manages Singapore's water supply, water catchment and used water in an integrated way.

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