CHAPTER 9

Environment Bureau
Drainage Services Department

Harbour Area Treatment Scheme Stage 2A

Audit Commission
Hong Kong
28 October 2019

This audit review was carried out under a set of guidelines tabled in the Provisional Legislative Council by the Chairman of the Public Accounts Committee on 11 February 1998. The guidelines were agreed between the Public Accounts Committee and the Director of Audit and accepted by the Government of the Hong Kong Special Administrative Region.

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HARBOUR AREA TREATMENT SCHEME
STAGE 2A

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HARBOUR AREA TREATMENT SCHEME STAGE 2A

Executive Summary

1. The Harbour Area Treatment Scheme (HATS) is one of the most important environmental protection programmes undertaken in Hong Kong to improve the water quality of Victoria Harbour (hereinafter referred to as the harbour). HATS is an integrated sewerage system for collecting and treating sewage generated from the harbour catchment in an efficient, effective and environmentally sustainable manner. A three-phase implementation strategy is adopted for HATS (i.e. Stages 1, 2A and 2B). HATS Stages 1 and 2A were commissioned in December 2001 and December 2015 respectively, and all sewage generated from the harbour catchment is transferred to the Stonecutters Island Sewage Treatment Works (SCISTW) for centralised chemically-enhanced primary treatment (CEPT) and disinfection before discharging into the harbour. For HATS Stage 2B, there is no firm plan for implementation at present. The Drainage Services Department (DSD) is responsible for the design, construction and operation of HATS. The Environmental Protection Department (EPD) is responsible for planning HATS and monitoring the marine water quality. The Environment Bureau (ENB) is responsible for overseeing the provision of sewerage and sewage treatment services by DSD and EPD.

2. Between December 2005 and April 2010, the Finance Committee (FC) of the Legislative Council and the Secretary for Financial Services and the Treasury (under delegated authority from FC) approved funding of $17,591.7 million in total for the investigations, detailed design and construction of HATS Stage 2A. The construction of HATS Stage 2A commenced in April 2008 and was implemented through awarding 14 works contracts (Contracts A to N). The design and construction supervision work of HATS Stage 2A were conducted under Consultancy X (for Contracts A to C by Consultant X) and Consultancy Y (for Contracts D to N by Consultant Y). After the substantial completion of the main works, HATS Stage 2A was commissioned in December 2015, which was one year later than the target commissioning date stated in the FC funding papers. As of July 2019, the Government had incurred $16,868.7 million for HATS Stage 2A. According to ENB and EPD, after the commissioning of HATS Stage 2A, the water quality of the harbour has shown further improvement. The Audit Commission

(Audit) has recently conducted a review to examine the Government's work in managing the implementation of HATS Stage 2A.

Construction of sewage conveyance system

3. The sewage conveyance system (SCS) under HATS Stage 2A comprises a network of: (a) vertical shafts for collecting sewage from the existing eight preliminary treatment works (PTWs) at the northern and south-western parts of Hong Kong Island; and (b) deep sewage tunnels for conveying the collected sewage to SCISTW. Contracts A to C (which had been completed with accounts finalised at a total final contract sum of $7,151 million) covered the construction of SCS (paras. 1.5, 2.2 and 2.3).

4. ***Works items in tenderers' design were omitted in the Bills of Quantities (BQ).*** Audit examination revealed that works items (involving temporary works) in tenderers' design were omitted in the respective BQ of Contracts A and B. In the course of subsequent contract administration of Contracts A and B, omissions of BQ items were claimed by the pertinent contractors and assessed by Consultant X, leading to payments of $188.8 million to Contractor A and $177.4 million to Contractor B for carrying out the works of the related omitted items. According to DSD, while a Technical Circular (prevailing at the time of tender invitations for Contracts A and B in December 2008) required that a tenderer's design should be priced as a lump sum item included in BQ, it was only applicable to permanent works but not "works of a short limited lifespan or temporary in nature" (which were subsequently included in the latest version of the Technical Circular in 2014). In Audit's view, in implementing a works project in future, DSD needs to include works items in a tenderer's design as a lump sum item in BQ (paras. 2.9 to 2.11).

5. ***Need to critically check the completeness of BQ items.*** According to Contract A, for the purposes of measurement of excavation in shafts, three types of excavated materials were defined in contract clauses and separate items should be provided in BQ for different types of excavated materials. However, under BQ of Contract A, items were provided for two of the three types of excavated materials. Consultant X assessed that the remaining type of excavated material was omitted in BQ. In the event, DSD paid $68.5 million to Contractor A for carrying out the works of the omitted items. According to DSD, since November 2015, it has required an independent checking of BQ of its works contracts. In Audit's view, in implementing

a works project in future, DSD needs to continue to make efforts to strengthen checking of BQ for ensuring the completeness and accuracy of BQ (paras. 2.13 to 2.16).

6. ***Scope for better ascertaining the presence of government structures in the vicinity of the works sites before inviting tenders.*** Audit examination revealed that, under Contract B, some government structures (an existing trunk sewer and an abandoned underground reinforced concrete structure of DSD) in the vicinity of the works sites for constructing a shaft were identified after contract award. Audit noted that: (a) at the design stage, Consultant X requested as-built drawings of structures near the shaft locations from DSD. However, DSD was unable to provide as-built drawings showing that the abovementioned underground structures existed at the works sites; and (b) after Contractor B encountered the underground reinforced concrete structure, Consultant X tried to obtain the then as-built drawings of that structure from DSD again and discovered that such drawings were kept in the records of DSD. In the event, extensions of time (EOTs) ranging from 95 to 411.5 days were granted for completion of various sections of works under Contract B, leading to prolongation costs of $323.3 million. In this connection, for Contracts I, L and M, Audit also noted similar issues relating to variations to the works due to the identification of government structures in the vicinity of the works sites after contract awards, resulting in significant prolongation costs and EOTs granted (paras. 2.20 and 2.21).

7. ***Scope for enhancing pre-tender site investigations***. The works under Contract C, covering the construction of deep sewage tunnels by a relatively new construction method at that time, commenced in August 2009 and were completed in May 2014, about 33 months (1,004 days) later than the original completion date of August 2011 (of which 130 days were due to inclement weather). Audit noted that the delays were mainly due to adverse ground conditions undetected in pre-tender site investigations, leading to granting of EOTs of 741 days for completing each of two sections of works under Contract C (para. 2.24).

Expansion and upgrading of Stonecutters Island Sewage Treatment Works

8. SCISTW (constructed under HATS Stage 1) was expanded and upgraded under HATS Stage 2A to increase its design daily treatment capacity and to provide

disinfection facilities. DSD awarded eight works contracts (Contracts D to K) for the related works. Except Contract K which was awarded in July 2019 with scheduled contract completion date of May 2021, all the other seven works contracts (Contracts D to J) had been completed with a total expenditure of $6,286.8 million as of July 2019 (paras. 3.2 and 3.3).

9. ***Need to draw on the experience gained in design changes of deodourisation (DO) facilities.*** Under Contract H, Contractor H was required to construct DO facilities at SCISTW. There were design changes of DO facilities during the construction stage of Contract H, including: (a) construction of double door enclosure systems for two buildings for handling sludge to enable better odour control; and (b) approval of Contractor H's cost saving design for reducing odour loading from the two buildings and issuing a variation order (VO) which included constructing two additional DO units adopting a more environmentally friendly DO system for serving the two buildings (with an estimated saving of about $49.5 million for recurrent cost over the design life of 15 years). According to DSD, the DO design was progressively made more cost effective. Audit considers that DSD needs to draw on the experience gained in design changes of DO facilities at SCISTW to further improve the design of DO facilities for sewage treatment works in future (paras. 3.8 to 3.11).

10. ***Need to continue to make efforts to monitor the odour situation and tackle the odour issue at SCISTW.*** To ensure no adverse air quality impact to the air sensitive receivers, in December 2014, DSD engaged Consultant Y to conduct an odour study for enhancing the odour management at SCISTW. In July 2017, the odour study was completed. Consultant Y found that certain odour sources at SCISTW had emitted high hydrogen sulphide (often highlighted as the indication of odour from sewage treatment works) levels as compared to the specified design requirements of the DO facilities and proposed further enhancement works to the existing DO facilities at SCISTW to cater for the worst case scenario. As it transpired, in July 2019, DSD awarded Contract K at a contract sum of $169 million for carrying out further odour reduction measures at SCISTW with a view to mitigating potential odour nuisance to the surrounding air sensitive receivers in future. Audit noted that odour emission from SCISTW was the main environmental concern during the operation phase and odour issue was complicated due to its dynamic and transient nature. In Audit's view, DSD needs to continue to make efforts to monitor the odour situation and tackle the odour issue at SCISTW (paras. 3.7, 3.12 to 3.15 and 3.17).

11. ***Scope for better assessing the ground conditions of existing structures before inviting tenders.*** The Dilution Water Pumping Station (DWPS), an underground reinforced concrete structure built under HATS Stage 1 to serve the CEPT process, was a key facility of SCISTW resting on reclaimed fill materials without any piling support and there was little provision in the DWPS design to accommodate excessive settlement. During the construction stage of Contract F, DWPS had undergone more-than-expected settlement. In order to safeguard DWPS from further settlement and to provide long term stability and integrity of DWPS, Consultant Y issued a VO (later valued at a cost of $9.5 million) to Contractor F for carrying out permanent stabilisation works for DWPS. In Audit's view, in implementing a works project in future, DSD and its consultants need to take further measures to better assess the ground conditions of existing structures before inviting tenders with a view to further mitigating the impact of construction works causing settlement of such structures as far as practicable (paras. 3.21 to 3.24).

12. ***Scope for better ascertaining the presence of underground utilities and buried underground structures in the vicinity of the works sites.*** After the commencement of Contract G, DSD conducted a comprehensive review of the original design of the Centrate Pipe Return System and then modified the design so as to further enhance its functionality and performance with due regard to the site constraints and the evolving operation needs. Notwithstanding that examination of all available site records for existing underground utilities and structures had been conducted at the design stage and site constraints had been considered when modifying the design of the system, during the excavation works, Contractor G encountered various uncharted underground utilities including cable ducts and other unforeseeable underground obstructions (e.g. sheet piles) which caused delay to the progress of works. In the event, EOTs of 88 days were granted for completion of a section of works, leading to prolongation costs of $16.4 million. Audit considers that, in implementing a works project in future, there is scope for better ascertaining the presence of underground utilities and structures in the vicinity of the works sites (paras. 3.25 and 3.26).

Upgrading of preliminary treatment works

13. Sewage is preliminarily treated at PTWs to remove large solids and grits to avoid deposition in the deep sewage tunnels and to protect downstream facilities from damage or blockage. The existing eight PTWs at the northern and south-western parts of Hong Kong Island were upgraded to cater for the technical requirements of HATS Stage 2A as well as future development and population growth of the

respective districts. Contracts L to N (which had been completed with a total expenditure of $1,546.2 million as of July 2019) covered mainly the upgrading works for the eight PTWs (paras. 4.2 and 4.3).

14. ***Delays in handover of works sites and completed civil works.*** Before carrying out the upgrading works at PTWs under Contracts L and M, certain portions of works sites or completed civil works were required to be handed over from contractors responsible for the construction works of SCS under Contracts A to C. The late handover of works sites and completed civil works (partly due to inclement weather) from Contractor A to Contractor L and the late handover of works sites (partly due to inclement weather) from Contractors B and C to Contractor M consequentially resulted in: (a) EOTs ranging from 196 to 496 days for completing three sections of works and prolongation costs totalling $56.2 million granted under Contract L; and (b) EOTs of 272 and 542 days respectively for completing two sections of works and prolongation costs totalling $56.4 million granted under Contract M (para. 4.5).

15. ***Need to notify appropriate higher-rank approving officer of the reasons for cost increase of contract variations as appropriate.*** According to DSD's Technical Circular, after a proposed variation has been approved by an approving officer, if it is anticipated that the estimated net value of the proposed variation will for reasons other than change in scope increase to the extent of exceeding the approval limit of that approving officer, then the appropriate higher-rank approving officer shall be notified with explanations of such increase as soon as it is known. As far as could be ascertained, for 5 VOs under Contract L (with an estimated cost of less than $0.3 million each and issued by Consultant Y within its financial authority), the up-to-date costs as of July 2019 exceeded the estimated costs by 130% to 969%. Audit noted that the up-to-date costs for the 5 VOs exceeded the financial authority (i.e. $0.3 million) of Consultant Y. However, DSD had no documentation showing that the appropriate higher-rank approving officer had been notified of reasons for the cost increase of the 5 VOs (paras. 4.12 to 4.14).

Audit recommendations

16. **Audit recommendations are made in the respective sections of this Audit Report. Only the key ones are highlighted in this Executive Summary. Audit has *recommended* that the Director of Drainage Services should:**

Construction of SCS

(a) **in implementing a works project in future:**

(i) **include works items in a tenderer's design as a lump sum item in BQ (para. 2.17(a));**

(ii) **continue to make efforts to strengthen checking of BQ for ensuring the completeness and accuracy of BQ (para. 2.17(b)); and**

(iii) **better ascertain the presence of government structures in the vicinity of the works sites before inviting tenders (para. 2.31(a));**

(b) **when implementing a works contract involving tunnelling works in future, further enhance pre-tender site investigations with a view to providing better information on site conditions as far as practicable (para. 2.31(b));**

Expansion and upgrading of SCISTW

(c) **draw on the experience gained in design changes of DO facilities at SCISTW to further improve the design of DO facilities for sewage treatment works in future (para. 3.18(a));**

(d) **continue to make efforts to monitor the odour situation and tackle the odour issue at SCISTW (para. 3.18(b));**

(e) **in implementing a works project in future:**

(i) **take further measures to better assess the ground conditions of existing structures before inviting tenders (para. 3.27(a)); and**

(ii) **better ascertain the presence of underground utilities and buried underground structures in the vicinity of the works sites (para. 3.27(b));**

Upgrading of PTWs

(f) **in implementing a multi-contract works project in future, consider taking further measures as appropriate to better minimise the impact arising from delays in handover of works sites and completed civil works between the contractors (para. 4.9); and**

(g) **in implementing a works project in future, take measures to ensure compliance with the requirements relating to notifying the appropriate higher-rank approving officer with explanations of cost increase of contract variations (para. 4.16).**

Response from the Government

17. The Director of Drainage Services agrees with the audit recommendations.

PART 1: INTRODUCTION

1.1 This PART describes the background to the audit and outlines the audit objectives and scope.

Background

1.2 The Harbour Area Treatment Scheme (HATS), formerly known as the Strategic Sewage Disposal Scheme (Note 1), was launched in 1989. It is one of the most important environmental protection programmes undertaken in Hong Kong to improve the water quality of Victoria Harbour (hereinafter referred to as the harbour) (Note 2). HATS is an integrated sewerage system for collecting and treating sewage generated from the harbour catchment in an efficient, effective and environmentally sustainable manner. It has the capacity to provide proper sewage treatment to serve 5.7 million people living at the two sides of the harbour.

1.3 The Drainage Services Department (DSD) is responsible for the design, construction and operation of HATS. The Environmental Protection Department (EPD) is responsible for planning HATS and monitoring the marine water quality. The Environment Bureau (ENB — Note 3) is responsible for policy matters on environmental protection and for overseeing the operation of DSD and EPD on the provision of sewerage and sewage treatment services.

Note 1: *The Strategic Sewage Disposal Scheme was renamed as HATS in March 2001.*

Note 2: *Before the commissioning of HATS, sewage generated from the harbour catchment was discharged into the harbour after preliminary treatment (i.e. screening and degritting) at local preliminary treatment works. This was a major pollution source which had a significant impact on the water quality of the harbour.*

Note 3: *In July 2007, ENB was formed to take over the policy responsibility for environmental matters. Before July 2007, the policy responsibility rested with the then Environment, Transport and Works Bureau (July 2002 to June 2007), the then Environment and Food Bureau (January 2000 to June 2002), the then Planning, Environment and Lands Bureau (July 1997 to December 1999) and the then Planning, Environment and Lands Branch (before July 1997).*

1.4 A three-phase implementation strategy is adopted for HATS (i.e. Stages 1, 2A and 2B). HATS Stages 1 and 2A were commissioned in December 2001 and December 2015 respectively, and all sewage generated from the harbour catchment is transferred to the Stonecutters Island Sewage Treatment Works (SCISTW) for centralised chemically-enhanced primary treatment (CEPT — Note 4) and disinfection before discharging into the harbour. HATS Stage 2B involves the provision of an underground secondary treatment facility (Note 5) adjacent to the existing SCISTW. At present, there is no firm plan for implementing HATS Stage 2B (Note 6). According to the Government, it would keep under review the implementation of HATS Stage 2B taking into account the water quality situation and the latest technological development in biological treatment.

HATS Stages 1 and 2A

1.5 HATS Stage 1 was commissioned in December 2001 (with construction works commenced in January 1995 and completed in December 2001). Under HATS Stage 1, sewage generated from Kowloon, Kwai Tsing, Tsuen Wan,

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Note 4: *In Hong Kong, there are five types of sewage treatment facilities, namely preliminary treatment, primary treatment, CEPT, secondary treatment and tertiary treatment. The primary treatment includes screening, removal of grit and a sedimentation process with solid waste and settleable suspended solids being removed from the sewage. CEPT enhances primary treatment through the addition of chemicals (coagulant and flocculating agents) to enable quicker and better settlement of suspended solids in the sewage. In SCISTW, ferric chloride and polymer are used as the coagulant and flocculating agents respectively.*

Note 5: *Under the secondary treatment, the sewage is purified by means of a biological treatment process after the primary treatment. The organic matter and nutrient in the settled sewage are decomposed by micro-organisms in the biological treatment process.*

Note 6: *In April 2005, the Chief Executive-in-Council approved to commence HATS Stage 2B upon the completion of HATS Stage 2A subject to a review in 2010-11. In June 2010, EPD commissioned a consultancy study to review the implementation of HATS Stage 2B. The study found that HATS Stage 2A would provide adequate capacity to handle the projected sewage flow and the water quality in most parts of the harbour would be in compliance with the Water Quality Objectives (established under the Water Pollution Control Ordinance (Cap. 358) to lay down water quality requirements for the water body) upon its commissioning, while the upgrading of treatment level from CEPT to biological treatment would not result in an observable improvement of the water quality of coastal waters. The study concluded that the implementation of HATS Stage 2B was not critical in terms of Water Quality Objectives compliance.*

Tseung Kwan O and north-eastern Hong Kong Island (representing about 75% of the total sewage generated from the harbour catchment) is collected and transferred via the sewage conveyance system (SCS — Note 7) with 23.6-kilometre (km) deep sewage tunnels to SCISTW for centralised CEPT before discharging into the harbour (without disinfection — Note 8). The construction of HATS Stage 2A commenced in April 2008. After the substantial completion of the main works, HATS Stage 2A was commissioned in December 2015. Under HATS Stage 2A:

(a) sewage generated from the northern and south-western parts of Hong Kong Island (representing the remaining 25% of the total sewage generated from the harbour catchment) is collected and transferred via SCS with 20.8-km deep sewage tunnels to SCISTW for centralised CEPT and disinfection (see item (b) below) before discharging into the harbour;

(b) SCISTW was expanded and upgraded to increase its design daily treatment capacity (from 1.7 million cubic metres (m^3) to 2.44 million m^3 to cater for the additional sewage flows from the future development and population growth in HATS catchment) and to provide disinfection facilities (Note 9); and

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Note 7: *SCS comprises a network of vertical shafts to collect sewage from preliminary treatment works and interconnected sewage tunnels to convey the collected sewage to SCISTW.*

Note 8: *Disinfection facilities were not provided at SCISTW under HATS Stage 1.*

Note 9: *After the commissioning of HATS Stage 1, there had been a substantial increase in the bacteria level in the Tsuen Wan beaches due to effluent discharged from SCISTW without disinfection. As a result, 4 more Tsuen Wan beaches, in addition to the 3 already closed in the mid-1990s, had been closed since the 2003 bathing season. As requested by the Public Accounts Committee of the Legislative Council when deliberating on Chapter 3 of the Director of Audit's Report No. 42 (see para. 1.12) in 2004, part of the disinfection facilities under HATS Stage 2A was advanced so as to reduce the bacteria level in the western harbour water and facilitate the early reopening of the closed beaches. With disinfection facilities at SCISTW provided under HATS Stage 2A, the chemically treated effluent undergoes disinfection treatment before discharging into the harbour to reduce the bacteria level. The advance disinfection facilities under HATS Stage 2A were commissioned in March 2010 and subsequently modified into final disinfection facilities with additional structures constructed during the upgrading works at SCISTW. With the commissioning of the advance disinfection facilities in March 2010, the water quality at the 7 Tsuen Wan beaches had shown improvement such that all of them had become suitable for swimming and were reopened in phases (4, 1 and 2 beaches were reopened in 2011, 2013 and 2014 respectively).*

(c) the existing eight preliminary treatment works (PTWs) at the northern and south-western parts of Hong Kong Island for collecting sewage and providing preliminary treatment by screening and degritting process were upgraded to cater for the technical requirements of HATS Stage 2A as well as future development and population growth of the respective districts.

1.6 Regarding HATS Stages 1 and 2A, Table 1 shows their major works components and Figure 1 shows their catchment areas and alignment of SCS. Figure 2 shows the sewage collection and treatment process of HATS Stage 2A.

Table 1

HATS Stages 1 and 2A

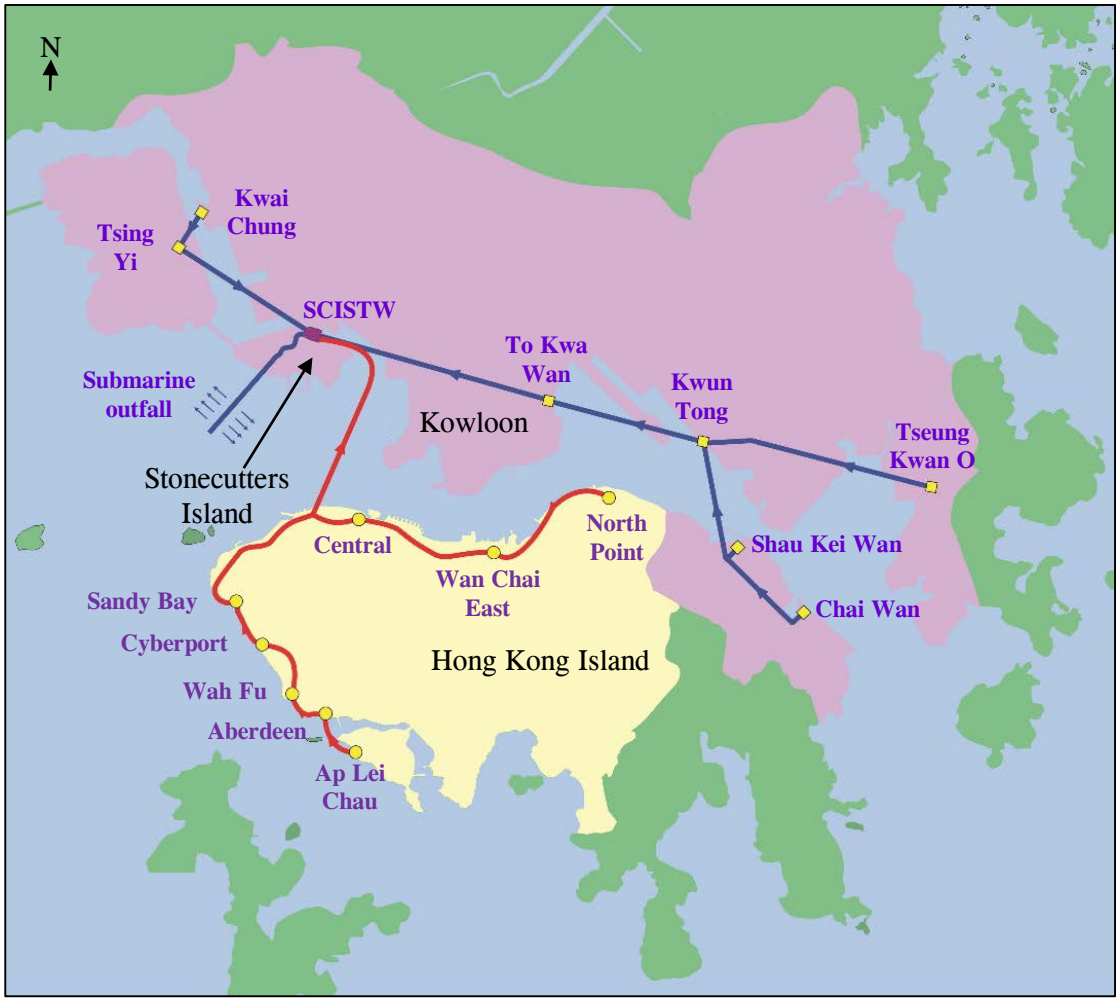
Stage	Major works component	Works commenced	Works completed	Project commissioned
1	• Construction of SCS • Construction of SCISTW and submarine outfall • Upgrading of seven PTWs at Kwai Chung, Tsing Yi, To Kwa Wan, Kwun Tong, Tseung Kwan O, Shau Kei Wan and Chai Wan	January 1995	December 2001	December 2001
2A	• Construction of SCS • Expansion and upgrading of SCISTW • Upgrading of eight PTWs at North Point, Wan Chai East, Central, Sandy Bay, Cyberport, Wah Fu, Aberdeen and Ap Lei Chau	April 2008	Main works: December 2015 Other works: January 2018 Further enhancement works: In progress (Note)	December 2015 (Note)

Source: *DSD records*

Note: *HATS Stage 2A was commissioned in December 2015 after the substantial completion of the main works. Some enhancement works at SCISTW are scheduled for completion in May 2021.*

Figure 1

Catchment areas and alignment of SCS of HATS Stages 1 and 2A



Legend:

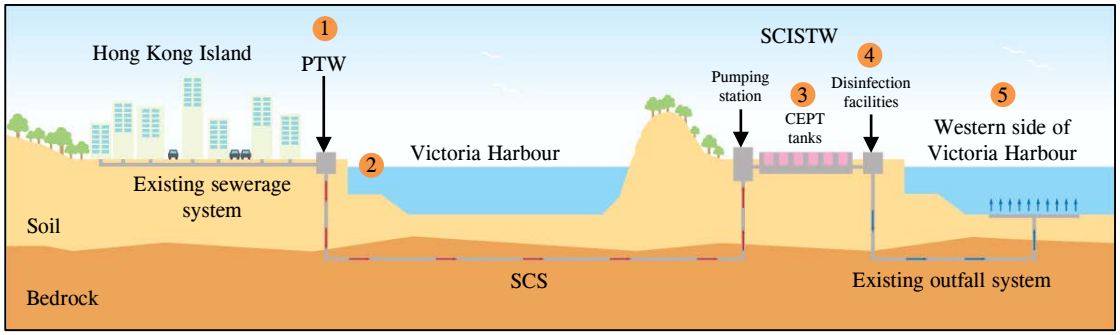
- Stage 1 catchment area
- Stage 2A catchment area
- Stage 1 SCS
- Stage 2A SCS
- SCISTW
- Stage 1 PTW
- Stage 2A PTW

Source: *DSD records*

Remarks: *Sewage from Northwest Kowloon is pumped direct to a PTW adjacent to SCISTW for preliminary treatment before transferring to SCISTW for further treatment.*

Figure 2

Sewage collection and treatment process of HATS Stage 2A



Legend:
1. Sewage is collected and preliminarily treated by screening and degritting process
2. Sewage is conveyed to SCISTW via SCS
3. Sewage undergoes CEPT at SCISTW
4. Sewage undergoes disinfection treatment
5. Treated effluent is discharged to the western side of Victoria Harbour

Source: *DSD records*

Implementation of HATS Stage 2A

1.7 HATS Stage 2A is implemented under five projects (Projects A to E). The approved project estimate (APE) of these projects totalled $17,591.7 million (see Table 2), comprising:

(a) a funding of $17,581.9 million in total approved by the Finance Committee (FC) of the Legislative Council between December 2005 and April 2010 for the investigations, detailed design and construction of HATS Stage 2A; and

(b) an increase in APE of Project C by $9.8 million or 8.9% (from $109.9 million to $119.7 million) approved by the Secretary for Financial Services and the Treasury (under delegated authority from FC) in April 2008.

Table 2

Funding approvals for HATS Stage 2A
(December 2005 to April 2010)

Date	Particulars	Approved amount ($ million)
Investigations and detailed design		
Project A		
December 2005	Environmental impact assessment (EIA), investigations and tunnel conveyance system design	166.5
Project B		
July 2007	Planning and design of the upgrading works of SCISTW and PTWs	105.6
Construction works		
Project C		
January 2008	Construction of advance disinfection facilities at SCISTW	109.9
April 2008	Increase in APE to cover increased construction costs as a result of higher-than-expected tender prices	9.8 (Note 1)
Project D		
June 2009	Construction of SCS and advance works for upgrading of SCISTW (Note 2)	9,286.5
Project E		
April 2010	Upgrading of SCISTW and PTWs (Note 2)	7,913.4
	Total	17,591.7

Source: *DSD records*

Note 1: *Under delegated authority from FC, the Secretary for Financial Services and the Treasury approved this increase in APE.*

Note 2: *Projects D and E included the works for expansion of SCISTW.*

1.8 Between January 2006 and September 2009, DSD awarded four consultancies relating to HATS Stage 2A (see Table 3), as follows:

(a) two consultancies for the design and construction supervision work of HATS Stage 2A which involved 14 works contracts (Contracts A to N — see para. 1.9);

(b) one consultancy for the EIA study; and

(c) one consultancy for the independent environmental checker (Note 10).

Table 3

Consultancies for HATS Stage 2A
(July 2019)

Consultancy	Consultant	Cost as of July 2019 ($ million)	Design and construction supervision work required
X (Awarded in January 2006)	X	69.1	SCS (Contracts A to C)
Y (Awarded in August 2007)	Y	98.8	SCISTW (Contracts D to K) PTWs (Contracts L to N)
EIA study (Awarded in February 2006)		8.2	N/A
Independent environmental checker (Awarded in September 2009)		4.9	N/A
Total		181.0	

Source: DSD records

Note 10: *An independent environmental checker is responsible for checking, reviewing, verifying and validating the overall environmental performance of a project, including the implementation of environmental protection and mitigation measures, submissions relating to environmental monitoring and auditing, and any other submissions required under the environmental permit for a project (which is issued by the Director of Environmental Protection under the Environmental Impact Assessment Ordinance (Cap. 499)).*

1.9 Between April 2008 and July 2019, DSD awarded 14 works contracts to 13 contractors (Note 11) for the implementation of HATS Stage 2A (see Table 4), comprising:

(a) 3 contracts for the construction of SCS (Contracts A to C);

(b) 8 contracts for the expansion and upgrading of SCISTW (Contracts D to K); and

(c) 3 contracts for the upgrading of PTWs (Contracts L to N).

For the 14 works contracts, the works under all contracts have been completed except Contract K (involving enhancement works at SCISTW) which was awarded in July 2019 with scheduled contract completion date of May 2021. For the 13 completed works contracts, 12 works contracts (i.e. except Contract B) were completed 1 to 33.3 months later than the respective original contract completion dates (see Table 4). According to DSD, extensions of time (EOTs — Note 12) due to various reasons, including inclement weather, had been granted to the contractors in accordance with the terms of the contracts for completion of works later than the original contract completion dates (except for 133 days under Contract C subject to

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Note 11: *Contracts L and M were awarded to the same contractor.*

Note 12: *According to the General Conditions of Contract for Civil Engineering Works, regarding contract works commencement, completion and delays: (a) the works and any section thereof shall be completed within the time or times stated in the contract calculated from and including the date for commencement notified by the Engineer or such extended time as may be determined; (b) if the contractor fails to complete the works or any section of works within the time for completion or such extended time as may be granted, then the Employer shall be entitled to recover from the contractor liquidated damages for delay; and (c) if in the opinion of the Engineer, the cause of any delay to the progress of the works or any section of works is any of those stipulated in the General Conditions of Contract (e.g. inclement weather, a variation order (see Note 24 to para. 2.24(a)) issued by the Engineer, the contractor not being given possession of site, etc.), then the Engineer shall within a reasonable time consider whether the contractor is entitled to an EOT for completion of the works or any section thereof. According to the Project Administration Handbook for Civil Engineering Works issued by the Civil Engineering and Development Department, an EOT for completion in effect deprives the Government of the right to liquidated damages for delay in completion of the works for the period of the extension and therefore has a financial implication.*

liquidated damages (see Note 4 to Table 7 in para. 2.3) and 59 days under Contract M being assessed by Consultant Y). In the event, HATS Stage 2A was commissioned in December 2015, which was one year later than the target commissioning date of December 2014 as stated in the papers seeking funding approvals from FC.

Table 4

Contracts A to N for HATS Stage 2A
(July 2019)

Contract	Works	Commencement date	Original contract completion date	Actual completion date (Note 1)	No. of months later than original contract completion date (Note 2)
A	Construction of SCS	31.7.2009	5.1.2015	11.11.2016	22.2
B		31.7.2009	5.1.2015	15.12.2014	N/A
C		17.8.2009	16.8.2011	16.5.2014	33.0
D	Expansion and upgrading of SCISTW	29.4.2008	26.8.2009	4.12.2009	3.3
E		30.10.2009	27.6.2012	8.9.2012	2.4
F		17.9.2009	18.12.2011	6.7.2012	6.6
G		24.2.2011	23.7.2016	31.8.2017	13.3
H		25.8.2010	19.5.2016	5.9.2017	15.6
I		30.6.2011	26.1.2015	21.1.2017	23.9
J		5.7.2013	3.2.2015 (Note 3)	4.3.2015 (Note 3)	1.0
K		9.7.2019	4.5.2021	In progress	
L	Upgrading of PTWs	6.1.2011	29.10.2014	30.6.2016	20.1
M		31.8.2011	31.3.2015	8.1.2018	33.3
N		31.8.2016	26.6.2017	15.12.2017	5.7

Source: *DSD records*

Note 1: *Actual completion date refers to the completion of all works under a contract. Some of the works were not main works (e.g. landscaping works) and would not affect the commissioning of HATS Stage 2A. After the substantial completion of the main works under the contracts, HATS Stage 2A was commissioned in December 2015. Enhancement works at SCISTW under Contract K are scheduled for completion in May 2021.*

Table 4 (Cont'd)

Note 2: *For the 13 completed works contracts (i.e. except Contract K which is still in progress), 12 works contracts (i.e. except Contract B) were completed later than the respective original contract completion dates. According to DSD, the contractors of the 12 completed works contracts were granted EOTs for completion of works later than the original contract completion dates due to various reasons, including inclement weather. EOTs for inclement weather, which did not attract prolongation costs (see Note 19 to para. 2.21), were granted for 11 of the 12 works contracts, ranging from 0.4 to 1.4 months for Contracts J and M, 1.5 to 4.9 months for Contracts C, D, E and G, and 5 to 8.7 months for Contracts A, F, H, I and L. When comparing with the extended contract completion dates due to inclement weather, 10 of the 11 works contracts (i.e. except Contract E) were completed later than the respective extended dates, ranging from 0.6 to 31.9 months.*

Note 3: *Contract J was a design-build-operate contract (relating to sludge handling and disposal facilities). The original contract completion date and actual completion date were related to the design and build portion. The operation period (10 years plus an optional extension of 5 years) commenced on the day following the completion date of the construction works.*

Costs of HATS Stage 2A

1.10 As of July 2019, $16,868.7 million (96%) of APE totalling $17,591.7 million (see para. 1.7) for HATS Stage 2A had been incurred. Of the $16,868.7 million, $14,874 million (88%) was related to expenditures for HATS Stage 2A under various works contracts (see Note 4 to Table 5) for:

(a) construction of SCS ($7,151 million);

(b) expansion and upgrading of SCISTW ($6,191.3 million); and

(c) upgrading of PTWs ($1,531.7 million).

The remaining $1,994.7 million (12%) mainly included resident site staff costs, consultancy fees and expenditures for works carried out by other government departments (see Table 6).

Table 5

Contract sums/expenditures of various works contracts under HATS Stage 2A (July 2019)

Contract	Original contract sum (a) ($ million)	Final contract sum/ up-to-date contract expenditure (Note 1) (b) ($ million)	Increase/ (decrease) (c) = (b) − (a) ($ million)	Increase/(decrease) in provision for price fluctuation adjustment (Note 2) (d) ($ million)	Increase/ (decrease) after price fluctuation adjustment (e) = (c) − (d) ($ million)
Construction of SCS					
A	3,763.1	4,043.8	280.7 (7.5%)	167.7 (4.5%)	113.0
B	2,544.8	2,827.2	282.4 (11.1%)	10.3 (0.4%)	272.1
C	236.5	280.0	43.5 (18.4%)	8.8 (3.7%)	34.7
Total	6,544.4	7,151.0	606.6 (9.3%)	186.8 (2.9%)	419.8 (6.4%)
Expansion and upgrading of SCISTW					
D	108.0	105.1	(2.9) (-2.7%)	—	(2.9)
E	188.8	188.2	(0.6) (-0.3%)	5.5 (2.9%)	(6.1)
F	533.8	604.5	70.7 (13.2%)	50.0 (9.4%)	20.7
G	2,385.7	2,711.9	326.2 (13.7%)	(97.5) (-4.1%)	423.7
H	1,358.5	1,448.9	90.4 (6.7%)	28.7 (2.1%)	61.7
I	680.0	864.1	184.1 (27.1%)	1.5 (0.2%)	182.6
J (Note 3)	432.3	364.1	(68.2) (-15.8%)	(45.4) (-10.5%)	(22.8)
Total	5,687.1	6,286.8	599.7 (10.5%)	(57.2) (-1.0%)	656.9 (11.6%)
Upgrading of PTWs					
L	625.0	767.4	142.4 (22.8%)	25.0 (4.0%)	117.4
M	528.4	767.4	239.0 (45.2%)	18.8 (3.6%)	220.2
N	11.5	11.4	(0.1) (-0.9%)	(0.7) (-6.1%)	0.6
Total	1,164.9	1,546.2	381.3 (32.7%)	43.1 (3.7%)	338.2 (29.0%)
All completed works contracts					
Overall	13,396.4	14,984.0 (Note 4)	1,587.6 (11.9%)	172.7 (1.3%)	1,414.9 (10.6%)
Enhancement works at SCISTW (scheduled for completion in May 2021)					
K	169.0	N/A (No expenditure incurred as of July 2019)			

Source: *DSD records*

Table 5 (Cont'd)

Note 1: *The accounts of 9 contracts (Contracts A to F, I, J and N) were finalised between July 2012 and March 2019. As of July 2019, the accounts of 4 contracts (Contracts G, H, L and M) had not been finalised and the respective amounts were the up-to-date contract expenditures.*

Note 2: *The original contract sums of Contracts A to C, E to J and L to N included provisions for price fluctuation adjustments. Contract D did not include a provision for price fluctuation adjustments.*

Note 3: *Contract J was a design-build-operate contract (relating to sludge handling and disposal facilities). The amounts shown in this Table were related to the design and build portion only.*

Note 4: *Of the $14,984 million, $14,863.9 million was related to HATS Stage 2A, $80.4 million was operating expenditure and funded under DSD departmental vote, $25.2 million was funded under block allocation relating to drainage works, and $14.5 million was related to works for public works laboratory and funded by the Civil Engineering and Development Department. After adding expenditure of $10.1 million which was construction in nature and incurred during the operation phase of Contract J, the total expenditures for HATS Stage 2A under various works contracts amounted to $14,874 million ($14,863.9 million + $10.1 million).*

Table 6

Other expenditures for HATS Stage 2A (July 2019)

Item	Amount ($ million)
Resident site staff costs (Note 1) paid to Consultants X and Y	1,559.6
Consultancy fees	181.0
Works carried out by other government departments (Note 2)	83.2
Miscellaneous costs (Note 3)	170.9
Total	1,994.7

Source: *DSD records*

Note 1: *Consultants are required to employ resident site staff of different grades (e.g. professional grade and technical grade) for supervising contractors' works. The Government reimburses consultants for the personal emoluments of resident site staff and pays an on-cost to consultants to cover their costs in managing the resident site staff.*

Note 2: *Works carried out by other government departments mainly included public works laboratory services provided by the Civil Engineering and Development Department and post-project monitoring of water quality improvement in the harbour due to the commissioning of HATS Stage 2A carried out by EPD.*

Note 3: *Miscellaneous costs mainly included expenditures on ground investigation works, excavation permits and hiring of services and equipment.*

Water quality of the harbour after commissioning of HATS Stage 2A

1.11 According to ENB and EPD:

(a) with the phased implementation of HATS, the water quality of the harbour has been significantly improved. After the commissioning of HATS Stage 2A in December 2015, the water quality of the harbour has shown further improvement;

(b) the bacteria level in the western side of the harbour has been largely reduced following the commissioning of the advance disinfection facilities in March 2010, leading to the reopening of 7 closed Tsuen Wan beaches between 2011 and 2014 (see Note 9 to para. 1.5(b));

(c) the cross-harbour swimming race, suspended since 1979 because of poor water quality and resumed since 2011 on the eastern side of the harbour, has moved to the legendary route in the central harbour since 2017 as a result of further water quality improvement achieved by the commissioning of HATS Stage 2A; and

(d) the improvements in water quality during the period from 2016 to 2018 in the harbour were largely in agreement with the predicted water quality benefits of HATS Stage 2A (see Appendix A for details).

Audit review

1.12 In 2004, the Audit Commission (Audit) completed a review on the implementation of HATS Stage 1 and reported the results in Chapter 3 of the Director of Audit's Report No. 42 of March 2004.

1.13 In April 2019, Audit commenced a review to examine the Government's work in managing the implementation of HATS Stage 2A. The audit review has focused on the following areas:

(a) construction of SCS (PART 2);

(b) expansion and upgrading of SCISTW (PART 3); and

(c) upgrading of PTWs (PART 4).

Audit has found room for improvement in the above areas and has made a number of recommendations to address the issues.

Acknowledgement

1.14 Audit would like to acknowledge with gratitude the full cooperation of the staff of ENB, DSD and EPD during the course of the audit review.

PART 2: CONSTRUCTION OF SEWAGE CONVEYANCE SYSTEM

2.1 This PART examines DSD's work in managing contracts for the construction of SCS, focusing on:

(a) management of Bills of Quantities (BQ) items (paras. 2.4 to 2.18); and

(b) other contract management issues (paras. 2.19 to 2.32).

Sewage conveyance system

2.2 SCS under HATS Stage 2A comprises a network of interconnected sewage tunnels (see Photograph 1 for an example) and vertical shafts (see Photograph 2 for an example). The vertical shafts collect sewage from eight PTWs in North Point, Wan Chai East, Central, Sandy Bay, Cyberport, Wah Fu, Aberdeen and Ap Lei Chau. The collected sewage is conveyed to SCISTW via deep sewage tunnels with a total length of 20.8 km and depths varying from 70 to 160 metres below sea level.

Photograph 1

Sewage tunnel

Photograph 2

Vertical shaft

Source: DSD records

2.3 Contracts A to C (with a total final contract sum of $7,151 million) were remeasurement contracts (Note 13) covering the construction of SCS (see Table 7). Consultant X was the Engineer responsible for supervising the contract works.

Table 7

Construction of SCS under Contracts A to C
(May 2018)

Contract	Alignment of SCS	Tunnel length (km)	Final contract sum (Note 1) ($ million)
A (Note 2)	North Point to Stonecutters Island	12.0	4,043.8
B (Note 3)	Aberdeen to Sai Ying Pun	7.5	2,827.2
C (Note 4)	Ap Lei Chau to Aberdeen	1.3	280.0
	Total	20.8	7,151.0

Source: *DSD records*

Note 1: *The accounts of Contracts A to C were finalised in April 2018, May 2018 and December 2015 respectively.*

Note 2: *DSD awarded Contract A to Contractor A in July 2009 at a contract sum of $3,763.1 million. The works commenced in July 2009 with a contract period of about 65 months. In the event, the contract works were completed in November 2016, about 22.2 months (676 days) later than the original completion date of January 2015 with EOTs (see Note 12 to para. 1.9) for the whole period granted to Contractor A (of which 151.5 days were due to inclement weather).*

Note 3: *DSD awarded Contract B to Contractor B in July 2009 at a contract sum of $2,544.8 million. The works commenced in July 2009 with a contract period of about 65 months. In the event, the contract works were completed in December 2014, about 0.7 month (21 days) earlier than the original completion date of January 2015.*

Note 4: *DSD awarded Contract C to Contractor C in August 2009 at a contract sum of $236.5 million. The works commenced in August 2009 with a contract period of about 24 months. In the event, with 110 days recovered from delay mitigation measures implemented by Contractor C as approved by DSD at a cost of $44.5 million under Contract C, the contract works were completed in May 2014, about 33 months (1,004 days) later than the original completion date of August 2011. Of the 1,004 days, EOTs of 871 days were granted to Contractor C (of which 130 days were due to inclement weather) whereas the remaining 133 days were the delays subject to liquidated damages (see Note 12 to para. 1.9) of $4.4 million recovered from Contractor C.*

Note 13: *Under a remeasurement contract, the costs of works are based on the actual quantities of works done to be remeasured and the prices of different works items as priced by the contractor in BQ (see paras. 2.4 to 2.6) according to the contract.*

Management of Bills of Quantities items

2.4 According to the Project Administration Handbook for Civil Engineering Works (hereinafter referred to as the Project Administration Handbook) issued by the Civil Engineering and Development Department (CEDD):

(a) BQ are a list of items giving brief identifying descriptions and estimated quantities of the works to be performed; and

(b) the main functions of BQ are to:

(i) allow a comparison of tender prices; and

(ii) provide a means of valuing the works.

Compilation of BQ

2.5 For a remeasurement contract, BQ are prepared after completing the works design. The nature and extent of works to be performed are based on the drawings, specifications and conditions of the works contracts, with reference to the Standard Method of Measurement for Civil Engineering Works (Note 14). Related works items are grouped into BQ sections. For each BQ item, an estimated quantity of works to be performed is included in BQ. During the tendering of the contract, tenderers are required to indicate in BQ:

(a) a rate for each BQ item;

(b) the amount of each BQ item (i.e. estimated quantity × BQ rate); and

(c) the sum of amounts for the BQ items.

Note 14: *The Standard Method of Measurement for Civil Engineering Works lays down the method and criteria for the measurement of civil engineering works undertaken for the Government.*

2.6 After the award of the contract, BQ form part of the contract. Upon completion of the BQ item works, payments are made to the contractor based on the actual quantity of works carried out and the BQ rate of the item.

Omitted items

2.7 An omitted item refers to the omission of an appropriate item in BQ for the works which are shown/provided in the contract drawings or specifications. According to the General Conditions of Contract for Civil Engineering Works, for an omitted item:

(a) the contractor is required to carry out the works of the omitted item;

(b) the Engineer shall correct any such omission, and ascertain and certify the value of the works actually carried out;

(c) if there is a similar item in BQ, the omitted item should be valued at the rate of the similar BQ item; and

(d) if there is no similar item in BQ, the omitted item should be valued at a rate:

  (i) based on the rates in the contract so far as may be reasonable and failing which, at a rate agreed between the Engineer and the contractor; and

  (ii) fixed by the Engineer in the event that the Engineer and the contractor fail to reach an agreement on a rate.

2.8 Audit noted that there was room for improvement in DSD's work in management of BQ items (see paras. 2.9 to 2.17).

Works items in tenderers' design were omitted in BQ

2.9 Audit examination revealed that works items in tenderers' design were omitted in the respective BQ of Contracts A and B. In the course of subsequent contract administration of Contracts A and B, omissions of BQ items were claimed by the pertinent contractors and assessed by Consultant X, leading to payments of $188.8 million to Contractor A (see Case 1) and $177.4 million to Contractor B (see Case 2) for carrying out the works of the related omitted items.

Case 1

Omitted items under Contract A

1. The tender drawings of Contract A showed an indicative design which included the construction of two temporary adits (commonly defined as a temporary, mostly horizontal passage into a mine, for access or drainage). A tenderer was asked to take the indicative design for reference and derive a final design (hereinafter referred to as adapted design) based on the specific methods it would use for construction. According to Contractor A's adapted design in its tendered technical submission, in addition to the two temporary adits shown on the tender drawings, there were three horizontal passages to provide safer and more flexible access from the opposite directions of the sewage tunnels. After the award of Contract A to Contractor A, the technical submission formed part of the contract.

2. Contractor A contended that works items for the horizontal passages were omitted in BQ. According to Consultant X's assessment on Contractor A's contention, the horizontal passages had not been measured in BQ so that a correction to BQ was required. DSD agreed with Consultant X's assessment. According to DSD, items for temporary adits in BQ were not applicable because they only referred to the temporary adits as shown on the tender drawings and did not cover the horizontal passages in Contractor A's technical submission. In the event, DSD paid $188.8 million to Contractor A for carrying out the works of the related omitted items.

Audit comments

3. Works items for three additional horizontal passages under Contractor A's adapted design in its tendered technical submission were omitted items and not included in BQ.

Source: Audit analysis of DSD records

Case 2

Omitted items under Contract B

1. The tender drawings of Contract B showed an indicative design which included the construction of two temporary adits. A tenderer was asked to take the indicative design for reference and derive a final design (i.e. adapted design) based on the specific methods it would use for construction. According to Contractor B's tendered technical submission, it adapted the indicative design into a final design by deleting the two temporary adits shown on the tender drawings and adding three new temporary adits at other site locations (hereinafter referred to as the new temporary adits). After the award of Contract B to Contractor B, the technical submission formed part of the contract.

2. Contractor B contended that works items for the new temporary adits were omitted in BQ and submitted a claim for the costs of performing the related works. According to Consultant X's assessment on Contractor B's contention, the new temporary adits had not been measured in BQ so that a correction to BQ was required. DSD agreed with Consultant X's assessment and considered that:

(a) the new temporary adits included in the technical submission made by Contractor B in the tender were part of the works under Contract B. This was because according to a contract clause of Contract B, the technical submission shall form part of the contract and Contractor B shall execute the works in accordance with the said submission; and

(b) there should be separate measurement items for temporary adits and the new temporary adits were omitted in BQ.

3. In the event, DSD paid $177.4 million to Contractor B for carrying out the works of the related omitted items.

4. Audit noted that:

(a) according to DSD, Contractor B entered "Not Applicable" in BQ for the two temporary adits in the indicative design as the concerned works items would not be constructed as proposed under Contractor B's technical submission;

(b) according to Consultant X, in the indicative design there were two temporary adits, which were measured and included under the BQ items. Contractor B priced BQ items as "Not Applicable", which maintained competitiveness of Contractor B's tender; and

Case 2 (Cont'd)

(c) according to Consultant X's assessment on Contractor B's contention, Contractor B introduced the new temporary adits in its technical submission and such adits were not measured and included under BQ items.

Audit comments

5. Works items for three new temporary adits under Contractor B's adapted design in its tendered technical submission were omitted items and not included in BQ.

Source: Audit analysis of DSD records

2.10 In response to Audit's enquiries about the requirements for dealing with a tenderer's design in BQ under the Project Administration Handbook and relevant technical circular, in September 2019, CEDD and DSD informed Audit that:

CEDD

(a) Development Bureau Technical Circular (Works) No. 3/2014 of April 2014 on "Contractors' Designs and Alternative Designs" (hereinafter referred to as the 2014 Technical Circular) set out the requirements on the matter. According to the 2014 Technical Circular, a tenderer's design shall be priced as a lump sum item supported by a fully priced and detailed Schedule of Rates. The lump sum item should be included in BQ;

(b) the temporary works in the adapted designs of Contractors A and B (see Cases 1 and 2 in para. 2.9) appeared to fall within the definition of tenderer's design under the 2014 Technical Circular; and

DSD

(c) while the previous version of the 2014 Technical Circular (prevailing at the time of tender invitations for Contracts A and B in December 2008 — Note 15) had set out the requirements in (a) above, it was only applicable to permanent works in a tenderer's design, but not "works of a short limited lifespan or temporary in nature" (which were subsequently included in the 2014 Technical Circular). As a result, the Circular at that time was not applicable to the temporary works in the adapted designs of Contractors A and B (see Cases 1 and 2 in para. 2.9) which involved temporary adits used solely by the pertinent contractors as construction method to facilitate their construction works.

2.11 In Audit's view, in implementing a works project in future, DSD needs to include works items in a tenderer's design as a lump sum item in BQ.

Need to critically check the completeness of BQ items

2.12 Audit examination revealed that the omission of BQ items for excavation in shafts involving one type of excavated materials led to payment of $68.5 million to Contractor A for carrying out the works of the related omitted items (see paras. 2.13 to 2.16).

2.13 Under Contract A, Contractor A was required to carry out excavation in shafts by either blasting method or mechanical/manual method. According to Contract A, for the purposes of measurement of excavation in shafts:

(a) different types of excavated materials were defined in contract clauses, as follows:

(i) for each length along the centreline of the permanent shaft covered by one round of blasting or excavation, the whole length shall be

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Note 15: *Environment, Transport and Works Bureau Technical Circular (Works) No. 25/2004 of August 2004 on "Contractors' Designs and Alternative Designs" was replaced by the 2014 Technical Circular.*

classified as "bedrock" (hereinafter referred to as Type 1 material) if not less than 75% of the area of the exposed ground surfaces on the bottom and sides of the shaft is formed by decomposition Grades I, II or III rock (Note 16), otherwise the whole length shall be classified as "ground other than bedrock" (hereinafter referred to as Type 2 material); and

(ii) where the ground condition requires excavation using mechanical/manual method (Note 17) that length of excavation will be measured as "material other than bedrock" (hereinafter referred to as Type 3 material); and

(b) separate items should be provided in BQ for excavation of different types of excavated materials in shafts.

2.14 Under BQ of Contract A, items were provided for excavation of Types 1 and 2 materials in shafts but not Type 3 material. Contractor A contended that works items for excavation of Type 3 material in shafts were omitted in BQ and submitted a claim for the costs of performing the related works. After an initial assessment, Consultant X rejected Contractor A's claim on the grounds that:

(a) the whole length of the shaft would fall into the definition of either Type 1 or Type 2 material; and

(b) Type 3 material had been adequately covered under the classification of Type 2 material.

2.15 Contractor A did not agree with Consultant X's assessment. Consultant X then conducted a further review of Contractor A's claim and assessed that excavation

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Note 16: *Decomposition grades of rock material are classified into Grades I to VI (with descending rock hardness) under the Guide to Rock and Soil Descriptions issued by the Geotechnical Engineering Office of CEDD.*

Note 17: *Excavation using mechanical/manual method is adopted unless blasting method is permitted by the Mines Division of CEDD. In addition, in soil or when the rock content is low, blasting method would not be applicable and excavation can only be carried out using mechanical/manual method.*

of Type 3 material in shafts by mechanical/manual method had not been measured in BQ so that a correction to BQ was required. DSD agreed with Consultant X's assessment and considered that BQ items for Type 2 material did not include Type 3 material in view of the following:

(a) Types 2 and 3 materials were referring to two totally different types of excavation method, namely blasting method and mechanical/manual method; and

(b) excavation by mechanical/manual method did not involve separate working cycles and there was no "area of the exposed ground surfaces" as in the case of excavation by blasting method. This implied that the contract clause mentioned in paragraph 2.13(a)(i) was not intended to be applicable for the measurement of excavation in shafts by mechanical/manual method.

In the event, DSD paid $68.5 million to Contractor A for carrying out the works of the related omitted items.

2.16 Audit noted that, in February 2010 (after the awards of Consultancy X and Contract A in January 2006 and July 2009 respectively), CEDD amended the Project Administration Handbook concerning preparation of BQ as follows:

(a) all works items should be included in BQ and omitted items should be minimised as far as practicable;

(b) BQ should undergo a checking process to ensure the completeness and accuracy of BQ and elimination of major errors; and

(c) the above measures would facilitate competitive tendering, reduce resources for valuation of omitted items and minimise the disputes arising from the valuation of omitted items.

According to DSD, since November 2015, it has required an independent checking of BQ of its works contracts. In Audit's view, in implementing a works project in future, DSD needs to continue to make efforts to strengthen checking of BQ for ensuring the completeness and accuracy of BQ.

Audit recommendations

2.17 **Audit has *recommended* that, in implementing a works project in future, the Director of Drainage Services should:**

(a) **include works items in a tenderer's design as a lump sum item in BQ; and**

(b) **continue to make efforts to strengthen checking of BQ for ensuring the completeness and accuracy of BQ.**

Response from the Government

2.18 The Director of Drainage Services agrees with the audit recommendations.

Other contract management issues

2.19 Apart from the management of BQ items, Audit noted that there was scope for DSD to enhance contract management work in other areas (see paras. 2.20 to 2.31).

Scope for better ascertaining the presence of government structures in the vicinity of the works sites before inviting tenders

2.20 Under Contract B, Contractor B was required to construct a shaft at the Aberdeen PTW. Audit examination revealed that some government structures in the vicinity of the works sites were identified after the award of Contract B in July 2009. The salient points are as follows:

(a) prior to the commencement of excavation works, Contractor B informed Consultant X in August 2009 that the location of the shaft at the Aberdeen PTW was in conflict with the actual alignment of an existing trunk sewer of DSD (based on the paper-based construction records created in 2003). To resolve the conflict, the alignments of the location of the shaft, connection channel and tunnel had to be revised. According to Consultant X, the revised works reduced the working space available

around the shaft at the Aberdeen PTW (including the areas for temporary storage of excavated materials and access by dump trucks to remove excavated materials) and the planned working efficiency (unable to achieve the blasting cycle of two blasts per day at the shaft), thereby causing delay to the progress of works;

(b) after the commencement of excavation works, Contractor B identified in October 2009 an abandoned underground reinforced concrete structure that belonged to DSD within the works site of the Aberdeen PTW. To enable the excavation works at the shaft to proceed, additional works had to be carried out to demolish and excavate through part of the structure, thereby causing delay to the progress of the excavation works; and

(c) Audit noted that:

(i) the possibility of underground government structures was investigated at the design stage by Consultant X who requested as-built drawings of structures near the shaft locations from DSD (i.e. Sewage Treatment Division and Hong Kong and Islands Division (Buildings/Civil Maintenance Team)). However, DSD was unable to provide as-built drawings showing that the underground structures (i.e. the trunk sewer and the reinforced concrete structure) existed at the works site of the Aberdeen PTW before inviting the tender; and

(ii) after Contractor B encountered the underground reinforced concrete structure (see item (b) above), Consultant X tried to obtain the then as-built drawings of that structure from DSD again and discovered in early October 2013 that such drawings were kept in the records of the Project Management Division of DSD. The underground reinforced concrete structure was the remaining structure of a screw pumping station inlet chamber that had been partially demolished, backfilled and grassed in 1998 under a DSD works contract and the related as-built drawings were submitted to DSD in 2004 (i.e. before the tendering of Contract B in 2009).

2.21 In the event, EOTs ranging from 95 to 411.5 days were granted for completion of various sections of works under Contract B (Note 18), leading to prolongation costs (Note 19) of $323.3 million. In this connection, for Contracts I, L and M, Audit also noted similar issues relating to variations to the works due to the identification of government structures in the vicinity of the works sites after contract awards, resulting in significant prolongation costs and EOTs granted (see Appendix B for details).

2.22 According to Environment, Transport and Works Bureau Technical Circular (Works) No. 17/2004 on "Impossibility/Unforeseen Ground Conditions/Utility Interference", project officers should:

(a) investigate the existence of any buried underground structures such as abandoned old seawalls, pile caps, etc. within or in the vicinity of the works site and verify the accuracy of the records of these buried structures; and

(b) satisfy themselves that the utility records obtained from utility undertakings or other sources are reasonably accurate before the completion of the detailed design. Depending on the scale and nature of the contract, project officers should conduct desk search and, if necessary, site inspection for the purpose of verifying the utility records.

2.23 In Audit's view, in implementing a works project in future, DSD and its consultants need to better ascertain the presence of government structures in the

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Note 18: *Although EOTs were granted for completion of various sections of works under Contract B, there was no delay for the overall completion of Contract B as the extended times for completion of these sections of works were earlier than the original contract completion date of January 2015.*

Note 19: *Prolongation costs are generally the time related costs (e.g. the costs of a contractor's site establishment, site overheads and general plant) that are typically affected by a delay to the critical path of construction works. Works contracts include provisions for granting EOTs for completion due to events covered by the contract provisions, such as additional works, inclement weather, etc. The Engineer would assess the actual situation of each case, with the prolongation costs calculated as the time related costs additionally incurred for the relevant delay duration of those events for which prolongation costs are grantable.*

vicinity of the works sites before inviting tenders (e.g. through collecting and reviewing as-built drawings of structures from the related divisions of DSD).

Scope for enhancing pre-tender site investigations

2.24 The works under Contract C, covering the construction of 1.3-km deep sewage tunnels between Ap Lei Chau and Aberdeen by the Horizontal Directional Drilling (HDD) method (Note 20), commenced in August 2009 with a contract period of about 24 months. In the event, the contract works were completed in May 2014, about 33 months (1,004 days) later than the original completion date of August 2011 (of which 130 days were due to inclement weather — see Note 4 to Table 7 in para. 2.3). The delays were mainly due to adverse ground conditions undetected in pre-tender site investigations relating to three events, as follows:

(a) construction works under Contract C involved the installation of steel casings (for supporting the soft ground for subsequent drilling operations) at the entry and exit points of the sewage tunnels at the Ap Lei Chau and Aberdeen PTWs. Contractor C encountered underground obstructions (large boulders and reinforced concrete slab — Note 21) that rendered the installation of steel casings by a trenchless placement technique (Note 22)

Note 20: *According to DSD, HDD method was:*

(a) a relatively new construction method at that time especially with such length of sewage tunnel involved. HDD is a surface-launched and remotely controlled drilling technique. The three-stage operation consists of drilling a pilot hole along the proposed alignment of the tunnel, then enlarging the pilot hole by reaming (see Note 26 to para. 2.24(b)), and followed by jointing and pulling of high density polyethylene pipes into the enlarged hole forming the tunnel; and

(b) used under Contract C (instead of the drill-and-blast method under Contracts A and B) to allow better control of the curving vertical and horizontal alignments of sewage tunnels.

Note 21: *According to DSD, there was no record showing whether the obsolete reinforced concrete slab was a structure belonged to DSD or other government departments.*

Note 22: *Trenchless placement technique refers to a construction method with most excavation works conducted underground that requires minimum or no excavation from the ground surface. The technique is being used for the installation of new, replacement or rehabilitation of existing underground infrastructure with minimal disruption to surface traffic, business and other activities.*

(a construction method specified under Contract C) at tunnel exit points at the Ap Lei Chau and Aberdeen PTWs physically impractical, and had to use an open trench technique (Note 23) to remove the boulders and slab. In the event, a variation order (VO — Note 24) (later valued at a cost of $9.5 million) was issued for revising the construction method and EOTs of 264.5 days were granted for completion of two sections of works, leading to prolongation costs of $6.3 million;

(b) cavities in rock led to two incidents of rapid loss of bentonite drilling fluid (Note 25) during the reaming (Note 26) and cleaning process of drilled holes along the sewage tunnels. Contractor C had to perform localised grouting (i.e. ground stabilisation works) to rectify the situation. In the event, EOTs of 116.5 days were granted for completion of two sections of works (Note 27); and

(c) increased hardness of rock caused delays in the drilling and reaming process along the sewage tunnels. Based on the site tests conducted after the commencement of works, the level of hardness of the rock encountered on site was significantly higher than that of the samples obtained during the

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Note 23: *Open trench technique is a traditional and common construction method for excavation works that involves digging a trench along the proposed pipeline route, placing the pipe in the trench on a suitable bedding material, and then backfilling.*

Note 24: *The Engineer shall order any variation to any part of the works that is necessary for the completion of the works or for any other reason shall in the Engineer's opinion be desirable for or to achieve the satisfactory completion and functioning of the works. The Engineer shall also determine the sum which in his opinion shall be added to or deducted from the contract sum as a result of issuing a VO.*

Note 25: *Bentonite drilling fluid is utilised in tunnelling works during drilling of pilot holes and their subsequent enlargement by reaming (see Note 26 to para. 2.24(b)) to lubricate the equipment, transport cuttings from the tunnels and provide support for the excavated tunnel walls.*

Note 26: *Reaming is a process used to enlarge the tunnel bore to facilitate installation of high density polyethylene pipes after the completion of pilot hole drilling.*

Note 27: *According to DSD, for the EOTs granted, Contractor C was not entitled to claim for additional payments of carrying out localised grouting and prolongation costs.*

pre-tender site investigations. In the event, EOTs of 360 days were granted for completion of two sections of works (Note 28).

In the event, EOTs totalling 741 days (264.5 days + 116.5 days + 360 days) were granted for completing each of two sections of works under Contract C due to adverse ground conditions undetected in pre-tender site investigations.

2.25 In September 2019, DSD informed Audit that:

(a) in anticipation of the complicated ground conditions in the construction of the 20.8-km long deep sewage tunnels under HATS Stage 2A, substantial pre-tender site investigations had been conducted to facilitate the construction works; and

(b) pre-tender site investigations included 116 vertical/inclined boreholes (totalling 16 km in length) and the use of the state-of-the-art Horizontal Directional Coring technique (Note 29) to extract horizontal cores at 6 sections of the tunnel alignment (totalling 5 km in length).

2.26 Audit noted that, in January 2005, the Geotechnical Engineering Office of CEDD issued GEO Technical Guidance Note No. 24 on "Site Investigation for Tunnel Works" providing guidance on site investigation for tunnelling works in Hong Kong (Note 30). According to the Technical Guidance Note, pre-tender site investigation should be as comprehensive as possible to provide adequate information for the design of tunnelling works and contract preparation.

Note 28: *According to DSD, for the EOTs granted, Contractor C was not entitled to claim for additional payment of prolongation costs.*

Note 29: *Horizontal Directional Coring technique provides a continuous core sample and more reliably identifies the extent of problematic ground and groundwater conditions along the tunnel alignment. Hence, the risk of unforeseen tunnelling conditions can be minimised compared to using only conventional vertical and inclined boreholes.*

Note 30: *The Technical Guidance Note was issued in response to an audit recommendation (included in Chapter 3 on "Harbour Area Treatment Scheme Stage 1" of the Director of Audit's Report No. 42 of March 2004) relating to the promulgation of guidelines for improving site investigations, particularly for tunnel projects.*

2.27 In the light of the experience gained under Contract C, Audit considers that, when implementing a works contract involving tunnelling works in future, DSD and its consultants need to further enhance pre-tender site investigations, particularly for works at critical locations, with a view to providing better information on site conditions for design and tender purposes as far as practicable.

Need to conduct post-completion review

2.28 According to the Project Administration Handbook:

(a) a post-completion review is a useful project management tool and shall be conducted upon the substantial completion of a major consultancy agreement or a major works contract on projects under the Public Works Programme;

(b) as a broad guideline, post-completion reviews are generally not warranted for consultancy agreements and works contracts of a project which has a total cost less than $500 million or of a project which does not involve complicated technical and management issues;

(c) indicators that a project involves complicated issues may include, among others, project involving a claim of a substantial sum, say over $1 million;

(d) works contracts with a significant amount of omitted items should be reviewed upon substantial completion of the contracts with a view to identifying areas for improvement in preparation of BQ;

(e) a post-completion review should be carried out within a reasonable period, say six months, after the substantial completion of a consultancy agreement or a works contract;

(f) for a project that comprises a number of contracts/consultancy agreements, the project office may elect, in view of the benefit of an overall review, to conduct a single post-completion review upon the substantial completion of the last contract; and

(g) upon the completion of a post-completion review, the department shall prepare a report documenting all concerned issues, findings, conclusions and recommendations for future reference by the department.

2.29 DSD completed a post-completion review for HATS Stage 1 in March 2004. The review found that, with the valuable experience gained in HATS Stage 1, various aspects (Note 31) in future delivery of similar projects could be improved.

2.30 Audit noted that HATS Stage 2A involved a significant project expenditure of $16,868.7 million as of July 2019 (see para. 1.10). Some of the works contracts under the project involved significant amounts of claims or omitted items (e.g. Contracts A and B involved omitted items for measurement of temporary adits of $188.8 million and $177.4 million respectively — see para. 2.9). As of September 2019, while all works contracts (except Contract K — see para. 1.9) of HATS Stage 2A had been substantially completed and it had been commissioned for some 3.7 years, no post-completion review was conducted. According to DSD:

(a) for a project that comprises a number of contracts/consultancy agreements, the project office may elect to conduct a single post-completion review upon the substantial completion of the last contract (see para. 2.28(f)); and

(b) while one works contract (i.e. Contract K) under HATS Stage 2A was still on-going and the post-completion review was intended to be conducted after the completion of this remaining works contract, DSD considered that conducting a post-completion review for those completed works contracts first would help identify areas for early improvement.

As post-completion review is a useful project management tool and such review was also conducted for HATS Stage 1 in 2004, Audit considers that it is an opportune time for DSD to conduct a post-completion review for those completed works contracts of HATS Stage 2A first with a view to identifying areas for early improvement.

Note 31: *The aspects included: (a) planning and design of deep tunnels; (b) risk management of underground works; (c) selection and management of contractors; and (d) the use of multiple contracts.*

Audit recommendations

2.31 **Audit has *recommended* that the Director of Drainage Services should:**

(a) **in implementing a works project in future, better ascertain the presence of government structures in the vicinity of the works sites before inviting tenders (e.g. through collecting and reviewing as-built drawings of structures from the related divisions of DSD);**

(b) **when implementing a works contract involving tunnelling works in future, further enhance pre-tender site investigations, particularly for works at critical locations, with a view to providing better information on site conditions for design and tender purposes as far as practicable; and**

(c) **consider conducting a post-completion review for those completed works contracts of HATS Stage 2A first with a view to identifying areas for early improvement.**

Response from the Government

2.32 The Director of Drainage Services agrees with the audit recommendations. He has said that:

(a) DSD is currently developing a system through the use of Building Information Modelling, Geographical Information System and Point Cloud techniques to strengthen the communication amongst parties concerned and the record-keeping of utilities and obsolete underground structures; and

(b) substantial pre-tender site investigations had already been conducted for the construction of the deep sewage tunnels under HATS Stage 2A. In future projects, in the light of the experience gained, more site investigations will be carried out as far as practicable to provide better information on site conditions. However, it should be noted that the risks of unexpected ground conditions cannot be removed completely even with more comprehensive site investigations.

PART 3: EXPANSION AND UPGRADING OF STONECUTTERS ISLAND SEWAGE TREATMENT WORKS

3.1 This PART examines DSD's work in managing contracts for the expansion and upgrading of SCISTW, focusing on:

(a) design and provision of deodourisation (DO) facilities (paras. 3.5 to 3.19); and

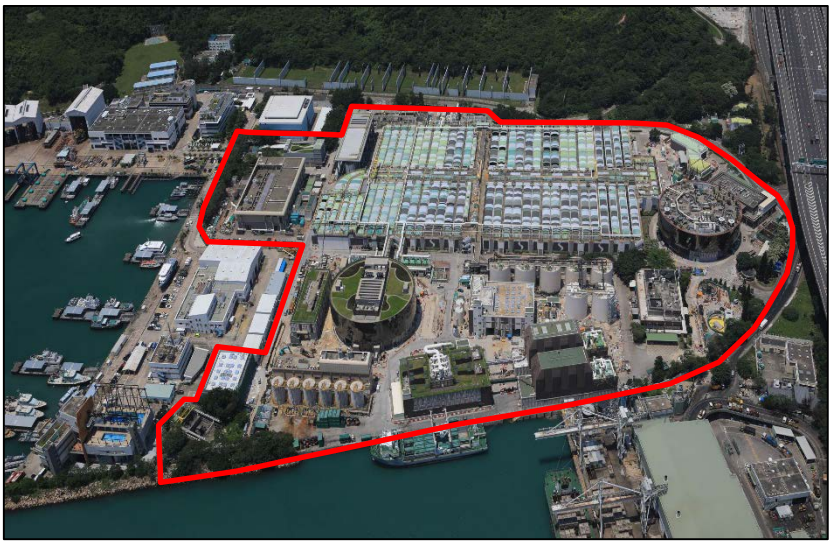
(b) other contract management issues (paras. 3.20 to 3.28).

Expansion and upgrading of Stonecutters Island Sewage Treatment Works

3.2 SCISTW (see Photograph 3), constructed under HATS Stage 1, occupies an area of 10.6 hectares and was expanded and upgraded under HATS Stage 2A to increase its design daily treatment capacity and to provide disinfection facilities (see para. 1.5(b)).

Photograph 3

SCISTW



Source: *DSD records*

3.3 DSD awarded eight works contracts (Contracts D to K) for the expansion and upgrading works for SCISTW. Except Contract K which was awarded in July 2019 with scheduled contract completion date of May 2021, all the other seven works contracts (Contracts D to J) had been completed between December 2009 and September 2017 (see Table 4 in para. 1.9) with a total expenditure of $6,286.8 million as of July 2019. Consultant Y was the Engineer responsible for supervising the contract works. Table 8 shows the works and expenditures under Contracts D to K. Figure 3 shows the locations of such works.

Table 8

Expansion and upgrading works for SCISTW under Contracts D to K (July 2019)

Contract	Contract type	Works	Final contract sum/ up-to-date contract expenditure (Note 1) ($ million)
D	Lump sum contract (Note 2)	Construction of advance disinfection facilities (see Note 9 to para. 1.5(b))	105.1
E		Provision of covers and DO facilities to the existing sedimentation tanks (Note 3)	188.2
F	Remeasurement contract	Construction of interconnection tunnel and diaphragm wall for Main Pumping Station (MPS) No. 2	604.5
G		Upgrading works – MPS No. 2, sedimentation tanks and ancillary facilities (Note 3)	2,711.9
H		Upgrading works – sludge dewatering facilities (Note 3)	1,448.9
I		Upgrading works – effluent tunnel and disinfection facilities (Note 3)	864.1
J	Design-build-operate contract (Note 4)	Upgrading works – sludge handling and disposal facilities	364.1 (Note 5)
K	Remeasurement contract	Enhancement of DO system	— (Note 6)
		Total	6,286.8

Source: DSD records

Table 8 (Cont'd)

Note 1: The accounts of five contracts (Contracts D to F, I and J) were finalised between July 2012 and March 2019. As of July 2019, the accounts of two contracts (Contracts G and H) had not been finalised and the respective amounts were the up-to-date contract expenditures.

Note 2: Under a lump sum contract, the quantities of various works items are substantially measured firm and the final price to be paid is ascertained by adding to/deducting from the contractor's accepted tender price the value of variations and other specified items (e.g. provisional quantities and contingency items).

Note 3: A total of 11 DO units were constructed under Contracts E (2 units), G (2 units), H (4 units) and I (3 units).

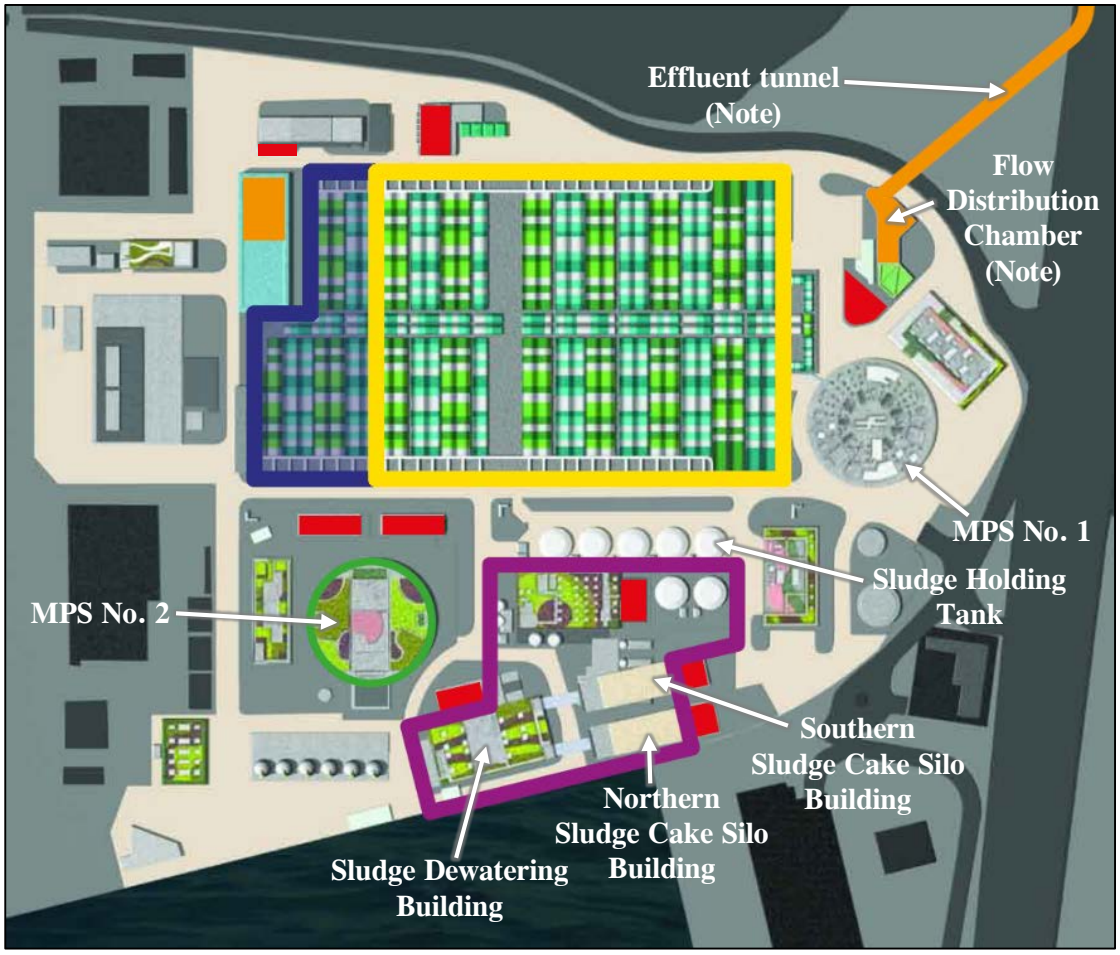
Note 4: Under a design-build-operate contract, the contractor takes on full responsibility for the design, construction, operation and maintenance of the works but the Government retains the ownership of the works.

Note 5: The amount was related to the design and build portion only.

Note 6: Contract K was awarded in July 2019 at a contract sum of $169 million with scheduled contract completion date of May 2021.

Figure 3

Expansion and upgrading works for SCISTW



Legend:
- Disinfection facilities
- Covers installation at sedimentation tanks
- DO units (with several sets of DO facilities inside each unit)
- MPS No. 2
- Expansion of sedimentation tanks
- Sludge dewatering facilities

Source: *DSD records*

Note: *The chemically treated effluent is conveyed to the Flow Distribution Chamber where bleach (sodium hypochlorite) is added for disinfection. The treated effluent undergoes disinfection process in the effluent tunnel to reduce the bacteria level in the effluent.*

Remarks: *Two DO units located at the end of the effluent tunnel and the underground interconnection tunnel transferring sewage between MPS No. 1 and MPS No. 2 are not shown in this Figure.*

3.4 All sewage generated from the harbour catchment is transferred via deep sewage tunnels to SCISTW for centralised CEPT and disinfection before discharging into the harbour (see Figure 4 for the sewage treatment process at SCISTW). The discharge from SCISTW is required to comply with the conditions of discharge licence issued by the Director of Environmental Protection under the Water Pollution Control Ordinance (Cap. 358). The conditions include limitations on the quantity and composition (i.e. suspended solids, *Escherichia coli*, biochemical oxygen demand and total residual chlorine) of discharge. According to DSD:

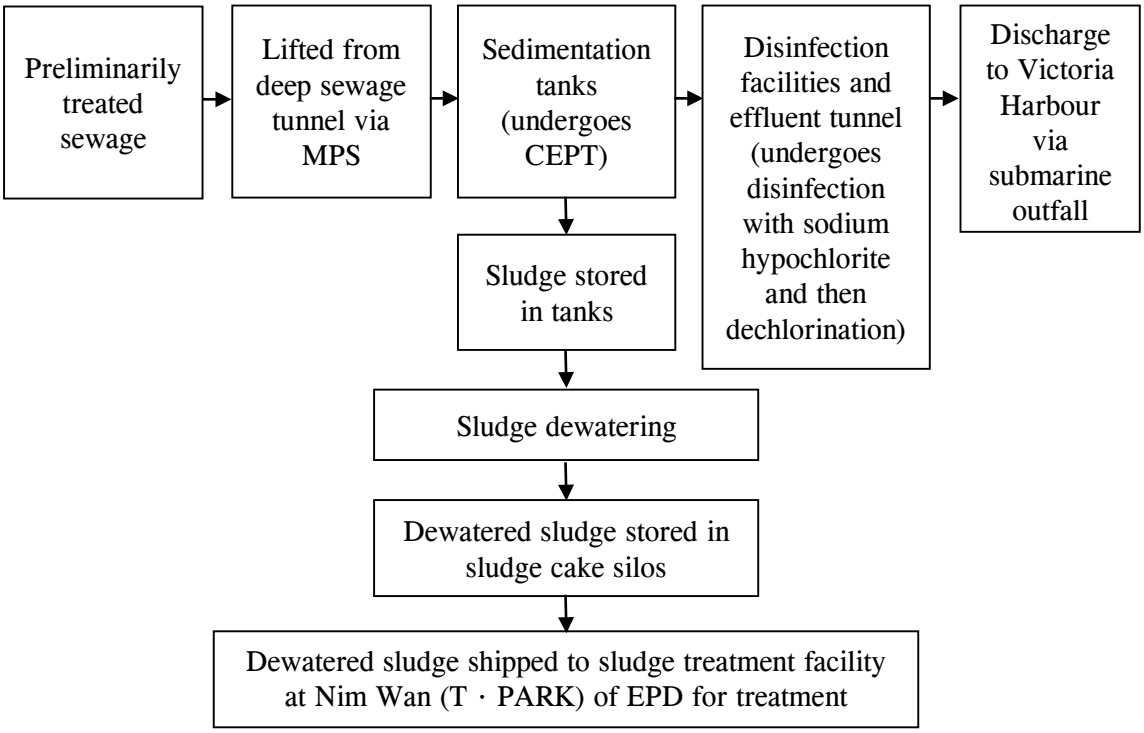
(a) the monitoring data relating to the quantity and composition of discharge from SCISTW is uploaded onto its website; and

(b) SCISTW generally complied with the conditions of discharge licence since the commissioning of HATS Stage 2A in December 2015 (Note 32).

Note 32: *According to DSD, there were four non-compliance cases (exceeding the percentile standard for biochemical oxygen demand of discharge) in August, November and December 2016 and one non-compliance case (exceeding the upper limit for total residual chlorine of discharge) in July 2017. There had not been any non-compliance with the conditions of discharge licence since August 2017 and up to July 2019.*

Figure 4

Sewage treatment process at SCISTW



Source: *Audit analysis of DSD records*

Design and provision of deodourisation facilities

3.5 Pursuant to the Environmental Impact Assessment Ordinance (EIAO) (Cap. 499 — Note 33), DSD commissioned a consultant to conduct an EIA study for HATS Stage 2A in February 2006. The study was completed in June 2008 and the EIA report was approved by the Director of Environmental Protection in October 2008. An environmental permit was issued in November 2008.

Note 33: *Under EIAO, a person who wishes to carry out a designated project needs to submit a project profile to the Director of Environmental Protection for issuing an EIA study brief. Thereafter, he needs to prepare an EIA report based on the EIA study brief for submission to the Director for approval, and to obtain an environmental permit before constructing or operating the project. HATS Stage 2A was a designated project (sewage collection, treatment, disposal and reuse) under EIAO.*

3.6 According to the EIA report, odour emission from sewage treatment works, including SCISTW, would be the main concern during the operation phase of the project. According to DSD, to contain the odour problem, all potentially odourous facilities at SCISTW, including the pumping stations, Sludge Dewatering Building (SDB), sludge cake silo buildings, sedimentation tanks, etc. are enclosed and controlled to provide an odour-free environment. The foul air inside the enclosures is extracted and ducted to designated DO facilities to undergo treatment using chemical scrubber, bio-trickling filter and activated carbon filter technology (Note 34) before it is released into the open air.

3.7 According to the criteria for evaluating air quality impact stipulated in the technical memorandum (Note 35) issued under EIAO, the odour level at an air sensitive receiver (Note 36) should not exceed 5 odour units (OU) based on an averaging time of five seconds (hereinafter referred to as the odour criterion). According to Consultant Y (who subsequently specified the design requirements of the DO facilities based on the EIA findings — Note 37), hydrogen

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Note 34: *Three commonly used DO technologies are as follows: (a) chemical scrubber allows the contact of odourous gas with a scrubbing solution. Odour contaminants are transferred from the gas stream to the scrubber liquid through adsorption, thereby oxidised by the scrubbing chemicals; (b) bio-trickling filter uses biological odour treatment technology for treating odourous gas. In bio-trickling filter, the micro-organism plays the main role for the entire DO process. The micro-organisms live in the air-permeable inert media inside the bio-trickling filter tower. When the air stream passes through the media, the micro-organisms can absorb and dissolve the smelly compounds to make the air clean; and (c) activated carbon filter is more commonly adopted for low hydrogen sulphide or odour level environment or used as secondary polishing unit in sewage treatment works. The odourous gas is introduced in the adsorber vessel and blown through the caustic impregnated activated carbon bed where the contaminants are entrained and oxidised.*

Note 35: *The technical memorandum sets out the principles, procedures, guidelines, requirements and criteria for compiling a project profile, an EIA study brief and an EIA report, and issuing an environmental permit.*

Note 36: *Any domestic premises, hotel, hostel, hospital, clinic, nursery, temporary housing accommodation, school, educational institution, office, factory, shop, shopping centre, place of public worship, library, court of law, sports stadium or performing arts centre shall be considered to be an air sensitive receiver.*

Note 37: *According to DSD, for the purpose of studying the effectiveness of the proposed odour mitigation measures, an in-situ odour sampling was conducted and computational modelling technique was used in the EIA study to assess the air quality impact at the air sensitive receivers.*

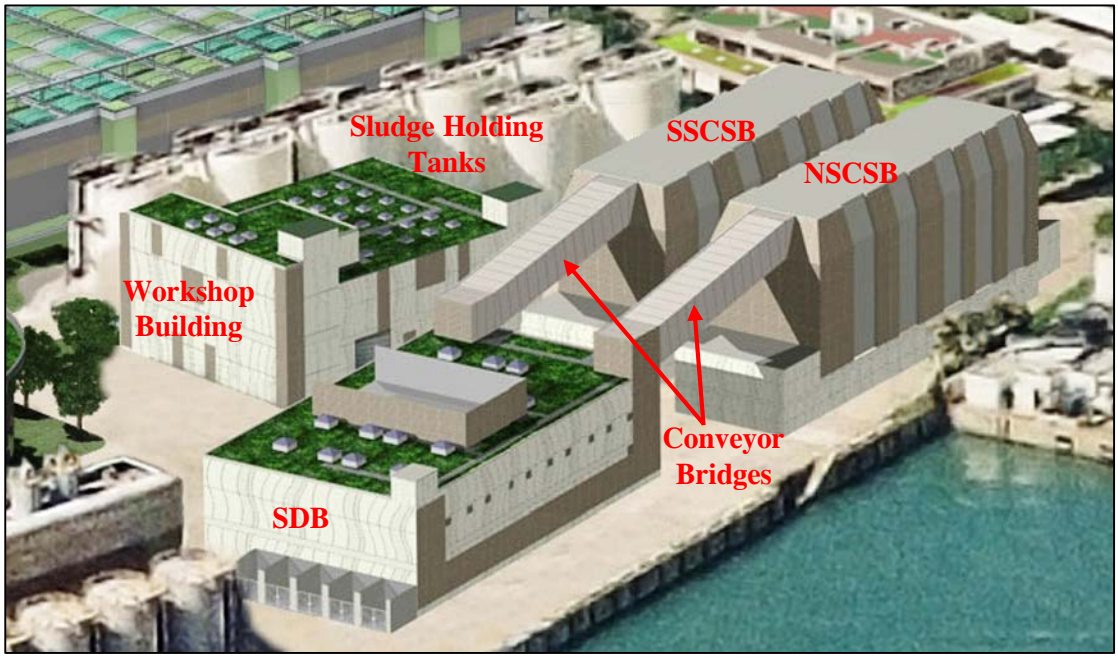
sulphide (H_2S — Note 38) is often highlighted as the indication of odour from sewage treatment works and 5 OU are roughly equivalent to 0.0025 part per million H_2S by volume.

Need to draw on the experience gained in design changes of DO facilities

3.8 Under Contract H, Contractor H was originally required to construct a DO unit as a centralised system for treating foul air extracted from SDB (including the Conveyor Bridges), the Northern Sludge Cake Silo Building (NSCSB) and the Southern Sludge Cake Silo Building (SSCSB) (see Figure 5). The original design of the DO unit (located at SDB) adopted chemical scrubber treatment with activated carbon filter technology due to the relatively high odour (H_2S) loading from the three buildings and the limited space available for accommodating the DO unit.

Figure 5

Schematic diagram of sludge dewatering facilities under Contract H



Source: *DSD records*

Note 38: *H_2S is a toxic gas and can be a health hazard especially in confined spaces. As H_2S is relatively easy to measure and particularly detected by the human nose, it is often used as a target indicator for odour.*

3.9 There were design changes of DO facilities after the award of Contract H. The salient points are as follows:

Tender stage

(a) according to DSD, notwithstanding the approval of the EIA report in accordance with EIAO before the tender invitation, during the tender stage of Contract H, key stakeholders requested tightening the odour control measures to further reduce the odour released from NSCSB and SSCSB when sludge container vehicles enter the buildings. As the tender would soon close at that time, DSD issued a tender addendum (Note 39) for incorporating a provisional sum (Note 40) in the tender which required the contractor to design and construct a double door enclosure system (Note 41) for each of NSCSB and SSCSB during the construction stage; and

Construction stage

(b) during the construction stage:

(i) Consultant Y issued site instructions to Contractor H to implement the works under the provisional sum (later valued at a cost of $18.3 million). Under the site instructions, Contractor H was required to design and construct one-storey reinforced concrete framed structures as extensions to the buildings (i.e. NSCSB and SSCSB), and the double door enclosure systems to enable better odour control;

Note 39: *If amendments to tender documents are found necessary after they have been issued to tenderers, such amendments shall be processed as a tender addendum to all tenderers.*

Note 40: *Provisional sum means a sum provided for works or expenditure which has not been quantified or detailed at the time the tender documents are issued.*

Note 41: *The construction of a double door enclosure system achieved better odour control by enclosing the air space within NSCSB and SSCSB for DO when sludge container vehicles enter the buildings.*

(ii) Contractor H proposed and DSD approved a cost saving design (Contractor H estimated that there would be a saving of $1.5 million for construction cost and about $24.7 million for recurrent cost over the design life of 15 years) under which all the dewatered sludge from SDB would be transferred to NSCSB and SSCSB in air sealed pipework, thereby reducing a considerable amount of the odour loading from NSCSB and SSCSB;

(iii) with the additional space made available at the roof of the double door enclosure systems (see item (b)(i) above) and the reduced odour loading (see item (b)(ii) above), Consultant Y took the initiative to revisit the use of bio-trickling filter treatment technology (which was considered infeasible during the design stage given the space limitations) and to review the original design of the DO unit. The review found that bio-trickling filter system (a more environmentally friendly system that uses less chemical and electricity as compared to a chemical scrubber system of the same DO capacity) was technically applicable for NSCSB and SSCSB; and

(iv) in the event, Consultant Y issued a VO (later valued at a cost of $28.2 million) to Contractor H for constructing a smaller size DO unit for serving SDB only, and two additional DO units adopting bio-trickling filter treatment with activated carbon filter technology for serving NSCSB and SSCSB. By carrying out the works under the VO, Consultant Y estimated that there would be a saving of about $49.5 million for recurrent cost over the design life of 15 years.

3.10 Regarding consultation with key stakeholders on odour control measures and design changes of DO facilities during the construction stage of Contract H, in September 2019, DSD informed Audit that:

(a) DSD had kept communicating with the nearby stakeholders and the public throughout project delivery (Note 42). Nearby stakeholders had been invited to visit SCISTW. Views and concerns were collected and addressed expeditiously. DSD had undertaken a prudent approach in respect of consultation; and

(b) the DO design was progressively made more cost effective (see para. 3.9(b)).

3.11 In the light of DSD's experience gained in progressively making the DO design at SCISTW more cost effective (see para. 3.10(b)), Audit considers that DSD needs to draw on the experience gained in design changes of DO facilities at SCISTW to further improve the design of DO facilities for sewage treatment works in future.

Need to continue to make efforts to monitor the odour situation and tackle the odour issue at SCISTW

3.12 In 2014, DSD observed that based on the actual on-site measurements, the maximum H_2S concentration measured at some enclosed inlets (Note 43) of DO units within SCISTW exceeded the maximum design inlet H_2S concentration. To ensure no adverse air quality impact to the air sensitive receivers, in December 2014, DSD engaged Consultant Y to conduct an odour study (additional services under Consultancy Y) for enhancing the odour management at SCISTW. The study included

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Note 42: *According to DSD, the work included, for example, that representatives from DSD had attended regularly the meetings of the Environmental and Hygiene Committee of the Sham Shui Po District Council to introduce HATS Stage 2A project and report the design and progress of DO enhancement works since January 2007, i.e. at the time of the EIA study.*

Note 43: *Inlet is the enclosed part of the odour emission facilities and located at the upstream of a DO unit. The foul air inside the inlet has not yet been treated by the DO unit.*

an odour review and monitoring to assess the odour strength at various locations within SCISTW and a review on the design of the existing DO facilities at SCISTW to identify enhancement measures for further odour abatement.

3.13 In July 2017, the odour study was completed (Note 44). Consultant Y found that:

(a) certain odour sources (e.g. pumping stations and sedimentation tanks) at SCISTW had emitted high H_2S levels as compared to the specified design requirements of the DO facilities (Note 45). Some of the measured maximum H_2S concentration from inlets of DO units exceeded their design maximum values by about 2 to 13 times during the sampling period; and

(b) based on the projection of the computer odour dispersion model using updated on-site measurements, the odour criterion (see para. 3.7) might be exceeded in future in the worst case scenario (Note 46). Further enhancement works to the existing DO facilities at SCISTW were therefore required to cater for the worst case scenario.

3.14 In August 2018, DSD approved to carry out further odour reduction measures at SCISTW (including enhancement works on 5 existing DO units constructed under Contracts E (2 units), G (1 unit), H (1 unit) and I (1 unit), and

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Note 44: *The odour study had been suspended between September 2015 and June 2016 due to HATS Stage 2A commissioning works. The study was resumed in July 2016 and completed in July 2017.*

Note 45: *According to DSD, the reasons for the disparity between actual odour levels of odour sources at SCISTW and those in the original design were mainly due to the increasing trend of higher temperature (H_2S generation increased with temperature) caused by climate change (the number of very hot days per annum increased steadily in the past 10 years).*

Note 46: *Outlet is located at the downstream of a DO unit. The air there has been treated by the DO unit and will be released into the open air. The treated air is the determinant whether the odour intensity is acceptable or not. The worst case scenario referred to all outlets of DO units emitting peak H_2S concentration at the same time in summer under certain wind direction.*

construction of a new DO unit for rapid mixing chamber (Note 47) as recommended by the odour study) with a view to mitigating potential odour nuisance to the surrounding air sensitive receivers in future. According to DSD:

(a) it had adjusted the operation of the DO facilities to increase the odour removal efficiency of the DO facilities. As a result, the odour intensity detected during the regular odour patrol at the site boundary of SCISTW (Note 48) remained non-detectable (86.5%), slight (13.4%) or moderate (0.1%) during the period from April 2016 to August 2019, indicating compliance with the odour criterion (see para. 3.7); and

(b) further odour reduction measures were required in view of the fact that:

(i) despite satisfactory performance of the DO units and the acceptable odour intensity detected during the regular odour patrol (see item (a) above), the odour emission might still be excessive from these facilities in future as revealed from the computer odour dispersion model's worst case scenario; and

(ii) there were recently completed new housing developments in the vicinity of SCISTW (Note 49).

3.15 In November 2018, DSD engaged Consultant Y to provide assistance in implementing the enhancement measures for DO system at SCISTW (additional services under Consultancy Y), including design, tender documents preparation and contract supervision work. In March 2019, DSD invited tender for the enhancement of DO system at SCISTW (i.e. Contract K). In July 2019, DSD awarded Contract K to Contractor K at a contract sum of $169 million. The works commenced in July 2019 and are scheduled for completion in May 2021.

Note 47: *Sewage is mixed with chemicals in rapid mixing chamber before entering the sedimentation tanks.*

Note 48: *According to DSD, regular odour patrol at the site boundary of SCISTW is conducted daily by staff of a laboratory accredited by the Hong Kong Laboratory Accreditation Scheme.*

Note 49: *According to DSD, Hoi Ying Estate and Hoi Lok Court (which are about 750 to 850 metres away from the edge of SCISTW) are examples of nearby housing developments completed recently.*

3.16 In September 2019, DSD informed Audit that:

(a) odour issue was complicated due to its dynamic and transient nature. The case was further complicated due to the large volume of sewage from both sides of the harbour treated by SCISTW; and

(b) DSD had adopted a pragmatic and incremental approach to tackle the odour issue by reviewing and monitoring the odour situation continuously. With the design changes and contract variations regarding DO facilities during construction stage and the adjusted operation of the DO facilities, the odour removal efficiency of the DO facilities was increased such that the odour intensity detected during the regular odour patrol remained acceptable (see para. 3.14(a)).

3.17 Audit noted that odour emission from SCISTW was the main environmental concern during the operation phase (see para. 3.6) and odour issue was complicated due to its dynamic and transient nature (see para. 3.16(a)). In Audit's view, DSD needs to continue to make efforts to monitor the odour situation and tackle the odour issue at SCISTW.

Audit recommendations

3.18 **Audit has *recommended* that the Director of Drainage Services should:**

(a) **draw on the experience gained in design changes of DO facilities at SCISTW to further improve the design of DO facilities for sewage treatment works in future; and**

(b) **continue to make efforts to monitor the odour situation and tackle the odour issue at SCISTW.**

Response from the Government

3.19 The Director of Drainage Services agrees with the audit recommendations.

Other contract management issues

3.20 Apart from the design and provision of DO facilities, Audit noted that there was scope for DSD to enhance contract management work in other areas (see paras. 3.21 to 3.27).

Scope for better assessing the ground conditions of existing structures before inviting tenders

3.21 The Dilution Water Pumping Station (DWPS — Note 50) is an underground reinforced concrete structure built under HATS Stage 1 to serve the CEPT process. According to Consultant Y:

(a) DWPS was a key facility of SCISTW;

(b) there was little provision in the DWPS design to accommodate excessive settlement/movement; and

(c) excessive settlement/movement of DWPS would no doubt compromise the structural integrity of DWPS and damage the pipeworks causing interruptions to the existing SCISTW operation.

3.22 According to DSD:

(a) at the design stage before the commencement of Contract F, a geotechnical design had been conducted to ascertain the existing soil nature/condition underlying SCISTW, including the location of DWPS, and assess the estimated settlement of the adjacent structures and utilities induced by the proposed excavation during construction. The geotechnical design was checked and approved by the Geotechnical Engineering Office of CEDD;

Note 50: *The function of DWPS is to draw effluent from CEPT tanks by gravity and to pump and inject the effluent into the polymer pipes for mixing and diluting the aqueous polymer for the sewage treatment process.*

(b) while DWPS was resting on reclaimed fill materials without any piling support and was thus prone to settlement/movement by construction works carried out in its vicinity, as assessed, the design report concluded that the induced settlement was considered acceptable and would not have any adverse effect on DWPS; and

(c) monitoring instrumentation was installed under Contract F in accordance with the recommendation of the design report to assess and control the influence of the induced settlement.

3.23 During the construction stage of Contract F, DWPS had undergone more-than-expected settlement. To address the safety concern, Contractor F put in place mitigation measures to stabilise DWPS. In order to safeguard DWPS from further settlement and to provide long term stability and integrity of DWPS, Consultant Y issued a VO (later valued at a cost of $9.5 million) to Contractor F for carrying out permanent stabilisation works for DWPS.

3.24 In Audit's view, in implementing a works project in future, DSD and its consultants need to take further measures to better assess the ground conditions of existing structures before inviting tenders with a view to further mitigating the impact of construction works causing settlement of such structures as far as practicable.

Scope for better ascertaining the presence of underground utilities and buried underground structures in the vicinity of the works sites

3.25 Under Contract G, Contractor G was required to complete the works for the Centrate Pipe Return System (Note 51). After the commencement of Contract G, DSD (involving different divisions, including the Sewage Treatment Division and the HATS Division) conducted a comprehensive review of the original design of the Centrate Pipe Return System and then modified the design so as to further enhance its functionality and performance with due regard to the site constraints and the

Note 51: *Centrate solution is generated from the discharges of sludge dewatering process at the sludge dewatering facilities (including SDB and the two sludge cake silo buildings) and from the overflow of Sludge Holding Tanks, and subsequently flows to the two MPSs through the Centrate Pipe Return System.*

evolving operation needs. Two VOs (later valued at a cost of $3.9 million for one VO and $0.3 million for the other) were issued for carrying out the works under the modified design (including the diversion of an existing water main to facilitate the construction works). According to DSD, notwithstanding that examination of all available site records for existing underground utilities and structures had been conducted at the design stage and site constraints had been considered when modifying the design of the system, during the excavation works, Contractor G encountered various uncharted underground utilities including cable ducts and other unforeseeable underground obstructions (e.g. sheet piles — Note 52) which caused delay to the progress of works. In the event, EOTs of 88 days were granted for completion of a section of works, leading to prolongation costs of $16.4 million.

3.26 Environment, Transport and Works Bureau Technical Circular (Works) No. 17/2004 requires project officers to investigate the existence of underground structures and verify the validity of utility records in carrying out the design and in preparing the tender documents (see para. 2.22). In Audit's view, in implementing a works project in future, DSD and its consultants need to better ascertain the presence of underground utilities and buried underground structures in the vicinity of the works sites with a view to further enhancing the planning of the related works as far as practicable.

Audit recommendations

3.27 **Audit has *recommended* that, in implementing a works project in future, the Director of Drainage Services should:**

(a) **take further measures to better assess the ground conditions of existing structures before inviting tenders with a view to further mitigating the impact of construction works causing settlement of such structures as far as practicable; and**

(b) **better ascertain the presence of underground utilities and buried underground structures in the vicinity of the works sites with a view to**

Note 52: *According to DSD, the ownership of the concerned sheet piles could not be confirmed.*

further enhancing the planning of the related works as far as practicable.

Response from the Government

3.28 The Director of Drainage Services agrees with the audit recommendations. He has said that:

(a) in future projects, any previous construction records, if exist, should be reviewed to better assess the ground conditions of existing structures at the design stage with a view to further mitigating the impact of construction works causing settlement of such structures as far as practicable; and

(b) measures should be taken to maintain proper records of underground utilities and buried structures with a view to diminishing the chance of encountering uncharted objects during construction. In this connection, DSD is currently developing a system through the use of Building Information Modelling, Geographical Information System and Point Cloud techniques to strengthen the communication amongst parties concerned and the record-keeping of utilities and obsolete underground structures.

PART 4: UPGRADING OF PRELIMINARY TREATMENT WORKS

4.1 This PART examines DSD's work in managing contracts for the upgrading of PTWs, focusing on:

(a) site access for upgrading works (paras. 4.4 to 4.10); and

(b) cost increase of contract variations (paras. 4.11 to 4.17).

Upgrading of preliminary treatment works

4.2 Sewage is preliminarily treated at PTWs to remove large solids and grits to avoid deposition in the deep sewage tunnels and to protect downstream facilities from damage or blockage. The existing eight PTWs (see Photograph 4 for the Central PTW as an example) at the northern and south-western parts of Hong Kong Island were upgraded to cater for the technical requirements of HATS Stage 2A as well as future development and population growth of the respective districts.

Photograph 4

Central PTW

Source: *DSD records*

4.3 Contracts L to N (with a total expenditure of $1,546.2 million as of July 2019) were remeasurement contracts covering mainly the upgrading works for the eight PTWs (see Table 9). The upgrading works included, among others, construction of fine screens and grit traps (FSGT — Note 53), DO rooms, and modification of existing inlet pumping stations at the eight PTWs. Consultant Y was the Engineer responsible for supervising the contract works.

Table 9

Upgrading works for PTWs under Contracts L to N
(July 2019)

Contract	Works	Final contract sum/ up-to-date contract expenditure (Note) ($ million)
L	Upgrading of three PTWs at North Point, Wan Chai East and Central	767.4
M	Upgrading of five PTWs at Sandy Bay, Cyberport, Wah Fu, Aberdeen and Ap Lei Chau	767.4
N	Demolition of CEPT tanks and associated facilities at the Cyberport Sewage Treatment Works	11.4
	Total	1,546.2

Source: *DSD records*

Note: *The account of Contract N was finalised in June 2018. As of July 2019, the accounts of Contracts L and M had not been finalised and the respective amounts were the up-to-date contract expenditures.*

Note 53: *According to DSD, FSGT remove screenings of over 4 millimetres and 95% of grits greater than 0.2 millimetres in size.*

Site access for upgrading works

4.4 Certain upgrading works at PTWs under Contracts L and M had interface with the construction works of SCS under Contracts A to C. Audit noted that there were delays in handover of works sites and completed civil works between contractors (see paras. 4.5 to 4.9).

Delays in handover of works sites and completed civil works

4.5 Before carrying out the upgrading works at PTWs under Contracts L and M, certain portions of works sites or completed civil works were required to be handed over from contractors responsible for the construction works of SCS under Contracts A to C (i.e. from Contractor A to Contractor L, and from Contractors B and C to Contractor M). The late handover of works sites and completed civil works from Contractor A to Contractor L and the late handover of works sites from Contractors B and C to Contractor M (Note 54) consequentially resulted in significant EOTs and prolongation costs granted under Contracts L and M (see Tables 10 and 11).

Note 54: *The late handover of works sites and completed civil works was due to the fact that Contractors A, B and C encountered conditions affecting their works progress (e.g. inclement weather, unexpected high groundwater inflow during excavation, underground obstructions and adverse ground conditions) with EOTs granted for completing the construction works (see Notes 2 and 4 to Table 7 in para. 2.3, and para. 2.21).*

Table 10

Late handover of works sites and completed civil works from Contractor A to Contractor L

Item	Incident of delay	Impact
1	Late handover of works sites from Contractor A to Contractor L (Note 1)	It caused delay to the progress of the construction of: (a) effluent pipes at the North Point PTW under a section of works of Contract L, resulting in EOTs of 196 days for completing this section of works and prolongation costs of $28.4 million; and (b) twin seawater pumping mains at the North Point PTW under another section of works of Contract L, resulting in EOTs of 197 days for completing this section of works and prolongation costs of $27.8 million.
2	Late handover of completed civil works (i.e. flume channels and drop shaft) from Contractor A to Contractor L (Note 2)	It caused delay to the progress of the installation of electrical and mechanical equipment in these completed civil works at the Wan Chai East PTW under another section of works of Contract L, resulting in EOTs of 496 days for completing this section of works. According to Consultant Y, no prolongation cost was granted as Contractor L had not provided detailed particulars to support its cost claim.

Source: *Audit analysis of DSD records*

Note 1: *According to DSD, the late handover of works sites from Contractor A to Contractor L was partly due to inclement weather of 19.5 days under Contract A which did not attract prolongation costs.*

Note 2: *According to DSD, the late handover of completed civil works from Contractor A to Contractor L was partly due to inclement weather of 157 days under Contract A which did not attract prolongation costs.*

Table 11

Late handover of works sites from Contractors B and C to Contractor M

Item	Incident of delay	Impact
1	Late handover of works sites from Contractor B to Contractor M	It caused delay to the progress of upgrading works at the Cyberport PTW under a section of works of Contract M, resulting in EOTs of 272 days for completing this section of works. According to Consultant Y, no prolongation cost was granted for this EOT.
2	Late handover of works sites from Contractor C to Contractor M (Note)	It caused delay to the progress of upgrading works at the Aberdeen PTW under a section of works of Contract M, resulting in EOTs of 542 days for completing this section of works and prolongation costs of $56.4 million.

Source: *Audit analysis of DSD records*

Note: *According to DSD, the late handover of works sites from Contractor C to Contractor M was partly due to inclement weather of 130 days under Contract C which did not attract prolongation costs.*

4.6 In September and October 2019, DSD informed Audit that:

(a) at the time of tender invitations for Contracts L and M, Consultant Y had reviewed the risks of delays in handover of works sites and completed civil works from Contractors A, B and C;

(b) having regard to the works nature and the delay risks, time gaps had been allowed for between the handover dates from Contractor A and site possession dates by Contractor L (e.g. 22 days for the handover of the works sites and completed civil works mentioned in Table 10 in para. 4.5) and 90 days had been allowed in BQ of Contract M for delayed possession of works sites (see para. 4.7);

(c) Consultant Y had taken appropriate and reasonable measures at the time of preparation of contract documents to reflect the anticipated delays in

handover of works sites between contractors and to minimise the impacts arising from such delays; and

(d) unexpected events still occurred causing the delays in handover.

4.7 In this connection, Audit noted that, in the tender documents of Contract M, tenderers were required to indicate in BQ the amount of compensation per day payable to the contractor for the first 90 days of delay after the specified site possession dates. Contractor M filled in "included" as the amount for this item (i.e. no compensation is payable for the first 90 days of delay in site possession), which became a BQ item in Contract M. However, in the tender documents of Contract L, there was no BQ item for delayed possession of works sites. According to Consultant Y, as delayed possession of works sites was not contemplated at the time of tendering of Contract L, no BQ item for delayed possession was provided separately in BQ. However, it transpired that there were delayed possession of works sites, resulting in prolongation costs granted to Contractor L (see para. 4.5).

4.8 In Audit's view, in implementing a multi-contract works project in future, there is merit for DSD to take further measures (e.g. inclusion of a BQ item for delayed possession of works sites) as appropriate to better minimise the impact arising from delays in handover of works sites and completed civil works between the contractors.

Audit recommendation

4.9 **Audit has *recommended* that, in implementing a multi-contract works project in future, the Director of Drainage Services should consider taking further measures (e.g. inclusion of a BQ item for delayed possession of works sites) as appropriate to better minimise the impact arising from delays in handover of works sites and completed civil works between the contractors.**

Response from the Government

4.10 The Director of Drainage Services agrees with the audit recommendation.

Cost increase of contract variations

Need to notify appropriate higher-rank approving officer of the reasons for cost increase of contract variations as appropriate

4.11 According to DSD requirements, for a proposed VO with an estimated cost of $0.3 million or below, the Engineer for the contract (i.e. Consultant Y) was the approving authority. For those with an estimated cost exceeding $0.3 million, Consultant Y was required to provide an estimate of cost for the proposed VO and obtain prior approval from DSD (approving authority based on the estimated cost for the proposed VO) before issuing a VO to contractors for ordering any variations to works.

4.12 According to DSD's Technical Circular No. 5/2015 of October 2015 on "Approval and Related Authorities for Variations and Claims under Works Contracts" (and the circular prevailing at the time from January 2003 to September 2015 — Note 55), if after a proposed variation has been approved by an approving officer, it is anticipated that the estimated net value of the proposed variation will for reasons other than change in scope (such as underestimation, remeasurement, contract price fluctuations and so forth) increase to the extent of exceeding the approval limit of that approving officer, then the appropriate higher-rank approving officer shall be notified (via the original approving officer) with explanations of such increase as soon as it is known.

4.13 As far as could be ascertained, for 5 VOs (VOs A to E) under Contract L, the up-to-date costs as of July 2019 exceeded the estimated costs by 130% to 969% (see Table 12).

Note 55: *Technical Circular No. 5/2015 replaced Technical Circular No. 2/2003 of January 2003 which had set out a similar requirement (i.e. if due to whatever reason the cost of a variation exceeds its estimate made at the time approval was given and the value of this variation turns out to be in excess of the limit of the officer who gave the approval, the project engineer should as soon as the deviation is known notify the appropriate approving officer through the original approving officer the reason for the increase in estimate).*

Table 12

Five VOs issued under Contract L with significant cost increase

VO	Works	Estimated cost per VO (Note 1) (a) ($)	Up-to-date cost as of July 2019 (Note 2) (b) ($)	Cost increase (c) = (b) – (a) ($)
A	Revisions to pile cap and structural layout of FSGT building at Central PTW	286,000	933,599	647,599 (226%)
B	Amendments to boundary wall alignment and associated road works at Wan Chai East PTW	139,000	850,000	711,000 (512%)
C	Revision to pile cap of FSGT building at North Point PTW	153,000	651,586	498,586 (326%)
D	Amendments to boundary wall alignment and landscaping layout at North Point PTW	281,000	647,667	366,667 (130%)
E	Modification of existing outfall chamber at North Point PTW	52,000	556,130	504,130 (969%)

Source: *Audit analysis of DSD records*

Note 1: *VOs A to E with an estimated cost of less than $0.3 million each were issued within the financial authority of Consultant Y (i.e. no prior approval from DSD was required before issuance).*

Note 2: *The amounts shown in this column were the up-to-date costs of VOs per the latest interim payment certificate and would be adjusted as necessary in the final account of Contract L.*

4.14 Audit noted that the up-to-date costs for VOs A to E exceeded the financial authority (i.e. $0.3 million) of Consultant Y. However, DSD had no documentation showing that the appropriate higher-rank approving officer (i.e. a Senior Engineer of

DSD — Note 56) had been notified of reasons for the cost increase of the 5 VOs. Audit considers that the appropriate DSD officer should have been notified of reasons for such cost increase in accordance with the requirements in the Technical Circular (see para. 4.12). In October 2019, DSD informed Audit that the appropriate higher-rank approving officer would be notified as necessary in accordance with the requirements in the Technical Circular.

4.15 In Audit's view, in implementing a works project in future, DSD and its consultants need to comply with the requirements in DSD's Technical Circular No. 5/2015 relating to notifying the appropriate higher-rank approving officer with explanations of cost increase of contract variations.

Audit recommendation

4.16 **Audit has *recommended* that, in implementing a works project in future, the Director of Drainage Services should take measures to ensure compliance with the requirements in DSD's Technical Circular No. 5/2015 relating to notifying the appropriate higher-rank approving officer with explanations of cost increase of contract variations.**

Response from the Government

4.17 The Director of Drainage Services agrees with the audit recommendation. He has said that the appropriate higher-rank approving officer should be notified once the explanations of cost increase of contract variations have come to light.

Note 56: *The approving authority for a proposed VO is determined based on the estimated cost for the VO as follows:*

Estimated cost for proposed VO	***Approving authority***
$0.3 million or below	*Engineer for the contract*
Exceeding $0.3 million and up to $1.4 million	*Senior Engineer or equivalent or above*
Up to $7 million	*Chief Engineer or above*
More than $7 million	*Director*

Appendix A
(para. 1.11(d) refers)

Water quality of the harbour after commissioning of Harbour Area Treatment Scheme Stage 2A

1. According to the paper seeking funding approval for Project E from FC in February 2010, HATS Stage 2A, when completed, would provide benefits to the water quality of the harbour further to those achieved in HATS Stage 1, as follows:

(a) reduce levels of *Escherichia coli* (Note 1) by 90% (as disinfection facilities were provided under HATS Stage 2A but not Stage 1);

(b) reduce toxic ammonia (Note 2) by 10% on average;

(c) reduce nutrients in terms of total inorganic nitrogen and phosphorus (Note 3) by 5% and 8% respectively; and

(d) increase dissolved oxygen (Note 4) levels by 5%.

2. In September 2019, EPD informed Audit that:

(a) the predicted water quality benefits on the five parameters mentioned in paragraph 1 above were based on best available mathematical modelling tools and techniques. In other words, because of limitations of modelling accuracy, fluctuations in water quality due to weather conditions and climate change, and other external factors like background pollution loading from Pearl River Delta, the numerical value of each of these parameters measured in the years after commissioning of HATS Stage 2A was expected to be spreading over a range above and below the predicted value;

(b) a more statistically robust conclusion of whether HATS Stage 2A achieved the predicted water quality benefits had to be based on serious statistical analysis on the individual parameters measured for sufficient periods of years before and after its commissioning. EPD had issued reports on annual monitoring results of the water quality of the harbour which gave some early indications of the water quality improvement in the initial years after commissioning;

(c) the immediate improvements in water quality during the first three years of full commissioning of HATS Stage 2A (Note 5) were as follows:

(i) *Escherichia coli* reduced by 85% (prediction per FC paper: 90%);

(ii) toxic ammonia reduced by 27% (prediction per FC paper: 10%);

(iii) nutrients in terms of total inorganic nitrogen and phosphorus reduced by 1.3% and 22% respectively (predictions per FC paper: 5% and 8% respectively); and

(iv) dissolved oxygen increased by 2.7% (prediction per FC paper: 5%); and

(d) as part of its core business, EPD had been actively reviewing the water quality of the harbour and would continue its regular water quality monitoring.

Source: *EPD records*

Note 1: *Escherichia coli is a kind of bacteria found in human faeces, often used as an indicator of sewage pollution. The level of Escherichia coli is a measure of the sewage bacteria in water. A high Escherichia coli count indicates greater faecal contamination and higher health risk. A decrease in Escherichia coli count represents an improvement in water quality.*

Note 2: *Ammonia is found at quite high levels in sewage. A high concentration of ammonia is toxic to marine life. An increase in ammonia represents a deterioration in water quality whereas a decrease represents an improvement.*

Note 3: *Total inorganic nitrogen and phosphorus measure the amount of nutrients in water. A large amount of total inorganic nitrogen or phosphorus may stimulate excess algal growth in water. An increase in total inorganic nitrogen or phosphorus represents a deterioration in water quality whereas a decrease represents an improvement.*

Note 4: *Dissolved oxygen indicates the total amount of oxygen dissolved in water. Most marine organisms need oxygen for respiration and maintenance of life. An increase in dissolved oxygen represents an improvement in water quality whereas a decrease represents a deterioration.*

Note 5: *The immediate improvements in water quality were based on a direct comparison of the averages of monthly water quality data for the five parameters collected at 10 water quality monitoring stations in the harbour between the post-HATS Stage 1 period (i.e. 2002 to 2015 for four parameters and 2002 to 2009 for the parameter of Escherichia coli as the advance disinfection facilities under HATS Stage 2A were commissioned in 2010 (see Note 9 to para. 1.5(b))) and the short post-HATS Stage 2A period (i.e. 2016 to 2018).*

Appendix B
(para. 2.21 refers)

Scope for better ascertaining the presence of government structures in the vicinity of the works sites under Contracts I, L and M

1. Audit examination revealed that there was scope for better ascertaining the presence of government structures in the vicinity of the works sites under Contracts I, L and M before inviting the tenders, as follows:

Contract I

1. During the excavation works under Contract I in December 2011, Contractor I encountered difficulties in dealing with the rock fill which caused delay to the progress of works. According to DSD:

(a) at the design stage, Consultant Y duly investigated the underground site conditions by reviewing various records (including as-built drawings, existing ground investigation reports, drillhole records, field measurement records, field test records and laboratory test records) obtained from DSD, CEDD and in-house database of Consultant Y. A borehole log located adjacent to the works site (i.e. riser shaft) showed that there were highly decomposed rock fragments, occasional concrete fragments and refuse. From these records, no buried structure or presence of rock fill at the works site was identified;

(b) the pre-drilling works carried out by Contractor I in September and October 2011 also did not reveal the presence of rock fill; and

(c) after Contractor I encountered the rock fill during the excavation works, DSD and Consultant Y conducted further searches and found in 2014 that the rock fill in question was a part of an underground seawall structure constructed under a government contract in the 1980s.

2. In the event, Consultant Y issued a variation order (later valued at a cost of $35 million) to Contractor I for carrying out additional works to remove part of the underground seawall structure which obstructed the excavation works, resulting in EOTs of 76 days for completing two sections of works and prolongation costs of $17.6 million.

Contract L

1. Contractor L was required to construct twin seawater pumping mains from the seawater pumping station to the fine screens and grit traps building at the North Point PTW under a section of works of Contract L. According to DSD and Consultant Y:

(a) in accordance with the arrangement agreed at the design stage, Consultant X was responsible for the design of the twin seawater pumping mains which would be constructed by Contractor L under Contract L. The as-built drawings concerned had been checked at the design stage and no buried structure was identified;

(b) due to clashing with the actual site location of underground pile cap of the pier of an existing flyover completed in January 1985 and maintained by the Highways Department, the alignment of the twin seawater pumping mains was revised; and

(c) during the excavation works for the construction of the realigned twin seawater pumping mains, Contractor L encountered underground obstruction (concrete thrust block of two existing sewage mains completed in December 2008 and maintained by DSD) which caused delay to the progress of works.

2. In the event, Consultant Y issued a variation order to Contractor L for carrying out additional works to change the pipe alignment to suit the site constraints, resulting in EOTs of 48.5 days for completing this section of works and prolongation costs of $6.6 million.

Contract M

1. Contractor M was required to construct flume channels at the Cyberport PTW under a section of works of Contract M. During the construction of the flume channels, Contractor M encountered underground obstruction (concrete cable encasement) which caused delay to the progress of works. According to DSD and Consultant Y:

(a) in accordance with the arrangement agreed at the design stage, Consultant X was responsible for the design of the flume channels which would be constructed by Contractor M under Contract M. The as-built drawings concerned had been checked at the design stage and no buried structure was identified;

(b) there were no indications given in the design drawings provided by Consultant X that any existing services, such as power cables, communication cables or water mains, would be directly in conflict with the flume channels and would obstruct the construction of the flume channels; and

(c) after investigation, Contractor M found that power and communication cables in use linking to the CEPT facility of the Cyberport Sewage Treatment Works (which was completed in 2002, and operated and maintained by the Sewage Treatment Division of DSD) were in the concrete encasement.

2. In the event, Consultant Y issued a variation order to Contractor M for carrying out additional works to remove the concrete encasement and live cables which obstructed the construction works, resulting in EOTs of 214 days for completing this section of works and prolongation costs of $26.6 million.

2. According to DSD, the above issues were due to some as-built drawings in the past not having adequately recorded the as-built situation of government structures. As the Government is promoting a comprehensive use of Building Information Modelling, the as-built details of government structures would be more accurately shown in the Building Information Modelling records for future reference.

3. In Audit's view, in implementing a works project in future, DSD and its consultants need to better ascertain the presence of government structures in the vicinity of the works sites before inviting tenders (see also para. 2.23).

Acronyms and abbreviations

APE	Approved project estimate
Audit	Audit Commission
BQ	Bills of Quantities
CEDD	Civil Engineering and Development Department
CEPT	Chemically-enhanced primary treatment
DO	Deodourisation
DSD	Drainage Services Department
DWPS	Dilution Water Pumping Station
EIA	Environmental impact assessment
EIAO	Environmental Impact Assessment Ordinance
ENB	Environment Bureau
EOT	Extension of time
EPD	Environmental Protection Department
FC	Finance Committee
FSGT	Fine screens and grit traps
HATS	Harbour Area Treatment Scheme
HDD	Horizontal Directional Drilling
H_2S	Hydrogen sulphide
km	Kilometre
m^3	Cubic metres
MPS	Main Pumping Station
NSCSB	Northern Sludge Cake Silo Building
OU	Odour units
PTW	Preliminary treatment works
SCISTW	Stonecutters Island Sewage Treatment Works
SCS	Sewage conveyance system
SDB	Sludge Dewatering Building
SSCSB	Southern Sludge Cake Silo Building
VO	Variation order