CHAPTER 12

THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

GENERAL REVENUE ACCOUNT

GOVERNMENT SECRETARIAT

Works Bureau

GOVERNMENT DEPARTMENT

Water Supplies Department

Water purchased from Guangdong Province

Audit Commission
Hong Kong
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WATER PURCHASED FROM GUANGDONG PROVINCE

Contents

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Summary and key findings

A. **Introduction.** Since 1960, the Government has entered into a number of agreements with Guangdong Province for the supply of Dongjiang water to meet the increasing water demand in Hong Kong. At present, Dongjiang water is Hong Kong's major source of water supply. In 1998, Guangdong Province supplied 760 million cubic metres (MCM) (83% of Hong Kong's water consumption) of Dongjiang water to Hong Kong. In 1998-99, the cost of purchasing Dongjiang water was $2,231 million. The 1989 Water Supply Agreement and the 1998 Loan Agreement are the latest water supply agreements, which cover the period 1995 to 2008 (paras. 1.1 to 1.8).

B. **Audit review.** Audit has recently conducted a review to ascertain whether there is room for improvement in the planning of the purchase of water from Guangdong Province and whether the quality of Dongjiang raw water and that of treated water comply with the required standards. The audit findings are summarised in paragraphs C to E below (para. 1.9).

C. **Quantity of Dongjiang water purchased.** The annual supply quantities for the period 1995 to 2000, as shown in the 1989 Water Supply Agreement, were based on an average annual growth rate of 3.43% in water consumption forecasted in 1987. As it transpired, the annual growth rate of actual water consumption dropped below the forecasted growth rate of 3.43%. From 1989 to 1998, the average annual growth rate of actual water consumption was only 1.28%. This was attributable to a significant drop in water consumption of the industrial sector following the relocation of manufacturing activities to the Mainland. As the growth in supply according to the 1989 Water Supply Agreement was more than the growth in demand, there is an excess water supply from Guangdong Province. Because unused Dongjiang water is stored in the reservoirs, the reservoir storage has built up. Given the high storage level, there is overflow of both rain water and excess Dongjiang water whenever there is heavy rainfall. From 1994 to 1998, the overflow quantity was 716 MCM and its financial implications could amount to $1,718 million. The WSD projected that the potential overflow quantity from 1999 to 2004 could amount to some 596 MCM. Audit observed that both the 1989 Water Supply Agreement and the 1998 Loan Agreement did not contain a provision for adjusting the annual supply quantity. Audit considers that there is an urgent need to formulate a strategy for determining the quantity to be supplied from Guangdong Province so as to minimise the overflow from reservoirs (paras. 2.3, 2.5, 2.7, 2.34 and 2.35).

D. **Quality of raw water from Dongjiang.** According to the 1989 Water Supply Agreement and the 1998 Loan Agreement, Dongjiang water supplied to Hong Kong should not be inferior to the Mainland's 1983 national standard for surface water. Audit noted that in the Mainland, an internationally comparable standard was published in 1988 to replace the 1983 Standard. However, there is no specific provision in both agreements that the quality of Dongjiang water should achieve the current 1988 Standard. In recent years, the quality of Dongjiang water has been deteriorating.

The results of Audit's analyses revealed that, from 1989 to 1998, the quality of Dongjiang water did not comply fully with the 1983 and 1988 Standards. In 1996, a WSD's consultancy study on the quality of Dongjiang water concluded that the quality of Dongjiang water would continue to deteriorate. Due to the substandard quality of Dongjiang water, additional capital costs of $35 million and recurrent treatment costs of $104 million from 1996-97 to 1998-99 were incurred by the WSD. Audit also observed that in the 1989 Water Supply Agreement and the 1998 Loan Agreement, there was no provision for penalty or compensation in case of non-compliance with the terms of the agreements by either party (paras. 3.3, 3.4, 3.11, 3.35 to 3.39).

E. **Treated water quality.** According to the results of the Audit's analyses of the treated water quality test data from 1995 to 1999, the treated water quality fully complied with the health-related guidelines of the 1993 World Health Organisation (WHO) Guidelines for Drinking Water Quality. However, the treated water quality did not fully comply with the 1993 WHO aesthetic level in respect of residual chlorine. Audit has observed that for three aesthetic parameters, namely turbidity, aluminium and residual chlorine, the treated water quality did not fully comply with the WSD's Final Treated Water Quality Targets. For two risky water-borne parasites, Cryptosporidium and Giardia, the Government has not established a contingency plan to deal with possible outbreaks of illness caused by these parasites. Audit also observed that, contrary to best international practices, the Waterworks Ordinance has not specified the number of parameters and the standards which the treated water should meet (paras. 4.6, 4.8, 4.9, 4.21 and 4.22).

F. **Audit recommendations.** Audit has made the following main recommendations:

— the Administration should:

(a) formulate a strategy for reducing overflow from the reservoirs (first inset of para. 2.38);

(b) incorporate greater flexibility into future water supply agreements so that the quantity can be adjusted according to changing circumstances (second inset of para. 2.38);

(c) continue to negotiate with the Guangdong Authority the possibility of charging at a reduced rate or simply not charging for the quantity of Dongjiang water not drawn by Hong Kong (fourth inset of para. 2.38);

(d) monitor closely the reservoir storage level and proactively stop drawing unneeded water if it is expected that such water would overflow from the reservoirs (fifth inset of para. 2.38);

(e) continue to negotiate with the Guangdong Authority with a view to stipulating in

future water supply agreements a requirement that the quality of water supplied to Hong Kong should comply with the current 1988 Standard (para. 3.42(a)); and

(f) in the negotiation with the Guangdong Authority to enable Hong Kong to draw less than the agreed quantity of Dongjiang water, take into account the additional treatment costs to be incurred by the WSD in the treatment of substandard Dongjiang water (para. 3.42(c)); and

— the WSD should:

(g) explore other better sources of water supply if the quality of Dongjiang water continues to deteriorate (para. 3.42(e));

(h) continue to negotiate with the Guangdong Authority a mechanism for effectively monitoring the quality of Dongjiang water (para. 3.42(g));

(i) take effective remedial measures to address the problem of non-compliance with the WSD's Final Treated Water Quality Targets and with the 1993 WHO aesthetic levels (para. 4.23(a));

(j) continue to monitor closely the level of chlorine in treated water to ensure that the residual level of chlorine is not hazardous to health (para. 4.23(b));

(k) continue to monitor closely the presence of Cryptosporidium and Giardia in the treated water and consider setting up a contingency plan for their possible outbreaks (para. 4.23(d));

(l) consider specifying the quality standards of treated water in the Waterworks Ordinance so that consumers are given a statutory undertaking of the quality of treated water (para. 4.23(e)); and

(m) publish actual data together with the adopted standards for treated water quality to enhance accountability to the public (para. 4.23(f)).

G. **Response from the Administration.** The Secretary for Works has generally agreed with the audit recommendations. The Director of Water Supplies has agreed to look at the audit recommendations positively with a view to taking them on board as far as practicable.

PART 1: INTRODUCTION

Background

1.1 Historically, Hong Kong depended on the collection of rain water as its main source of water supply. However, the erratic nature of rainfall resulted in many periods of water restriction. During the severe drought of 1960, the Guangdong Authority offered to supply 22.7 million cubic metres (MCM) of Dongjiang water to Hong Kong. Since then, Dongjiang water has flowed across the border. Even with the supply of Dongjiang water, there was still a need for water restriction from time to time, resulting in inconvenience to the daily life and disruptions to economic activities of Hong Kong.

1.2 ***Increasing water supply from Guangdong Province.*** Following the severe drought in 1962 and 1963, in 1964 the Guangdong Authority agreed to increase the supply of Dongjiang water to 68.2 MCM a year. In 1965-66, with the supply of Dongjiang water, Hong Kong was able to enjoy continuous 24-hour water supply for the first time in its history. Since then, to meet Hong Kong's growing demand, the Guangdong Authority has progressively increased the annual water supply to Hong Kong. The need to impose water restriction had eased. However, due to capacity constraint, the supply of Dongjiang water was insufficient to meet Hong Kong's demand in dry years and water restriction was still required from time to time. The last water restriction was imposed in 1982. Dongjiang water is now Hong Kong's major source of water supply. In 1998, the Guangdong Authority supplied 760 MCM of Dongjiang water to Hong Kong, which was 83% of Hong Kong's water consumption of 916 MCM. In 1998-99, the cost of purchasing Dongjiang water was $2,231 million.

Dongshen Water Supply System

1.3 Dongjiang water is supplied to Hong Kong through the Dongshen Water Supply System (DWSS). Figure 1 on the centre pages is a general layout plan of the DWSS. The DWSS is located downstream of Dongjiang. Water from Dongjiang is pumped over a series of dams built across the Shima River, which is one of Dongjiang's tributaries, into some artificial water channels in Dongguan. After the construction of the DWSS, the water course of the Shima River has been used as a DWSS open water channel. Dongjiang water flows through Dongguan and Shenzhen into the Shenzhen Reservoir. It then flows across the border into large reception tanks at the Muk Wu Pumping Stations near Lo Wu in Hong Kong.

1.4 The DWSS draws water from Dongjiang and the DWSS drainage basin. The DWSS has a large catchment area with abundant water resources and is therefore capable of meeting Hong Kong's water demand. To meet Hong Kong's future water demand, in 1994, the annual capacity of the DWSS was expanded to 1,100 MCM.

Water supply and treatment in Hong Kong

1.5 In Hong Kong, the Water Supplies Department (WSD) is the authority responsible for operating the water supply system. There are 17 impounding reservoirs, 19 water treatment works, seven major pumping stations, and a network of water mains for the distribution of fresh water. **The total water storage capacity of the impounding reservoirs is 586 MCM.** Dongjiang water is pumped from the Muk Wu Pumping Stations either directly to the WSD's water treatment works for treatment or to the impounding reservoirs for storage. The treatment capacity of the water treatment works is 4.3 MCM a day. After treatment, the water is distributed through the WSD's water supply system to consumers throughout the territory as potable water.

The 1989 Water Supply Agreement

1.6 Since 1960, the Government has reached a number of water supply agreements with the Guangdong Authority to increase the water supply to Hong Kong. The latest agreement was made in 1989. Following the endorsements of the Executive Council (ExCo) and the Finance Committee (FC) of the Legislative Council in November 1989, in December 1989 the Government signed an agreement with the Guangdong Province on the supply of Dongjiang water to Hong Kong (hereinafter referred to as the 1989 Water Supply Agreement). The major provisions of the Agreement are as follows:

— ***Quantity of water supply.*** From 1995 onwards, upon completion of the extension works of the DWSS, the water quantity would be increased annually by 30 MCM, from 690 MCM in 1995 to 840 MCM in 2000 (see Appendix A), with the maximum annual supply of 1,100 MCM planned to be reached by 2008. Both sides would review the water supply situation each year. If there was a need for an ad hoc increase in supply to Hong Kong, the Guangdong Authority would do its best to accommodate such a request;

— ***Interest-free advance payment of water charges.*** The Government would make an interest-free advance payment of water charges of $1,580 million to the Guangdong Authority for the extension works of the DWSS;

— ***Quality of water.*** Water supplied to Hong Kong should meet the water quality standard of Guangdong Province currently in force and should not be inferior to the Environmental Quality Standard for Surface Water GB3838-83 Class II (hereinafter referred to as the 1983 Standard) which was published by the Mainland in September 1983;

— ***Price of water.*** The price of water in the ensuing years would be decided by both sides through mutual consultation. Price increases would be based on increases in operation

costs and would take into account changes in relevant price indices in Guangdong and Hong Kong, and the exchange rate between the Hong Kong Dollar and the Renminbi; and

— ***Revision to agreement.*** **Any alteration and revision to the Agreement would be decided by both sides through mutual consultation.**

The 1998 Loan Agreement

1.7 Some of the provisions in the 1989 Water Supply Agreement have been amended by a loan agreement reached in 1998. In recent years, the quality of Dongjiang water has deteriorated due to the rapid urban and industrial development along the DWSS. In 1998, the Government reached a loan agreement with Guangdong Province. The loan agreement is intended to help finance a works project in Guangdong to improve the quality of Dongjiang water. The project involves the construction of a new closed aqueduct so that the risks of pollution along the existing open channel of the DWSS would be effectively eliminated upon completion of the project.

1.8 Following the endorsements of ExCo in March 1998 and the FC in April 1998, in July 1998 the loan agreement was signed between the Government and the Guangdong Authority (hereinafter referred to as the 1998 Loan Agreement). The major provisions of the Loan Agreement are as follows:

— ***Quantity of water supply.*** **The annual increase of water quantity will be reduced from 30 MCM to 10 MCM from 1998 to 2004 (see Appendix A).** Regarding the annual supply quantities after 2004, both sides agreed that this would be discussed at a later date. The Guangdong Authority undertook to take into account the future water demand growth and the reservoir storage situation in Hong Kong in considering the future supply, and agreed not to insist on reaching the supply quantity of 1,100 MCM by 2008, i.e. the full design capacity of the DWSS and originally set by the 1989 Water Supply Agreement;

— ***Quality of water supply.*** The quality of water supply for the period before the completion of the closed aqueduct project should continue to follow the same provision as that stipulated in the 1989 Water Supply Agreement. Upon completion of the project by the end of 2002, the Guangdong Authority will strive to improve the quality of Dongjiang water up to the Environmental Quality Standard for Surface Water GB3838-88 Type II (hereinafter referred to as the 1988 Standard — see Note 15 of paragraph 3.1 below) published by the Mainland in April 1988; and

— ***Interest-free loan.*** The Government will provide to Guangdong Province an interest-free loan of HK$2,364 million, to be drawn down in eight equal instalments of $295.5 million each between December 1998 and June 2002, to fund part of the construction cost of the closed aqueduct project. The Guangdong Authority will repay the loan by 20 equal yearly instalments starting from the commissioning of the closed aqueduct project or the year 2003, whichever is earlier.

Audit review

1.9 An audit has recently been carried out to ascertain:

— whether there is any room for improvement in the planning of the purchase of water from Guangdong Province;

— whether the quality of Dongjiang water complies with the requirements of the water supply agreements and whether the quality has been properly monitored; and

— whether the quality of treated water complies with World Health Organisation (WHO) Guidelines for drinking water quality.

The audit focused on the quantity and quality of Dongjiang water purchased from Guangdong Province as these are the main problem areas. The audit did not include a review of the price of water.

PART 2: QUANTITY OF DONGJIANG WATER PURCHASED

2.1 Since 1994, there has been an excess water supply from Guangdong Province mainly because water consumption in Hong Kong increased at rates lower than those forecasted. The main reason is that water consumption of the industrial sector has dropped significantly following the relocation of manufacturing activities to the Mainland. As supply exceeds demand, the water in the reservoirs often reaches a high level, resulting in reservoir overflow whenever there is heavy rainfall. Details are described in paragraphs 2.2 to 2.37 below.

Basis of fixing the quantity of water supply in the 1989 Water Supply Agreement

2.2 The annual supply quantities of Dongjiang water from May 1989 to February 1995 were fixed by a water supply agreement between the Government and Guangdong Province in 1987. In 1989, the Government requested the Guangdong Authority for an increase in water supply. During the negotiation of the 1989 Water Supply Agreement, the Guangdong Authority said that fixed annual quantities would be required to facilitate the planning of the DWSS extension works, power supply and other resources. To provide some flexibility, the WSD proposed that, in addition to a basic minimum annual supply quantity, an optional ad hoc increase in quantity should be catered for. Consequently, in the 1989 Water Supply Agreement, annual supply quantities for the period 1995 to 2000 were agreed. If there was a need for an ad hoc increase in supply, the Guangdong Authority would do its best to accommodate such a request. Both sides also agreed that, if there was a need to charge above the prevailing water price for an ad hoc increase in supply, the extra charge should not exceed 10% of the prevailing water price.

2.3 The annual supply quantities from 1995 to 2000, which had been agreed in the 1989 Agreement, were determined based on the WSD's forecasted average annual growth rate of 3.43% in water consumption. The forecasted average annual growth rate was determined in the 1987 Water Demand Forecast (Note 1). According to the 1987 Water Demand Forecast, for the period 1974 to 1987, the actual average growth rate of water consumption was 6% per annum. As regards the long-term growth in water demand, the 1987 Water Demand Forecast made an upper-bound estimation of 5% per annum and a lower-bound estimation of 3.43% per annum. However, to optimise the use of water resources, the WSD used the lower-bound estimation to fix the minimum annual supply quantities in the 1989 Water Supply Agreement.

Increase in supply of Dongjiang water

2.4 Appendix B shows a comparison of the growth of water consumption with the increase in agreed supply of Dongjiang water from 1986 to 1998. From 1986 to 1988, the growth rates of actual water consumption were higher than the rates of increase in the supply of Dongjiang water. For those years, the increase in water consumption was more than the increase in the agreed supply quantities of Dongjiang water. In view of this, the Government had to negotiate with the

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Note 1: *The WSD carried out a review to forecast water demand and to assess the adequacy of existing facilities for receiving and distributing Dongjiang water. The forecast of water demand was updated before the issue of the final report in February 1989.*

Guangdong Authority for the purchase of more Dongjiang water to enable the territory to tide over the dry years without imposing water restriction.

2.5 **The situation has changed since 1989 when the annual growth rate of water consumption began to drop. From 1989 to 1998, the annual increase in agreed supply of Dongjiang water (as a percentage of actual consumption) had always been higher than the growth rate of water consumption. However, from 1988 to 1991, as the rainfall was below the long-term average (see Appendix D), the Government had to negotiate with the Guangdong Authority for the purchase of more Dongjiang water in addition to the agreed quantities. From 1992 to 1998, as the annual increase in agreed supply was more than the actual increase in water consumption and the annual rainfall recorded was above the long-term average, the water level of the reservoirs had often reached the maximum, thus increasing the risk of water overflow (see paragraph 2.9 below).**

Drop in actual water consumption

2.6 ***Drop in the growth of actual water consumption.*** As indicated in Appendix B, from 1990 onwards, the growth rate of water consumption for each of the years was below the forecasted average growth rate of 3.43%. In 1990 and 1991, the growth rates were 3.31% and 1.26% respectively. However, the rates of increase in the agreed supply of Dongjiang water (as a percentage of actual water consumption) were 4.97% in 1990 and 4% in 1991. In addition, there was substantial rainfall from February to June 1992. Consequently, supply outstripped demand and the reservoir storage began to build up.

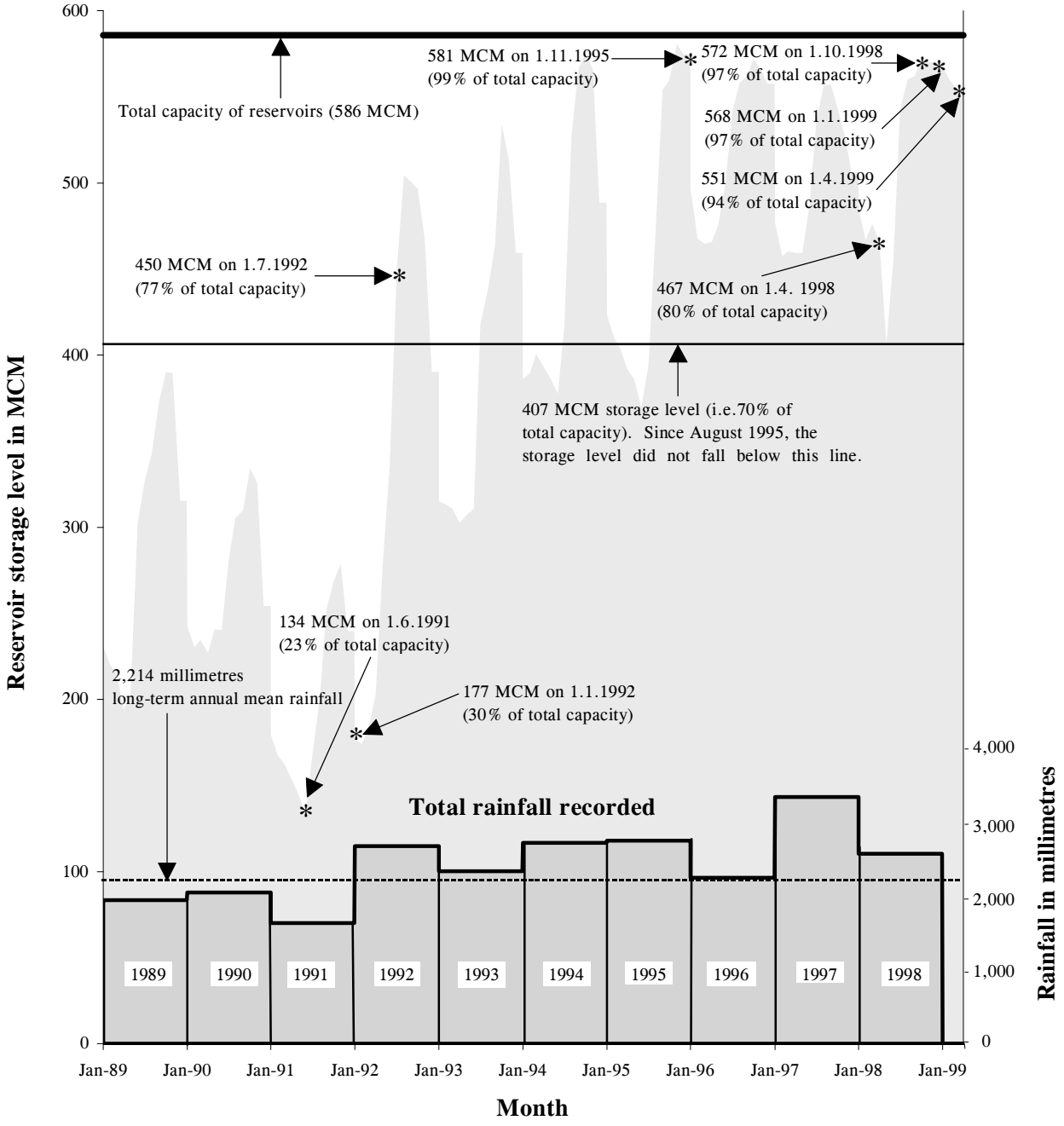
2.7 ***Decrease in actual industrial water consumption.*** Appendix C shows the actual water consumption by sectors from 1988 to 1998. Since 1990, the industrial water consumption has decreased. The biggest decrease was in 1994 in which industrial water consumption dropped 19.31% compared with that of 1993. In 1998, the industrial water consumption was only 66 MCM, a drop of 116 MCM compared with that of 1989. In the past ten years, the average annual rate of decrease of industrial water consumption was **8.72%**. This was mainly due to the relocation of manufacturing activities to the Mainland. Consequently, from 1989 to 1998, the average rate of increase of total water consumption was only 1.28% (compared with 3.43% forecasted in the 1987 Water Demand Forecast).

Increase in reservoir storage since 1992

2.8 ***Low reservoir storage level in 1990 and 1991.*** Figure 2 below shows the reservoir storage level on the first day of each month from January 1989 to April 1999. In 1990 and 1991, the water storage level in the reservoirs was low because the rainfall was below the long-term average. The annual rainfall recorded was 2,047 millimetres in 1990 and 1,639 millimetres in 1991 (see Appendix D). On 1 June 1991, the total reservoir storage level dropped to 134 MCM (i.e. 23% of total capacity). To maintain a normal supply of water, in 1991, the Government purchased an extra quantity of 138 MCM of Dongjiang water (see Appendix B). On 1 January 1992, the reservoir storage level increased slightly to 177 MCM (i.e. 30% of total capacity). In view of the low storage level and to ensure that there was adequate supply, in February 1992 the WSD requested the Guangdong Authority to supply an additional quantity of 105 MCM of water for 1992 (see Note 3 of Appendix B).

Figure 2

Reservoir storage level of each month from January 1989 to April 1999 and annual rainfall from 1989 to 1998



Source: The WSD's records

2.9 ***Increase in reservoir storage level.*** In mid-1992, the situation changed due to heavy rainfall. The total rainfall during the five-month period from February to June in 1992 was 2,013 millimetres, which was close to the long-term annual mean rainfall of 2,214 millimetres. With the drop in the growth of actual water consumption and heavy rainfall, supply exceeded demand. On 1 July 1992, the reservoir storage reached a high level of 450 MCM (i.e. 77% of total capacity). Therefore, it was likely that water would overflow from the Plover Cove and the High Island Reservoirs in which Dongjiang water was stored. To reduce the risk of overflow, the WSD agreed with the Guangdong Authority to defer the drawing of 38 MCM of the agreed water supply for 1992 to the period May 1993 to February 1994. Despite this deferment, in 1992, 31.8 MCM of water overflowed from the reservoirs (see Figure 3 in paragraph 2.18 below). Since 1993, the reservoir storage has continued to build up. As shown in Figure 2 above, since August 1995, the storage level has not fallen below 407 MCM (i.e. 70% of total capacity). On 1 November 1995, the storage level reached 581 MCM (i.e. 99% of total capacity).

Forecasted growth rates revised downwards in 1991 and 1992 Water Demand Forecasts

The 1991 Water Demand Forecast

2.10 Before 1991, the WSD did not conduct water demand forecast annually. Since 1991, the WSD has conducted forecasts annually in order to closely monitor the consumption trend. Appendix E shows a comparison of the WSD's forecasted growth rates with the actual growth rates of water consumption. While the growth in water consumption decreased in early 1991, because of the limited data available at that time, the WSD found it difficult to predict whether such a decrease would continue. As shown in Appendix E, the Water Demand Forecast made in November 1991 still forecasted an average annual growth rate of 3.18% for the period 1992 to 1995.

2.11 In June 1992, the WSD informed the Guangdong Authority that there was a slight decrease in the growth of water consumption since 1991 and that the agreed annual increase of 30 MCM of Dongjiang water (from 690 MCM in 1995 to 960 MCM in 2004 — see Appendix A) stipulated in the 1989 Water Supply Agreement might result in a surplus. Since the long-term trend in water consumption was not clear, it was agreed that the situation should be monitored. In July 1992, ExCo was informed of the situation.

The 1992 Water Demand Forecast

2.12 As mentioned in paragraph 2.6 above, since 1990, there was a drop in the growth rate of actual water consumption. To find out the reasons for the drop, in 1992 the WSD conducted the 1992 Water Demand Forecast (Note 2). The WSD sought the advice of the Industry Department

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Note 2: *The first draft of the 1992 Water Demand Forecast was issued in August 1992 and the final report was issued in January 1993.*

and the Financial Services Bureau (FSB). **The Director-General of Industry opined that there would be a 4% and 2% drop in industrial water consumption in 1992 and 1993 respectively (Note 3). The FSB advised the WSD that:**

> **"... it is desirable that the planning strategy should pay greater attention to avoid erring on shortages. The growth of water consumption should be reviewed more frequently and the water purchase arrangements should preferably seek to incorporate greater flexibility."**

2.13 As shown in Appendix E, in the 1992 Water Demand Forecast, the WSD revised the forecasted average growth rate of water consumption downwards to 1.9% for the period 1993 to 2002, which was much lower than the forecasted average growth rate of 3.43% made in the 1987 Water Demand Forecast.

2.14 In the 1992 Water Demand Forecast, the WSD came to the following conclusions:

- **the forecasted water consumption would be less than the quantity supplied from Guangdong Province plus the mean rainfall yield from 1993 onwards**;

- **action should be taken to draw up a strategy to review in due course the water quantity to be supplied from Guangdong Province**; **and**

- frequent review and close monitoring of the consumption trend should be carried out at yearly interval until a stable trend was observed.

The WSD did not request reduction in water supply from the Guangdong Authority in 1993 and 1994

2.15 Taking into account the results of the 1992 Water Demand Forecast, in May 1993, the WSD informed ExCo that the growth rate of water consumption was declining due to the shift of major water-consuming industries from Hong Kong to the coastal cities of the Mainland. Notwithstanding the significant decline of the growth rate of water consumption, the Administration considered that it would be premature to request the Guangdong Authority to reduce supply as a declining trend of water consumption could not be established at that time. Consequently, at the

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Note 3: *The actual drop in industrial water consumption in 1992 and 1993 turned out to be 7.47% and 9.94% respectively.*

business meeting with the Guangdong Authority (Note 4) held in July 1993, the Government said that the annual increase of 30 MCM from 1995 to 2004 stipulated in the 1989 Water Supply Agreement might be on the high side, and that a long-term water consumption trend had to be established. However, no request was made to the Guangdong Authority to reduce the Dongjiang water supply.

2.16 ***The 1993 Water Demand Forecast.*** In the 1993 Water Demand Forecast, which was completed in December 1993, the WSD forecasted a low long-term growth rate of water consumption from 1994 to 2002. As indicated in Appendix E, the forecasted average growth rate was 1.73%. Notwithstanding the low forecasted growth rate, the Government did not formally raise the issue of reducing Dongjiang water supply at the business meeting held with the Guangdong Authority in May 1994.

2.17 ***The 1994 Water Demand Forecast.*** In the 1994 Water Demand Forecast, which was completed in November 1994, the WSD forecasted a low long-term growth rate of 1.43% of water consumption from 1995 to 2003 (see Appendix E). This forecasted average growth rate was much lower than the average growth rate of 3.43% forecasted in the 1987 Water Demand Forecast.

Reservoir overflow

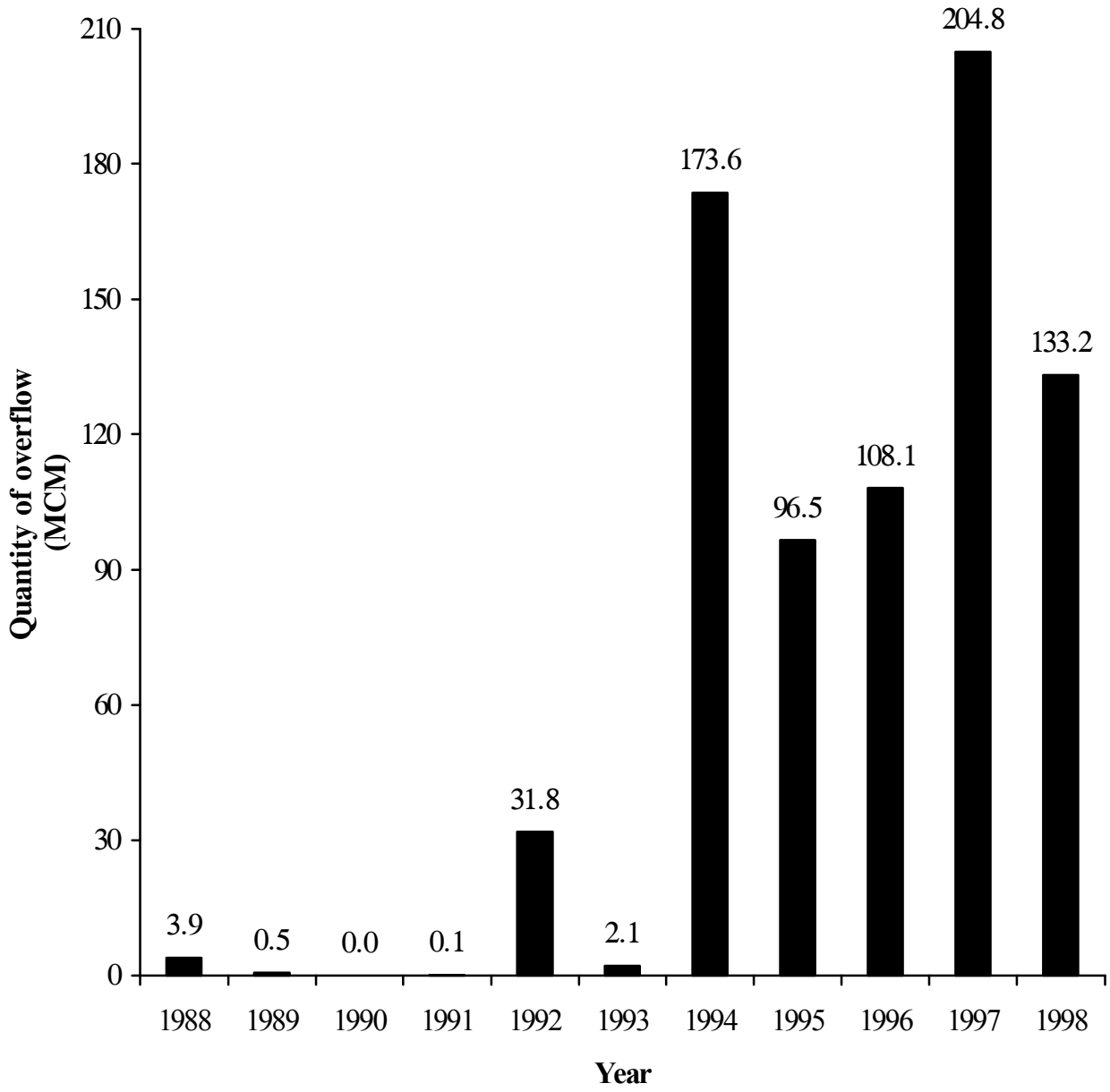
2.18 ***Serious overflow in 1994.*** Figure 3 below shows the quantity of water which had overflowed from the reservoirs from 1988 to 1998. With the high reservoir storage level of 386.2 MCM on 1 January 1994 and the heavy rainfall in June 1994 (Note 5), there was serious overflow (173.6 MCM) in 1994.

Note 4: *According to the 1989 Water Supply Agreement, the Government and the Guangdong Authority have to convene a business meeting once a year.*

Note 5: *In 1994, the total rainfall recorded was 2,726 mm. According to the WSD's explanation, because of the low rainfall from January to May 1994 (there was only about 40% of the average rainfall for the period), there was concern over the supply position. Studies of the need for requesting extra supply from Guangdong Province were made in preparation for the June 1994 business meeting. However, the heavy rain in June 1994 quickly reversed the position.*

Figure 3

Water overflow from reservoirs
1988 to 1998



Source: *The WSD's records*

Note: *From 1994 to 1998, the total quantity of overflow was 716.2 MCM.*

2.19 ***Review of reservoir storage in 1995.*** In view of the significant quantity of overflow in 1994, in April 1995, the WSD completed a Review of Reservoir Storage Positions. In the review, the WSD used the reservoir storage level of 423.4 MCM (i.e. 72% of the total capacity) as at 1 January 1995 as the beginning storage level, and a mean rainfall yield of 287 MCM a year to assess the probability of overflow (Note 6). In addition, the WSD also reviewed the reservoir storage position based on the assumption that the Dongjiang water supply would be reduced by 30 MCM in 1996 and 60 MCM in 1997. **The review concluded that in 1996 and 1997 the probability of reservoir overflow would be above 50%, and that there was a need to reduce the water supply from Guangdong Province in 1996 and 1997 in order to conserve water.** The WSD recommended that the Government should negotiate with the Guangdong Authority with a view to reducing the supply and adjusting the normal even rate of water supply so as to maintain a higher daily rate during the dry season.

Negotiations with the Guangdong Authority from 1995 to 1997

Negotiation in 1995

2.20 Following the completion of the 1994 Water Demand Forecast and the 1995 Review of Reservoir Storage Positions, in June 1995, the WSD informed ExCo that**:**

- since the latter half of 1990, the water demand growth rate had dropped significantly, largely due to the decrease in demand from the industrial sector;

- based on the 1994 Water Demand Forecast, from 1995 to 2000, the demand growth rates were between 1.26% and 1.56% a year. These demand forecast rates were much lower than the previous demand growth projection of 3.43% per annum;

- overflow would occur from 1996 onwards, assuming average local rainfall. The total overflow would be 432 MCM from 1996 to 2000; and

- **the financial implications of the potential overflow of 432 MCM were the loss of $933 million (at the 1995 purchase price of $2.16 per cubic metre of Dongjiang water). The WSD considered it necessary to negotiate with the Guangdong Authority for a reduction in the water supply.**

2.21 At the June 1995 annual business meeting with the Guangdong Authority, the Government requested the Guangdong Authority to:

Note 6: *The assessment of the probability of overflow was based on the assumption that all the individual reservoir systems were integrated and that it would be possible to transfer any quantity of water among the different reservoirs to balance their storage.*

— reduce the agreed annual water supply quantities for the period 1996 to 2000;

— adjust the even rate of daily water supply so that a higher daily supply would be drawn during the dry months of each year, while the total agreed yearly quantity remained unchanged; and

— supply additional water, if required, after the reservoir storage review of the WSD in October each year.

2.22 ***Guangdong Authority's response.*** The Government's request was not agreed. The Guangdong Authority said that the failure to take the agreed quantities covered in the 1989 Water Supply Agreement would deny them a reasonable return because the DWSS had been expanded to 1,100 MCM in 1994 based on the annual supply quantities proposed by the WSD in 1989 (to reach an ultimate design capacity of 1,100 MCM in 2008). The Government's request would adversely affect the Guangdong Authority's plans.

2.23 ***Agreed arrangement.*** The Guangdong Authority also stressed that the Government had to make payment in accordance with the water supply agreement even if the agreed quantity was not drawn in full. However, the Guangdong Authority agreed to reduce the daily supply rate in the event of overflow in Hong Kong due to heavy rainfall. As the agreed annual supply quantity had to remain unchanged, the effectiveness of the reduction in daily supply to tackle the problem of over-supply was limited. In 1995, this arrangement reduced the reservoir overflow by a relatively small quantity (8 MCM).

Negotiation in 1996

2.24 ***Freezing the supply quantity.*** At the June 1996 annual business meeting with the Guangdong Authority, the Government raised the issue of freezing the annual supply quantities at the 1996 level (720 MCM) up to the year 2000. However, the Guangdong Authority again declined the Government's request.

Negotiation in 1997

2.25 ***Request for a deferment of water supply.*** At the May 1997 annual business meeting held with the Guangdong Authority, the Government again requested a freeze of the annual supply quantities at the 1997 level (750 MCM) up to the year 2000, and a deferment of part of the supply to future years in order to minimise the overflow from reservoirs. However, the Guangdong Authority again rejected the request, restating its argument that it had invested heavily in expanding the capacity of the DWSS. It said that the investment would only produce a reasonable return 13 years after the DWSS had been in operation. **Nevertheless, the Guangdong Authority offered a nominal reduction of the annual supply quantities by 5.5 MCM in 1998, 6.5 MCM in 1999 and 7.5 MCM in 2000.** The Government considered that:

— the quantity of reduction in water supply offered by the Guangdong Authority was insignificant; and

— there was an opportunity of striking a better deal in view of the Guangdong Authority's request for an interest-free loan for the construction of a closed aqueduct of the DWSS.

The Government and the Guangdong Authority agreed to leave the issue open and to explore other options in future meetings. Meanwhile, it was agreed that the rate of supply should continue to be adjusted so that less water would be drawn in the rainy season to minimise reservoir overflow.

Excess supply of water not drawn from Guangdong Province

2.26 Before the May 1997 annual business meeting with the Guangdong Authority, in April 1997, ExCo directed the Administration that, if the Guangdong Authority did not accept the proposal of deferring part of the supply, the practicalities of simply not drawing the excess water each year should be examined. Therefore, in June 1997, the WSD stopped drawing unneeded water from Guangdong Province in order to avoid wasting water due to overflow. **In 1997, 52 MCM (see Note 4 of Appendix B) of water was not drawn (Note 7).** In doing so, the WSD achieved some savings in the electricity cost of pumping operations although full charges for the agreed total annual supply were paid to the Guangdong Authority.

2.27 **However, in 1998, the WSD did not take the same measure to reduce the overflow. According to the Review of Reservoir Storage Positions conducted by the WSD in April 1998, the probability of overflow in 1998 ranged from 83% to 89% because of the high reservoir storage level (i.e. 80% of total capacity on 1 April 1998).** On 1 October 1998, the reservoir storage level reached 97% of the total capacity (see Figure 2 in paragraph 2.8 above). The reservoirs had almost no capacity for storing Dongjiang water. However, the agreed annual quantity of 760 MCM was all drawn in 1998 (Note 8), resulting in the overflow of 133.2 MCM.

2.28 In order to draw Dongjiang water from Guangdong Province, the WSD has to operate the Muk Wu Pumping Stations. In 1998, the electricity cost of operating the pumping stations was $66 million. **Audit estimated that the WSD could have at least saved $4 million in electricity cost, if 50 MCM of Dongjiang water had not been pumped in 1998 (based on the undrawn quantity in 1997).**

Significant overflow from 1994 to 1998

2.29 Between 1993 and 1998, the total increase in agreed water supply from Guangdong Province was 136 MCM, whereas the increase in water consumption was only one MCM, as shown in Table 1 below:

Note 7: *According to the WSD's explanation, this was due to the extraordinarily high rainfall recorded in 1997.*

Note 8: *According to the WSD's explanation, as the normal wet season had come to an end, the WSD therefore did not consider it necessary to further reduce the newly agreed supply quantity.*

Table 1

Comparison of the agreed annual increase in water supply with the annual increase in actual water consumption

Year	Agreed quantity	Year-on-year increase	Actual water consumption	Year-on-year increase
	(MCM)	(MCM)	(MCM)	(MCM)
1993	624	—	915	—
1994	660	36	923	8
1995	690	30	919	(4)
1996	720	30	928	9
1997	750	30 (Note)	913	(15)
1998	760	10	916	3
		Total 136 (Note)		**1**

Source: *The WSD's records*

Note: *Although the agreed annual increase in 1997 was 30 MCM, the WSD did not draw 52 MCM of Dongjiang water. Therefore, the actual water drawn in 1997 was 22 MCM less than the agreed quantity in 1996.*

The excess supply situation arose because no agreement had been reached to reduce the annual supply from Guangdong Province and there had been little growth in demand in Hong Kong. Water drawn from Guangdong Province is mainly stored in the Plover Cove and High Island Reservoirs. The reservoir storage continued to build up. On 1 January 1999, the reservoir storage level reached 97% of the total storage capacity. Given such a high storage level, water will overflow from the reservoirs whenever there is heavy rainfall (Note 9).

Financial implications of reservoir overflow

2.30 **As indicated in Figure 3 in paragraph 2.18 above, the total quantity of overflow from 1994 to 1998 was 716 MCM (Note 10). Based on the WSD's method of quantifying the financial implications of potential overflow in 1995 (see 4th inset of paragraph 2.20), Audit has**

Note 9: *According to the WSD's explanation, this was the result of shifting the shutdown period from December 1997 to April 1998. The rainfall recorded in the first seven months of 1999 was low and there was little overflow until late August 1999 when heavy rainfall came with Typhoon Sam.*

Note 10: *According to the WSD's explanation, this was mainly due to the exceptionally high and erratic rainfall during the period.*

estimated that the financial implications of the overflow from 1994 to 1998 could amount to $1,718 million (see Appendix F).

Reduction of annual supply quantities from 1998 to 2004

2.31 In July 1998, the Government finally succeeded in obtaining the Guangdong Authority's agreement to reduce the annual water supply quantities to minimise the extent of overflow. In return for an interest-free loan of $2,364 million for the construction of the closed aqueduct, the Guangdong Authority agreed to reduce the annual increase from 30 MCM to 10 MCM from 1998 to 2004 (see paragraph 1.8 above and Appendix A). However, they would not accept any larger reductions. The Guangdong Authority further agreed not to insist on reaching the supply quantity of 1,100 MCM by 2008.

Potential overflow from 1999 to 2012

2.32 ***WSD's estimate of potential overflow from 1999 to 2004.*** Despite the reduction in the agreed supply quantities in the 1998 Loan Agreement, it is likely that the reservoirs will continue to overflow from 1999 onwards. As indicated in Appendix B, the rate (0.33%) of growth of water consumption for 1998 was still lower than the rate (1.10%) of increase in supply. In May 1999, the WSD estimated that overflow would occur every year from 1999 to 2004 under normal rainfall conditions because of the high reservoir storage level. **The supply quantities from Guangdong Province for the period 1999 to 2004 were fixed in the 1998 Loan Agreement. According to the WSD's estimation, potential reservoir overflow from 1999 to 2004 would be 596 MCM. The financial implications could amount to some $1,839 million at the 1999 purchase price of $3.085 per cubic metre of Dongjiang water (Note 11).**

2.33 ***Potential overflow from 2005 to 2012.*** The annual water supply from Guangdong Province from 2005 onwards has not been fixed. Based on the WSD's 1998 Water Demand Forecast for the period 1998 to 2012, Audit estimated that the potential reservoir overflow (Note 12) could amount to 679 MCM from 2005 to 2012, assuming that there was normal rainfall and that the annual supply from Guangdong Province could be frozen at the 2004 level (i.e. 820 MCM).

Audit observations on quantity of water supply from Guangdong Province

2.34 **Audit observed that there had been serious reservoir overflow since 1994. From 1994 to 1998, the overflow quantity was 716 MCM. The financial implications could amount to $1,718 million.** Although the annual supply quantities were somewhat reduced in the 1998 Loan

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Note 11: *The calculation is as follows:*

$$\$3.085 \times 596\ MCM = \$1,839\ million$$

Note 12: *Audit's estimate of potential overflow is based on the same assumptions as those used in the WSD's Review of Reservoir Storage Positions of May 1999. The projected consumption from 2005 to 2012 is based on the WSD's 1998 Water Demand Forecast.*

Agreement, the projected potential overflow quantity from 1999 to 2004 would still amount to some 596 MCM. The financial implications of the potential overflow could amount to $1,839 million. Overflow from reservoirs is an "expensive waste" (Note 13). Audit noted that the water demand situation is not the same as that of the 1987 Forecast on which the 1989 Water Supply Agreement was based. The growth of water consumption has been decreasing. As the growth in supply according to the 1989 Water Supply Agreement was more than the growth in demand, the excess supply had resulted in high reservoir storage levels, and overflow in the years 1994 to 1998. Given the high reservoir storage level (e.g. 94% on 1 April 1999), the capacity of local reservoirs to store natural water and Dongjiang water will be very limited. Both rain water and expensive excess Dongjiang water will overflow, and be wasted. **Audit considers that there is an urgent need to formulate a strategy for determining the quantity of water to be supplied from Guangdong Province so as to minimise the overflow from reservoirs which is an expensive waste.**

2.35 **Audit observed that the annual supply quantities were fixed a few years ahead according to the WSD's demand forecast. Other key factors, such as the reservoir storage level at the beginning of the rainy season and the actual consumption of the previous year, were not taken into account in determining the supply quantity of the ensuing year.** Audit appreciates that there is a need to plan the water supply a few years ahead, particularly if capital works for expanding the capacity are involved. However, the 1989 Water Supply Agreement had committed Hong Kong to a long period of fixed supply quantity (Note 14). Both the 1989 Water Supply Agreement and the 1998 Loan Agreement did not contain a mechanism, such as the option of a deferment of part of the supply, for adjusting the annual supply quantities of the ensuing years, despite the fact that the expansion works of the DWSS were completed in 1994.

2.36 Audit observed that, in the 1992 and 1993 Water Demand Forecasts, the WSD forecasted that the growth rates of water consumption from 1993 to 2002 would be lower than the lower-bound projection of the 1987 Water Demand Forecast, based on which the minimum annual supply quantities from the DWSS were determined. However, when a low forecasted growth rate was noted in 1993 and 1994, the WSD did not request a reduction in the annual supply quantities from Guangdong Province. Audit considers that earlier action should have been taken to renegotiate with the Guangdong Authority for a reduction of the annual supply quantities in order to minimise the potential overflow.

2.37 Audit also observed that the WSD stopped drawing excess Dongjiang water in 1997. However, the WSD did not do so in 1998. Audit considers that such a measure should have been taken to conserve water and to save some $4 million of electricity cost.

Note 13: ***The WSD informed ExCo in July 1992 that overflow from Plover Cove Reservoir into the sea would be "an expensive waste" if rainfall was normal for the rest of the year and Dongjiang water was supplied as agreed.***

Note 14: *Among the water supply agreements since 1960, the 1989 Water Supply Agreement was the one which fixed the annual supply quantities for the longest period i.e. 1995 to 2008 (see Note of Appendix A).*

Audit recommendations on quantity of water supply from Guangdong Province

2.38 **Audit has *recommended* that the Administration should**:

- **formulate a strategy for planning water supply so as to reduce the overflow from reservoirs. The strategy should aim at minimising temporary excess supply (e.g. by re-scheduling shut-down periods of the DWSS to the beginning of the rainy season and adjusting the rate of supply);**

- **incorporate greater flexibility into future water supply agreements so that the quantity can be adjusted according to changing circumstances (e.g. by providing a lower basic annual minimum intake quantity and a higher quantity of optional increase);**

- **continue to negotiate with the Guangdong Authority with a view to reducing the annual water supply quantities fixed in the 1998 Loan Agreement, taking into account the storage level of reservoirs, the forecasted quantity of water consumption and the need to reduce reservoir overflow;**

- **for the quantity of Dongjiang water which the Administration decides not to draw, continue to negotiate with the Guangdong Authority the possibilities of:**

  (i) **not charging for the undrawn water; or**

  (ii) **charging the undrawn water at a reduced rate; and**

- **monitor closely the reservoir storage level and proactively stop drawing unneeded Dongjiang water if it is expected that water would overflow from the reservoirs. In doing so, water will be conserved, the electricity cost of pumping Dongjiang water will be saved and more use will be made of the water of local origin which has a better quality.**

Response from the Administration

2.39 The **Secretary for Works** agrees with the audit recommendation that, despite the strong resistance from the Guangdong Authority on the reduction of supply quantities, the Government should continue to pursue the issue. He has said that the subject of charging Dongjiang water not drawn by Hong Kong at a reduced rate has been explored but was rejected by the Guangdong

Authority at the July 1999 Business Meeting. He agrees with the audit recommendation that the Government should continue to explore such possibility and try to incorporate flexibility into water supply quantities when negotiating for future water supply agreements. Notwithstanding the fact that the term "excessive" depends very much on the weather, he also agrees with the audit recommendation that the Government should consider stop drawing "excessive" water if it will not impose excessive risk of inadequate supply to the consumers. He has also said that:

— in the past few years, the Government has tried very hard each time to negotiate with the Guangdong Authority for a reduction in the supply quantity. The Guangdong Authority declared clearly that the 1989 Water Supply Agreement was signed between the two Governments with an agreed supply quantity and should be respected. No agreement on a reduction of supply quantity could be reached because of the persistent resistance from the Guangdong Authority; and

— an opportunity arose in 1997 when the Government negotiated a loan agreement with the Guangdong Authority to help finance the construction of the closed aqueduct project. After tough negotiations, in the 1998 Loan Agreement the Guangdong Authority accepted an annual reduction of 20 MCM of supply quantity from 1998 to 2004. The Guangdong Authority also agreed to review the supply quantities in 2004 taking into account Hong Kong's future demand.

2.40 The **Director of Water Supplies** agrees to look at all the audit recommendations positively with a view to taking them on board as far as practicable. He has also said that:

(a) given Hong Kong's limited natural water resources, water rationing was more the rule than exception in the 1960s. In an attempt to sustain the development and growth of Hong Kong, the Government has been purchasing water from Guangdong Province as a solution. Thus, water from Guangdong Province has made a vital contribution towards Hong Kong's growth and prosperity in the last few decades;

(b) the quantity of water to be purchased has always been subject to prudent considerations. Having regard to social, economical and other pertinent factors, the Government has adopted a prudent and responsible approach in water resources planning. In respect of rainfall, a target has been set to secure a quantity of supply to enable provision of full (24-hour) supply with the worst drought scenario on available records, i.e. a drought of 1 in 100 years;

(c) in forecasting future water demand, which is highly changeable, the WSD has had to adopt a conservative yet responsible approach. While paying more attention to avoid erring on the side of shortages, the WSD normally adopts lower-bound demand forecasts whenever a trend could be established. Adopting conservative supply strategies

necessarily means that the WSD is accepting that, when natural yield is abundant and/or when demand growth falters significantly, overflow from reservoirs will be an accepted common phenomenon. It is a price that the WSD has, albeit implicitly, considered and accepted to sustain the territory's growth and prosperity without unacceptable disruption;

(d) by virtue of its erratic nature, unpredictability in occurrence and uneven distribution, rainfall is the dominant factor governing reservoir overflow. Focusing primarily on the consumption side (demand forecasts) without adequate recognition of the very high rainfall out-turn and its very erratic and uneven distribution from 1992 to 1998 would present an unbalanced view of the reservoir overflow issue;

(e) limitations of the reservoir system also have a significant effect on the issue of reservoir overflow. For instance, even in relatively dry years, some old reservoirs can easily overflow after heavy rainstorms because of their smaller capacity. Besides, given a finite storage capacity against a growing demand, the need to maintain a high storage level to tide over dry periods, and the annual shutdowns of supply from Guangdong Province, the WSD is increasingly left with little room to manoeuvre reservoir operations;

(f) the estimated costs of reservoir overflow in money terms are notional losses as they do not represent a real financial loss of the amounts stated. The excess rain water and possibly also some Dongjiang water will likely overflow when reservoirs are full; and

(g) the terms of the agreements with the Guangdong Authority were made through negotiations and discussions. In case of differences, both sides came to a compromise before an agreement could be reached. The agreement terms and agreed water prices go "hand in hand" as a package. Suggested deletion, addition or alteration of any of the terms by one side will, apart from being subject to the agreement of the other party, likely attract a different (higher) water price. Thus punitive clauses or the like to provide an absolute right for Hong Kong to refuse taking in water to avoid overflow or to reject substandard water may or may not work to Hong Kong's advantage. If the agreement had made provisions for variation in supply quantities at Hong Kong's will or penalty for variation in quality, the water prices could have been higher because the Guangdong Authority would naturally take the impact of such provisions into account in their pricing strategy.

PART 3: QUALITY OF RAW WATER FROM DONGJIANG

Water quality standard applicable to Dongjiang water

3.1 As mentioned in the third inset of paragraph 1.6 above, in September 1983, the Mainland published the 1983 Standard which took effect from 1 January 1984. In April 1988, the Mainland published the 1988 Standard which replaced the one issued in 1983 (see the second inset of paragraph 1.8 above). The 1988 Standard, which was effective from 1 June 1988, is still currently being used in the Mainland. Limiting values set in the 1988 Standard are more stringent than those of the 1983 Standard. Two operationally significant parameters, namely un-ionised ammonia and total manganese which affect the dosage of chlorine to be used for treating water (not found in the 1983 Standard), have been included in the 1988 Standard. A comparison of the two Standards is shown in Appendix G. Because Dongjiang water is for human consumption, its quality is expected to comply with the parameters of Type II surface water of the 1988 Standard (Note 15).

3.2 ***The 1988 Standard is internationally comparable.*** In 1989, the WSD compared the 1988 Standard with other international standards of surface water, such as those of the Council Directive of the European Communities. The international standards selected for comparison lay down the required quality of surface water that could be used for drinking. The WSD's comparison indicated that the 1988 Standard was comparable to other international standards.

The 1983 Standard stipulated in the 1989 Water Supply Agreement

3.3 In 1989, during the negotiation with the Guangdong Authority on the terms of the 1989 Water Supply Agreement, the Government proposed that the 1988 Standard plus some additional parameters on organic compounds and pesticides should be included in the agreement. However, the Guangdong Authority said that the 1988 Standard had not yet been adopted by Guangdong Province. The Guangdong Authority did not agree to include the 1988 Standard in the Agreement because it had adopted the 1983 Standard for the quality of Dongjiang water and also because the dilution effect of the increased flow volume from the enlarged DWSS would improve the water quality. As a result, the 1989 Water Supply Agreement stated that the water supplied to Hong Kong should meet the water quality standard of Guangdong Province currently in force and should not be inferior to the 1983 Standard.

The 1983 Standard stipulated in the 1998 Loan Agreement

3.4 For the 1998 Loan Agreement signed in July 1998 (see paragraph 1.8 above), there was again no stipulation that the quality of Dongjiang water should comply with the 1988 Standard, despite the fact that the 1988 Standard has been in force for eleven years. The 1998 Loan Agreement stated that the water quality provision of the 1989 Water Supply Agreement should

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Note 15: *The Mainland's 1988 Environmental Quality Standard for Surface Water classifies surface water into five types according to the purpose for which it is used and the target to which protection is given. Type II refers to "Water in Class I protection areas, which are sources of centralised potable water supplies, and in precious fish sanctuaries, fish and shrimp spawning grounds, etc.".*

continue to apply, i.e. the quality of Dongjiang water should not be inferior to the 1983 Standard. However, according to a clause of the Loan Agreement, the Guangdong Authority only agreed to strive to improve the quality of Dongjiang water to the 1988 Standard after the completion of the closed aqueduct project (see paragraph 3.19 below). If the quality of water supplied to Hong Kong falls below the Standard specified in the clause, the Guangdong Authority will take remedial action. If requested by Hong Kong, the supply quantity can be reduced appropriately but the reduction in the supply quantity has to be recouped later in that year.

Deteriorating quality of Dongjiang water

3.5 For some years after 1965, the quality of Dongjiang water had been generally satisfactory. However, in recent years, the quality of Dongjiang water has been deteriorating due to rapid industrial and urban development in the DWSS drainage basin and along Dongjiang.

3.6 To ascertain whether the quality of Dongjiang water complied with the 1983 Standard and the current 1988 Standard, Audit analysed water quality test data collected by the WSD at the Muk Wu Pumping Stations from 1989 to 1998 (Note 16). Audit selected five parameters, namely dissolved oxygen, total phosphorus, total nitrogen, total manganese and pH (Note 17), for analysis (Appendix H refers).

Failure to comply with the 1983 Standard stipulated in the 1989 Water Supply Agreement

3.7 ***Failure to comply with the 1983 Standard.*** Audit's analyses in Table 2 below revealed that the raw water from Dongjiang, in general, failed to comply with some of the key parameters of the 1983 Standard. For dissolved oxygen, total phosphorus, total nitrogen and pH, some of the test data showed that, from 1989 to 1998, the water quality did not comply with the 1983 Standard as follows:

— ***Dissolved oxygen.*** On average, 62% of the test data showed that the water quality did not comply with the 1983 Standard. In 1997 and 1998, the test data showed that Dongjiang water was almost depleted of dissolved oxygen;

— ***Total phosphorus.*** On average, 12% of the test data showed that the water quality did not comply with the 1983 Standard;

— ***Total nitrogen.*** On average, 83% of the test data showed that the water quality did not comply with the 1983 Standard. Nitrogen concentration in Dongjiang water exceeded the 1983 Standard by as much as five times in 1998; and

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Note 16: *The test data are obtained from the Water Science Division of the WSD.*

Note 17: *pH is the concentration of hydrogen ion in a solution that measures its acidity and alkalinity.*

— ***pH.*** On average, 2% of the test data showed that the water quality did not comply with the 1983 Standard.

Table 2

Percentage of test data of Dongjiang water NOT complying with the 1983 and 1988 Standards from 1989 to 1998

	Percentage of non-compliance				
	1983 and 1988 Standards			1983 Standard	1988 Standard
Year	**Dissolved oxygen** (Note 1)	**Total phosphorus**	**pH**	**Total nitrogen** (Note 2)	**Total manganese** (Note 3)
1989	32%	0%	0%	50%	1%
1990	32%	0%	0%	55%	0%
1991	30%	0%	0%	50%	6%
1992	61%	0%	0%	79%	9%
1993	51%	0%	2%	100%	34%
1994	65%	5%	2%	100%	69%
1995	89%	5%	7%	99%	60%
1996	80%	0%	6%	100%	67%
1997	83%	42%	0%	100%	76%
1998	94%	67%	0%	100%	79%
Average	**62%**	**12%**	**2%**	**83%**	**40%**

Source: Audit analyses of the WSD's records

Note 1: The test data showed that the Dongjiang water was almost depleted of dissolved oxygen in 1997 and 1998.

Note 2: Total nitrogen is not a parameter in the 1988 Standard. Its concentration in Dongjiang water exceeded the 1983 Standard by as much as five times in September 1998.

Note 3: Total manganese is not a parameter in the 1983 Standard. Its concentration in Dongjiang water exceeded the 1988 Standard by as much as eight times in September 1995.

Non-compliance of the quality of Dongjiang water with the 1988 Standard

3.8 Audit also compared the water quality test data of Dongjiang water with the 1988 Standard from 1989 to 1998. As dissolved oxygen, total phosphorus and pH of both the 1983 Standard and the 1988 Standard have the same limiting values, the extent of non-compliance of these parameters with the 1983 Standard and the 1988 Standard are the same. Total nitrogen is not a parameter of the 1988 Standard (Note 18).

3.9 ***Percentage of test data not complying with the 1988 Standard.*** Audit also selected for analysis an additional key raw water quality parameter of the 1988 Standard, namely total manganese, which was not included in the 1983 Standard. **As indicated in Table 2 above, from 1989 to 1998, on average, 40% of the test data showed that the total manganese did not comply with the 1988 Standard.** Audit's analysis also revealed that, in September 1995, the concentration of total manganese exceeded the 1988 Standard by as much as eight times.

3.10 ***Ammoniacal nitrogen.*** Ammoniacal nitrogen in water is an indicator of possible contamination by bacteria, sewage and animal waste. It has to be removed before the water is treated. The ammoniacal nitrogen level in Dongjiang water has been one of the major issues discussed between the Government and the Guangdong Authority. In the WSD's consultancy study on the quality of Dongjiang water (see paragraph 3.11 below), the WSD's consultant used ammoniacal nitrogen as a parameter to measure the ammonia content of Dongjiang water. Audit therefore also selected ammoniacal nitrogen for analysis. Since both the 1983 and 1988 Standards do not include ammoniacal nitrogen as a parameter (Note 19), Audit used the ammoniacal nitrogen standard of the Guangdong Province's water quality control index values as a benchmark for comparison (Note 20). Audit's analysis revealed that from 1989 to 1998, on average, 49% of the test data showed that the ammoniacal nitrogen in the water exceeded the index value. In March 1998, the ammoniacal nitrogen level exceeded the index value by as much as seven times.

WSD's consultant confirmed the substandard quality of Dongjiang water

3.11 In 1995, the WSD commissioned a consultant to study the deteriorating quality of Dongjiang water. The consultant collected water quality data from laboratory testing of water samples taken from various strategic locations along the DWSS. The consultant used the parameters of the 1983 Standard, the 1988 Standard and the Guangdong Province's water quality

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Note 18: *Total nitrogen is the sum of the nitrogen in ammonia, nitrite, nitrate and other organic compounds. The 1988 Standard does not stipulate total nitrogen because separate standards with limiting values are set for un-ionised ammonia, nitrite and nitrate.*

Note 19: *Both un-ionised ammonia and ammoniacal nitrogen are indicators of sewage and industrial contamination. The WSD only measures the ammoniacal nitrogen in Dongjiang water as it is easier to measure.*

Note 20: *The WSD consultant also used this standard as the benchmark for comparison in its consultancy on the quality of Dongjiang water.*

control index values for evaluating the quality of Dongjiang water. In April 1996, the consultant reported the following findings:

— ***Substandard quality of Dongjiang water.*** Most of the samples showed that the levels of chemical oxygen demand, total phosphorus, total manganese and ammoniacal nitrogen were higher than the limiting values set by the Mainland's regulatory authorities;

— ***Sources of ammoniacal and manganese contamination.*** The discharge of untreated sewage and industrial waste water in the DWSS basin was the main source of ammoniacal contamination. In addition, the suspended solids of untreated sewage and industrial wastes settled to the bottom of the water channels and reservoirs. They built up a bottom layer of nutrients which would undergo anaerobic digestion in the absence of oxygen. Under anaerobic conditions, the insoluble manganese in the soil was released as soluble manganese into the water; and

— ***Future quality of Dongjiang water.*** The consultant concluded that the quality of the raw water supplied by the DWSS would continue to deteriorate. The entire DWSS drainage basin was urbanised with on-going residential, commercial and industrial development. There was little control over domestic and commercial discharge of waste water. The capability of commissioned and planned waste water treatment works would be inadequate to remove nutrients, such as nitrogen and phosphorus, from the waste water.

3.12 ***The consultant's recommendations.*** The consultant recommended, among others, that the WSD should:

— negotiate with the Guangdong Authority with a view to setting up a programme and appointing an independent party to monitor the water quality along the DWSS;

— carry out testing of total organic carbon and dissolved organic carbon at the Muk Wu Pumping Stations; and

— consider the possibility of negotiating for a second source of water supply.

3.13 ***Comments from the WSD.*** Regarding the consultant's recommendations, the WSD said that:

— the recommendation for monitoring the quality of Dongjiang water seemed worthy of pursuing as this would not physically affect the water treatment works; and

— however, detailed planning would be required before the WSD could determine a second source of water supply, because this could affect the water supply strategy.

Remedial measures taken by Guangdong Province

3.14 ***Measures to improve the quality of Dongjiang water.*** Earlier, in 1993, the Government raised its concern over the deteriorating quality of Dongjiang water to the Guangdong Authority at the annual business meetings and at the Operation and Management Technical Sub-group meetings (Note 21). In response, the Guangdong Authority said that the following measures had been taken:

— improvement in law enforcement and education on protecting the quality of Dongjiang water;

— improvement in the planning and design of measures for protecting the river;

— faster expansion of sewage treatment plants and of the sewage disposal system;

— improvement in the water supply and operating arrangements; and

— introduction of measures to enhance the quality of Dongjiang water.

3.15 In addition to the above remedial measures, the Guangdong Authority also agreed to temporarily adjust the daily supply quantity when the water quality was beyond the capability of the water treatment works in Hong Kong. This measure would enable the WSD to blend and dilute Dongjiang water with more water from the local reservoirs before treatment.

3.16 ***Construction of a closed aqueduct.*** Subsequently, at the annual business meeting held in May 1997, the Guangdong Authority said that the quality of Dongjiang water was deteriorating and was a growing problem. Due to serious pollution along the DWSS, which was an open water channel, the Guangdong Authority planned to construct a closed aqueduct and sought financial assistance from the Government (see paragraph 1.7 above).

No remedial clause for non-compliance with water quality standard in the water supply agreements

3.17 On 3 June 1997, ExCo was informed of the outcome of the May 1997 annual business meeting. Concern was raised over the issue of legal remedy if the Guangdong Authority failed to supply water of the agreed standard. **The Secretary of Justice said that, in the next agreement, an effective and independent dispute resolution clause (Note 22) should be included.** In response to the Secretary for Works' enquiry, the Department of Justice said that:

Note 21: *According to the 1989 Water Supply Agreement, the Operation and Management Technical Sub-group has to meet not less than twice a year.*

Note 22: *The 1989 Water Supply Agreement did not contain any explicit provisions about the rights or obligations of a party in the event of non-compliance of the agreement by the other party.*

— given the nature of the 1989 Water Supply Agreement, it would seem that there was very little that the Government could do by way of legal remedy if the Guangdong Authority failed to supply water of the agreed standard;

— a clause of the Agreement which allowed consultations at meetings of the Water Quality Sub-group would be the only prospect of bringing the water quality problem to the attention of the Guangdong Authority; and

— when the Agreement was due for a review, the Government might have to consider putting in an arbitral process for dispute resolution and a penalty clause to ensure that commitments would be honoured.

3.18 In February 1998, when drafting the 1998 Loan Agreement, the Government proposed a clause which stated that any differences in opinion concerning the execution of the agreement would be settled through mediation by a mutually acceptable third party. However, the Government did not succeed in including the proposed clause into the Loan Agreement.

3.19 **In July 1998, the 1998 Loan Agreement was signed without the inclusion of any dispute resolution or penal clause.** There was no specific provision in the Loan Agreement that the quality of Dongjiang Water would be up to the 1988 Standard. The Loan Agreement only contained a clause which said that the Guangdong Authority would strive to improve the quality of Dongjiang water up to the 1988 Standard after the completion of the closed aqueduct project in 2002.

Additional treatment costs due to the substandard quality of Dongjiang water

3.20 ***Remedial measures taken by the WSD.*** In principle, the better the quality of the raw water, the easier and cheaper it is to treat it. In May 1993, in the light of the deteriorating quality of Dongjiang water, the WSD held a special meeting to tackle the problem and decided:

— to provide an aeration plant at the Muk Wu Pumping Stations. Photograph 1 on the centre pages shows the operation of the aeration plant in the reception culvert of the Muk Wu Pumping Stations;

— to upgrade the pre-chlorination equipment in some water treatment works. Photograph 2 on the centre pages shows the pre-treatment process at the water inlet of the Sha Tin Water Treatment Works (STWTW); and

— to transfer some raw water to the impounding reservoirs for blending prior to pumping it to the water treatment works.

3.21 To implement the above measures, the WSD incurred additional costs, such as the cost of chemicals and electricity, and capital costs. Details are given in paragraphs 3.22 to 3.26 below.

WSD's estimation of additional recurrent costs incurred in 1996-97

3.22 In mid-1997, the WSD estimated that, in 1996-97, an additional recurrent cost of $33 million was incurred for treating Dongjiang water. The WSD took the following factors into account in estimating the additional cost:

— 1992-93 was used as the base year for assessing the increase in the cost of chemicals. (This was because the dosage of chemicals used annually for water treatment for the years before 1993-94 was about the same);

— since late 1993, a large portion of Dongjiang water had been pumped to and blended with the water in the Plover Cove Reservoir. The blended water was then pumped back to the STWTW. Additional electricity cost had been incurred because of the additional pumping operations; and

— additional costs had been incurred to operate the aeration plant installed at the Muk Wu Pumping Stations for pumping oxygen into the Dongjiang raw water.

Audit's estimation of additional recurrent costs in 1997-98 and 1998-99

3.23 Using the same bases of the WSD's estimation, Audit estimated that additional costs of $34 million and $37 million were incurred in 1997-98 and 1998-99 respectively due to the substandard quality of Dongjiang water. Appendix I is a summary of these additional recurrent costs.

Additional capital costs for upgrading the water treatment works

3.24 The WSD also incurred additional capital costs for the provision of an aeration plant at the Muk Wu Pumping Stations and for upgrading the pre-chlorination equipment in various water treatment works. Audit estimated that the additional capital costs incurred from 1994-95 to 1998-99 were $35 million.

Multiple-stage water treatment process for new plants

3.25 To cater for the substandard quality of Dongjiang water, a multiple-stage water treatment process has been designed for the following two new water treatment works (Note 23):

— ***Ngau Tam Mei Water Treatment Works.*** In the design and construction of the Ngau Tam Mei Water Treatment Works, a multiple-stage water treatment process, which involves two ozonation stages and a biofiltration treatment stage, will be adopted; and

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Note 23: *The Ngau Tam Mei Water Treatment Works and the Tai Po Water Treatment Works will be opened in late 1999 and early 2002 respectively.*

— ***Tai Po Water Treatment Works.*** In the design and construction of the new Tai Po Water Treatment Works, a multiple-stage water treatment process, which includes a clarification stage, a primary aerated biological filtration stage (for removing ammonia and manganese) and a secondary biological filtration stage, will be adopted.

3.26 The capital costs of constructing the multiple-stage water treatment works are higher than those of constructing the conventional water treatment works (e.g. the STWTW). The use of a multiple-stage water treatment process has resulted in high capital costs for building the two new water treatment works.

Recent measures to improve the quality of Dongjiang water before it reaches Hong Kong

3.27 Since the trial running of a biological nitrification plant for Dongjiang water in Shenzhen in December 1998, the quality of Dongjiang water had somewhat improved. For the first six months of 1999, the average level of ammoniacal nitrogen in Dongjiang water decreased, although it still exceeded the relevant Guangdong Province's water quality control index values (see paragraph 3.10 above). During the same period, the levels of manganese and dissolved oxygen in Dongjiang water also decreased. However, the level of dissolved oxygen in Dongjiang water still failed to comply with the stipulated quality standard, i.e. the 1983 Standard.

Monitoring of the quality of Dongjiang water

3.28 According to the WSD's record, the Guangdong Authority carries out water quality tests on a monthly basis (Note 24). The frequency of testing will be increased if abnormal test results are observed.

3.29 ***WSD's practice of monitoring the quality of Dongjiang water.*** The WSD monitors the quality of Dongjiang water at the Muk Wu Pumping Stations and at the water inlets of the various water treatment works. Water quality tests for certain significant quality parameters, such as ammoniacal nitrogen, total manganese and pH, are carried out at least daily. Other parameters, such as dissolved oxygen and total phosphorus, are monitored on a weekly basis or at a less frequent interval. The WSD will increase the frequency of testing if there is a significant change in the quality of Dongjiang water.

3.30 ***Consultant's recommendation.*** As mentioned in paragraph 3.11 above, the WSD's consultant considered that the quality of Dongjiang water would continue to deteriorate because of pollution. The consultant recommended that the WSD should carry out tests on water samples in respect of total organic carbon and dissolved organic carbon. The WSD considers that the recommendation is worth pursuing.

Note 24: *Information on the number of parameters monitored by the Guangdong Authority is not available.*

Discrepancies in the testing results

3.31 The Guangdong Authority would carry out additional testing of Dongjiang water only if the WSD's test results indicated an abnormal change in water quality. However, the results of the Guangdong Authority's testing were usually not the same as those of the WSD.

3.32 In 1993, the WSD's test results showed that the quality of Dongjiang water failed to comply with the 1983 Standard (see paragraph 3.7 above). However, at the business meeting held in July 1993, the Guangdong Authority said that, according to their test results, the quality of Dongjiang water was in line with the 1983 Standard. The discrepancies in the test results between the two parties could occur because the location and the time of taking the samples were different.

Exchange of water quality data

3.33 Before 1994, there was no exchange of water quality data between the WSD and the Guangdong Authority. In July 1994, the Guangdong Authority agreed to increase the testing frequency of ammoniacal nitrogen to once a day, and to exchange the test results with the WSD weekly. Since July 1995, the WSD has obtained the test results of six parameters of the 1983 Standard and ten parameters of the 1988 Standard from the Guangdong Authority (Note 25).

3.34 ***Specific clause in 1998 Loan Agreement.*** The 1998 Loan Agreement provided that both parties would continue to exchange water quality data and that the procedure for monitoring the technical details would be subject to further negotiations by the Operation and Management Technical Sub-group.

Audit observations on raw water quality of Dongjiang water

Raw water quality standards

3.35 ***1989 Water Supply Agreement.*** As mentioned in paragraphs 3.1 and 3.2 above, in the Mainland, the 1988 Standard, which is more comprehensive and internationally comparable, has replaced the 1983 Standard. The 1988 Standard includes two key water quality parameters which were not found in the 1983 Standard, namely un-ionised ammonia and total manganese. **Audit observed that, although the 1989 Water Supply Agreement was signed in December 1989, no agreement had been reached to include a provision in that Agreement which would require the supplier to comply with the 1988 Standard. The 1989 Water Supply Agreement only provided that the water would meet the water quality standard of Guangdong Province currently in force and would not be inferior to the 1983 Standard. It did not explicitly specify that the quality of Dongjiang water should meet the 1988 Standard which is comparable to other international standards (see Note 15 of paragraph 3.1 above).**

Note 25: *The six parameters in the 1983 Standard are dissolved oxygen, phosphorus, biochemical oxygen demand, total nitrogen, pH and temperature. In addition to these parameters (other than total nitrogen which is not a parameter of the 1988 Standard), five other parameters, viz. nitrite, nitrate, chlorides, iron and total manganese, are also provided to the WSD.*

3.36 ***1998 Loan Agreement.*** When the 1998 Loan Agreement was concluded in July 1998, again no agreement was reached to include a provision which would require the supplier to ensure that the quality of Dongjiang water would comply with the 1988 Standard, notwithstanding that the 1988 Standard had already been in use in the Mainland for eleven years. **The 1998 Loan Agreement only provided that the Guangdong Authority would strive to attain the 1988 Standard. Audit considers that this provision, as well as the provision in the 1989 Water Supply Agreement, is unsatisfactory because there is no specific provision in the form of an enforceable contract which requires the supplier to ensure that the quality of Dongjiang water will comply with the 1988 Standard.**

Substandard quality of Dongjiang water

3.37 ***The quality of Dongjiang water failed to comply with promulgated Standards.*** Audit observed that the quality of Dongjiang water did not fully comply with the Mainland's quality standards for surface water. Three key water quality parameters (i.e. dissolved oxygen, total phosphorus and total nitrogen) out of four parameters selected for audit analysis did not comply with the 1983 Standard. Three parameters (i.e. dissolved oxygen, total phosphorus and total manganese) did not meet the 1988 Standard. For ammoniacal nitrogen, the quality of Dongjiang water could not meet the requirement of the Guangdong Province's quality control index values. Moreover, the WSD's consultant has indicated that the quality of Dongjiang water will further deteriorate. Although the construction of the closed aqueduct may improve the quality of Dongjiang water to some extent, there is no specific provision in the 1998 Loan Agreement that Dongjiang water would meet the 1988 Standard.

3.38 ***Absence of a remedial clause in the agreements.*** **Audit observed that both the 1989 Water Supply Agreement and the 1998 Loan Agreement did not contain a dispute resolution clause and a provision for penalty or compensation in case of non-compliance with the terms of the agreements by either party, despite the fact that this had been suggested by the Secretary for Justice.** There is no legal remedy if the water supplied does not meet the stipulated quality standard.

3.39 ***Additional water treatment costs.*** The WSD has undertaken a number of remedial measures to tackle the substandard quality of Dongjiang water. Additional recurrent costs of $104 million ($33 million+$34 million+$37 million — see paragraphs 3.22 and 3.23 above) were incurred for the years 1996-97 to 1998-99. To upgrade the water treatment works, capital costs of $35 million had been incurred.

3.40 **The increase in chlorine dosage to treat water has also resulted in an increase in the formation of Trihalomethanes (THMs) in the treated water (Note 26) (see paragraph 4.7 below).** The higher the level of chlorine dosage, the greater the potential of the formation of

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Note 26: *Two members of the THM group of chemicals (i.e. chloroform and bromodichloromethane) are classified by the World Health Organisation as "in Group 2B", meaning that they are "possibly carcinogenic to human". The other two members of the THM group of chemicals (i.e. dibromochloromethane and bromoform) are classified as "in Group 3", meaning that they are "not classifiable as to their carcinogenicity to human".*

THMs. Therefore, Audit considers that there is a need to continue to monitor the trend of THMs in the treated water.

Monitoring of raw water quality

3.41 Audit observed that there was no agreed mechanism between the WSD and the Guangdong Authority for monitoring and reporting of the quality of Dongjiang water. Water quality tests were separately carried out at different frequencies and locations by both parties. **Audit believes that the presence of an agreed mechanism for reconciling the test results, and the existence of an accredited independent testing and reporting system will help resolve differences and disagreement between both parties.**

Audit recommendations on raw water quality of Dongjiang water

3.42 **Audit has *recommended* that**:

Raw water quality standard

(a) **the Administration should continue to negotiate with the Guangdong Authority with a view to stipulating in future water supply agreements a requirement that all water supplied to Hong Kong should comply with the 1988 Standard which is currently in force. This will ensure that the quality of raw water supplied to Hong Kong will comply with the current standard of surface water suitable for human consumption;**

Substandard quality of Dongjiang water

(b) **the Administration should consider the inclusion of a remedial clause in future water supply agreements which will state explicitly the rights of a party if the other party does not comply with the terms stipulated in the agreements, particularly those concerning water quality;**

(c) **in the negotiation with the Guangdong Authority to enable Hong Kong to draw less than the agreed quantity of Dongjiang water, the Administration should take into account the additional treatment costs to be incurred by the WSD in the treatment of substandard Dongjiang water;**

(d) **the Director of Water Supplies should continue to monitor closely the quality of Dongjiang water and urge the Guangdong Authority to continue stepping up efforts to control water pollution along the DWSS and Dongjiang so as to improve the quality of Dongjiang water;**

(e) **the Director of Water Supplies should explore other better sources of water supply if the quality of Dongjiang water continues to deteriorate;**

(f) **the Director of Water Supplies should continue to monitor closely the use of chlorine in treating Dongjiang water and the presence of carcinogenic substances to ensure that the treated water will continue to comply with the 1993 WHO health-related guidelines (see paragraph 4.7 below);**

Monitoring of raw water quality

(g) **the Director of Water Supplies should continue to negotiate with the Guangdong Authority a mechanism which will specify the number of parameters to be tested, the method of analysing the water quality for the parameters stipulated in the agreement, the scope and frequency of testing, exchange of test results, and the means of reconciliation of test results so as to effectively monitor the quality of Dongjiang water**; **and**

(h) **the Director of Water Supplies should explore with the Guangdong Authority the option of appointing an independent accredited body to monitor and report on the quality of Dongjiang water.**

Response from the Administration

3.43 The **Secretary for Works** agrees with the audit recommendation that the Government should continue to negotiate with the Guangdong Authority with a view to stipulating a requirement in future water supply agreements that water supplied to Hong Kong should comply with the 1988 Standard. He has also said that:

— through various channels and meetings, the Government has urged the Guangdong Authority to step up measures to protect the quality of Dongjiang water. The Government will certainly continue with such efforts; and

— regarding the proposal for the inclusion of a remedial provision for the reduction of the price for substandard Dongjiang water, such a proposal had been rejected persistently by the Guangdong Authority. However, at a recent meeting with the Guangdong Authority in 1999, they reaffirmed their commitment to protecting Dongjiang water which not only serves Hong Kong's six million people but also, even more importantly, serves nearly another 12 million people in Guangdong. Notwithstanding this, the Government will continue to liaise with the Guangdong Authority to improve the quality of Dongjiang water.

3.44 Regarding the monitoring of raw water quality, he also agrees with the audit recommendation that the Government should continue to negotiate with the Guangdong Authority to agree on the method of, and the parameters for, monitoring the quality of Dongjiang water.

3.45 The **Director of Water Supplies** agrees to look at the audit recommendations concerning the quality of Dongjiang water positively with a view to taking them on board as far as practicable.

PART 4: QUALITY OF TREATED WATER

Background

4.1 The WSD has to treat raw water by the addition of suitable chemicals and by filtering out impurities. In general, chlorine is added to remove ammonia and manganese in the pre-chlorination process (Note 27). Alum is added to coagulate the impurities in the water to produce large particles for sedimentation in the clarification stage. Residual impurities are removed by the rapid gravity-filtration process. After filtration, a fluoride compound is added to the water for dental protection. Finally, for disinfection purposes, chlorine is added in the post-chlorination process so as to maintain an adequate level of residual chlorine in the treated water, which is then distributed to consumers. Figure 4 on the centre pages shows a diagram of a typical conventional two-stage water treatment process adopted by the WSD.

Treated water quality standard

4.2 ***WHO Guidelines.*** The WSD adopts the WHO Guidelines for Drinking Water Quality as the quality standard for treated water. This is documented in the WSD's internal instruction. The WHO Guidelines are intended to be used as the basis for the development of national water quality standards (Note 28). The standard, if properly implemented, will ensure the safety of treated water by eliminating, or reducing to a minimum, the health-hazardous impurities. The WHO set health-related guidelines in respect of certain impurities in treated water which had a direct impact on public health. Besides the health-related guidelines, the WHO also set out the levels of certain substances in treated water which may affect its appearance and give rise to complaints from consumers (hereinafter referred to as the aesthetic levels) (Note 29).

4.3 ***Revision of WHO Guidelines.*** In 1984, WHO published the first set of Guidelines for Drinking Water Quality (hereinafter referred to as the 1984 WHO Guidelines). In 1993, this was replaced by a new set of Guidelines for Drinking Water Quality (hereinafter referred to as the 1993 WHO Guidelines). The number of health-related parameters increased from 27 in the 1984 WHO Guidelines to 94 in the 1993 WHO Guidelines. The number of aesthetic parameters also increased from 13 to 25. Appendix J shows some of the 1993 WHO health-related parameters and some aesthetic parameters.

Note 27: *In the pre-chlorination process, chlorine is added to raw water at the inlet of water treatment works before water treatment.*

Note 28: *Some countries, such as Japan and Australia, use the WHO Guidelines as a basis for the development of their national water quality standards. Other countries, such as Singapore, adopt the 1993 WHO Guidelines in full.*

Note 29: *The aesthetic levels are not expressed in precise numbers. Problems may occur at lower or much higher levels, depending on the circumstances. The national drinking water quality standards of the United States of America (USA), Australia and Japan also include aesthetic levels which may affect the acceptability to consumers.*

4.4 ***WSD's Final Treated Water Quality Targets.*** In addition to adopting the WHO Guidelines, the WSD also establishes day-to-day operational targets, called the WSD's Final Treated Water Quality Targets, to monitor the quality of the treated water. The WSD's Final Treated Water Quality Targets are also the required specifications for constructing water treatment works. Except for ten targets separately specified by the WSD, the Final Treated Water Quality Targets were based on WHO Guidelines. Appendix K is a comparison of the 1993 WHO health-related guidelines and aesthetic levels with the WSD's Final Treated Water Quality Targets. As shown in Appendix K, the Targets are in general more stringent than 1993 WHO health-related guidelines and the 1993 WHO aesthetic levels.

Quality of treated water

4.5 To assess the quality of treated water, Audit selected seven health-related parameters and six aesthetic parameters of the treated water to ascertain the extent of compliance with the 1993 WHO Guidelines and the WSD's Final Treated Water Quality Targets. The parameters and their significance are summarised in Appendix L.

Compliance with 1993 WHO health-related guidelines

4.6 Audit analysed the treated water quality testing data from the STWTW from January 1995 to April 1999. Table 3 below is a summary of the results of the audit analyses of the treated water quality testing data in respect of the seven health-related parameters. Audit's analyses revealed that, for the seven health-related parameters, the quality of the treated water complied with the 1993 WHO health-related guidelines.

Table 3

Compliance of treated water quality with the 1993 WHO health-related guidelines from January 1995 to April 1999

Parameter	Compliance with the 1993 WHO health-related guidelines
Arsenic	√
Chromium	√
Mercury	√
Manganese	√
THMs	√
Residual chlorine	√
Benzo(a)pyrene	√

Source: The WSD's records

4.7 ***Increasing presence/concentration of THMs.*** For the treated water leaving the STWTW for the period 1989 to 1998, the THMs were still below the level of the 1993 WHO health-related guidelines. **However, the level of the THMs showed an increasing trend (see Appendix M for details). It seems that the WSD should continue to monitor closely the trend of THMs in view of their harmful effect to health.**

Compliance with 1993 WHO aesthetic levels

4.8 The aesthetic levels have no direct consequences to health. However, in assessing the quality of treated water, consumers will evaluate the quality and the acceptability of treated water on the basis of appearance, odour or taste. It is therefore very important to ensure that the quality of water is acceptable to consumers (Note 30). Audit analysed the treated water quality test data of six parameters, namely turbidity, colour, iron, aluminium, residual chlorine and manganese. Audit's analyses revealed that, of the six parameters analysed, five parameters met the 1993 WHO aesthetic levels from 1996 to 1998. **The only parameter in the treated water which did not fully meet the 1993 WHO aesthetic level was residual chlorine.** The percentages of the test data of residual chlorine which exceeded the WHO aesthetic level were significant. In 1998, 53% of the test data exceeded the WHO aesthetic level (see Appendix N). The failure to comply with the aesthetic level (Note 31) implies that the residual chlorine level in treated water may result in complaints from consumers.

Compliance with the WSD's Final Treated Water Quality Targets

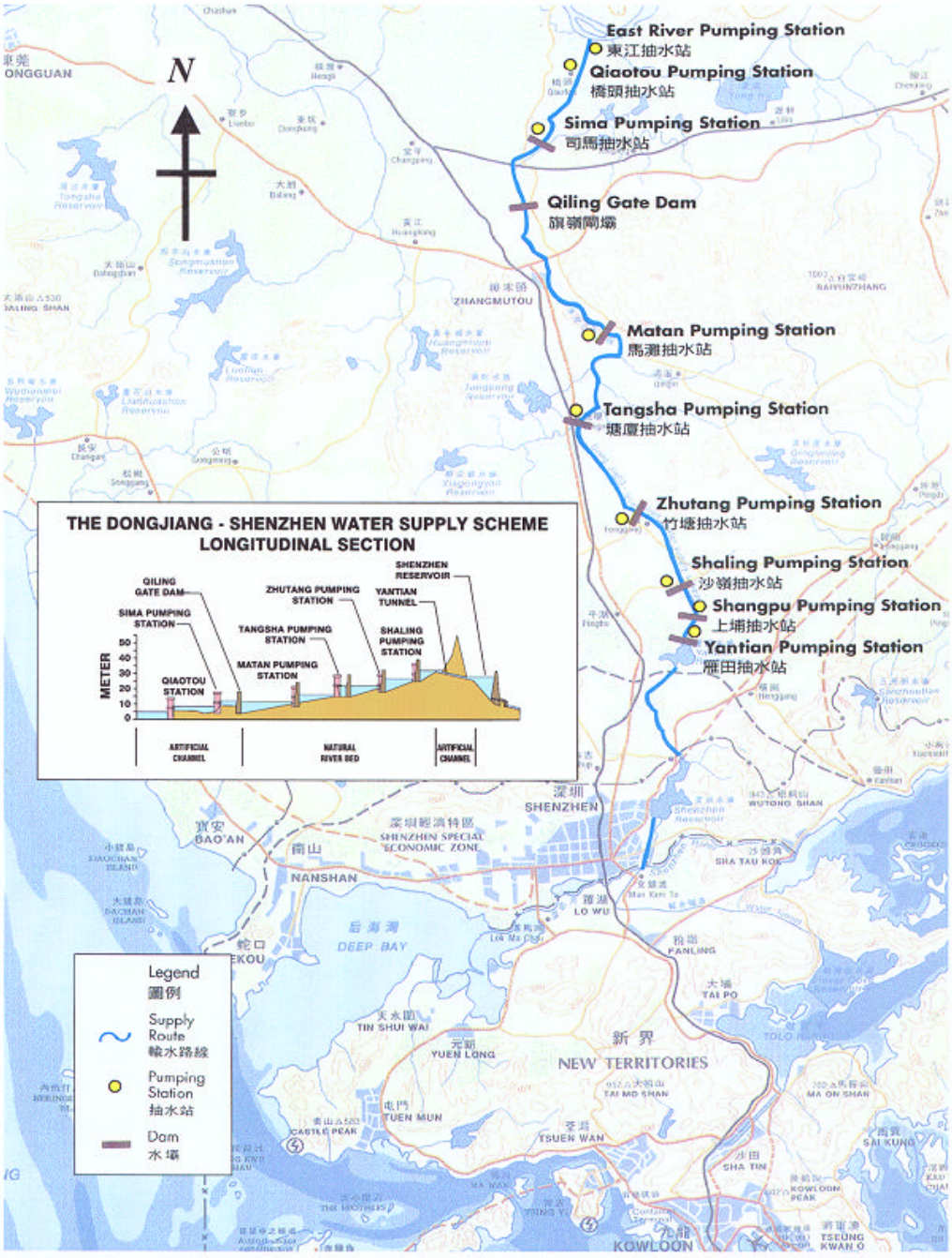
4.9 Audit analysed the treated water quality testing data from the STWTW from January 1995 to April 1999 for the six aesthetic parameters selected from the ten targets separately specified by the WSD as mentioned in paragraph 4.4 above. Audit's analyses revealed that for three parameters, namely colour, iron and manganese, the treated water quality complied with the WSD's Final Treated Water Quality Targets. For the remaining three parameters, namely residual chlorine (Appendix N refers), turbidity (Appendix O refers) and aluminium (Appendix P refers), the treated water quality did not fully comply with the WSD's Targets. However, the percentages of test data failing to comply with the Targets were not significant.

Note 30: *The concentration at which such constituents are offensive to consumers depends on the individual and local factors. Therefore, the WHO considers it inappropriate to set guideline values for substances which affect the acceptability of water to consumers but which are not directly relevant to health.*

Note 31: *The treated water is considered to have failed to comply with the aesthetic level if more than 5% of the test data of residual chlorine exceeds the aesthetic level.*

Figure 1

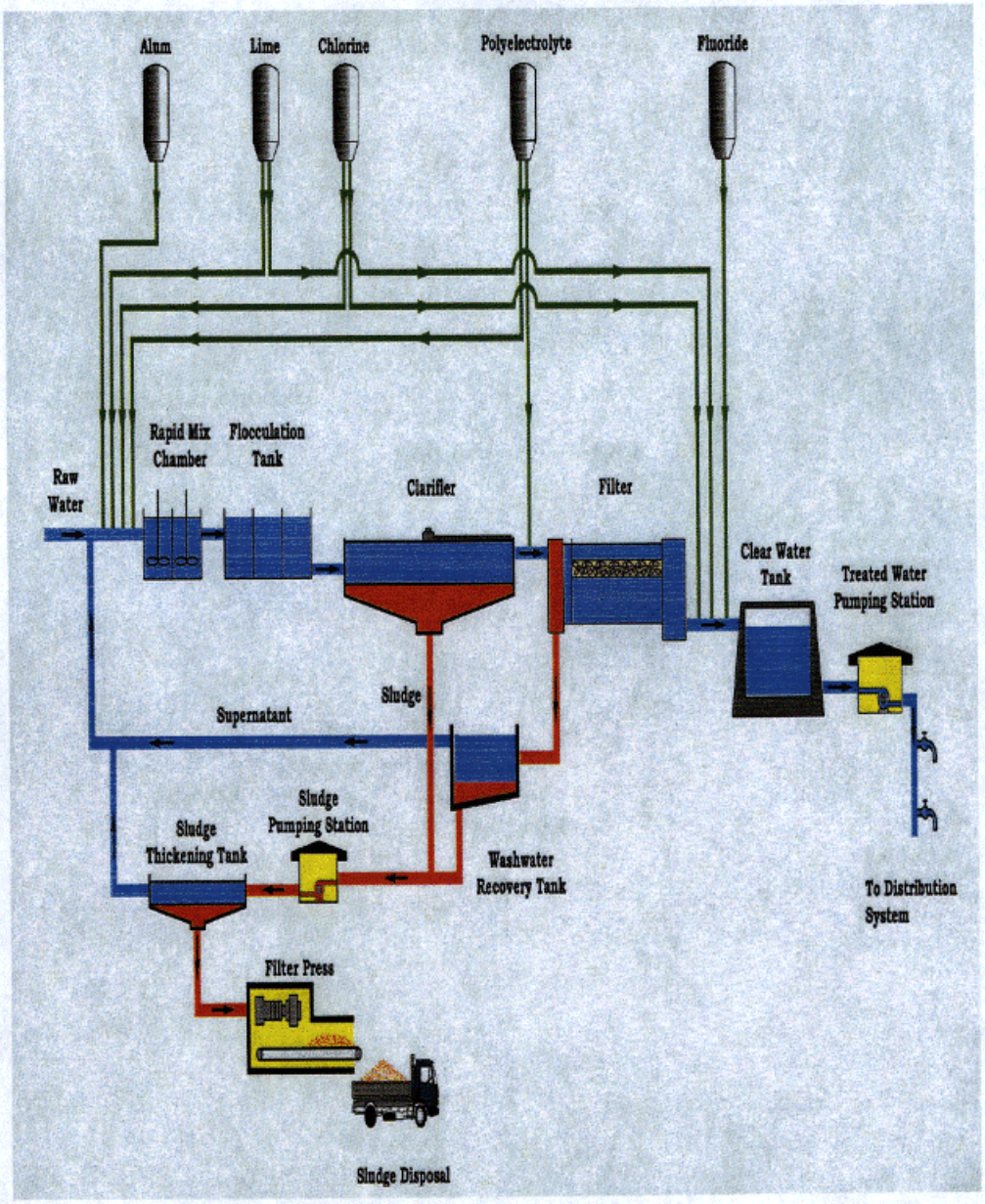
Dongshen Water Supply System (General Layout Plan)



Source: *The WSD's record*

Figure 4

Conventional two-stage water treatment process

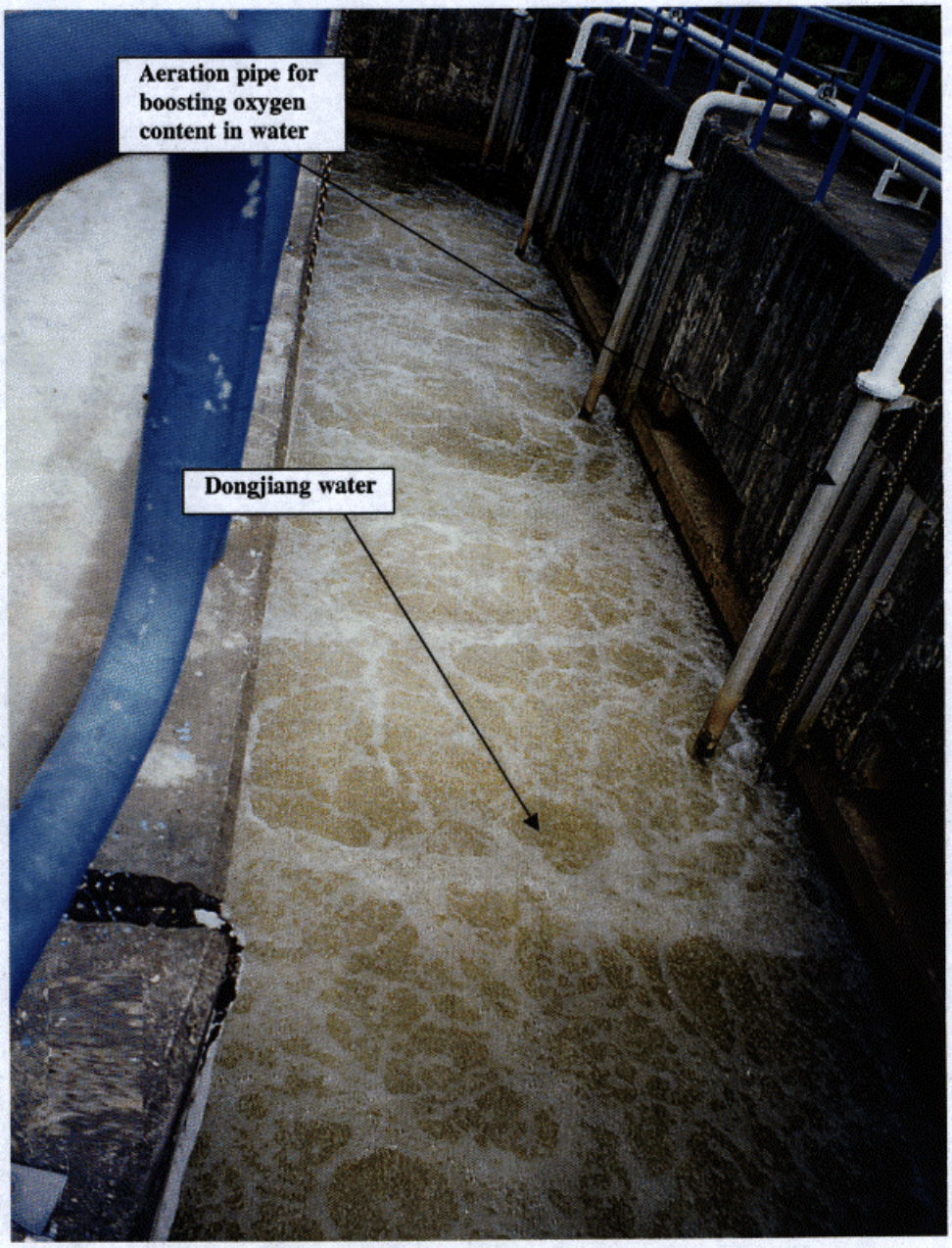


Source: *The WSD's record*

Note: *The STWTW, for example, uses this process to treat water.*

Photograph 1

Aeration plant in the reception culvert at Muk Wu Pumping Stations



Source: *Photograph taken by Audit*

Photograph 2

Pre-treatment process at water inlet of Sha Tin Water Treatment Works

Source: *Photograph taken by Audit*

Note: *Chlorine, lime and alum are added to the raw water for pre-treatment.*

Health surveillance over water-borne parasites

4.10 Recently, there was public concern over the presence of two water-borne parasites, Cryptosporidium and Giardia (Note 32) in the treated water. There are no WHO guidelines in respect of the two parasites. In 1997, the WSD introduced the technique of testing the two water-borne parasites. In 1998, the WSD formulated an action plan to closely monitor the situation. The frequency of sampling was once every three months. Since July 1998, the WSD had increased the frequency of sampling when some of the samples were found to have contained Cryptosporidium and Giardia.

4.11 In April 1999, the WSD participated in the "International Conference on Minimizing the Risk from Cryptosporidium and Other Waterborne Particles" (Note 33) to learn about the latest development. The Conference concluded that there was insufficient information for setting a health-related standard for Cryptosporidium and Giardia in treated water and that the development of a warning and management system for treated water had practical difficulties. However, it was generally agreed that a well-established and rehearsed contingency plan would be needed to cater for possible outbreaks of cryptosporidiosis and giardiasis (Note 34).

Monitoring of treated water quality

Performance pledge

4.12 Since 1993-94, the WSD has made an annual performance pledge setting out, in plain words, the standards of services which the WSD delivers to the public. One of the WSD's performance pledge is that "the water supplied to the consumers at connection points (Note 35) fully complies with the WHO Guidelines". To ensure compliance with the WHO Guidelines, the WSD monitors the quality of treated water throughout the entire water distribution system.

4.13 With the introduction of the 1993 WHO Guidelines, the WSD has set up additional teams to analyse all the health-related parameters of the WHO Guidelines using advanced analytical

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Note 32: *Cryptosporidium and Giardia are pathogenic intestinal parasites found in water contaminated with human or animal wastes. These parasites have caused several large outbreaks of gastro-intestinal illness such as diarrhoea in other parts of the world.*

Note 33: *The conference was co-organised by the International Association on Water Quality, the International Water Services Association, Association Internationale des Services d'Eau and the International Ozone Association.*

Note 34: *Illnesses caused by Cryptosporidium and Giardia are called cryptosporidiosis and giardiasis.*

Note 35: *A connection point is the point where the WSD's water supply system connects to the lot boundary of the consumers' premises. After the connection points, it is the responsibility of the consumers to ensure that the distribution system inside their building will deliver the same quality of water to the individual consumer's tap.*

instruments. In August 1999, the WSD informed Audit that the WSD had been capable of analysing all the health-related parameters of the 1993 WHO Guidelines since June 1999.

Legislation on treated water quality

4.14 The primary objective of setting guidelines for treated water quality is the protection of public health. In certain advanced countries, legislations have been enacted to establish national treated water quality standards. However, in Hong Kong, no legislation has been enacted concerning treated water quality.

4.15 In the USA, the Safe Drinking Water Act was enacted in 1974 to establish national treated water quality standards which specified the maximum admissible levels of contaminants. The potential health effect from ingestion of water containing the contaminants is also set out in the standards. To increase public awareness of the quality of their treated water, water suppliers in the USA are required by the Safe Drinking Water Act to notify the public whether there is any violation of the Act. The water suppliers give consumers an annual report on the quality of treated water. They also issue a consumers' guide to help consumers understand water-related terms.

4.16 In Japan, 46 parameters are included in the Drinking Water Quality Standards under the Water Works Law. In the United Kingdom, the Water Act 1989 set out regulatory provisions to water suppliers. There is legislation that applies primarily to the regional water authorities. Technical assessors check whether the water suppliers conformed to statutory obligations.

Audit observations on treated water quality

4.17 ***1993 WHO Guidelines.*** As indicated in Table 3 of paragraph 4.6 above, the treated water quality complied with the selected 1993 WHO health-related guidelines. However, the THMs level in the treated water, though still within the 1993 WHO Guidelines, has been increasing over the past ten years. The increase in the level of THMs in the treated water of the STWTW was attributable to the high level of residual chlorine as a result of the increase in chlorine dosage for treating Dongjiang water. However, a similar increase in the level of THMs was not observed in the treated water of the Aberdeen Water Treatment Works used for treating local water. **The treated water quality did not fully comply with the aesthetic levels of residual chlorine of the 1993 WHO Guidelines.**

4.18 ***The WSD's Final Treated Water Quality Targets.*** **Audit observed that the treated water quality did not fully comply with the WSD's Final Treated Water Quality Targets for turbidity, aluminium and residual chlorine.**

4.19 ***Effective disinfection requirement.*** To monitor the residual chlorine in treated water, the WSD will boost the chlorine dosage when the residual chlorine is below the minimum requirement.

According to the remarks to the health-related guidelines set out in the 1993 WHO Guidelines, the level of residual chlorine should not be less than 0.5 mg per litre for effective disinfection. However, during some of the periods under review, Audit observed that the level of residual chlorine in treated water leaving the STWTW did not meet the minimum requirement.

4.20 ***WSD's internal instructions not updated.*** Audit observed that the WSD's target and current performance standards set out in the Supply and Distribution Branch Instruction were based on the 1984 WHO Guidelines, notwithstanding that the WHO Guidelines were revised in 1993. Audit also observed that the Final Treated Water Quality Targets for Water Treatment Works set out in an operational instruction were based on the 1984 WHO Guidelines, instead of the 1993 WHO Guidelines.

4.21 ***No contingency plan for outbreak of Cryptosporidium and Giardia.*** Audit observed that the WSD has been closely monitoring the level of Cryptosporidium and Giardia by conducting more testing and making reference to international practices. To date, no global health and treatment standards have been set concerning the level of Cryptosporidium and Giardia in treated water. The WSD has yet to establish a contingency plan to cater for possible cryptosporidiosis and giardiasis outbreaks.

4.22 ***Legislation on treated water quality.*** Under the Waterworks Ordinance (Cap. 102), the WSD is responsible for the quality of water up to the connecting points of consumers' buildings. **Audit noted that the Waterworks Ordinance has not specified the number of parameters and the standards which the treated water should meet. Without such statutory standards, the monitoring of the quality of treated water is essentially a self-regulatory process of the WSD. This is not in line with international best practices.**

Audit recommendations on treated water quality

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

(a) **take effective remedial measures to address the problem of non-compliance with the WSD's Final Treated Water Quality Targets and non-compliance with the aesthetic levels of the 1993 WHO Guidelines;**

(b) **continue to monitor closely the level of chlorine in treated water to ensure that the residual level of chlorine is not hazardous to health;**

(c) **regularly review and update the performance standard in WSD's internal operational instructions so as to bring such standard into line with current international guidelines (such as the guidelines issued by the WHO);**

(d) **continue to monitor closely the presence of Cryptosporidium and Giardia in the treated water and consider setting up a contingency plan for possible cryptosporidiosis and giardiasis outbreaks;**

(e) **consider specifying the quality standards of treated water in the Waterworks Ordinance so that consumers are given a statutory undertaking of the quality of treated water; and**

(f) **publish actual data together with the adopted standards for treated water quality to enhance accountability to the public.**

Response from the Administration

4.24 The **Secretary for Works** agrees with the audit recommendations that the Government should continue to follow the WHO Guidelines including that relating to the level of residual chlorine in treated water. He has said that the WSD will regularly review and update the WSD's performance standard in this respect. He has also said that:

— the WSD will work closely with the Department of Health to formulate a contingency plan for possible Cryptosporidiosis and Giardiasis outbreaks;

— as part of the continuous improvement exercise, the WSD regularly reviews and updates its performance pledge and operational instructions. At present, the WSD has the capability of testing all the health-related parameters in the 1993 WHO Guidelines instead of sending some samples overseas for testing; and

— it is more transparent to publish the pledged targets with regular announcement of key results achieved on the quality of treated water. The public can monitor the quality of treated water more effectively through this customer-oriented arrangement than specifying the quality standards in the Waterworks Ordinance.

4.25 The **Director of Water Supplies** agrees to look at the audit recommendations concerning the quality of treated water positively with a view to taking them on board as far as practicable. He has said that:

— the WSD's Final Treated Water Quality Targets are meant for day-to-day operational control, whereas the WHO Guidelines are for long-term quality monitoring. The parameters of the Targets are in general more stringent than those of the WHO 1993 Guidelines;

— the 1993 WHO Guidelines were available in June 1994. In August 1994, the WSD commenced action to secure additional resources with a view to achieving capability of analysing all the parameters. This was achieved by June 1999; and

— the aim of monitoring the drinking water quality in accordance with the WHO Guidelines is to ensure the safety of the drinking water. Thus, the primary focus of monitoring is directed to the parameters for the protection of public health. Where the cost-effective utilisation of available resources permits, the monitoring of aesthetic parameters is also undertaken in the overall assessment of water quality to ensure the acceptability to consumers. However, in any routine monitoring, health-related parameters take precedence over aesthetical qualities.

4.26 The **Director of Health** agrees with the audit recommendation that the presence of Cryptosporidium and Giardia should be closely monitored. She has said that the Department of Health will coordinate with the WSD to decide on what action need to be taken on this aspect. Up till now, there is insufficient information for setting a health-related standard for Cryptosporidium and Giardia in drinking water. She has also said that:

— the WHO guideline values are not mandatory limits. With a large number of parameters, care should be taken to selecting parameters for which local standards will be developed. A number of factors should be considered, including the geology of the region and the types of human activities that could lead to the contamination of water;

— a guideline value represents the concentration of a constituent that does not result in any significant risk to the health of the consumer over a lifetime of consumption. Short-term deviations above the guideline values therefore do not necessarily mean that the water is unsuitable for consumption. It should be a signal for investigation of the cause. Furthermore, guideline values relating to health hazards are always given higher priority than those for aesthetic reasons; and

— the guideline values for carcinogenic substances have been computed from hypothetical mathematical models. At best, these values can only be regarded as rough estimates of the risk of causing cancer. However, the models used are conservative, erring on the side of caution. Moderate short-term exposure to levels exceeding the guideline value for carcinogens does not significantly affect the risk.

Appendix A
(paragraphs 1.6, 1.8, 2.11 and 2.31 refer)

Quantity of water supply from 1995 to 2004 stipulated in the 1989 Water Supply Agreement and the 1998 Loan Agreement

Year	Quantity per 1989 Water Supply Agreement (MCM) (Note)	Revised quantity per 1998 Loan Agreement (MCM)
1995	690	—
1996	720	—
1997	750	—
1998	780	760
1999	810	770
2000	840	780
2001	870	790
2002	900	800
2003	930	810
2004	960	820

Source: *The WSD's records*

Note: *The 1989 Water Supply Agreement only stipulates the annual supply quantities up to 2000. The Agreement includes projections that the designed maximum capacity of 1,100 MCM per year will be reached by 2008, by assuming an annual increase of 30 MCM per year after 2000.*

Appendix B
(paragraphs 2.4, 2.6, 2.8, 2.26 and 2.32 refer)

Comparison of growth of water consumption with the increase in agreed supply of Dongjiang water from 1986 to 1998

Year	Quantity per supply agreement	Extra quantity	Total quantity supplied	Water supply of local origin	Total water consumption	Annual increase in actual water consumption	Annual growth rate of water consumption	Increase in agreed supply as a percentage of water consumption
	(a)	(b)	(c) = (a) + (b)	(d)	(e) = (c) + (d)	(f)	(g) (Note 1)	(h) (Note 2)
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)	(%)	(%)
1985	283	—	283	354	637	—	—	—
1986	346	14	360	343	703	66	10.36%	9.89%
1987	388	44	432	318	750	47	6.69%	5.97%
1988	423	92	515	293	808	58	7.73%	4.67%
1989	486	124	610	235	845	37	**4.58%**	**7.80%**
1990	528	62	590	283	873	28	**3.31%**	**4.97%**
1991	563	138	701	183	884	11	**1.26%**	**4.00%**
1992	594	69 (Note 3)	663	226	889	5	**0.57%**	**3.51%**
1993	624	3 (Note 3)	627	288	915	26	**2.92%**	**3.37%**
1994	660	23 (Note 3)	683	240	923	8	**0.87%**	**3.93%**
1995	690	—	690	229	919	(4)	**(0.43%)**	**3.25%**
1996	720	—	720	208	928	9	**0.98%**	**3.26%**
1997	750	(52) (Note 4)	698	215	913	(15)	**(1.62%)**	**3.23%**
1998 (Note 5)	760	—	760	156	916	3	**0.33%**	**1.10%**
					Average (1989-1998)		**1.28%**	**3.84%**

Source: *The WSD's records*

Note 1: $(g) = \dfrac{(f)}{(e) \text{ of the preceding year}} \times 100\%$

Note 2: $(h) = \dfrac{(a) \text{ of the year} - (a) \text{ of the preceding year}}{(e) \text{ of the preceding year}} \times 100\%$

Note 3: *In 1992, only 69 MCM of the ad hoc increase (105 MCM) requested by the WSD was drawn. The delivery of the remaining balance was deferred to 1993 and 1994. Eventually only a total 95 MCM of the ad hoc increase quantity was drawn.*

Note 4: *In 1997, 52 MCM of water was not drawn.*

Note 5: *In 1998, the increase in agreed supply quantity was reduced to 10 MCM according to the 1998 Loan Agreement. The total agreed annual quantity of 760 MCM was all drawn.*

Appendix C
(paragraph 2.7 refers)

Actual water consumption by sectors from 1988 to 1998

Year	Domestic		Industrial		Service Trades		Others		Total	
	MCM	Growth rate	MCM	Growth rate	MCM	Growth rate	MCM	Growth rate	MCM	Growth rate
1988	221	—	170	—	119	—	298	—	808	—
1989	226	2.26%	182	**7.06%**	122	2.52%	315	5.70%	845	4.58%
1990	230	1.77%	179	**(1.65%)**	128	4.92%	336	6.67%	873	3.31%
1991	230	0%	174	**(2.79%)**	130	1.56%	350	4.17%	884	1.26%
1992	232	0.87%	161	**(7.47%)**	134	3.08%	362	3.43%	889	0.57%
1993	243	4.74%	145	**(9.94%)**	139	3.73%	388	7.18%	915	2.92%
1994	251	3.29%	117	**(19.31%)**	147	5.76%	408	5.15%	923	0.87%
1995	255	1.59%	96	**(17.95%)**	147	0%	421	3.19%	919	(0.43%)
1996	258	1.18%	87	**(9.38%)**	145	(1.36%)	438	4.04%	928	0.98%
1997	264	2.33%	75	**(13.79%)**	144	(0.69%)	430	(1.83%)	913	(1.62%)
1998	274	3.79%	66	**(12.00%)**	146	1.39%	430	0%	916	0.33%
Average		**2.18%**		**(8.72%)**		**2.09%**		**3.77%**		**1.28%**

Source: The WSD's records

Appendix D
(paragraphs 2.5 and 2.8 refer)

Recorded annual rainfall from 1986 to 1998

Year	Millimetres
1986	2,338
1987	2,319
1988	1,685
1989	1,945
1990	2,047
1991	1,639
1992	2,679
1993	2,344
1994	2,726
1995	2,754
1996	2,249
1997	3,346
1998	2,565

Source: The WSD's records

Note: The long-term annual mean rainfall is 2,214 millimetres.

Appendix E
(paragraphs 2.10, 2.13, 2.16 and 2.17 refer)

Comparison of the forecasted growth rates with the actual growth rates of water consumption

Year	WSD's forecasted growth rates made in					Actual growth rates (%)
	1987 (%) (Note 1)	1991 (%) (Note 2)	1992 (%) (Note 3)	1993 (%) (Note 3)	1994 (%) (Note 3)	
1989	3.55%	—	—	—	—	4.58%
1990	4.19%	—	—	—	—	3.31%
1991	4.15%	—	—	—	—	1.26%
1992	2.58%	1.94%	—	—	—	0.57%
1993	3.42%	3.58%	0.90%	—	—	2.92%
1994	3.42%	3.56%	1.57%	2.19%	—	0.87%
1995	3.52%	3.65%	1.43%	1.93%	1.41%	(0.43%)
1996	3.51%	—	1.52%	1.47%	1.28%	0.98%
1997	3.29%	—	1.39%	1.45%	1.26%	(1.62%)
1998	3.47%	—	2.11%	2.14%	1.56%	0.33%
1999	3.08%	—	2.28%	1.80%	1.43%	—
2000	2.98%	—	2.43%	1.57%	1.52%	—
2001	—	—	2.57%	1.54%	1.39%	—
2002	—	—	2.79%	1.52%	1.47%	—
2003	—	—	—	—	1.55%	—
Average growth rate	**3.43%**	**3.18%**	**1.90%**	**1.73%**	**1.43%**	**1.28%**

Source: *The WSD's records*

Note 1: *The forecasted growth rates were the lower-bound projection of the 1987 Water Demand Forecast.*

Note 2: *In 1991, the WSD forecasted the growth rates for only four years due to limited data on the decrease in water consumption.*

Note 3: ***The forecasted growth rates made in 1992, 1993 and 1994 were lower than those made in 1987.***

Appendix F
(paragraph 2.30 refers)

Estimated financial implications of overflow from 1994 to 1998

	Overflow quantity				Costs of overflow		
Year	**Plover Cove and High Island Reservoirs**	**Other reservoirs**	**Total**	**Unit purchase price of water**	**Plover Cove and High Island Reservoirs**	**Other reservoirs**	**Total**
	(MCM)	**(MCM)**	**(MCM)**	**($ per cubic metre)**	**($ million)**	**($ million)**	**($ million)**
	(a)	**(b)**	**(c) = (a) + (b)**	**(d)**	**(e) = (a) ´ (d)**	**(f) = (b) ´ (d)**	**(g) = (e) + (f)**
	(Note)						
1994	90.5	83.1	173.6	1.940	175.6	161.2	336.8
1995	26.6	69.9	96.5	2.160	57.5	151.0	208.5
1996	82.4	25.7	108.1	2.405	198.2	61.8	260.0
1997	129.5	75.3	204.8	2.613	338.4	196.8	535.2
1998	99.2	34.0	133.2	2.839	281.6	96.5	378.1
	428.2	**288.0**	**716.2**		**1,051.3**	**667.3**	**1,718.6**
			(say 716 MCM)				**(say $1,718 million)**

Source: *The WSD's records*

Note: *The Plover Cove and High Island Reservoirs are connected by an aqueduct to enable water to be pumped from the Plover Cove Reservoir to the High Island Reservoir. The storage capacity of the two reservoirs is 511 MCM, i.e. 87% of the total storage capacity of 586 MCM. When the risk of overflow from the High Island Reservoir is high, water will not be pumped to it. Hence, overflow from the High Island Reservoir is much less frequent than that from the Plover Cove Reservoir.*

Appendix G
(paragraph 3.1 refers)

Comparison between the 1983 and the 1988 Environmental Quality Standards for Surface Water of the Mainland

Parameters	**1983 Standard**	**1988 Standard**
Un-ionised ammonia	not included	< 0.02 mg/litre
Total manganese	not included	< 0.1 mg/litre (Note)
Volatile phenols	< 0.005 mg/litre	< 0.002 mg/litre
Mercury	< 0.0005 mg/litre	< 0.00005 mg/litre
Total number of parameters	**19**	**30**

Source: The WSD's records

Note: Limiting value may be adjusted according to local characteristics.

Appendix H
(paragraph 3.6 refers)

Dongjiang raw water quality parameters selected for audit analysis

Parameter	Significance
Dissolved oxygen	Low concentration allows growth of nuisance micro-organisms causing taste and odour problems.
Total phosphorus (Note)	The source of phosphorus is phosphate. Water supply containing phosphate is usually contaminated by minerals, fertilizers, detergents, sewage or industrial waste.
Total nitrogen (Note)	This is an indicator of sewage and industrial contamination.
Total manganese	Manganese reduces the disinfection efficiency of chlorine. It occurs naturally in water. Manganese should be low in surface water and it is usually high in oxygen-depleted water.
pH	pH control is necessary in all stages of water treatment to ensure satisfactory water clarification and disinfection.

Source: *"1993 WHO Guidelines"; "Handbook of Drinking Water Quality" by John De Zuane (1997); "Drinking Water Quality, Problems and Solutions" by N.F. Gray (1996); and "Australian Drinking Water Guidelines".*

Note: *The limiting values for total phosphorus and total nitrogen are used as reference standards for enclosed water bodies in the 1983 Standard.*

Appendix I
(paragraph 3.23 refers)

Estimated additional recurrent costs due to the substandard quality of Dongjiang water

	1997-98	1998-99
	($ million)	($ million)
Cost of chemicals (Note 1)	26	29
Electricity cost for blending (Note 2)	7	7
Electricity cost for aeration (Note 3)	1	1
	34	37

Source: Audit analyses of the WSD's records

Note 1: More chlorine is dosed into the water in the pre-chlorination process for removing ammonia and manganese in the Dongjiang water. To neutralise the effect of the increased dosage of chlorine, a corresponding increase in the quantity of lime and aluminium sulphate is required. The cost of chemicals excluded the changes in prices, if any.

Note 2: Up to late 1993, Dongjiang water was directly pumped to the STWTW. Since then, a large portion of Dongjiang water is transferred to and blended with the water in the Plover Cove Reservoir. The mixed water is then pumped back to the STWTW for treatment. Additional electricity cost has been incurred because of the increased pumping operations.

Note 3: This was the additional recurrent cost for operating the aeration plant installed at the Muk Wu Pumping Stations for pumping oxygen into the raw Dongjiang water.

Appendix J
(paragraph 4.3 refers)

Some health-related and aesthetic parameters of the 1993 WHO Guidelines selected for audit analysis

Health-related parameters	**1993**
Arsenic	< 0.01 mg/litre
Chromium	< 0.05 mg/litre
Mercury	< 0.001 mg/litre
Manganese	< 0.5 mg/litre
Trihalomethanes (THMs)	(Note 1)
chloroform	< 200 µg/litre (Note 2)
bromodichloromethane	< 60 µg/litre (Note 2)
dibromochloromethane	< 100 µg/litre
bromoform	< 100 µg/litre
Residual chlorine	< 5 mg/litre
Benzo(a)pyrene	< 0.7 µg/litre
Aesthetic parameters	
Turbidity	< 5 NTU (Note 3)
Colour	< 15 TCU (Note 4)
Iron	< 0.3 mg/litre
Aluminium	< 0.2 mg/litre
Residual chlorine	within 0.6 - 1.0 mg/litre
Manganese	< 0.1 mg/litre

Source: The 1993 WHO Guidelines

Note 1: No guideline value has been set for total Trihalomethanes. However, the 1993 WHO Guidelines recommended that the fractionation approach (i.e. the sum of the ratio of each member of the THMs to its guideline value should not exceed one) could be taken to establish a total Trihalomethanes standard.

Note 2: According to the 1993 WHO Guidelines, the guideline value for carcinogenic substance represents one additional cancer per 100,000 of the population ingesting drinking water containing the substance for 70 years. A daily consumption of two litres by a person weighing 60 kg was generally assumed. However, such an assumption may underestimate the consumption of water, and thus exposure, for people living in hot climate as well as for infants and children, who consume more fluid per unit weight than adults.

Note 3: Nephelometric turbidity units (NTU)

Note 4: True colour unit (TCU)

Appendix K
(paragraph 4.4 refers)

Comparison of the 1993 WHO health-related guidelines and aesthetic levels with WSD's Final Treated Water Quality Targets

Parameters	1993 WHO health-related guidelines	1993 WHO aesthetic levels	WSD's Final Treated Water Quality Targets
Manganese	< 0.5 mg/litre	< 0.1 mg/litre	< 0.05 mg/litre
Residual chlorine	< 5 mg/litre (Note 1)	within 0.6 - 1.0 mg/litre	within 0.5 – 1.5 mg/litre
Fluoride	< 1.5 mg/litre	not included	± 10% of 0.5 mg/litre
Colour	not applicable	< 15 TCU	< 5 TCU
Turbidity	not applicable	< 5 NTU	< 1.0 NTU (Note 2)
Iron	not applicable	< 0.3 mg/litre	< 0.1 mg/litre
Aluminium	not applicable	< 0.2 mg/litre	< 0.1 mg/litre
pH	not applicable	preferably < 8.0	within 8.2 - 8.8
Taste and colour	not applicable	should be acceptable	unobjectionable
E. coli and coliform organism	not detectable	not applicable	absent

Source: The WSD's records and WHO Guidelines

Note 1: The remarks to residual chlorine in the health-related guidelines stated that there should be a residual concentration of chlorine of 0.5 mg/litre for effective disinfection.

Note 2: It is applicable to water prior to final pH conditioning.

Appendix L
(paragraph 4.5 refers)

Key parameters selected from 1993 WHO Guidelines for audit analysis

Health-related parameters	**Significance**
Arsenic	It is carcinogenic, causing also skin damage and circulatory system problems.
Chromium	Some people who use water containing chromium in excess of the maximum contaminant level over many years could experience allergic dermatitis.
Mercury	It causes kidney and central nervous system problems.
Manganese	The WHO is of the opinion that by the oral route, manganese is often regarded as one of the least toxic elements.
THMs	They occur in drinking water as the by-products of chlorine. They cause liver, kidney and central nervous system problems and increase the risk of cancer (Note 1).
Residual chlorine	A minimum level of residual chlorine is required for effective disinfection. However, excessive residual chlorine in the treated water will enhance the potential of forming THMs (Note 2).
Benzo(a)pyrene	It causes problems to the reproductive system and increases the risk of cancer.
Aesthetic parameters	
Turbidity	It has no health effect but can provide a medium for the growth of microbes. High levels of turbidity can protect micro organisms from the effect of disinfection and can stimulate bacterial growth. The turbidity must be low for disinfection to be effective.
Colour	Some colour-forming organic compounds can react with chlorine to form by-products such as THMs. Therefore, it is desirable to remove such compounds before chlorine is added.
Iron	It stains laundry and plumbing fixtures, promotes the growth of "iron bacteria" and deposits a slimy coating on the piping.
Aluminium	Its presence in excess of 0.2 mg/litre often leads to consumer complaints due to the deposition of aluminium hydroxide floc in the distribution system.
Residual chlorine	Residual chlorine has an acceptability threshold of 0.6 mg/litre to 1 mg/litre.
Manganese	It stains sanitary wares and laundry and causes an undesirable taste in beverages. It also forms a coating on pipes, which may slough off as a black precipitate.

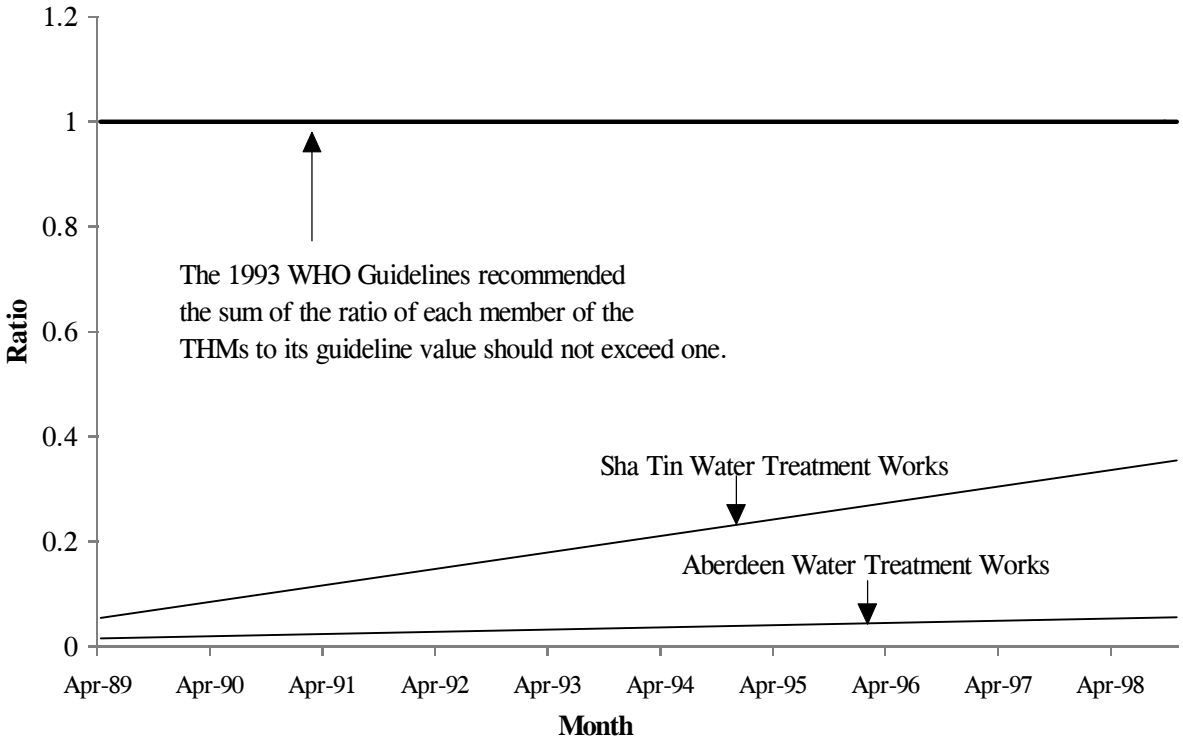
Source: 1993 WHO Guidelines; US Environmental Protection Agency National Primary Drinking Water Regulations

Note 1: THMs occur in drinking water as by-products of the reaction of chlorine with organic materials. With respect to drinking-water contamination, only four members of the group, which usually occur together, namely chloroform, bromoform, dibromochloromethane and bromochloromethane, are important. Chloroform and bromodichloromethane are classified as substances which are possibly carcinogenic to human by International Agency for Research on Cancer. The remaining two members are classified as "not classifiable as to its carcinogenicity to human".

Note 2: The WSD disinfection practice is based on maintaining a minimum level of residual chlorine in the treated water.

Appendix M
(paragraph 4.7 refers)

Comparison of the ratio of THMs in the treated water of the Sha Tin Water Treatment Works with that of the Aberdeen Water Treatment Works from 1989 to 1998



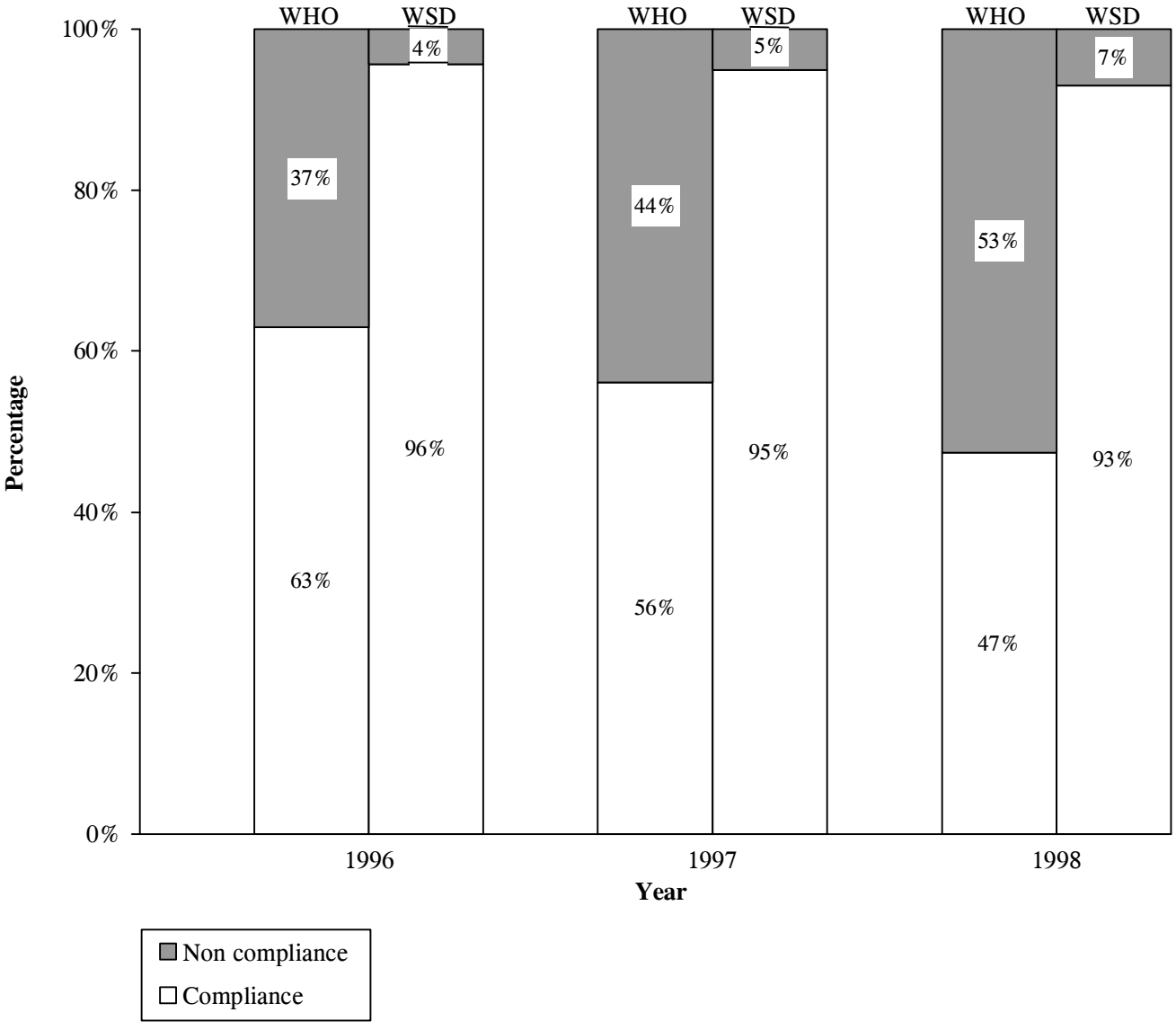
Legend: ——— *the trend lines of THMs in the treated water of the water treatment works*

Source: *The WSD's records*

Note: *The STWTW is fed by Dongjiang water and pre-chlorination is required. The Aberdeen Water Treatment Works is fed by water from local reservoirs and no pre-chlorination is required.*

Appendix N
(paragraphs 4.8 and 4.9 refer)

Compliance of treated water with WHO aesthetic levels and WSD's Final Treated Water Quality Targets in respect of residual chlorine from 1996 to 1998



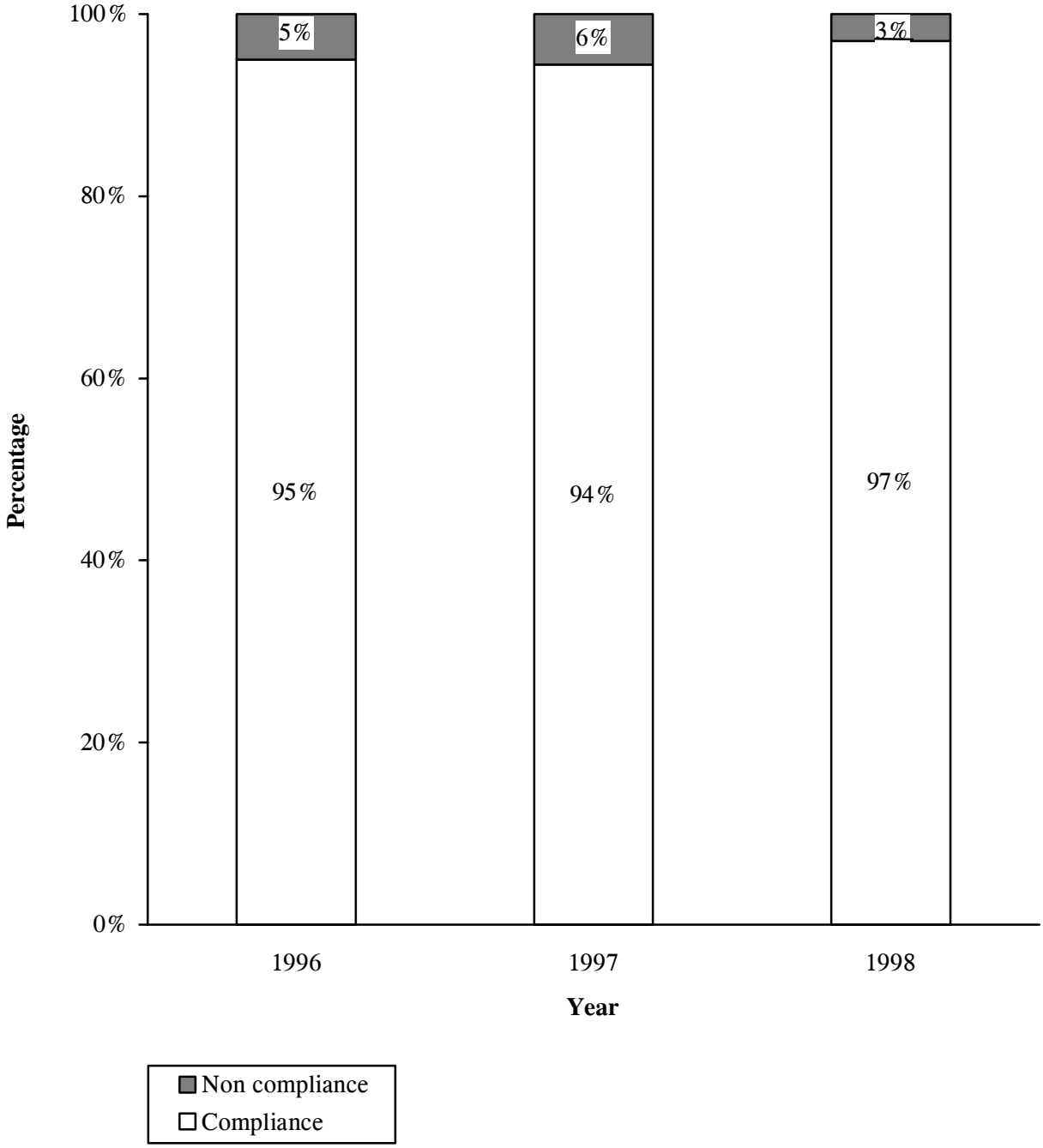
Source: *The WSD's records*

Note 1: *According to the 1993 WHO Guidelines, a residual chlorine concentration of between 0.6 mg/litre and 1.0 mg/litre will generally begin to cause problems with acceptability. However, some people are able to taste chlorine or its by-products at concentrations below 5 mg/litre, and some at levels as low as 0.3 mg/litre.*

Note 2: *The WSD's Final Treated Water Quality Targets set a value of not less than 0.5 mg/litre and not more than 1.5 mg/litre.*

Appendix O
(paragraph 4.9 refers)

Compliance of treated water with WSD's Final Treated Water Quality Targets in respect of turbidity from 1996 to 1998

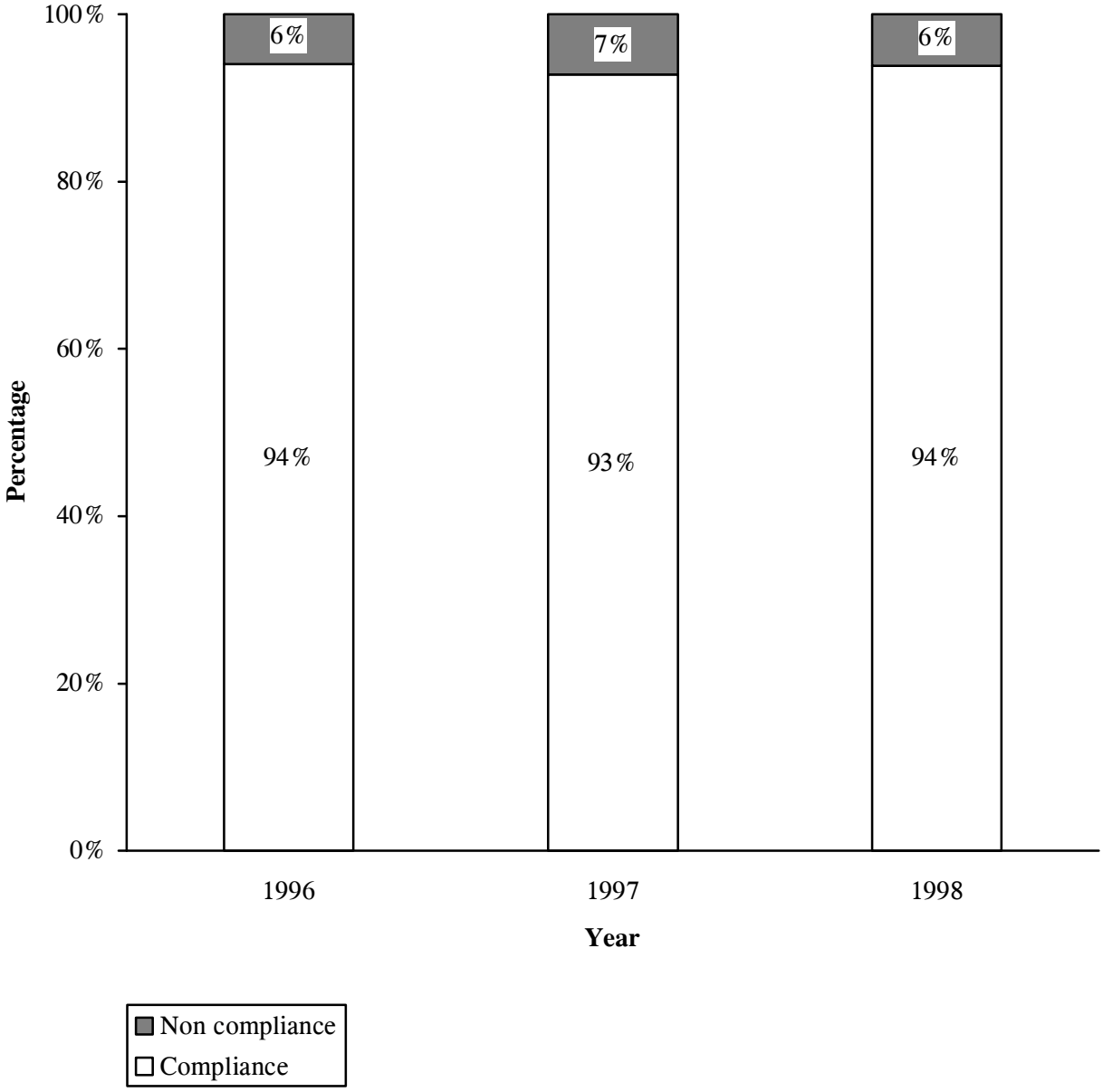


Source: *The WSD's records*

Note: *The WSD's Final Treated Water Quality Targets set a value of not exceeding 1.0 NTU (prior to final pH conditioning) for turbidity.*

Appendix P
(paragraph 4.9 refers)

Compliance of treated water with WSD's Final Treated Water Quality Targets in respect of aluminium from 1996 to 1998



Source: *The WSD's records*

Note: *The WSD's Final Treated Water Quality Targets set a value of not exceeding 0.1 mg/litre for aluminium.*

Chronology of key events

1960	The first agreement with the Guangdong Authority for the supply of Dongjiang water was drawn up.
1964	Another agreement was reached in 1964 with the Guangdong Authority to increase the water supply. Thereafter, the Government made further agreements with the Guangdong Authority to progressively increase the annual water supply to Hong Kong.
1974	The USA enacted the Safe Drinking Water Act to establish national treated water quality standards.
September 1983	The Mainland published an Environmental Quality Standard for Surface Water.
1984	The WHO published a set of Guidelines for Drinking Water Quality.
January 1984	The 1983 Standard was effective.
1987	The Government made a water supply agreement with the Guangdong Authority. The agreement fixed the annual supply quantities from May 1989 to February 1995.
April 1988	The Mainland published the 1988 Standard to replace the 1983 Standard.
June 1988	The 1988 Standard was effective and is still in use in the Mainland.
February 1989	The WSD issued the final report on the 1987 Water Demand Forecast.
November 1989	The FC approved the funding for an interest-free loan to the Guangdong Authority which formed part of the 1989 Water Supply Agreement.

December 1989	The Government signed the 1989 Water Supply Agreement with Guangdong Province.
November 1991	The WSD issued the 1991 Water Demand Forecast. Since 1991, the WSD conducted the forecast of water demand annually to closely monitor the consumption trend.
January 1992	The WSD requested the Guangdong Authority to increase the water supply by 105 MCM for 1992. The Government paid the Guangdong Authority $27 million to upgrade the DWSS to accommodate this increase in water supply.
June 1992	The WSD informed the Guangdong Authority that there was a slight downward trend in water consumption since 1991 and that the annual increase of 30 MCM of water from Guangdong Province might result in a surplus.
July 1992	The WSD agreed with the Guangdong Authority to defer 38 MCM of the 1992 agreed water supply to May 1993 to February 1994.
1993	The WHO published a new set of Guidelines for Drinking Water Quality to replace the 1984 WHO Guidelines.
1993	Since 1993, the WSD has issued a performance pledge annually.
January 1993	The WSD issued the 1992 Water Demand Forecast. The forecast average growth rate of water consumption was revised downward from 3.43% made in the 1987 Water Demand Forecast to 1.9%.
May 1993	The WSD informed ExCo that the growth rate of water consumption was declining due to the shift of major water-intensive industries from Hong Kong to Mainland coastal cities. However, the WSD considered it would be premature to request the Guangdong Authority to reduce supply.
May 1993	The WSD convened a special meeting to tackle the problem of the deteriorating quality of Dongjiang water.

July 1993	At the fourth annual business meeting, the WSD informed the Guangdong Authority that the increase of 30 MCM a year over the basic supply might be on the high side.
December 1993	The WSD issued the 1993 Water Demand Forecast. The forecast made a lower long-term growth rate of water consumption than the one made in the 1987 Water Demand Forecast.
May 1994	At the fifth annual business meeting, the WSD did not raise the issue of reducing water supply from Guangdong Province.
July 1994	The Guangdong Authority agreed to increase the testing frequency of ammoniacal nitrogen to once a day. The test results on ammoniacal nitrogen would be exchanged with the WSD weekly.
November 1994	The WSD issued the 1994 Water Demand Forecast. A forecast of low long-term growth rates of water consumption ranging from 1.26% to 1.56% for the years 1995 to 2003 was made.
April 1995	The WSD conducted a comprehensive review of reservoir storage. This review recommended that the WSD should negotiate with the Guangdong Authority with a view to reducing the supply quantity.
June 1995	The Guangdong Authority agreed to reduce the daily supply rate through consultation in the event of overflow in Hong Kong caused by heavy rainfall.
April 1996	The WSD's consultant issued a report on the quality of Dongjiang water.
June 1996	At the seventh annual business meeting, the Guangdong Authority declined the WSD's request of freezing the annual supply quantities.
May 1997	At the eighth annual business meeting, the Guangdong Authority admitted that the quality of Dongjiang water was deteriorating and sought financial assistance from the Government for construction of a closed aqueduct.

June 1997	The WSD stopped drawing excess supply of water from Guangdong. A total of 52 MCM of water was not drawn in 1997.
June 1997	At an ExCo meeting, the Secretary of Justice said that it would be important for the future water supply agreements to contain an effective and independent dispute resolution mechanism.
1998	The WSD did not stop drawing excess water from Guangdong Province.
April 1998	The FC approved the funding for an interest-free loan to the Guangdong Authority which formed part the 1998 Loan Agreement.
July 1998	The 1998 Loan Agreement was signed between the Government and the Guangdong Province.
July 1998	The WSD had increased the frequency of sampling when some of the samples were found to contain Cryptosporidium and Giardia.
April 1999	The WSD participated in the International Conference on Minimizing the Risk from Cryptosporidium and Other Waterborne Particles.

Appendix R

Acronyms and abbreviations

DWSS	Dongshen Water Supply System
ExCo	Executive Council
FC	Finance Committee
FSB	Financial Services Bureau
MCM	Million cubic metres
NTU	Nephelometric turbidity units
STWTW	Sha Tin Water Treatment Works
TCU	True colour unit
THMs	Trihalomethanes
USA	United States of America
WHO	World Health Organisation
WSD	Water Supplies Department