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Editorial Note

South Asian Journal of Management Research (SAJMR), is a scholarly journal that publishes scientific research on the theory and practice of management. All management, computer science, environmental science related issues relating to strategy, entrepreneurship, innovation, technology, and organizations are covered by the journal, along with all business-related functional areas like accounting, finance, information systems, marketing, and operations. The research presented in these articles contributes to our understanding of critical issues and offers valuable insights for policymakers, practitioners, and researchers. Authors are invited to publish novel, original, empirical, and high quality research work pertaining to the recent developments & practices in all areas and disciplined.

Cross-functional, multidisciplinary research that reflects the diversity of the management science professions is also encouraged, the articles are generally based on the core disciplines of computer science, economics, environmental science, mathematics, psychology, sociology, and statistics. The journal's focus includes managerial issues in a variety of organizational contexts, including for profit and nonprofit businesses, organizations from the public and private sectors, and formal and informal networks of people. Theoretical, experimental (in the field or the lab), and empirical contributions are all welcome.The journal will continue to disseminate knowledge and publish high-quality research so that we may all benefit from it.

Dr. Pooja M. Patil
Editor

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C O N T E N T S

Stormwater Management with Public Amenities at East Coast Park, Singapore

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Abstract

Singapore lies about 1 degree latitude north of the equator and experiences rainfall throughout the year primarily through the Northeast monsoon from December to March and the Southwest monsoon from June to September. Due to the small landmass of about 700km^2 coupled with rapid urbanization, surface runoff from storm events is a major concern. The Public Utilities Board (PUB), a statutory board under the Ministry of Sustainability & the Environment (MSE), has developed a 3-pronged approach to manage stormwater, namely, provision of drainage in advance of urban developments, implementation of flood protection measures and continual drainage improvements to be in line with climate change needs.

This paper outlines the approach to stormwater runoff monitoring and quality management in Singapore. Together with a case study project where a traditional concretized drain system was upgraded to enhance flow capacity in view of increased runoffs and to accommodate climate change requirements, as well as inclusion of water sensitive design features. A holistic approach combines continuous monitoring of existing and upcoming changes with concurrent rehabilitation and reconstruction of drainage features. About 300 water level sensors and an SMS alert system are deployed at flood-prone drainage and canal locations to provide data real-time site conditions during heavy storms. These are backed by a comprehensive mechanism of water quality monitoring from source to tap and testing of samples collected from reservoirs, waterworks/desalination plants and distribution systems. The intent of flood management and water storage has been furthered by harnessing the assets and working with other statutory agencies to bring people closer to water thereby contributing to the Green-Blue plan whereby the country becomes a City of Gardens and Water under the Active, Beautiful, Clean Waters (ABC) programme. This work was performed by the author as part of his work at AECOM.

Keywords — stormwater management, water sensitive urban design, therapeutic plants

Introduction

This paper covers the approach to stormwater management in Singapore, and particularly a project within a coastal park area, in which the traditional concrete drainage system is combined with water sensitive urban design feature using a vegetated swale for runoff treatment. A key impact arising from climate change is the monitoring and conveyance of stormwater runoff especially in extreme events. Two-third of the limited land mass of the country is utilized as water catchment, the extensive drainage system made up of drains, rivers, stormwater collection ponds and canals of over 8000 km collects rainwater and channels to 17 reservoirs that form 1 out of the 4 parts for water supply to the residents and industries. As a water stressed country, Singapore has developed an integrated approach for stormwater management, capturing some for water-supply and storage purposes and minimizing flood risk at the same time. This is part of the Four National Taps strategy in which stormwater is collected in catchment areas and treated for use as seen in Figure 2. The other sources are as follows:

- Through water purchase agreement with Malaysia i.e., imported water.
- High-grade reclaimed water i.e., NEWater
- Sourcing from desalination plants i.e., Desalinated water.

As part of the case study shared, the existing drainage system was required to be upgraded. This was to allow for increased flows expected from upstream developments as well as need to blend with the upcoming park redevelopment to be done by Others. Development of the outfall area has been undertaken with people centric features such as seating areas and therapeutic plants to enhance stakeholder experience. Thus, by harnessing the assets and working with other statutory agencies in a collaborative manner, has brought people closer to the water thereby contributing to the Blue-Green plan whereby the country becomes a City of Gardens with urban stormwater managed as part of the Active, Beautiful, Clean Waters (ABC) programme.

Literature review

This paper is based on design approach and construction guidelines from the Singapore water industry. Concepts of water sensitive urban design, stormwater management and the like are in accordance with those set by the Public Utilities Board, the water agency.

Methodology

The national water agency of Singapore, Public Utilities Board (PUB), has developed a 3-pronged approach to manage stormwater, namely, provision of drainage in advance of urban developments, implementation of flood protection measures and continual drainage improvements to be in line with climate change needs. For Singapore, climate change has meant an increase in the frequency and intensity of rainfall events as historical data over the past 30 years has indicated. This is indicative in the increase in maximum hourly rainfall tracked by the meteorological agency which in turn has led to an increase in the average number of days with more than 70mm rain in a 1-hour period at an average rate of 1.5 days[1]. PUB has adopted the Source-Pathway-Receptor approach to tackling stormwater runoff in the country, as there is a challenge in terms of space with drains and canals adjacent to urban buildings and infrastructure. Under this methodology, which came out of the findings of the Expert Panel on Drainage Design and Flood Protection Measures[2] in 2012, a range of intervention measures were recommended to build resilience for Singapore's stormwater system. Figure 1 provides an overview of this Source-Pathway-Receptor approach.

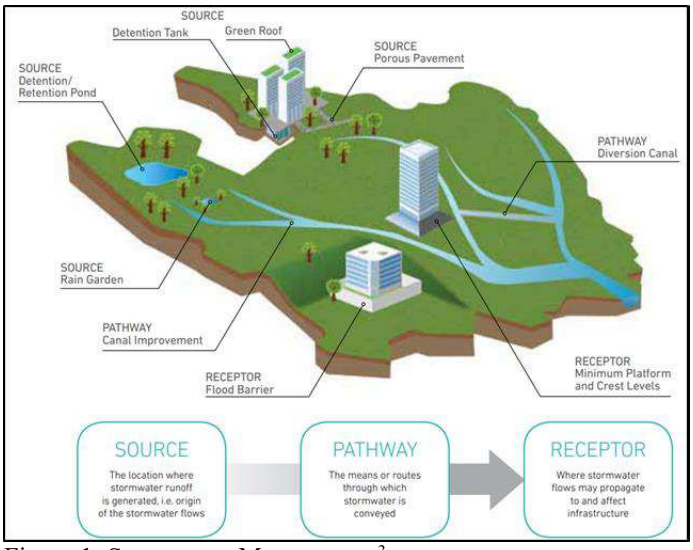


Figure 1: Stormwater Management[3]

- ***Source category***: where stormwater runoff is generated, the flow is controlled through provision of detention tanks, porous pavements, green roofs, water sensitive urban design features, retention ponds amongst others.
- ***Pathway areas***: where stormwater is conveyed through, the flow is managed by the construction and widening/deepening of drains and canals, refurbishment of older outlets, and the addition of centralized detention tanks with diversion canals to channel excess runoff.
- ***Receptor locations***: where stormwater collects and has the potential to impact life and property, the measures include raising of platform levels for structures, provision of crests at entrances, implementation of flood barriers and gates to keep out water as well as storage in reservoirs. Figure 3 provides an overview of this Source-Pathway-Receptor approach.

The intent is to get the strategy right from the start by setting out clear guidelines and enhancements for the system. Early allocation of land for drainage in newer towns and developments with advance infrastructure construction with relevant protection measures included in design ensured that the space for management of stormwater flows was reserved. Appreciating the limitation of available space for drainage systems to cater to the extreme storm events, the government has mandated since 2014, for developments greater than 0.2 hectares to implement source control measures to slow down the flow of stormwater into the public drainage system. The design standards and relevant Code of Practice (COP)[4] were refined in 2011 to consider more intense rainfall events for drainage systems and updates to the Intensity-Duration-Frequency (IDF) curves have enabled localized requirements for the curves to be considered, considering regional

variations in rainfall instead of a single curve. Since 2014 all new developments and re-developments of 0.2 hectares or more are required to implement 'source' solutions to slow down stormwater runoff entering the public drainage system such as detention tanks or rain gardens and bioretention swales ie sustainable urban drainage systems. Through the ground elevation guidance, PUB advises on the minimum platform level for structures, and this level is increased for more critical structures (e.g. tunnel entrances, mass rapid transit systems amongst others) by accommodating higher rainfall return periods i.e., 50 years, 100 years ('receptor' protection). PUB's island-wide drainage improvement programme to continually upgrade drainage infrastructure is includes cater for new developments, as well as alleviate flood risk and rehabilitate aging infrastructure. These 'pathway' improvements include widening and deepening the existing drains and canals, constructing diversion canals and catchment level detention systems. The projects are easily tracked using the interactive map available online as shown in Figure 2 below. A holistic approach combines continuous monitoring of existing and upcoming changes with concurrent rehabilitation and reconstruction.

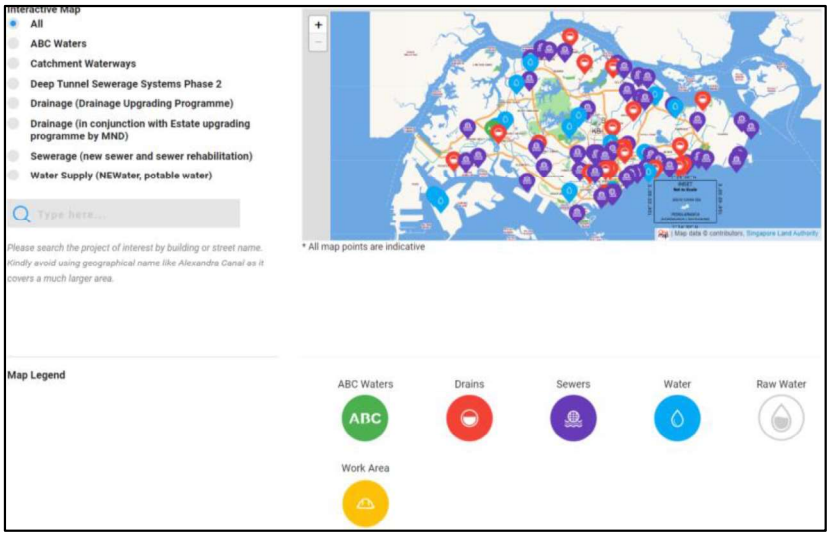


Figure 2: Locations of Project Works[7]

PUB has a dedicated Catchment and Waterways Operations System for real-time monitoring of reservoir and drainage operations to capture storm related information in a single platform (refer Figure 3). About 300 water level sensors are deployed at flood-prone drainage and canal locations to provide data real-time site conditions during heavy storms. These provide information on water levels in the drainage network which enhances the monitoring of site conditions and response time. At selected critical locations, CCTV's have also been placed to view pictures of the drainage condition, alongside the water level sensors. With a time-lag of 5 minutes, the CCTVs are useful to the Board & public to gauge the condition of stormwater drainage system in the vicinity.

An SMS alert system as shown in Figure 6 has been developed and is available for the public to subscribe for information on rising water level in their vicinity. The data is tied to the weather report through a collaborative approach between the agencies for public knowledge. It is free of charge and provides benefit to users by informing the public on potential flash floods based on the nearest water level sensor station. The details provide advice on the locations of potential flash floods to avoid as well as the time of the alert being generated. In addition, information on flash flood occurrence as well as subsidence is provided to users that also helps for traffic management. Besides, information is given out through social media as well as radio broadcasts.

These are backed by a comprehensive mechanism of water quality monitoring from source to tap and testing of samples collected from reservoirs, waterworks/desalination plants and distribution systems. Annually, almost 450,000 water quality tests are undertaken for raw and treated water through sample collection as well as online sensors and tests across 300 parameters undertaken at PUB's accredited water quality laboratories. In reservoirs and waterways, online monitoring profiler systems are placed which provide data on physical, chemical, and biological parameters. NUSwan (New Smart Water Assessment Network) are smart robots disguised as life-sized swans which collect water quality data autonomously near

water surface and provide spatial water quality data and are especially useful in reaching remote locations within the catchment locations. Complementing these is a live Fish Activity Monitoring System (FAMS) to monitor water quality in the systems by providing counts of fish via video cameras and image analysis software – abnormal water quality triggers alerts which can be then investigated further. Mobile PUB laboratories can test up to 16 parameters online using the equipment installed within the vehicle which gives efficiency in times of incidents.

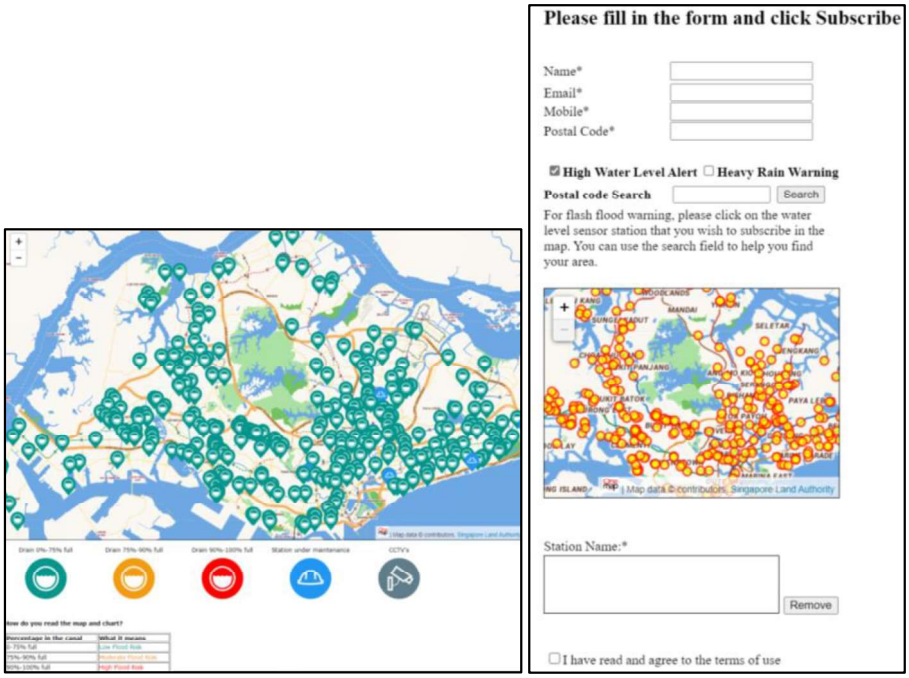


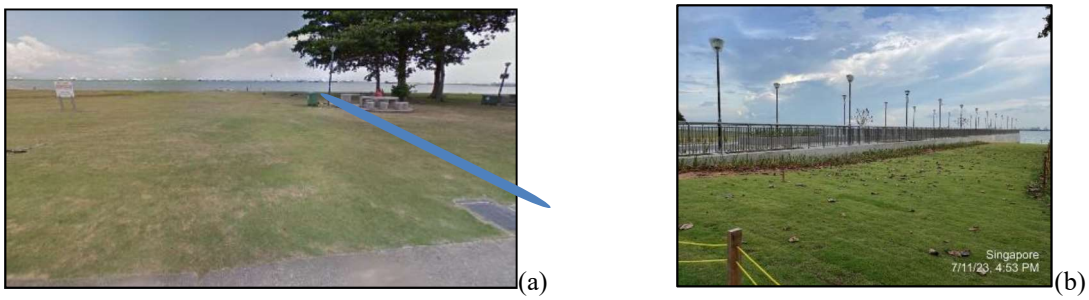
Figure 3: Water Level Sensor and Online Form for messaging service

The intent of flood management and water storage with living spaces cohabiting with public needs is to integrate the stormwater system with the surrounding environment thus creating community spaces. These include detention/retention features such as bioretention basis, vegetated swales, implementation of cleansing biotopes and sedimentation basins amongst others to slow down peak runoff as well as improve the quality of water. The primary aims are to reduce the urban load of Total Suspended Solids (TSS) by 80%, Total Nitrogen (TN) by 45% and Total Phosphorus (TP) by 45% from runoff before it reaches the waterways, which in turn contributes to cleaner systems with comparatively lower maintenance needs. To encourage structural growth of plants and concurrently to bring back wildlife, the concept of habitat cells which incorporates vegetated reinforced soil slope (VRSS) as a soil bioengineering system has been developed. In 2018, guidelines were fine-tuned based on latest research and development findings as well as case studies alongside section on construction management and maintenance of such features. The organization employing the author has been involved through a dedicated Water & Urban Development team to support statutory boards as well as private sector developers in drainage and catchment projects, with focus growing on ABC aspects in renewal projects. The government has initiated and encouraged a certification of projects and qualification for professionals who can contribute to such projects through the ABC Waters Professional (ABC WP) programme[5] which complements the traditional Professional / Chartered Engineer (PEng / CEng) programs.

Case Study - Parbury Outlet Drain with ABC (Blue-Green) Features.

This section provides an overview of a case study project to redevelop an outlet drain at Parbury site at East Coast Park (hereafter referred to as 'ECP') with ABC enhancements[6] at connecting to the sea is shared to demonstrate the change that can come from a well thought of approach for redevelopment of stormwater management projects. It was carried out as part of the upgradation of an existing concrete drain to increase capacity at Parbury location within the East Coast Park in the south-east part of Singapore. The site is close to carpark F2 and the almost 300m long drainage improvement works were carried in coordination with multiple agencies who were planning to upgrade the surrounding vicinities as part of regeneration of the

park. In anticipation of upstream upcoming developments and periodic upgrading of outlet drain, a major bottleneck for conveyance was resolved at the outlet by removal of the existing pipe drain with box structure that doubled up as a space for public to access and enjoy (refer Figure 4 and 5).

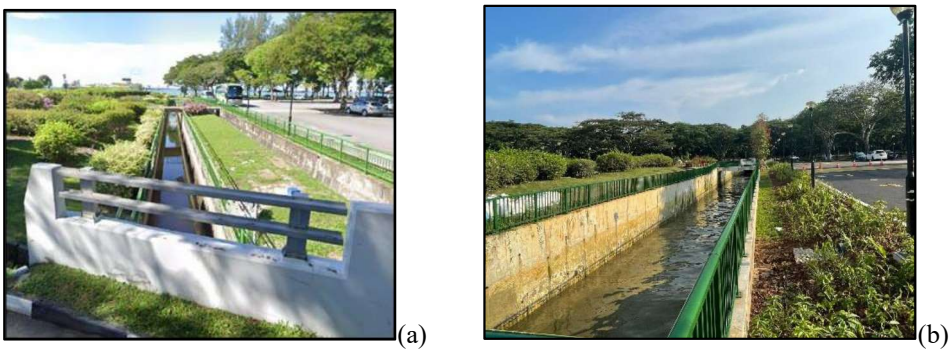


(a) (b)

Figure 4: Replacement of concealed pipe outfall drain marked in blue.
(a) with box structure and planting on sides (b)

Figure 5: Public amenities provision as seating area, lighting, planter boxes
(proposed and actual)

A short section of surface flow area beside the existing drain was converted into a vegetated swale (refer Figure 6) to provide cleansing action for pollutants from the adjacent car-park area. There being space constraint, the provision is expected to have limited improvements with primary function envisaged for Total Suspended Solids reduction.



(a) (b)

Figure 6: Provision of vegetated swale in lieu of overland flow
(a): original condition, (b): implemented swale.

A detailed discussion with the National Parks Board (NParks), which maintains the park space beyond the dedicated drainage reserve, was conducted to ensure that the planting palette for trees and shrubs aligns with the overall redevelopment intent. The specific greenery provision is meant to blend with the vision to develop this part of the overall park as a therapeutic zone (refer Figure 7). The coordination is part of the collaboration between PUB and NParks which have overlapping and adjacent developments and land ownership.

Figure 7: Planting palette implemented for Parbury outlet drain[8]

Conclusion

This project enhanced the flow capacity of the drainage system by 50% and is expected to increase visitor numbers in this part of the park with the public convenience features provided. Besides stormwater considerations, the structural detailing has been undertaken to cater for future increase in ground levels accounting for future sea level rise to accommodate impacts from climate change as well.

With updated design guidelines, availability of data and collaboration with agencies, stormwater runoff can be managed effectively as well as co-develop as recreational spaces for public. Stormwater management is an ongoing activity which will get more complicated with changes in climate that impact directly on the design and maintenance of the waterways as well as the quantity and quality of runoff.

Detailed clarity on planning requirements by a collaborative approach from government agencies can substantially improve the deliverables of a project, especially considering the new-found appreciation among the populace for green public spaces post-COVID. A balanced approach of renewal in the form of water sensitive details coupled with improvement of drainage measures as part of stormwater management projects and coordinated with other stakeholders to regenerate an area will provide for a better future for people and property.

Acknowledgement

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