

CHAPTER 1

Development Bureau Water Supplies Department

Expansion of Tai Po Water Treatment Works

**Audit Commission
Hong Kong
27 October 2023**

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.

Report No. 81 of the Director of Audit contains 8 Chapters which are available on our website (<https://www.aud.gov.hk>).



The Audit Commission website

Audit Commission
6th Floor, High Block
Queensway Government Offices
66 Queensway
Hong Kong

Tel : (852) 2867 3423
Fax : (852) 2824 2087
E-mail : enquiry@aud.gov.hk

EXPANSION OF TAI PO WATER TREATMENT WORKS

Contents

	Paragraph
EXECUTIVE SUMMARY	
PART 1: INTRODUCTION	1.1 – 1.11
Audit review	1.12
Acknowledgement	1.13
PART 2: CONSTRUCTION WORKS OF TAI PO WATER TREATMENT WORKS	2.1
Planning and implementation of construction works	2.2 – 2.25
Audit recommendations	2.26
Response from the Government	2.27
On-site chlorine generation plants	2.28 – 2.42
Audit recommendations	2.43
Response from the Government	2.44
PART 3: OTHER CONTRACT MANAGEMENT ISSUES	3.1
Project cost estimation and preparation of Bills of Quantities	3.2 – 3.7
Audit recommendations	3.8

	Paragraph
Response from the Government	3.9
Defects rectification works and performance reporting	3.10 – 3.15
Audit recommendations	3.16
Response from the Government	3.17
Site safety	3.18 – 3.28
Audit recommendations	3.29
Response from the Government	3.30
 PART 4: OPERATION AND MAINTENANCE OF TAI PO WATER TREATMENT WORKS	 4.1 – 4.2
Operation and maintenance of facilities	4.3 – 4.15
Audit recommendations	4.16
Response from the Government	4.17
Output capacity and treated water quality	4.18 – 4.24
Audit recommendations	4.25
Response from the Government	4.26
 Appendices	 Page
A : Water Supplies Department: Organisation chart (extract) (31 March 2023)	65
B : Acronyms and abbreviations	66

EXPANSION OF TAI PO WATER TREATMENT WORKS

Executive Summary

1. The Tai Po Water Treatment Works (TPWTW) and the Sha Tin Water Treatment Works (STWTW) are major water treatment works in Hong Kong. TPWTW was commissioned in 2003 and supplied treated water to Tai Po and Central Kowloon. In order to maintain a continuous supply of treated water to the supply zones during the planned in-situ reprovisioning of STWTW (after more than 40 years of services as of 2009) in stages, it was necessary to increase the output capacity of TPWTW from 250 to 800 million litres per day (Mld) in phases for taking up part of the loading of STWTW. Upon completion of the expansion works, the increased output capacity of TPWTW could take up the loading of STWTW for supplying fresh water to Central and West Kowloon, and Central and Western District of Hong Kong Island. The Development Bureau (DEVB) is responsible for the formulation of water supply policies and coordinating their implementation. The Water Supplies Department (WSD) was the works agent responsible for implementing a project for the expansion of TPWTW (the Project).

2. The Project was implemented under Project Votes I to III. A total funding of \$6,480 million was approved by the Finance Committee of the Legislative Council between May 2009 and January 2013. In June 2008 and June 2009, WSD awarded two consultancies (Consultancies X and Y) to a consultant (Consultant M) for the Project. Between February 2010 and September 2013, WSD awarded three works contracts (Contracts A to C) to three contractors (Contractors A to C) for the implementation of the Project. The Project commenced in February 2010 and was substantially completed in December 2019. As of March 2023, \$4,986.4 million (77%) of the approved project estimate (APE) totalling \$6,480 million for the Project had been incurred. WSD, which is committed to providing a safe, clean and reliable water supply to customers in Hong Kong, is responsible for the operation and maintenance of TPWTW. The Audit Commission (Audit) has recently conducted a review of WSD's work in implementing the Project and operation and maintenance of TPWTW.

Executive Summary

Construction works of Tai Po Water Treatment Works

3. Contracts A to C were substantially completed between January 2013 and December 2019, which were 2.7 to 19.1 months later than the respective original contract completion dates. Full extensions of time (EOTs) had been granted to the three contracts according to the contractual provisions. Consultant M was the Engineer or Supervising Officer responsible for supervising the contract works. The total final contract sum of the three contracts was \$4,309.3 million (para. 2.3).

4. *Scope for improvement in setting out the Employer's Requirements.* Under Contract B, Contractor B was required to design and construct two washwater storage tanks at the base of the two new process buildings for storing washwater required for filter washing. According to the Employer's Requirements of Contract B, the washwater storage tanks should be designed to provide adequate volume for storage for backwashing at least two filters. According to Consultant M, the size of washwater storage tanks proposed by Contractor B in Contractor's Proposals deviated from the Employer's Requirements as given on the Employer's Drawings. According to the Legal Advisory Division (Works) of DEVB, the Employer's Drawings were merely an outline or reference design, which was not binding on the contractor, and the request to amend the Contractor's Proposal for larger tanks would likely constitute a variation. In the event, in September 2018, Consultant M issued a variation order (VO) (later valued at a cost of \$78.7 million) under Contract B to instruct Contractor B to increase the volume of the washwater storage tanks in the two new process buildings from 2,800 to 3,600 cubic metres (m³) and 3,000 to 6,066 m³ respectively. EOTs of 124 days were also granted to Contractor B. In Audit's view, there is scope for improvement in setting out the Employer's Requirements (paras. 2.4, 2.6 and 2.8 to 2.10).

5. *Need to better ascertain the conditions of the existing structures.* According to Consultancy Y, during the review and design phase of Contracts A to C, Consultant M shall conduct a condition survey to assess and baseline the conditions of the existing structures that may potentially affect or be affected by the project. Audit noted that: (a) the condition survey report submitted by Consultant M for Contract C in March 2010 did not include the results of the conditions of existing waterstops installed at the existing compartment of the Butterfly Valley Fresh Water Primary Service Reservoir. After commencement of works under Contract C, additional physical tests on six samples of existing waterstops found that all six samples failed to meet the specified requirements of Contract C and the test results

Executive Summary

inferred that all waterstops were likely to be defective; and (b) in the event, Consultant M issued a VO (later valued at a cost of \$2.7 million) under Contract C to instruct Contractor C to remove and replace the defective waterstops. In Audit's view, in implementing works projects, WSD needs to take measures to conduct condition surveys as comprehensively as practicable with a view to better ascertaining the conditions of the existing structures (paras. 2.11 and 2.12).

6. *Need to critically assess the method for mainlaying works.* In April 2009 and December 2012, the Public Works Subcommittee of the Finance Committee of the Legislative Council was informed that the trenchless method would be adopted where practicable and WSD anticipated that such method would be used for laying water mains at the junction of Cornwall Street and Chak On Road South. Audit noted that: (a) Consultant M did not identify any parts of the water mains that must be constructed by trenchless techniques to avoid unacceptable traffic conditions in the final traffic impact assessment report; and (b) after the unsuccessful implementation of the original temporary traffic arrangements (TTAs) (using open-trench excavation method) for three road sections (including the Cornwall Street and Chak On Road South section), Consultant M took about 2.3 to 7.9 months to submit and obtain approval of the revised TTAs (changing to trenchless method) before issuing 3 VOs (later valued at a total cost of \$3.9 million) to instruct Contractor C to carry out the mainlaying works. According to WSD, in June 2021, a Design Review Committee was established to, amongst others, conduct design review. In particular, the feasibility of using trenchless method for water mains works would be considered in the preliminary design review. In Audit's view, in implementing mainlaying works, WSD needs to remind its staff and consultants to follow the latest requirements in assessing the methods for mainlaying works (particularly at busy roads) (paras. 2.22 to 2.25).

7. *Need to early consult the relevant authorities about the statutory requirements.* According to WSD, chlorine is used for disinfection of drinking water produced in water treatment works in Hong Kong. In 2016 (i.e. after commencement of the expansion works of TPWTW), WSD decided, as a departmental policy, to adopt the on-site chlorine generation (OSCG) technology for all water treatment works and pre-chlorination station in Hong Kong starting from December 2018. After obtaining WSD's approval, in February 2017, Consultant M issued a VO (VO A) at an estimated cost of \$180 million (later valued at \$310.5 million) under Contract B to supply and install four sets of OSCG plant at TPWTW. Based on the site conditions of TPWTW, OSCG plant would be installed in the existing chlorine store of TPWTW (i.e. on the lower level) while liquid chlorine was being stored and used on the upper

Executive Summary

level of the same building. The then-existing liquid chlorine system would be demolished after the commissioning of OSCG plant. There are four types of chemicals involved in the OSCG plant which are dangerous goods (DG) under the Dangerous Goods Ordinance (Cap. 295). Relevant approvals for storage and manufacturing of DG should be obtained from the Fire Services Department (FSD). Audit noted that: (a) in March 2017, Consultant M submitted the application for approval for storage of DG for the OSCG plant at TPWTW to FSD. FSD advised WSD in April 2017 that the siting of DG store immediately above or below another DG store was not acceptable; (b) according to WSD, it took about 7 months to implement the alternative measures (through revising VO A in April 2017 at an estimated cost of \$40 million (later valued at \$62.7 million)) to address the problems arising from the decommissioning of the then-existing liquid chlorine system and supply of chlorine before the commissioning of OSCG plant at TPWTW; and (c) after the decommissioning of the then-existing liquid chlorine system at TPWTW in November 2019, approvals for manufacturing and storage of DG for the OSCG plant at TPWTW were obtained from FSD in the same month. In Audit's view, in implementing works projects, WSD needs to take measures to early consult the relevant authorities about the statutory requirements relating to the storage and manufacturing of DG and chemicals (paras. 2.28 to 2.34).

8. ***Need to finalise the design of works before issuing the related VO.*** Audit noted that VO A's cost (see para. 7) had increased significantly from the original total estimated cost of \$220 million by \$153.2 million (70%) to the final value of \$373.2 million. According to Consultant M, the estimated cost of VO A was provided by Contractor B and vetted by Consultant M in the absence of a detailed design of works. According to WSD, there was urgency to request Contractor B to purchase and install OSCG plant and the cost estimate of VO A was prepared based on the available information at the time of preparation of VO A and preliminary consultation with the stakeholders. In Audit's view, in implementing works projects, WSD needs to finalise the design of works before issuing the related VO as far as practicable (paras. 2.35 to 2.38).

Other contract management issues

9. ***Need to take measures to ensure that project costs are estimated as accurately as possible.*** The APE for Project Vote III was \$6,176.7 million. Audit noted that, as of March 2023, the total expenditure under Project Vote III was \$4,724.5 million (i.e. \$1,452.2 million (24%) less than the APE of \$6,176.7 million).

Executive Summary

In Audit's view, in implementing works projects, WSD needs to take measures to ensure that project costs are estimated as accurately as possible (paras. 3.3 and 3.4).

10. ***Need to ensure timely completion of required works during maintenance period.*** Under Contract B, Contractor B was required to carry out any outstanding works and defects rectification works within the 12-month maintenance period at its own cost. Audit noted that: (a) as of December 2020 (end of the 12-month maintenance period), of the 22,373 defects or outstanding works items identified, 358 (2%) had not yet been rectified or completed by Contractor B; and (b) all the defects and outstanding works were only rectified and completed by end of February 2022 (i.e. more than one year after the end of the maintenance period) (paras. 3.10 and 3.11).

11. ***Scope for improvement in preparing contractors' performance reports.*** According to the Project Administration Handbook for Civil Engineering Works issued by the Civil Engineering and Development Department, the basic objective of the contractors' performance reports is to monitor the contractors' performance and assess their suitability for future work. Audit noted that Contractor B's performance reports of the relevant period had not reflected instances related to its late reporting of 7 (out of 10 — see para. 12) reportable accidents and unauthorised access to the chlorine building by its worker in June 2018 (see para. 13) (paras. 3.13 and 3.14).

12. ***Scope for enhancing construction site safety.*** According to the Construction Site Safety Manual issued by DEVB and WSD guidelines, contractors are required to complete an injury report form within 7 days from the date of an accident. Audit noted that, of the 11 non-fatal reportable accidents (i.e. accident resulting in an injury with incapacity for more than three days) happened at the construction site of Contract B between June 2014 and January 2019 (according to WSD, enhancement measures for site safety had been implemented by Contractor B), late reporting of reportable accidents by Contractor B was found in 10 accidents, ranging from 14 to 263 days (paras. 3.19, 3.21, 3.23 and 3.24).

13. ***Scope for enhancing security of construction sites.*** According to WSD, chlorine building is classified as hazardous/restricted area and any person entering the chlorination plant or store room of the chlorine building should sign the register maintained in the station control room. During a site safety inspection conducted by WSD at TPWTW in June 2018, it was observed that a worker of Contractor B entered

Executive Summary

the first floor of chlorine building through a lock-broken door and used the water from the fire hydrant inside the chlorine building without authorisation. According to Consultant M, in late June 2018, it was subsequently found that the locks of 16 (38%) of the 42 doors at the chlorine building were out-of-order. In Audit's view, there is scope for enhancing security of construction sites (paras. 3.26 to 3.28).

Operation and maintenance of Tai Po Water Treatment Works

14. *Scope for enhancing the administration of works orders for maintenance works.* As of July 2023, 283 works orders for maintenance works of TPWTW (with a target commencement date within the period from January 2020 to March 2023) had been finalised. Audit noted that: (a) of these 283 finalised works orders, the actual expenditures of 36 (13%) works orders were higher than the original estimates by 5% (i.e. \$1,553) to 418% (i.e. \$103,732) (averaging 62%) and the works of 6 (2%) works orders were completed 10 to 263 days (averaging 103 days) after the target completion dates; and (b) according to WSD guidelines, photographic records of the works carried out on site should be taken by WSD and uploaded onto the Maintenance Works Management System (MWMS) as soon as possible. For 15 finalised works orders, photographs relating to the works of 6 (40%) works orders were not available in MWMS (paras. 4.13 and 4.14).

15. *Need to keep under review the demand of treated water of TPWTW.* Audit noted that, since the commissioning of TPWTW after expansion in December 2019, the treated water out from TPWTW was approaching the output capacity of 800 Mld for some days. In 2021 and 2022, there were 107 and 179 days with treated water out from TPWTW over 700 million litres respectively. The maximum daily volumes of treated water out from TPWTW were 778 and 766 million litres in 2021 and 2022 respectively, which were quite close to the design capacity of 800 Mld. According to WSD, the site of TPWTW has allowed for further expansion with an ultimate output capacity of 1,200 Mld. In Audit's view, WSD needs to keep under review the demand of treated water of TPWTW with a view to early considering the need for further expansion of TPWTW (paras. 4.18 and 4.19).

16. *Scope for improvement in monitoring the treated water quality of TPWTW.* According to WSD guidelines, TPWTW's water quality is monitored by taking and analysing samples at different stages of the water treatment process.

Executive Summary

According to WSD, from April 2019 to March 2023: (a) the quality of fresh water supplied to customers (including the treated water of TPWTW) were of 100% compliance with the Hong Kong Drinking Water Standards (HKDWS); and (b) there were incidents that the test results of water samples collected at different stages of the water treatment process at TPWTW did not meet the relevant performance indicators, which are, in general, more stringent than HKDWS and provide early indication for monitoring operation of water treatment works. Follow-up actions had been taken on such instances and, as a result, the final water of TPWTW was considered satisfactory. Audit noted that the record sheet for recording the water quality test results of TPWTW and the follow-up actions taken was a manual record. According to WSD, the digitalisation of the manual record sheet was feasible and would be included as one of the requirements in future system upgrade. In Audit's view, WSD needs to keep under review the treated water quality of TPWTW and complete the digitalisation of the manual record sheet as soon as practicable (paras. 4.22 to 4.24).

Audit recommendations

17. **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 Water Supplies should:**

Construction works of TPWTW

- (a) **in implementing works projects under a design-and-build contract, clearly set out the requirements on essential works in the Employer's Requirements (para. 2.26(a));**
- (b) **in implementing works projects:**
 - (i) **take measures to conduct condition surveys as comprehensively as practicable with a view to better ascertaining the conditions of the existing structures (para. 2.26(b)(i));**
 - (ii) **take measures to early consult the relevant authorities about the statutory requirements relating to the storage and manufacturing of DG and chemicals (para. 2.43(a)); and**

Executive Summary

- (iii) **finalise the design of works before issuing the related VO as far as practicable with a view to better ascertaining the works needed and assessing the estimated VO cost (para. 2.43(b));**
- (c) **in implementing mainlaying works, remind WSD staff and consultants to follow the latest requirements in assessing the methods for mainlaying works (particularly at busy roads) (para. 2.26(c));**

Other contract management issues

- (d) **in implementing works projects:**
 - (i) **take measures to ensure that project costs are estimated as accurately as possible (para. 3.8(a));**
 - (ii) **remind WSD staff and consultants to closely monitor the outstanding works and defects rectification works of contractors and take measures to ensure the timely completion of such works (para. 3.16(a));**
 - (iii) **take measures to ensure that performance issues of contractors are duly reflected in their performance reports (para. 3.16(b));**
 - (iv) **make continued efforts to enhance construction site safety and take measures to ensure that WSD contractors timely report accidents at construction sites in accordance with related requirements (para. 3.29(a) and (b)(i)); and**
 - (v) **take measures to tighten the controls on access to hazardous/restricted areas with a view to preventing unauthorised access to and use of facilities in these areas (para. 3.29(b)(ii));**

Executive Summary

Operation and maintenance of TPWTW

- (e) **take measures to ensure that:**
 - (i) **works orders for maintenance works of TPWTW are timely completed and their costs are estimated as accurately as possible (para. 4.16(d)(i)); and**
 - (ii) **complete and up-to-date information of works orders for maintenance works of TPWTW is recorded in MWMS (para. 4.16(d)(ii));**
- (f) **keep under review the demand of treated water of TPWTW with a view to early considering the need for further expansion of TPWTW (para. 4.25(a)); and**
- (g) **keep under review the treated water quality of TPWTW and complete the digitalisation of the manual record sheet for recording the water quality test results of TPWTW and the follow-up actions taken as soon as practicable (para. 4.25(c)).**

Response from the Government

18. The Director of Water Supplies 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 Tai Po Water Treatment Works (TPWTW) and the Sha Tin Water Treatment Works (STWTW) are major water treatment works in Hong Kong. TPWTW was commissioned in 2003 with an output capacity of 250 million litres per day (Mld). It supplied treated water to Tai Po and Central Kowloon. STWTW was commissioned in 1964 with subsequent expansions in 1973, 1976 and 1983 to increase its output capacity to 1,060 Mld (Note 1). It supplied treated water to the northern part of Hong Kong Island and a substantial part of Kowloon.

Expansion of TPWTW

1.3 The Development Bureau (DEVB) is responsible for the formulation of water supply policies and coordinating their implementation. According to DEVB:

- (a) as of 2009, STWTW (after more than 40 years of services) had reached a stage of requiring substantial reprovisioning as its plant and equipment were approaching the end of their service life and its operation was also not efficient by modern day standard, particularly in treating raw water of variable quality. In order to maintain a continuous supply of treated water to the supply zones during the planned in-situ reprovisioning of STWTW

Note 1: *STWTW comprises the South Works (commissioned in 1964) and the North Works (commissioned in stages from 1973) with an output capacity of 360 and 700 Mld respectively.*

Introduction

in stages (Note 2), it was necessary to increase the output capacity of TPWTW from 250 to 800 Mld in phases for taking up part of the loading of STWTW so that STWTW could be partially shut down for the in-situ reprovisioning works; and

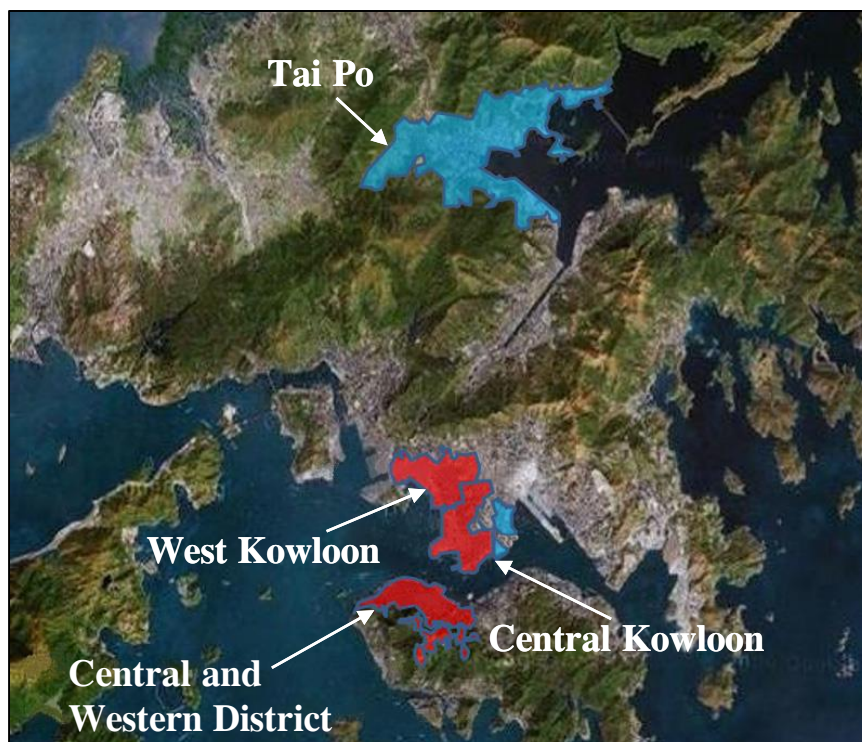
- (b) upon completion of the expansion works, the increased output capacity of TPWTW could take up the loading of STWTW for supplying fresh water to Central and West Kowloon, and Central and Western District of Hong Kong Island (see Figure 1 for the supply zones of TPWTW before and after expansion). This could pave the way for the in-situ reprovisioning of STWTW, while enhancing the overall resilience, flexibility and reliability of the water supply system.

The Water Supplies Department (WSD) was the works agent responsible for implementing a project for the expansion of TPWTW (hereinafter referred to as the Project).

Note 2: *The in-situ reprovisioning of the South Works of STWTW has been implemented in two stages (i.e. advance works and main works). The advance works commenced in October 2015 and were substantially completed in April 2020, and the main works commenced in August 2020 for completion in the first quarter of 2026. The output capacity of the South Works would be increased from 360 to 550 Mld in order to meet the anticipated increase in fresh water demand due to progressive implementation of new public and private housing developments within the supply zones.*

Figure 1

Supply zones of TPWTW before and after expansion



Legend: ■ Supply zone before expansion
■ Additional supply zone after expansion

Source: WSD records

Implementation of the Project

1.4 The Project commenced in February 2010 and was substantially completed in December 2019. The works under the Project were carried out in two phases, as follows:

- (a) **Part 1 works.** The scope of Part 1 works included the following:
 - (i) upgrading the existing water treatment facilities (i.e. Stream I) at TPWTW to increase its output capacity from 250 to 400 Mld; and

Introduction

- (ii) uprating the pumping capacities of the existing Tai Po Fresh Water Pumping Station and Tai Po Tau No. 4 Raw Water Pumping Station to match with the increased capacity of TPWTW; and
- (b) **Part 2 works.** The scope of Part 2 works included the following:
 - (i) further uprating the existing water treatment facilities (i.e. Stream I) and constructing additional water treatment components (i.e. Stream II) at TPWTW to further increase its output capacity from 400 to 800 Mld;
 - (ii) further uprating the pumping capacities of the existing Tai Po Fresh Water Pumping Station and Tai Po Tau No. 4 Raw Water Pumping Station to match with the increased capacity of TPWTW;
 - (iii) expanding the storage capacity of the existing Butterfly Valley Fresh Water Primary Service Reservoir (FWPSR) from 40,000 to 120,000 cubic metres (m³); and
 - (iv) laying of about 900 metres associated fresh water mains in Sham Shui Po and Kowloon City.

Photograph 1 shows TPWTW after expansion.

Photograph 1

TPWTW after expansion (March 2022)



Source: WSD records

1.5 The Project was implemented under three project votes (hereinafter referred to as Project Votes I to III). A total funding of \$6,480 million was approved by the Finance Committee of the Legislative Council between May 2009 and January 2013 for the Project (see Table 1).

Table 1

**Funding approvals for the Project
(May 2009 to January 2013)**

Date	Particulars	Approved amount (\$ million)
<i>Project Vote I</i>		
May 2009	Design and site investigation	43.4
<i>Project Vote II</i>		
February 2010	Part 1 works	259.9
<i>Project Vote III</i>		
January 2013	Part 2 works	6,176.7
Total		6,480.0

Source: WSD records

1.6 In June 2008 and June 2009, WSD awarded two consultancies for the Project (see Table 2) respectively, as follows:

- (a) Consultancy X for the investigation study; and
- (b) Consultancy Y for the design and construction supervision work of the Project, which involved three works contracts (Contracts A to C — see para. 1.7).

Table 2
Consultancies awarded for the Project
(March 2023)

Consultancy	Consultant (Note 1)	Particulars	Consultancy fee (\$ million)
X (Awarded in June 2008)	M	Investigation study	7.6 (Note 2)
Y (Awarded in June 2009)	M	Design and construction supervision work	88.6 (Note 3)
Total			96.2

Source: WSD records

Note 1: Consultancies X and Y were awarded to the same consultant (i.e. Consultant M) through competitive tendering.

Note 2: For Consultancy X, the consultancy fee of \$7.6 million was funded under the block vote of WSD.

Note 3: For Consultancy Y, the consultancy fee of \$88.6 million was funded under Project Votes I to III.

1.7 Between February 2010 and September 2013, WSD awarded three works contracts (Contracts A to C) to three contractors (Contractors A to C) for the implementation of the Project. Contracts A, B and C were substantially completed in January 2013, December 2019 and February 2018 respectively, which were 2.7 to 19.1 months later than their respective original contract completion dates (see Table 3).

Table 3

**Contracts awarded for the Project
(February 2010 to December 2019)**

Contract	Works	Commencement date	Original contract completion date (Note 1)	Actual completion date (Note 1)	No. of months later than original contract completion date (Note 2)
<i>Part 1 works</i>					
A (Awarded in February 2010)	Uprating of Stream I and pumping stations (Note 3)	25.2.2010	22.10.2012	11.1.2013	2.7
<i>Part 2 works</i>					
B (Awarded in January 2013)	Uprating of Stream I and pumping stations (Note 3), and design and build of Stream II	6.2.2013	25.5.2018	27.12.2019	19.1
C (Awarded in September 2013)	Expansion of the Butterfly Valley FWPSR and laying of associated fresh water mains	24.9.2013	22.1.2017	28.2.2018	13.2

Source: WSD records

Note 1: For Contracts A to C, the original contract completion date and actual completion date referred to the dates of completion of all works excluding the 12-month defects liability period or maintenance period.

Note 2: According to WSD, extensions of time for the whole period were granted under Contracts A to C mainly due to inclement weather of 0.9, 12.9 and 6 months respectively and other reasons (mainly variation of works) of 1.8, 6.2 and 7.2 months respectively.

Note 3: The pumping stations include the Tai Po Fresh Water Pumping Station and the Tai Po Tau No. 4 Raw Water Pumping Station.

Project costs

1.8 The accounts of Contracts A to C (see Table 4) were finalised between March 2014 and August 2022. As of March 2023, \$4,986.4 million (77%) of the approved project estimate (APE) totalling \$6,480 million (see para. 1.5) for the Project had been incurred. Of this \$4,986.4 million:

- (a) \$4,309.3 million (86%) was related to expenditures for the Project under Contracts A to C; and
- (b) the remaining \$677.1 million (14%) comprised resident site staff (RSS) costs (Note 3) of \$530.3 million, consultancy fees of \$88.6 million (see Table 2 in para. 1.6), and other costs of \$58.2 million.

Note 3: *Consultants are required to employ RSS of different grades (e.g. professional grade and technical grade) for supervising contractors' works. The Government reimburses consultants for the personal emoluments of RSS and pays an on-cost to consultants to cover their costs in managing RSS.*

Table 4

**Contract expenditures of Contracts A to C
(March 2023)**

Contract	Original contract sum (a) (\$ million)	Final contract sum (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)
Part 1 works					
A	188.9	173.5	(15.4) (-8.2%)	— (—)	(15.4) (-8.2%)
Part 2 works					
B	3,252.1	3,760.4	508.3 (15.6%)	106.3 (3.2%)	402.0 (12.4%)
C	336.4	375.4	39.0 (11.6%)	(2.8) (-0.8%)	41.8 (12.4%)
Total	3,777.4	4,309.3	531.9 (14.1%)	103.5 (2.7%)	428.4 (11.4%)

Source: WSD records

Note 1: The final contract sum of Contract A was funded by Project Vote II and the final contract sums of Contracts B and C were funded by Project Vote III.

Note 2: The original contract sums of Contracts B and C included provisions for price fluctuation adjustments.

Operation and maintenance of TPWTW

1.9 WSD is responsible for the operation and maintenance of TPWTW. The operation of Stream I and Stream II under TPWTW after expansion commenced on 12 January 2013 and 28 December 2019 respectively. According to WSD, since the commissioning of TPWTW after expansion (i.e. Stream II) in December 2019, the daily volume of treated water out from TPWTW from January 2020 to December 2022 ranged from 352 to 778 Mld (averaging 626 Mld — i.e. about 78% of the output capacity of 800 Mld).

1.10 According to WSD, it is committed to providing a safe, clean and reliable water supply to customers in Hong Kong. It monitors the quality of water treated at

TPWTW through a comprehensive sampling and testing programme with examination of water samples taken at different stages of treatment to ensure that treated water quality fully complies with the Hong Kong Drinking Water Standards (HKDWS — Note 4) and the Aesthetic Guidelines (Note 5).

Responsible Region/Divisions of WSD

1.11 The Consultants Management Division under the New Works Branch of WSD was responsible for, among others, the implementation of the Project. The following Region/Divisions of WSD are responsible for the operation and maintenance of TPWTW:

- (a) the New Territories East Region under the Supply and Distribution (New Territories) Branch is responsible for, among others, the operation of TPWTW and maintenance of its civil structures. As of March 2023, 39 staff (Note 6) and 8 staff (Note 7) of this Region were involved in TPWTW's operation and maintenance of its civil structures respectively;
- (b) the Maintenance Division under the Mechanical and Electrical Branch is responsible for, among others, the maintenance of mechanical and electrical (M&E) plant and equipment at TPWTW. As of March 2023, 15 staff and 17 staff of this Division were involved in mechanical maintenance and electrical maintenance of TPWTW respectively; and

Note 4: *According to WSD, it is a common international practice that individual countries/places establish their own set of drinking water standards that is suitable and appropriate to their local context. In September 2017, WSD adopted the respective guideline values/provisional guideline values in the World Health Organization's Guidelines for Drinking-water Quality as HKDWS, which was subsequently updated in April 2021.*

Note 5: *According to WSD, the Aesthetic Guidelines was established in April 2021 to ensure the aesthetic quality of the drinking water in Hong Kong (e.g. taste and odour).*

Note 6: *According to WSD, 1 of the 39 staff was also involved in the operation of other water treatment works.*

Note 7: *According to WSD, the 8 staff were also involved in the maintenance of other WSD's headworks facilities (e.g. raw water mains, service reservoirs and impounding reservoirs) in Tai Po and Northern Districts.*

Introduction

- (c) the Water Science Division under the Development Branch is responsible for, among others, monitoring and advising on the water treatment process of TPWTW to ensure that its water supply complies with HKDWS. As of March 2023, 7 staff of this Division were directly involved in the operation of TPWTW.

An extract of WSD's organisation chart as at 31 March 2023 is at Appendix A.

Audit review

1.12 In May 2023, the Audit Commission (Audit) commenced a review of WSD's work in implementing the Project and operation and maintenance of TPWTW. The audit review has focused on the following areas:

- (a) construction works of TPWTW (PART 2);
- (b) other contract management issues (PART 3); and
- (c) operation and maintenance of TPWTW (PART 4).

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

Acknowledgement

1.13 Audit would like to acknowledge with gratitude the full cooperation of the staff of WSD during the course of the audit review.

PART 2: CONSTRUCTION WORKS OF TAI PO WATER TREATMENT WORKS

2.1 This PART examines WSD's work in managing the construction works of TPWTW, focusing on:

- (a) planning and implementation of construction works (paras. 2.2 to 2.27);
and
- (b) on-site chlorine generation plants (paras. 2.28 to 2.44).

Planning and implementation of construction works

2.2 The expansion works of TPWTW were implemented in two stages (i.e. Part 1 works and Part 2 works). Between February 2010 and September 2013, WSD awarded three works contracts for the works (see Tables 3 and 4 in paras. 1.7 and 1.8 respectively), as follows:

- (a) **Part 1 works.** Contract A (with an original contract sum of \$188.9 million) under Project Vote II (with an APE of \$259.9 million); and
- (b) **Part 2 works.** Contracts B and C (with a total original contract sum of \$3,588.5 million) under Project Vote III (with an APE of \$6,176.7 million).

2.3 Contracts A to C were substantially completed between January 2013 and December 2019, which were 2.7 to 19.1 months later than the respective original contract completion dates. Full extensions of time (EOTs) had been granted to the three contracts according to the contractual provisions (i.e. they were completed within the extended contract completion dates). Consultant M (under Consultancy Y) was the Engineer or Supervising Officer responsible for supervising the contract works. All contract accounts had been finalised between March 2014 and August 2022, and the total final contract sum was \$4,309.3 million. Table 5 shows the works and expenditures under Contracts A to C.

Construction works of Tai Po Water Treatment Works

Table 5

**Construction works under Contracts A to C
(March 2023)**

Contract	Contract type	Works	Final contract sum (Note 1) (\$ million)
Part 1 works			
A	Lump sum contract (Note 2)	<ul style="list-style-type: none"> • Upgrading the existing water treatment facilities at TPWTW to increase its output capacity from 250 to 400 Mld • Upgrading the pumping capacities of the existing Tai Po Fresh Water Pumping Station and Tai Po Tau No. 4 Raw Water Pumping Station 	173.5
Part 2 works			
B	Lump sum design-and-build contract (Note 3)	<ul style="list-style-type: none"> • Upgrading the existing water treatment facilities and constructing additional water treatment components at TPWTW to increase its output capacity from 400 to 800 Mld • Upgrading the pumping capacities of the existing Tai Po Fresh Water Pumping Station and Tai Po Tau No. 4 Raw Water Pumping Station 	3,760.4
C	Remeasurement contract (Note 4)	<ul style="list-style-type: none"> • Expanding the storage capacity of the existing Butterfly Valley FWPSR from 40,000 to 120,000 m³ • Laying of about 900 metres fresh water mains in Sham Shui Po and Kowloon City 	375.4
Total			4,309.3

Source: WSD records

Note 1: The accounts of Contracts A to C were finalised between March 2014 and August 2022.

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: Under a design-and-build contract, the contractor is required to design and construct the works in accordance with the Employer's Requirements.

Note 4: 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 the Bills of Quantities according to the contract.

Scope for improvement in setting out the Employer's Requirements

2.4 Under Contract B, Contractor B was required to design and construct two washwater storage tanks at the base of the two new process buildings (i.e. Primary Biological Filtration II and Secondary Rapid Gravity Filtration II) for storing washwater required for filter washing (Note 8). According to the Employer's Requirements of Contract B (Note 9), the washwater storage tanks should be designed to provide adequate volume for storage for backwashing at least two filters.

2.5 During the construction stage of Contract B, in August 2013, Consultant M rejected the sizes of the two washwater storage tanks proposed by Contractor B in its design submissions in the Contractor's Proposals submitted at the tender stage in March 2012 (see Table 6).

Note 8: *According to Consultant M, the water treatment process involved filtering the water through filter media, which would become increasingly clogged over time. It was necessary to backwash the filters (i.e. pumping water in a reverse direction to normal flow) on a regular basis. Two tanks (one at the base of each of the two process buildings) were necessary to store the washwater.*

Note 9: *Under Contract B, Contractor B shall design and build Stream II in response to and in conformance with the Employer's Requirements. Contractor B should submit the Contractor's Proposals in its tender for the works in accordance with the Employer's Requirements.*

Table 6**Volume of the washwater storage tanks under Contract B**

Location of washwater storage tank	Size proposed by Contractor B in Contractor's Proposals (a) (m³)	Size instructed by Consultant M (b) (m³)	Variance (c) = (b) – (a) (m³)
Primary Biological Filtration II	2,800	3,600	800 (29%)
Secondary Rapid Gravity Filtration II	3,000	6,066	3,066 (102%)

Source: WSD records

2.6 According to Consultant M:

- (a) the size of washwater storage tanks proposed by Contractor B in Contractor's Proposals deviated from the Employer's Requirements as given on the Employer's Drawings (Note 10);
- (b) the Employer's Drawings showed washwater storage tanks of capacity of 3,600 m³ and 6,066 m³ for Primary Biological Filtration II and Secondary Rapid Gravity Filtration II respectively by taking off the lines and levels of the tanks shown on the Drawings. This had taken into account the operation

Note 10: *According to Contract B, Employer's Drawings illustrate outline designs for the works including a reference design for the process plant and equipment. The Employer's Drawings define certain requirements (e.g. maximum and minimum dimensions and levels). In particular, but without limitation, no warranty is given that the dimensions, levels or clearances illustrated, shown or implied on the Employer's Drawings are sufficient to meet the Employer's Requirements. The Employer's Requirements shall take precedence over the Employer's Drawings, in the event of conflicting requirements. The contractor shall develop the works as illustrated on the Employer's Drawings, including the reference process plant and equipment design, to meet the Employer's Requirements.*

requirements of WSD (e.g. an alternative backwash mode — “enhanced backwash” when there had been prolonged very poor water quality); and

- (c) the design of Contractor B did not cater for the worst case scenario as suggested by the Employer (e.g. minimum plant flow condition, high turbidity situation and prolonged poor water quality).

2.7 Contractor B contended that:

- (a) Contract B was a design-and-build contract which encouraged the contractor to innovate and develop its design proposals while achieving the Employer’s Requirements;
- (b) the Employer’s Drawings did not provide sufficient information to determine/ascertain the exact tank size volume. The extent of requirements as shown on the Employer’s Drawings (e.g. whether the exact dimensions, shape and levels as shown on the Drawings shall be followed) was not clear; and
- (c) its design submissions were in compliance with the Employer’s Requirements and the requests of Consultant M to enlarge the tanks were additional requirements which constitute a variation to the contract.

2.8 The matter was later referred to the Legal Advisory Division (Works) of DEVB for advice. According to the Legal Advisory Division (Works):

- (a) the Employer’s Drawings were merely an outline or reference design, which was not binding on the contractor;
- (b) the Employer’s Requirements did not clearly spell out the important parameters for calculating the necessary capacity of the washwater tanks and other operation requirements (e.g. the need for the washwater tanks to handle double wash/enhanced wash in the worst water quality scenario); and
- (c) the request to amend the Contractor’s Proposal for larger tanks would likely constitute a variation.

Construction works of Tai Po Water Treatment Works

2.9 In the event, in September 2018, Consultant M issued a variation order (VO) (later valued at a cost of \$78.7 million) under Contract B to instruct Contractor B to increase the volume of the washwater storage tanks in Primary Biological Filtration II and Secondary Rapid Gravity Filtration II from 2,800 to 3,600 m³ and 3,000 to 6,066 m³ respectively so as to cope with the operation need (see Table 6 in para. 2.5). According to Consultant M, as the progress of works was delayed by the redesign and construction of the washwater storage tanks, EOTs of 124 days were also granted to Contractor B.

2.10 According to the Administrative Procedures 2015 for Use with the Government of the Hong Kong Special Administrative Region General Conditions of Contract for Design and Build Contracts 1999 Edition issued by DEVB in August 2015 (Note 11), the Employer's Requirements must incorporate all the elements and requirements that the end user or the client wants to include in the project, and shall include all relevant information related to the project. In Audit's view, in implementing works projects under a design-and-build contract, WSD needs to clearly set out the requirements on essential works in the Employer's Requirements.

Scope for better ascertaining the conditions of existing structures and enhancing consultation with stakeholders in identifying enhancement works for existing facilities

2.11 According to Consultancy Y, during the review and design phase of Contracts A to C, Consultant M shall:

- (a) conduct a condition survey covering both topographic survey of the ground and pre-condition survey of existing buildings, structures, surface, subsurface infrastructures and utilities, and other properties that may be susceptible to damage or affected by the implementation of the project prior to commencement of construction. It aims to assess and baseline the existing conditions and to record any existing trend of movement of ground surface/subsurface, structures, infrastructures and utilities that may potentially affect or be affected by the project; and

Note 11: *According to WSD, the requirements in the 2015 version were in force before the award of Contract B in January 2013.*

- (b) prepare the outline design of the electrical and mechanical installations for Part 1 works (i.e. under Contract A) for the purpose that it is sufficient for tendering and subsequent design and construction by the contractor.

2.12 *Need to better ascertain the conditions of the existing structures.*

According to Contract C, waterstops (Note 12) shall be of a proprietary type approved by the Engineer (i.e. Consultant M) and properties stipulated in the Contract (Note 13). According to Consultant M, waterstops had been installed in roof slab, floor slab and walls of the existing structure of the Butterfly Valley FWPSR to facilitate future extension. Audit noted that:

- (a) the condition survey report (Note 14) submitted by Consultant M in March 2010 did not include the results of the conditions of existing waterstops installed at the existing compartment of the Butterfly Valley FWPSR;
- (b) after commencement of works under Contract C, in February 2014, Consultant M issued a VO (later valued at a cost of about \$50,000) to instruct Contractor C to conduct additional physical tests (Note 15) on six samples of existing waterstops installed at the existing compartment of the Butterfly Valley FWPSR to determine their current properties. The test results were as follows:
 - (i) all six samples failed to meet the specified requirements in the General Specifications of Contract C; and

Note 12: *According to WSD, waterstops should be provided at construction joints in water retaining structures and watertight structures.*

Note 13: *According to Contract C, waterstops shall be natural or synthetic rubber or extruded polyvinyl chloride and shall have the stipulated properties in terms of density, hardness, tensile strength, elongation at break point, water absorption and softness number.*

Note 14: *According to Consultancy Y, a condition survey report should be prepared by Consultant M to assemble and document the results, findings and conclusions of the survey carried out.*

Note 15: *Physical tests included tests on density, hardness, tensile strength, elongation at break point, water absorption and softness number.*

Construction works of Tai Po Water Treatment Works

- (ii) the test results inferred that all waterstops were likely to be defective. Replacement of the existing waterstops in entirety at the estimated total length of 308 metres was deemed necessary to provide watertightness for the two new reservoir compartments along the connections to the existing reservoir; and
- (c) in the event, in August 2014, Consultant M issued a VO (later valued at a cost of \$2.7 million) under Contract C to instruct Contractor C to remove and replace the defective waterstops.

In October 2023, WSD informed Audit that, as the waterstops installed at the compartment of the Butterfly Valley FWPSR were protected by brickworks with sand infill, it was proposed that the brickworks were not to be removed during the condition survey. In Audit's view, in implementing works projects, WSD needs to take measures to conduct condition surveys as comprehensively as practicable with a view to better ascertaining the conditions of the existing structures.

2.13 *Scope for enhancing consultation with relevant stakeholders in identifying enhancement works required for improving existing facilities.* Under Contract A, Contractor A was responsible for expanding the reliable output capacity of TPWTW from 250 to 400 Mld by improving the existing water treatment facilities of TPWTW (i.e. Stream I) in addition to the installation of new process equipment. Audit noted that:

- (a) during the design stage of Contract A in 2009, a list of enhancement works to the existing TPWTW had been identified by stakeholders (Note 16) and included in the scope of works of Contract A;
- (b) after the award of Contract A in February 2010, additional issues on the operation and maintenance of existing TPWTW (Note 17), which could

Note 16: *According to WSD records, in the meeting held between WSD and Consultant M in June 2009, the proposed scope of works for inclusion in Contract A was discussed.*

Note 17: *According to Consultant M, it was related to operation simplicity, equipment operation to ensure even wear and tear, water quality sampling, obsolete equipment without vendor support, lifting facilities to minimise machine downtime, chemical dosing to deal with poor raw water quality, etc.*

affect the reliability of TPWTW in providing a continuous output of 400 Mld and the plant maintenance downtime, had been further identified by Consultant M (e.g. during the course of checking the design submissions of Contract A against the existing installation and discussions with WSD on interfaces and plant shutdown requirements); and

- (c) in the event, 14 VOs (later valued at a total cost of \$5.5 million) were issued under Contract A between February and July 2012 to instruct Contractor A to carry out the enhancement works.

In October 2023, WSD informed Audit that the additional issues on the operation and maintenance of TPWTW identified after the award of Contract A had not been anticipated by stakeholders during the design stage. In Audit's view, in implementing works projects, WSD needs to make continued efforts to enhance the consultation with relevant stakeholders in identifying enhancement works required for improving existing facilities.

Need to strengthen the monitoring of the contractor's on-site works

2.14 According to Contract C, Contractor C was responsible for expanding the storage capacity of the existing Butterfly Valley FWPSR. On 29 November 2017, WSD informed Consultant M that some unknown materials were found floating in the water within the northeastern compartment of the Butterfly Valley FWPSR. During the period from 29 November to 7 December 2017, WSD and Consultant M conducted several joint site inspections and noted that:

- (a) some unknown reddish brown materials were found attached at the wall joint between the existing wall and the newly constructed wall in the northeastern compartment of the Butterfly Valley FWPSR; and
- (b) the unknown materials were the hardened grout material after spilling out from the contact points between the joint sealant and the concrete, and contacting with water.

Construction works of Tai Po Water Treatment Works

2.15 According to Contractor C:

- (a) at the end of October 2017, while applying joint sealant to the outstanding wall joint between the existing wall and the newly constructed wall in the northeastern compartment of the Butterfly Valley FWPSR, its workers discovered that there was minor water leakage inside the joint groove and joint sealant could not be applied;
- (b) as there was a rush to have all the outstanding works completed on or before the commissioning ceremony on 4 November 2017, its workers therefore decided to carry out an injection grout on 1 November 2017 for cutting off the water leakage inside the joint groove, such that they could apply joint sealant to the outstanding wall joint; and
- (c) having considered that the method of rectifying water leakage (i.e. injection grout) and the injection grout materials used had been approved by Consultant M under Contract C in May 2016, the grouting operation was carried out by the workers without notifying Consultant M.

2.16 According to Consultant M:

- (a) notwithstanding that the injection grout materials used by Contractor C were suitable for use with water intended for human consumption and the results of the rapid toxicity test of the water samples taken on 29 November 2017 indicated that the water was not toxic and was safe for consumption:
 - (i) in January 2018, Consultant M instructed Contractor C to carry out the rectification works at the cost of Contractor C, including removal and replacement of defective joint sealants and joint fillers at the wall joint between the existing wall and the newly constructed wall in the northeastern compartment of the Butterfly Valley FWPSR; and
 - (ii) Contractor C had been warned of its improper acts on the incident and was urged to exercise proper control over its workers to prevent any reoccurrence of similar incident; and

- (b) as the joint sealants at the existing walls of the northeastern compartment were seriously damaged due to aging, water leakage was thus found inside the joint groove of the northeastern compartment as noticed by the workers of Contractor C (see para. 2.15(a)). In the event, in January 2018, Consultant M issued a VO (later valued at a cost of \$1.2 million) under Contract C to instruct Contractor C to carry out the rectification works at the existing walls, including removal and replacement of defective joint sealants and joint fillers, and application of adhesive tapes at all joints of the existing walls so as to ensure that they were completely free from water leakage.

2.17 In October 2023, WSD informed Audit that a guidance note “Enhanced Supervision of Contractors and Consultants” was issued in August 2018, which amongst others, promulgated the implementation of enhancement measures (e.g. enhanced checking arrangement by project officers and early reporting of incidents related to serious unsatisfactory quality of works) to safeguard the quality of works for works contracts and to ensure the quality of project delivery.

2.18 In Audit’s view, in implementing works projects, WSD needs to remind its staff and consultants to follow the latest guidelines in monitoring the contractor’s on-site works.

Need to critically assess the method for mainlaying works

2.19 According to Consultancy Y, Consultant M shall carry out traffic impact assessment for the proposed works, as follows:

- (a) the assessment should cover the cumulative traffic impact arising from the proposed works and other projects in vicinity, including other works by WSD; and
- (b) Consultant M should, among others, identify those parts of the water mains that must be constructed by trenchless techniques to avoid unacceptable traffic conditions.

Construction works of Tai Po Water Treatment Works

2.20 Under Contract C, to facilitate transfer of treated water between the supply zones of TPWTW and STWTW, Contractor C was required to carry out mainlaying works of laying about 900 metres fresh water mains in Sham Shui Po and Kowloon City, some of which were located at busy road sections (Note 18). In February 2010, Consultant M submitted the final traffic impact assessment report and proposed temporary traffic arrangement (TTA) at different road sections in accordance with its assessment of traffic impact arising from the construction works (Note 19).

2.21 In the funding submissions, WSD informed the Public Works Subcommittee of the Finance Committee of the Legislative Council in April 2009 and December 2012 that:

- (a) it would work closely with other works departments and public utilities companies with a view to implementing works projects which required opening of roads at the same site concurrently and trenchless method would be adopted where practicable;
- (b) it had already anticipated that the laying of water mains at the junction of Cornwall Street and Chak On Road South would need to be conducted using the more costly trenchless method to minimise the traffic impacts; and
- (c) since the trenchless method would necessitate the excavation of the launching pit and the receiving pit, and that the very busy road sections at Waterloo Road and Prince Edward Road West had to be decked over for

Note 18: *According to Consultant M, mainlaying works covered road sections in: (a) Sham Shui Po (including Cornwall Street westbound, Nam Cheong Street, Chak On Road South and Tai Po Road); and (b) Kowloon City (including Cornwall Street/Waterloo Road junction and Prince Edward Road West/Waterloo Road junction).*

Note 19: *According to Consultant M, Traffic Management Liaison Group (comprising representatives from WSD, the Hong Kong Police Force, the Highways Department and the Transport Department, Consultant M, Contractor C and its traffic consultant) meeting should be held during construction stage in order to discuss all TTA scheme in details and trial run should be arranged prior to the implementation. Comments from the Hong Kong Police Force, the Highways Department and the Transport Department had been incorporated into the final traffic impact assessment report.*

Construction works of Tai Po Water Treatment Works

vehicular use during busy hours, certain traffic management measures would have to be taken during construction.

2.22 Due to the implementation of the original TTAs by adopting open-trench excavation method proposed by Contractor C for three road sections (including the Cornwall Street and Chak On Road South section mentioned in para. 2.21(b)) was unsuccessful, Consultant M submitted revised TTAs (changing to trenchless method) which were approved between November 2014 and November 2016. Consultant M then issued 3 VOs (later valued at a total cost of \$3.9 million) under Contract C between July 2015 and August 2017 to instruct Contractor C to revise the construction method of the mainlaying works at the three road sections from open-trench excavation method to trenchless method (Note 20).

2.23 Audit noted that:

- (a) in April 2009 and December 2012, the Public Works Subcommittee was informed that the trenchless method would be adopted where practicable and WSD anticipated that such method would be used for laying water mains at the junction of Cornwall Street and Chak On Road South (see para. 2.21(a) and (b)). However, as far as could be ascertained, Consultant M did not identify any parts of the water mains that must be constructed by trenchless techniques to avoid unacceptable traffic conditions in the final traffic impact assessment report submitted in February 2010 (see para. 2.20); and

Note 20: *The VOs for the three road sections were as follows:*

<i>Road section</i>	<i>Date of issuance of VOs</i>	<i>Actual cost (\$ million)</i>
<i>Between Cornwall Street and Chak On Road South</i>	<i>9.7.2015</i>	<i>1.2</i>
<i>Between Cornwall Street and Nam Cheong Street</i>	<i>18.5.2017</i>	<i>1.5</i>
<i>Tai Po Road</i>	<i>2.8.2017</i>	<i>1.2</i>
<i>Total</i>		<i>3.9</i>

Construction works of Tai Po Water Treatment Works

- (b) after the unsuccessful implementation of the original TTAs (using open-trench excavation method) for the three road sections (see para. 2.22), Consultant M took about 2.3 to 7.9 months to submit and obtain approval of the revised TTAs (changing to trenchless method) before issuing the VOs to instruct Contractor C to carry out the mainlaying works.

2.24 In October 2023, WSD informed Audit that:

- (a) according to its experience, for some busy road sections, open-trench excavation method would be feasible if approval could be obtained for working during the restricted working hours (e.g. 10:00 a.m. to 4:00 p.m.). However, the actual approval would be subject to the actual traffic conditions at the time of the construction works;
- (b) the traffic impact assessment report (see para. 2.20) had been circulated to the relevant parties during the design stage, and no objection to the recommendation on the proposed use of open-trench excavation method during the restricted working hours at the busy road sections concerned was received;
- (c) for the purpose of cost control, open-trench excavation method, which was comparatively less costly, was adopted in the design in the first place;
- (d) no EOTs for contract completion of Contract C were granted as the works for using trenchless method under the VOs (see para. 2.22) were not on the critical path; and
- (e) in June 2021, a Design Review Committee was established to, amongst others, conduct design review with a view to improving the buildability of designs. In particular, the feasibility of using trenchless method for water mains works would be considered in the preliminary design review.

2.25 In Audit's view, in implementing mainlaying works, WSD needs to remind its staff and consultants to follow the latest requirements in assessing the methods for mainlaying works (particularly at busy roads).

Audit recommendations

2.26 **Audit has *recommended* that the Director of Water Supplies should:**

- (a) **in implementing works projects under a design-and-build contract, clearly set out the requirements on essential works in the Employer's Requirements;**
- (b) **in implementing works projects:**
 - (i) **take measures to conduct condition surveys as comprehensively as practicable with a view to better ascertaining the conditions of the existing structures;**
 - (ii) **make continued efforts to enhance the consultation with relevant stakeholders in identifying enhancement works required for improving existing facilities; and**
 - (iii) **remind WSD staff and consultants to follow the latest guidelines in monitoring the contractor's on-site works; and**
- (c) **in implementing mainlaying works, remind WSD staff and consultants to follow the latest requirements in assessing the methods for mainlaying works (particularly at busy roads).**

Response from the Government

2.27 The Director of Water Supplies agrees with the audit recommendations.

On-site chlorine generation plants

2.28 According to WSD, chlorine is used for disinfection of drinking water produced in water treatment works in Hong Kong (Note 21). As there was no local chlorine manufacturer in Hong Kong, Hong Kong had all along imported chlorine in liquid form (i.e. liquid chlorine — Note 22) from the Mainland and transported to different water treatment works for storage and use (Note 23).

2.29 *Adoption of the on-site chlorine generation (OSCG) technology.* In April 2016, WSD conducted an internal study on the feasibility of local generation of chlorine to replace imported liquid chlorine for use in all water treatment works in Hong Kong. WSD concluded that the technology of OSCG facilities was ready for adoption in the water treatment works in Hong Kong. In the event, in 2016, WSD decided, as a departmental policy, to adopt the OSCG technology for all water treatment works and pre-chlorination station in Hong Kong starting from

Note 21: *According to WSD, chlorine is toxic and was classified as Category 2 dangerous goods under the Dangerous Goods Ordinance (Cap. 295). Vigilant operation procedures had been implemented to ensure safety during transportation, storage and handling during dosing.*

Note 22: *According to WSD, liquid chlorine was either stored in 1-tonne drums or 50-kilogram cylinders to facilitate storage and transportation. Liquid chlorine will be converted into gas form by gas draw-off evaporator before dosing into the process water in water treatment works. The transportation and storage processes of liquid chlorine were subject to a stringent quantitative risk assessment and adequate safety measures had been adopted to ensure safety and reliability of the disinfection operation.*

Note 23: *According to WSD, for safe custody of liquid chlorine in bulk volume, most of the water treatment works are classified as Potentially Hazardous Installations in accordance with the Hong Kong Planning Standards and Guidelines with potential hazards to the surrounding population. Within the Consultation Zone of Potentially Hazardous Installations, planning restrictions may need to be imposed on future developments. Proposed developments will be referred to the Coordinating Committee on Land-use Planning and Control relating to Potentially Hazardous Installations for consultation.*

Construction works of Tai Po Water Treatment Works

December 2018 (Note 24) and to phase out the import of liquid chlorine (Note 25). The OSCG technology has the following benefits:

- (a) provide a more reliable and secured supply of chlorine; and
- (b) eliminate or reduce the transportation and storage requirements of liquid chlorine and thus reduce the potential hazards to the vicinity.

2.30 ***Procurement and installation of OSCG plant at TPWTW.*** According to WSD:

- (a) the expansion works of TPWTW had already commenced in February 2013 when WSD decided to install OSCG plant to replace imported liquid chlorine in 2016 (see para. 2.29). In January 2017, it gave approval for Consultant M to issue a VO (VO A) at an estimated cost of \$180 million (later valued at \$310.5 million) under Contract B to supply and install four sets of OSCG plant (including a standby unit) at TPWTW before September 2018. In February 2017, Consultant M issued VO A to instruct Contractor B to carry out the related works; and
- (b) based on the site conditions of TPWTW, OSCG plant would be installed in the existing chlorine store of TPWTW (i.e. on the lower level of the existing chlorine building) while liquid chlorine was being stored and used on the upper level of the same building. The then-existing liquid chlorine system would be demolished after the commissioning of OSCG plant.

Note 24: *According to WSD, there were five water treatment works (i.e. the Cheung Sha Water Treatment Works, the Red Hill Water Treatment Works, the Tai O Water Treatment Works, the Tai Po Road Water Treatment Works (decommissioned in April 2023) and the Sham Tseng Water Treatment Works) not subject to OSCG technology due to unavailability of OSCG facilities with small production capacity in the market at the moment and therefore using sodium hypochlorite solution for drinking water disinfection.*

Note 25: *According to WSD, in April 2016, WSD launched a pilot scheme by installing one set of OSCG plant at the Ngau Tam Mei Water Treatment Works to verify the technical feasibility of local generation of chlorine gas for use in water treatment works in Hong Kong. The installation was completed in December 2016 and subsequent testing found that the daily production rate of chlorine gas by the OSCG plant met the requirements.*

Need to early consult the relevant authorities about the statutory requirements

2.31 According to a detailed investigation study of a consultant (Note 26), OSCG plant should be designed to a high standard of safety and should comply with all local statutory requirements. Approval of the Fire Services Department (FSD) and the Environmental Protection Department (EPD) should be obtained for the design of the OSCG plant before proceeding with the OSCG plant construction/installation works, as follows:

- (a) **FSD.** There are four types of chemicals involved in the OSCG plant (Note 27) which are dangerous goods (DG). These chemicals are classified as Category 3 (i.e. corrosive substances) and Category 4 (i.e. poisonous substances) DG under the Dangerous Goods Ordinance (Cap. 295). Relevant approvals should be obtained from FSD, as follows:
 - (i) **Approval for storage of DG.** Design of storage for Categories 3 and 4 DG shall comply with the related requirements. For every OSCG plant installation, approval should be obtained from FSD on storage of DG before commencement of construction works; and
 - (ii) **Approval for manufacturing of DG.** In an OSCG plant, sodium hydroxide will be produced as a co-product. Besides, sodium hypochlorite solution (i.e. produced by reacting sodium hydroxide with chlorine gas) will be transported to small water treatment works for regular water disinfection use or to large water treatment works for emergency use. Approval should be obtained from FSD on manufacturing of sodium hydroxide and sodium hypochlorite during detailed design stage; and

Note 26: *In June 2016, WSD commissioned a consultant to conduct a detailed investigation of using local generated chlorine for all water treatment works and pre-chlorination station in Hong Kong by December 2018. According to WSD, the detailed investigation study report had been circulated to the relevant departments (e.g. the Fire Services Department and the Environmental Protection Department) for review and comments.*

Note 27: *According to WSD, the four types of chemicals involved in the OSCG plant at TPWTW are hydrochloric acid, sodium bisulphite, sodium hydroxide and sodium hypochlorite.*

- (b) **EPD.** For all water treatment works with continued liquid chlorine operation, based on the design, operation and maintenance of new facilities, WSD needs to assess the risks and hazards associated with the construction/installation works inside or near the existing chlorine stores prior to the commencement of OSCG plant construction/installation works (Note 28).

2.32 Regarding the approvals for manufacturing and storage of DG at TPWTW, Audit noted that:

- (a) in March 2017, Consultant M submitted the application for approval for storage of DG for the OSCG plant at TPWTW to FSD. In April 2017, FSD advised WSD that:
 - (i) the siting of DG store immediately above or below another DG store was not acceptable; and
 - (ii) it would not allow the operation of the new OSCG plant together with the then-existing liquid chlorine system in TPWTW concurrently due to safety concerns. Therefore, the then-existing liquid chlorine system must be fully decommissioned and inspected to FSD's satisfaction prior to the issuance of the required DG approval for the testing and commissioning of the new OSCG plant;
- (b) according to EPD, it advised WSD in May 2017 that as retrofitting of OSCG plant with continued liquid chlorine operation could result in potential hazard to human life, concurrent liquid chlorine storage and OSCG plant construction/installation works should be avoided as far as possible. According to WSD, the hazard to life assessment (see para. 2.31(b)) was conducted and concluded that the risk level during the construction/installation stage would be acceptable with implementation of the risk reduction/mitigation measures, which were subsequently approved by EPD in June 2017;

Note 28: *According to the consultant of the detailed investigation study, preliminary environmental review and quantitative risk assessment on individual water treatment works should be submitted for EPD's approval prior to the commencement of OSCG plant construction/installation works.*

Construction works of Tai Po Water Treatment Works

- (c) after the decommissioning of the then-existing liquid chlorine system at TPWTW in November 2019, approvals for manufacturing and storage of DG were obtained from FSD in the same month (i.e. about 2.7 years after the first submission of application to FSD in March 2017); and
- (d) according to WSD, to address the problems arising from the decommissioning of the then-existing liquid chlorine system and supply of chlorine before the commissioning of OSCG plant at TPWTW in November 2020 (Note 29), it implemented the following measures:
 - (i) ***Purchase of an additional OSCG plant at the Ngau Tam Mei Water Treatment Works (NTMWTW).*** In April 2017, Consultant M, through revising VO A (see para. 2.30(a)), instructed Contractor B to supply and install one set of OSCG plant at NTMWTW (Note 30) at an estimated cost of \$40 million (later valued at \$62.7 million) under Contract B to produce and provide sodium hypochlorite solution for disinfection of treated water until the completion of testing and commissioning of the OSCG plant at TPWTW. The OSCG plant at NTMWTW was put into testing and commissioning in the second quarter of 2019; and
 - (ii) ***Manning the operation of OSCG plant at NTMWTW.*** NTMWTW had 2 sets of OSCG plant (1 installed under the pilot scheme in December 2016 (see Note 25 to para. 2.29) and another one installed under VO A in early 2019 (see (i) above)). They were

Note 29: *According to WSD, upon the obtaining of DG approval in November 2019 (see para. 2.32(c)), the testing and commissioning of OSCG plant was originally scheduled to commence in December 2019 for completion in the second quarter of 2020. Due to the chlorine gas leakage incident in January 2020, the testing and commissioning of OSCG plant was suspended by FSD. Besides, the remedial works were hindered due to the outbreak of coronavirus disease and its subsequent effect since late January 2020. Consequently, FSD was satisfied with the remedial works and approved the re-commissioning of the OSCG plant in end August 2020. The testing and commissioning of OSCG plant finally resumed in end September 2020 and completed in October 2020.*

Note 30: *According to Consultant M, based on the site condition at that time, TPWTW did not have sufficient space to accommodate the additional set of OSCG plant. An alternative location was identified at NTMWTW, where sufficient space was immediately available and the installation would not require any major civil works.*

designated to produce and provide sodium hypochlorite solution for TPWTW. Consultant M issued 13 VOs between July 2018 to August 2019 at a total estimated cost of \$21 million (later valued at a total cost of \$30 million) under Contract B to instruct Contractor B to provide sufficient manpower for maintaining the operation of both sets of OSG plant at NTMWTW, covering the period from June 2018 to October 2020 (i.e. until the completion of testing and commissioning of the OSG plant at TPWTW).

2.33 Audit noted that, in March 2017, Consultant M submitted the application for approval for storage of DG for the OSG plant at TPWTW to FSD. FSD advised WSD in April 2017 that the siting of DG store immediately above or below another DG store was not acceptable (see para. 2.32(a)(i)). According to WSD, while waiting for the approvals for manufacturing and storage of DG at TPWTW from FSD (see para. 2.32(a) and (c)), it took about 7 months to implement the alternative measures to address the problems (i.e. the period between the submission to FSD for approval for storage of DG at TPWTW in March 2017 (not acceptable by FSD in April 2017) and the submission to FSD for approvals for manufacturing and storage of DG for the OSG plant at NTMWTW in October 2017 (see para. 2.32(d)(i))). Consultant M contended that the requirements imposed by FSD and EPD were unforeseen one and inevitably caused serious impacts to progress of the works. Audit however noted that the general siting requirements (i.e. the DG store should not be located directly under or above another DG store on the next higher floor or the next lower floor respectively) was included in “A Guide to Application for Dangerous Goods Licence” issued by FSD in June 2009 (Note 31).

2.34 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, FSD should be consulted at an early stage for DG approval for the storage of DG and chemicals. In Audit’s view, in implementing works projects, WSD needs to take measures to early consult the relevant authorities about the statutory requirements relating to the storage and manufacturing of DG and chemicals.

Note 31: *The Guide to Application was subsequently revised and the latest version (which was renamed as “A Guide to Application for Dangerous Goods Licence and Approval”) was issued in February 2023. Similar requirements remain applicable.*

Need to finalise the design of works before issuing the related VO

2.35 As of August 2022 (i.e. upon the finalisation of Contract B's account), VO A's cost had increased significantly from the original total estimated cost of \$220 million (i.e. \$180 million (see para. 2.30(a)) + \$40 million (see para. 2.32(d)(i)) for supplying and installing four sets and one set of OSCG plant at TPWTW and NTMWTW respectively) by \$153.2 million (70%) to the final value of \$373.2 million (i.e. \$310.5 million (see para. 2.30(a)) + \$62.7 million (see para. 2.32(d)(i))).

2.36 According to Consultant M:

- (a) the estimated cost of VO A issued under Contract B was provided by Contractor B and vetted by Consultant M in the absence of a detailed design for the five sets of OSCG plant, as the design was yet to be fully developed by Consultant M or Contractor B at the time when the original estimates were made;
- (b) the original estimates shall be construed as the best estimate only to the extent of the limited information that was made available, including conceptual layout plan, quotations from the supplier and budget proposal from Contractor B with reference to the OSCG plant at NTMWTW;
- (c) the design of OSCG plant was continuously reviewed, developed and improved to optimise its performance. Implementation of the identified enhancement and improvement works resulted in the cost increases; and
- (d) additional requirements from stakeholders (e.g. increase in number of spare parts required) were not anticipated at the initial stage, and therefore were not included in the original cost estimates.

2.37 In October 2023, WSD informed Audit that:

- (a) as OSCG technology was a new technology of this kind in Hong Kong, the cost estimate of VO A had been made based on the best available information; and

- (b) as the expansion works of TPWTW had already commenced in February 2013 (i.e. before WSD decided to install OSCG plant to replace imported liquid chlorine in 2016), there was urgency to request Contractor B to purchase and install OSCG plant before Contractor B placed order for the supply and installation of the disinfection equipment that used liquid chlorine as required under Contract B. As a result, the cost estimate of VO A was prepared based on the available information at the time of preparation of VO A and preliminary consultation with the stakeholders. The project team made further consultation with the stakeholders to finalise all requirements for the design of OSCG plant (e.g. requirements of additional spare parts) and the cost estimate subsequently.

2.38 In Audit's view, in implementing works projects, WSD needs to finalise the design of works before issuing the related VO as far as practicable with a view to better ascertaining the works needed and assessing the estimated VO cost.

Scope for improvement in transporting chemicals among various sites

2.39 According to WSD, before the commissioning of OSCG plant at TPWTW, WSD installed another OSCG plant at NTMWTW for producing and providing sodium hypochlorite solution (see para. 2.32(d)(i)) as an intermediate measure for disinfection of the treated water during the testing and commissioning and performance tests of Stream II of TPWTW. During the period, sodium hypochlorite solution (which is classified as DG under the Dangerous Goods Ordinance) was delivered by truck from NTMWTW to TPWTW for disinfection of treated water after decommissioning of the then-existing liquid chlorine system and until the commissioning of the OSCG plant at TPWTW.

2.40 Audit noted that there was an incident on the leakage of sodium hypochlorite solution during the delivery of the solution from NTMWTW to TPWTW in October 2019. According to Consultant M:

- (a) on 29 October 2019, the operator of NTMWTW loaded out sodium hypochlorite solution produced by OSCG plant at NTMWTW into 17 tanks for delivery to TPWTW by truck. Upon arrival at TPWTW, sodium

Construction works of Tai Po Water Treatment Works

hypochlorite solution was found on the truck and a crack was found on 1 of the 17 tanks;

- (b) a fish pond owner subsequently reported to the operator of NTMWTW that some white bubbles were found on the water surface running along the nullah/natural stream located near his fish ponds;
- (c) two fish pond owners (including the one mentioned in (b) above) claimed that some fishes and shrimps in their fish ponds were found dead after water from the natural stream was pumped into their fish ponds;
- (d) it was suspected that about 70 to 100 litres of sodium hypochlorite solution had been leaked to the soil surface, followed by seepage into the nullah/natural stream;
- (e) in the event, fresh water was then continuously flushed into the nullah/natural stream to dilute the contaminated water. Water samples had been obtained from both the fish ponds concerned and the downstream of the nullah/natural stream for testing with no abnormality noted; and
- (f) the service contractor engaged for delivering sodium hypochlorite solution expressed its willingness to compensate the losses of the fish pond owners. Accordingly, a settlement was reached among the delivery service contractor and the fish pond owners.

2.41 In October 2023, WSD informed Audit that, immediately after the incident, review of the incident was conducted and improvement measures (e.g. enhancement of the loading procedure and storage arrangement for the chemicals concerned, and provision of refresher training to relevant site staff and workers) had been implemented to prevent occurrence of similar incident.

2.42 In Audit's view, in implementing works projects, WSD needs to remind its staff and consultants to follow the improvement measures adopted in transporting chemicals (particularly DG) in a safe manner.

Audit recommendations

2.43 **Audit has *recommended* that, in implementing works projects, the Director of Water Supplies should:**

- (a) **take measures to early consult the relevant authorities about the statutory requirements relating to the storage and manufacturing of DG and chemicals;**
- (b) **finalise the design of works before issuing the related VO as far as practicable with a view to better ascertaining the works needed and assessing the estimated VO cost; and**
- (c) **remind WSD staff and consultants to follow the improvement measures adopted in transporting chemicals (particularly DG) in a safe manner.**

Response from the Government

2.44 **The Director of Water Supplies agrees with the audit recommendations.**

PART 3: OTHER CONTRACT MANAGEMENT ISSUES

3.1 This PART examines other contract management issues, focusing on:

- (a) project cost estimation and preparation of Bills of Quantities (paras. 3.2 to 3.9);
- (b) defects rectification works and performance reporting (paras. 3.10 to 3.17); and
- (c) site safety (paras. 3.18 to 3.30).

Project cost estimation and preparation of Bills of Quantities

Need to take measures to ensure that project costs are estimated as accurately as possible

3.2 According to the Project Administration Handbook:

- (a) project engineers are responsible for keeping the works within the approved scope and estimate. They must ensure that estimates are carefully prepared and given the same attention to detail as other aspect of project preparation; and
- (b) any estimate must be as accurate as possible as it affects the management of public funds and it has a direct effect on fund allocation.

3.3 The APE for Project Vote III mainly covered the works of Contracts B and C (with final contract sums of \$3,760.4 million and \$375.4 million respectively — see Table 4 in para. 1.8). Regarding Contract B, Audit noted that:

- (a) in May 2011, the pre-tender estimate of \$2,600 million for Contract B was drawn up by Consultant M (Note 32);
- (b) in June 2011, tenders for Contract B were invited (Note 33) and the tender closing date was March 2012 (Note 34);
- (c) in June 2012, the three tenders received were evaluated by the Tender Assessment Panel against the marking scheme with a two-envelope system. The recommended tender sum of Contract B was \$3,252.1 million (Note 35);
- (d) in mid-December 2012, WSD submitted the funding proposal for Project Vote III of \$6,176.7 million (covering Contract B) to the Public Works Subcommittee. The sum allowed for Contract B in the project cost estimate was \$4,795 million (i.e. \$1,542.9 million (47%) more than the recommended tender sum of

Note 32: *According to Consultant M, due to the lack of similar design-and-build contracts for comparison, the pre-tender estimate was based on the rates for similar items or quotations in some previous works contracts of WSD or from the electrical and mechanical equipment vendors and contractors respectively.*

Note 33: *According to WSD, approval to invite tenders for Contract B before funding approval was given by the Secretary for Development in June 2011.*

Note 34: *According to WSD, the original tender closing date was September 2011. Upon the request for extension of the tender closing date from the three tenderers, the closing date was extended to October 2011. The closing date was further extended to December 2011 and March 2012 in order to allow more time for the tenderers to better prepare their tenders due to the complexity of the contract.*

Note 35: *Under a two-envelope system, upon the completion of the assessment of the technical submissions received from the tenderers, the pricing documents would be opened and examined for further evaluation and compilation of the overall score. In late December 2012, WSD submitted the tender report of Contract B to the Central Tender Board. In January 2013, on the recommendation of the Central Tender Board, the Permanent Secretary for Financial Services and the Treasury (Treasury) approved the award of Contract B.*

Other contract management issues

\$3,252.1 million — Note 36). The funding was approved by the Finance Committee in January 2013 (see Table 1 in para. 1.5); and

- (e) in January 2013, WSD awarded Contract B to Contractor B (Note 37) at a contract sum (i.e. recommended tender sum) of \$3,252.1 million. Its final contract sum was \$3,760.4 million.

As of March 2023, the total expenditure under Project Vote III was \$4,724.5 million (i.e. \$1,452.2 million (24%) less than the APE of \$6,176.7 million).

3.4 In Audit's view, in implementing works projects, WSD needs to take measures to ensure that project costs are estimated as accurately as possible.

Need to strengthen checking of Bills of Quantities

3.5 Contract C was a remeasurement contract. 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 the

Note 36: *According to WSD, the difference of \$1,542.9 million was mainly due to the following reasons: (a) upon the completion of the Project, the increased output capacity of TPWTW could take up the existing loading of STWTW for supplying fresh water to a significant part of Kowloon, and Central and Western District of Hong Kong Island, which could pave the way for the in-situ reprovisioning of STWTW, while enhancing the overall resilience, flexibility and reliability of the water supply system; and (b) appropriate level of contingencies was allowed to cater for the potential risks (including site constraints in relation to maintaining operation of the existing TPWTW during construction, limited working space in the project area, environmental requirements and underground conditions, fluctuation of plant, equipment and material costs, and contract variations resulting from change in design and site conditions) that might hinder the timely completion of the works.*

Note 37: *According to WSD, the date of expiry of validity of tenders had been postponed from June 2012 to February 2013 in order to suit the funding schedule of Project Vote III.*

Bills of Quantities (BQ — Note 38) according to the contract. Audit noted that there were 52 omitted items (Note 39) (later valued at \$11.2 million — Note 40) under Contract C.

3.6 According to the Project Administration Handbook:

Before award of Contract C

- (a) from the viewpoints of financial control, omitted items should be kept to an absolute minimum through proper preparation of a BQ and Particular Preambles;
- (b) all works items should be included in BQ and omitted items should be minimised as far as practicable. BQ should undergo a checking process to ensure the completeness and accuracy of BQ and elimination of major errors. This would facilitate competitive tendering, reduce resources for valuation of omitted items and minimise the disputes arising from the valuation of omitted items;

Note 38: *Under a remeasurement contract, a BQ, which forms part of the tender document and subsequently the contract documents after the award of a contract, contains estimated quantities of various works items. A tenderer needs to provide a tender price for the relevant BQ items. For the successful tenderer, the BQ prices would be used for valuing the actual work performed.*

Note 39: *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 any omitted item: (a) the contractor is required to carry out the works in accordance with the contract drawings and specifications; and (b) the Engineer shall correct any such error or omission, and ascertain and certify the value of the works actually carried out.*

Note 40: *Of the 52 omitted items, 3 items (with value ranging from \$2 million to \$3.8 million) accounted for \$8.7 million (78%) of the total value of \$11.2 million. According to Consultant M, these 3 items were provided in the contract drawings but omitted from BQ.*

Other contract management issues

After award of Contract C (promulgated in 2014)

- (c) a pre-tender cross-checking procedure should be introduced in the preparation of BQ;
- (d) if resources permit, project office should conduct spot-checking on the quantities of some selected cost significant items after the BQ has been prepared by the Consultants; and
- (e) an officer of the project office at a rank not lower than Directorate Grade 1 should chair a meeting to vet the BQ to ensure all the checking and cross-checking procedures have been duly completed and documented.

3.7 In Audit's view, in implementing works projects, WSD needs to remind its staff and consultants to follow the latest requirements in checking of BQ to ensure its completeness and accuracy.

Audit recommendations

3.8 **Audit has *recommended* that, in implementing works projects, the Director of Water Supplies should:**

- (a) **take measures to ensure that project costs are estimated as accurately as possible; and**
- (b) **remind WSD staff and consultants to follow the latest requirements in checking of BQ to ensure its completeness and accuracy.**

Response from the Government

3.9 The Director of Water Supplies agrees with the audit recommendations.

Defects rectification works and performance reporting

Need to ensure timely completion of required works during maintenance period

3.10 Under Contracts A to C, the contractors were required to carry out any outstanding works and defects rectification works (Note 41) within the 12-month maintenance period (Note 42) at their own cost. Upon the expiry of the maintenance period and when all outstanding works and defects rectification works should have been completed, Consultant M should issue maintenance certificates stating the dates on which the contractors should have completed their obligations to execute the works under the contracts.

3.11 Audit noted that the outstanding works and defects rectification works under Contract B were completed 14 months after the end of the maintenance period (Note 43), as follows:

- (a) as of December 2020 (end of the 12-month maintenance period), of the 22,373 defects or outstanding works items identified, 358 (2%) had not yet been rectified or completed by Contractor B;

Note 41: *Under Contract A, Contractor A was required to carry out any works of repair or rectification, or make good any defect identified. Under Contracts B and C, Contractors B and C were required to carry out maintenance works including any works of repair or rectification, or make good any defect, imperfection, shrinkage, settlement or other fault identified. For simplicity, these works are both referred to as the defects rectification works in this Audit Report.*

Note 42: *Under Contract A, the relevant period is known as defects liability period. Under Contracts B and C, the relevant period is known as maintenance period. For simplicity, defects liability period under Contract A is also referred to as maintenance period in this Audit Report.*

Note 43: *For Contract A, the works had been timely completed. For Contract C, such works were completed 4.3 months after the end of the maintenance period. According to Consultant M, the delay was caused by the postponement of water mains connection works due to urgent repair works and some compensatory trees planted damaged by wild monkeys. The delay was reflected in the quarterly performance report of Contractor C for the period from December 2017 to February 2018 (e.g. adherence to programme aspect was rated as “poor”).*

Other contract management issues

- (b) from June 2019 to November 2021, Consultant M issued nine letters to Contractor B to express concern on the slow progress on defects rectification and completion of outstanding works, and lack of resources deployed to the site during the maintenance period; and
- (c) all the defects and outstanding works were only rectified and completed by end of February 2022 (i.e. more than one year after the end of the maintenance period) (Note 44).

3.12 In Audit's view, in implementing works projects, WSD needs to remind its staff and consultants to closely monitor the outstanding works and defects rectification works of contractors and take measures to ensure the timely completion of such works.

Scope for improvement in preparing contractors' performance reports

3.13 According to the Project Administration Handbook, the basic objective of the contractors' performance reports is to monitor the contractors' performance and assess their suitability for future work. It forms the major basis on what action will be taken as to upgrading, suspension, downgrading or deletion from the Lists of Approved Contractors for Public Works.

3.14 Audit noted that Contractor B's performance reports of the relevant period had not reflected instances related to its late reporting of 7 reportable accidents (see para. 3.24) and unauthorised access to the chlorine building by its worker in June 2018 (see Note 52 to para. 3.27(a)).

3.15 In Audit's view, in implementing works projects, WSD needs to take measures to ensure that performance issues of contractors are duly reflected in their performance reports.

Note 44: *According to Consultant M, the delay in completing the outstanding works and defects rectification works were reflected in the quarterly performance reports of Contractor B for the period from December 2020 to November 2021 (e.g. adherence to programme aspect was rated as "poor").*

Audit recommendations

3.16 **Audit has *recommended* that, in implementing works projects, the Director of Water Supplies should:**

- (a) **remind WSD staff and consultants to closely monitor the outstanding works and defects rectification works of contractors and take measures to ensure the timely completion of such works; and**
- (b) **take measures to ensure that performance issues of contractors are duly reflected in their performance reports.**

Response from the Government

3.17 The Director of Water Supplies agrees with the audit recommendations.

Site safety

3.18 According to Contracts A to C, contractors should:

- (a) throughout the progress of the works, take full responsibility for the adequate stability and safety of all operations on the site and have full regard for the safety of all persons on the site; and
- (b) keep the site and the works in an orderly state appropriate to the avoidance of danger to all persons.

3.19 According to the Construction Site Safety Manual issued by DEVB and WSD guidelines, contractors are required to:

- (a) verbally report dangerous occurrences and accidents involving death, serious injury, serious damage or with worker admitted to the hospital to the Engineer's site staff immediately, followed by preliminary accident report within 24 hours; and

Other contract management issues

- (b) promptly report all reportable accidents (i.e. accident resulting in death, serious injury and injury with incapacity for more than three days) to the Engineer's Representative. The contractor shall complete an injury report form within 7 days from the date of an accident.

3.20 Furthermore, according to DEVB Technical Circular (Works) No. 1/2020 and its superseded version No. 26/2000 "Score Card for Assessment of Site Safety Performance", Score Card system (being a quantitative tool to assess the safety performance of contractors in a consistent approach) was implemented for assessing the contractor's site safety performance (including the timeliness in reporting accidents at construction sites) in quarterly performance reports for public works contracts.

Scope for enhancing construction site safety

3.21 According to WSD, from February 2010 to February 2022, 1 fatal accident happened at the construction site of Contract B (see para. 3.22) and 13 non-fatal reportable accidents (i.e. accident resulting in an injury with incapacity for more than three days) happened at the construction sites of Contracts A to C (see paras. 3.23 and 3.24).

3.22 ***Fatal accident.*** The fatal accident happened at the construction site of Contract B. On 9 December 2013, during the casing extraction of a concreted bored pile at TPWTW, a steel casing, which was lifted up by a crawler crane and suspended at a height of 1 metre by the auxiliary cable, fell off and hit the head of a worker working at the oscillator platform and killed him (Note 45). According to WSD, enhancement measures (e.g. appointment of a supervisor in supervising the operation of the crane and provision of appropriate training to the workers) had been

Note 45: *Contractor B and the crane operator were prosecuted for violation of the Occupational Safety and Health Ordinance (Cap. 509) and the Factories and Industrial Undertakings Ordinance (Cap. 59) respectively. In March 2016, Contractor B and the crane operator were convicted and fined \$18,000 and \$12,000 respectively.*

implemented by Contractor B and adverse performance was reflected in Contractor B's performance report (Note 46).

3.23 *Non-fatal reportable accidents.* There were 13 non-fatal reportable accidents at the construction sites of Contracts A to C (1, 11 and 1 reportable accidents under respective contracts), involving sick leave ranging from 9 to 339 days. Regarding Contractor B which had the highest number of 11 non-fatal reportable accidents, according to WSD, between July 2013 and April 2018, Consultant M had taken various actions relating to Contractor B's site safety performance (e.g. conducting site inspections, issuing letters urging Contractor B to step up control over site safety and management, and requiring Contractor B to submit improvement proposal and monthly reports on the implementation of mitigation measures) (Note 47). According to WSD, enhancement measures for site safety (e.g. stepping up daily site safety inspection by site management team, strengthening the morning safety briefing to subcontractors, and more frequent safety review meetings with subcontractors and frontline site personnel, provision of more safety training and increase of resources to enhance site conditions) had been implemented by Contractor B in this regard and the site safety performance of Contractor B was found improving as reflected from its quarterly performance reports that the site safety aspect had been generally rated as either "satisfactory" or "good" since the third quarter of 2016 (Note 48).

3.24 Contractors are required to complete an injury report form within 7 days from the date of an accident (see para. 3.19(b)). Audit noted that, of the 11 non-fatal reportable accidents happened at the construction site of Contract B between

Note 46: *In the quarterly performance report of Contractor B for the period from December 2013 to February 2014, the site accident record aspect was rated as "very poor" and other aspects (e.g. provision of information, instruction and training, and provision and implementation of safe systems of work) were rated as "poor".*

Note 47: *According to WSD, Contractor B's deficiencies in site safety performance was reflected in the quarterly performance reports of the following periods: (a) September to November 2013; (b) June to August 2015; and (c) March to May 2016.*

Note 48: *According to WSD, exception was noted in the first quarter of 2020 due to the chlorine gas leakage incident in January 2020 (see Note 29 to para. 2.32(d)) and Contractor B's performance in the site safety aspect was rated as "poor".*

Other contract management issues

June 2014 and January 2019, late reporting of reportable accidents by Contractor B was found in 10 accidents, ranging from 14 to 263 days. Audit noted that, of these 10 reportable accidents, the late reporting issue for 7 accidents was not reflected in the quarterly performance reports of Contractor B for the respective periods (see para. 3.14) (Note 49).

3.25 In Audit's view, in implementing works projects, WSD needs to:

- (a) make continued efforts to enhance construction site safety with a view to safeguarding safety of all operations and all persons on sites; and
- (b) take measures to ensure that WSD contractors timely report accidents at construction sites in accordance with related requirements and appropriate follow-up actions are taken in a timely manner.

Scope for enhancing security of construction sites

3.26 According to WSD:

- (a) chlorine building is classified as hazardous/restricted area (Note 50) due to the storage of liquid chlorine drums (i.e. DG) inside the building; and
- (b) any person entering the chlorination plant or store room of the chlorine building should sign the register maintained in the station control room.

Note 49: *The late reporting issue for 3 accidents were reflected in Contractor B's quarterly performance reports for the respective periods with rating in site accident record aspect adjusted from "good" to "satisfactory".*

Note 50: *According to Contract B, permit-to-work systems should be implemented to control access to hazardous areas or the carrying out of any hazardous operations including, but not limited to, hot work, electrical work, work in confined space, maintenance of material hoist, area or operation liable to release of flammable or toxic liquid or gas, etc.*

3.27 According to WSD, during a site safety inspection conducted by WSD at TPWTW in June 2018, it was observed that a worker of Contractor B entered the first floor of chlorine building through a lock-broken door and used the water from the fire hydrant inside the chlorine building for cooling down the coring machine outside the chlorine building without authorisation (Note 51). According to Consultant M:

- (a) Contractor B had been warned of its unacceptable acts (Note 52) and was urged to:
 - (i) take immediate action to improve the situation and strengthen its management/site control to avoid recurrence of similar incident in future; and
 - (ii) remind its workers that they could not enter the existing buildings of TPWTW and could not take any water from the existing fire hydrant/water point unless proper approval had been obtained; and
- (b) in late June 2018, it was subsequently found that the locks of 16 (38%) of the 42 doors at the chlorine building were out-of-order. Assistance from WSD had been solicited to fix those defective door locks in order to maintain an effective system for restricting unauthorised entrance to the chlorine building.

3.28 In Audit's view, in implementing works projects, WSD needs to take measures to tighten the controls on access to hazardous/restricted areas with a view to preventing unauthorised access to and use of facilities in these areas.

Note 51: *According to Waterworks Ordinance (Cap. 102), except with the permission of the Water Authority (i.e. the Director of Water Supplies), no person shall take water through a fire service for any purpose other than for fire fighting.*

Note 52: *This issue was not reflected in the quarterly performance report of Contractor B (see para. 3.14 for the related findings).*

Audit recommendations

3.29 Audit has *recommended* that, in implementing works projects, the Director of Water Supplies should:

- (a) make continued efforts to enhance construction site safety with a view to safeguarding safety of all operations and all persons on sites; and**
- (b) take measures to:**
 - (i) ensure that WSD contractors timely report accidents at construction sites in accordance with related requirements and appropriate follow-up actions are taken in a timely manner; and**
 - (ii) tighten the controls on access to hazardous/restricted areas with a view to preventing unauthorised access to and use of facilities in these areas.**

Response from the Government

3.30 The Director of Water Supplies agrees with the audit recommendations.

PART 4: OPERATION AND MAINTENANCE OF TAI PO WATER TREATMENT WORKS

4.1 This PART examines WSD's work in operation and maintenance of TPWTW, focusing on:

- (a) operation and maintenance of facilities (paras. 4.3 to 4.17); and
- (b) output capacity and treated water quality (paras. 4.18 to 4.26).

Water treatment process at TPWTW

4.2 According to WSD, the water treatment process at TPWTW comprises various stages, namely pre-treatment/flocculation, clarification, filtration and disinfection (see Figure 2).

Figure 2

Water treatment process at TPWTW

<i>Pre-treatment/ flocculation</i>	Raw water flows into TPWTW and is pre-treated by dosing with chemicals (e.g. alum and polyelectrolyte — Note 1)
<i>Clarification</i>	Pre-treated water flows into the dissolved air flotation tanks (Note 2) for removing relatively large particles and impurities
<i>Filtration</i>	Clarified water flows into the primary biological filters and secondary rapid gravity filters (Note 3) for filtering out the more finely divided particles
<i>Disinfection</i>	Filtered water is disinfected by adding chlorine in the chlorine contact tanks before supply to the public

Source: WSD records

Note 1: According to WSD, alum is added into raw water to coagulate impurities and polyelectrolyte is added to facilitate coagulation.

Note 2: According to WSD, dissolved air flotation is a robust and efficient process that employs a mixture of air and water to lift coagulated solids to the water surface for subsequent removal.

Note 3: According to WSD: (a) for biological filter, ammonia and manganese are removed biologically under a controlled environment; (b) for rapid gravity filtration, the remaining turbidity in the water is removed; and (c) the filter beds of both biological and rapid gravity filters are periodically cleaned by flushing in the reverse direction sequentially with compressed air and water (i.e. backwash water). To conserve water, the backwash water at TPWTW would be collected and then channelled back into the raw water inlet to go through the treatment process again.

Remarks: According to WSD, chlorine (for Stream I) or ozone (for Stream II) is also used at various stages of the treatment process for oxidation of impurities, taste and odour control as well as disinfection.

Operation and maintenance of facilities

4.3 The New Territories East Region under the Supply and Distribution (New Territories) Branch is responsible for the operation of TPWTW and maintenance of its civil structures, and the Maintenance Division under the Mechanical and Electrical Branch is responsible for the maintenance of M&E plant and equipment, including related instruments, at TPWTW (Note 53). The facilities of TPWTW mainly include dissolved air flotation tanks, primary biological filters, secondary rapid gravity filters, chlorine contact tanks, OSCG plant and ozone contact tanks.

Need to keep under review the performance and efficiency of OSCG plant

4.4 Regarding the performance and efficiency of the OSCG plant at TPWTW, Audit noted that:

- (a) ***Performance of OSCG plant.*** In November 2020, WSD issued a letter to Consultant M to express grave concern about the performance of the OSCG plant at TPWTW, including high content of silica in brine (Note 54) and its inability to effectively remove moisture from wet chlorine through dehumidification system (Note 55). According to WSD, the performance issue had been resolved by Consultant M by modification works on the brine tanks and the dehumidification system completed in February 2021 and February 2022 respectively; and

Note 53: *According to WSD: (a) as Stream II of TPWTW would increase the treated water output of TPWTW from 400 to 800 Mld, TPWTW was classified as critical infrastructure upon the completion of the Project; and (b) enhanced security systems including site perimeter boundary (e.g. intruder detection system and surveillance camera system) and access control (e.g. card reader access control system) had been implemented.*

Note 54: *According to WSD, the deposition of silica in brine would cause operational problems and adversely affect the service life and performance of the membranes and electrolyzers in the OSCG plant.*

Note 55: *According to WSD, the moisture would cause long-term maintenance problems (e.g. clogging of valves and pipes, corrosion of metal parts, etc.) to the OSCG plant.*

Operation and maintenance of Tai Po Water Treatment Works

- (b) ***Efficiency of OSCG plant.*** From August 2021 to June 2023, the efficiency of the OSCG plant at TPWTW varied between 78% to 99% over the period (Note 56), as follows:
- (i) from August 2021 to August 2022, the efficiency of the OSCG plant ranged from 80% to 87%;
 - (ii) in September 2022, the efficiency of the OSCG plant dropped to 78%. According to WSD, after the enhancement works (e.g. routine cleansing of pipework), the efficiency of the OSCG plant had been significantly improved; and
 - (iii) from October 2022 to June 2023, the efficiency of the OSCG plant varied between 85% and 99% (Note 57).

4.5 In Audit's view, WSD needs to keep under review the performance and efficiency of OSCG plant and implement enhancement measures as needed.

Need to complete the knowledge transfer of OSCG plant at TPWTW as scheduled

4.6 During the implementation of OSCG at TPWTW, in February 2019, WSD informed the Legislative Council that:

- (a) specialist contractor would be employed to provide support to in-house staff to operate the OSCG plant and to take up the repair and maintenance; and
- (b) in the long run, WSD would explore to set up dedicated teams and provide adequate training to ensure that the teams possess the expertise and experience to operate, repair and maintain OSCG plant.

Note 56: *According to WSD, the benchmark efficiency level was not provided by the supplier of the OSCG plant.*

Note 57: *According to WSD, the efficiency of the OSCG plant at TPWTW had increased to over 91% since February 2023 and attained 99% in June 2023.*

Operation and maintenance of Tai Po Water Treatment Works

4.7 Audit noted that, since 2021, WSD has engaged term contractors for the initial operation and maintenance of OSCG plant installed at various water treatment works (including TPWTW) (Note 58). According to WSD in May 2023:

- (a) it had formulated a plan to facilitate the gradual transfer of specialised knowledge from overseas experts to in-house staff and to cope with the planned deployment of operation and maintenance resources;
- (b) it was found that the operation and maintenance of OSCG plant were far more complicated than that was envisaged. Much more staff resources and time were required to train up in-house staff with sufficient knowledge and competency to operate and maintain the OSCG system on their own; and
- (c) the transfer of specialised knowledge from experts to in-house staff of TPWTW was expected to be fully achieved by the end of 2025.

4.8 Audit noted that the term contract for operation and maintenance of OSCG plant at TPWTW would expire on 31 December 2023 (see Note 58 to para. 4.7). In October 2023, WSD informed Audit that an implementation plan for in-house operation of the OSCG plant at TPWTW had been developed. The plan contains training arrangement for knowledge transfer from experts to in-house staff and the relevant training has commenced since May 2023 according to the staff deployment schedule for OSCG operation at TPWTW. In Audit's view, WSD needs to take measures to ensure that the knowledge transfer from experts to in-house staff of TPWTW relating to the operation and maintenance of OSCG plant at TPWTW is completed as scheduled.

Note 58: *In 2021, WSD awarded a term contract for operation and maintenance of OSCG plant at TPWTW and NTMWTW for three years from 1 January 2021 to 31 December 2023 at a contract sum of \$69.6 million. In 2022, WSD awarded another term contract for operation and maintenance of OSCG plant at the water treatment works located in New Territories and Lantau Island for four years from 23 March 2022 to 22 March 2026 at a contract sum of \$239.4 million.*

Scope for enhancing the compilation of management information from existing records on the usage of chemicals produced by OSCG plant

4.9 According to WSD:

- (a) in addition to the production of chlorine gas, OSCG plant can generate sodium hypochlorite solution through a chemical process, which would then be supplied to other water treatment works (e.g. small-scale one) for drinking water disinfection (see para. 2.31(a)(ii)); and
- (b) the amount of sodium hypochlorite solution produced should be based on the scheduled requirements of other water treatment works receiving the solution and the amount of solution required to be maintained at TPWTW for contingency use. The remaining amount of solution would be further supplied to other salt water pumping stations for flushing water disinfection.

4.10 According to WSD, from February 2021 to March 2023, a total of 3,951.1 m³ sodium hypochlorite solution was produced by the OSCG plant at TPWTW and the usage of the solution was as follows:

- (a) 1,793.8 m³ solution was used at TPWTW;
- (b) 1,941.3 m³ solution was transported to other water treatment works (Note 59); and
- (c) the remaining 216 m³ solution was transported to other salt water pumping stations for flushing water disinfection.

4.11 Audit noted that information on the usage of sodium hypochlorite solution was compiled by WSD based on various source records. As sodium hypochlorite

Note 59: *According to WSD, of the 1,941.3 m³ of sodium hypochlorite solution, 766 m³ (39%) and 617 m³ (32%) were transported to the Siu Ho Wan Water Treatment Works and the Ma On Shan Water Treatment Works respectively and the remaining 558.3 m³ (29%) was transported to eight other water treatment works.*

solution is categorised as DG under the Dangerous Goods Ordinance, in Audit's view, WSD needs to enhance the compilation of management information (e.g. preparing a monthly summary) from existing records on the usage of chemicals (i.e. sodium hypochlorite solution) produced by OSCG plant.

Scope for enhancing the administration of works orders for maintenance works

4.12 According to WSD, all waterworks buildings and M&E equipment of various waterworks facilities are maintained through its maintenance term contractors. Works orders are processed under Maintenance Works Management System (MWMS — Note 60) and issued to the term contractors for carrying out the related works.

4.13 ***Scope for enhancing the monitoring of works orders.*** According to WSD records, WSD issued a total of 337 works orders under 6 term contracts for carrying out maintenance works of TPWTW with a target commencement date that falls within the period from January 2020 to March 2023. As of July 2023, 283 (84%) works orders had been finalised while the works for the remaining 54 (16%) were still in progress. Of these 283 finalised works orders, Audit noted that:

- (a) ***Actual cost higher than estimated cost for some works orders.*** The actual expenditures of 36 (13%) works orders were higher than the original estimates by 5% (i.e. \$1,553) to 418% (i.e. \$103,732) (averaging 62%); and
- (b) ***Delay in completing some works orders.*** The works of 6 (2%) works orders were completed 10 to 263 days (averaging 103 days) after the target completion dates (Note 61).

Note 60: *According to WSD, MWMS is a web-based information system for processing works orders, managing all natures of direct labour work, recording mandays of individual labour for each maintenance work and enabling efficient communication, both internally for all divisions and units and externally for the contractors.*

Note 61: *According to WSD records, no EOTs had been granted for the additional time required by the term contractors in completing the works and liquidated damages of \$420 to \$35,746 had been deducted from the payment to the term contractors. The delay in completing these works orders arose mainly from the shortage of manpower and delay in materials supply.*

Operation and maintenance of Tai Po Water Treatment Works

4.14 *Scope for enhancing the record keeping of works orders in MWMS.* According to WSD guidelines, photographic records of the works carried out on site are useful for supervisory checking of the scope, feature, extent, progress and quantity of works carried out on site. In general, photographs should be taken by WSD and uploaded onto MWMS as soon as possible. Audit selected 15 finalised works orders for examination and noted that the photographs relating to the works of 6 (40% of 15) works orders were not available in MWMS.

4.15 In Audit's view, WSD needs to take measures to ensure that:

- (a) works orders for maintenance works of TPWTW are timely completed and their costs are estimated as accurately as possible; and
- (b) complete and up-to-date information of works orders for maintenance works of TPWTW is recorded in MWMS.

Audit recommendations

4.16 **Audit has recommended that the Director of Water Supplies should:**

- (a) **keep under review the performance and efficiency of OSCG plant and implement enhancement measures as needed;**
- (b) **take measures to ensure that the knowledge transfer from experts to in-house staff of TPWTW relating to the operation and maintenance of OSCG plant at TPWTW is completed as scheduled;**
- (c) **enhance the compilation of management information (e.g. preparing a monthly summary) from existing records on the usage of chemicals (i.e. sodium hypochlorite solution) produced by OSCG plant; and**
- (d) **take measures to ensure that:**
 - (i) **works orders for maintenance works of TPWTW are timely completed and their costs are estimated as accurately as possible; and**

- (ii) **complete and up-to-date information of works orders for maintenance works of TPWTW is recorded in MWMS.**

Response from the Government

4.17 The Director of Water Supplies agrees with the audit recommendations.

Output capacity and treated water quality

Need to keep under review the demand of treated water of TPWTW

4.18 According to WSD, the output capacity of TPWTW has been increased from 250 to 800 Mld after the uprating works (see para. 1.4 (a)(i) and (b)(i)). Audit noted that, since the commissioning of Stream II of TPWTW in December 2019, the treated water out from TPWTW was approaching the output capacity for some days, as follows:

- (a) in 2021, there were 107 days with treated water out from TPWTW over 700 million litres, ranging from 701 to 778 million litres. In 2022, it increased by 72 to 179 days, ranging from 701 to 766 million litres; and
- (b) the maximum daily volumes of treated water out from TPWTW were 778 and 766 million litres in 2021 and 2022 respectively, which were quite close to the design capacity of 800 Mld.

4.19 According to WSD, the site of TPWTW has allowed for further expansion with an ultimate output capacity of 1,200 Mld. In Audit's view, WSD needs to keep under review the demand of treated water of TPWTW with a view to early considering the need for further expansion of TPWTW.

Need to complete the review of HKDWS as scheduled

4.20 According to WSD:

Operation and maintenance of Tai Po Water Treatment Works

- (a) it is committed to supply the public with wholesome potable water that is safe for consumption. The quality of potable water shall comply chemically, bacteriologically and radiologically with HKDWS (see para. 1.10);
- (b) prior to 2017, the supply of drinking water was in accordance with the World Health Organization's Guidelines for Drinking-water Quality. Based on the World Health Organization's Guidelines for Drinking-water Quality, HKDWS was first established in September 2017 with a total of 92 water quality parameters. In line with international practices, the Government would assess from time to time the need to trigger review of HKDWS based on new international developments in drinking water standards;
- (c) in 2018, WSD commissioned an overseas consultant to conduct a consultancy study to review the new developments in practices/guidelines in two international organisations (Note 62) and seven overseas nations (Note 63) with due regard to the local context of Hong Kong. The selection of water quality parameters into HKDWS followed a generic framework which has been endorsed by the Drinking Water Safety Advisory Committee (Note 64). In April 2021, HKDWS was subsequently updated and the number of water quality parameters had been revised from 92 to 60 (Note 65). Besides, the Government had established two other

Note 62: *According to WSD, it included the World Health Organization and the European Union.*

Note 63: *According to WSD, it included Australia, Canada, Japan, New Zealand, Singapore, the United Kingdom and the United States of America.*

Note 64: *In January 2018, the Government set up a Drinking Water Safety Advisory Committee with members comprising academics and experts of related fields to give advice to DEVB on various drinking water safety issues including, inter alia, the review of HKDWS, and to examine the Government's efforts in safeguarding drinking water safety.*

Note 65: *According to WSD, it involved the inclusion of two new parameters (namely perchlorate and total trihalomethanes) and the exclusion of 34 irrelevant parameters. Specifically, the excluded parameters had all along been undetectable under the routine water quality monitoring programme of WSD, indicating that their levels were negligible, if not nil, in the drinking water of Hong Kong, which were far below the level that would cause adverse health risk. WSD would continue the surveillance of these excluded parameters in the drinking water.*

lists, namely the Surveillance List (Note 66) and the Watch List (Note 67), and the Aesthetic Guidelines; and

- (d) in 2022, the World Health Organization updated its Guidelines for Drinking-water Quality while various jurisdictions (including Australia, the Mainland, New Zealand and the United States of America) updated their drinking water standards. Having assessed these new international developments in drinking water standards or guidelines, the Drinking Water Safety Unit (Note 68) of DEVB initiated a review of HKDWS, including the Surveillance List, the Watch List and the Aesthetic Guidelines. In August 2022, WSD commissioned a consultant to conduct the review (covering the prevailing Standards for Drinking Water Quality in the Mainland and other overseas jurisdictions' standards), which was expected to be completed by early 2024.

4.21 In Audit's view, WSD needs to complete the review of HKDWS, including the Surveillance List, the Watch List and the Aesthetic Guidelines, as scheduled.

Scope for improvement in monitoring the treated water quality of TPWTW

4.22 According to WSD guidelines:

Note 66: *According to WSD, the Surveillance List includes parameters subject to surveillance monitoring, such as chemical parameters with low or even undetectable levels in the drinking water of Hong Kong and far below a level that would cause adverse health risk, and microbial parameters which serve to indicate the sanitary of drinking water supply systems.*

Note 67: *According to WSD, the Watch List serves to keep in view of the international development and includes parameters with their potential health risk not yet fully established scientifically.*

Note 68: *The Drinking Water Safety Unit, a dedicated team in DEVB, is responsible for overseeing and monitoring the performance of WSD in respect of drinking water safety.*

Operation and maintenance of Tai Po Water Treatment Works

- (a) TPWTTW's water quality is monitored by taking and analysing samples at different stages of the water treatment process (Note 69) in accordance with its sampling/testing schedule for testing of a comprehensive set of water quality parameters (Note 70); and
- (b) with a view to optimising the water treatment process and keeping a stringent control on the treated water quality of TPWTTW, specific guideline values (i.e. performance indicators — Note 71) had been established for certain water quality parameters (e.g. aluminium and fluoride). For water samples fail to meet the performance indicators, laboratory staff of TPWTTW should immediately inform the operator of TPWTTW and record relevant water quality test results in a manual record sheet "Record of Notification/Advice to Water Treatment Works Operators" (Note 72). In response to this, the operator of TPWTTW should record all follow-up actions taken in the record sheet.

Note 69: *According to WSD, samples were taken from, for example, raw water, dosed water, clarified water, filtered water, final water, etc. They would be tested by TPWTTW's on-site laboratory and WSD's three other laboratories (i.e. New Territories East Regional Laboratory, New Territories West Regional Laboratory and Ma On Shan Trace Analysis Laboratory).*

Note 70: *According to WSD guidelines, the sampling/testing schedule stipulates the testing frequency for each water quality parameter at different stages of the water treatment process.*

Note 71: *According to WSD, performance indicators refer to operational targets and critical limits, which are, in general, more stringent than HKDWS and provide early indication for monitoring operation of water treatment works. Operational targets are established with a view to optimising the water treatment process and keeping a stringent control on the treated water quality while critical limits are established for each water treatment process based on the impact on water safety. In general, operational targets are more stringent than critical limits. For example, for aluminium in final water, its operational target is less than or equals to 0.1 milligrams per litre, while its critical limit in final water is less than or equals to 0.2 milligrams per litre.*

Note 72: *According to WSD, the manual record sheet "Record of Notification/Advice to Water Treatment Works Operators" should be maintained by the laboratory staff of TPWTTW for recording communications (including follow-up actions taken) with the operator of TPWTTW.*

4.23 According to WSD, TPWTW's water sample testing is performed by its on-site laboratory and three other WSD laboratories (see Note 69 to para. 4.22(a)), which would send the test results to TPWTW's on-site laboratory for taking follow-up actions as appropriate. In addition, water quality reports summarising the water quality results of TPWTW are generated and submitted to relevant recipients for review and information regularly. These reports serve the purpose of closely monitoring the performance of water treatment works and ensuring the quality of the drinking water supply. From April 2019 to March 2023:

- (a) the quality of fresh water supplied to customers (including the treated water of TPWTW) were of 100% compliance with HKDWS; and
- (b) there were incidents that the test results of water samples collected at different stages (i.e. raw water, dosed water, clarified water, filtered water and final water) of the water treatment process at TPWTW did not meet the relevant performance indicators (Note 73), which are, in general, more stringent than HKDWS (see Note 71 to para. 4.22(b)). Follow-up actions had been taken on such instances (e.g. adjusted the chemical dosage added and increased the capacity of dissolved air flotation tanks). As a result, the final water of TPWTW was considered satisfactory.

4.24 Audit noted that the record sheet (i.e. "Record of Notification/Advice to Water Treatment Works Operators") for recording the water quality test results of TPWTW and the follow-up actions taken (see para. 4.22(b)) was a manual record. In October 2023, WSD informed Audit that the digitalisation of the manual record sheet was feasible and would be included as one of the requirements in future system upgrade. In Audit's view, WSD needs to keep under review the treated water quality of TPWTW and complete the digitalisation of the manual record sheet as soon as practicable.

Note 73: *According to WSD records, from April 2019 to March 2023, there were 528 incidents (comprising 162, 106, 233 and 27 incidents in 2019-20, 2020-21, 2021-22 and 2022-23 respectively) that the test results of water samples collected from TPWTW (mainly final water) did not meet the performance indicators (i.e. either operational targets or critical limits) of certain water quality parameters (mainly pH value and fluoride).*

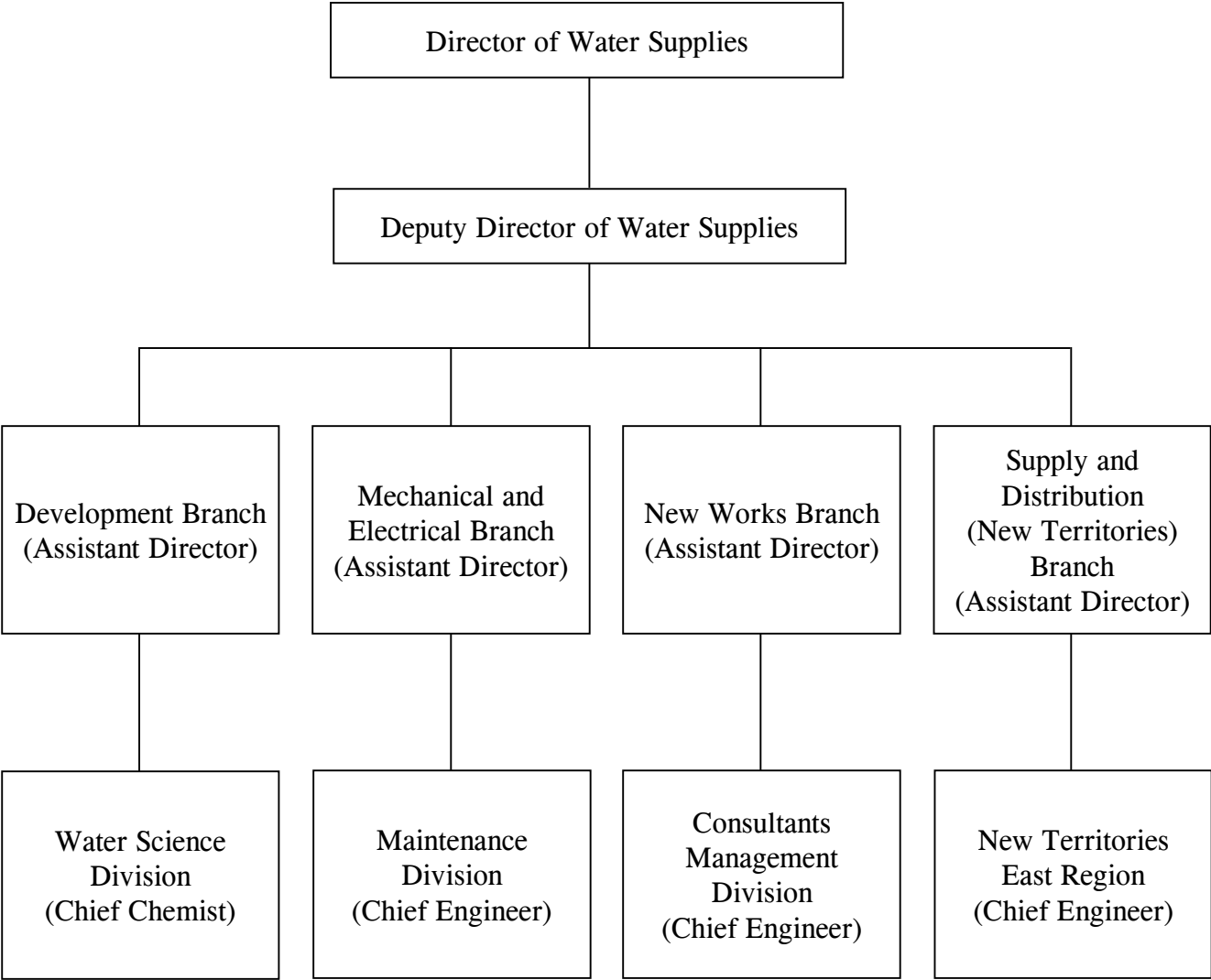
Audit recommendations

- 4.25 **Audit has *recommended* that the Director of Water Supplies should:**
- (a) **keep under review the demand of treated water of TPWTW with a view to early considering the need for further expansion of TPWTW;**
 - (b) **complete the review of HKDWS, including the Surveillance List, the Watch List and the Aesthetic Guidelines, as scheduled; and**
 - (c) **keep under review the treated water quality of TPWTW and complete the digitalisation of the manual record sheet for recording the water quality test results of TPWTW and the follow-up actions taken as soon as practicable.**

Response from the Government

- 4.26 **The Director of Water Supplies agrees with the audit recommendations.**

**Water Supplies Department:
Organisation chart (extract)
(31 March 2023)**



Source: WSD records

Acronyms and abbreviations

APE	Approved project estimate
Audit	Audit Commission
BQ	Bills of Quantities
DEVB	Development Bureau
DG	Dangerous goods
EOTs	Extensions of time
EPD	Environmental Protection Department
FSD	Fire Services Department
FWPSR	Fresh Water Primary Service Reservoir
HKDWS	Hong Kong Drinking Water Standards
m ³	Cubic metres
M&E	Mechanical and electrical
Mld	Million litres per day
MWMS	Maintenance Works Management System
NTMWTW	Ngau Tam Mei Water Treatment Works
OSCG	On-site chlorine generation
RSS	Resident site staff
STWTW	Sha Tin Water Treatment Works
TPWTW	Tai Po Water Treatment Works
TTA	Temporary traffic arrangement
VO	Variation order
WSD	Water Supplies Department