Sewerage and Flood Protection
DRAINAGE SERVICES 1841-2018

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It gives me great pleasure to congratulate the Drainage Services Department (DSD) on its 30th anniversary.

Established in 1989, the DSD is committed to providing professional wastewater and stormwater drainage services, striving to create a better living environment for the community. Over the past three decades, the DSD has adopted multi-pronged strategies to prepare for the challenges ahead. By undertaking infrastructure projects with careful planning and advanced technologies, the DSD has substantially enhanced Hong Kong’s flood prevention capacity and helped reduce pollution, contributing significantly to improving our environment.

Hong Kong’s complex topography and dense population, coupled with the increasing occurrence of extreme weather conditions, pose great challenges to the DSD’s flood prevention work. Thanks to the hard work of colleagues, the DSD has developed a comprehensive flood prevention strategy for Hong Kong and carried out effective flood prevention works despite all difficulties. The DSD also launched the Harbour Area Treatment Scheme (HATS) in the 1990s, which is by far the largest sewerage infrastructure project in Hong Kong. Since the implementation of the HATS, we have seen marked improvement in the water quality of the Victoria Harbour. In June 2018, the HATS was awarded the 15th Tien-yow Jeme Civil Engineering Prize under the Municipal Engineering Category in recognition of its outstanding achievements in technological innovation and application.

Innovation and technology, which tops the policy agenda of the current-term Government, is also the key to the DSD’s success over the years. Apart from developing new technologies on its own, the DSD has conducted research projects in collaboration with local research experts to meet the city’s development needs. In recent years, the DSD has put into practice new concepts of sustainable development, such as “sponge city” and “blue-green infrastructure”. It has incorporated more environmentally friendly and green elements into its facilities, enhancing our city’s flood resilience while conserving the ecological environment. All these demonstrate the DSD’s innovative spirit and dedication to providing quality services for the community.

I would like to extend my heartfelt gratitude to all colleagues in the DSD for their unwavering commitment to serving the public with professionalism over the years. Looking ahead, I am sure that the DSD will continue to strive for excellence and innovation in providing world-class wastewater and stormwater drainage services for the public, promoting the sustainable development of Hong Kong and making Hong Kong a more liveable city.

(Mrs Carrie Lam)
Chief Executive
Hong Kong Special Administrative Region
The Drainage Services Department (DSD) has been committed to providing world-class sewage treatment and stormwater drainage services in Hong Kong. This year marks the 30th anniversary of the DSD. To commemorate this historical moment, we have published this monograph which not only provides an opportunity to learn from the changes and challenges in the past, but also sets out a vision of the future for passing on our mission. With the inclusion of extracts from the 20th anniversary monograph “Sewerage and Flood Protection — Drainage Services 1841–2008” and a newly-written account of DSD’s development and achievements in the past decade, this monograph records a history of drainage services in Hong Kong for well more than a century (i.e. from 1841 to 2018), which has been closely associated with the development of Hong Kong society. Cherishing good memories of the bygone era, I would like to take this opportunity to extend my heartfelt gratitude to each and every person who has engaged in and contributed to the development of our drainage services.

In the past 30 years, the DSD has made steady strides forward, striving to raise sewage treatment and flood prevention standards in Hong Kong. During the period, the DSD successfully completed numerous challenging flood prevention and sewage treatment projects, such as mega-size stormwater tunnels, underground stormwater storage schemes, deep sewage tunnel systems and large-scale sewage treatment works. Besides, the DSD spared no effort to promote the “development of blue-green infrastructure” and “revitalisation of water bodies”, bringing Hong Kong’s flood protection and sewage treatment systems up to world-class standard. Meanwhile, we collaborated with the Shenzhen Municipal Government to regulate the Shenzhen River for the purpose of turning Shenzhen River into a quality water environment with multi-functions pertaining to flood relief, navigation and ecology.

The results of our work to date have indeed been encouraging. We have been honoured with various awards for our projects. The credit must go to all of our colleagues, who are committed to serving the community with dedication and professionalism, upholding our motto “Do it from the Heart”. With the DSD’s major projects completed and put into operation one after another in recent years, achievements have been secured in flood protection and sewerage treatment. Meanwhile, we shall stay alert at all times to the challenges resulting from climate change, seize the opportunities arising from the overall development of Hong Kong and collaborate with various departments and professionals, with a view to developing Hong Kong into a livable, green and low-carbon smart city.

Looking to the future, we will unswervingly uphold our vision, mission and values, maintain our traditions, and encourage continuous innovation to keep up with the times. Further, we will develop and introduce new technologies and ideas to improve our services, as well as keeping on shouldering the responsibility for protecting the pleasant environment in Hong Kong.

Mr Kelvin K W LO  
Director of Drainage Services
Part I
Sanitation and Drainage 1841-1971
Chapter 1: Early Development of Hong Kong and the Advent of the Bubonic Plague 1841–1894

Sanitation and the City of Victoria

When Hong Kong Island came under British occupation in 1841, it was a small island with no modern buildings. Modern infrastructure such as roads and drainage systems were virtually non-existent. Immediately then, plans were made to construct accommodations for the new British settlement, and in August 1843, Sir Henry Pottinger, the first Governor of Hong Kong, wrote to Britain to seek approval for building the City of Victoria.

The layout of the settlement as conceived by the Governor was entirely different from that planned by the War Office. After the signing of Treaty of Nanking in 1842, the War Office sent Major Aldrich to Hong Kong to prepare a scheme for housing the garrisons and other military personnel. For this purpose Aldrich proposed a grandiose plan which would allow the military presence not only in the existing military area but also in much of the land west of present-day Garden Road where government offices and the Zoological and Botanical Gardens now stand. The Governor strongly opposed to this plan. He explained that it would make the face of the Island a mere military garrison, not a vast emporium of commerce and wealth. While he was willing to give the military all the land they needed at West Point, he wished to cut down the military area in Central and reserve the land for community development.
The question was left undecided until Pottinger ceased to be Governor. Eventually, it was decided that a large part of the west side of the nullah, now Garden Road, should be saved for civilian purposes. The town which was called the City of Victoria, hitherto referred to as Queen’s Town, was in fact today’s Central District, and its boundaries did not cover present-day Wan Chai and Sai Ying Pun.

In 1843, the post of Surveyor General was created to empower a high-ranking government official to oversee and inspect the planning and construction of the City of Victoria. It was in this period that the construction of Queen’s Road began, with planning already commenced in 1841. Queen’s Road Central was completed in 1842, and by 1844 the other two sections, Queen’s Road East and Queen’s Road West, were formally in use.

From then on, under the direction of the Surveyor General’s Office, a network of drainage systems began to take shape in Hong Kong. Wong Nai Chung Valley was drained in 1845. Other constructions also took place, for example the street sewers and drainage nullahs in the City of Victoria, the first Praya reclamation scheme of 1851 which led to the construction of more drainage and sewerage systems, and the Bowrington Canal, 600 feet long and 90 feet wide, were all constructed in 1860.
The drainage services mentioned above were built largely as a result of recommendations made by the Committee of Public Health and Cleanliness which was established in August 1843. The Committee had five members. They were Dr. Peter Young and William Scott, who were unofficial members, and three government officials — Land Officer A. T. Gordon, Assistant Magistrate Charles B. Hillier and Acting Colonial Surgeon Charles A. Winche.

The major function of the Committee was to advise the Governor on strategies for improving the sanitary conditions in Hong Kong. The proposals put forward by the Committee included, inter alia, the setting up of a drainage system, the maintenance of cleanliness in the streets and the drawing up of a sanitary code for all residents. For the first time in the history of Hong Kong, the question of drainage services was linked to the question of sanitation in the territory.
The Praya along Connaught Road near Pedder Street junction. At low tides, sewage outfalls were exposed above water mark and gave out offensive stench.

The roots of the earliest complaints against Hong Kong’s insanitary and unhealthy living conditions can be traced to the Tai Ping Shan District of the City of Victoria, a district inhabited by poor Chinese labourers. In 1854, Dr. J. Carroll Demster, the then Colonial Surgeon, mentioned in his annual report to the Government his regret concerning Hong Kong’s filthy and unhealthy living conditions:

I shall avert to topics which I considered to be of very great and vital importance, namely, sewerage, drainage, ventilation, and cleanliness; … I must express my regret that Hong Kong should present so much filth and so many nuisances.

In the same report, he went on to say:

The lanes (certainly not streets) are in most objectionable state, containing almost invariably cowsheds, pigsties, stagnant pools, the receptacles of every kind of filth, all which nuisances have remained unheeded for a considerable time. In this district are two large open drains, which are at all times most offensive. These drains receive all the refuse of the district through which they pass, and being open through most of their course (excepting when they cross a road) filth of all sorts is thrown into them, and necessarily evaporates deleterious gases from their entire surface … The great want of privies and suitable depots for dirt is observable everywhere the native population reside.

Overlooking the Happy Valley racecourse from Morrison Hill. British soldiers died of tropical diseases were buried at the nearby cemeteries. The paddy fields in the valley were filled up to curb mosquito breeding in 1845. Wong Nai Chung River was diverted to Bowrington Canal.

Most British soldiers died of tropical diseases had their funeral service at this chapel inside the Happy Valley cemeteries.
He continued further by saying, “Nothing can be more offensive than the laying out to dry of large quantities of manure on small patches of ground in the rear of this locality…” He also criticised the quality of the local dwellings as not meeting the sanitary requirements: “That the dwellings of the natives are faulty in construction, being erected apparently with the view of having the greatest number in the smallest possible space, and without any regard to ventilation and drainage”.

He concluded that the insanitary conditions in the district would eventually lead to the outburst of disease:

The absence of sanitary measures in Hong Kong leads to the outburst and dissemination of disease. It is well known that damp and dirt, nuisance of all kinds, and particularly animal and vegetable matters in a state of decomposition, are circumstances that favour the propagation of disease; whatever renders the atmosphere impure impairs the health and predisposes the body to disease, and when numbers of the sick are crowded together in close, dirty and unventilated rooms, disease spreads with virulence and malignity.

At the end of the report Dr. Demster made one recommendation for the situation, saying: “I am, therefore, of opinion that Victoria is in need of drainage and sewerage, of better paving and scavenging”.

Dr. Demster’s opinions were apparently not taken seriously by the authorities, for his successor, Dr. I Murray, had to sound the same warnings by echoing his predecessor’s thoughts. In 1858 these warnings were reiterated by Dr. T. A. Chaldecott, the then Acting Colonial Surgeon:

That the sanitary condition of this colony stands in great need of improvement has been more than once pointed out in previous Colonial Surgeon’s Reports; but I am moved to insist upon this necessity the more pressingly in the present report, in consequence of the colony having been visited … [by] ‘preventable diseases’, … most fearfully aggravated and extended by neglect of proper drainage and cleanliness, the evil results of which must act with double force in a community so crowded together as that of Victoria, and in a climate so favourable to the decomposition of animal and vegetable products.
In 1874 Dr. Phineas Ayres succeeded Dr. I. Murray as Colonial Surgeon and in his annual report he also fired accusations against Hong Kong’s insanitary and unhealthy conditions, in very much the same way as Dr. Demster did twenty years ago:

*Houses were occupied by five to ten families … The construction of this class of house is against every sanitary rule with no yard and no ventilation; the ground floor is of mud or stone or tiles; the floors of upper storey are so thin that they could not be washed without the water dripping through to the room below. Three to eight families live in one room, each paying one and a half or two dollars a month. Pigs are universally kept in kitchens, or upstairs, and a very favourite place for them is under the bed; often a room is divided into four families, each with its pigs.*

Surprisingly, these insanitary conditions were seldom mentioned in the Hong Kong Annual Administration Reports submitted by the Hong Kong Government to the British Government. For instance, the 1859 Report contained the statement “There is a manifest improvement, year by year, in the sanitary condition of Hong Kong”. The Reports of the following years continued to make similar statements: in 1862, the health condition was generally satisfactory; the year of 1864 continued to be healthy; in 1870 the government continued to record the improvement of health in Hong Kong; the report of health in 1874 was very satisfactory while sanitary improvements in 1875 had been progressing.

In 1880 Sir John Pope-Hennessy, then Governor of Hong Kong, defended the sanitary condition of the Chinese quarters when he criticised the Ordinance for Buildings and Nuisances for being unrealistically harsh on Chinese living habits:

*The Ordinance … gives the local Government complete control over the construction of all buildings in the Colony. This law contains a series of minute and stringent rules, with adequate penalties, framed to prevent the construction of any houses that are built on what was then supposed to be the best sanitary principles. The Ordinance was evidently copied almost entirely from certain Sanitary and Building Acts in force, at that time in England. I cannot find that the Chinese house-holders were in any way consulted on the subject when it was being framed and passed, and the result is that some of its provisions are entirely unsuited to this colony and would do more harm than good if enforced.*
Hennessy pointed out in particular one clause that required a sufficient water-closet or privy. He said that the system of water-closets and house privies was a system “quite out of place in a tropical Colony, and not in accordance with the customs of the Chinese people”. He opined that the Chinese house-bucket system was better than a system of water-closets and house privies.

He sympathised with the Chinese inhabitants who complained that Surveyor Generals and Colonial Surgeons in the past had tried to force on them Western sanitary science that was not based on sound principles. To support his own views, he quoted the following passage from ‘The Disease of China’, a paper written by Dr. Dudgeon of Peking, one of the most experienced medical practitioners in China:

*Much that is recommended at home in the way of ventilation, water supply, and disinfection of privies is rendered in China unnecessary. … The industrious and frugal habits of the Chinese, and even their very poverty, thus work to their advantage (all sanitary measures more than repay their cost), for it compels them to utilise all excrementitious matter. … The private privies, which are out of doors, are visited daily by these manure collectors, and so great is the demand for it, that no payment is made to these scavengers. … The healthiness of our foreign settlements in China is, in a great measure, owing to the absence of water closets in the dwelling houses, which in Europe are a fruitful source of disease. … China is par excellence, the country of bad smells, and yet, as we have seen, the people do not seem to suffer from them.*

Hennessy then turned to officials of the Hong Kong Government:

*Those officials advocate an underground network of drains and sewers in Hong Kong, and are compelling the Chinese to build their houses and to modify their domestic arrangements in accordance with ‘the methods of western sanitary science.’ I have pointed out to them that the methods of western sanitary science of a few years ago, which they are so fond of quoting, are no longer considered infallible; and that some public health officers in England seem even disposed to take a lesson from the experience of China, and to adopt views similar to those of Dr. Dudgeon. I have reminded them that the only fatal cases of typhoid fever that occurred in Hong Kong since my arrival have been in European built houses with water-closets, and that the Chinese residents do not appear to suffer from typhoid fever or diphtheria.*
He then commented further on the question of bathing, and concluded that the Chinese were clean people:

No doubt certain Europeans in Hong Kong, as well as in California and Australia, denounced the Chinese as a dirty race, who never bathe, but the fact is that, in this important sanitary practice, they are clean people, and even in the lower classes set a good example, which our soldiers and sailors here would do well to follow.

As to the question of public health, Hennessy shared the views of his predecessors without taking much heed of the reports submitted by the Colonial Surgeons. He cited the years from 1874 to 1876 as example:

During those very years, 1874, 1875, 1876, complaints were made of the alarming consequences to the public health from the influx of Chinese into the Colony and the way they were living so closely packed. ... I was able to point out that whilst the reports in question foretold immediate outbreaks of typhoid fever, cholera, and smallpox amongst this increasing Chinese community, Sir Arthur Kennedy and Mr. Austin had carefully tested those assertions and found them entirely inconsistent with the annual statistics of sickness and mortality.

A great rainstorm of the century occurred on 30 May 1889, one hundred years before DSD was established. A total rainfall of 697.1mm was recorded in 24 hours, amounting to one third of the yearly rainfall. This picture shows the storm damage near Ice House Street. The severe rainstorm had worsened the already poor sanitary conditions.

Wellington Street at end of 1890s. Housing and sanitary problems were aggravated by influx of people immigrated from the Mainland.
Judging the Colonial Surgeons’ reports from a political angle, Hennessy believed that they were drafted without adequate consultation and were written with impractical imagination. He stressed this point further by mentioning the following case:

One of the Government officials had submitted certain rules respecting Chinese burials and graves which were about to be carried into effect. … I found that they had been devised apparently for sanitary purposes only. I could not avoid seeing that the rules did not show much respect for the customs or prejudices of the natives on the subject of graves. … Those rules had been drawn up by three European gentlemen. The Chinese community had not been consulted and knew nothing of the sweeping reform that was impending.

Despite the sympathy of Governor Hennessy, however, the insanitary and unhealthy conditions in the Tai Ping Shan District were factual beyond rebuttal. In addition, the rate of death and sickness among the British troops remained high, reminding people vividly of the gloomy picture of the 1843 epidemic infection. Sixty men in ten weeks from one regiment stationed at West Point were killed that year. The death rate of 1848 among European troops rose to 20.43% while that of the local population was only 1.78% and 0.65% in 1849. Observations such as these nurtured dissatisfaction among the British troops and made them hate the insanitary environment in Hong Kong.

In response to these sentiments, the British Government was strongly urged to take effective steps to improve Hong Kong’s sanitary conditions. The Secretary of State for the Colonies eventually commissioned Osbert Chadwick, a former Royal Engineer, to study the situation and make recommendations for improvement.
Chadwick's reports on the sanitary conditions of Hong Kong

Over a period of twenty-one years, Sir Osbert Chadwick paid three visits to Hong Kong: in 1881, 1892 and 1902. One major impact of these visits was the establishment of the Sanitary Board. The other impacts were concerning drainage services.

In a report submitted to the authorities in 1882, Chadwick addressed the problem of drainage services by referring first to the housing conditions in Tai Ping Shan District. He commented that typical Chinese houses in Hong Kong were essentially different from houses in Mainland China. If the land was flat, the houses were often built back-to-back, with no lane or space between them. If the ground was on a slanting slope, there would be a lane or a gully at the back of the houses, usually not more than 5 feet wide.

In back-to-back houses the ground floor was ventilated and the smoke escaped by a “smoke-hole” on the first floor, usually about 4 or 5 square feet. There were similar smoke-holes on the upper floors and on the roof. If there were no smoke-holes, the smoke would escape by the windows, “blackening the walls in a most unsightly manner”.

He then went on to describe the domestic drainage and sewerage system of these houses. To carry off dirty water, a drain led from a sink in the cookhouse to the public sewer, and arrangement of these house drains varied considerably. Sometimes each house had an independent drain, running out under the floor to the street in front. More often the drain ran from cookhouse to cookhouse, under the parting walls of adjacent tenements, till it reached the end of the row, or was brought out under someone's house to the front.

Style of Chinese houses Chadwick described. Houses built on flat land were back-to-back tenements with no lane or space between. For houses built on sloping ground, there would be a lane or a gully at the back of the houses.

Drawings of Chinese houses by Chadwick. On account of high price of land and great cost of land levelling, the style of buildings were developed upon the necessity for economy of space.
What had happened to the public drainage and sewerage systems? Apparently, public sewers had been constructed, but they were used more as drains to carry off stormwater than as sewers to remove from habitats the foul waters usually known as sewage. Neither their form nor their construction was considered desirable for the latter purpose. They did not appear to have been made on any general plan, but constructed from time to time as the necessity arose. Several of the large sewers ran under private property apparently without any need. No manhole existed. When a sewer had to be examined, the street had to be broken up.

There were no special ventilating openings either at the inlets or outlets, nor did the necessity for ventilation appear to have been recognised. The drains which received the waters of ravines above the town had openings at their upper intakes, so that they were to some extent ventilated. When the drains did not run up to the hillside there was no proper ventilation.

The general principles guiding the construction of both house drains and sewers were, firstly, that they must have sufficient fall. This would produce a current in them that was sufficient to prevent disposition of suspended matter. Secondly, both sewers and drains should be ventilated so as to prevent accumulation of foul gas inside. House drains also needed to be trapped and disconnected, so that gas could not enter the dwelling through them.

The sewers above Queen’s Road, owing to the very steep falls they possessed, were usually quite free from sediment. A considerable amount of sand and sludge was deposited in the more level portions of the sewers running from Queen’s Road across the low-lying district of Sheung Wan to the sea. Here the drains must be opened and cleaned annually or biennially.

During heavy rains, a large amount of sand and mud was brought down from the hillsides above the town and deposited in the harbour at the mouth of the sewer. Usually there were no catch-pits at the head of the sewer to receive the water from the hillsides to mitigate this evil.
Chadwick had much more to say on the question of street sewers in connection with the sanitary conditions of Hong Kong. He pointed out that while the sewers ran through the Praya wall and that their outfalls led straight into the harbour, the tide current was weak at all times. No measures had been considered to extend the sewers to below the low-water mark so that when the sewage was discharged there it could meet the tidal current. Hence on a warm still day, at low tide, the stench along the Praya was most offensive. At low tide also, the large outlets of the sewer were uncovered and exposed to the full force of the northerly winds. At such times it was possible for the pressure of the wind to force the sewer gas to rise and make its escape through the gully-holes and the un-trapped house drains.

The first step towards using interception was determining the position of the outfall. To do this, engineers had to study carefully the tidal currents of the harbour. The direction of the currents at different states and points of the tide points must be carefully observed.

The remedy was to construct an intercepting sewer to collect and convey the sewage to some distant point for discharge without causing inconvenience. The first step was determining the location of the outfall for discharge. As the tides differed greatly in their character during summer and winter, it was necessary to study the tidal current in the harbour at different times of the day and different seasons of the year. Experiments of such nature had in fact been conducted. Observations yielded the following information, which could be useful later:

1) No material benefits would ensue from the discharge of sewage collected by an intercepting sewer at its outfall anywhere in the town.

2) There was little hope of finding a satisfactory outlet towards the eastern end of Hong Kong Island.

3) Apparently, the most desirable position for the outfall was in Sulphur Channel which divided Green Island from Hong Kong Island.
Until the location of the outfall was finally determined, it was premature to discuss the construction of an intercepting sewer. However, many other improvements could be made for the general health of the community.

Because of the small level-difference between the sewers and the sea, there was insufficient gravity pull to convey all the sewage into the sea. It was, however, possible to intercept the sewage from the greater part of the town, i.e. the area above Queen's Road, and let it be conveyed by gravity to the sea for discharge. The remaining small quantity of sewage below Queen's Road must be either pumped into an intercepting sewer or discharged into the harbour by improved outlets, thereby minimising the nuisance.

Should the existing sewers continue to convey both sewage and stormwater, only one minor improvement would be required – the installation of a weir. When the flow quantity was increased by heavy rains, the flow would overtop the weir and convey the sewage to the harbour. The effluent would thus be diluted and become less offensive.
To solve the problem of heavy deposition of silt in the sewers, catch-pits (now called desilting openings) should be provided at the upstream sections of the sewers. Silt deposited could then be easily removed. These catch-pits could be formed by constructing masonry dams above the sewers.

Another problem receiving increasing attention was the unpleasant smell caused by the ventilation of sewers. The cause of the nuisance could be traced back to the improper design of house drainage. Owing to prolonged deposition and stagnation of sewage in the house drains, the sewage entering the sewers were usually in a state of active putrefaction or decay and much offensive and dangerous gas was emitted. The construction of ventilating shafts could only lessen the effect of the problem but could not eliminate it. Where the house drains and sewers were properly designed, the sewage would be completely removed before decay could commence, and little or no gas would be emitted.

During the long process of remediing and completing a proper drainage system, ventilation for sewers was required. Main sewers should be built along hill-slopes and above the town. The upstream end of the sewers should be open for ventilation. Vertical shafts of masonry dams constructed at the end of the sewers could promote ventilation. It would be highly desirable if the sewer gas could be discharged above the level of the town. However, the effect of ventilation shafts was usually local.

It was emphasised that there was only one way to eliminate the sewer gas nuisance – prevent its formation by immediately removing the sewage discharged from the house drains.
The above is a summary of Chadwick’s report of 1882. The report explained how a better drainage and sewerage system would improve the sanitary conditions of Hong Kong and also described how such a system could be constructed. In 1891, the Government set up a Water and Drainage Sub-Department under the Public Works Department. Although this could be interpreted as a step aimed at building the drainage and sewerage system proposed by Chadwick, little or no progress was actually made. At the same time, the danger of epidemic outburst was brewing, threatening to destroy the well-being of Hong Kong’s inhabitants.

**Attack of the bubonic plague**

The bubonic plague attacked Hong Kong in 1894. The plague had originated in Yunnan Province, where it was first detected in about 1850 and became an endemic disease after an epidemic outburst in 1860. In 1893 it spread eastward across Guangxi Province, reached the city of Guangzhou swiftly, and finally hit Hong Kong in 1894.
The plague was caused by the spreading of the plague bacillus passed on by infected rats. Human beings were immune from infection under normal circumstances but could become infected if bitten by fleas carried by infected rats. If sanitation were maintained at a high level and all rats were kept away, outbreak of the plague would be highly unlikely.

Unfortunately, the sanitary conditions of Hong Kong, in particular those of the Tai Ping Shan District, were seriously inadequate. Despite repeated warnings given by Colonial Surgeons since 1843 and by Osbert Chadwick 12 years ago, few people voiced concern about the potential dangers. The outbreak of the bubonic plague epidemic was thus inevitable.

The term ‘bubonic plague’ is derived from the appearance of swollen glands in the armpits or groins of those infected by the plague bacillus. Infection would not be deadly if treatment could be applied by the use of antibiotics such as streptomycin and tetracycline. However, no such medication was available at that time, and therefore the infection became fatal for many infected victims. The visit of the plague did serious damage to Hong Kong, and the city had little alternative but to rebuild its infrastructures and drainage systems in the next two decades.

**Overview**

In the earlier years when Hong Kong came under British possession, combined drainage and sewerage system was adopted to wash away sewage with stormwater runoff into the harbour. As a result of drastic population increase, the wastewater and environmental hygiene problems deteriorated, with Tai Ping Shan District having the worst insanitary conditions. However, the Government had taken no action to rectify the problems. Later on, a former Royal Engineer, Sir Osbert Chadwick was commissioned to visit Hong Kong and to investigate the public health situations. Based on his recommendations, the Government established the Hong Kong Sanitary Board in 1883 and enacted a few drainage related undertakings. Yet, the most crucial recommendations by Sir Chadwick, including the construction of properly designed drainage and sewerage networks, were not undertaken. The inaction eventually led to the outbreak of bubonic plague in 1894, a raging epidemic took its toll for 30 years.
Chapter 2: Impact of the Bubonic Plague on the Urban Development of Hong Kong 1895–1940

Actions to combat the bubonic plague

The bubonic plague, which exerted terrible impact on Hong Kong for 30 years, was literally a nightmare for the inhabitants of the territory. The annual threat was keenly felt by the people until 1923 when the epidemic ceased to attack. In 1895 there were 1,204 cases of infection, 1,078 of which reported deaths. The mortality rate in that year was 89%, a little lower than that of 1894, the previous year, when there were 2,550 deaths and the mortality rate was 93.4%. The number of plague cases went down to 21 in 1897 but rose to 1,315 in 1898, and 1,240 of the infected victims were Chinese. Fatal cases in 1898 amounted to 1,111, and the mortality rate was 89.6%.

From then on, plague cases averaged over 1,000 per year until the year of 1904. From 1904 to 1911, the number of infected cases decreased sharply, and fatal cases in 1910 went down to 23. However, the number of fatal cases rose again to 1,768 in 1912 and reached 2,020 in 1914. In 1922, just a year before the plague’s total disappearance, the number of fatal cases was still as high as 1,071.

At the onset of the Bubonic Plague, the government only resorted to inhabitation measures that involved burning of plague-struck homes and furniture as deterrent to spread of the epidemic.

At the Central District in 1901, dead bodies of the epidemic victims were carried away from the scene.

As the Bubonic Plague spread in Tai Ping Shan, quite a number of residences migrated to Mainland China as the epidemic became serious.
In this desperate situation, drastic actions had to be taken by the Government to combat the epidemic. One of these actions was the dismantling of the Tai Ping Shan District, where sanitary conditions were particularly poor. This area of altogether 6.25 acres was resumed by the Government on 26 September 1894. As a first step, much of the woodwork was removed, and some of the buildings were demolished.

On 20 September 1895, construction of a stormwater drain running from Caine Lane to Hollywood Road was commenced. Later that year, construction of the lower portion of Pound Lane and Tai Ping Shan Street was also started, involving the erection of heavy retaining walls along the frontage of these streets. Construction was completed towards the end of the year, and a new area was thus laid out, bounded by Market Street, Po Yan Street, (Upper) Station Street and Pound Lane.

After the demolition of Tai Ping Shan District in 1895, the site was later rebuilt as Blake Garden.
A harbour view, circa 1900s. Though interrupted by the visitations of the plague, the Hong Kong economy was on the road to steady development.

Other sweeping actions to maintain and improve the sanitary conditions of Hong Kong were also started, noticeably in the construction of sewerage and drainage systems. This was the result of repeated complaints voiced by the commercial sector against the Government.

On 7 June 1901, Mr. Chatterton Wilcox, then Secretary of the Hong Kong General Chamber of Commerce, sent a letter to the Colonial Secretary to state his views on the situation. He observed that although the bubonic plague seemed to have become an annual visitation at the time, the authorities were practically as helpless as they had been in 1894. The number of infected cases was almost the same as the number of deaths, and the exodus of the Chinese was accelerating on a formidable scale.

Wilcox referred to a speech given by the Medical Officer of Health, Dr. William Francis Clark, which mentioned a number of recommendations made by Osbert Chadwick in 1882. He argued that all these recommendations suggested necessary action, but up to 1901 few actions had been carried out, and most of the recommendations were simply ignored. He therefore urged the Government to take vigorous steps to secure the continued development of the colony and to adequately protect merchants' commercial interests which were gravely affected by the annual outburst of the epidemic.
Having settled with the Government authorities some minor disagreement over the choice of words in their formal exchanges, the Hong Kong General Chamber of Commerce eventually affirmed their recommendation to expedite improvements to the sanitary conditions in Hong Kong, and assured the Government of the loyal support and co-operation of the Chamber.

As a result of these exchanges, Osbert Chadwick was invited to come to Hong Kong for a third time in 1902, to give advice, once again, on the territory’s sanitary conditions. In his report, he proposed to construct the drainage and sewerage system into two separate systems. With regard to the street sewerage system, he submitted seven proposals:

1) Complete sewage outfalls across the New Reclamation (Praya);
2) Enhance the clearance of rubbish being dumped into the sewers;
3) Replace existing gully trap gratings with improved traps and gratings;
4) Test the effectiveness of vigorous flushing at low tides with well or sea water on a section of sewers near outfall. If the effect was good, the same system could be extended to other sections;
5) Close ventilation openings in the sewer manholes;
6) If ventilation openings proved to be necessary, provide house sewers with either ventilating pipes or separate elevated vent-pipes to prevent smelling gas from entering the house;
7) Cut down trees wherever their roots obstructed the sewers, or replace cast iron pipes for stone-ware pipes with lead and yarn joints to allow movement of sewage.
Drainage systems

There are two types of drainage systems, the Combined System and the Separate System. In the Combined System, which was adopted worldwide in the 19th century, the stormwater and foul sewage use the same drainage network. The Separate System, on the other hand, is constructed to separate the sewerage system from the stormwater system.

Regarding the stormwater drainage system, Chadwick proposed the following:

1) Cover drains or nullahs as far as possible;
2) Keep inverts of outfalls at mean sea level or higher if possible;
3) In flat areas near the sea, wherever covered drains were necessary, align drains by the shortest possible route to special outlets to the sea but do not connect them to main drains or nullahs that were tide-locked;
4) In new districts, plan alignment and levels of streets to minimise the length and size of the underground drains;
5) As keeping sewage out of the drains was the main function of sewers, it was more important to exclude sewage from the drains than to keep out rainwater from the sewers. With the gradients in Hong Kong it was almost always possible to provide stormwater overflows should any sewer become filled with rain-water;
6) Produce a complete record plan for the drains in Hong Kong, so that a definite scheme could be worked out.

Street sewers at Central District, circa 1920s.  
Waterfront in Central District in early 1920s. Outfall of sewers are visible along the seawall.
The impact of the bubonic plague prompted the Government to take immediate action to redistribute Hong Kong’s population away from the old Tai Ping Shan District and even away from the City of Victoria. This was not to say that redistribution of population was not a problem for consideration before the outbreak of the plague, for over-population had always been a problem in the City of Victoria. In 1881, the inhabitants of the City of Victoria alone accounted for 71.5% (70.8% in 1891, 61.6% in 1901, and 47.7% in 1911) of Hong Kong's total population, posing a very serious threat to sanitation. Subsequent to the outbreak of the plague in 1894, redistribution of population away from the City of Victoria had become a pressing problem of grave concerns.

Overcrowded housing condition in Sheung Wan, circa 1910s.
Expansion of Hong Kong Island

When working out the overall plan for population redistribution, the Government decided to find more land for the growth of the city both on Hong Kong Island and Kowloon peninsula. Thus began the expansion of Hong Kong Island to its east-end and west-end and a phase of city planning and expansion in Kowloon. According to the recommendation of Chadwick, the drainage infrastructures should be designed with a very clear goal to keep sewage out of the drains, which meant that the sewerage system should be separated from the drainage system.

The expansion of Hong Kong Island was to be realised through the implementation of the East and West Praya Reclamation Scheme. In 1875, actions were taken to initiate reclamation in Western District, but little progress was made owing to shortage of funds and disputes with the existing lot holders and the military over land rights along the Praya. In 1887, Paul Chater of the Hong Kong and Kowloon Wharf and Godown Company sought to re-energise the Scheme. In that year, consensus was finally reached between the Government and the business sector to enable the full-scale launching of this ambitious reclamation project.
The reclamation works extended westward to the gas works of Hong Kong and China Gas Co. Ltd. at West Point and eastward to Murray Pier, covering a distance of 3 400 yards (10 200 feet) with a width of 250 feet, yielding an area of about 59 acres. Clearly, the reclaimed land would relieve the pressure created by the rising influx of immigrants in the late 19th Century. According to the then Surveyor General, Mr. J. M. Price, large areas of flat land were required on Hong Kong Island to house an annual population increase of 8 000 in 1887, which represented a jump from a net increase of 1 500 people in 1873.

Of the 59 acres of land created by the West Praya Reclamation Scheme, an area of 26.2 acres was made available for commercial and residential developments. An estimated 1 320 tenements could be built to house 39 000 people. The reclaimed area would be sufficient to meet the additional housing requirements for the next five years, given the forecast of the annual net increase of 8 000 people in 1887 made by the Surveyor General. The Praya West Reclamation Scheme, commenced in 1889, was completed in 1903.

In 1897, when the Western District-Central Reclamation was in full swing, the Government commenced planning for the Praya East Reclamation. It began from the junction of Hennessy Road and Johnston Road to Percival Street. The project had the same aim of easing population density in the City of Victoria and of providing better sanitary conditions for the inhabitants of Hong Kong.
Unfortunately, during its early stage the Praya East Reclamation project encountered the same obstacles faced by its Western District counterpart. Little or no progress was seen in its formative years dating from 1901. The project was held up for 20 years owing to reservations held by the Royal Navy against the relocation of the Naval Hospital.

Through the perseverance of Paul Chater, reclamation was finally commenced on 1 November 1921. Originally, the project was planned to be completed within six years. Owing to various problems it was not finished until 1931. An area of approximately 90 acres of new land was created. The scheme built a total of 13,645 feet of roads with a width of 75 feet and another 2,080 feet with a width of 100 feet.
The existing drainage system was to some extent affected by the reclamation. The original drainage system on Nos. 68–80 and 99–116 of Praya East had to be raised by two feet to align with the new drainage system. In addition, 18 993 feet of sewers and 14 360 feet of stormwater drains had to be reconstructed. To connect the road drainage to the seafront, it was necessary to construct a 36-foot wide nullah at Bowrington Canal stretching over a distance of 650 feet. New sewers installed at the reclamation area totalled 22 239 feet in length, with another 16 276 feet of stormwater drains.

The completion of the Praya East Reclamation project produced a total area of about 3 739 600 square feet (approximately 90 acres) of new land. This enabled the erection of 608 Chinese houses along the Praya with modern hygiene facilities, fulfilling at the time the call for better sanitation and more decent housing conditions for the community.
The activities relating to the drainage infrastructures constructed in Hong Kong Island during the period of 1895–1940:

1903 Construction works began at Tytam Tuk, including the reconstruction of street gullies and the training of nullahs for improving the sanitary conditions of some residential districts.

1904 About $40 000 was spent on nullah training in the Colony and $20 000 on the reconstruction of street gullies to improve the city drainage system.

1906 Reconstruction of gullies and extension of nullah training continued. $10 000 was spent on the former and over $16 000 on the latter. A large tank for flushing a portion of the sewerage of the city was constructed in Blake Garden.

1907 Reconstruction of gullies and extension on nullah training continued. $10 000 was spent on the former and over $23 500 on the latter.

A large tank for flushing a portion of the sewerage of the city was constructed at the junction of Water Street and Queen's Road West.
1908  The raising of a considerable section of sunken sewers in Connaught Road was carried out.

1910  Work was completed on the reconstruction of gullies and the training of the large nullah, west of the University site, from Hill Road to the Pokfulam Conduit. Replacement of defective earthenware pipes by iron pipes was in progress.

Since the laying of sewer in 1911, the sanitation condition in houses on the southern slopes of Mount Gough was improved.

1911  The training of some nullahs between Bowen Road and Magazine Gap to the east of the Military Hospital was completed. Similar work over a considerable length of nullahs was in progress south of Magazine Gap in the valley below the Military Sanatorium. A considerable length of the nullah at No. 12 Bridge, Shau Kei Wan, was also trained and the stream flowing past Pokfulam Village was channeled or otherwise improved.

Underground tanks were constructed at the junction of Arbuthnot Road and Wyndham Street and in Stone Nullah Lane for the purpose of flushing sewers with flat gradient, and connections with the sewerage were made.

The laying of a sewer in Craigmin Road to intercept wastewater from houses on the southern slopes of Mount Gough was undertaken. Extensive drainage works were also carried out in Shau Kei Wan West.
1912  The training of a section of the Wong Nei Chong Nullah in the vicinity of Wong Nei Chong Village was in progress. Provision was made for the discharging of stormwater from the site of the University of Hong Kong by the laying of drains in Bonham Road and Hill Road. The sewer in Craigmin Road to intercept wastewater from houses on the southern slopes of Mount Gough was completed. Iron pipes replaced earthenware pipes for sewers in Matheson Street, Leighton Hill Road and Wong Nei Chong Valley.

1913  Streams in the Wong Nei Chong, Wan Chai, Bowen Road, Magazine Gap, and Mount Austin districts were trained.

1914  10,000 feet of streams were trained in the vicinity of Shau Kei Wan and Pokfulam, in the City of Victoria and Hill Districts and in Kowloon. Large-scale extensions of sewers for new building lots were carried out in Hong Kong and Kowloon.

1917  The training of the extensive system of nullahs in So Kun Po Valley was completed.

1921  The project of Ap Lei Chau Reclamation was completed.

1923  The existing outfall from below Wan Chai Gap was extended to the sea near Aberdeen.

1924  On Hong Kong Island, a 9.6 feet horseshoe concrete culvert from Wan Chai Road to the Praya was finished and a 7.6 feet concrete culvert from Leighton Hill Road to the Praya was under construction, which was finished in 1925.

1926  On Hong Kong Island, satisfactory progress was made on the reconstruction of Wong Nei Chong Nullah. Sections 1 and 2 from Blue Pool Road to the Race Stand were completed. Good progress was made on the rehabilitation of drainage in the areas between the Praya and Queen's Road East in the Praya East Reclamation Scheme.

1927  On Hong Kong Island, the construction of Section 3 (from Bowrington Canal to the Chinese Race Stand) of the Wong Nei Chong Nullah was about half-finished at the end of the year. New sewers and stormwater drains were laid to a length of 2,500 feet. Stream courses were trained to a length of 2,450 feet.

Wong Nei Chong was under development, circa 1930s. The nullah was located on Village Road, shown in the center of the photo.
1928  Construction of Section 3 of the Wong Nei Chong Nullah was completed at the end of November. Construction of Section No. 4 (in front of the Jockey Club Stand) commenced in March and was half-finished at the end of the year.

1931  On Hong Kong Island, new sewers and stormwater drains were constructed to a length of 6,186 feet. Stream courses were trained to a length of 263 feet. Improvement to the main sewer at Aberdeen Valley began.

The project of the Praya East Reclamation was completed.

1935  On Hong Kong Island, underground drains and sewers were constructed to a length of 11,997 feet and nullahs were constructed up to a length of 334 feet.

1938  On Hong Kong Island, new sewers and stormwater drains were constructed to a length of 5,522 feet and open channels of varying sections to a length of 851 feet were laid. 1,114 feet of parapet wall on nullahs were constructed.

The Tai Hang Nullah bridge was reconditioned, strengthened and extended.
**Urbanisation of the Kowloon Peninsula**

Urban development by the Government was also extended to the Kowloon Peninsula. After it was ceded to and occupied by the British in 1861, the area, in particular Tsim Sha Tsui, had in fact been developed into a military region with foreign dwellings. The most notable move, however, was the decision in 1909 by the Government to reclaim the land around Yau Ma Tei and Mong Kok Tsui (renamed Mong Kok in the 1930s) for the construction of the Yau Ma Tei Typhoon Shelter. The reclaimed land was later developed into a town with modern roads and buildings.

The three districts of Tsim Sha Tsui, Yau Ma Tei and Mong Kok, situated at the tip of the Peninsula, were gradually developed into three prosperous regions, each with its own unique history of development. Their growth was largely the consequence of the Government's land policy. In developing the Kowloon Peninsula, the Government attempted to reduce its financial commitments by including reclamation projects into its land sales. All the specific reclamation stipulations were laid down by the authorities before the land was auctioned. This was of course intended for effective supervision during construction.

Since the 1880s, the Government had received a large number of land extension applications from the Marine lot owners who offered to undertake the reclamation at their own expense and to pay additional land premiums and Crown rent. The Government, in line with its existing policy, approved most of these applications, thereby reducing its financial commitments in the development of the Kowloon Peninsula. This illustrated the influential role of private developers in urbanising the Kowloon Peninsula.

The southern tip of Kowloon Peninsula, circa 1870s. Except for few villages in Tsim Sha Tsui, there was no other large-scaled development.

At the early stage of Kowloon development, the government focused on developing Yau Ma Tei and Tsim Sha Tsui areas. After completing the reclamation works of northward expansion on Nathan Road and Shanghai streets, large-scaled communities were established. Photo above shows the wreckage along the waterfront at Shanghai street in Yau Ma Tei after typhoon rampage. Kwun Chung Hill lies at the front.
Streams that ran along Kowloon Tong village, circa 1900s. Population at Kowloon Peninsula was sparse.

Carnarvon Road, circa 1900s, Apart from serving as military camps and warehouses, Tsim Sha Tsui was then inhabited by the Portuguese.

Water carts running across Granville Road, circa 1910s.

The activities relating to drainage infrastructures conducted in Kowloon (New Territories included) during the period of 1895–1940:

1896 Streets were laid out at Tai Kok Tsui in Kowloon as part of city planning and expansion.

1899 Laying out of streets at Mong Kok Tsui, north of Yau Ma Tei, was begun as part of city planning and expansion.

1905 The Tai Kok Tsui reclamation project was finished. The system of 100-foot roads in Kowloon was extended. Construction of the section of Robinson Road (later renamed Nathan Road) from north to south between the sea and the Yau Ma Tei Theatre was completed.

1906 Construction of the entire Nathan Road was completed. The original name of the road was Robinson, but the name was later changed to commemorate Governor Nathan's contribution in designing this road which ran northwards from the southern tip of the Peninsula to Boundary Street.
1908  Work on the reconstruction of gullies and extension of nullah training in Waterloo Road, Kowloon, was completed.

1909  The Proclamation of Hung Hom Reclamation Ordinance by the Government was enacted.

1911  In Kowloon, an extension of the nullah in Waterloo Road to the north of No. 4 Railway Bridge was carried out. Extensive drainage works were carried out in Sham Shui Po.

1912  In Kowloon, a further extension of the nullah in Waterloo Road to the north of No. 4 Railway Bridge was nearing completion. A new stormwater drain was laid in Mody Road to intercept the stormwater formerly flowing across Kowloon Inland Lot 575.

1913  An extension of the nullah at the railway yard, Hung Hom, was carried out with a view to obviating the flooding of the yard during heavy rainstorms and subsequent deposit of massive detritus. Various extensions of sewers for new building lots were carried out and further drainage works were conducted at Sham Shui Po in connection with the reclamation works going on there.

1914  Large-scale extensions of sewers for new building lots were carried out in Kowloon. Construction of Castle Peak Road and the road from Tai Po to Fan Ling was completed.

1917  The Sham Shui Po Improvement Scheme continued to make progress during which time demolition of entire old villages was carried out and new houses and other buildings were erected on good wide roads.
1919  Construction of the road from Tsuen Wan to Castle Peak was completed.

1921  Construction of a nullah at Mong Kok Tsui between Tai Po Road and the old Kowloon boundary line near Kowloon Tong was in progress. Training and diversion of the large stream course to the east of Lai Chi Kok began.

1922  Extension of the Mong Kok Tsui Nullah eastward through the railway bridge and the excavation for foundations were well underway. The training and diversion of the stream course to the east of Lai Chi Kok was completed.

1923  The Waterloo Road Nullah was completed in November. Training and diversion of the main stream course at Ma Tau Chung began in October. The work was conducted together with the Chatham Road Extension and Kowloon Bay West Reclamation.

1924  In Kowloon, the extension of the Mong Kok Tsui Nullah to the Old Kowloon Boundary was completed. Construction of the Ma Tau Chung Nullah made slow progress. The Nam Cheong Street Nullah from the waterfront to Tai Po Road was completed. The extension of the Mong Kok Tsui Nullah from the old Kowloon Boundary to the Kowloon range of hills was in satisfactory progress.
1925  The Ma Tau Chung Nullah again made slow progress.

1926  The Ma Tau Chung Nullah was completed. Stormwater drains from 15 inches to 66 inches in diameter were constructed in the Ma Tau Chung District, to a length of 5,600 feet.

The main sewer from Fuk Tsun Heung to Kowloon Tong, east of the Railway, was completed with widths ranging from 6 inches to 33 inches and a length of 8,500 feet. Other sewers and stormwater drains were constructed to an extent of 7,000 feet.

The drainage of the Kowloon Tong Development Area proceeded with construction of sewers and stormwater drains to the extents of 6,500 feet and 3,000 feet respectively. Other sewers and stormwater drains were laid to an extent of 2,900 feet.

The extension of the Mong Kok Tsui Nullah from the Old Kowloon boundary to the Kowloon range of hills was in slow progress.

1927  A section of the large stormwater culvert in Tong Mi Road was completed. A large nullah in the New Cemeteries Area, Ho Man Tin, commenced construction. New sewers and stormwater drains were constructed to a length of 9,030 feet.

New sewers and stormwater drains were constructed to a length of 3,930 feet in the Kowloon Tong Estate. The length of drains constructed was 13,346 feet. Nullah training was carried out on the hillsides north of N.K.I.L. Nos. 420 and 362, Cheung Sha Wan.

1928  In Kowloon, the training of the large nullah in the New Cemeteries Area at Ho Man Tin was completed. New sewers and stormwater drains were constructed to a length of 6,400 feet.

New sewers and stormwater drains were constructed on the Kowloon Tong Development Area to a length of 6,900 feet.

The construction of the nullah on the east side of the Kowloon Tong Development Area was completed.

In the New Territories, sewers were constructed to a length of 200 feet, and about 300 feet of stream course training was completed.

1931  In Kowloon, new sewers and stormwater drains were constructed to a length of 12,682 feet.

In New Kowloon, new sewers and stormwater drains were constructed to a length of 15,471 feet.

In the New Territories, improvements on the Yuen Long nullahs were completed.

1935  Construction of sewers up to a length of 14,641 feet, including 113 feet of open nullahs and 1,278 feet of partially-open nullahs, was completed in Kowloon and the New Territories.

1938  In Kowloon, New Kowloon and the New Territories, new sewers and stormwater drains were constructed up to a length 12,923 feet.

The construction of the Pat Heung Nullah at Shek Kong, New Territories, commenced in 1936, was completed at the end of this year.
Overview

The outbreak of Bubonic Plague in 1894 exerted a devastating impact on Hong Kong. It was only until 1923 that the plague ceased to attack the territory. To contain the Bubonic Plague, the Government vigorously dismantled Tai Ping Shan District, the sanitation black spot. It also took up reclamation projects to create new lands so that population could be re-distributed. The newly erected Tenement Houses in the newly reclaimed districts were provided with modernized sanitation facilities so that more habitable living conditions were rendered to the public.

Sir Chadwick was re-invited to come to Hong Kong to give advice on the territory’s sanitary conditions. The Government adopted his recommendations on “separate drainage and sewerage systems”, followed by the building of separate sewerage and stormwater drainage systems across Hong Kong and Kowloon districts. Sanitary conditions in Hong Kong were improved ever since. The pathway towards an independent planning and running for sewerage and stormwater drainage systems was set in place, which had also laid the cornerstone for the later development of drainage services in Hong Kong.
In 1892, the Government’s Water and Drainage Sub-department, just established a year ago in 1891, was renamed the Waterworks Office. In 1924, while the Praya East Reclamation project was still being carried out, the Drainage Section under the Waterworks Office was reconstituted into the Drainage Office. The new Drainage Office was put under the charge of an Executive Engineer with the title of Drainage Engineer.

The Drainage Office was established to perform the following objectives: the design and construction of all extensions to sewers and stormwater drains; nullah drainage in connection with anti-malarial work; the maintaining of water supplies from wells and nullahs; and the maintenance and cleansing of the existing sewers and public septic tanks. These objectives, especially those concerning anti-malarial work and the cleansing of old sewers, showed clearly that the principal function of the Drainage Office was to tackle public sanitation and the health problems of the community. This was very natural, as the visit of the bubonic plague had stopped only a year ago, in 1923.
Japanese occupation

When Second World War broke out, all infrastructural works came to a complete halt as the Government had to give its top priority to Hong Kong’s defense requirements. Towards the end of December 1941 Hong Kong was formally occupied by the Japanese. During the Japanese Occupation, there was practically no new infrastructural development. Hong Kong’s drainage services suffered the same fate without exception, although the Home Affairs Bureau of the Government of the Captured Territory also had a Drainage Services Department.

The only large-scale construction undertaken by the Japanese in occupied Hong Kong was the extension of the Kai Tak Airfield. To allow two runways to be built on site, almost perpendicular to one another, it was necessary to clear the twenty villages located near the Kai Tak Airfield south of Kowloon City, including Po Kong, Ma Tau Chung, Kau Pui Shek, etc. As a result of the airfield extension, a new nullah, subsequently known as Kai Tak Nullah, was constructed for channeling and draining the existing stream course and preventing flooding. The granite used for the construction of the nullah was partly taken from the wall of the century-old Kowloon Walled City.
**Post-war construction of sewerage infrastructures**

With the ending of the Second World War, the Drainage Office was reinstated. In the post-War period, from 1946 to 1952, water supply took priority in public works as the population was significantly on the rise (2 015 300 in 1951, 3 129 648 in 1961, and 3 936 630 in 1971). It was therefore hard to trace information on the actual work done in drainage services at that time.

With the drainage system left unattended, it is bound to give rise to unwelcome consequences. Bothersome fouling conditions in the part of Victoria Harbour facing western Kowloon were detected in the sewer outfalls. Not until 1953 was consideration given to the laying of an intercepting sewer and the construction of a new outfall to low tide level. It was expected that the tidal currents would effectively remove the sewage and safeguard the Harbour against pollution.

From this point on, new schemes of sewerage networks were planned to abolish the numerous outfalls into the Harbour, bringing the sewage to selected sites where it could be treated. The treatment process actually employed was only one of preliminary screening, in which large objects were removed. After which, the screened sewage was discharged via submarine outfalls.
The concept of using screening plants with submarine outfalls for efficient wastewater dilution and dispersion was applied to the coastal areas around Victoria Harbour. The first screening plant was built in 1956 at Anchor Street, Tai Kok Tsui, and the first submarine outfall was at West Kowloon.

**Submarine Outfall**

The function of a submarine outfall is to discharge the effluent at a sufficiently far distance from the shore, where the water is deeper and the current is faster, to ensure that the processes of diluting and dispersing the sewage, coupled with natural purification, will adequately reduce the concentration of pollutants to acceptable levels.

Workers from the Department of Health were cleaning roadside gullies. To prevent outbreak of epidemic in a densely populated community, keeping the pavements clean and sewers cleared of blockage were vital.

Food stalls have been part of the Hong Kong culture. Yet since the stalls' operators had not probably treated the waste water discharge, polluted sewerage channels and clogging were resulted.

The Government built new market building to accommodate street hawker, with proper sewerage systems to reduce wastewater discharged to the harbour. This pictures shows the first market building built at Bridges Street in 1953, which is now classified as a grade III historic building.
In 1959, three years after its planning was commenced, the sewerage scheme for the eastern side of the Kowloon Peninsula and the Wan Chai area was completed and in operation. The scheme for the southern Kowloon Peninsula also commenced. It continued into 1963, and works were also launched in North Point, Tsuen Wan and Kwai Chung. In the following years the scheme had developed more locations, namely Yau Ma Tei, Kowloon South, Kowloon East and Central. At the same time, studies were made to develop treatment and sewage disposal schemes for Tsuen Wan, Yuen Long and Shek Wu Hui.

With the rise of satellite towns in Hong Kong (see below), it was widely accepted that the major function of sewage disposal was to have all sewage, after preliminary treatment, discharged through submarine outfalls into the coastal waters around the territory.
In 1964 the Government re-organised the Offices of Drainage, Development, Port Works and Roads and merged them to form the Civil Engineering Office. Under the new Civil Engineering Office there were three Roads and Drainage Offices, one each for Hong Kong, Kowloon, and the New Territories.

The year of 1969 saw further re-organisation of the Public Works Department. Drainage Services functions handled by the Roads and Drainage Offices were put under the new Drainage Works Division of the Civil Engineering Office. In 1982, the Drainage Works Division was replaced by three Liquid and Solid Wastes Divisions, i.e. Planning, Construction and Pollution Control. In 1986, the Liquid and Solid Wastes Divisions were restructured to become the Drainage Branch in the Civil Engineering Services Department. The Drainage Branch had four divisions — the Drainage (Construction) Division, the Drainage (Design) Division, the Urban Drainage Division and the New Territories Drainage Division.

The road and drainage construction works along Nathan Road in Yau Ma Tei, in proximity to Nanking street, were handled by the Roads and Drainage Offices.
Decking and culverting of open nullahs

During the post-War period, there were also activities to deck and culvert open nullahs located on roads in built-up areas. The aim was to improve traffic conditions as such open nullahs were normally built in the middle of the roads.

The nullahs were often 10 feet or wider and almost rectangular in section, which made their presence tremendously inconvenient to traffic, both vehicular and pedestrian. Such obstruction must therefore be removed. Since the mid-1950s works were implemented steadily, and many nullahs were either decked or culverted, greatly relieving the undesirable traffic congestion hitherto caused by them.
A nullah ran along Hill Road in Kennedy Town and later decked over with a flyover built above.

The Waterloo Road Nullah before it was decked, 1964.

Bowrington Canal before it was decked, 1962.
Beginning from 1958, extensive culvert constructions were carried out at resettlement estates such as Wong Tai Sin, Wang Tau Hom, Chai Wan, Jordan Valley, and in the satellite towns of Tsuen Wan, Kwai Chung, Kwun Tong, and Shek Wu Hui. The works were done for either site clearance or for diverting existing stream courses so that building works could be carried out. In 1967, work was carried out to deck the open nullah in Wong Nei Chung Road, to culvert part of the nullah in Aberdeen, and also to extend Bowrington Canal as a result of the new reclamation there.
Satellite towns

The massive influx of immigrants from Mainland China in the 1950s and 1960s transformed the economic scene of Hong Kong, bringing to the territory enormous volumes of capital, professional expertise and low-cost labour. The additional resources and the rapidly growing population called for industrial expansion and sufficient residential allocation, and the Government was pressed for a solution to provide new industrial districts and residential accommodations. It was decided that construction of satellite towns would best cater to the situation, and this in turn called for large-scale design and construction of sewerage and drainage systems in these areas.

Kwun Tong

At the end of 1954 the Government reached a decision to develop Kwun Tong, and in May 1956 a working committee appointed by the Executive Council proposed that 244 acres of new land should be formed in Kwun Tong: 111 acres for industrial use, 84 acres for 1 180 residential units, 37 acres for resettlement estates and the balance of 12 acres for commercial use. The aim was to develop Kwun Tong into a community with a population of 120 000. Reclamation began immediately. From 1956 to 1966, a total area of 641 acres of new land was created, a surplus of 397 acres more than the original estimate of 244 acres.

Beginning from 1959, a total of six resettlement estates was constructed in Kwun Tong. In the late 1960s Kwun Tong became part of urban Kowloon, equipped to support a population of 500 000. By 1971, a total of 452 836 people were living in Ngau Tau Kok and Lei Yue Mun. These resettlement estates provided 56 818 housing units accommodating 258 814 residents.
Tsuen Wan

Tsuen Wan was another development plan drawn up by the Government in the 1950s. The Government planned three centres in Tsuen Wan District: Tsuen Wan, Tsing Yi and Kwai Chung. Reclamation and site formation works in Tsuen Wan Bay started in 1954, and by 1957 an area of 121 acres of land was formed. In 1959 the Government endorsed the blueprint to develop Tsuen Wan into a one-million-strong community. Between 1969 and 1976, an additional 306 acres of land were reclaimed from Gin Drinker’s Bay, enlarging the area of Tsuen Wan to 6,000 acres, a size that was bigger than the Kowloon Peninsula south of Boundary Street.

By 1961 the population in Tsuen Wan had exceeded 80,000, and the district had about 247 factories. In the same year, 20% of Hong Kong’s total industrial workforce was located in Tsuen Wan. In 1971, the population of the whole district of Tsuen Wan had grown to about 270,000, the majority of which was residing in public housing units.

At the early stage of Tsuen Wan Satellite Town development, Castle Peak Road was the only access to the district. The building in the picture was once the tallest commercial mansion in the district, now rebuilt as Nan Fung Centre.

Tsuen Wan circa 1965. The industrial and residential areas were separated by a nullah. The nullah was decked in the 1980s and Tai Chung Road was constructed on top of it.

Castle Peak

The development plan for Castle Peak was formulated in 1964 to form 1,041 acres of land capable of supporting a population of one million. The development would consist of 171 acres of existing low-lying areas, 463 acres of hilly ground and 407 acres of reclaimed land. The area would be further divided to cater for the following usages:

1) Resettlement estates (179 acres);
2) Other low-cost government housing (58 acres).
3) Private residential accommodation (335 acres),
4) Industrial development (379 acres),
5) Central area (34 acres),
6) Government, institutional and community area (34 acres), and
7) Formed open space (25 acres).

The first stage of reclamation commenced in 1966 and formed 220 acres of land. In its subsequent development, Castle Peak served as testing ground in two respects. Firstly, the satellite town was meant for a pilot project for the territory’s public housing scheme. By the end of the 1970s, four large scale public housing projects had been completed in support of the 10-year housing programme announced by the Government in 1973. Out of the 483 600 people living in the Castle Peak area, 344 000 resided in public housing estates.

The Castle Peak development also served as a testing ground for early town-planning. It incorporated views from professional engineers, architects, town-planners and other professionals. The assembled views were then coordinated to form an integrated plan for the development of new satellite towns.
Threats and damage by rainstorms before 1971

In addition to increasing the catchment and paved areas and hence the quantity of surface runoff, land reclamation associated with urban development and new town development pushed the final outlets of stormwater drainage systems further and further out from the original shore line and created significant pressure on the stormwater drainage systems. Inevitably, the gradient of the extension drains and channels were very flat, which were not favourable for drainage purpose. Silt and mud from upstream tended to settle along the flat sections of drain and channels and their drainage capacity was significantly affected. At times of heavy rainstorms, flooding often occurred.

Typhoon Mary, 3–12 June 1960

Typhoon Mary was initially formed on 3 June as a tropical depression south of Hong Kong. It passed northward sweeping over the western part of the New Territories on the early morning of 9 June, causing considerable loss of lives and damage to property.

The storm centre passed close to Cheung Chau, with the wind direction changed to southwesterly, a direction to which the anchorages and villages were exposed. The rainfall recorded in one day during the attack was 236.1 millimetres. Casualties recorded included 45 dead, 11 missing, 127 injured and 15 000 affected.

Downpour of torrents had brought about serious devastation to St. Francis Street, Wanchai, a section of road surface near Queen's Road East.

Boats were carried ashore as Typhoon Mary turmoil Cheung Chau
Typhoon Wanda, 27 August to 2 September 1962

Typhoon Wanda developed on 27 August as a tropical depression moving slowly towards Hong Kong over the Pacific Ocean. One of the striking features during Typhoon Wanda’s attack on Hong Kong was the disastrous flooding it caused in Tolo Harbour.

On 1 September 1962, the predicted maximum high water mark in Tolo Harbour at 11:31 am was 7.2 feet, which was within its daily normal average. It was an unfortunate coincidence that Typhoon Wanda should pass Hong Kong at about the same time. Its gale force winds blew rather suddenly to develop an internal tidal wave, the effect of which was for the tide in Tolo Harbour to rise approximately 10 more feet above the predicted water mark. Wind-driven waves had contributed an additional 6 feet onto the shore line near Sha Tin.

At Sha Tin Village Police Post, the high water mark was 17 feet 3 inches above chart datum or 5 feet above road level. At Tai Po Fire Station, the high water mark was 16 feet 7 inches above chart datum. At the Shell Installation at Tai Po Kau, the level was 17 feet 9 inches above chart datum, and waves were reported to reach as high as the fence surrounding the Installation, approximately 23 feet above chart datum.

Victims of floods in Shatin impaired by Typhoon Wanda

A scene along waterfront of Gloucester Road subsequent to typhoon on 1st September 1962
The effect of such flooding was obviously disastrous. A total of 869 acres of farm land were flooded with sea water, 277 acres in Sha Tin, 314 acres in Tai Po and 278 acres in Sha Tau Kok. 179 acres of low-lying farms, mostly in Sha Tin, were still affected two months later owing to breached bunds.

More than 300 fishing boats out of a total fleet of just over 1 000 were wrecked in the Tolo Harbour area. Approximately 3 000 huts and 5 village-type houses were damaged or destroyed in Sha Tin. Various roads near the seaside were breached, including Ting Kok Road near Tai Po and Luk Keng Road near Sha Tau Kok. The main Tai Po Road and the rail-line were both blocked with boats, flotsam and silt.

The daily rainfall recorded was 203 millimetres and overall casualties of the territory amounted to 130 dead, 53 missing and 72 000 homeless.

Monsoon trough on 12 June 1966

Beginning from early June 1966, a low pressure trough began to develop along the coast of Guangdong Province, bringing unstable weather to the territory. On the morning of 12 June, the Hong Kong Royal Observatory recorded very heavy hourly rainfall of 108.2 millimetres, a record high at that time in the month of June in Hong Kong.

The consequences of the rainstorm were very serious. In Ming Yuen Western Street, North Point, floodwater broke out through the hill slopes, rushed down the street and swept the cars parked there into a huddled heap. In Central District, the City Hall Low Block was flooded, so that musical performances scheduled there had to be suspended. A power substation on Hong Kong Island was damaged by the rainwater, and consequently electricity supply to certain regions of the Island had to be curtailed. In Kowloon, a wall of La Salle College collapsed as a result of heavy rainfall.

Records showed that in the entire territory the daily rainfall registered was 382.6 millimetres, while the hourly rainfall in Aberdeen was 157 mm, a record high of the district. Overall casualties added up to 64 dead with 29 injured. Disastrous landslides and washouts on Peak Road, Stubbs Road and Ming Yuen Western Street had forced 8 561 people to be evacuated from their homes. The cost of repairs to public works stood at HK$ 31 million.
After the devastation of torrents, large volume of silt and debris were carried into the underground culvert. Drainage workers had to resort to mechanical equipment to clear off silt and debris.

King’s Road was flooded after rainstorm.

Aftermath of rainstorm at Ming Yuen Western Street, North Point.
Overview

Soon after Hong Kong had recovered from the threat of Bubonic Plague, the government set up the “Drainage Office” in 1924 to initiate measures and projects to tackle with the sanitation and health problems. As population in Hong Kong surged rapidly since the end of Second World War, environmental pollution and sanitary problems were on the rise. The government began to formulate various schemes on sewerage networks. Sewage was diverted to a handful of selected sites for preliminary screening and treatment, while later discharged into the Harbour via submarine outfalls.

The government had to explore and create new lands to meet the pressing demand for housing. It subsequently developed satellite towns in Kwun Tong, Tsuen Wan and Castle Peak. As districts and satellite towns speedily grew in full swing, so did the pressure on stormwater drainage system. Under such circumstances, building well-suited flood prevention systems had turned into an inevitable issue.
Brave the Challenges
1971–1988
Part II: Transition to a New Era 1971–1988
Chapter 4: Transition to New Frontier of Environmental Protection 1971–1988

It can be clearly seen, from the previous three chapters, that drainage services were often associated with sanitation whenever problems occurred, as was the case in Hong Kong for over a hundred years. Drainage services played a very important role in containing the sanitary catastrophes of the territory hence protecting the health of the people. Towards the end of the 1960s, keeping abreast with developments in other parts of the world, the role of drainage services in Hong Kong began to shift from sanitary containment and health protection to environmental protection in a much wider context.

Open channels at Kwai Chung Licensed Area (left) and stormwater drains at Kowloon Tsai squatter area (right) during late 1960s. At that time, environment issues of any drainage services were seldomly accounted for.
Bowring Road Nullah in Wanchai (Canal Road of to-date). Stormwater drains carried away untreated wastewater, rubbish, oil spill and other pollutants, together with sand and silt into the nullah. Man-entry into open nullahs for manual removal of sand and silt has become uncommon nowadays.
Watson's Report

In July 1971, J. D. & D. M. Watson presented a report to the Hong Kong Government entitled Marine Investigation into Sewage Discharges: Report and Technical Appendices.

The Report, citing opinions from renowned engineers, while commended on the existing developments at the same time reminded that the population of Hong Kong would reach 6.14 million by 1991. The engineers made several recommendations to tackle the problems of sewerage, outfalls, night soil and refuse tipping. It was further pointed out that drainage services in the urban areas were operated on a nominally ‘separate’ system. The storm water drainage system had been affected by sewage discharge through illegal connection.

The Report also pointed out that the sewage was not given any pre-treatment before discharging into the sea or rivers. It had thus polluted areas such as Castle Peak, Brewery Bay, Tsuen Wan, Aberdeen, and Chai Wan. This, the Report pointed out, had led to water pollution and wider implications of environmental protection.

Watson's Report formed the blueprint for the strategy for wastewater treatment and disposal in Hong Kong in the 1970s. Counting on the natural assimilative capacity and beneficial use of the receiving water bodies, the study recommended the construction of 1) screening plants with submarine outfalls for areas around Victoria Harbour; and 2) wastewater treatment plants for areas discharging into inland and enclosed coastal waters such as Tolo Harbour and Deep Bay.

Environmental protection and water pollution

In those decades it was common for people to try and find solutions to environmental issues that preferably would not force them to take stands on questions of value which could become personal, difficult and subjective. In particular, while looking for neutral and impersonal methods, it would leave all questions of value, for instance the concept of “sustainability”, to the personal realm.

Today, however, ‘sustainability’ is a universal concept. People all over the world agree that human systems should be sustainable, and if they are not sustainable it is usually because of three essential reasons:

1) The systems are producing levels of pollution which exceed the local, regional, and even global capacity to absorb and render them harmless;

2) The systems will exhaust finite nonrenewable resources;

3) The systems are using renewable resources such as forests faster than such resources can be naturally regenerated.

If human systems exceed the capacity of our planet to supply resources for dealing with our wastes, they will erode our planet’s ability to support life. To create a sustainable future, mankind must revamp the systems that support our lives. The challenge is twofold: we must adjust our existing systems to make them as sustainable as possible, and we must build new systems using the principles of sustainable design.

In the 1950s, the wastewater from cleaning the manure buckets was drained directly into the surface drains and discharged into the harbour, resulting in pollution.
Drainage services basically deal with one very important aspect of environmental protection, i.e. the control of water pollution. To approach this problem, we must first of all define what water pollution is and understand what its sources are.

Water pollution is any physical or chemical change in water that adversely affects organisms. The problem is global in scope, but the types of pollution vary according to a country's level of development. In under-developed non-industrial countries, water pollution is mainly caused by human and animal wastes, pathogenic organisms from such wastes, pesticides, and sediment from unsound farming and timbering practices.

Developed industrial nations, on the other hand, create an additional assortment of potentially hazardous pollutants such as heat, toxic metals, acids, pesticides and organic chemicals. In between these two extremes are numerous countries which have achieved various degrees of industrialisation. Often, these countries do not have laws, or only have inadequate laws, to combat water pollution. Even when there are such laws, the lack of funding may prevent them from being effectively enforced.

Shan Pui River in Yuen Long originates from hilltop in Tai Tong and flows through the Yuen Long town centre, Mai Po and Wang Chau, and converges with Kam Tin River into Deep Bay. Because of untreated livestock waste, water in the main nullah in the town centre of Yuen Long was used to be contaminated and malodorous.
Sources of water pollution

Numerous sources, both natural and anthropogenic, contribute to water pollution. As a rule, anthropogenic sources are the most important because they tend to be localised and thus contribute significantly to the deterioration of local waterways or groundwater. In short, water pollution arises from identifiable point sources such as factories, and from diffuse non-point sources such as farm fields and streets. Point sources are much easier to control.
Signs and warnings of water pollution in Hong Kong

The combined effects of industrial development and population increase during the 1950s and 1960s in Hong Kong were signified by obvious signs of water pollution in the territory. The situation worsened as the pace of development accelerated in the 1970s and 1980s. The marine environment deteriorated rapidly as most of Hong Kong’s sewage and wastewater ended up in the sea with the bulk of it receiving little or no treatment before discharge. This in turn led to increases in organic and inorganic pollutants, reductions in the oxygen content of the water, and increases in the bacteria level. The Cross-Harbour Swimming Race, a major sport event in Hong Kong, was held in Victoria Harbour in 1973 for the last time, to the regret of many people.
To house the growing population, the Government began building new towns in the 1980s. This certainly did not benefit the surrounding environment. For example, two of the new towns, Sha Tin and Tai Po, were built in the catchment area for Tolo Harbour which, owing to its enclosed nature, could easily become polluted by pollutants from these two new towns.

Another major problem of marine water pollution in the past few decades was the untreated waste generated by the livestock industry. In the early 1980s, many parts of the New Territories and some urban areas were home to thousands of pig farms and chicken farms. Large volumes of effluent from these farms were discharged directly into Hong Kong’s rivers, carrying the pollutants out to sea.
In the 1980s, Hong Kong was home to many industrial enterprises. Thousands of factories, particularly those in the Kwun Tong and Tsuen Wan areas, discharged their untreated waste directly into sewers that led to the sea. The waste was particularly high in chemical and metal content as they were, among other sources, originated from factories belonging to the prominent textile, electroplating, bleaching and dyeing industries.

Pollution of streams

In as early as 1974, the attention of the Government was drawn to the problem of stream pollution in Hong Kong. A consultant firm commissioned by the Government carried out a survey and study of the subject in that year. It was reported that, of the 250 miles of stream covered by the survey, about 150 miles (60%) could be classified as clean (with water showing little or no sign of pollution). Of the remainder, 60 miles (24%) could be classified as polluted (but not offensive) and 40 miles (16%) as grossly polluted (offensive in appearance and/or smell).

The unpolluted streams were generally in uplands above the 200 feet contour. The polluted or grossly polluted streams were situated in the lowlands where the rural population of the New Territories resided.

Sewage and night-soil contributed to 10% of the total polluting load discharged or dumped into the streams. This could be explained by the fact that only 16% of the population in the New Territories was served by public sewers and a further 3% with WC's draining to septic tank systems.
Industrial effluents, virtually all of which were discharged untreated, accounted for about 22% of the total polluting load entering the streams. About 90% of the total flow of industrial effluent originated from three groups of dyeing and bleaching factories in Tsuen Wan, Fo Tan and Ho Chung. The rest was discharged from more than 200 factories of various industries like slaughter-houses, tanneries, chemical works that were scattered throughout the New Territories.

There were more than 13 000 pig farms with a total of about 370 000 pigs. At least 80% of the excreta were discharged into the streams without any form of treatment. The number of poultry in the New Territories was about 6 million, of which 90% were chickens. 350 tonnes of droppings were produced daily in the New Territories, and more than 50% of it was dumped into the streams.
Pollution of coastal waters

Apart from stream pollution, the water quality of the coastal waters and Victoria Harbour also came under scrutiny. A report produced in 1982 made the following assessment on the coastal waters:

1) Western Hong Kong: In general the water quality was fair, with relatively high turbidity and low dissolved oxygen. The major areas of significant pollution were Deep Bay and the beaches along Castle Peak Road. This was likely due to the dense population and industrial development in the Tsuen Wan and Tuen Mun areas. The water quality of Deep Bay was deteriorating, as shown by (i) reduction in the total number of species captured in the shrimp ponds; (ii) high nutrient nitrate and phosphate level; (iii) longer period of time taken by oysters to grow to market size.

2) Eastern Hong Kong: As this area was open to the currents and waves from the South China Sea with high waste receiving capacity, the coastal waters were of high quality in general. There were, however, certain exceptions, e.g. in Tolo Harbour, where it was found that (i) the water quality was poor, with high coliform content; (ii) there was an increasing occurrence of red tide; (iii) the clams collected from the inner harbour were unfit for human consumption; (iv) there were mass mortalities of the benthos in 1972, 1979 and 1980; (v) the dissolved oxygen in the water was low, especially at the bottom of the harbour. In short, the inner harbour was grossly polluted.
The same report also commented on the water quality of Victoria Harbour. Before 1960, most of the sewage that ended up in the Harbour was untreated except where there was limited treatment by septic and Imhoff tanks. From 1960 onwards, though screening plants and submarine outfalls were constructed, the Harbour remained grossly polluted particularly in the following areas:

1) The northern coast of west Kowloon, where the water had high coliform content;

2) The typhoon shelter area between Kwun Tong and the Kai Tak Airport runway, where the water was black with bad smell and the coliform content was high;

3) The northwest coast of Hong Kong Island near Sheung Wan and Yau Ma Tei and Causeway Bay Typhoon Shelter, where the water had high coliform content.

Sham Shui Po, circus 1975, untreated wastewater, garbage, oil spills and other pollutants were discharged into drainage system, which eventually flew into the Victoria Harbour.

Boat squatters within typhoon shelter in Yau Ma Tei in 1979

Typhoon Shelter in Causeway Bay by the end of 1960s
Jordan Road Ferry Pier, and Man Wah Sun Chuen in Yau Ma Tei under construction. Most wastewater at that time only undergone simple treatment or no treatment before conveyed into the Victoria Harbour, causing deterioration in water quality in the Harbour.
Preparatory measures taken by the Government to combat water pollution

The above surveys and studies revealed that the quality of Hong Kong’s waters in the late 1970s was severely threatened by a mixture of pollution sources, while its controls were mostly inadequate. In response to such challenges, the Government began to draw up a blueprint to contain the deterioration of Hong Kong’s marine environment under the new Water Pollution Control Ordinance (1980).

The ordinance divided the Hong Kong’s marine waters into ten Water Control Zones (WCZs). A set of Water Quality Objectives (WQOs) and discharge standards was established for each WCZ.

These WQOs outlined the qualitative and quantitative standards of water that needed to be met as conservation goals, and they were also used to support the various beneficial uses of different water bodies. In other words, they were designed as long term environmental goals to safeguard Hong Kong’s marine environment.

In the same year, the Waste Disposal Ordinance was enacted. Among other things, it provided for the preparation of a statutory Waste Disposal Plan (WDP), the notification of certain classes of toxic and difficult wastes, and measures to control the storage of agricultural wastes. Wastes from agriculture, especially pig wastes, had caused widespread pollution in the New Territories for some decades, and much of the problem was caused by the then practice of discharging the wastes into water courses. The legislation aimed at putting a stop to this practice.

Also in 1986, the Environmental Protection Department was established and entrusted with the task of monitoring Hong Kong’s marine waters. It devised a comprehensive marine water monitoring programme which was first implemented in 1986 and later given regular revisions and expansions. The monitoring programme was crucial for measuring whether individual Water Control Zones complied with the WQOs. Based on the information, the Government was able to assess the effectiveness of its pollution control measures for further strategies.

The programme was designed with the following aims and objectives:
1) to indicate the state of health of coastal waters;
2) to assess compliance with the statutory WQOs;
3) to reveal long term changes in water quality;
4) to provide a basis for the planning of water pollution control strategies.

In retrospect, the efforts showed positive signs of improvement in the marine environment, particularly in areas where Hong Kong’s marine waters are relatively enclosed or near urban areas and receive large volumes of waste water, e.g. in Tolo Harbour and Victoria Harbour. By 1988, only a year before the establishment of the Drainage Services Department, Hong Kong had reached the threshold of a new frontier of environmental protection in combating water pollution. Much work had to be done before anything meaningful could be accomplished.
**Post-1971 construction of sewerage infrastructures**

**Sewage treatment plants for Victoria Harbour**

Following the successful commissioning of the first sewage screening plant at Anchor Street in 1956, similar plants along both sides of Victoria Harbour were built in the 1950s and 1960s. Simple preliminary treatment involving only removal of large particles was adopted then as the appropriate technology for treating sewage in Hong Kong. Bar screens and rotating drum screens were typical equipment for coarse and fine screening of sewage. Grit channels were also used to allow heavier grit particles to settle.

The Watson's Report (1971) had recommended the continuous adoption of preliminary treatment plants with submarine outfalls for areas around Victoria Harbour to best utilise the flushing effects of the strong tidal currents in the Harbour. Many more advanced screening plants were built in the 1970s and 1980s, installed with fine screens to improve the quality of the discharge.

**Typical operation flow within a preliminary treatment plant**

The Anchor Street Sewage Screening Plant. It was decommissioned in 1992 after commissioning of the North West Kowloon Sewage Treatment System.
Sewage treatment plants for inland waters

Beginning from the 1970s, more and more people have been moving into the new towns in the New Territories. Unlike Hong Kong Island and the Kowloon Peninsula, these new towns are not close to a water body like Victoria Harbour, and sewage discharge with preliminary treatment were inadequate. The Watson’s Report therefore recommended that sewage treatment with standard higher than preliminary should be adopted.

In order to select the most appropriate technology for Hong Kong and to gain first hand operational experience, the Government set up a pilot secondary treatment plant in 1974 at Shek Wu Hui where different technologies for secondary treatment, namely the oxidation pond, the trickling filter and the activated sludge process, were tested and evaluated. These technologies were further developed after the United States passed the Federal Water Pollution Control Act Amendments of 1972. The conclusion of the trial was that the activated sludge process was the most suitable technology for secondary sewage treatment in Hong Kong, and this decision set direction for the subsequent full-scale development of secondary treatment plants.
The first large-scale secondary sewage treatment plant was commissioned in 1979 in Tai Po to serve the industrial estate and the new town. Being a semi-landlocked water body, Tolo Harbour has much less capacity to assimilate the sewage arising from the Sha Tin and Tai Po new towns. To cope with the new towns’ development, secondary treatment plants were urgently required.

The Stage I works of TPSTW were completed in October 1979 with a treatment capacity of 9,500 cubic metres/day, serving the Tai Po Tai Yuen Estate and the industrial demands in the area. The Stage II works were completed in July 1983 with treatment capacity increased to 33,600 cubic metres/day to cope with the development of the new town.
Sha Tin New Town

The Sha Tin development plan was first considered in 1963 and was revised in 1965. The revised plan incorporated more high-density housing to satisfy pressing needs. The plan was to be implemented in four phases over a period of 15 years. It could support a population of 1.09 million and yield new land amounting to 2,135 acres, of which 232 acres could be used to build 540,000 low-income housing units.

The first phase of the project involved areas around the Shing Mun River and the feng shui hill in Yuen Chau Kok. The major areas of work were drainage, reclamation and water supply. In 1973–1974, before the launching of the 10-year housing programme, the Sha Tin development was making very slow progress. In 1973, not even the first stage of construction was completed. The development plan was further refined in 1976 and a blueprint that largely resembled the layout of present-day Sha Tin was finalised in 1977.

As a stop-gap measure to control water pollution in the Sha Tin area, a temporary and interim sewage treatment plant was commissioned in phase since 1975 in a site near the downstream section of the Fo Tan Nullah (at present Jockey Club Ti-I College), adopting respectively extended aeration process and contact stabilisation process.

Shatin temporary secondary sewage treatment plant started operation since October 1978 and testing completed by then as well.
In 1982, Stage I of the Sha Tin Sewage Treatment Works, capable of treating 102,870 cubic metres of sewage per day, was commissioned to take over the duty of the interim secondary sewage treatment plant. Stage II of the sewage treatment works was commissioned in 1986, increasing the treatment capacity to 205,000 cubic metres/day.

In early 1980s, the district of Sha Tin was developed into several industrial areas: Fo Tan, Tai Wai, Siu Lek Yuen and Shek Mun. Since then, Sha Tin has been transformed into a modern town, bustling with business enterprises and industrial activities.
Other secondary sewage treatment works

Following the Tai Po and Sha Tin STWs, additional secondary treatment plants were built in the 1980s at Shek Wu Hui, Yuen Long and Sai Kung from which effluent was discharged into inland waters or coastal waters with limited self-purification capacity.

In 1984, Stage I of Shek Wu Hui STW was constructed and commissioned to handle a dry weather flow of 60,000 cubic metres/day, serving an equivalent population of 220,000 from the new town developments in the Sheung Shui and Fanling areas.

The Yuen Long STW was designed to treat both domestic wastewater from Yuen Long town and industrial wastewater from Yuen Long Industrial Estate. Stage I was commissioned in 1984 to provide a treatment capacity of 53,000 cubic metres/day.

The Sai Kung Sewage Treatment Works, occupying an area of about two hectares on reclaimed land at Tui Min Hoi, Sai Kung, was commissioned in November 1988. It was designed to treat sewage generated from a population of 42,000 in Sai Kung District with a dry weather flow of 15,200 cubic metres/day.
Sewage treatment plants for small communities

Apart from large-scale secondary treatment plants designed to combat pollution, small or package sewage treatment plants were built for small communities, including institutions such as military camps, prisons and quarters, in remote areas in the New Territories and Outlying Islands.

Various technologies were adopted in these plants, depending on the assimilation power and the water quality objectives of the receiving water bodies. The first primary treatment plant in Hong Kong was built in 1983 at Tai O where an Imhoff Tank was built for processing of the sewage. The Imhoff Tank consists of a top compartment which serves as a sedimentation tank and a lower compartment in which the settled solids are collected and anaerobically stabilised. Another primary treatment plant was built in 1985 in Cheung Chau to serve the community on the island.
Other secondary treatment processes such as trickling filters, oxidation ditches, and rotating biological contactors were chosen for other locations.

The trickling filter consists of a bed of highly permeable media on whose surface a mixed population of microorganisms is developed as a slime layer. The passage of wastewater through the filter causes the bacteria, protozoa and other organisms in the slime layer to consume the organic matters in the wastewater.

The oldest trickling filter plant was the Tam Mei Barracks sewage treatment plant in Ngau Tam Mei. It began functioning in 1953, and had a treatment capacity of 288 cubic metres/day serving a domestic military population of approximately 1 200 people.

The first Rotating Biological Contactor (RBC) plant for government institutions was commissioned at Shek Pik Prison in 1984. It consists of a series of discs attached to a common shaft. The discs are partially submerged in a trough of continuously flowing wastewater and a film of microorganisms grows on the discs. As the discs rotate, the microorganisms consume oxygen from the air and organic matters from the wastewater. In this way, organic matters are removed from the wastewater.
The advantage of RBCs over trickling filters is that RBCs are more reliable and can withstand sudden change in hydraulic and organic load.

The first oxidation ditch plant at Hei Ling Chau Correctional Institute, with a treatment capacity of 900 cubic metres/day, was put into service in 1984. It is a small wastewater treatment device operated on extended aeration. It consists of a long channel of an elliptical or circular shape, and a rotor for generating water flow and aerating the water in the channel by stirring. With its simple structure, it is easy to operate and can remove nitrogen efficiently.

Hei Ling Chau Oxidation Ditch Plant

Secondary Treatment — Generally refers to using micro-organisms in biological treatment process to stabilise organic matters including dissolved solids left in the sewage after primary treatment. This process can remove over 90% of both the suspended solids and biochemical oxygen demand.

Overview

From 1950s, population in Hong Kong has rapidly increased, but most of the wastewater were discharged direct to the nearby drains, causing severe water pollution in the rivers and the harbour. In the beginning of the 1970s, the government based on the recommendations in the Watson’s Report on Marine Investigation into Sewage Discharges and proceeded to formulate overall strategy for the territory-wide sewage treatment, followed by upgrading the screening facilities for the sewage screening plants to improve the quality of the discharge, along with building sewage treatment plants with treatment standard higher than preliminary for the New Towns. However, water pollution problem remained serious.

In 1980, to tackle the water pollution problems, the government legislated the Hong Kong’s marine waters into several Water Control Zones to control wastewater discharge. In the same year, the Waste Disposal Ordinance was enacted. Legislations for pollution control and implementation of the recommendations in the Watson’s Report had led Hong Kong to the threshold of a new frontier of environmental protection.

Primary and secondary treatment processes

Primary Treatment — In addition to screening and degritting, it includes the reduction of settleable solids in sewage by plain sedimentation. This process can remove 50% to 70% of suspended solids and 25% to 40% of biochemical oxygen demand — an indicator of sewage strength.

Chemically Enhanced Primary Treatment — Chemicals are added in the primary sedimentation process to enhance removal of solids to achieve removal of around 80% suspended solids and 70% of biochemical oxygen demand.
Chapter 5 : Threats and Damage of Rainstorms before 1989

Hong Kong is constantly under the threats and damage of flooding which can be attributed to a number of factors, namely topography, geology, rainfall, land use and population.

The topography of Hong Kong Island is rugged with steep natural slopes of residual soil mantles. Apart from coastal reclaimed land, natural slopes exceeding 30 degrees with heights rising to 450 meters are common. On the other hand, a large part of Kowloon Peninsula is leveled, while major roads in fairly newly-developed housing estates have been built with deep cuttings, large-scale platforming and substantial embankments.

The rainfall of Hong Kong is seasonal, averaging about 2,214 millimetres each year. During the wet season from April to October, rains mostly come in heavy downpours, lasting a number of days. On average, about 25 per cent of the annual rainfall is due to tropical cyclones. The rest is largely caused by the active southwest monsoon and its associated troughs which bring continuous rain, each time for a number of days. Tropical cyclones are often associated with strong to gale force winds and can also produce intense rainfall, but each
In 1960s, farms and fish ponds at Sheung Shui were submerged in floodwater.

On 17th June 1983, rainfall of 346.7 millimetres was recorded, which was the fifth highest daily rainfall recorded in Hong Kong (1884–2017).

cyclone visit seldom lasts for more than a few days. As the troughs also produce very heavy rainfall, they tend to have more destructive effects than the tropical cyclones with regard to slope failures that often lead to catastrophic disasters.

Another important factor closely related to flooding is land use and population. The 1960s saw a massive population increase in Hong Kong, putting pressure on housing requirements. Demands for social services, water supply and linking roads were high. To keep abreast with this development, it was natural for a large number of residential blocks and schools to be built higher and higher up slopes and embankments.

The flatter land in the rural areas in the New Territories faced a different problem. Fish ponds and farmland used to serve as flood storage areas but they were gradually converted to built-up areas thereby significantly increased the demand of artificial stormwater drainage infrastructures in the New Territories.

The combined effects of the above-mentioned factors are closely related to flooding which has brought unfathomable threats and massive damage to Hong Kong. This can be seen in the following significant events that took place in the period before 1989.
Typhoon Rose on 10–17 August 1971

Typhoon Rose was one of the most severe and destructive typhoons that have wreaked havoc on Hong Kong. Like other tropical cyclones, it approached Hong Kong from the south, bringing very heavy rainfall.

A daily rainfall of 288.1 millimetres was recorded by the Hong Kong Royal Observatory on 17 August 1971. The casualty was 100 dead and 5,644 people from 1,032 families were made homeless. 653 huts were destroyed and about 24 buildings were devastated on 12 locations, of which 6 were beyond repair. Affected cables rendered some 30,000 telephones out of order. There were numerous landslides resulting in 110 cases of road blockage, and flooding occurred in 35 locations across the territory.
Monsoon trough on 16–18 June 1972

On 16–18 June 1972, a total of 652.3 millimetres of rainfall was recorded, causing two most tragic disasters in Hong Kong. First, on Kowloon Peninsula, on 18 June 1972, a filled slope approximately 130 feet in height was washed on to the Sau Mau Ping Class II Licensed Area where nearly 400 people lived in licensed and unlicensed huts, killing 71.

On Hong Kong Island, at 8 pm on the same night, a major landslip measuring 900 feet from top to bottom and 200 feet across 3 roads crushed en bloc onto a two-storey building on Po Shan Road and other huts in the vicinity. Almost at the same time, a 12-storey building on Kotewall Road was also devastated, killing 67 people.

The total casualty of these two incidents killed 138 people. In other parts of the territory, there were also 56 injured, flooding at 53 locations and 7,800 people rendered homeless. On 18 June 1972 alone, 232.6 millimetres of rainfall with a peak hourly rate of 98.7 millimetres from 11 am to noon was recorded.
Severe tropical storm Ellen on 24–25 August 1976

Unfortunately, Sau Mau Ping received a second strike from Severe Tropical Storm Ellen on 24–25 August 1976. The embankment adjoining an estate block collapsed and the landslip buried much of the ground floor of the estate, killing 18 people.

Away from Sau Mau Ping, landslips also took place in many other locations, causing 2 424 people to be evacuated from their homes. 511.6 millimetres of rainfall was recorded in the two days with a daily rainfall of 416.2 millimetres on 24 August 1976 alone.

Rainfall from 28 May 1982 to 2 June 1982

Between 28 May 1982 and 2 June 1982, 676 mm of rainfall was recorded by the Royal Observatory. In northwestern New Territories, in the same period, rainfall was in the range of 524 millimetres to 697 millimetres. The highest daily total rainfall occurred on 29 May 1982, with over 400 mm being recorded in the upper catchment area of the Kam Tin River on the slopes of Tai Mo Shan. Coinciding with the peaks in rainfall and tide level, the peak flood level in Kam Tin occurred between 2 am and 6 am on 29 May 1982, and persisted for a few hours before receding.

Following the event, the New Territories Development Department conducted field surveys to determine the extent of flooding and flood levels. Generally, areas with ground levels lower than 5 m PD in the tidal floodplain area were inundated. The then Agriculture & Fisheries Department’s records indicated that in the New Territories as a whole 1 000 hectares of farmland and 400 hectares of fish ponds were inundated. Livestock losses amounted to 10 000 pigs and 700 000 heads of poultry. The total agricultural losses were reported at HK$ 23 million.
Typhoon Ellen on 29 August to 9 September 1983

Typhoon Ellen passed Hong Kong at about 7 nautical miles southwest of Fan Lau, the southwestern tip of Lantau Island. Hurricane Signal No. 10 was hoisted for a period of 8 hours. The highest gust over Hong Kong, 248 kilometres/hour, was recorded at Stanley. At Waglan Island, the maximum gust of 225 kilometres/hour was the highest since 1964.

The most seriously affected areas were Yuen Long and Kam Tin. 120 hectares of fish ponds were flooded, mostly in Tin Shui Wai, Kam Tin and Ngau Tam Mei. Some 80,000 households in Kowloon and the New Territories suffered from power failure. Some places in Kwun Tong, Sha Tin, Fanling, Sai Kung, Yuen Long and Lantau Island were deprived of electric supply for 4 days. Water supply was also interrupted in Ha Kwai Chung and Mei Foo Sun Chuen.

There were a total of 150 reports of flooding and 250 reports of road blockage. The casualty was 10 dead, 12 missing, 333 injured and 1,607 homeless. The daily rainfall recorded on 9 September 1983 was 172.4 millimetres.
**Typhoon Warren on 14–20 July 1988**

Typhoon Warren affected Hong Kong on 14–20 July 1988. Heavy rains associated with Warren caused severe flooding in several parts of the New Territories. According to press reports, flooding also occurred in Shenzhen. During the one-hour period between 3 am and 4 am on 18 July 1988, 65.5 millimetres of rainfall was recorded by the Royal Observatory.

Damage caused by the flooding was severe. A total of 118 cases of flooding and five minor landslips were reported. Flooding was most severe in Tuen Mun and in north and northwestern New Territories. The low-lying areas were inundated. Many village houses were submerged. In Sheung Shui, more than 20 people were stranded by severe flooding in Tin Ping Shan and had to be rescued from rooftops of squatter huts by helicopters and rubber dinghies. About 100 hectares of fish ponds in San Tin, Kam Tin, Sheung Shui and Lam Tsuen were flooded and 220 tonnes of fish lost. Fish farmer estimated a total loss of HK$760 000. In addition, 270 hectares of agricultural land were also flooded, 60 hectares of which were in Yuen Long, Tuen Mun, San Tin and Pat Heung. The remaining 210 hectares were in Sheung Shui, Fanling, Ta Kwu Ling and Tai Po. Livestock farmers reported that 1 370 pigs and 133 000 heads of poultry were drowned. During the passage of Warren, 12 people were injured and a 5-year old boy was reported missing after falling into the sea at Tsim Bei Tsui.

**Typhoon Brenda on 16–21 May 1989**

Typhoon Brenda struck Hong Kong on 16–21 May 1989. At Tate’s Cairn, the maximum gust speed was 187 km/h. On 20 May 1989, rainbands associated with Brenda brought periods of heavy rain and frequent squally downpours. The stormy weather stopped in the early morning of 21 May 1989, but isolated showers continued into the rest of the day. The amount of rain recorded at Shek Pik on 20 May 1989 was 382.5 millimetres.

Torrential rain associated with Brenda resulted in 100 cases of landslides and 118 floods in Hong Kong. In Tsz Wan Shan, more than 20 tonnes of mud and rocks crashed down a hillside and struck three squatter huts, leaving two people dead. In Yuen Long, a mud slide created a 100 square metre cavern at Lam Kam Road. Flooding was most severe in the northwestern part of the New Territories and 100 villagers had to be evacuated by boat in Au Tau, Yuen Long. Serious flooding also occurred in Nam Bin Wai and Ha Tsuen. About 130 hectares of fish ponds were flooded. The loss of fish was estimated to be 250 tonnes and worth about HK$2.8 million. The affected areas included Sheung Shui, San Tin, Ngau Tam Mei, Kam Tin, Lok Ma Chau, Pak Nai and Yuen Long. In addition, about 190 hectares of farmland were inundated and huge livestock losses were incurred, including some 66 000 chickens, 6 000 ducks, 1 000 pigs and 1 300
pigeons. Damage to crops and livestock in Pat Heung, San Tin, Kam Tin, Ha Tsuen, Shap Pat Heung, Ping Shan, Tuen Mun, Ta Kwu Ling, Sha Tau Kok, Kwu Tung and Sheung Shui was estimated to worth HK$6 million. There were also reports of fallen trees and collapsed scaffoldings. At the airport, more than 100 flights were diverted, delayed or cancelled. During the passage of Brenda, six people were killed, one was reported missing, 119 were injured and 899 were made homeless.

Overview

Hong Kong has been exposed to the threats of typhoons and rainstorms for years. A number of severe typhoons and rainstorms have caused destructions and casualties, with the memory of all such catastrophes still remain fresh with us to-date. Most new housing estates and major roads involved extensive slope-cutting, forming of large platforms or substantial road embankments, which were prone to slope failures under heavy rains. Over in the rural areas in the New Territories, fish ponds and farmland were levelled off to give way to housing development, thereby diminishing their flood storage function and causing these newly built-up areas vulnerable to flooding.

The government was fully aware of the need for comprehensive stormwater drainage planning and main river training works. Works on a series of flood protection schemes were commenced to overcome the flooding problems.
Typhoon Brenda had brought about serious floods in Kam Tin in 1989.
Charter
A Vibrant Course
1989-2008
Chapter 6: Sewage Collection and Treatment
The establishment of the Drainage Services Department

《White Paper: Pollution in Hong Kong — A Time to Act》

In 1989, the Government published the White Paper: Pollution in Hong Kong — A Time to Act ("White Paper"). This White Paper on environmental protection policy objectives and initiatives pointed out that the Hong Kong community generated over 2 million tonnes of wastewater daily in the late 1980s. The wastewater was discharged by multiple routes into the sea. Roughly 10% of the wastewater received biological treatment before discharge, 40% received partial treatment before discharge offshore through submarine outfalls, and the remaining 50% was discharged to the sea, near shore, without any treatment. The inadequacy of public sewerage and sewage treatment facilities led to the deterioration of the quality of the coastal waters and inland watercourses, and consequently the closure of bathing beaches, outbreaks of red tides, contaminated seafood, and visual pollution.

The White Paper listed the new sewage facilities built in the 1980s. Wastewater collected in the sewerage systems was conveyed either to the eight secondary sewage treatment works at Sha Tin, Tai Po, Yuen Long, Shek Wu Hui, Sai Kung, Sha Tau Kok, Hei Ling Chau and Mui Wo, or to one of the screening plants, before discharge into inland watercourses or sea. As for places with insufficient or without sewerage system, (such as Middle Bay and Clear Water Bay), new developments were required to install biological treatment plants.

The White Paper further reviewed the prevailing pollution control regulations and introduced enactment of new legislation on water pollution control. According to the proposal made in the White Paper, the Government combined the Drainage Works Division under the Civil Engineering Services Department (CESD) with several divisions of the Electrical and Mechanical Services Department (EMSD) to form the new Drainage Services Department (DSD) as an executive arm for the Environmental Protection Department (EPD) to combat water pollution in Hong Kong.
The key responsibilities of the DSD are to manage the sewerage and stormwater drainage systems in Hong Kong. On sewerage, the Department is responsible for the implementation of sewerage proposals of the EPD, entailing design, construction, operation, maintenance and upgrading of the collection, treatment and disposal of wastewater. On stormwater drainage, the Department is responsible for implementing flood prevention measures to minimise the occurrence of flooding. Its roles also include strategic planning, design, construction, operation, maintenance and upgrading of drainage systems to collect stormwater runoff from the land and convey it to the receiving waters.

Challenges abound

Improper discharge of wastewater had been the cause of odour nuisance on Kowloon Bay seafront for years. Such a phenomenon was also common in many areas on both sides of the Victoria Harbour.

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Challenges abound

The inshore water quality problem in Hong Kong in the late 1980s was not merely due to the inadequacy of infrastructure. The crux of the problem was the widespread connection of sewers from industrial facilities, restaurants and residential buildings directly into stormwater drains. As a result, wastewater was carried along with stormwater to the vicinity of seawalls or even typhoon shelters for discharge, frequently causing sea seawater to turn black and foul in Kowloon Bay, Yau Ma Tei and Causeway Bay Typhoon Shelters. While as much as 90% of wastewater in some catchment areas was discharged into stormwater drains, it was common that 50% of wastewater in other catchment areas was discharged in the same manner. Another reason for the deterioration of water quality in inland waters was that public sewers had not yet been laid in rural areas such as the southern side of Hong Kong Island and Clear Water Bay.

The challenge posed to the Government was how to treat the wastewater collected from the sewerage systems in a cost-effective and environmentally friendly manner. There were two feasible options at that time. One option was to adopt an extremely high level of wastewater treatment and then dispose of the effluent in the vicinity of inshore waters. Another option was to adopt conventional treatment by which the effluent was to be discharged via especially long submarine outfalls into the waters well away from the shores, where it could be diluted and purified by seawater. Two months after the release of the White Paper, the Government completed the Sewage Strategy Study and made its decision, under which a long-term strategy for collection, treatment and disposal of municipal wastewater was formulated to meet the water quality objectives, while substantial improvements were recommended for the public sewerage facilities in Hong Kong. The strategy consisted of two parts: Strategic Sewage Disposal Scheme and Sewerage Master Plans.

Smooth seas never make good sailors. It can be seen from the preceding sections that the newly founded Drainage Services Department was to play a major role in accomplishing the specific goals set by the Government.
Sewerage Master Plans

Between 1989 and 1996, EPD commissioned consultants to compile Sewerage Master Plans (SMPs) for 16 sewerage catchments in Hong Kong. Each of the 16 SMPs contained recommendations to upgrade and expand the sewerage, sewage pumping stations and sewage treatment facilities for the efficient collection, treatment and disposal of wastewater generated from each catchment. The objectives of SMPs were to ensure that the sewerage could cope with the existing and future development needs, and that the collection systems would have sufficient capacity to accommodate and convey all sewage collected instead of overflowing into stormwater drainage systems.

Overviews of the SMPs for three regions out of the 16 SMPs are described below to illustrate the general scopes and characteristics of the works under SMPs:

Hong Kong Island South

Completion and commissioning of the sewerage improvement works and sewage treatment and disposal facilities in the Southern District according to the recommendations in the Hong Kong Island South SMP is considered as one of the major achievements of the DSD in its first 10 years. Throughout the years before the works were completed, coastal water pollution in the district, particularly the beach areas from Shek O to Deep Water Bay, had deteriorated as a result of increase in population, tourism and commercial activities. The sewerage then had not been adequately extended to cover those areas and its treatment capacity could not cope with wastewater generated by new developments. Consequently, in 1989 the DSD began to implement a comprehensive collection, treatment and disposal system to raise the water quality in the coastal waters in the district to an acceptable standard. For instance, the beach at Repulse Bay was seriously polluted and almost on the verge of closure in the late 1980s. The annual geometric means of E. coli was over 400 counts per 100 millilitres of seawater and the beach water quality was ranked Poor. After implementation of the Hong Kong Island South SMP, the hygienic conditions of this reputable beach were gradually improved.

The Hong Kong Island South SMP works consisted of construction of 24 kilometres of sewers, 17 sewage pumping stations, a preliminary treatment works in Shek O, a secondary treatment works built inside cavern in Stanley, and rehabilitation of 8 km of sewers. All works were completed in 2000.
Yuen Long and Kam Tin

Implementation of sewerage improvement works would inevitably encounter with different challenges. The planning for the sewage treatment infrastructure under the Yuen Long and Kam Tin SMP had been carried out analytically and flexibly to meet future changes in land use and urban development in the north western New Territories.

Yuen Long Sewage Treatment Works was designed to treat domestic wastewater from Yuen Long Town, Nam Sang Wai and Kam Tin, and industrial wastewater from Yuen Long Industrial Estate. The plant was completed in two stages. When Stage I was commissioned in 1984, the plant could treat 53,000 cubic metres of wastewater per day, equivalent to a population of 194,000. After the commissioning of Stage II in 1992, the sewage treatment capacity increased to 70,000 cubic metres per day, equivalent to a population of 256,400. The treatment process comprised screening, primary sedimentation, biological treatment, anaerobic sludge digestion with energy recovery from biogas, and sludge dewatering.

To improve and protect the water quality of Deep Bay and its neighbouring ecological environment and to cope with the sewage increase based on the population forecast and due to extension of village sewerage, the DSD has planned to upgrade Yuen Long Sewage Treatment Works into Yuen Long Effluent Polishing Plant with tertiary treatment standard, with new facilities for effluent reuse, co-digestion for imported organic wastes, enhancement on deodorising system, energy recovery, extensive greening features and space for public amenity. These elements are aimed at improving the environmental performance and efficiency of the effluent polishing facility. The sewage treatment capacity will be increased in phases to 150,000 cubic metres per day.
Wan Chai East and North Point

The sewers built in early years in Wan Chai East and North Point districts had insufficient capacity to cope with the development needs. Besides, more than a quarter of the sewage systems were seriously silted up due to inadequate gradients, which resulted in more than 10% of the untreated wastewater (about 10,000 cubic metres) overflowed into Victoria Harbour everyday through stormwater drainage systems.

Works under the Wan Chai East and North Point SMP included the construction of more than 18 km of sewers, a new pumping station, and rectification of expedient connections in the area. An essential but a very difficult part of the works was the construction of the trunk sewer of diameter more than 1.8 metres and more than 10 metres below some of the busiest roads, including Electric Road, Java Road, Hennessy Road, Gloucester Road, Yee Wo Street and Percival Street, the construction activities of which would have serious impacts on the lives in the neighbourhood and the traffic. To minimise the adverse impact and to elicit supports from the local residents and shop operators, the sewerage works had adopted many innovative measures, including trenchless construction, transparent hoarding, and unprecedented engagement of community relations officers to enhance communication with the residents and shop operators. These measures to cultivate community relations have become an exemplar model for future road works to follow suit.

Review of Sewerage Master Plans in eight regions

In the late 1990s, the EPD re-grouped the 16 SMPs into eight areas to conduct review studies on the SMPs. The scope of the review studies covered Hong Kong’s latest population forecast, land use planning and new development proposals, with an aim to ensure that sewerage works proposed under the 16 SMPs would be able to keep in pace with the rapid changes in Hong Kong. The eight areas on Sewerage Master Plan Reviews are as follows:

- Yuen Long and Kam Tin
- Central Kowloon and East Kowloon
- Tuen Mun and Tsing Yi
- Outlying Islands Phase II
- Hong Kong Island
- North District and Tolo Harbour
- West Kowloon and Tsuen Wan
- Port Shelter and Tseung Kwan O
The DSD followed the recommendations in the Sewerage Master Plans and the Sewerage Master Plan Reviews and implemented the sewerage works in stages for the rehabilitation, expansion and upgrading of the existing sewerage infrastructures. Today, the DSD substantially completed the sewerage improvement works recommended under the SMPs. The DSD continues to review and carry out sewerage improvement works over the territory to cope with latest development of Hong Kong.

**Sewage treatment works and sewage pumping stations in Hong Kong**

**Sewage treatment works**

Sewage treatment facilities are important elements in the sewerage systems. The DSD has about 310 sewage treatment works, including sewage pumping stations and treatment works ranging from preliminary (screening) to tertiary treatment levels.

When the DSD was established in 1989, there were eight major sewage treatment works already in operation located in Sha Tin, Tai Po, Shek Wu Hui, Sai Kung, Yuen Long, Sha Tau Kok, Hei Ling Chau and Mui Wo. Since then, more major sewage treatment works were commissioned, including those in Stanley, Stonecutters Island, Sham Tseng, Siu Ho Wan and Ngong Ping. Over the years, the DSD continually upgrade the existing plants so that they perform as the forefront of world-class sewage treatment facilities.

**Stanley Sewage Treatment Works**

Stanley is a small coastal town south of Hong Kong Island renowned for its natural scenery, ethnic villages and market. The Stanley Sewage Treatment Works (Stanley STW) located at Wong Ma Kok was commissioned in 1995 with a designed treatment capacity of 11,600 cubic metres per day, serving a population of 27,000 in Stanley, Tai Tam, Chung Hom Kok and Red Hill areas. Sewage is conveyed from 13 sewage pumping stations in the area to the Stanley STW for secondary treatment.

The Stanley STW was built inside three caverns, each about 120 metres long, 15 metres wide and 17 metres high, with over 450 metres of road access, ventilation tunnels and shafts. The sewage treatment works would hardly be noticed by the passers-by and its daily operation would cause minimal impact on the surrounding environment. The Stanley STW is the first of its kind built inside a cavern in Southeast Asia.

The Stanley STW originally adopted an “extended aeration activated sludge” treatment process. The sewage entered the bioreactor after screening and de-gritting. With extended retention time, the microorganism assimilated the pollutants and converted ammonia nitrogen in the sewage to nitrate. The final sedimentation tank was...
Ngong Ping Sewage Treatment Works

Ngong Ping Sewage Treatment Works was commissioned in 2005 and is the first tertiary treatment works with reclaimed water facilities in Hong Kong. Ngong Ping is situated on a plateau on Lantau Peak within the water-gathering ground for Shek Pik Reservoir. The area is nestled by verdant country parks, with nearby rivers and woods supporting the largest population of Romer’s Tree Frog (Philautus romeri) in Hong Kong. To protect water quality in the water-gathering ground and nearby coasts, Ngong Ping Sewage Treatment Works adopts tertiary treatment process to treat and purify the sewage before discharge. The sewage treatment system consists of a sequencing batch reactor, a double-layer gravel filter and disinfection facilities to reduce organic pollutants, suspended solids, nutrients and pathogenic microorganisms in the sewage to extremely low levels. The plant recycles the treated effluent for toilet flushing in the nearby public lavatories and for irrigating plants and rearing fish within the treatment works.

The Ngong Ping Sewage Treatment Works compound is designed to blend harmoniously with the surrounding scenic environment. Most of the facilities are built underground to reduce the building heights. The design of the building facade is aesthetically pleasing, complemented with nicely designed landscaping to create an endearing and tranquil environment.

equipped with lamella plate settlers to increase the settling efficiency while requiring less floor space. The effluent was finally disinfected by multi-point chlorination systems before discharge to the sea through a submarine outfall. The settled sludge was dewatered and dispatched using sealed containers to the sludge treatment facility in T. PARK Tuen Mun.

To further improve the water quality in the Southern District of Hong Kong Island, the DSD introduced an advanced sewage treatment technology in the 2000s. The treatment process at the Stanley Sewage Treatment Works was upgraded to the “Combined Biofilm and Activated Sludge” process, with an enhanced anoxic zone installed for denitrification. After this upgrading, not only that the total nitrogen content in the effluent was substantially reduced, but the sewage treatment capacity of Stanley Sewage Treatment Works was also increased by more than 30%. In terms of sludge treatment, a filter press dehydrator was installed to replace the two original belt filter sludge dehydrators so that the sludge would comply with the revised solid content requirement for disposal.

The Ngong Ping Sewage Treatment Works blends harmoniously with its surrounding natural environment.
Tai Po Sewage Treatment Works

Tai Po Sewage Treatment Works is located in the southeast of Tai Po Industrial Estate, and to the west of a defunct landfill. It provides sewage treatment services for a population of more than 300,000 in Tai Po District. The plant was commissioned in 1979 and was the first large-scale secondary sewage treatment works in Hong Kong. In the 1990s, the plant undertook improvement works to introduce nitrifying and denitrifying activated sludge systems to achieve a reduction of the total nitrogen level in the sewage by as much as 70%. To meet the rapid development in the District and more stringent effluent discharge standards, further expansion and upgrading works were completed in 2015 to increase the sewage treatment capacity from 90,000 cubic metres to 120,000 cubic metres per day. The improvement works included an ultraviolet disinfection system to improve the effluent quality. Digested sludge is dewatered by filter presses to reduce moisture content and volume before dispatch to the sludge treatment facility in T-PARK Tuen Mun.

The Government has commenced a pilot scheme in early 2019 to try out food waste/sewage sludge anaerobic co-digestion, under which Tai Po Sewage Treatment Works would receive a maximum of 50 tonnes of pre-treated food waste per day from Shuen Wan Leachate Pre-treatment Works for the trial. This co-digestion technology would help to raise the food waste treatment capability and biogas yield, which is a form of renewable energy, thus fulfilling the Turning Waste to Energy objective.

Shek Wu Hui Sewage Treatment Works

Shek Wu Hui Sewage Treatment Works commenced operation in 1984. It provides secondary treatment services for Sheung Shui, Fanling and areas in the vicinity. Today, the sewage treatment works adopts the activated sludge biological treatment process. The plant is designed for a sewage treatment capacity of 93,000 cubic metres per day. After treatment and ultraviolet disinfection, the effluent is discharged through Ng Tung River and Shenzhen River to Mai Po Inner Deep Bay. Along with the population growth and extension of the sewerage network to the unsewered areas, Shek Wu Hui Sewage Treatment Works is close to operate at its original designed capacity. To meet the increasing influent flow and to raise the effluent discharge quality, the DSD is undertaking expansion and upgrading works in Shek Wu Hui Sewage Treatment Works in stages. Advance engineering works for the expansion commenced in 2015 and expected to be completed by 2019. Upon completion, the sewage treatment capacity will be increased to 105,000 cubic metres per day. On
completion of the subsequent Main Works in 2034, Shek Wu Hui Effluent Polishing Plant will provide tertiary treatment standard with an ultimate designed treatment capacity of 190,000 cubic metres per day.

### Sewage pumping stations

Sewage from residential, industrial or commercial buildings in Hong Kong is normally conveyed to the sewage treatment works by gravity sewers. However, if the building is distant from the sewage treatment works or situated at difficult topography, sewage pumping station will be required to pump the sewage via rising mains to downstream sewage treatment works.

There are basically four types of sewage pumping stations in Hong Kong, namely, wet/dry well pumping stations, submersible pumping stations, screw pumping stations and vacuum pumping stations. Centrifugal pumps and screw pumps are two main types of pumps used.

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**Cheung Sha Wan Sewage Pumping Station**

The Cheung Sha Wan Sewage Pumping Station mainly handles wastewater collected in Sham Shui Po, Lai Chi Kok and Mei Foo. A total of ten sets of centrifugal sewage pumps are installed to convey sewage to the North West Kowloon Preliminary Treatment Works on Stonecutters Island via twin 2 metres diameter rising mains, which are the largest rising mains in Hong Kong. The pumping station has a maximum designed flow rate of 14.7 cubic metres per second. A 3.3 kilovolts high-voltage motor is installed to drive each high power centrifugal sewage pump. Compared with typical low-voltage system, the facility occupies less working space with higher energy-efficiency. The whole pumping system is automatically operated and performance of each sewage pump is monitored with sensors.

![3.3 kilovolts high-voltage centrifugal sewage pump in the Cheung Sha Wan Sewage Pumping Station](image)
Kwun Tong Intermediate Sewage Pumping Station

The Kwun Tong Intermediate Sewage Pumping Station (KTISPS) is another sewage pumping station in the town centre. Situated on Hoi Bun Road in Kwun Tong, and in the vicinity of Kwun Tong Public Pier, the pumping station has five sets of large-scale screw pumps with a maximum design flow of 9.2 cubic metres per second to convey wastewater collected from Kai Tak, Kowloon Bay and Kwun Tong to the Kwun Tong Preliminary Treatment Works for treatment. Keeping abreast with the neighbouring community development, the DSD infused landscaping and greening features into the KTISPS to make it integrate better with the community. Furthermore, the KTISPS is equipped with effective deodorisation system to eliminate the odour of wastewater, thereby mitigating its impact on the nearby environment.
Sewage pumping stations at Stonecutters Island Sewage Treatment Works

Under the Harbour Area Treatment Scheme (HATS), the Main Pumping Station No. 1 and the Main Pumping Station No. 2 at the Stonecutters Island Sewage Treatment Works are designed to lift the wastewater from the deep tunnels to the sedimentation tanks above ground for treatment. Both Main Pumping Stations are circular structures. The Main Pumping Station No. 1 is 50 metres in diameter and at a depth of 34 metres, while the Main Pumping Station No. 2 is 55 metres in diameter and at a depth of 40 metres. The latter is one of the largest underground sewage pumping stations in the world. Each Main Pumping Station is equipped with 8 giant centrifugal sewage pumps with four variable speed drives at the base level. Each pump is designed for a pump rate of 4 to 8 cubic metres per second, and when all pumps operate concurrently, they can achieve a maximum flow rate of 63.5 cubic metres per second. The two Main Pumping Stations are provided with automatic control systems to control all the peripheral preliminary treatment works under the HATS.

With the expansion of sewerage networks to cover remote unsewered areas, there is a need for better septicity and odour control for sewage pumping stations. When sewage remains in the sewerage for a period of time, chemical changes would take place and the sewage would release highly poisonous and corrosive hydrogen sulphide gas. To prevent sewage from becoming septic in the sewer and hence releasing of hydrogen sulphide, sewage pumping station design must adopt various preventive measures, including optimising the design of sewage collection systems, additions of oxygen or chemicals such as calcium nitrate. Besides, the DSD tackles the odour problem at source, for instance, by adding deodorising agents to the upstream systems, affixing covers to potential odourous facilities in sewage treatment works, installation of activated carbon systems, chemical scrubbers, as well as bio-filters for odour removal.
Moreover, to create a more pleasing surrounding environment, design of sewage pumping stations must also consider aesthetic appearance, odour and noise control, and landscaping works. Since 2006, construction or rehabilitation of above-ground buildings (including sewage pumping stations) by the department are required to consider aesthetically pleasing, greening and other related elements so that these buildings would be in harmony with the local environment.
Dealing with polluted flows in stormwater drains

Despite the expansion of the sewerage networks to collect wastewater discharged through proper means, a substantial quantity of wastewater was improperly disposed of and found their ways into the stormwater drainage systems. For example, sewerage outlets of some buildings were incorrectly connected to the public stormwater drainage systems in urban areas, and in the unsewered rural areas, sewage from village houses might go straight into nearby watercourses. In order to contain such pollution problem, the DSD has constructed a number of special facilities (including dry weather flow interceptors and inflatable rubber dams) to re-direct polluted flow from stormwater drainage systems back to the sewerage networks.

Dry weather flow interceptors

Dry weather flow interceptors intercept and divert polluted dry weather flows in stormwater drains to the sewerage systems, while allowing the stormwater drainage systems to accommodate the passage of high flows in rainy season. In general, the quantity of dry weather flow to be intercepted is controlled by adjusting the flow depth: flow below the control depth is discharged through the intercepting pipe into the sewerage system, while on rainy days, flow above the control depth is partly intercepted into the intercepting pipe and partly into the stormwater system downstream.
**Inflatable rubber dam**

Many of the drainage channels in the northern and northwestern New Territories are affected by the polluted tidal waters of Deep Bay. The DSD not only needs to deal with polluted flow from upstream in these drainage channels, but also has to resolve the nuisance caused by the backflow of polluted tidal water. To address this problem, an inflatable rubber dam was first installed at Yuen Long Main Nullah in 1992, and subsequently a few more were installed in other locations alike. During high tides, the dams are inflated to their full heights and shut off the polluted tidal water. When there are high stormwater flows from upstream, the dams are deflated and lowered to allow the passage of high flow to downstream. Dry Weather Flow Interceptors are provided as part of the inflatable dam system to redirect the polluted dry weather flow to the sewerage.

Inflatable dam at San Tin Eastern Main Drainage Channel near its confluence with Shenzhen River, the highest inflatable dam in Hong Kong with a 5 metres full height.
**Village sewerage**

The SMPs included implementation programmes to provide public sewerage to unsewered villages (commonly referred to as village sewerage) for collecting sewage from village houses for proper treatment and disposal as a long term solution to improve village environment and sanitary conditions in watercourses. Village houses in these areas generally use septic tanks and soakaway systems for sewage disposal. As the number of village houses increased, septic tanks and soakaway systems had shown increasing operation and maintenance problems, affecting the sanitary conditions and posing threats to public health.

Under the village sewerage projects, public sewerage networks are extended to the lot boundary of the village houses. Village house owners are then required to connect their own sewers to the public sewers in compliance with the Water Pollution Control (Sewerage) Regulation (Cap. 358, Laws of Hong Kong). Prior to any connection works by the villagers themselves, the DSD would provide technical advice to resolve any connection issues. For those villages where village sewerage works have been completed, the villagers should be delighted to share their experience on the improvement in both the environment and the quality of living, along with an appreciation of property value.

When planning for the village sewerage programmes, the DSD would systematically investigate those unsewered areas and consider the proposed extent of sewerage coverage, to ensure that it was both technically feasible and cost-effective to implement. For villages remote from the main sewerage, or incurring very costly sewage pumping facilities, or where the construction of the facilities would involve substantial land resumption, septic tank systems would remain as an acceptable sewage treatment option, as populations in these areas are usually small and its impact on the environment is often limited.

Village sewerage usually adopts gravity sewers for carrying wastewater. Yet, where topographic and site constraints prevail, sewage pumping stations and rising mains are constructed for wastewater conveyance. By the end of 2018, about 530 villages have been included in the village sewerage programme, among which about 240 villages are now served by public sewerage, and village sewerage in the remaining villages will be implemented according to the village sewerage programme in the coming decade.

When public sewers are extended to the lot boundary of the village houses, individual house owners are required to connect their own sewers to the public sewers.

Sewage pumping stations are constructed in some village sewerage projects to convey wastewater.
Village sewerage fosters noticeable improvement in the environmental and hygienic conditions of villages in the New Territories where they were not previously connected to public sewers.
Tolo Harbour Effluent Export Scheme

The Sha Tin and Tai Po New Town Developments in the 1980s have resulted in the population in the Tolo Harbour catchment area doubled from the previous 500,000 to 1 million in recent years. Due to the limited natural purification capacity of Tolo Harbour, the population growth inevitably affected its water quality with increasing red tide incidents. Besides, the original design of the Tai Po and Sha Tin Sewage Treatment Works on nutrient removal did not meet the prevailing higher effluent quality requirements. In the 1980s, the effluent from the sewage treatment works in Sha Tin and Tai Po were discharged into Tolo Harbour, and this had led to the increase of nitrogen loading in the water of the latter and the outbreak of red tides from time to time.

As problems related to water quality in Tolo Harbour came to surface, the Government immediately drew up a Tolo Harbour Action Plan in 1986 declaring Water Control Zone, introducing livestock waste control, livestock ban and sewerage first-aid measures. Public consultation was made and the plan was rolled out in the following year.

To reduce the nitrogen content in the effluent, the DSD has implemented a series of measures. First of all, in 1992, upgrading works were undertaken within the sewage treatment works to improve nutrient removal level. Secondly, the sewerage were extended to cover the unsewered rural areas, such that wastewater from these areas could be intercepted and diverted. The third was the implementation of Tolo Harbour Effluent Export Scheme in 1994. From 1995 to 1998, the biologically treated effluent from the Sha Tin and Tai Po Sewage Treatment Works was gradually diverted through a new effluent tunnel below the Kowloon Hills to Kai Tak Nullah (today renamed as Kai Tak River) for discharge into Victoria Harbour. The Tolo Harbour Effluent Export Scheme had helped to resolve the red tide problem in Tolo Harbour and had a side benefit of improving the water quality at Kai Tak River due to flushing by the transferred effluent.
The water quality in Tolo Harbour has been steadily restored to normal after completion of the Tolo Harbour Effluent Export Scheme works in the mid-1990s.

The major facilities of the Tolo Harbour Effluent Export Scheme are as follows:

Tai Po Effluent Export System — This comprises the Tai Po Effluent Pumping Station, a 500 metres long rising main and a 6 500 metres long submarine pipeline across Tolo Harbour to transport treated effluent from Tai Po Sewage Treatment Works to Sha Tin Sewage Treatment Works.

Sha Tin Effluent Export System — This comprises the Sha Tin Effluent Pumping Station and a 1 730 metres long twin pumping mains to transport the combined treated effluent from Tai Po and Sha Tin Sewage Treatment Works to the inlet of the effluent tunnel.

Effluent Tunnel System — Effluent from the two sewage treatment works is discharged by gravity from the Sha Tin Effluent Tunnel Portal, through a 3 metres diameter, 7.4 kilometres long tunnel, to the Terminal Access Shaft in Diamond Hill on Kowloon side, and subsequently to the downstream Kai Tak River and Victoria Harbour.
Overview

In 1989, following the recommendations in the White Paper: Pollution in Hong Kong — A Time to Act, the DSD was established to assume the great responsibilities for sewage treatment and stormwater drainage in Hong Kong.

In the same year, the Government formulated a long-term strategy and implemented the Sewerage Master Plans to meet the development needs. In accordance with the above Plans and the recommendations in the Review Studies on Sewerage Master Plans, the DSD designed and constructed sewage treatment works and facilities in various districts in stages, while improving the existing sewage treatment facilities and constructing village sewerage, with a view to increasing the sewage treatment capacity in various districts.

Water pollution in Tolo Harbour worsened in 1980s. The DSD then proposed expanding the sewage treatment works in the districts and diverting the effluent in stages from the treatment works via a newly-constructed drainage tunnel to Kai Tak Nullah for discharge into Victoria Harbour, which has higher purification capacity. From then onwards, the water quality of Tolo Harbour has been improving.

While the sewerage infrastructures in Hong Kong were being gradually enhanced, the Department should at the same time bear the yoke for flood prevention and control to safeguard the lives and property of the public.
Chapter 7: Flood Prevention

Confluence of two river channels
Since the DSD was established in 1989, the Government has allocated more resources on provision of flood prevention infrastructure. Although planning for the respective improvement works commenced before 1989, it took time to complete the works and the facilities only came into operation in succession after 1989. To date, the total capital investment for flood prevention in Hong Kong has amounted to HK$30 billion.

**When typhoon and rainstorm became a menace**

Despite that Hong Kong still experienced typhoon and rainstorm damage each year, the situation had improved since the establishment of the DSD. The flood prevention works have started to take the effect.

In its early years, apart from handling emergency repairs or undertaking quick-fix improvement works, the DSD had to implement inspection and preventive maintenance programmes for the drainage and sewerage assets and strategic planning for medium and long-term drainage and sewerage improvements. The DSD also set up an Emergency Control Centre and an Emergency and Storm Damage Organisation to attend to flood-related incidents during heavy rainstorms, and the subsequent follow-up, case studies and analyses. The Department also had a 24-hour hotline to receive public enquiries and flood reporting.

In addition, many natural watercourses in the New Territories lie within private land. In the past, some flood incidents were caused by the lack of maintenance of major watercourses in private land. The Government experienced great difficulties to obtain consent from private land owners so as to gain access to private land and to carry out maintenance works to the watercourses. To rectify the situation, the Government enacted the Land Drainage Ordinance in 1994, empowering the Government to gain access to private land for maintenance and removal of obstructions on those watercourses which are designated as main watercourses.

**Threats and casualties caused by severe rainstorms in 1989-2008**

In May 1989, Severe Tropical Storm Brenda swept across the Philippines and Mainland China, causing many casualties. As Brenda moved closer to Hong Kong, the Hong Kong Observatory hoisted the No. 8 Southeast Gale or Storm Signal on the afternoon of 20 May. During the storm, severe flooding occurred in the northern and northwestern parts of the New Territories, where areas from Sheung Shui to Yuen Long were submerged, and many pieces of agricultural land were inundated. Six people were reported dead and one missing. Brenda wreaked havoc and caused extensive damage in the northern and northwestern parts of the New Territories, underscoring the pressing need to improve the drainage systems in those areas. As a result, this issue was on the list of the priorities to be dealt with by the DSD after its establishment.
On 8 May 1992, a trough of low pressure hit Hong Kong. In the early hours, the weather deteriorated rapidly, with thunder rumbling, lightning flashing and rain pouring down. The Observatory recorded 109.9 millimetres of rainfall between 6:00 am and 7:00 am, the third highest hourly rainfall recorded between 1884 and 2017. Many streets across Hong Kong were seriously flooded and road traffic was paralysed. It happened that the Hong Kong Certificate of Education Examination was held on that day. Since the then Education Department had not made any appropriate announcement to cancel the examination, students needed to get to examination venues despite the heavy rain. Eventually, the heavy rain claimed five lives, including an engineer from the Hong Kong and Islands Division of the DSD, who was investigating a flooding case in Baguio Villa. This rainstorm disaster prompted the Observatory to launch a system of rainstorm warning signals categorised into four levels, namely “Green”, “Amber”, “Red” and “Black”.

It took the city by storm that on the first day rainstorm warning signal issued by the Observatory would necessarily soar to the highest “Black”. From 17 to 18 July 1992, Tropical Storm Faye slammed Hong Kong. In the early morning of July 18, the weather turned worse and the wind rapidly gathered force and increased to full gale. As strong winds and heavy rain became rampant, the Observatory issued the first Red and Black rainstorm warning signals on record. The heaviest rain fell in the north western part of the New Territories that more than 300 millimetres of rainfall was recorded on that day. When Hong Kong was hit head-on by Faye, 152 cases of flooding were reported. The storm also caused 2 deaths and 24 injuries.

The year 1993 was just another stormy and wet year. Within the year, a total of eight typhoons affected Hong Kong. Four times had the Observatory issued No. 8 Gale or Storm Signals. On 17 September, as Typhoon Becky was closing in, the Observatory swiftly issued No. 8 Northeast Gale or Storm Signal at midnight. A total of 223.9 millimetres of rain was recorded during the passage of Becky. Sheung Shui and San Tin in the New Territories were severely flooded. The storm brought 1 death and 130 injuries. At sea, 6 vessels sank leaving 11 people dead and about 70 missing. The menace of Typhoon Becky spread to the neighbouring Shenzhen. On 26 and 27 September, heavy downpour caused extensive flooding at almost every street corner. Depths of flood water along the roads in Lo Wu District reached 2 metres. Earlier in the year on 16 June, Shenzhen was already struck by another torrential rain. As flood disasters took their toll, Shenzhen suffered from heavy direct economic loss. Shenzhen and Hong Kong governments established a Joint Working Group and decided to expedite the implementation of the Stage I and Stage II of Shenzhen River Regulation.
In the following years, typhoons and rainstorms had exerted particularly severe impact on the northern part of the New Territories. Typhoon Sibyl ripped through Hong Kong on 3 October 1995, causing serious flooding in Sheung Shui, where 25 villagers were stranded in Yin Kong Tsuen. Firefighter had to rescue the villagers by dinghies. By 1997, heavy rainstorms tended to haunt more frequently in the urban areas. Heavy rains led to serious landslips on 3 August 1997. A landslide near Ching Cheung Road forced the closure of this trunk road for several weeks for emergency repairs. On the 22 of the same month, Typhoon Zita battered Hong Kong. Red rainstorm warning signal was issued. Mong Kok was flooded where knee-deep flood water at Nathan Road paralyzed traffic and forced many stores to close. In 1998, flooding continued to batter almost everywhere on Nathan Road and Boundary Street in Mong Kok.

In 1998, the Observatory had refined the rainstorm warning system and streamlined it into three tiers, i.e., “Amber”, “Red” and “Black”, which are still applied to-date.
In September 1999, Typhoon York caused 18 deaths in Manila and 25 in Zhuhai. The Hong Kong Observatory hoisted the Hurricane Signal No. 10 in the early morning of 16 September. During York’s passage in Hong Kong, one windsurfer was killed in Cheung Chau and another man died in Tseung Kwan O. More than 4,000 trees were uprooted. Over 400 window glass panes in the Wan Chai Government Offices Buildings were shattered, including the DSD’s offices on the 42nd to 44th floors of Revenue Tower.

In July 2001, it was unusual in Hong Kong that Gale or Storm Signal No. 8 was hoisted twice in two separate occasions in the same month. Typhoon Utor landed on 5 July, bringing 150 millimetres of rain to most parts of Hong Kong and more than 300 millimetres of rain to Lantau Island. A total of 25 cases of flooding were received by DSD. Storm surges caused severe flooding in many low-lying areas in Hong Kong, including Tai O, Lau Fau Shan and Sheung Wan. On 25 July, Typhoon Yutu struck Hong Kong, causing 10 injuries and numerous trees blown down.

On 16 July 2006, an active southwest monsoon brought heavy downpour and squally thunderstorms. The Observatory recorded 115.1 millimetres of rainfall within an hour between 2 a.m. and 3 a.m., the second highest hourly rainfall between 1884 and 2017 on record. Out of sheer luck, the rainstorm did not cause any serious damage.
At the end of May 2008, an active trough of low pressure affected the South China coastal areas and the northern part of South China Sea. Occasional heavy rain and squally thunderstorms persisted for the first seven days of the month. Around dawn on 7 June, torrential rain arrived in Hong Kong and focused on Lantau Island, Kowloon and Hong Kong Island. From 8:00 am to 9:00 am on that day, the Observatory recorded 145.5 millimetres of rainfall, the record-high one-hour rainfall since 1844. Floods and landslides triggered by heavy rains caused 2 deaths and 16 injuries.

The DSD received a total of 1,000 flooding cases on that day, the highest reported cases on record. Except two cases, all complaints were handled by noon of the day followed. With the full support of the Emergency Control Centre, the Direct Labour Force and the term contractors, the DSD was enabled to meet its performance pledges during such critical situations. Based on the experience on 7 June 2008, the Department thoroughly reviewed the Emergency and Storm Damage Organisation, re-allocated the resources and renovated the ancillary facilities at the Emergency Control Centre. The operation of the Emergency Control Centre will be described in Chapter 9 below.

On the morning of 7 June 2008, Hong Kong was wrecked by torrential rains and flooding. On the afternoon of that day, the then Secretary for Development Ms. Carrie Lam cordially visited the affected shop operators and residents in Wing Lok Street, Sheung Wan.

Torrential rain swept over Hong Kong on 7 June 2008 had caused debris flows onto the North Lantau Highway. Serious flooding followed. The DSD helped clear the devastated spots so that the carriageways could be opened to traffic as soon as possible.
Territorial Land Drainage and Flood Control Strategy Study — Phases I, II and III

A systematic solution to the drainage problem would necessitate a holistic flood control strategy. From 1988 to 1995, the Government commissioned the Territorial Land Drainage and Flood Control Strategy Study (TEL) — Phases I, II, and III to develop a comprehensive flood prevention strategy for the whole territory. The Study established flood protection standards for new drainage systems to withstand severe rainstorm events and overall flood control strategies for the New Territories. The DSD would formulate strategies to reflect the unique characteristics of each catchment area and to strike a balance between developments and engineering feasibility.

Drainage Master Plans and Review Studies

From 1994 to 2010, the DSD implemented eight Drainage Master Plan Studies and three Drainage Studies in phases to cover all flood-prone areas in Hong Kong:

- West Kowloon
- Yuen Long, Kam Tin, Ngau Tam Mei and Tin Shui Wai
- Northern Hong Kong Island
- Tsuen Wan, Kwai Chung and Tsing Yi
- Tuen Mun and Sham Tseng
- Northern New Territories

- Sha Tin and Tai Po
- Sai Kung, East Kowloon and South Lantau
- Southern Hong Kong Island
- Tseung Kwan O
- Ngong Ping

The Drainage Master Plans and Drainage Studies assessed the performance of existing drainage systems and recommended short-term and long-term drainage improvement measures to meet the current standards and future needs. According to the recommendations of TEL Phases I and II, computational hydrological and hydraulic models were widely used to evaluate the effectiveness of the proposed improvement measures. Computer model technology has advanced rapidly in the late 20th century and helped to secure more cost-effective solutions to flooding problems with more precise evaluations and prediction data.

The improvement works recommended under the Drainage Master Plans were very substantial, including the training of 120 kilometres of rivers and channels, and upgrading and construction of 130 kilometres of stormwater drains and drainage tunnels. By the late 2000s, the DSD completed the investigation, design and construction of most of the improvement works with the remaining in progress.

From 2008, the DSD had begun the Drainage Master Plan Review Studies to review the drainage capacity of the existing drainage systems and to propose improvement works to match with the latest development in the districts, effects of climate change and sustainable development. Review Studies on the Drainage Master Plans for Yuen Long, North District, Happy Valley and Kowloon have been completed, and those for Tai Po, Sha Tin and Sai Kung have been substantially completed, whereas Review Studies on Northern Hong Kong Island, Lantau Island and Outlying Islands, Tuen Mun, Tsuen Wan and Kwai Tsing, Repulse Bay and Tai Tam are in progress with Review Studies on the remaining areas in the planning stage.
Flood prevention in the New Territories

In the past, flooding was common in the New Territories, especially in the north and north western parts, due to their low-lying topography. In the 1980s and 1990s, flooding still occurred regularly in the New Territories, greatly affecting the daily life of the public.

In 1990, a year after its establishment, the DSD began constructing main drainage channels and local drainage improvement works to safeguard the life and property of villagers in low-lying areas in the North District. Flood prevention works in the New Territories can broadly be classified into two categories: drainage channels to collect and convey stormwater to the sea; and village flood protection schemes to protect villagers in low-lying areas from the threat of flooding.

Large-scale river training works in the New Territories

With extensive developments and changes in land use in the New Territories, improving the drainage capacities of existing rivers had become imminent. Drainage channels were no doubt the preferred option where the catchment areas were large in size, which could be aesthetically pleasant to blend with the natural surroundings.

In the past, some narrow and sinuous river sections in the New Territories were easily silted up. As a result, the flood plains along these old river sections were often threatened by flood of a depth of 1 metre to 1.5 metres. At that time, the river networks most in need of improvement works were scattered across the north and north western New Territories and Lam Tsuen River in Tai Po. The rivers in the north and north western New Territories basically belong to two major networks: 1) the Shenzhen River network including Ng Tung River, Sheung Yue River, Ping Yuen River etc., and 2) Yuen Long and Kam Tin Rivers network, both of which discharged into Deep Bay. The gradual completion of drainage channels and improvement works led to significant reduction of flooding risk in these regions.
Kam Tin River, Yuen Long

In early 1990s, the DSD began construction of new drainage channels to improve the drainage capacities of Kam Tin River and Shan Pui River. The DSD had subsequently awarded more than 10 construction contracts to regulate and train different river sections in the drainage networks. The lower reaches of the river channels in Yuen Long, Kam Tin and Ngau Tam Mei were completed in the late 1990s, and the upper tributaries were completed between 2002 and 2005. These drainage channel works had basically resolved the flooding problems in Kam Tin, Yuen Long and Tin Shui Wai areas.

Construction of Yuen Long Bypass Floodway started in early 2003 and was completed in 2006. At that time, the drainage network in Yuen Long Town was already under capacity. The above works had alleviated the flooding risk induced by the increased surface runoff due to urbanisation by diverting about 40% of the runoff away from Yuen Long Town through the bypass floodway to the downstream of Kam Tin River on the other side of the town. About 86 000 people benefited from this flood prevention project.

Although Kam Tin River was diverted and widened, the original river course was preserved to minimize the impact due to the drainage improvements on the ecological environment.

Yuen Long Bypass Floodway diverted part of the runoff from Yuen Long town centre to Kam Tin River east of Yuen Long to reduce the risk of flooding in the Yuen Long Town.
Ping Yuen River and Ng Tung River

Improvement of Shenzhen River in stages (information related to this project is contained in Chapter 8 below) has provided an opportunity to improve the tributary networks, including Ng Tung River, Sheung Yue River and Ping Yuen River. The works at Sheung Yue River and Ng Tung River were completed in 2002 and 2003 respectively. Since then, the Lo Wu, Tin Ping Shan, Ho Sheung Heung and Yin Kong areas were no longer suffered from flooding threats. The works at Ping Yuen River were completed in 2006, and the Shenzhen River Regulation Project Stage III was completed in the same year, relieving the flooding risk in Ta Kwu Ling.
Ho Chung River

Ho Chung River flows alongside Ho Chung Road and discharged to Hebe Haven. Owning to the rapid developments in Sai Kung, the surface runoff had increased significantly and the original Ho Chung River could not meet the flood protection standards. The DSD had based on the recommendations in the Drainage Master Plan and carried out improvement works in Ho Chung River to improve its drainage capacity and alleviate the flooding risks in the nearby areas. The project started in 2007 and was completed in 2009. The DSD had widened the river channel by setting back the southern river bank to relieve flood risks. In addition, new ecological conservation features were introduced to enrich the aquatic and riparian environment and thus enhancing the ecology of the river. The Ho Chung River improvement works have unfolded a new chapter in channel design and construction in respect of river ecology in Hong Kong.
Village flood protection scheme — the polder construction

When the DSD was established in 1989, the two major river networks, the Shenzhen River network and the Yuen Long & Kam Tin Rivers network, in the north and north western New Territories discharged into Deep Bay were most in need of improvement. Once these two major river networks were improved, the flood risks in the north and north western New Territories were significantly reduced. To complement to these major river training works, village flood protection schemes were implemented in some villages in the New Territories to protect these villages from flooding.

Notwithstanding the construction of major drainage channels in the New Territories, there were 35 villages in low-lying areas which would still be susceptible to flooding due to natural topography or constraints by existing developments. Without any improvement, if the water levels in the drainage channels downstream were not too high, runoff from these low-lying villages could flow by gravity into the drainage channels via underground drains or surface channels. In the event of high water level in the downstream channels during heavy rainstorms, however, the floodwater could not be discharged by gravity to the downstream channels but would flow back to the low-lying villages, where it would cause flooding and threaten lives and property. Village flood protection schemes were therefore required.
Village flood protection schemes address the flooding problem in the low-lying village areas by building a polder to prevent floodwater from entering the low-lying village areas, and draining the runoff from within the low-lying village areas to a flood storage pond and using pump to remove floodwater to outside of the polder.

To protect these flood-prone low-lying villages, the DSD has so far completed 27 village flood protection schemes, providing protection to 35 low-lying villages. The first polder was built in 1988 at Sik Kong Wai village in Tin Shui Wai. Other village flood protection schemes were subsequently completed providing flood protection to over 250 hectares of low-lying areas and rendering 31 000 people safe from the threat of flooding.
Multiple-solution approach — flood relief in Mong Kok

Repeated flooding in 1997 and 1998 in Mong Kok indicated an imminent flood problem. The DSD had implemented measures to raise the flow capacity of the drainage systems in West Kowloon. Apart from laying of 44 kilometres of underground drains using traditional method, the DSD had introduced new approaches of stormwater storage, flow interception and transfer to minimise trench excavations in this prominent commercial district in Kowloon.

The DSD began the drainage improvement works in Nathan Road first, and unprecedentedly, closed off Nathan Road between Lai Chi Kok Road and Boundary Street for traffic in two stages from October 1998, in a bid to shorten the construction period from 60 months to 19 months under such contentious temporary traffic arrangements. At the end, the project team had made a concerted effort to complete the works in less than a year, greatly lessening the inconvenience caused to the public by the works.
A section of Nathan Road was closed for a year in 1998 to facilitate the drainage improvement works.
The Tai Hang Tung Flood Storage Scheme included an underground flood storage tank with a capacity of 100,000 cubic metres at a depth of more than 10 metres underneath the Tai Hang Tung Recreation Ground, which would store excessive stormwater diverted from upstream under heavy rainstorm. When the heavy rainstorm had subsided, the stormwater in the flood storage tank would be pumped out to the downstream drainage system. This innovative flood storage scheme could attenuate the floodwater peak flows downstream, and reduce both the extent of drainage upgrading works in Mong Kok and the need for road excavation along heavily trafficked roads. The cost of the flood storage tank was HK$290 million, and the project was completed in 2004.

The Kai Tak Transfer Scheme utilised a 1.5-kilometre-long drainage tunnel of 4.4 metres inner diameter to intercept and transfer about 60% of the stormwater runoff from the existing nullah at the junction of Waterloo Road and Hereford Road in Kowloon Tong to the Kai Tak River in San Po Kong. The Kai Tak Transfer Scheme at a cost of about HK$380 million is the first drainage diversion tunnel system built in Hong Kong and is a vital part of the overall scheme to resolve the flooding problems in West Kowloon. The project was completed in 2004 summer. By diverting part of the stormwater runoff to Kai Tak River, the volume of stormwater flow entering the drainage system downstream in West Kowloon was reduced substantially.
Severe acute respiratory syndrome in 2003

From February to June 2003, a deadly acute respiratory syndrome (SARS) epidemic broke out in Hong Kong. A total of 1,755 cases were recorded, resulting in 299 deaths. The epidemic was the most severe in Hong Kong in recent years and caused far-reaching impacts on Hong Kong’s politics, economy and society. The epidemic spread rapidly all over the world, with SARS cases appearing in countries from Southeast Asia to Australia, Europe and North America. Hong Kong was listed as a SARS affected place by the World Health Organization (WHO) on 15 April and was not removed from the list until 23 June.

During the SARS outbreak, Hong Kong people fought against the epidemic and worked together to stop its spread. According to the analysis of the infection cases, the virus was likely to spread through the sewerage system in buildings, people-to-people contact and the use of large public facilities. At that time, the DSD fought side by side with other departments of healthcare, home affairs, environmental hygiene in Hong Kong to respond to and act on territory-wide anti-epidemic work.

After receiving real-time information of suspected SARS infection cases through a dedicated online e-SARS database, the DSD staff worked with the drainage maintenance contractors to undertake thorough cleansing of the public drains and sewers in the areas where the suspected cases were located to minimize any possibilities of wastewater overflow, entering private streets for emergency cleansing if necessary. Stringent guidelines on occupational safety and personal hygiene were adhered to by the staff and contractors. In particular, those direct labour force workers and staff in the sewage treatment works were urged to strictly abide by the guidelines and take safety as the top priority. In order to replace any defective sewer pipes as soon as possible for prompt improvement to the sanitary conditions, the DSD adopted the “complete first, pay later” approach to assist residents to replace their defective private sewer pipes in private streets or patios. Although the DSD was not responsible for maintenance of drains and sewers in private buildings, colleagues from its Mainland South Division and the Laboratory Services Sub-division still entered the quarantine area of Block E of Amoy Gardens in Ngau Tau Kok during the SARS period to assist clinical experts on epidemiological investigations. The epidemic eased slightly at the end of April and the WHO lifted travel advisory for Hong Kong on 23 May, and removed Hong Kong from the list of epidemic areas on 23 June, ending the 106-day epidemic.
Nullah decking

After experiencing the SARS, the public's awareness of epidemic prevention had generally increased, and they were paying more attention to the sanitary conditions of nullahs in urban areas. The public considered nullahs as unsightly, incongruous with the surrounding environment, and often used as open sewers, causing public health hazards. The Chief Executive announced in his 2005 Policy Address that the Government planned to deck over 16 nullahs in the next 10 years, of which 3 nullahs were located in Hong Kong, 6 in Kowloon and 7 in the New Territories. However, during public consultation, the public had different expectations for nullahs (details are set out in Chapter 9). Therefore, some of the 16 nullahs planned to be decked over in the Policy Address were improved by river revitalisation instead. By 2008, a total of 8 nullahs out of these 16 nullahs were either decked over or revitalised, including the first one completed at Mong Kok Road. Works for the other 4 nullahs were completed by 2011. Decking over or river revitalisation for the remaining nullahs, including the Wong Chuk Hang Road nullah which overlapped with the South Island Line (East), and the section of Kai Tak River near Sha Tin Pass Road, were completed in recent years. The land created by nullah decking was used for public purposes, such as greening, recreation or road widening.
Completion of the Fire Dragon Path above the Tai Hang Nullah between Tung Lo Wan Road and Causeway Bay Road in 2012 connotes the decking over of the entire Tai Hang nullah from Tai Hang Road to Causeway Bay Typhoon Shelter.

Jordan Valley Nullah in 1964

Tai Hang Nullah in Causeway Bay in 2000s

The decked area of Jordan Valley Nullah was developed into Choi Ha Road amenity area.
Flood monitoring and reporting system

In the 1990s severe flooding frequently occurred in the northern districts. To assist in flood control, the DSD had developed a Flood Monitoring and Reporting System in 1994 to monitor the flooding locations in Tin Shui Wai, Yuen Long, San Tin, Sheung Shui and Ta Kwu Ling.

Gauging stations

The Flood Monitoring and Reporting System comprises more than 100 automated gauging stations installed at river channels for 24-hour real-time water level measurements and collecting hydrological data including rainfall intensity and tide levels. The real-time hydraulic data are sent back to the DSD’s control centre through internet.

The officers on duty at the DSD’s control centre would quickly analyse any flooding situation, using this real-time hydrometric information, video images and the operational status of the gauging stations. When necessary, the DSD’s officers on duty would alert other departments, such as Hong Kong Police Force, Fire Services Department and the Home Affairs Department, to prepare for rescue, evacuation and the opening of flood shelters. At the same time, the drainage maintenance teams would be informed to take flood relief actions.
Hydrometric Information System

Besides its own gauging station networks, the DSD also obtains information on rainfall intensities and tide levels from the Observatory and the Civil Engineering and Development Department on other river basins through government network and transmits the information to the Hydrometric Information System. With the benefit of sufficient information, the DSD’s duty officers at the control centre can assess more accurately the flooding situation and make timely and appropriate responses to deal with the incidents.

As an interim measure before long-term drainage improvement projects in the New Territories are completed, the DSD has provided flood alarm system at flood-prone villages to inform the villagers when the floodwater reaches a predetermined alert level. The purpose of the flood alarm system is to alert villagers before flooding occurs, so that they have enough time to prepare evacuation or take preventive measures. In the past, flood alarm systems were installed at various locations. Following the completion of more than 100 kilometres of river channels and the commissioning of 27 village flood protection schemes, many villages no longer needed these flood alarm systems.

Overview

After the establishment of the DSD, the Government had invested substantially more resources on provision of flood prevention infrastructure. However, it took time to complete the works and Hong Kong was still threatened by severe rainstorms each year.

Completion of the major river training works and village flood protection schemes in the early 1990s had effectively protected the low-lying villages in the New Territories. In mid-1990s, the DSD adopted a new approach of stormwater storage, interception and transfer to tackle flooding problems. The first underground stormwater storage scheme in Hong Kong was then built in Tai Hang Tung to relieve the flooding threat in West Kowloon. Between 1994 and 2010, the DSD rolled out the Drainage Master Plans to improve drainage systems in various districts. In 2008, to take into account of climate change and the latest land developments, the DSD launched the Drainage Master Plan Review Studies to review the flood resilient abilities in different districts.
Different Courses
Same Dream
2009-2018
Part IV:
Accomplish Remarkable Achievement
2009–2018
Chapter 8: Arrival of World-class Infrastructure

Around 1970s, the Government focused on new town developments in the New Territories. Civil, electrical and mechanical engineering works under the Mass Transit Railway Modified Initial System were rolled out. Completion of the High Island Reservoir had secured stable supply of fresh water. The city developed rapidly but at the great expense of environmental pollution. Since the Victoria Harbour (the Harbour) had become very polluted, the Cross Harbour Swimming Race was suspended after the 66th Race held in 1978.

The Strategic Sewage Disposal Scheme (SSDS) (renamed as Harbour Area Treatment Scheme (HATS) in 2001) is the largest ever world-class environmental infrastructure project undertaken in Hong Kong. The construction works spanned over 20 years with a total expenditure amounting to HK$25.8 billion. In 1987, in an effort to improve the overall water quality of the Harbour, the government conducted the Sewage Strategy Study and drew up a blueprint in connection with the Harbour for collection, treatment and disposal of wastewater. This visionary scheme was to be carried out in several stages, aiming at building a centralised system to collect wastewater from the huge catchment areas on both sides of the Harbour and convey the wastewater to the newly built Stonecutters Island Sewage Treatment Works for proper treatment.

A key component of the Scheme was the construction of a deep sewage conveyance tunnel conveyance system on both sides of the Harbour. The wastewater would undergo preliminary treatment before entering the tunnel and conveyed to the Stonecutters Island Sewage Treatment Works for chemically enhanced primary treatment before discharge to the sea via a submarine outfall.

A total of 44 kilometres of deep sewage tunnels, with diameters ranging from 1.23 metres to 3.54 metres, have been formed at depths of up to 163 metres. There is a minimum of 30 metres of sound rock above the tunnel crown. The tunnel system was carefully planned to avoid road excavation and hence major traffic and social disruptions were minimised. The tunnel would not have any conflict with the MTR underground railways, major underground public utilities and foundations of existing buildings. The sewage tunnel system is designed to operate as an inverted siphon whereby the wastewater collected is conveyed from the preliminary sewage treatment works and discharged into the tunnels before pumping out at the downstream end to Stonecutters Island Sewage Treatment Works for treatment. This inverted siphon design significantly reduces the energy consumption for pumping.
In 1992, Stage I of the SSDS and the six related SMPs (including Chai Wan and Shau Kei Wan, Tseung Kwan O, the East Kowloon, North and South Kowloon, Northwest Kowloon and Tsuen Wan/Tsing Yi/Kwai Chung) were incorporated into the Sewage Services High Priority Programme.

**Strategic Sewage Disposal Scheme Project**

Works for SSDS Stage I took off in 1994, preluded by the construction of a chemically enhanced primary treatment (CEPT) plant on Stonecutters Island and a 90 metres deep and 1.7 kilometres long submarine outfall. All works were completed in 2001 and the Stage I system was commissioned and went into operation. It provides further purification for 75% of the preliminary treated sewage from both sides of the Harbour prior to discharge into the western side of the Harbour. Water quality in the Harbour was significantly improved.

Perched as a galaxy warrior’s helmet in the movies, this is one of the 24 protective domes now laid at deep sea bottom to protect the diffusers of the submarine outfalls at the Stonecutters Island Sewage Treatment Works from damage by ship anchors.
According to the original scheme in early 1990s, the SSDS Stage 1 would be as follows:

**Stage 1: Kowloon and Northeast Hong Kong Island Collection and Treatment System**

At a cost of HK$8.2 billion, Stage I works included the construction of a 23.6 kilometres long deep sewage conveyance tunnel system to transfer sewage from Kowloon stretching from Tsuen Wan to Tseung Kwan O, and from Chai Wan and Shau Kei Wan on Hong Kong Island to a new sewage treatment works on Stonecutters Island for chemically enhanced primary treatment before discharge to the western side of the Victoria Harbour. Stage I works would also include upgrading of the preliminary treatment works in Chai Wan, Shau Kei Wan, Tseung Kwan O, Kwun Tong, To Kwa Wan, Tsing Yi and Kwai Chung.

Construction of the deep tunnels started in early 1995, and several tunnel boring machines were deployed. Progress was hampered due to ground water ingress into the tunnel and contractual disputes with the contractor. The Government eventually forfeited the tunnelling contracts in December 1996 and re-awarded three tunnelling contracts in 1997. However, adverse geological conditions such as faults and weak ground continued to pose challenges to the tunnelling works. When faults or weak ground were encountered during tunnel excavation, stabilisation measures such as grouting and erection of temporary supports had to be taken before proceeding further.

Despite difficulties and challenges were encountered during construction, a major breakthrough was achieved with the boring through of the last tunnel section at the end of 2000, leading to the completion of the Stage 1 works in 2001. Since Stage 1 has come into full operation, the deep tunnel conveys about 1.7 million cubic metres of sewage to Stonecutters Island Sewage Treatment Works for treatment every day, thereby stopping the discharge of about 600 tonnes of sludge into the Harbour each day. The water quality in the central and eastern sides of the Harbour is greatly improved.
To sustain the water quality improvement in the Harbour, the Government commissioned an International Review Panel of local and overseas experts to review the planning of the remaining stages of SSDS in April 2000. In November of the same year, the Panel submitted its final report with four options for sewage treatment and discharge, all of these options recommending CEPT and Biological Aerated Filter treatment, deep sewage conveyance tunnel system and short outfall for disposal.

In 2001, the SSDS was renamed as HATS. In 2004, the Government conducted public consultation on the way forward for the project. The results reflected that the public were generally overwhelmed by the improvement of the water quality in the Harbour and supported the cleaning up of the Harbour in a step-wise but timely manner. Subsequently the Government decided to proceed with Stage 2 in 2 phases. The Stage 2A works would upgrade the preliminary treatment works on the northern and south western sides of Hong Kong Island and to convey sewage from these preliminary treatment works to Stonecutters Island, while the Stage 2B works would upgrade the Stonecutters Island Sewage Treatment Work to secondary biological treatment level.

**Stage 2A**

Stage 2A comprises the construction of a deep sewage tunnel system of about 21 kilometres long and from 70 metres to 163 metres below ground. The sewage from the preliminary treatment works on the northern and south western sides of Hong Kong Island would then be conveyed via deep sewage tunnels to the Stonecutters Island Sewage Treatment Works for centralised treatment. The CEPT capacity of the Stonecutters Island Sewage Treatment Works would be expanded from the original design level of 1.7 million cubic metres to 2.45 million cubic metres per day. The sewage conveyed and treated under Stage 2A of HATS is about 25% of the sewage collected from the urban areas around the Harbour.
During the Stage 1 deep sewage tunnel construction, the project team was relatively inexperienced to handle massive ingress of groundwater into the excavated tunnel and had reluctantly accepted to postpone the construction completion dates. Equipped with the experience from Stage I, for Stage 2A works the DSD decided to adopt high-pressure grouting and drill-and-blast method (including pre-excavation grouting, drilling holes on rock face to be filled with explosives, blasting and rubble removal) in lieu of tunnel boring machines. This method provides more working space at the excavation surface for temporary supports and for carrying out pre-grouting, and allowing more flexibilities on controlling groundwater ingress. The drill-and-blast method enables larger sizes of rocks be excavated, which are recycled as building materials after screening and sorting. A tunnel section between Ap Lei Chau and Aberdeen was constructed by horizontal directional drilling due to its smaller diameter.

In addition to the construction of deep sewage tunnel network, the Stage 2A works entail upgrading the CEPT capacity and the disinfection facilities of the Stonecutters Island Sewage Treatment Works in anticipation of the increased sewage flow and further water quality improvement.

After arriving at the Stonecutters Island Sewage Treatment Works, the sewage would undergo CEPT process by adding ferric chloride and polymer in the sedimentation tanks. The Stonecutters Island Sewage Treatment Works adopt double-decked sedimentation tanks to reduce the footprint area. No doubt the Stonecutters Island Sewage Treatment Works is regarded as one of the leading treatment works in the world, considering its footprint of only 10 hectares (about half the size of Victoria Park) but serving more than 5.7 million people.

After sedimentation, the treated effluent would enter a new effluent tunnel for disinfection using sodium hypochlorite solution to remove pathogens. Sodium bisulphite would then be added to the effluent to remove any residual chlorine before the effluent is discharged into the western side of the Harbour via the submarine outfalls.
In addition, Stage 2A works included upgrading the facilities at eight existing Preliminary Treatment Works at North Point, Wan Chai East, Central, Sandy Bay, Cyberport, Wah Fu, Aberdeen and Ap Lei Chau that had been operated for more than 20 years. After upgrading, solids and grits from the preliminary treatment works would be prevented from entering the deep sewage tunnel to protect downstream treatment facilities.

Stage 2A works commenced in 2009 and were completed and commissioned in 2015. It costs HK$17.5 billion, and together with Stage 1, can treat 2.45 million cubic metres of sewage per day, and intercept 1,200 tonnes of sludge daily which would otherwise be discharged into the sea and causing pollution to the Harbour. Commissioning of HATS Stage 2A has further improved the water quality of the Harbour. The Dissolved Oxygen of the seawater is increased by 13%, whereas 70% of Biochemical Oxygen Demand, 80% of Suspended Solids and more than 99% of E. coli are removed from the treated effluent before discharge to the Harbour.

The successful restoration of the water quality of the Harbour following the full commissioning of HATS Stage 2A has led to the long-awaited resumption of Cross-harbour Swimming Race in 2011 and re-opening of Tsuen Wan beaches.
Stage 2B

Stage 2B includes a proposed additional underground biological treatment facility adjacent to the Stonecutters Island Sewage Treatment Works to treat all the effluent of Stages 1 and 2A. The Government will study and monitor the water quality of the Harbour and keep abreast of the latest developments in biological treatment technology and reviewing the timing and need of Stage 2B.

The HATS is gradually rewarded with tangible results. The Hong Kong Amateur Swimming Association resumed the Cross-harbour Race in the eastern waters of the Harbour in 2011 and since 2017, returned to the legendary cross-harbour race route between Tsim Sha Tsui Public Pier and Golden Bauhinia Square.

The HATS is honoured with multi-award winning in China and overseas. After being elected as one of the ten Hong Kong People Engineering Wonders in the 21st Century organised by the Hong Kong Institution of Engineers in 2013, in June 2018 the HATS was awarded the Tien-yow Jeme Civil Engineering Prize under the Municipal Engineering Category to recognise the outstanding achievements of HATS in scientific and technological innovation and application. The HATS was also awarded the 2018 Edmund Hambly Medal by the Institution of Civil Engineers in the United Kingdom for the outstanding achievements of the HATS in sustainable development.

The HATS is honoured with Edmund Hambly Medal from the Institution of Civil Engineers

The HATS is gradually rewarded with tangible results. The Hong Kong Amateur Swimming Association resumed the Cross-harbour Race in the eastern waters of the Harbour in 2011 and since 2017, returned to the legendary cross-harbour race route between Tsim Sha Tsui Public Pier and Golden Bauhinia Square.
Over 44 kilometres of deep sewage tunnels weaved between both sides of the Harbour. Full commissioning of HATS has substantially resolved the long endured water pollution in Victoria Harbour.
Regulation of Shenzhen River

The effectiveness of the flood prevention works in the northern New Territories depends on the drainage capacity of the middle stream and downstream of Shenzhen River. Therefore, regulation of Shenzhen River is of upmost importance.

Originating from Lin Ma Hang near Pak Kung Au, Shenzhen River meanders south-westward into Deep Bay. The Shenzhen River is 27.5 kilometres long and has a catchment area of 313 square kilometres, with 60% of the catchment area falling in Shenzhen and 40% within Hong Kong. The original river channel of Shenzhen River was narrow. The average width was 15 metres at the upstream, 40 to 45 metres at the middle stream and 140 metres in the estuary. The main tributaries are Shawan River, Buji River and Futian River in Shenzhen, and Ping Yuen River, and Ng Tung River in Hong Kong.
In the past Shenzhen River was narrow and meandering and affected by tidal, which restricted its drainage capacity. Whenever heavy rainstorm hit the upstream catchments, the peak flow would quickly reach the urban areas of Shenzhen city and the northern New Territories of Hong Kong, causing flood damages on both sides of the river.

Over the years, the natural land on both sides of the Shenzhen River was replaced by paved areas causing deterioration in water infiltration. Soil erosion further reduced the drainage capacity of the river to a degree that the river could only be capable of handling rainstorm runoff of not more than a return period of 2 years.

In 1982, the Shenzhen Municipal People's Government and the Hong Kong Government established a Joint Working Group to jointly regulate the Shenzhen River. In April 1985, the Joint Working Group completed a report that detailed solutions to solve the flooding problem. Both sides had established a phased implementation plan to regulate Shenzhen River.

In the aftermath of Severe Tropical Storm Becky, which struck Hong Kong on 17 September 1993, Shenzhen River in the vicinity of Lo Wu and Ng Tung River were seriously flooded.
Section of Shenzhen River at Liu Pok downstream of the Lo Wu Control Point after river regulation to widen and straighten the river section
The Shenzhen River Regulation Project was planned to be implemented in four stages, to realign, widen and deepen about 18 kilometres of the middle stream and downstream of the existing river. According to the plan, the middle stream and the estuary of Shenzhen River would be widened to 80 metres and 210 metres respectively, while the hydraulic capacity would be increased from 600 cubic metres per second to 2 100 cubic metres per second. The flood protection standard will be substantially improved from 2 years return period to 50 years return period.

The Shenzhen River Regulation Project was one of the DSD’s key projects to address the flooding problem in northern New Territories. At that time, the channel improvement works at the upper stream of Ng Tung River and Ping Yuen River were in full swing and hopefully would enable a completion date in tandem with that of the Shenzhen River Regulation Project, thus yielding a final solution to solve the flood threat in the northern New Territories.

On 11 May 1995, the representatives of the Shenzhen Municipal and Hong Kong governments formally signed an agreement on the regulation works. Stage 1 was wholly entrusted to Shenzhen Municipal government, though the cost would be shared by both parties. Yet, the overall project was supervised and monitored by the Joint Working Group. As a key member of the Joint Working Group representing Hong Kong, the DSD was responsible for vetting technical and contractual details and coordination among all parties.
Stage 1

The major works included straightening of the river bends at Liu Pok and Lok Ma Chau, river channel widening and deepening, river bed protection under the Lo Wu railway bridge, excavation of the Lecky Pass, a flood control gate at Futian, new river embankments and landscaping works. Stage 1 works were substantially completed in April 1997. It was the first time that the Shenzhen Municipal and Hong Kong governments conducted a joint tendering exercise for the Shenzhen River Regulation project. Tender process was administered in compliance with the international practices, including open tendering, publication of tender notices on newspapers and prequalification assessments. After stringent prequalification and tendering exercises, 10 out of the 43 potential contractors were selected for bidding the Stage 1 tender.

Completion of Stage 1 of Shenzhen River Regulation Project in April 1997 was followed by commencement of other cross-border infrastructure projects.

Stage 2

While construction of the Stage 1 works was underway, planning for Stage 2 commenced concurrently. The Stage 2 works started in November 1996 and was completed in June 2000. The works involved widening, deepening and realignment of two sections of the river channel, from Buji River estuary to Futian River estuary, and from Huanggang Bridge to the estuary of Deep Bay. A total of 6.4 kilometres of new channels were built. The river channel at Lo Wu was widened to 105 metres and the estuary of Deep Bay was widened to 210 metres. Stage 2 works also included provisions of 5.8 hectares of mangroves on the south bank and 3 hectares in the Futian Mangrove Nature Reserve. Though two flood events occurred during Stage 2 construction, the flood menace was considered as less serious, compared with the condition prior to the project, as water levels during the floods remained low and flood water receded quickly. This showed that Stage 1 and 2 works have improved the drainage capacity of Shenzhen River.
Stage 3

After the completion of Stage 2, the DSD and the Shenzhen River Regulation Office immediately began the Stage 3 project to regulate approximately 4 kilometres of the upper stream of Shenzhen River, from the Ping Yuen River estuary to the Ng Tung River estuary at Lo Wu. Apart from river widening and deepening, embankment construction, and habitat conservation at river meanders, the Stage 3 works also covered more complicated works such as reconstruction of existing railway bridge, road bridges and footbridge and diversion of Dongjiang water pipes.

A great challenge in Stage 3 was to dismantle the former Lo Wu railway bridge and rebuild a new bridge at the original site. The picture depicts the instance when the first train was speeding across the temporary railway bridge.

A glimpse of Shenzhen River at Lo Wu Control Point after Stage 3 works. The span of the new Lo Wu railway bridge extended from 32 meters to 40 meters.

Cloud glowing at dusk over Shenzhen River and the glory of sunset filling both sides of the border river.
A glimpse of Shenzhen River at Lo Wu Control Point after Stage 3 works. The span of the new Lo Wu railway bridge was extended from 32 metres to 40 metres.
Stage 4

On completion of Stages 1 to 3 of the Project, the 18-kilometre long Shenzhen River was transformed to a straighter and wider 13.5-kilometre long river channel.

In August 2013, the Shenzhen Municipal government and Hong Kong government officially kicked off Stage 4 of Shenzhen River Regulation Project that involved the regulation of about 4.5-kilometre section at the upstream of Shenzhen River from its confluence with Ping Yuen River to Pak Fu Shan. Besides raising the flood prevention standard of Shenzhen River, the Stage 4 works have incorporated ecological conservation elements into the design to enhance the ecological values of the river.

The design has abandoned the conventional approach by straightening, and instead followed the original river profile and meandering features as far as possible. Ecological conservation and environmental protection elements were adopted in the river training works (including use of ecological bank protection, river side greening and preservation of natural riverbed), to reduce downstream sedimentation. With the dry weather flow interception, pollution to the river was reduced.

The meanders of the Shenzhen River were preserved to maintain the natural river and riparian habitats for the growth of fauna and flora. A 22 000 square metres of ecological flood retention lake with a storage capacity of 80 000 cubic metres was built at the largest meander. During heavy rainstorms, water would enter the flood retention lake through overflow weirs and return to the river through control gates when the water level in the river is lower than the flood retention lake, and as a result the peak flows downstream would be attenuated.

Spanning almost four decades and implemented in four stages, the Shenzhen River Regulation Project witnessed the seamless collaboration between the Shenzhen and Hong Kong governments. Upon completion of the Project, remarkable results were achieved. The boundary river also saw the tremendous changes and development on both sides of the river in the past 40 years. With Stage 4 of the Project fully commissioned in 2018, the Shenzhen River with its completely new look will continue to serve the places it intends to protect, nurturing more lives and ushering in even greater development.
Flood prevention strategy in urban area

Hong Kong has a complex topography. During the rainy seasons between April and October each year, sudden torrential rains may occur at times, which pose great challenges for flood prevention. The DSD has adopted a three-pronged flood prevention strategy, that is stormwater interception at upstream, stormwater storage at mid-stream and drainage improvement at downstream. A number of flood prevention projects have been implemented to solve flooding problems in urban areas, including stormwater storage schemes and drainage tunnels. These flood prevention works are complementary with each other for the most efficient and effective means to protect the urban areas from flooding threats.

Stormwater storage and interception schemes

Stormwater storage is a common approach to temporarily retain storm flow from upland catchment in order to attenuate the peak runoff loading on the downstream drainage system.

In Hong Kong, urban development is gradually moving to the upstream portion of the catchment and there is a need to improve the capacity of downstream drainage systems. Stormwater storage scheme facilitates effective flood control and helps to alleviate the burden to the downstream drainage system.

Sheung Wan Stormwater Storage Scheme

As mentioned in Chapter 7, the Tai Hang Tung Stormwater Storage Scheme commissioned in 2004 is the first underground stormwater storage scheme in Hong Kong. The second underground stormwater storage scheme was built in 2009 by the harbour front at the former Sheung Wan Gala Point site.

More than 10 hectares of land around Wing Lok Street in Sheung Wan on Hong Kong Island is low-lying. The lowest ground level is only 2.64 metres above the principal datum, barely above the sea level. At times of high tides coinciding with rainstorms, the drainage system would be under capacity and floods usually followed. Between 2001 and 2008, there had been five serious flooding incidents in this low-lying area, with flood depth reaching as much as 1.5 metres.

To resolve the flooding problem in Sheung Wan, the DSD constructed the Sheung Wan Stormwater Storage Scheme and the Queen's Road Central Intercepting Drains using the stormwater interception and storage approaches.

The Sheung Wan Stormwater Storage Scheme has a capacity of 9 000 cubic metres (equivalent to about four standard swimming pools) at a project cost of about HK$ 200 million.

A diversion chamber is built near to the outfall with penstocks to stop seawater backflow at high tides and to divert the stormwater from the upstream low-lying areas to the storage tank during rainstorms for storage before discharging it to the harbour.
While construction of the Sheung Wan Stormwater Storage Scheme was on-going, intercepting drains were being laid along Queen's Road Central to intercept the surface runoff from the Mid-levels catchment. The stormwater entering the low-lying area drainage system is reduced by about 30%.

The project raises the flood protection level in the Sheung Wan low-lying area to withstand rainstorms of a return period of 1 in 50 years.

To meet the public expectation, the project team endeavoured to design the pump house with minimum footprint and building height in order to reduce the visual barrier to the harbour. Electrical and mechanical facilities and pipe works are housed centrally underground and covered by multipart covers. An area of 320 square metres at the ground floor is created for public Tai Chi exercise area and recreational amenities. On top of the pump house is the first green roof built by the DSD. Above the underground storage tank at the ground level, a 5700 square metres of public open space is created with facilities such as waterfront promenade and pet garden. The footprint of the above ground structure of the pump house occupies only 7% of the total public open space area.

In 2010, Sheung Wan Stormwater Storage Scheme was honoured with the Structural Excellence Award by the Hong Kong Institution of Engineers and the Institution of Structural Engineers in the United Kingdom.
The Happy Valley Underground Stormwater Storage Scheme (HVUSSS)

In the past, a number of severe flooding incidents occurred at Wan Chai and Happy Valley during heavy rainstorms. In these densely populated urban areas, to improve the drainage systems by extensive upsizing of existing underground drains with conventional open-cut methods would have great impact to the local residents and shop operators and would be difficult to proceed due to congested underground utilities. Moreover, extreme rainstorms, rising sea level and rapid urbanisation, all continue to lead to the increase of stormwater runoff and further burden to the drainage system. Therefore, an innovative, viable and effective solution to the flooding problem is essential.

The HVUSSS would temporarily store part of the runoff from the upstream catchment during heavy rainstorms and attenuated the peak flow through the downstream drainage system. Stages 1 and 2 works were completed and operation commenced in 2015 and 2017 respectively. The storage scheme has a capacity of 60 000 cubic
metres, which is equivalent to 24 standard swimming pools. The maximum pump rate of the pump house reaches 1.5 cubic metres per second. Since its commissioning, the storage scheme has proved its effectiveness many times during rainstorms and typhoons that Happy Valley and its adjoining areas are at last safeguarded from flooding threat.

The HVUSSS was the first flood storage scheme in Hong Kong equipped with a movable overflow weir system with a Supervisory Control and Data Acquisition (SCADA) system. This design effectively reduces the construction cost and time while saving power for operation. It fulfills the dual purposes of flood prevention and environmental protection. Compared to the conventional fixed weir design, this movable overflow weir system is controlled based on real-time tidal levels, water levels inside the storage tank and in the box culvert upstream and downstream of the storage tank. The operation system maximises the effectiveness of the flood storage tank and reduces the required design tank volume.

In addition, a mound is formed on the top of the pump house by turfing which acts as heat insulation for the pumping station below and provides a viewing platform for the public to enjoy the panoramic view of the Happy Valley Recreation Ground.

On Sau Road Underground Stormwater Storage Scheme
The underground stormwater storage tank beneath On Sau Road in Kwun Tong is the latest underground stormwater storage scheme in Hong Kong, and it came into operation in 2018 for storing stormwater during heavy rain so as to reduce the flood risk downstream. Football fields and recreational facilities are to be provided on the top of the underground storage tank for public use as a realisation of land co-use concept.

The On Sau Road Underground Stormwater Storage Scheme with a capacity of 18 000 cubic metres. Situated on a higher ground, the storage tank allows the stored stormwater to drain away by gravity without the need for pumping.
Drainage tunnels

The Kai Tak Transfer Scheme introduced in Chapter 6 was the first drainage tunnel built in Hong Kong. In the 2000s, the DSD planned and built another three drainage tunnels in Tsuen Wan, Lai Chi Kok and Hong Kong Island West respectively. These three drainage tunnels were completed between 2012 and 2013. They are located at mid-hill to intercept surface runoff from uplands for discharge into the sea, bypassing the densely populated urban areas downstream. These tunnels are like a silent shield to protect the downstream areas from flooding.

Tsuen Wan Drainage Tunnel

The drainage systems in Tsuen Wan and Kwai Chung had been in place for over 30 years. Due to rapid urbanisation, the runoff had significantly increased, resulting in flooding during severe rainstorms. In May 1997, for example, several rainstorms caused flooding, extensive damage, power failure and landslip in many areas of the Tsuen Wan and Kwai Chung districts. The Tsuen Wan Drainage Tunnel would definitely provide a long-term flood prevention solution for the area.

The Tsuen Wan Drainage Tunnel is 5.1 kilometres long and 6.5 metres in diameter, running westward from the junction of Shing Mun Road and Wo Yi Hop Road in Kwai Chung, to the south of Yau Kam Tau in Tsuen Wan. The runoff collected from the upstream catchment is discharged through an outfall near Yau Kam Tau to the Rambler Channel, thereby alleviating the burden on the downstream drainage systems and obviating the need to carry out extensive pipe upgrading works in busy roads of Tsuen Wan and Kwai Chung.
Construction of the intake shaft for the drainage tunnel

Buffer walls adjacent to the sea side of the outfall at Yau Kam Tau for modulating the speed of the collected stormwater to reduce the impact on seabed.

The intake at Tso Kung Tam was situated at a natural stream. Natural boulders and boulder-like concrete units were used to construct the buffers for blending with the natural environment.

Although Tsuen Wan Drainage Tunnel only has three intakes, its catchment area of 1,370 hectares is the largest among the four drainage tunnels. Its maximum flow rate of 223 cubic metres per second, which is capable of filling up a standard Olympic swimming pool in 11 seconds, is again the highest among all drainage tunnels. With such flow rate, the tunnel is well capable of intercepting the surface runoff from uphill catchment for discharging to the sea almost instantly.

To balance between ecology and flood relief objective, all intakes along the tunnel are designed to intercept surface runoff from natural streams only when rainstorm warning is in force. This will ensure adequate water flow to be maintained in the existing downstream drainage systems.
Lai Chi Kok Drainage Tunnel

The Lai Chi Kok Drainage Tunnel is located in the Northwest Kowloon, formed by a 2.5-kilometre long branch tunnel at mid-levels along Ching Cheung Road, a 1.2-kilometre long main tunnel running underneath Lai Chi Kok urban area, a stilling basin between the main tunnel and the branch tunnel and an outfall at Stonecutters Island. The tunnel provides a flood relief measure for the flood-prone urban areas in Lai Chi Kok, Cheung Sha Wan and Sham Shui Po. Construction commenced in November 2008 and the facility was commissioned in October 2012.

The Lai Chi Kok Drainage Tunnel is the only drainage tunnel in Hong Kong where high pressure tunnelling technology was applied in its construction. The technology was used to prevent infiltration of groundwater and erosion, and to reduce the impact on adjacent foundations and underground facilities. The main tunnel is located 45 metres below ground in an urban reclamation area. The geology is mainly soft ground, mixed boulders and debris. The tunnel was constructed in close proximity to major transport infrastructure including four railways in operation, the Express Rail Link under construction and the pile-foundations of highway viaducts.

Hong Kong West Drainage Tunnel

The northern part of Hong Kong Island had long been under the flooding threat in the past. To resolve the flooding problem, a stormwater interception approach is adopted by construction of a drainage tunnel to intercept surface runoff in the mid-hill for discharge to the sea near Cyberport.
The Hong Kong West Drainage Tunnel project includes 34 intakes to intercept the existing drains and streams. Surface runoff intercepted is discharged via dropshafts, adits and the main tunnel to the sea. Most of the intake dropshafts were built by the Raise Boring Method. Under the Raise Boring Method, a reverse drilling rig was erected at the ground surface of the shaft with a smaller reamer affixed to the drill rod to drill a smaller diameter pilot hole downwards from the ground to the tunnel. When this pilot hole is formed, the smaller reamer would be removed and replaced by a large diameter reaming head. The drilling would then be reversed by excavating upward to the ground surface, forming a large diameter dropshaft. All excavated spoils during downward or reverse drilling would fall to the adit and then carried away through the tunnel. Raise boring offers several advantages over the conventional shaft excavation from top to bottom including less construction vehicles on the road for spoil haulage, and reduced environmental nuisances.
The Hong Kong West Drainage Tunnel project made several breakthroughs in design and construction, and overcame many challenges. The project earned international recognitions, including the prestigious title of Tunnelling Project of the Year 2011 at the International Tunnelling Awards organised by British engineering magazines New Civil Engineer and Ground Engineering, and the second runner up of the Hong Kong People Engineering Wonders in the 21st Century organised by the Hong Kong Institution of Engineers.
Threat and damage by severe rainstorm from 2009 to 2018

Into the third decade since the founding of the DSD, severe typhoons and rainstorms continued to hit Hong Kong each year. Flood protection projects completed and commissioned during the years have garnered results in raising the flood protection levels in flood-prone areas. From 1995 to 2018, a total of 125 flooding blackspots were eliminated, reducing the number of flooding blackspots to six. Drainage improvement works for the remaining flooding blackspots have either been completed and under monitoring, or in various stages of planning and implementation. The accomplishment on flood prevention works by the DSD over the past 30 years is evident. Yet, Hong Kong is still under the menace of severe weather and rainstorms stemming from climate change.

In July 2010, unstable weather with heavy rain and thunderstorms affected Hong Kong when Tropical Storm Chanthu was approaching. On 22 July, the Observatory issued the Amber Rainstorm Warning and changed to Red Rainstorm Warning followed by the Black Rainstorm Warning in less than an hour (4:35 pm to 5:30 pm) during the afternoon rush hours. Rainfall exceeded 150 millimetres in many places within 3 hours and caused serious flooding and traffic standstill in major roads. A flash flood swept past Sha Po Tsai Village at Wun Yiu, Tai Po, claiming one life. When the tragedy occurred, the DSD was undertaking river training works at Sha Po Tsai Village. After the incident, the DSD conducted an investigation into the causes of this incident. An internationally renowned hydraulics expert was also appointed to conduct an independent review of the DSD’s investigation report on the causes of flooding.

In 2014, Hong Kong experienced heavy rain and thunderstorms as in previous years. Showers and thunderstorms affected Hong Kong on 29 March, and became even more intense on the evening of 30 March. Over a period of 3 to 4 hours, more than 100 millimetres of rainfall were recorded in Kowloon and the New Territories. Rainfall in Yuen Long, Tuen Mun, Tsuen Wan and Sha Tin exceeded 150 millimetres. Black Rainstorm Warning was issued at 8:40 p.m., the first time in March since the Rainstorm Warning System commenced operation in 1992. Squalls and thunderstorms mixed with hail struck many locations in Hong Kong. During the period, the DSD received 29 reports of flooding cases, including a case related to flooding at a large shopping mall in Kowloon Tong due to ceiling leakage after damage by falling hailstones.

After the devastation by torrential rain on 22 July 2010, Sha Po Tsai Village in Tai Po was left with muds and boulders.
On 24 May 2017, heavy showers and squally thunderstorms swept through Hong Kong when a tropical depression affected the coast of Guangdong. The Observatory issued the first Black Rainstorm Warning that year. Rainfall exceeded 300 millimetres in Kwai Tsing and Sham Shui Po. During the period, the DSD received 19 reports of flooding cases. At Princess Margaret Road near Oi Man Estate, the flood depth was up to 400 millimetres. At Shau Kei Wan Main Street East, a taxi was stranded at a depressed area which caught much media attention.

On 23 August 2017, Super Typhoon Hato headed direct to Hong Kong. The Observatory issued the Gale or Storm Signals No. 8 and No. 9, and then Hurricane Signal No. 10, all within 4 hours. Hato caused storm surges of about 1.2 metres higher than normal which coincided with the astronomical high tide. The sea level at Quarry Bay reached a maximum of 3.57 metres above Chart Datum. Severe sea water flooding and damage occurred in many low-lying areas, such as Heng Fa Chuen, Lei Yue Mun and Tai O. Flooding in Tai O was reported to be more damaging than that of Hagupit in 2008. The Heng Fa Chuen promenade was inundated, with sea water filling up a nearby underground car park. On 27th and 28th of the same month, rain and squalls associated with the outer rainband north of Typhoon Pakhar affected the city. The Observatory issued Amber Rainstorm Warnings on two consecutive mornings. More than 250 millimetres of rainfall were recorded in most parts of Hong Kong, and 16 reports of flooding cases were received by the DSD within the period.

Typhoon Mangkhut registered the most extreme overall wind intensity in 35 years, second only to Typhoon Ellen in 1983. National Meteorological Information Center of CMA, Macao Meteorological and Geophysical Bureau and Hong Kong Observatory joined forces for the first time to devise precautionary measures.

The Hong Kong Observatory seldomly issues a Tropical Cyclone Warning Standby Signal No. 1 so much in advance as in the case when the fast-moving Typhoon Mangkhut was still 1,110 kilometres away. It is even rarer to issue Hurricane Signal No.10 for more than 10 hours such as that during the passage of Mangkhut, the second longest duration of Signal No. 10 since World War II, and next only to the record of 11 hours during the passage of Typhoon York in 1999. It was the first time in 56 years that the Observatory had issued Hurricane Signal No. 10 for two consecutive years. The passage of Mangkhut, which was characterised by its extensive circulation, violent winds, fast moving speed, record-breaking storm surges and the severe and widespread impacts, must have been engraved in the memories of many Hong Kong people in the years to come, just as Super Typhoon Wanda did in 1962.

Tropical cyclones cause storm surges as well as torrential rains. In September 2018, Super Typhoon Mangkhut hit direct at Hong Kong and has become the strongest storm ever threatening the city.

Downpours on 19 July 2017 caused muddy flood water overflowing from Shan Liu River at Ting Kok Tsuen, Tai Po and gushing into the villages.
During the passage of Mangkhut, the DSD received 47 reports of flooding. Storm surge had caused serious damage to low-lying and coastal areas. The sea level of Quarry Bay rose to a maximum of 3.88 metres above Chart Datum. The storm surges recorded were up to 2.35 metres, surpassing the previous record high of 1.77 metres set by Wanda in 1962. At Tai Po Kau in Tolo Harbour, a maximum water level of 4.71 metres above Chart Datum and a record high storm surge of 3.40 metres were recorded. More than 100 millimetres of rainfall were recorded over most parts of the territory on that day, and exceeded 200 millimetres in some places. Sai Kung, Heng Fa Chuen and Tseung Kwan O South were devastatingly battered by huge waves. Structures along seafront facing southeast suffered different levels of damage. Huge overtopping waves and roaring seawater backflow caused serious flooding in the side streets in Heng Fa Chuen and the nearby Shing Tai Road, with flood water more than 300 millimetres deep. Sai Kung Town including the seawall and revetment in Tui Min Hoi and Sai Kung Sewage Treatment Works, sustained widespread damage. Over 60 000 trees were reported fallen. The typhoon also caused unstable power supply in some of the DSD sewage and flood control facilities. Thanks to the tireless effort of the emergency response teams in gearing up the precautionary measures and speedy recovery of facilities after the storm, the operation of malfunctioned flood protection facilities and sewerage works had resumed normal within the shortest possible period.

Low-lying coastal areas such as Tai O and Lei Yue Mun are prone to flooding when storm surge coincides with heavy rainfall. However, the DSD has learnt the lesson from Typhoon Hato in 2017. In 2018, resources were deployed much in advance of the approach of Mangkhut on installing demountable flood barriers, stacking up sand bags and other temporary flood protection measures in Tai O and Lei Yue Mun in order to mitigate the effects due to seawater backflow and storm surges. These precautionary measures turned out to be very effective in protecting these areas from the record high storm surges during the passage of Mangkhut.

For districts which were used to be susceptible to flooding during heavy rain (including West Kowloon, Happy Valley, Sheung Wan, Tsuen Wan and Northern New Territories), they have been spared from flooding in recent years, which have demonstrated the effectiveness of flood prevention works by the department.

Extreme weather including super typhoons will become more frequent under climatic change. The DSD will sum up the experience from Super Typhoon Mangkhut and adopt more forward-looking, more innovative mindset and more advanced technologies to improve the city’s flood resilience and to implement sustainable flood prevention measures.

Demountable flood barriers have been installed in Tai O Creek along the river wall since 2014.

The low-lying village houses in Tai O effectively protected by demountable flood barriers installed along the river wall at times of high storm surges.
Overview

Since its establishment, the DSD has completed a number of large-scale drainage and sewerage infrastructures, some of which were very challenging and fraught with difficulties.

HATS is the largest world-class environmental infrastructure project ever built in Hong Kong. With Stage 1 and Stage 2A works commissioned in 2001 and 2015 respectively, the water pollution problem in the Harbour was thoroughly solved. The Cross-harbour Swimming Race resumed in 2011 and returned to its legendary route in Central Harbour in 2017.

The Shenzhen River Regulation Project is one of the vital components of flood prevention networks in the northern New Territories. Upon completion of the first three stages of the Regulation Project, the flood protection capacity of the Shenzhen River has been greatly enhanced. Commenced in 2013, Stage IV of the Regulation Project covering the upstream section of the Shenzhen River was infused with a number of ecological conservation designs. The Shenzhen River Regulation Project witnessed the seamless collaboration between the governments of Shenzhen and Hong Kong in regulating the boundary river with remarkable results.

Following the commissioning of its second underground stormwater storage scheme at the waterfront of Sheung Wan, the DSD completed the Happy Valley Underground Stormwater Storage Scheme in 2015. In that project, the Movable Weir and Supervisory Control and Data Acquisition System with low energy consumption were adopted for the first time in Hong Kong to meet the dual objectives of flood prevention and environmental protection.

Having entered the 21st century, the DSD has constructed three drainage tunnels in Tsuen Wan, Lai Chi Kok and Hong Kong West respectively, thereby further improving the flood protection capacity of the urban areas. The notable success of the underground stormwater storage schemes and drainage interception tunnels testifies to the effectiveness of the DSD’s three-pronged flood prevention strategy, i.e. stormwater interception at upstream, flood storage at mid-stream and drainage improvement at downstream.

The DSD’s Direct Labour Force worked painstakingly during adverse weather to clear drainage blockages so that traffic could resume normal as soon as possible.
Chapter 9: Maintenance and Revitalisation for Sustainability

Adapting to climate change

Drainage and sewerage infrastructure and services in Hong Kong have kept up with the development of the city to evolve from primitive in the mid-to-late 19th century to international standard, reliable and trustworthy in the 21st century. The DSD has worked to the public expectations of wastewater treatment and stormwater drainage, and yet, we are confronting with the long-term challenges tossed by climatic change. The community as a whole must stay alert and be prepared.

Human activities are impacting the climate system, resulted in more frequent occurrences of extreme weather events. According to the Hong Kong Observatory’s records, the average temperature in Hong Kong has increased by 0.18°C every 10 years for the 30 years between 1988 and 2017. On the morning of 18 May 2018, the Observatory issued a Very Hot Weather Warning, which was in force for 348 hours till the evening of 1 June, a record since its introduction in 2000. On 16 September of the same year, record-breaking storm surges were triggered by Super Typhoon Mangkhut that most areas in Hong Kong were hazarded by severe floods. The maximum storm surges exceeded the records set by Typhoon Wanda in 1962 and Hope in 1979.

To combat the drastic challenges of climatic change and to ensure proper operation of its drainage and sewerage facilities, the DSD has to revive experience and knowledge acquired over past years on the development of drainage services and to upkeep all facilities through proper maintenance, enhancement, revitalisation, adoption of innovative technologies and sustainable designs with public engagement for providing quality services to the community.

Management and maintenance of drainage and sewerage systems

Before the DSD was established in 1989, management and maintenance of drainage and sewage treatment systems (including sewage treatment works and sewage pumping stations) were shared among the former Civil Engineering Services Department, Electrical and Mechanical Services Department, Architectural Services Department and Highways Department. These functions were gradually taken up by the DSD.
In 1998, a new Buildings and Civil Maintenance (BCM) Team was formed under the Hong Kong and Islands Division to take over the building and civil engineering maintenance for sewage treatment systems from Architectural Services Department for more efficient maintenance. Today, the BCM Team has also assumed the maintenance for drainage tunnels and underground stormwater storage schemes.

With sewage services covering nearly 94% of Hong Kong’s population, it is imperative that each process of the sewerage system, namely, in the wastewater collection, conveyance and treatment functions properly to safeguard the environmental hygiene. On full commissioning of the HATS, the burdens on maintenance have inevitably increased.

Today, the DSD carries out preventive inspection and cleansing to sewers and drains, and preventive maintenance works in accordance with the preventive programmes. The internal conditions and structural integrities of sewers and drains are inspected by closed-circuit television surveys regularly. During dry seasons, the DSD will carry out routine inspection and maintenance for storm water pumps and the ancillary facilities.

**Servicing and maintenance of sewage treatment facilities**

To ensure the effective operation of sewage treatment facilities, the DSD has carried out regular maintenance and repair works, and has adopted measures for continual improvement in the operation performance and treatment standards, including timely upgrading, renewal, and regular maintenance of the plant facilities to reduce the risk of plant breakdown. Contingency plans for all facilities are established for possible emergency situations.

At the same time, the DSD has introduced different computer systems and operation platforms for supporting the sewage treatment facilities, such as Management Information System (MIS) and the Maintenance Management Systems (MMS), and the Sewage Treatment Operations and Maintenance Management Information System (STOMMIS) that combines the MIS and MMS. The STOMMIS allows the DSD staff to
monitor unmanned plants in remote sites from a Regional Control Centre, and to collect real-time data for computer analysis, reporting and formulating E&M equipment maintenance schedules. In addition, the system has an automatic alert function, which sends out real-time alert messages to mobile phones so that the DSD staff can quickly attend to any plant equipment performance problems.

There is no doubt that the wider use of information technology systems has resulted in more effective operation of sewage treatment facilities and higher flexibility in resources deployment, which helps the department to deliver more cost-effective and quality sewage services.
The DSD has incorporated energy conservation and emission reduction measures in its maintenance work. For instance, water collected at the Lai Chi Kok Drainage Tunnel stilling basin area is filtered and disinfected, and supplied to the Butterfly Valley Road pet garden for irrigation, toilet flushing and pipe cleansing. The DSD is in the process of acquiring more advanced high pressure water jetting units with water recycling system to capture and recycle jetting water, and hence reducing water usage.

The DSD generates about 480 tonnes of yard waste each year from river channel maintenance. Since the composting facility at the North District Drainage Maintenance Depot commenced operation in 2017, the department has begun to turn the yard waste to compost materials for use in the greening areas in the plants, instead of disposing the yard waste to landfill.
Dye test for the submarine outfall in Sha Tin Sewage Treatment Works. Non-toxic dye rose to the water surface at the diffuser locations.

The DSD completed digitization of all drainage records as early as 1996. In 2002, the Automated Mapping/Facilities Management (AM/FM) System was launched to form a central database for the drainage records. Starting from 2016, the public can gain access to the DSD’s drainage records through the Lands Department’s Geographic Information System as well as by visiting the Drawing Offices in DSD Operations and Maintenance Divisions.

Effluent from sewage treatment works is discharged to the receiving waters via submarine outfalls. In 2018, the DSD operates a total of 42 submarine outfalls and two effluent tunnels. Regular inspection and maintenance of the submarine outfalls are necessary. Among all methods for inspection, dye test is the one most commonly used. Preventive inspection and maintenance for submarine outfalls include underwater inspection, hydrological and sonar survey, flushing and desilting.
Laboratory services

To ensure that treated sewage meets the statutory requirements, laboratory services for sewage treatment were set up in the sewage treatment works in Sha Tin, Tai Po, Sai Kung, Shek Wu Hui and Yuen Long before the DSD was established to conduct water and sludge sampling and testing.

To enhance the efficiency in coping with the mounting workload, in 2004 the DSD transferred the testing services to the new Sha Tin Central Laboratory at Sha Tin Sewage Treatment Works for processing centrally. In 2018, Sha Tin Central Laboratory has been accredited under the Hong Kong Laboratory Accreditation Scheme (HOKLAS) for 32 laboratory tests, including *E. Coli* count in disinfected effluent, while the Stonecutters Island Laboratory at Stonecutters Island Sewage Treatment Works has gained accreditation for 7 tests in the same year. Other smaller laboratories in sewage treatment works also provide laboratory testing services for individual sewage treatment works. The Laboratory Services Sub-division conducted more than 266 000 analyses in 2017, providing important analytical data to enable monitoring of the performance of wastewater and sludge treatment processes and ensure that the effluent quality meets the Discharge License Conditions set by the EPD.
In order to raise the efficiency of sewage treatment analytical testing, the DSD is committed to the automation of the laboratory work flow for its laboratory services as a long-term goal. The DSD is the first department in Hong Kong to adopt the Laboratory Information Management System (LIMS) to facilitate the consolidation of laboratory results and operation data, and a major upgrading of the System was carried out in 2011. Automated information management reduces staff resources required for processing the operation data with higher precision and improved efficiency. The updated and past laboratory test reports and analytical results can be quickly retrieved from DSD Intranet at any time and at any outpost stations. The LIMS has greatly improved the efficiency on management of the sewage and sludge treatment process in each sewage treatment works.

In 2016, a biochemical oxygen demand automatic analyser was installed in the Sha Tin Central Laboratory which is capable of processing more than 100 samples simultaneously. In the following year, the DSD purchased an inductively coupled plasma-optical emission spectrometer, which has further improved the performance on detecting heavy metals in sewage and sludge samples.
Management of underground drainage and sewerage networks

In 2018, the DSD managed more than 4,100 kilometres of underground sewers and stormwater drains, of which more than 1,800 kilometres have been in use for 30 years or more. Aging and wearing have been found in many sewers and drains. As mentioned in previous section, the DSD has scheduled regular inspections and monitoring on the conditions of the pipelines and carried out rehabilitation works as and when necessary. In 2016–17, the DSD rehabilitated 22 kilometres of sewers and drains at a cost of about HK$138 million. Since 2017, the DSD has implemented a territory-wide rehabilitation programme for the aged sewers and drains using risk-based approach. It is anticipated that the DSD will seek funding approval in the range of hundreds of millions dollars each year on condition survey and rehabilitation of high risk underground pipes in phases. At the same time, the Department endeavours to explore and adopt advanced technologies on the repairs and rehabilitation of underground pipes for achieving greater cost-effectiveness of the works.

On pipe rehabilitation, the DSD would employ insitu internal lining method as an alternative to excavation and pipe replacement. This technique is especially suitable for pipes laid below heavily trafficked roads or for those pipes with slight damage. In situ internal lining method was invented in early 1970s and introduced to Hong Kong in mid-1980s, initially for repairing defective sewers due to settlement and is now widely used to rehabilitate aged pipes. In general, internal lining works can be completed within 12 hours. Below are some common insitu internal lining methods used by the DSD.

Cured-in-place pipe lining

Glass fibre is a common material used in cured-in-place pipe lining method. The liner is first cut to the length of the pipeline under repair, and then impregnated with resin, pulled or pushed into the pipe through a manhole, and then expanded tight-fit against the pipe wall by water, compressed air or steam. The liner is then cured, by hot water or steam, for four or five hours until it hardens. A new curing method is to use ultraviolet lamp, which has shorter curing time compared with hot water or steam curing.
Fiberglass reinforced pipe (FRP) slip-lining

The FRP slip-lining method uses fiberglass reinforced pipe of diameter slightly smaller than that of the original pipe so that it can be pulled or pushed into the original pipe, and the annular space between the slip-lined pipe and the original pipe is filled with cement or chemical grouting. Temporary flow diversion during lining works is not necessary, which makes this lining method very suitable for sewers with high flow.

Steel-reinforced polyethylene strip is slowly wound by a winding machine and fed into the underground pipe from a manhole to form pipe lining.

A slip-lined pipe formed inside the original pipe

The project team is inspecting the spiral pipe liner wound by the winding machine

Spiral wound pipe rehabilitation

Spiral wound pipe lining is a new pipe rehabilitation method. Steel reinforced polyethylene strips are mechanically wound by a special winding machine to form a complete slip-lined pipe within the original pipe. The annular space between the slip-lined pipe and the original pipe is then grouted. Temporary flow diversion is not necessary, but the cost is relatively high.

Hydraulic jack is used to push the fiberglass reinforced pipe into the underground pipe under repair

Steel-reinforced polyethylene strip is slowly wound by a winding machine and fed into the underground pipe from a manhole to form pipe lining.
Emergency and Direct Labour Force

Emergency Control Centre

When the Water Supplies Department Kowloon West Regional Building at Lai Hong Street in Cheung Sha Wan was completed in 2001, the DSD relocated its Emergency Control Centre (ECC) from Kowloon Government Offices in Yau Ma Tei to this new building.

During severe weather condition or emergency requiring DSD’s action, the DSD will activate the ECC. The duty staff drawn from the divisions under the Emergency and Storm Damage Organization (ESDO) will attend the ECC. The ECC will liaise with other government emergency organisations to deal with drainage related complaints and assign emergency work to DSD’s Calls Coordination Centre, where the Direct Labour Force (DLF) or the maintenance term contractor’s teams would be deployed to deal with the adverse situations on site if required. During adverse weather, the contractor’s teams will station in flood-prone areas to expedite responses to any flooding incidents. In 2017, the DSD received a total of 37,000 calls for assistance, mostly related to drainage blockages or flooding.

The advance in technology in the past 30 years has transformed the communication equipment used in the ECC from radio broadcasting, fixed-line telephone, fax machine, and pager to wall-mounted multi-screen, desktop computer, Internet, and smart phone at present. As mentioned in Chapter 7 above, on 7 June 2008 the ECC received a record high of more than 1,000 reports of complaint cases, which well exceeded its handling capacity. To improve the flood relief services to the public, the DSD refurbished the ECC and restructured the ESDO in 2008. The DSD also joins forces with 1823 Call Centre of the Efficiency Unit to help the DSD receive and respond to emergency calls under critical circumstances. Needless to say, the DSD will continue to improve their service in keeping up with public expectations.

Direct Labour Force

The DSD took over the former Sewer Gang Section from the Highways Department and set up its own DLF after its establishment. The DLF consists of a number of sewer gangs to handle pipe blockage cases. After arriving at the location, the sewer gang will first use portable tools for clearing blockages. If the blockage problem persists, a high pressure water jetting unit will be deployed on site. The high pressure water jetting unit is equipped with a high pressure hose and other drain clearance equipment which can normally flush away the blockage to restore the flow conditions of the sewer or drain. For unresolved blockages or repeated complaint cases, the DLF will refer them to the district engineers for follow-up investigation.
Harnessing renewable energy

The DSD operates over 300 flood control and sewage treatment facilities, which operate round the clock and consume a lot of energy. The electricity consumption of the DSD constitutes about 10% of overall electricity consumption of government departments. Therefore, the DSD has constantly explored opportunities on enhancement of energy management and emission control at different facilities through raising energy efficiency and wider use of renewable energy. To take forward the initiative, the DSD has conducted extensive research, developed and adopted various technologies, including reuse of effluent and effective use of biogas produced by sludge, turning waste into usable resources.

The DSD has also commissioned consultants to carry out research and development projects, such as anaerobic co-digestion, enhanced production of biogas and biogas-powered fuel cells. Among these, solar power and biogas are the most extensively used renewable energy sources in the department.
Solar energy

Over the years, the DSD has installed in its major facilities solar water heaters, photovoltaic (PV) panels and hybrid lamp posts equipped with solar panel and mini wind turbine for energy conservation. Standalone and grid-connected photovoltaic (PV) systems are installed to provide electricity for the plant equipment in its major facilities, including the sewage treatment works at Sha Tin, Sham Tseng, Yuen Long, Sai Kung, Shek Wu Hui, Siu Ho Wan, Sandy Bay and Stonecutters Island. These PV systems are usually mounted on the roofs or the walls to capture the solar energy. The following is an introduction on one of the largest solar farms in Hong Kong at the Siu Ho Wan Sewage Treatment Works.
When commissioned in 2016, the solar farm at the Siu Ho Wan Sewage Treatment Works was the largest PV system in Hong Kong at that time, with more than 4 200 polycrystalline silicon solar photovoltaic panels and total generation capacity of 1 100 kilowatts. The renewable energy generated can meet about one fifth of the current annual electricity demand of the Siu Ho Wan Sewage Treatment Works, equivalent to annual electricity consumption of 230 households. The electricity generated is fed through an internal power distribution network to various facilities inside the treatment works, such as screening facilities, a workshop, an administration building, sludge treatment facilities and an ultra-violet disinfection system, which results in the reduction of 770 tonnes of carbon dioxide emission per year.

The installation of the Solar Farm costs about HK$27 million. The Solar Farm works commenced in February 2015 and was completed in December of the following year. The Solar Farm has an intelligent detection system to enable speedy detection and identification of any faulty panel out of the 4 200 no. of PV panel.

A Paper on the Solar Farm at the Siu Ho Wan Sewage Treatment Works received the Hong Kong Institution of Engineers — Certificate of Merit of 2017 Environmental Paper Award and the CarbonCare® Label 2016 from CarbonCare InnoLab.

Biogas

Biogas is a by-product of anaerobic digestion process. It is produced after sewage sludge is digested and decomposed by anaerobic microorganisms in the absence of oxygen. Biogas is a mixture of gas, containing about 65% methane. It is a renewable energy source and can be used as a fuel for dual-fuel (biogas and diesel) generators, boilers and combined heat and power (CHP) system in power and/or heat generation. The heat generated is used for maintaining the optimum temperate of the digesters for anaerobic digestion of sludge.

The DSD has adopted the anaerobic digestion process for treatment of sludge at its four major secondary sewage treatment works in Sha Tin, Tai Po, Shek Wu Hui and Yuen Long. The biogas produced in the last few years at Sha Tin Sewage Treatment Works, for instance, has met nearly 40% of its energy demand.
The Tai Po Sewage Treatment Works uses biogas as fuel to supply heat and electricity to the power generation system. These generators are large capital investments as each generator costs more than a few million dollars, depending on its capacity.

By 2019, there are a total of six CHP generators at the sewage treatment works in Sha Tin, Tai Po and Shek Wu Hui. The first biogas-powered micro-turbine generator in Hong Kong, installed at the Yuen Long Sewage Treatment Works, has been in used for power generation since 2013.
Energy saving and emission reduction

The DSD has been committed to developing and using new sewage treatment technologies and equipment to save energy and reduce emission. High-efficiency pump motors and variable speed drives for sewage pumping and sludge dewatering, light emitting diode lamps and magnetic bearing high speed turbo blowers in aeration system are among the energy saving equipment that have been adopted for use in recent years. Ultra-fine bubble air diffusion system is also adopted for use in bioreactor for its higher oxygen transfer efficiency and improved energy effectiveness for aeration. Through monitoring the pressure of the air diffuser and various operation parameters, cleaning frequency for the air diffusion system could be optimized for better energy utilisation.

Furthermore, energy consumption of sewage treatment facilities can be reduced through enhancement of the control system. Oxygen demand for aeration fluctuates according to different seasons and different water temperatures. The smart aeration control system on trial use at Shek Wu Hui Sewage Treatment Works is able to monitor the ammonia and residual dissolved oxygen levels in the aeration basin and automatically adjust the total air supply to avoid over aeration and thus saving in energy consumption. On the other hand, using the novel variable speed blower technology combined with inlet guide vanes and variable outlet diffuser would further improve the energy efficiency of the aeration system during the biological treatment process.

Compact coagulation — flocculation — sedimentation technology

The DSD has adopted the innovative compact coagulation — flocculation — sedimentation technology when Pillar Point Sewage Treatment Works was upgraded in 2014 from preliminary treatment to chemically-enhanced primary treatment with UV disinfection. This technology is a combined physical-chemical settling system to remove scum and solid substances in the sewage, offering advantages such as rapid system start-up, shortening the treatment time, and smaller footprint. This technology involves an innovative and proprietary system and therefore joint-venture partnering with its proprietary manufacturer is necessary for its implementation.
Sponge City for adapting to climatic change

Over the past 30 years, the DSD has moved forth into a new era of drainage sustainability — water body revitalisation through adoption of the Sponge City concept.

Sponge City refers to a city that resembles a sponge in response to flooding threats and adaptable to environmental changes and natural disasters. During rainy days, a Sponge City absorbs, stores and purifies stormwater through natural means, and releases the stored rainwater to enhance the ecological function of the city and reduce flood risk. Sponge City is a modern urban stormwater management strategy that advocates reduction of urban impervious pavement to lessen the demand of large-scale flood prevention engineering works.

In recent years, the DSD has adopted the Sponge City concept and actively promoted Blue-Green Infrastructure to create more aesthetically pleasing and liveable spaces. For instance, green roofs, porous pavement, bio-swales, rain garden etc. are incorporated in DSD’s facilities to improve filtration and reduce surface runoff. Recreational facilities with stormwater storage function, such as riverside parks and flood attenuation lakes, are planned to collect and store the stormwater. The stored stormwater can be purified through natural means and used as city water supply. Thus, Sponge City concept provides a sustainable solution to lower the burdens on the drainage systems, transforming the city with greener and healthier urban spaces while enhancing the flood resilience level of the city.

Chapter 8 has illustrated some of the DSD’s “flood interception and flood storage” projects. Other engineering works that have adopted the “Sponge City” concept are described below.

Blue-Green Infrastructure

In the light of increasing public concern on environmental protection in recent years, environmental and ecological considerations have to be taken into account in drainage projects so as to preserve the natural profile, landscape and ecological value of natural rivers and streams. In 2005, The DSD compiled a Practice Note “Guidelines on Environmental Considerations for River Channel Design”. Drainage improvement works at Ma Wat River, Ho Chung River, River Silver of Pak Ngan Heung in Mui Wo, and Lam Tsuen River were designed in accordance with such guidelines, as well as in compliance with the Environmental Impact Assessment Ordinance.

Black-faced Spoonbills and Little Egrets wading on the mudflats of Shan Pui River. The Mai Po Ramsar Site at Shan Pui River estuary is designated as a Wetland of International Importance.
The Yuen Long Main Nullah built in the 1960s and 1970s were designed for fast flood relief. Aesthetic or ecological factors were secondary considerations.
The term “Blue” used in “Blue-Green Infrastructure” represents water bodies in the city and “Green” refers to plants. The synthesis of “Blue”, “Green” and “Infrastructure” exhibits an urban drainage network that integrates natural environment, local characteristics and contemporary functions.

The 2015 Policy Address promulgates that in large-scale drainage improvement works and planning drainage networks for New Development Areas, the concept of revitalisation of water body should be adopted. In this regard, the DSD, through incorporation of the “Blue-Green Infrastructure” concept, while enhancing the flood prevention capacity, would build a greener, healthier and cleaner environment with ecosystems, luxuriant vegetation and beautiful waterscape so that the public will have more opportunities to get closer to the water bodies of maximised biodiversity for learning to cherish natural resources. In 2015, the DSD updated the above Practice Note to “Guidelines on Environmental and Ecological Considerations for River Channel Design”, with new contents covering Blue-Green Infrastructure, river greening and ecological design.

The 2017 Policy Agenda proposes to review and evaluate the revitalisation potential of all major nullahs in Hong Kong, and identify suitable nullahs for revitalisation so as to enhance their ecological value and provide a greener environment for the community. In 2018, the DSD has completed the review and evaluation, and developed revitalisation schemes for Tai Wai Nullah, Fo Tan Nullah and Jordan Valley Nullah. Through the revitalisation, a better living environment will be created for the public to cherish the natural beautification, biodiversity and water friendliness.
Water management and sustainable drainage system

Global water resources are increasingly scarce. The DSD proactively studies and develops sustainable water resources on rainwater harvesting and use of reclaimed water. Later in this chapter there is an introduction to the proposed Inter-Reservoir Transfer Scheme to transfer the collected runoff from the Kowloon group of reservoirs to Lower Shing Mun Reservoir, yielding additional 3.4 million cubic metres of fresh water each year while achieving flood prevention objective. Firstly, below is a brief introduction to water harvesting in sewerage and drainage facilities of the DSD.

Happy Valley Underground Stormwater Storage Scheme

Happy Valley Underground Stormwater Storage Scheme is the first project in Hong Kong to apply the leading edge hydraulic mathematical modelling for more precise flood control design, further lowering the construction cost and time, and the operation power consumption, fulfilling dual purposes of flood protection and environmental protection.

The DSD has constructed a water harvesting system under the Happy Valley Underground Stormwater Storage Scheme to recover groundwater through the sub-soil drainage system, which after purification is used for irrigation, cleaning and toilet flushing in the adjacent Happy Valley Recreation Ground.

Kowloon City Sewage Pumping Stations

The Kowloon City Sewage Pumping Stations No.1 and No.2 adjacent to the Kai Tak Development have adopted sustainable design and created an oasis in the city. There are many green elements used in these two pumping stations, such as permeable pavement, vertical greening, green roof and rain garden, providing a green area of 4 300 square metres. The pumping stations are also provided with water harvesting systems to collect rainwater for irrigation. The green roofs also feature unique landscaping design by growing plants of different colours and textures to create vivid geometric patterns of high aesthetic and visual values.

The Kowloon City Sewage Pumping Station No.1 was commissioned in 2012. It is the first government infrastructure to be bestowed the highest BEAM Plus Final Platinum rating for New Buildings in 2016.
Uses of reclaimed water

Use of reclaimed water is part of the total water management. At present, the DSD applies sewage purification technologies to further purify the secondary treated effluent to produce reclaimed water for non-potable uses.

Since 2006, the DSD and the EPD have been conducting tests to verify the purification process and applications of reclaimed water, at the Ngong Ping Sewage Treatment Works in Lantau Island and the Shek Wu Hui Sewage Treatment Works in Sheung Shui to purify and reuse the treated effluent for public toilet flushing and garden irrigation.

In the DSD, the water reclamation facility at Sha Tin Sewage Treatment Works is relatively large-scale. The facility is capable of producing 1,000 cubic metres of reclaimed water per day for irrigation, toilet flushing and chemical dilution at the plant.

It is the first time that the DSD uses pressure exchanger energy-saving technology in the reverse osmosis membrane facility for this water reclamation system, which results in power saving of 20% of the whole system.
River revitalisation

Eco-conservatory elements commonly used in recent major river improvement projects include:

1) grassed cellular paving at channel beds and riverbanks to create greenery and establish microbial environment — examples are Kam Tin River, Lam Tsuen River, Ng Tung River and Yuen Long Bypass Floodway;

2) gabion baskets and geotextile mattress to stabilise riverbank — examples are Tong Fuk, Sha Po River and Kam Tin River tributaries;

3) unlined riverbed to create natural river environment for procreation of flora and fauna — examples are Kam Tin River and Lower Ng Tung River;

4) unlined riverbank to provide natural ground for plant growth — examples are Ng Tung River and Sheung Yue River;

5) preservation of original or natural river meanders — examples are Ng Tung River, Kam Tin River and Sheung Yue River;

6) shallow ponds with aquatic vegetation to attract freshwater fish, amphibians and water birds — example is Ping Yuen River;

7) wetland and reed beds to increase biodiversity — examples are Yuen Long Bypass Floodway and San Tin Eastern Main Drainage Channel; and

8) bird holes, fish ladders, and in-stream boulders to attract birds and fishes — examples are Lam Tsuen River, Ho Chung River and Kai Tak River.

Aspirations for ecological river have prompted more and more requests from the public that channels be rehabilitated through revitalisation instead of decking over. Upcoming works such as revitalisation of Tsui Ping River, artificial flood attenuation lake in the development of Anderson Road Quarry Site and Tung Chung riverside park have attracted much public attention.
The Tin Shui Wai Channel is lined with mangroves. Its downstream is dwelled with the "Mai Po Bent-winged Firefly" *Pteroptyx maipo*, a species unique in the world.

Natural bedding at the Kam Tin River provides ideal feeding places for amphibians and wetland birds.

Lam Tsuen River

To alleviate the flood risk in the Lam Tsuen River Basin, the DSD undertook the River Improvement Works in Upper Lam Tsuen River in 2007 with construction completed in 2012. Given the extraordinary ecological conservation value of the Upper Lam Tsuen River, the DSD proceeded with the design, construction and management of the project in such way that the impacts of the river improvement works on the environment and ecology would be minimized. In the design, the original natural river course was preserved as far as practical with river sections having sufficient drainage capacity being left undisturbed. Fish ladders are provided across cascades to maintain ecological continuity along the river channel. Other conservation measures include the use of gabion walls as river banks to cultivate a natural ecology within the riparian zones, re-use of the original riverbed materials for restoring the rip-rap base of the river channel, and avoiding the use of concrete to create a natural stream environment.

The Hong Kong newt lives in clean aquatic environment and is a biological indicator of good water quality.
After river improvement works, the natural environment of the Upper Lam Tsuen River is reinstated. The Lam Tsuen River uses natural material for riverbed and gabion baskets for river bank.

Aquatic and riparian vegetation was established quickly after completion of the river improvement works in Upper Lam Tsuen River. The number of rare species (such as Hong Kong newt) climbs even higher than that before the river improvement works. In addition, the biodiversity in the river course is also maintained, with the number and species of birds, fishes and dragonflies being restored to its pre-construction level.

The DSD has invited green groups, for the first time, to participate in formulating and assessing construction options during design stage. The green groups have provided valuable insights in areas such as biological migration. The successful collaboration with green groups in the river improvement works in this Upper Lam Tsuen River project has paved the path of collaboration between the DSD and the green groups on delivery of ecological river channel works thereafter.

Fish ladders allow fish and other aquatic creatures to travel between the upstream and downstream of the river.
Kai Tak River

The 2.4 kilometres long Kai Tak River was previously known as Kai Tak Nullah and is one of the major drainage channels in East Kowloon. Due to urbanisation and extreme weather conditions, the drainage capacity of Kai Tak River could no longer meet the current flood protection standards. Serious flooding occurred in Choi Hung Road abutting Kai Tak River and affected Wong Tai Sin and San Po Kong during rainstorms. Kai Tak River is one of the 16 nullahs to be decked over within 10 years as announced in the 2005 Policy Address. Through public engagement exercises before commencement of works, the DSD was able to conclude the design principles, with flood prevention as the priority focus, and surrendering the decking over option, replacing with the revitalisation of the Kai Tak River as an urban green river corridor.

The Kai Tak River Improvement Works commenced in 2011 and was completed in 2018.
The Kai Tak River has cultivated a mangrove field, which is a rare wetland in the urban area of Hong Kong.

**Engineered wetland of the Yuen Long Bypass Floodway**

Yuen Long Bypass Floodway is a 3.8 kilometres long drainage channel built at the south of Yuen Long Town, intercepting 40% of the runoff originally flowing through Yuen Long Town Centre and diverting the runoff to the downstream of Kam Tin River. The project has affected some fish ponds and farmland. In order to make up for the ecological losses, the DSD has transformed three abandoned fish ponds into a 7 hectares engineered wetland to create ecologically enriched habitat for wild birds, amphibians and dragonflies.

The engineered wetland mainly consists of three main ponds, a seasonal shallow pond and a permanent shallow pond. It also includes a crushed brick pond, an oyster shell pond, reed beds and a deep pond. Various aquatic plants, reeds and trees are planted in the engineered wetland with a bamboo woodland in the south, which is suitable for habitation of herons.

The water from the low flow channel of the Yuen Long Bypass Floodway first flows through the sedimentation ponds to allow solid particles such as sand and silt to settle. After being filtered and purified by passing through the crushed brick pond and oyster shell pond, the water is equally distributed into four reed beds for removal of nutrients before discharging into the engineered wetland.

After years of cultivation, the 7-hectare engineered wetland is now developed into a sustainable ecological habitat.
Since the wetland was established in December 2006, an accumulation of 118 species of birds have been recorded. In addition, a total of 21 species of dragonflies, 30 species of butterflies, 7 species of amphibians and 4 species of reptiles were also recorded including 7 species of butterflies not commonly found in Hong Kong. A total of 130 plant species were recorded in September 2009, of which 68% were native species. The recorded biological species include black-faced spoonbills, needle-tailed ducks, frogs, fireflies and mudskippers.
Nam Sang Wai River Education Trail

To educate the public on river training works done by the Government and to raise the public awareness on river conservation, the DSD has designated a Nam Sang Wai River Education Trail in November 2014. The trail begins at Castle Peak Road in Yuen Long, goes around Nam Sang Wai via the Yuen Long Bypass Floodway, new channel of Kam Tin River and Shan Pui River. The trail is about 5.5 kilometres long and takes 2 hours to complete. Ten exhibition panels are erected along the Trail to provide information on river training works and river ecology, as well as introduction on natural environment and species along the Trail. Visitors can read or listen to the education contents by scanning the QR code with their mobile phones.

Plant facilities to change from grey to green.

Greening enhances the quality of life. The DSD has been striving to apply greening effort to soften its facilities in harmony with their surroundings, and making quality greening as an integral part in drainage and sewerage projects. To counter the adverse visual effects inherent to sewage treatment works and flood prevention facilities, different greening measures have been adopted to transform their outfits from dull and greyish to pleasant and chromatic. Besides, greening helps to improve biodiversity and microclimate, absorbing heat and reducing dust. Different species of trees and shrubs are planted to provide a sense of seasonal change.

Peripheral landscape includes planter wall and buffer planting strip along the boundary, or landscaped podium opened for public use.

Landscaping works raise green coverage ratio and create harmonious visual effect, resituating the public impressions on concrete structures, sedimentation tanks, pumping stations, vents and boundary walls from solemn and monotonous to lively and appealing. Exemplars are the Stonecutters Island Sewage Treatment Works, Sha Tin Sewage Treatment Works and Cyberport Sewage Treatment Works.
In order to select suitable plants for planting at different facilities, the DSD set up a 2 000 square metres plant nursery at the Siu Ho Wan Sewage Treatment Works in 2014, in which more than 50 species of native plants were cultivated and were in trial planting under different conditions, including trial aquatic planting in water of different salinity. The Landscape Unit in the DSD selected appropriate plant species for planting in different facilities according to various site characteristics, not only beautifying the environment and maintaining biodiversity, but also bringing a new look to the facilities.
Skylights and solar photovoltaic panels are installed on the roof of the Kowloon Bay Sewage Interception Pumping Station. The transplanted Bead tree *Melia azedarach* can be seen at the top right corner of the photo.

The Bead tree *Melia azedarach* sitting in a steel-made basin was getting ready for transplantation during construction of the Kowloon Bay Sewage Interception Pumping Station.

The DSD also accords priority to green design when building new facilities. In 2016, the Kowloon Bay Sewage Interception Pumping Station was bestowed the highest BEAN Plus Final Platinum rating for New Buildings. The sewage interception facilities at the Kowloon Bay Sewage Interception Pumping Station operate its overflow weir automatically by analysing weather warning signals obtained from the Hong Kong Observatory. Polluted dry-weather flow from Jordan Valley box culvert is intercepted to the trunk sewers to reduce the dry-weather flow discharging to Kai Tak approach channel and Kwun Tong Typhoon Shelter, thus reducing pollution and odour nuisance. The design concept of this automatic overflow weir was later adopted in the Happy Valley Underground Stormwater Storage Scheme.

It is noteworthy that an eight metres high and over 40 years old Bead tree *Melia azedarach* was transplanted successfully during construction.
Future plans for revitalization and optimization

Relocation of Sha Tin Sewage Treatment Works to Caverns

Land supply has always been a great challenge to the development in Hong Kong. In Chapter 2 above, it has been mentioned about the large scale reclamation carried out as early as in 1860s by levelling hills and reclaiming the harbour to create new land for the sustainable development of Hong Kong.

The existing Sha Tin Sewage Treatment Works (STSTW) has been operating for more than 30 years. In facing the ever increasing amount of sewage from the district, the open-air designed STSTW would have to deal with a greater challenge on odour control. As such, the DSD initiated to relocate the STSTW into rock caverns in Nui Po Shan at Tai Shui Hang. The existing 28 hectares of land can be released for other beneficial uses, and will also improve the neighbouring environment.

The relocation also provides an opportunity to adopt the “state-of-the-art” sewage and sludge treatment technologies for improving its operational efficiency and enhancing its energy efficiency.

The first stage of the project comprising construction of a connecting tunnel has commenced in 2019 and the whole project is expected to take 11 years to complete.
Inter-Reservoirs Transfer Scheme

The Kowloon group of reservoirs consists of the Kowloon Reservoir, the Shek Lei Pui Reservoir, the Kowloon Reception Reservoir and the Kowloon Byewash Reservoir. The Kowloon Byewash Reservoir is at the lowest geographical location, while the Kowloon Reservoir was the first reservoir among the group constructed in 1910. The Kowloon Byewash Reservoir was completed in 1931 and was the last reservoir built among the group. Under the Inter-Reservoir Transfer Scheme, the DSD is building a water tunnel of about 2.8 kilometres long and 3 metres in diameter from the Kowloon Byewash Reservoir to the Lower Shing Mun Reservoir to transfer the collected runoff from the Kowloon group of reservoirs to the Lower Shing Mun Reservoir. This Scheme, when completed in 2022, will improve the flood protection level in West Kowloon areas to combat climate change, and effectively create a designated storage capacity in the Kowloon Byewash Reservoir to receive further runoff from the catchment. It is estimated that an additional 3.4 million cubic metres of fresh water can be collected each year on average, thus achieving both flood prevention and water conservation objectives.
Dry weather flow interceptor at the Cherry Street Box Culvert

The polluted dry weather flow from the stormwater drainage systems in Kowloon Tong, Mong Kok and Yau Ma Tei is discharged into the New Yau Ma Tei Typhoon Shelter, which creates serious water pollution problem and long-standing odour nuisance.

The stormwater drainage systems that serve the above districts are connected to the Cherry Street Box Culvert for discharging into the New Yau Ma Tei Typhoon Shelter. According to the West Kowloon and Tsuen Wan Sewerage Master Plans Study Review completed in 2010, the dry weather flow in the Cherry Street Box Culvert was polluted and affecting the water quality of the receiving waters at Kowloon West. Therefore, the Review recommended to build a dry weather flow interceptor at the outfall of the Cherry Street Box Culvert to intercept the polluted dry weather flow from the urban areas and prevent it from entering the New Yau Ma Tei Typhoon Shelter.

The proposed underground dry weather flow interceptor and the sewage pumping station will be built along the waterfront of the New Yau Ma Tei Typhoon Shelter with automatic penstocks and desilting facilities. The polluted dry weather flow in the Cherry Street Box Culvert will be intercepted and diverted to the sewerage at the nearby Lin Cheung Road and conveyed to the Stonecutters Island Sewage Treatment Works. It is estimated that the dry weather flow interceptor will reduce about 70% of the polluted dry weather flow that enters the typhoon shelter a year. The project involves construction of the dry weather flow interceptor and 85 metres long waterfront promenade. The superstructure of the dry weather flow interceptor will be designed as a green garden in harmony with the adjacent promenade, which will be opened to the public.

The construction works of the project started in 2017 for completion in 2022.
Revitalisation of Tsui Ping River

Situated between residential area and bustling industrial and business districts, Tsui Ping River runs along Tsui Ping Road and King Yip Street at the heart of Kwun Tong. Given its superb location and unique riverine characteristics, Tsui Ping River is well-positioned to become a valuable urban riverside public space. The DSD plans to revitalize this one-kilometre-long existing open nullah through the provision of attractive waterscape, landscape and ecological enhancement works. Riverside walkways, cross-river walkways and landscaped decks will be built to enhance connectivity in the area and to provide riverside amenity. Public waterside sitting-out facilities will be provided for amenity. To achieve better results for this river revitalisation project, the DSD has conducted public engagement through which public opinions have been collected to refine the scheme. The Tsui Ping River Revitalization project will be one of the focal river revitalization projects in the urban areas in the coming years.
Tsui Ping River passes through the industrial/business districts and the residential areas. It is one of the few river channels remains in Kowloon East.

Design concept for the Tsui Ping River Revitalization project (near King Yip Street)

Enhancement works for Kwun Tong Sewage Pumping Station

Kowloon East is the core business district in Hong Kong. To cope with its future development, the DSD is carrying out enhancement works for the Kwun Tong Sewage Pumping Station to build an underground sewage balancing facility of capacity 16,000 cubic metres to provide temporary storage of excessive preliminarily treated sewage from Kwun Tong Preliminary Treatment Works and balance the sewage flow rate during extreme peak flow periods.

The enhancement works involves construction of a landscaped deck with the theme “Dancing Ribbon”, to be built on the roof of the pump house creating a pleasure ground for public enjoyment so as to achieve the purpose of space sharing and multi-use of one venue, releasing more open space for public enjoyment. The enhancement works for the Kwun Tong Sewage Pumping Station was commenced in 2017 for completion in 2022.

The landscaped deck will include green corridors, viewing platforms, picnic sites, children playground and fitness facilities for the elderly.
Overview

The DSD draws up annual programmes for inspection and preventive maintenance of its facilities to ensure their smooth operation. The DSD has digitized drainage records and set up central electronic database for ease of retrieval of drainage information. The DSD has set up laboratories in some sewage treatment works to ensure that the sewage treatment processes comply with the statutory requirements. The DSD will gear up automation of the laboratory work flows to further enhance the efficiency of laboratory work. When adverse weather prevails or an event of emergency occurs, the DSD will activate the Emergency Control Centre to provide mitigation service for the public, whereas its Direct Labour Force will handle the daily drainage blockage cases.

The DSD’s 350 flood protection and sewage treatment facilities account for about 10% of the total electricity consumption of the Government. The Department is committed to developing renewable energy (solar energy and biogas, etc.) for energy conservation and emission reduction. Among the facilities, the Siu Ho Wan Sewage Treatment Works is equipped with one of the largest solar farms in Hong Kong.

In recent years, the DSD has been implementing “Blue-Green Infrastructure” based on the “Sponge City” concept to promote natural greening, revitalise water bodies and achieve sustainable development, while actively developing and adopting the latest smart technologies to provide world-class sewage treatment and stormwater drainage services to Hong Kong.
Chapter 10: Thirty Years of Creativity and Innovation, in Pursuit of Higher Honour with Wholeheartedness

The DSD and the professional, academics and the industry sector join hands as one team to venture the path of research and development
Today, science and technology advance rapidly. If we remain too conservative and close-minded, we will not be able to keep up with the pace of the 21st century. It has been 30 years since the inception of the DSD, which is now managing about 350 drainage facilities (including 67 sewage treatment works) and 4 600 kilometres of drains and sewers. We have been moving with times and striving to promote innovation, scientific research in local engineering projects and environmental protection, with a view to applying the research results to enhance of our sewage treatment and stormwater drainage services.

Research and development

In its early day, the DSD already had a senior engineer designated to co-ordinate and conduct research and development projects. The Department gradually anchored strong footholds in the research and development field over the course of time. A Research and Development Steering Committee chaired by the Deputy Director was even set up in 1998. The Committee comprises two research and development teams, co-ordinating scientific research activities in civil engineering and electrical and mechanical engineering.

Today, the DSD fosters collaboration with local and overseas experts, academics, international scientific research institutions and industry stakeholders on research and development projects across a wide spectrum of multi-disciplinary fields.

Since 2006, the Department has been holding the Research and Development Forum every year. Industry leaders, professors and experts are invited to deliver thematic speeches, while stakeholders exchange ideas, appraise the latest technologies and explore collaborative opportunities. Participants at the Forum include representatives from construction and environmental sectors, government departments, engineering consultants, contractors, and students from tertiary institutions. In addition, the DSD is frequently honoured with awards for its research and development findings presented and exhibited at international conferences.

In November 2014, to celebrate its 25th anniversary, the Department hosted the DSD International Conference 2014, which attracted more than 300 participants from Hong Kong and overseas, and a total of 36 technical papers were published. In 2019, which falls in its 30th anniversary, the DSD co-organised the 8th IWA-APSIRE Conference and Exhibition with the International Water Association Asia Pacific Regional Group and other organisations. The 3-day Conference and Exhibition attracted over 1 000 participants from all over the world and hundreds of papers on wastewater and stormwater management were presented by international water professionals. On both occasions, the DSD and the IHE Delft Institute for Water Education (formerly known as UNESCO-IHE) signed the five-year-term Memorandum of Understanding on Knowledge and Capacity Development in Sustainable Stormwater Management.

The research and development projects undertaken by the DSD on sewage treatment focus on advancing sewage and sludge treatment technologies, odour management and renewable energy development, while those on stormwater drainage centre on hydrology and hydraulics, sustainable drainage system, asset management, smart drainage system, design and material applications, as well as project management.

In the past 10 years, the DSD completed nearly 100 research and development projects. Some of those 50 projects, which were ongoing during 2018, are outlined as follows:
Compact sewage treatment technologies

Advances in sewage treatment technologies and equipment have provided the opportunities to build compact sewage treatment plants that are of smaller footprint and yet are able to produce high effluent quality. Many sewage treatment specialist firms design and build customised compact sewage treatment modules for individual plants and communities. The Department has carried out trials on different compact sewage treatment technologies to assess their suitability for wider use in Hong Kong.

The study on the application of hybrid biological sewage treatment technology using a combination of biofilm and activated sludge is a good example. Developed in northern Europe, this technology utilises specialised polyethylene media of complex profiles as biofilm carrier in activated sludge reactor to increase the total amount of microorganisms for achieving greater and faster decomposition of pollutants. After trial use at the Stanley Sewage Treatment Works in 2009, this technology was proved to be successful in removing nitrogen. This technology requires a smaller footprint and is most suitable for upgrading that are the capacity of activated sludge system to meet increased demands.

Membrane Bioreactor (MBR) is another technology which has been studied. An MBR comprises a bioreactor and a membrane filtration unit. The membranes in an MBR can filter out suspended solids and produce high quality effluent. An MBR has the advantage of a small footprint and therefore it facilitates upgrading of a sewage treatment works with limited footprint. Between 2014 and 2015, the DSD carried out a pilot study to try out sidestream MBR and an immersed MBR at the Sha Tin Sewage Treatment Works. The results showed that both technologies could meet the specified effluent quality standards. The pilot project further revealed that the immersed MBR outperformed the sidestream MBR in terms of energy efficiency, chemical consumption, maintenance requirements and treatment capacity. A DSD engineer from the research and development team had written a paper based on this study and received the Hong Kong Institution of Engineers (HKIE) Outstanding Paper Award for Young Engineers/Researchers 2016.
Co-settling technology

In 2011, the DSD started adopting the “Co-settling Technology” to recycle portion of surplus activated sludge after secondary biological treatment by returning the sludge back to the primary sedimentation tanks via specially designed return system. This technology enables sedimentation, biological treatment and sludge thickening processes to take place simultaneously, thus saving time and energy required by on sludge treatment and improving the efficiency in anaerobic digestion. With more biogas thereby produced, more electricity would be generated as another benefit of this technology.

While implementing this technology at the Sha Tin Sewage Treatment Works, the plant has saved its annual electricity consumption by about 40%. With the reduction of sludge and increased production of biogas, approximate $6 million could be saved in annual electricity cost. The project has received several awards including the Certificate of Merit in the 2012 Hong Kong Awards for Environmental Excellence, the 2013 Innovation Award for the Engineering Industry of the Hong Kong Institution of Engineers, and the 2014 International Water Association (IWA) Project Innovation Awards.

Odour control — Superoxygenation system at Tung Chung Sewage Pumping Station

Sewage collected at Tung Chung and Chek Lap Kok Airport is conveyed to the Tung Chung Sewage Pumping Station and then pumped to the Siu Ho Wan Sewage Treatment Works over a six kilometres long rising mains. Sewage would become septic over such a long sewage conveyance network in the absence of oxygen to form malodorous compounds. When these compounds are released to the atmosphere, they will cause odour nuisance and safety hazards to workers in sewage treatment works. Dosing sewage with calcium nitrate in sewage is a general approach for the abatement of odour due to sulphide formation.

In July 2010, the DSD conducted a study on the application of Superoxygenation technology developed in the United States at Tung Chung Sewage Pumping Station to suppress hydrogen sulfide (the malodorous compound) generation for tackling the odour problems. Test results have revealed that the Superoxygenation technology could reduce hydrogen sulfide concentration from 1 000 ppm to only 1.6 ppm. The recurrent cost of this technology is comparable to that of the current practice of adding calcium nitrate. The DSD continues to gain more experience in utilizing the technology and review its application and efficiency in odour abatement.

Part of the sewage will be conveyed to this conical oxygen dissolving tank where it is oxygenated and then returned to the main sewer.
Odour control — Hydrogel

The malodour suppression Hydrogel is a revolutionary product developed in Hong Kong for inhibition of bacteria growth and odour control. The underground drainage systems provide suitable environment for anaerobic bacteria to grow and generate large amount of hydrogen sulfide which is a common malodour gas. At the end of 2016, the DSD invited the Hong Kong University of Science and Technology (HKUST) to develop a Hydrogel product that could control odour through smart inhibition of bacteria growth. The research team formulated a granular Hydrogel by mixing Hydrogel with catalysts that could inhibit bacteria growth and suppress hydrogen sulfide. The team conducted field study to evaluate the Hydrogel performance in stormwater and sewerage systems at 10 locations (including Shing Mun River, the Cherry Street box culvert, the Jordan Valley box culvert and Kowloon Bay Sewage Interception Pumping Station). The study confirmed that the Hydrogel could effectively reduce hydrogen sulphide concentration by 99% to 0.1 ppm (one ten-millionth), which is nearly undetectable.

SANI wastewater treatment technology

Another innovative technology developed in Hong Kong is the integrated wastewater treatment process called the Sulphate reduction, Autotrophic denitrification, and Nitrification Integrated (SANI) process. A demonstration of this technology was carried out at the Sha Tin Sewage Treatment Works by the DSD jointly with HKUST researchers in mid-2010s. Hong Kong has been using seawater for toilet flushing since 1950s, making it one of the few cities in the world that use seawater extensively for toilet flushing nowadays. In view of the characteristics of the sewage in Hong Kong with high sulphate content, the SANI wastewater treatment process pioneered the use of sulphate existing in the saline wastewater as a medium to introduce a sulphur cycle into the traditional carbon and nitrogen cycles for sulphate reduction, nitrification and autotrophic denitrification. Owing to the slow growth of micro-organisms in the process, this technology can significantly reduce sludge production by as much as 70%, thereby achieving energy and space efficiency.
Study on operating conditions of food waste/sewage sludge anaerobic co-digestion

Hong Kong disposes of more than 3,600 tonnes of food waste daily to the landfill sites, which is not in line with the principle of sustainable development and has a negative impact on the environment. Therefore, in addition to providing organic waste treatment facilities to deal with the food waste, the Government advocated, in the 2016 Policy Address, the use of existing sewage treatment facilities for food waste/sewage sludge anaerobic co-digestion to raise food waste treatment capability. To this end, the DSD and the University of Hong Kong (HKU) conducted a series of tests called the Study on Operating Conditions of Food Waste/Sewage Sludge Anaerobic Co-digestion in the university’s laboratory to establish the operating conditions required for the Food Waste/Sewage Sludge Anaerobic Co-digestion Trial Scheme, including quantitative studies on the increase in biogas production during the anaerobic co-digestion process and reduction in sludge volume.

Furthermore, the Government built the food waste pre-treatment facilities which commenced operation in 2019 at the Shuen Wan Leachate Pre-treatment Works in Tai Po. These facilities provide a maximum of 50 tonnes of pre-treated food waste a day to the sludge anaerobic digestion system at the Tai Po Sewage Treatment Works for food waste/sewage sludge anaerobic co-digestion.

Workers working inside the anaerobic sludge digester

A section of draft tube is being installed in the sludge anaerobic digester at the Tai Po Sewage Treatment Works to facilitate the Food Waste/Sewage Sludge Anaerobic Co-digestion Trial Scheme

Food waste/sewage sludge anaerobic co-digestion technology testing equipment in HKU laboratory
Conversion of a CHP system into a CCHP tri-generation system

To improve energy utilisation in sewage treatment works, the DSD and the Hong Kong Polytechnic University (PolyU) have jointly conducted a feasibility study on combined cooling, heating and power (CCHP) tri-generation system. The team has installed an absorption chiller at Sha Tin Sewage Treatment Works and connected it to the existing combined heat and power (CHP) biogas generator. The residual heat of the generator drives the absorption chiller to produce chilled water that cools the intake air of the generator, thereby improving its performance.

From a conventional single-function power generation system and municipal electricity supply to the CHP generator using the biogas generated during sludge treatment process, and then from that to the CCHP tri-generation system, these significant changes are the milestones in the DSD's persistent pursuit of improvements in energy efficiency and reduction in emissions and waste.

Heat island effect study

In mid-2016, the DSD commissioned the consultants on river revitalisation study and the Chinese University of Hong Kong (CUHK) to investigate the effect of various land covers on urban heat island effect and thermal comfort in Hong Kong. The study results show that rivers, streams and other water bodies improve thermal comfort. Different riverbed materials and design would have effects on the riverbed temperature. If Blue-Green elements could be added to the river revitalisation projects, they would improve the thermal environment and mitigate the heat island effect to create a more pleasant, water-friendly environment for the public. The findings of the study are useful for the formulation of river revitalisation design guidelines and management strategies.

The CCHP tri-generation system installed at Sha Tin Sewage Treatment Works utilises the residual heat of generators to produce chilled water for cooling some facilities within the plant.

The heat island effect study has found that the surface temperature over concrete channel bed under sunlight could be as high as 62°C.
Eco-hydraulics study on green channels

In recent years, the DSD has introduced the “Blue-Green Infrastructure” concept in green river channel design. To assess environmental benefits of green channel design and hydraulic characteristics of different ecological and environmental improvement measures, the Department has conducted an eco-hydraulics study on green channels to provide important insights into the merits and demerits of various green channel design in terms of ecological rehabilitation and hydraulic performance. The study also assessed the hydraulic resistance of green plants suitable for growing in green river channels. The first stage of the study commenced in early 2012 and was completed in mid-2014.

Site trials for the second stage began at the end of 2015, and the ecological enhancement works were completed in early 2017. One of the trials took place at a section of Lower Lam Tsuen River near Mui Shue Hang Playground in Tai Po. Different ecological environments, such as pools, rapids, bird habitats and aquatic plants were created, and natural materials were used to replace concrete riverbeds and riparian zones. Other trial sites include a section of the Ma Wat River near Fanling Highway and the downstream section near Jockey Club Road. After completion of the ecological enhancement project, plant varieties in river channels have increased. The native plants and wetland plants at both sides of the channels have created ecological environments suitable for animal inhabitation. The trial scheme includes drafting guidelines for green river channel maintenance and river ecological values for reference by green river management teams. This study won the Silver Award of the 2016 Hong Kong Institute of Landscape Architects Design Awards.
Smart drainage monitoring system

The DSD endeavours to set up a smart drainage monitoring system that would allow real-time monitoring of the flow velocity of the drainage systems, water levels in manholes, gas concentrations, etc. In 2013, the DSD collaborated with the Department of Electrical Engineering of the CUHK to develop a wireless sensor network for monitoring changes in water levels, concentrations of three hazardous gases (i.e. hydrogen sulfide, sulphur dioxide and methane) and the opening status of manhole covers in the drainage systems. The monitoring devices transmit data through a wireless network to desktop computers or mobile applications, and thereby facilitating data analysis. The smart drainage monitoring system was tested in Kowloon Bay in 2016 with satisfactory results. Further studies on data transmission technology and system reliability in older urban districts such as Hung Hom are planned.

River biodiversity improvement

Fireflies require a high level of cleanliness in their natural habitats. The DSD invited the Firefly Conservation Foundation to jointly work on a pilot project to restore river ecology and improve biodiversity at several rivers in the New Territories. The improvement measures at Kwan Tei River achieved remarkable results and attracted fireflies to return. Within 12 months, the number of fireflies increased from a few to about 30 to 50, including *Luciola ficta*, a species of aquatic firefly that was considered to be extinct in Hong Kong for 100 years.
Shuen Wan Drainage Improvement Works

The Shuen Wan Drainage Improvement Works in Tai Po adopted stormwater storage and interception approaches in the flood prevention design. A box culvert was constructed in the upper stream of Wai Ha River to divert part of the runoff to Plover Cove, and excessive water would be stored in a 0.8 hectare low-lying wetland. Since commissioning in 2014, the works have been effective in mitigating the flood risks to Tung Tsz Road and nearby villages. Nevertheless, the ecological conditions of the wetland deteriorated due to less tidal water backflow into the wetland. To remedy the situation, the DSD engaged consultants to explore the feasibility of allowing more ingress of seawater into the wetland by lengthening the opening time of the automatic penstock (especially on clear days, or cloudy days with or without drizzle).

The original penstock operation was based solely on tidal levels. An optimisation scheme was then devised to take into account the weather forecast and real-time rainfall measurements. For instance, the penstock could be closed at a higher tide level during the winter period from December to February and on non-rainy days, whereas during other periods, the penstock would be closed at a lower tide level. Site trials and hydraulic model simulation were conducted to assess the potential flood risks under the optimisation scheme.

Following the study, the DSD engaged a contractor to design a new operation programme and provide ancillary facilities. The new operation programme determines the penstock operation mode based on the prevailing rainstorm warning signal, real-time rainfall measurements, as well as forecast rainfall amount from SWIRLS (Short-range Warning of Intense Rainstorms in Localised Systems) nowcasting system of the Hong Kong Observatory. This is the first flood prevention system in Hong Kong that takes into account regional weather forecasts and real-time rainfall measurements. After a phased trial in 2015, the system was officially implemented in 2017. Field tests confirmed that this optimisation scheme successfully extended the penstock opening time, allowing more ingress of seawater from Plover Cove to the upstream wetland without compromising the drainage capacity of the Shuen Wan stormwater drainage system. In the past few years, even in heavy rains and during the passage of the two super typhoons (i.e. Hato in 2017 and Mangkhut in 2018), there was no flood incident reported on Tung Tsz Road and in adjacent villages.
Creativity and Innovation

“Whether a community or industry can thrive on innovation is dependent on the willingness of the community to change in accepting innovation, and the room for allowing failure in being innovative”, put forward by Mr. Edwin Tong Ka-hung, former Director of Drainage Services, in a forum hosted by the Civil Division of the Hong Kong Institution of Engineers, and at the Development Bureau “Project Capability Building Programme” in 2018. To thrive for application of innovative ideas, the DSD must brave the challenges and dare to bear the risks in order to implement the widely accepted innovative ideas.

The DSD is committed to promoting innovative culture and self-initiated research and development, nurturing creative and innovative mentality within the Department, consulting engineers, contractors, and working partners. Over the years, the DSD has initiated many innovative ideas within the fields of engineering design, construction and maintenance. Three of such innovative technologies adopted by the Department are cited in the following, while many others are illustrated in the previous chapters.

Tunnelling technology

Deep tunnelling

The HATS Stage 2A, apart from being a world-class environmental infrastructure project, has taken on cutting-edge deep tunneling technology. The works under the project comprised the construction of 21 kilometres of sewage tunnel located at depths varying from 70 metres to over 160 metres below sea level, using drill-and-blast for some sections. As the blasting took place in deep subsea levels, the amount of explosives to be deployed had to be carefully calculated, the locations of drill holes carefully chosen and the pre-excavation grouting (PEG) executed in order to control the groundwater ingress. Besides using the latest PEG technology to meet the stringent groundwater ingress levels during tunnel construction, at some difficult locations the project team used highly concentrated brine frozen to -30°C to freeze the ground around the tunnel before excavation. This artificial ground freezing method is applicable to tunnelling through complicated ground conditions such as mixed silt and gravel foundations adjoining seawalls.
In 2010, the DSD constructed the twin 600 millimetres inner diameter sewage tunnel between Ap Lei Chau and Aberdeen under the HATS Stage 2A with the horizontal directional drilling (HDD) method. The tunnels are 1,400 metres long, reaching 100 metres below sea level. A pilot hole of 300 millimetres diameter was first drilled down from the ground surface at Ap Lei Chau along the designed alignment level in the seabed using bentonite slurry to stabilise the drilled hole. The pilot hole was then enlarged by reaming gradually till it reached 900 millimetres in diameter for a high density polyethylene pipe of 600 millimetres inner diameter to be pulled from the other side of the seashore, forming a new sewer.

Horizontal directional drilling technology was employed for construction of the twin sewage tunnels between Ap Lei Chau (shown in the picture) and Aberdeen bypassing high voltage sub-marine electric cables.

After construction of the sewage tunnels between Ap Lei Chau and Aberdeen by HDD, the DSD employed the same technology to construct two submarine outfalls, each of 500 metres and 750 metres in length, in Yung Shue Wan and Sok Kwu Wan on Lamma Island to avoid disturbing the offshore corals and the fish culture zones. This is the first time Hong Kong applied the HDD technology in a “land-to-sea” circumstance, with the back reaming and pipe pull-back operations carried out seaward.
Trenchless technology — pipe jacking

Pipe laying is generally carried out by open-cut or trenchless excavation. Open-cut excavation is a traditional method of laying pipes in an open trench, while trenchless construction is similar to tunnelling method where most of the processes are taken place underground, causing less noise nuisance or impact on road users. Trenchless construction, however, requires more sophisticated technical skills and involves higher risks, putting its cost several times higher than that of open-cut excavation.

The DSD started using trenchless technology on laying trunk sewers in early 1990s for projects under the Sewerage Master Plans and Drainage Master Plans. Pipe jacking techniques are commonly adopted.

Pipe jacking (or micro-tunnelling) involves boring of a tunnel for laying pipes. A pipe is jacked forward incrementally by a hydraulic jack from a launching shaft towards a receiving shaft, while the ground materials would be excavated manually inside a hand shield, or more commonly by a automatic remote controlled tunnelling machine.

In early 1990s, a project team used the pipe jacking method to install pipelines successfully over 1 000 metres long under the West Kowloon Reclamation hinterland drainage works phase 2. In the late 1990s, another project team under Wan Chai East and North Point sewerage works made a breakthrough by using the pipe jacking method to lay 440 metres of trunk sewers with a diameter of 1 200 millimetres and hyperbolic alignments. In 2017, the DSD adopted the same method to lay a twin pipe trunk sewer of 250 metres with a diameter of 1 500 millimetres for each pipe underneath Shing Mun River Channel in Sha Tin.

In recent years, the DSD has adopted the pipe jacking method to lay pipes across major obstacles, such as the Dongjiang watermains, railway lines and trunk roads.
Set sail our own fleet of vessels

After commissioning of the HATS Stage 2A in 2015, the sewage treatment capacity of the Stonecutters Island Sewage Treatment Works (SISTW) is expected to be increased correspondingly, with the amount of sludge to be treated daily surging from 600 tonnes (about 50 sludge containers) to 800 tonnes (about 65 sludge containers). Should the conventional tug and barge transportation method continue to be used to transport the sludge from the SISTW to the sludge treatment facility in Tuen Mun, when typhoon signal No. 3 or above is hoisted, the barges would have to return to typhoon shelters and sludge would be disposed of by land transport. After the passage of typhoons, it would take much longer time to resume the marine transportation. As such, the DSD has decided to enlist its own fleets, that two ocean-going vessels, Clean Harbour 1 and Clean Harbour 2, constructed by the DSD, officially set sail in 2015. These two vessels are also the first ever eco-friendly diesel-electric powered vessels registered in Hong Kong. Even if typhoon signal No. 3 is in force, the two Clean Harbour vessels can still operate, avoiding sludge piling up at the treatment plant. Each vessel has a displacement tonnage of 3 400 tonnes and accommodate up to 90 sludge containers, transporting about 1 200 tonnes of sludge.
**Revitalisation of water bodies**

The main objective of river improvement works in early days in Hong Kong was flood prevention with a prime aim that the flood prevention facilities could be commissioned as soon as possible for early flood risk mitigation. River channels built at that time were dull and plain with little ecological value. As times change, river channel design has undergone significant improvements, with more emphases being given on aesthetical appearance, ecological and environmental considerations.

The DSD is committed to revitalising the water bodies to create a lively and water-friendly environment for supporting more diverse flora and fauna, as well as attracting citizens to enjoy the waterfront, making the water bodies become local landmarks. Turning from open nullahs built during the 1960s to 1970s with mainly hard materials such as concrete, to channels with green elements in the 1990s, and to channels built today which fulfil the purposes of flood prevention, river revitalisation, eco-conservation and water-friendliness objectives, the DSD, as one of the major departments managing water bodies in Hong Kong, has made strenuous efforts to innovate.

The illustrations below depict some innovative green measures on river revitalisation.

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Fish shelters and deflector stones at the Kai Tak River provide habitats for marine creatures

Various species of flowers and shrubs planted along the riverbanks of the Ng Tung River create a breathtaking scenery

The use of natural materials for riverbed construction is a key element in the Revitalisation of Kai Tak River
Constructed wetland at the Ping Yuen River in the North District purifies river water and improves biodiversity.

Gabions filled with bio-balls form biofilms for removing contaminants caused by livestock wastes.

The planting raft at the Yuen Long Bypass Floodway on trial basis commenced in 2017, providing rest places for birds in deeper river channels.

Trees reserved to form artificial tree island and enhance ecological conservation.
The DSD will continue to incorporate innovative and creative water body revitalisation designs into the forthcoming river improvement projects and the daily river maintenance works, including the Revitalisation of Tsui Ping River which is under detailed design, as well as revitalisation of Tai Wai Nullah, Fo Tan Nullah and mid-stream of Tuen Mun River Channel, where the respective feasibility studies are in progress.
Do it from the heart

Since its inception in 1989, the DSD has been committed to providing Hong Kong with world-class wastewater treatment and stormwater drainage services, while upholding the service motto “Do It from the Heart”.

Public engagement  Do it from the heart

In the late 1990s, during temporary closure of Nathan Road to make room for its drainage improvement works, the DSD specifically designed an “Apology” signage to show its apology to people affected by the works. Making an apology by the Government was extremely rare by then, but local shop operators, residents and road users welcomed it. Subsequently, the Joint Utilities Policy Group (comprising representatives of utility undertakers, the Highways Department, the Water Supplies Department and the DSD) accepted the DSD’s design and today, the signage has become a standard signboard for road works. The Wan Chai East and North Point Sewerage Works also adopted a number of avant-garde concepts to strengthen communications with the communities. Examples are distributing telephone cards with the contact mobile phone numbers of the project team for public enquiries, pioneering the use of transparent or translucent site hoardings, recruiting community relations officers, and delivering project newsletters and traffic notices on temporary road diversions. The aforementioned project unfolded a new chapter of public engagement for the DSD’s works. The project team was honoured with the Silver Prize of Team Award in the Civil Service Outstanding Service Award Scheme 2005.

The Queen’s Road Central Intercepting Drains project in the mid-2000s was boosted with even more innovative public engagement activities, including on-street exhibitions, public forums, newsletters, regular goodwill visits, project hotlines and stand-by liaison vehicles and work teams during inclement weather. As times change, these measures have become standard practice. In 2009, the project team was honoured with the Gold Prize of Team Award in the Civil Service Outstanding Service Award Scheme 2009.
Connect with the public through multiple channels

The DSD values public feedback highly. Over the years, the Department has proactively arranged many public engagement exercises, such as open days, tea gatherings with the media and stakeholders, guided tours and school outreach activities, through various channels to interact with different sectors in society, disseminate information on major projects and their current status to the public, gauge their feedback and promote the image of the Department. In the past few years, the Department received over 12 000 visitors of the public (including primary school students) yearly on average through guided tours or outreach educational activities, introducing its daily operation. In early 2018, a new media art exhibition entitled “After the Deluge” was held jointly by the DSD and the Hong Kong Art Development Council (HKADC) at the Tai Hang Tung Stormwater Storage Tank (THTSST) for the first time. This exhibition used “water” as the main theme, combining the artwork and engineering, with the use of the Chinese classic mythology of “Dayu Tames the Water” to bring forth the contemporary “Dayu” flood prevention story. The event attracted over 10 000 visitors.

A new media art exhibition, “After the Deluge” staged inside the THTSST.

Primary school students at the Lai Chi Kok Drainage Tunnel Exhibition Centre

A new media art exhibition, co-organised with the HKADC at the THTSST, attracted over 10 000 visitors.
Experience sharing forum with institutions and academic bodies from Mainland
Outreach educational programme at schools
Visitors took a glimpse of the DSD's routine operation on the Open Day at the ShaTin Sewage Treatment Works
Sharing sessions with representatives from overseas governments and professional bodies
Holding forums with Mainland officials
Experience sharing forum with institutions and academic bodies from Mainland
Building a trustworthy partnership

New Engineering Contract

In 1997, the former Works Bureau implemented a non-contractual partnering trial scheme in the hope that through a partnership charter, mutual trust and collaborative working relationship would be strengthened with the contractors to jointly manage construction risks, improve contract management efficiency and minimise contractual dispute. The DSD’s Kai Tak Transfer Scheme was one of the works contracts participating in this scheme.

In 2005, the DSD was invited by the former Environment, Transport and Works Bureau (renamed the Development Bureau in July 2007) to roll out a contractual partnering pilot scheme. To this end, the department set up a working group with the Legal Advisory Division (Works) of the Bureau to draft the implementation proposal, and prepare a sample contract form applicable to Hong Kong based on the New Engineering Contract (NEC) suite of contract forms of the Institution of Civil Engineers (ICE). The modified NEC model document was then submitted to a steering committee under the Bureau for endorsement. Members of the steering committee comprises representatives from the Works Branch of the Development Bureau, various works departments and the Independent Commission Against Corruption (ICAC).

The contract of the Improvement of Fuk Man Road Nullah in Sai Kung was awarded in 2009, becoming the first public works contract using the NEC outside the United Kingdom. The contract was completed six months ahead of schedule with a cost saving of about 5% (about HK$4 million dollars). The DSD convened a number of seminars and workshops for various works departments, the Hong Kong Construction Association (HKCA) and utility undertakers to brief the contractual partnering scheme. Mock tendering exercises were also organised for the contractors.

Today, the DSD has used the NEC in about 88 works contracts and 20 consultancy contracts, among which, the Happy Valley Underground Stormwater Storage Scheme is the largest project ever completed so far in Hong Kong using the NEC. The completion date of this project was 14 months earlier than scheduled, enabling the storage scheme to commence operation in one rainy season earlier and accruing a cost saving of about 10% (approximately HK$110 million).

Through implementation of the NEC, the DSD achieves the original objectives of establishing mutual trust and collaboration among contracting parties and promoting gradual changes to the work culture on construction sites.
Design-Build-Operate

Besides the New Engineering Contract (NEC) form of contract, the DSD has also adopted the Design-Build-Operate (DBO) form of contract for sewage treatment works projects in recent years. The Pillar Point Sewage Treatment Works (PPSTW), commissioned in 2014, is the first sewage treatment works operated under the DBO contract in the DSD. This contract form specifies a longer operation period for bringing in longer term operating partners to build a mutual and trustworthy relationship and encouraging the contractors to make their designs of plant facilities more durable and cost-effective in terms of operation and maintenance. The DBO contract of PPSTW has successfully attracted the contractor to adopt cutting-edge wastewater treatment technologies developed in Europe. Based on the experience from the PPSTW, the DSD has modified the contract arrangement and adopted the same DBO form of contract on the Upgrading of San Wai Sewage Treatment Works, which is under construction for anticipated commissioning in 2020.

Green partners

The DSD attaches great importance to ecological conservation and environmental protection for boosting the sustainable development in Hong Kong. The Department started to collaborate with green groups in mid-2000s on the River Improvement Works in Lam Tsuen River to seek their expert advice on ecological conservation issues including fauna migration. The DSD and green groups began to have regular meetings and site visits from early 2010 to exchange views on proposed works involving water ecology and conservation, and to discuss measures on enhancing ecological conservation and environmental protection during construction stage. Representatives from green groups have been very generous in offering precious information and professional advice, bringing much benefit to the DSD project teams. More importantly, through ongoing communication, the previous tense relationship between government project teams and green groups has turned to a long-term collaborative one.

To cultivate further collaboration and strengthen the awareness of its project teams on ecological conservation, the Department often invites green groups to co-organise training courses, seminars and research and development forums on river ecology to share and consolidate experience gained in drainage works, as well as to explore opportunities for river revitalisation in Hong Kong.
At thirty, we stand firm and upon solid rock we built

Knowledge management

Today, the DSD possesses specialised and highly efficient teams. For this, the Department is obliged to invest more resources in knowledge management and staff development.

The DSD organises nearly 700 training courses each year, including induction courses, in-house training, duty visits, overseas conferences, seminars and workshops. These diversified programmes help enhance its staff’s professional skills and knowledge. The average number of training hours per staff member each year is over 33 hours, far above that of employees in Hong Kong according to statistics from the Hong Kong Institute of Human Resource Management (18.3 hours in 2016).

To cope with forthcoming greater challenges, the DSD not only continuously encourages its staff to take part in local training courses and overseas duty visits to broaden their vision and learn about the latest technological management, but also arranges secondment to policy bureaux or overseas trainings for them. Through active participation and experience sharing with experts in the industry, innovative concepts could be introduced into the Department, hence improving its overall quality of service.

The transfer and management of knowledge is crucial to a works department. The DSD endeavours to promote experience sharing activities, talks and task groups for in-depth discussions on specific subjects, rendering support to less experienced colleagues. Electronic knowledge management portal is also set up for storing and sharing valuable information and experience.

Electronic platform

Apart from establishing the electronic knowledge management portal, the DSD has long been striving for improvement of efficiency, energy saving and waste reduction through computerisation and digitalised operations, in the pursuit of greener office and construction site.

For instance, in 2011 the DSD launched a paperless meeting portal, where meeting documents could be directly uploaded to it and attendees view the documents via tablets any time, without having to print out hardcopies, which greatly reduces the use of paper. Moreover, various office workflows have been computerised to replace paper forms or records, thereby saving substantial amount of paper and staff resources on circulation and filing of documents.

In 2015, the DSD asserted further on the paperless initiative and took the lead in establishing a certified electronic recordkeeping system. Apart from facilitating dispatch of files and archives, the system incorporates customised workflows for individual divisions, allowing better communication and coordination among team members without relying on hardcopy circulation. In early 2018, the Department was one of the first few departments having its electronic recordkeeping systems certified as official electronic archive systems. The Department also endeavours to introduce digitalised operations and practices to construction sites to keep abreast with the widely used Building Information Modelling (BIM), enabling personnel on design, construction, site management and operations and maintenance, to work on a common electronic management or BIM platform for information sharing and problem discussion under a paperless environment.
While striving to promote innovation and scientific research, forge contractual partnerships, liaise with stakeholders from various sectors and nurture supporting staff through in-house training, the DSD, being a government department, fully understands that it must maintain integrity, comply with procedures, make good use of public money and be accountable to various sectors. Wavering and vacillating in the course of striking a balance and making a choice are sometimes inevitable. Against the constraints under the existing system, the social trend towards criticism in recent years, and the succession problem resulting from the post-war baby boomers reaching retirement age in the civil service, any slackness might easily lead to conservatism, bureaucracy and traditionalism. It will sure be a long-term challenge for the Department to stay open-minded, embrace changes, take initiatives and grasp the nettle.

On the firm foundation built by all workmates, old or new, the DSD will make steady strides, both internally and externally, in improving on hard-earned results, continuing with open-mindedness, team spirit, partnering culture and people-oriented pragmatism, as well as leveraging professional skills to interact and co-operate with the public, industry, academia and researchers.

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The construction industry has played an instrumental driver of the development of Hong Kong’s economy and community, making Hong Kong one of the most reputable and dynamic cities in the world. The Government has launched Construction 2.0 in 2018 to maintain and strengthen Hong Kong’s leading position in the construction industry, whilst enhancing the sustainability and long term growth of the industry. The three key pillars embodied in Construction 2.0: innovation, professionalisation and revitalisation, will undoubtedly help the Hong Kong construction industry reach a new milestone. Being part of the construction industry, the DSD will join force with its industrial partners to facilitate continuous advancement of the construction industry in Hong Kong.

Responding to the Construction 2.0 initiatives on the existing basis, the DSD has consolidated the drives in respect of Innovation, Smart and Interaction. This sets a new stage for the Department to grasp development opportunities and reach a new horizon, with a principal objective of providing strong and sustainable world-class wastewater and stormwater drainage services.

“Innovation” includes innovation in procurement, design, technological applications and facility management. The DSD is striving to push the boundaries on exploring various possible non-conventional procurement modes, like inclusion of “life cycle cost” estimation in tender evaluation, use of different options in “NEC” forms of contract. Over the years, the Department fosters innovation and applies cutting edge technologies in engineering design, construction, operation and maintenance. In terms of research and development, the DSD has made strenuous efforts to undertake diversified and multi-disciplinary innovative research projects.

“Smart” is a predominant trend worldwide. The DSD is committed to digitalised management, wider use of BIM and other technologies, within the department and with industry partners, to enhance the quality of its assets during their life cycles, from conception to commission.

“Interaction” applies both internally and externally. This includes provision of facilities ranging from intangible platforms and spaces to
tangible landscaped gardens and water features, for its staff, industry partners, academics, community groups and citizens, equipped with highly efficient management, quality support, and intelligent facilities in order to promote mutual communication and collaboration.

To this end, the Expansion of the Sha Tau Kok Sewage Treatment Works Phase 1 works with a project cost of HK$1 billion has been selected as a pilot project to adopt Construction 2.0. Along the direction of the three key pillars under Construction 2.0, the DSD puts into the practice the “off-site construction”, “digitalisation of management”, BIM, to raise the standards of site safety, innovation and technological advancement.

The Department will take the lead to launch more pilot projects on trying out the new generation of construction models; further our knowledge exchange with science and technology talents; set up local and overseas R&D information exchange networks; and encourage and support stakeholders to promote innovation and technology development with an aim to boost better results on interaction and collaboration. The DSD endeavours to provide highly intelligent, more environmentally friendly and more operationally efficient wastewater and stormwater drainage services, by joining hands with different sectors of the community to make Hong Kong a more liveable city.

The DSD has the great honour in its 30th Anniversary to be one of the co-organisers of the 8th International Water Association Asia-Pacific Regional Group Conference and Exhibition held in Hong Kong under the theme of “Smart Solutions for Water Resilience”, joining hands with local and overseas water professionals for sustainable and equitable water management.
Overview

The DSD has been moving with the times since its establishment 30 years ago, endeavouring to promote innovative thinking and scientific research development. Set up in 1998, the Research and Development Steering Committee was chaired by the Deputy Director, with two research and development teams co-ordinating scientific research activities in collaboration with academics, the industry stakeholders and researchers.

The DSD is striving for innovation, while adopting cutting-edge technologies and novel ideas in its projects. Looking ahead, the DSD will continue to promote innovation and scientific research, cherishing its traditions and passing them on to the coming generations, with a view to striving for excellence and enabling Hong Kong to reach a new milestone towards a smart and environmental-friendly city.
"Full of grace, a beacon to pass on". This commemorative monograph records the development and evolution of drainage infrastructure in Hong Kong in the past century and more, as well as the achievements of the DSD over the past thirty years. Sir Osbert Chadwick (an engineer and a university professor) proposed in 1882 that an intercepting sewer be laid on Hong Kong Island to collect and convey sewage to the west of the Island and dispose of it into the waters in the vicinity after simple treatment, with a view to reducing water pollution in the central Victoria Harbour. Though in resemblance to the Harbour Area Treatment Scheme of today, this recommendation was never taken on board then. On the other hand, the Bowrington Canal in Wan Chai (beneath the Canal Road Flyover of today) that was built in the 1880s separated the residential area in the west and the industrial area in the east. The engineers built along the canal a promenade lined with trees to provide the public with a green, revitalised and water-friendly sitting-out environment, the concept of which resembles that of “Blue-Green Infrastructure” and river revitalisation of today.

"History is a mirror of the future”. The above exemplars bear testimony to the fact that the project team, with sincerity and spirit of adventure, has been consistently providing people-oriented services. In retrospect, while natural disasters and epidemics have presented both challenges and opportunities, Hong Kong has been developing and evolving through all these trials and tribulations. Nowadays, Hong Kong has reliable sewerage and flood protection infrastructures, as well as professional and highly efficient human assets. We will remain true to our predecessors’ aspiration and belief, and at the same time pass them on to the coming generations, striving with dedication to provide high quality sewage treatment and flood protection services to the public.

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