CHAPTER 2

THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

GENERAL REVENUE ACCOUNT

GOVERNMENT SECRETARIAT

Planning, Environment and Lands Bureau

Works Bureau

GOVERNMENT DEPARTMENTS

Electrical and Mechanical Services Department

Water Supplies Department

The use of energy-efficient air-conditioning systems in Hong Kong

Audit Commission
Hong Kong
11 October 1999

THE USE OF ENERGY-EFFICIENT AIR-CONDITIONING SYSTEMS IN HONG KONG

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Summary and key findings

A. **Introduction.** Electricity is the most widely used form of energy in Hong Kong. The commercial sector is the largest consumer of electricity. In a typical commercial building, the air-conditioning system can account for more than 50% of the total electricity consumption. Therefore, the air-conditioning system is often the area where significant energy saving can be achieved by adopting energy-efficient designs and good energy management practices (paras. 1.1 and 1.2).

B. **The benefits of energy-efficient air-conditioning systems and the extent of their use in Hong Kong.** Water-cooled air-conditioning systems (WACS) are more energy-efficient than air-cooled air-conditioning systems (AACS). Despite the substantial economic and environmental benefits of WACS, the vast majority of the central air-conditioning systems in Hong Kong are AACS. This is due to the limited supply of sea water and the ban on the use of mains water for air-conditioning purposes (paras. 2.7, 2.11 and 2.12).

C. **The Government's effort in promoting the wider use of energy-efficient air-conditioning systems.** Since 1991, there have been discussions in government advisory committees on the wider use of WACS. In 1998, the Electrical and Mechanical Services Department (EMSD) commissioned a consultancy study on WACS. However, the scope of the consultancy study did not include a detailed examination of the rationale for disallowing the use of mains water for air-conditioning purposes. The emphasis of the study was on a district-by-district basis (paras. 3.1, 3.5 and 3.12).

D. **The WSD's ban on the use of mains water for air-conditioning purposes.** The Water Supplies Department (WSD) disallows the use of mains water for air-conditioning purposes with exemptions granted only for industrial processes or essential purposes. The ban on the use of mains water for air-conditioning purposes was imposed a long time ago when there was a shortage in water supply and air conditioning was considered a luxury. Nowadays, air conditioning is no longer simply for comfort and has become a basic requirement for commercial operations. A reduction in the electricity cost of air conditioning will mean a reduction in the operating costs of businesses. In this context, the use of water for WACS in order to reduce electricity consumption should not be regarded as a waste of water. The demand for fresh water by WACS should be catered for by the water supply system. An audit survey has revealed that developed countries and Mainland cities do not impose a similar ban on the use of mains water for air-conditioning purposes. A survey of cooling towers conducted by the EMSD in 1996 indicated that there were many water cooling towers installed for comfort cooling, with water supplied from unauthorised connections to the mains. However, little monitoring and prosecution work has been carried out by the WSD on these unauthorised connections (paras. 4.3 and 4.6 to 4.10).

E. **The demand and supply of fresh water in Hong Kong.** The supply of water from Guangdong Province and rainfall catchment can meet the future need of water consumption in Hong Kong. Moreover, there was a decline in the consumption of fresh water in Hong Kong due mainly to the relocation of manufacturing industries outside Hong Kong. Therefore, there is ample capacity in the water supply system to meet future growth. Audit estimates that there will be a forecasted surplus supply of fresh water for the years from 1999 to 2012 and the additional demand for fresh water by WACS can be fully met by the surplus supply (paras. 5.4, 5.7, 5.8 and 5.17).

F. **Health concern over the operation of fresh water cooling towers.** In promoting the wider adoption of WACS using fresh water cooling towers, special care has to be taken because the operation of fresh water cooling towers has been found to be associated with Legionnaires' Disease (LD). Some developed countries have established technical and administrative measures to prevent and minimise the risk of LD. In 1985, the Government established the Prevention of Legionnaires' Disease Committee (PLDC) to formulate strategies for the prevention and management of the possible outbreak of LD. However, the PLDC can only promote voluntary compliance with the preventive measures. This is because the requirements of the Code of Practice issued by the PLDC to ensure the proper operation and maintenance of cooling towers are not legally enforceable. According to the 1996 EMSD's survey, 14% of the cooling towers were not properly installed and 47% of them were not properly maintained. There is an urgent need for the Administration to regulate the operation of illegal water cooling towers (paras. 6.1, 6.16, 6.18, 6.26, 6.28 and 6.29).

G. **Audit recommendations.** Audit has made the following major recommendations:

- the Secretary for Planning, Environment and Lands and the Director of Electrical and Mechanical Services should:

  (i) promote and facilitate the wider use of WACS in Hong Kong with a view to obtaining the economic and environmental benefits at an early date (first inset of para. 2.17);

  (ii) focus on using fresh water from the mains as the way forward for promoting and facilitating the use of WACS (first inset of para. 3.19); and

  (iii) review the scope and direction of Phase 1 and Phase 2 of the consultancy study and make necessary adjustments with a view to making proposals to facilitate the use of fresh water for WACS (second inset of para. 3.19);

- the Secretary for Works and the Director of Water Supplies should:

  (i) critically review the rationale for disallowing the use of fresh water for WACS (para. 4.12); and

  (ii) consider formulating an action plan to relax the ban on the use of mains water for air-conditioning purposes at an early date (para. 5.22);

- the Secretary for Works and the Director of Electrical and Mechanical Services should consider ways, including the setting up of a registration and licensing system, of requiring operators and owners of cooling towers to comply with the Code of Practice on the proper operation of cooling towers (para. 6.30); and

- the Director of Electrical and Mechanical Services should:

  (i) conduct regular surveys of cooling towers to ascertain and monitor the operating conditions of cooling towers, particularly those which are not properly installed or maintained (first inset of para. 6.31); and

  (ii) inform owners of the cooling towers of the requirements of the Code of Practice and advise them of the potential risk of LD (second inset of para. 6.31).

H. **Response from the Administration.** The Administration agrees with most of the audit recommendations.

PART 1: INTRODUCTION

Electricity consumption in Hong Kong

1.1 Electricity is the most widely used form of energy in Hong Kong. As shown in Appendix A, the electricity consumption in Hong Kong is increasing year after year. The electricity consumption can be analysed under three sectors, i.e. the commercial, domestic and industrial sectors. The commercial sector is the largest and growing consumer of electricity. Details are at Appendix B. As the economy of Hong Kong becomes more service-oriented, the demand for high quality air-conditioned commercial buildings also increases. This has resulted in a steady increase in the proportion of electricity consumed in the commercial sector. In 1998, the commercial sector accounted for 59% of the total electricity consumption.

1.2 In a typical commercial building, the air-conditioning system can account for more than 50% of the total electricity consumption. Therefore, the air-conditioning system is often the area where significant energy saving can be achieved by adopting energy-efficient designs and good energy management practices.

Energy conservation and environmental protection

1.3 Electricity in Hong Kong is generated by burning fossil fuels, primarily coal and natural gas. As Hong Kong is dependent on the import of fuels, the expenditure on electricity consumption is affected by price changes of such fuels. Saving in electricity consumption will bring about a substantial reduction in the expenditure on fuels for the power companies and in the electricity bill for consumers. By reducing the overall consumption of electricity, the need for constructing new power plants can be deferred. The emission of air pollutants (i.e. carbon dioxide, sulphur dioxide and nitrogen oxides) and particulates from burning fuels can also be reduced.

Administrative framework

1.4 The Government has long recognised the need to take measures to ensure that Hong Kong uses energy more efficiently. The Secretary for Planning, Environment and Lands leads the Government's efforts to promote energy efficiency as part of his responsibility for policy on environmental protection. In February 1991, the then Governor-in-Council directed that a policy should be established to increase energy efficiency and approved the establishment of an Energy Efficiency Advisory Committee (EEAC). The EEAC was set up in April 1991 to advise the Government on proposals to bring in early improvements in energy efficiency in Hong Kong as well as to formulate a comprehensive energy efficiency policy in the long run. The EEAC was chaired by the Secretary for Planning, Environment and Lands and consisted of representatives from the academic field, public utility companies, the property sector, professional bodies and the

government departments concerned. In August 1994, the Electrical and Mechanical Services Department (EMSD) set up the Energy Efficiency Office to provide technical support to the Planning, Environment and Lands Bureau in developing and implementing energy efficiency and conservation programmes. The EEAC was dissolved in April 1996 and subsumed into the Energy Efficiency and Conservation Sub-Committee (EECSC) of the newly formed Energy Advisory Committee (EAC). The EECSC continues to perform the work of the former EEAC with similar terms of reference and membership. The Government has also reached agreements with the two electricity supply companies to introduce a Demand Side Management Programme for reducing the consumption and growth in demand for electricity.

1.5 The policy on water supply impinges on the adoption of energy-efficient air-conditioning systems using water for cooling. In this regard, the Secretary for Works is responsible for relevant water supply policy. The Water Supplies Department (WSD) is responsible for providing an adequate and satisfactory supply of water to the territory. The Secretary for Works is also responsible for the policy related to the prevention and control of Legionnaires' Disease (LD). LD is an illness connected with the improper operation and maintenance of evaporative cooling towers used in air-conditioning systems.

Audit objectives and scope

1.6 As air-conditioning systems account for about 50% of the total electricity consumption in commercial buildings, Audit recently conducted a review (with the assistance of a consultant specialised in energy management) of the use of energy-efficient air-conditioning systems in Hong Kong. The audit has revealed that there is a need to explore the potential for the wider adoption of energy-efficient air-conditioning systems in order to achieve energy saving, and that there is room for improvement in a number of areas.

PART 2: THE BENEFITS OF ENERGY-EFFICIENT AIR-CONDITIONING SYSTEMS AND THE EXTENT OF THEIR USE IN HONG KONG

Different types of central air-conditioning systems

2.1 The central air-conditioning systems installed in commercial and industrial buildings consist of a group of components and equipment connected together to control the environmental parameters (i.e. temperature and relative humidity) of the buildings. A typical central air-conditioning system includes the following components:

— the chiller, located usually at the plant room or roof top, for generating chilled water;

— the primary pump for circulating the chilled water to terminal units; and

— terminal units (including air-handling units, primary air-handling units and fan coil units) located on individual floors for utilising the chilled water to produce cooled air.

2.2 The chiller of a central air-conditioning system consists of the following three components:

— the evaporator for absorbing heat from the chilled water to the refrigerant;

— the compressor for compressing the refrigerant leaving the evaporator; and

— the condenser for removing heat from the compressed refrigerant.

2.3 There are different heat rejection methods for removing heat from the condenser of the chiller. The central air-conditioning systems in Hong Kong can be classified into the following two categories by their heat rejection methods:

— ***Air-cooled air-conditioning systems (AACS) using air for cooling.*** Heat is transferred from the refrigerant to the air drawn through the condenser by a fan; and

— ***Water-cooled air-conditioning systems (WACS) using water for cooling.*** WACS can be further divided into two typical designs for removing heat from the condenser of the

chiller: the once-through system using sea water and the evaporative system using fresh water cooling tower.

The schematic diagrams of the chillers of typical AACS and WACS using sea water and fresh water are shown in Figure 1 on the centre pages. Water-cooled chillers can be used in large central air-conditioning systems with a cooling capacity of 100 refrigeration tons (Note 1) or more, and in standalone air-conditioning systems of smaller cooling capacity of 5 to 100 refrigeration tons.

2.4 For buildings located along the sea front, sea water can be obtained through dedicated pump pits for cooling purposes. This type of WACS usually uses the once-through design in which the sea water enters the condenser, carries away the heat and is then discharged back to the sea. Water consumption is very high for the once-through system.

2.5 The evaporative system using a cooling tower consumes less water than the once-through system. Cooling water enters the condenser and carries away the heat to the cooling tower where the heat will be dissipated by evaporating a portion of the cooling water. The cooling water is circulated in a closed loop where additional water is required to replenish the loss of water. In principle, either sea water or fresh water can be used. However, because of maintenance problems associated with circulating sea water, fresh water is predominantly used in the evaporative system.

Differences between AACS and WACS

2.6 The design and operation of AACS and WACS differ in many aspects. The differences between AACS and WACS using fresh water cooling towers are as follows:

(a) ***Operating costs.*** In AACS, the chiller accounts for roughly 50% of the total electricity consumption of the air-conditioning system. For the same cooling capacity, WACS are more energy-efficient than AACS in that water-cooled chillers consume about 30% to 40% less electricity than air-cooled chillers. On the other hand, WACS require additional costs for maintenance, water treatment and water consumption. In general, the total operating costs of WACS are less than those of AACS;

(b) ***Capital costs.*** The equipment cost of WACS is less than that of AACS with the same cooling capacity. On the other hand, the installation cost of WACS is generally higher than that of AACS. On the whole, the capital cost of WACS and AACS is about the same;

Note 1: *Refrigeration ton is a thermal measurement unit. One refrigeration ton is equivalent to 12,000 British Thermal Units (BTU).*

(c) ***Space required for installation.*** WACS are normally installed in-house and usually occupy the basement and ground floor space. Therefore, more indoor space is required. On the other hand, AACS, normally installed on the roof top, require more outdoor space than WACS and additional costs for structural reinforcement of the roof. Overall, there is no significant cost difference between AACS and WACS in terms of space required for installation;

(d) ***Environmental benefits.*** Reduction in electricity consumption of WACS can bring about substantial environmental benefits in terms of reduction in the emission of air pollutants and particulates from the power generation process;

(e) ***Environmental nuisance.*** AACS cause considerable environmental concern and create nuisance to neighbouring buildings due to their noise level and the emission of hot air. Such nuisance could be reduced with the use of WACS;

(f) ***Technology and equipment.*** The technology of WACS is proven and widely known among local engineers. The equipment for installing WACS is also readily available in the market. Therefore, the implementation of WACS will not involve a technology transfer problem;

(g) ***Consumption of water.*** WACS require the consumption of water for cooling and the periodic discharge of waste water. There may be some impact on the water supply system and the sewage system; and

(h) ***Health concern.*** The risk of developing LD has often been associated with WACS, in particular in the operation of fresh water cooling towers. However, with proper system design and maintenance, the risk can be minimised. The issue of LD is dealt with in paragraphs 6.1 to 6.35 below.

Impact on electricity consumption

2.7 The use of WACS will reduce electricity consumption substantially. In addition, it will also reduce the peak demand for electricity and further reduces the electricity bill for consumers using WACS. As a result, the peak demand of the whole territory will be reduced and the aggregate reduction in demand may defer the need for building new power plants.

Case study by the EMSD

2.8 In July 1996, the EMSD conducted a study to examine the pros and cons of WACS using fresh water cooling towers. The EMSD's study indicated that, for a typical 40-storey commercial building, an annual saving of $1.58 million in electricity consumption would be achieved by using WACS instead of AACS. After deducting the additional operating costs of $0.45 million on maintenance and water consumption, there would be a net annual saving of $1.13 million. Details are at Appendix C.

2.9 The EMSD estimated that for all the new commercial buildings completed in 1997, the saving in electricity consumption from using WACS would be about $12.4 million a year. The additional cost of annual water consumption, estimated to be 0.48 million cubic metres (MCM) or 0.05% of the total fresh water consumption, was $2.78 million. Therefore, the net annual saving from using WACS, instead of AACS, in all the new commercial buildings completed in 1997 would be about $9.6 million.

Audit observations

Saving in business operating costs from using WACS

2.10 Based on the saving figures of the EMSD's study, Audit estimates that the total saving in electricity consumption in the commercial sector will be about $1.2 billion a year if WACS are widely used in Hong Kong. The estimated annual saving in operating costs is about $847 million, after taking into account the additional costs of water consumption and maintenance. Details are at Appendix D.

Limited use of WACS in Hong Kong

2.11 Despite the substantial benefits of WACS, the vast majority of the central air-conditioning systems in Hong Kong are AACS. This is due to the limited supply of both sea water and fresh water for WACS. Sea water is only available to those buildings located along the sea front where sea water is obtained via pump pits. For buildings far away from the sea front, the supply of sea water is very expensive and sometimes technically not feasible.

2.12 When sea water is not available, the only other source is mains water. Mains water includes both fresh water and flushing water (treated sea water) obtained through the WSD's mains supply. **However, the WSD disallows the use of mains water for air-conditioning purposes on the grounds of water conservation (see paragraphs 4.1 to 4.3 below).**

2.13 Because of the limited supply of sea water and the ban on the use of mains water for air-conditioning systems, most of the property developers and engineers are left with no choice but to adopt AACS even though they are more expensive to operate.

Adoption of WACS in developed countries and Mainland cities

2.14 Audit has conducted a survey on the use of WACS in developed countries and Mainland cities listed at Appendix E. The results of the audit survey are as follows:

— all countries and cities responding to the survey indicated that they had widely used WACS because of the substantial saving in electricity consumption; and

— the supply of water for WACS came mainly from two sources:

(i) water from natural sources (e.g. sea, lake and river); and

(ii) fresh water from the mains.

2.15 The wide use of WACS in developed countries and Mainland cities has resulted in substantial savings in electricity consumption and reduced the operating costs of their businesses. This provides a good reference for Hong Kong in promoting the wider use of WACS.

Scope for the wider use of WACS in Hong Kong

2.16 **The limited use of WACS has deprived Hong Kong of the opportunity of realising substantial economic and environmental benefits and increasing the competitiveness of its businesses. Audit considers that there is scope for the wider use of WACS in Hong Kong.** As the major obstacle to using WACS is the supply of water, there is a need for the Administration to consider the feasibility of allowing the use of fresh water from the mains to enable WACS to be more widely used and the benefits of their use to be reaped.

Audit recommendations

2.17 **Audit has *recommended* that the Secretary for Planning, Environment and Lands and the Director of Electrical and Mechanical Services should:**

— **promote and facilitate the wider use of WACS in Hong Kong with a view to obtaining the economic and environmental benefits at an early date (see the first inset of paragraph 3.19 below); and**

— **in conjunction with the Secretary for Works and the Director of Water Supplies, explore the feasibility of allowing the use of fresh water from the mains for operating WACS (see paragraph 4.12 below).**

Response from the Administration

2.18 The **Secretary for Planning, Environment and Lands** has said that:

— he is delighted to see Audit taking an interest in the use of energy-efficient air-conditioning systems in Hong Kong. He very much hopes that findings of the review will help overcome difficulties faced in promoting energy-efficient air-conditioning systems; and

— he welcomes the audit recommendations and intends to promote and facilitate the implementation of more energy-efficient WACS where it is feasible.

2.19 The **Director of Electrical and Mechanical Services** has said that:

— the calculation done by the EMSD in July 1996 was a broad-brush preliminary estimation based on constant performance efficiency of the chiller of a 40-storey commercial building. As the efficiency of the chiller is also affected by the outdoor air temperature, the effective energy saving for the chiller in WACS cannot be maintained at 30% to 40% all year round. The additional maintenance cost assumption was also on the low side. Based on the latest available data, the saving in electricity consumption and the net saving in operating costs would be lower than the estimates made in 1996; and

— he agrees with the audit recommendations mentioned in paragraph 2.17 above except that the Administration should not be limited just to focus on using fresh water from the mains.

2.20 The **Secretary for Works** supports the initiative of using more energy-efficient air-conditioning systems as far as it is economically and financially justifiable. He has said that he will work closely with the Planning, Environment and Lands Bureau, the EMSD and the WSD in the formulation of long-term strategies on the implementation of WACS based on the findings of the consultancy study commissioned by the EMSD and the audit recommendations.

PART 3: THE GOVERNMENT'S EFFORT IN PROMOTING THE WIDER USE OF ENERGY-EFFICIENT AIR-CONDITIONING SYSTEMS

Discussions in advisory committees

3.1 At the time of inception of the EEAC in 1991, the subject of using WACS as a potential area of energy saving was raised. The Director of Water Supplies held the view that, for the sake of water conservation, fresh water should not be used for operating WACS. In 1993, the EEAC closed the subject without any concrete resolution. In December 1996, the EAC raised the question of the wider use of WACS again and decided that the subject should be further discussed by the EECSC.

3.2 At a meeting held in January 1997, the EECSC was in support of the wider use of WACS in Hong Kong and requested the Government to study how to take this matter forward. The EECSC considered that:

— air conditioning in commercial premises was no longer simply for comfort, but had become a basic requirement for business operations. If new buildings could adopt WACS, the energy saving would be significant;

— despite the WSD's strong reservations, the additional demand for fresh water would not be significant because new buildings would be constructed over a long period of time. The WSD was of the view that an increase in demand for fresh water by 10%, due to the use of fresh water for air conditioning, would create great pressure on the water supply. However, the EECSC considered that the shrinking of the industrial sector would enable the commercial sector to absorb the fresh water supply;

— there were technical and administrative barriers to using WACS, but they should not be insurmountable; and

— the environmental costs and benefits should be carefully analysed.

3.3 At an EECSC meeting held in July 1997, in response to the EECSC's request, the Government advised that a consultancy study would be conducted on the feasibility of, and economic justifications for, the wider use of WACS. The consultancy study, comprising a series of studies and with an estimated cost of $50 million, would be carried out over a period of six years, with earlier phases supporting policy decision making and later phases addressing specific implementation problems.

3.4 During the meeting, some members of the EECSC commented that it was disappointing to note that the Government only proposed to conduct a consultancy study and urged the Government to reconsider the programme. They pointed out that:

— most professionals would agree that WACS would be more energy-efficient than AACS and this did not need to be re-established. The reason why WACS were not used was due to the lack of water supply; and

— developers would have gone for WACS if they had sufficient water supply. It was a waste of time to carry out a feasibility study to adopt WACS.

3.5 At the conclusion of the meeting, the EECSC urged the Planning, Environment and Lands Bureau to see whether the study could be treated as a high priority project. In the event, the Preliminary Phase of the consultancy study commenced in October 1998.

Consultancy study on the wider use of WACS in Hong Kong

3.6 The series of consultancy studies, commissioned by the EMSD, were intended to:

— analyse and compare the energy efficiency and technical feasibility of various types of WACS;

— review existing water supply systems and infrastructure;

— forecast future water supply sources and demand conditions;

— assess the economic benefits and environmental impact of different types of WACS in comparison with AACS; and

— suggest ways, including institutional arrangements, of achieving the objectives.

3.7 The consultancy study was divided into the following three phases:

— ***Preliminary Phase.*** This phase would include a comprehensive estimation of energy and economical savings as well as institutional and environmental issues related to various kinds of WACS, including the more sophisticated centralised cooling systems. The study would also focus on the groundwork for facilitating the preparation of Phase 1 and Phase 2 studies;

— ***Phase 1.*** This phase would focus on a district-wide study based on recommendations from the Preliminary Phase. Detailed feasibility study would be carried out specifically on three districts (i.e. South East Kowloon Development District, a new reclamation district and another existing district). This phase would provide the necessary documents and report packages for the Administration:

(i) to take all necessary statutory, administrative and consultative steps;

(ii) to decide on the suitable project delivery process from detailed design to physical completion, and operation and maintenance of the project; and

(iii) to proceed with project implementation by either inviting the private sector to tender or arranging the necessary resources within the suitable works departments to deliver the project for the districts; and

— ***Phase 2.*** This phase would include a comprehensive territory-wide study which would examine and identify specific geographic areas in which the use of WACS might be feasible. It would recommend the corresponding infrastructure, resources and WACS schemes that might be required.

3.8 The centralised cooling systems covered in the Preliminary Phase involved the provision of water for air-conditioning purposes within a district through a dedicated distribution network. Compared with independent systems, the centralised cooling systems have advantages in terms of economy of scale and diversity (i.e. the different usage patterns of various users will result in a reduction of the capacity of the central plant). The centralised cooling systems consist of the following two main categories:

— ***Centralised piped supply of sea water system.*** This system consists of a large pump house at the sea front where sea water is pumped, centrally treated and transmitted to the buildings within a district for cooling the condenser using the once-through method or the evaporative cooling tower method; and

— ***District cooling system.*** This system consists of a large centralised dedicated chiller plant for generating and distributing chilled water to the buildings within a district for air-conditioning purposes. Each building no longer needs to install its own chiller and requires only a heat exchanger.

3.9 There are many complications and problems associated with the establishment of the centralised cooling systems. The setting up of a separate distribution network involves complicated technical and administrative problems, and has to be incorporated into the development plan of a district at an early stage. Thus, it may not be feasible for developed areas. It also involves the establishment of a body to operate the centralised system, devising a scheme of control if the body is a private company and monitoring the supply and charge for the service.

3.10 In order to tie in with the time-frame of the South East Kowloon Development, the EMSD plans to advance the completion of part of the Phase 1 Study to the end of 2000. Thereafter, government bureaux/departments will conduct consultations with the interested parties and potential operators. The Government will select operators by 2002 for the South East Kowloon Development to fit in its master development schedule so that the operators will be ready for operation by 2006.

3.11 The Preliminary Phase of the consultancy study, commenced in October 1998 at a consultancy fee of $3.15 million, was completed in May 1999. The study has shown that WACS are technically feasible and are economically and financially viable. The consultants also suggested that the Phase 2 Study Programme should be accelerated to overlap with the Phase 1 Study so that some districts suitable for a less intensive WACS infrastructure approach could be identified earlier than the sequential approach.

Audit observations

3.12 Audit noted that, although the scope of the consultancy study had included an examination of the water supply infrastructure and the future demand and supply in Hong Kong, the study took it for granted that the use of mains water was a constraint. It did not include a detailed examination of the rationale for disallowing the use of mains water for air-conditioning purposes. The emphasis of the study was on a district-by-district basis.

3.13 Audit considers that the major obstacle to the wider use of WACS is that, under the existing practice, the WSD does not allow the use of mains water for air-conditioning systems for comfort cooling. The possibility of making use of mains water for air-conditioning purposes was discussed extensively by the EEAC and the EECSC. The Secretary for Planning, Environment and Lands and the Director of Water Supplies had different views on the use of mains water for air-conditioning purposes. The Director of Water Supplies' views were that:

— the supply of flushing water from the mains could not be considered for serving WACS because of the small capacity and the low reliability of the system; and

— the policy of not allowing the use of mains water for air-conditioning purposes had to remain unchanged.

3.14 The Secretary for Planning, Environment and Lands was very keen on the idea of promoting the wider use of WACS because there were potentially very significant benefits to the community in his policy areas (i.e. energy efficiency, energy conservation and greenhouse gas emission). He was of the view that it was not the exclusive preserve of the WSD to decide government policy, even on issues which involve water. The difficulties and constraints did not appear to be insurmountable.

3.15 In February 1997, the Secretary for Planning, Environment and Lands appealed to the Secretary for Works for his support on further examining the possibility of using mains water for WACS. In response, the Secretary for Works said that:

— the supply of fresh water from Guangdong Province was steady and reliable. Therefore, the availability of fresh water did not appear to be a constraint provided that agreement could be reached with Guangdong Province for additional supply and that sufficient lead time was allowed for the expansion of the supply infrastructure; and

— he would not rule out the possibility of making use of fresh water for air-conditioning purposes as it was just another form of the industrial use of water.

3.16 **Audit considers that the most effective approach to promoting the wider use of WACS is to make available mains water for air-conditioning purposes. Developers and users should be given the option of installing WACS in new buildings and also in existing buildings when their air-conditioning plants are due for replacement. This approach will require little government intervention and allow the private sector to make use of WACS to save energy.** According to the results of an audit survey on the use of WACS in Hong Kong, the local professional engineering bodies and organisations are generally well aware of the use and benefits of WACS. They will recommend the use of WACS to their clients if there is no restriction on the use of mains water for air-conditioning purposes.

3.17 Audit considers that the first issue to be addressed in promoting the use of WACS is to carry out a thorough study on the WSD's ban on the use of mains water and the feasibility of making use of mains water for WACS. In Audit's view, the use of fresh water for air-conditioning purposes is a reasonable use of water. Moreover, the supply and demand forecast indicates that there is surplus fresh water in the water supply system to meet the additional demand by WACS (see paragraph 5.17 below).

3.18 **Audit also considers that the consultancy study is not addressing the issue of using energy-efficient air-conditioning systems in the most effective way. Unless the issue of the use of mains water for air-conditioning purposes is effectively tackled, little progress can be made to promote the wider use of WACS at an early date.**

Audit recommendations

3.19 **Audit has *recommended* that the Secretary for Planning, Environment and Lands and the Director of Electrical and Mechanical Services should:**

— **focus on using fresh water from the mains as the way forward for promoting and facilitating the use of WACS; and**

— **review the scope and direction of Phase 1 and Phase 2 of the consultancy study and make necessary adjustments with a view to making proposals to facilitate the use of fresh water for WACS.**

Response from the Administration

3.20 The **Secretary for Planning, Environment and Lands** has said that he acknowledges the audit recommendations mentioned in paragraph 3.19 above and will review the scope and phasing of further implementation studies. For new reclamations such as South East Kowloon Development, he sees there is opportunity for adopting more energy-efficient WACS, such as seawater-cooled district cooling systems. In areas/districts where it would be difficult to implement district cooling systems, he will work closely with the Works Bureau and the WSD to

examine how best to promote conversion to WACS using the WSD's fresh water and flushing water supplies.

3.21 The **Director of Electrical and Mechanical Services** has said that, although he agrees in principle that opening up mains water for WACS is an effective way, the Administration should optimise the use of energy from an energy conservation and sustainable development angle. The Preliminary Phase of the consultancy study revealed that the centralised cooling systems have much higher energy and environmental benefits which should be looked into. In view of the higher energy saving potentials of the centralised cooling systems, studies should still be made to explore the possibility of using them both in existing and new districts. He has also said that:

— the Preliminary Phase of the consultancy study was making comparison between various WACS with AACS;

— as fresh water usage for cooling towers did form an important part of the consultancy study and emphasis (if there was any) in the study on centralised cooling systems would only be made with a comparison of various scenarios. The Preliminary Phase of the consultancy study had not ruled out the use of fresh water which remained as one of the options throughout the study. Comparisons were then made with centralised cooling systems for energy efficiency and economic benefits in an objective manner; and

— he has modified the WACS consultancy study programme based on the findings of the Preliminary Phase of the consultancy study. He will bring forward the Phase 2 Study and make it as a Territorial Study which would commence in mid-2000. The original Phase 1 Study will become district studies for one new district in South East Kowloon Development and for one existing district in Wan Chai and Causeway Bay.

3.22 The **Secretary for Works** has said that:

— in the Preliminary Phase of the consultancy study completed recently on WACS, the economic and financial benefits of various types of WACS are compared. In general, the district cooling system is found to be the most energy-efficient option which has the highest economic and financial benefits;

— the consultancy study has also identified a number of key concerns and constraints that needed to be further addressed before any WACS option can be implemented on a wider scale. The EMSD will commission a territory-wide study to examine and identify areas where the wider use of WACS could be promoted taking account of the environmental, regulatory, institutional, financial, technical and land administration issues; and

— the WSD has started an internal review early this year on WACS. The review result will be available very soon to provide the necessary input to the territory-wide study.

PART 4: THE WSD'S BAN ON THE USE OF MAINS WATER FOR AIR-CONDITIONING PURPOSES

The Waterworks Regulations and the WSD's practice

4.1 As mentioned in paragraphs 2.11 to 2.13 above, the main reason for the limited use of WACS in Hong Kong is due to the WSD's ban on the use of mains water for air-conditioning purposes on the grounds of water conservation.

4.2 According to Regulation 13 of the Waterworks Regulations (Cap. 102), except with the permission in writing of the Water Authority, no person shall use water from the waterworks for any heating, cooling or humidification plant. The WSD's Departmental Instruction No. 902 "Use of Mains Water for Cooling/Air-Conditioning/Humidification Purposes" states that mains water is only allowed for use in WACS under the following circumstances:

— evaporative air-conditioning systems essential to an industrial process, whether this is for cooling or air-conditioning purposes, provided that water losses arise from evaporation only; and

— evaporative air-conditioning systems for essential purposes other than industrial processes provided that water losses arise from evaporation only. Approval of this type is limited to those cases where air-conditioning systems are absolutely necessary (e.g. air-conditioning systems for operating theatres in hospitals).

4.3 The WSD disallows the use of mains water for air-conditioning purposes with exemptions granted only for industrial processes or essential purposes. Under this arrangement, exemption will not be granted for air-conditioning systems for comfort cooling. This arrangement is incorporated in the WSD's publication "A Guide to the Preparation of Plumbing Proposals" for the information of plumbing practitioners and the public.

Enforcement of the ban

4.4 The ban on the use of mains water for air-conditioning purposes has been in force for a long time. According to the WSD's records, only 116 cases had been granted exemption in the past 20 years. Details are shown in Appendix F.

4.5 The number of approvals in recent years has shown a sharp decline. For the ten-year period from 1979 to 1988, 108 cases had been approved. However, for the ten-year period from

1989 to 1998, only eight cases had been approved. This was the direct result of fewer applications of air-conditioning systems for industrial processes or essential purposes.

Audit observations

4.6 The ban on the use of mains water for air-conditioning purposes was imposed a long time ago when there was a shortage in water supply and air conditioning was considered a luxury. Water restrictions were imposed in 1963, 1967, 1977, 1981 and 1982. Tremendous efforts were made by the Government to secure an adequate supply of water to meet the growing demand. Nowadays, 76% of the water supply in Hong Kong is secured by the supply from Guangdong Province.

4.7 **However, air conditioning is no longer simply for comfort and has become a basic requirement for commercial operations. Air conditioning provides a vital support for business activities.** A reduction in the electricity cost of air conditioning will mean a reduction in the operating costs of businesses. This will in turn enhance their competitiveness. In this context, the use of water for WACS in order to reduce electricity consumption should not be regarded as a waste of water. Notwithstanding the need for water conservation, Audit considers that, under the present circumstances, this is a good cause for using water and should no longer be subject to a ban.

4.8 Audit notes that the WSD has not imposed a similar restriction on the use of mains water on other trades or specific uses of water. **Audit considers that the need for the present ban on the use of mains water for WACS is questionable and that the demand for fresh water by WACS should be catered for by the water supply system.**

Practices in developed countries and Mainland cities

4.9 The audit survey mentioned in paragraph 2.14 above has also revealed that the developed countries and Mainland cities responding to the survey do not impose a similar ban on the use of mains water for air-conditioning purposes. The examples of Singapore and some Mainland cities, including Beijing, Shanghai, Guangzhou and Shenzhen, are particularly relevant. Water conservation is given high priority in these areas and yet there is no restriction on the use of mains water for air-conditioning purposes.

Enforcement of the ban

4.10 In 1996, a survey of cooling towers conducted by the EMSD found that there were about 12,000 cooling towers in Hong Kong (see paragraph 6.22 below). In comparison, the total number of approvals given by the WSD to use fresh water for air-conditioning purposes was only 116 for

the past 20 years. The EMSD's survey was intended for the prevention and control of LD and did not identify the source of water supply for the cooling towers surveyed. Audit noted that:

— according to professionals of the building services industry, it was common knowledge that most of the water cooling towers were installed by small to medium undertakings like restaurants, retail shops and small factories for comfort cooling, with water supplied from unauthorised connections to the mains; and

— little monitoring and prosecution work had been carried out by the WSD on unauthorised connections. In 1997 and 1998, the WSD only prosecuted six cases of misuse of water for air-conditioning purposes.

Another source of revenue for water supply services

4.11 The use of fresh water for air-conditioning purposes can be seen as another form of industrial use of water. For the past ten years, the consumption of fresh water by the industrial sector and the Government's revenue from this source had been decreasing steadily. The use of fresh water for WACS can make good use of the water supply available from the reduced consumption of the industrial sector, and provide a new source of revenue for the Government.

Audit recommendation

4.12 **Audit has *recommended* that the Secretary for Works and the Director of Water Supplies should critically review the rationale for disallowing the use of fresh water for WACS after taking into account the following factors:**

— **the need for WACS in commercial premises;**

— **the practices of developed countries and Mainland cities; and**

— **the economic and environmental benefits of relaxing the ban.**

Response from the Administration

4.13 The **Director of Water Supplies** has said that he welcomes Audit's interest in the subject on the wider use of WACS in Hong Kong. The findings of the audit review in general have addressed the crux of the subject. He has also said that:

— the use of mains water for air conditioning for comfort purpose has always been his concern and the subject was last reviewed in 1995. He did not relax the policy on the use of mains water at that time because the capacity of the treatment works was not adequate to cope with the anticipated additional demand of the evaporative-type WACS. Also at that time, there was no government policy to encourage the use of mains water for WACS for comfort purpose. The study recommended that a further review should be conducted by 2000. As part of his resource planning and in response to the EMSD's study on the wider use of WACS, he has advanced his review on the subject to early 1999. The review will be completed in November 1999;

— the WSD's stance on disallowing the use of mains water for air-conditioning purposes was made against the background of insufficient treatment capacity envisaged at the time to meet the additional air-conditioning water demand before 2000 and the possibility of accelerated population growth after 1997. There was no prejudice against the use of mains water for WACS (Note 2); and

— the WSD supplies water for evaporative-type air cooling for essential industrial and other processes. However, the WSD has not been able to extend such use to air cooling for comfort because of the limited water resources available and inadequate system capacity to cope with the additional requirement. It should be mindful to note that not very long ago, Hong Kong faced some dry years which almost triggered off water rationing.

4.14 The **Director of Architectural Services** has said that he fully supports the promotion of WACS in Hong Kong and the relaxation of the ban on the use of fresh water for air-conditioning purposes as early as possible.

Note 2: *Audit notes that the WSD had raised objection to the use of fresh water for operating WACS when the EEAC and the EECSC considered, in 1991 and 1997 respectively, the wider adoption of WACS (see paragraphs 3.1 and 3.2 above).*

PART 5: THE DEMAND AND SUPPLY OF FRESH WATER IN HONG KONG

The water supply system in Hong Kong

5.1 The water supply system operated by the WSD consists of a fresh water supply system and a sea water supply system for flushing purposes. The fresh water supply system includes 17 reservoirs, 19 treatment works, 141 pumping stations, 166 service reservoirs, 4,809 kilometres of water mains, and about 300 kilometres of catchwaters and tunnels. The total water storage capacity is 586 MCM and the daily water treatment capacity is 4.3 MCM.

5.2 The system for supplying sea water for flushing purposes in the urban areas and the new towns is a completely separate network consisting of 38 pumping stations, 49 service reservoirs and 1,111 kilometres of water mains. The consumption of flushing water in 1998 was 199 MCM. Because of its small capacity and relatively low reliability of supply, the supply of flushing water from the mains cannot be used for air-conditioning purposes.

Supply of fresh water

5.3 Fresh water in Hong Kong mainly comes from two sources, i.e. rainfall catchment and water purchased from Guangdong Province. Water purchased from Guangdong Province accounts for most of Hong Kong's fresh water supply. Details are at Appendix G. The present water purchase agreement, signed in 1989, secures water supplies to meet Hong Kong's needs up to 2011. Negotiations on the new agreement will take into account the forecasted demand of Hong Kong for fresh water.

Audit observations on supply of fresh water

5.4 The present infrastructure for the supply of water from Guangdong Province has a design capacity of 1,100 MCM a year. As the mean annual rainfall catchment is about 288 MCM, the total capacity of water supply in Hong Kong is 1,388 MCM. In 1998, the total consumption of fresh water was 916 MCM. Compared with the capacity of 1,388 MCM, there was a significant margin to cater for the growth in water consumption.

5.5 Audit notes that the WSD has revised the planned supply of fresh water from Guangdong Province. As the increase in water consumption is less than that estimated, the annual increase in the planned supply of water from Guangdong Province has been revised downward from 30 MCM to 10 MCM as shown in Appendix H.

Consumption of fresh water

5.6 For the past 20 years up to 1990, the consumption of fresh water had been on an upward trend at about 6% a year. From 1991 to 1998, the growth rates of fresh water consumption varied from −1.62% to 2.92%. Actual consumption ranged from 750 MCM to 928 MCM, while industrial consumption showed a declining trend. The consumption of fresh water in Hong Kong from 1987 to 1998 is shown in Appendix I.

Audit observations on consumption of fresh water

5.7 According to the records of the WSD, the decline in the consumption of fresh water in Hong Kong was mainly attributed to the significant decrease in consumption by the industrial sector as a result of the relocation of manufacturing industries, particularly the water-intensive textile and clothing industries, outside Hong Kong. Appendix I shows that there was a significant reduction in industrial consumption of 116 MCM from its peak consumption of 182 MCM in 1989 to 66 MCM in 1998.

5.8 The WSD's projection for the supply of fresh water for the years from 1999 to 2012 is shown in Appendix J. It can be seen that Hong Kong has a forecasted surplus supply of fresh water for the years from 1999 to 2012. The surplus will vary from the lowest of 69 MCM in 2004 to the highest of 164 MCM in 2011 and 2012. Moreover, Audit notes that the supply of water from Guangdong Province can run up to 1,100 MCM a year. If this figure is used in the forecast of supply as shown in Appendix J, the forecasted surplus will be as high as 349 MCM in 2004 and 374 MCM in 2011. **In Audit's view, there is ample capacity in the water supply system to meet future growth and additional demand for fresh water.**

The additional consumption of fresh water by WACS

Consumption of water in WACS using evaporative cooling towers

5.9 In the evaporative cooling towers of WACS, water is consumed through:

— evaporation loss of the circulating cooling water;

— drift loss through the air grilles of the cooling towers; and

— the periodic replacement of a small portion of the circulating cooling water by clean fresh water to maintain the water quality.

The total loss of water is about 1.3% to 1.8% of the circulating cooling water and additional water is required for replenishment.

5.10 If WACS are widely used in Hong Kong, it will bring about additional demand for fresh water. However, in view of the substantial capital cost of WACS, it is unlikely that the non-domestic sectors will switch to WACS immediately. Instead, WACS will only be used when AACS are due for replacement. **As AACS have an average life span of about 15 to 20 years, the conversion of AACS to WACS will take place over a long period of time and the increase in water consumption will also be gradual. Audit considers that there should be ample time to adjust the infrastructure of the water supply system, if necessary, to cater for the additional demand for fresh water.**

The 1995 WSD study on the possible relaxation of the ban

5.11 In August 1995, due to the increasing pressure for the relaxation of the ban on the use of mains water for air-conditioning purposes, the WSD conducted a study on the possibility of a general relaxation of the ban.

5.12 Based on the engineering assumptions on air-conditioning systems provided by the Architectural Services Department and the statistics of floor areas in commercial and industrial premises published by the Rating and Valuation Department, the WSD projected the demand for fresh water by WACS in Hong Kong. The results indicated that the demand would steadily increase from 39.3 MCM in 2000 to 119.6 MCM in 2015. Details are at Appendix K.

5.13 The WSD's projection on additional water consumption was based on a number of assumptions including the following:

— the air-conditioning systems for all the floor areas of the commercial and industrial premises would be converted from AACS to WACS; and

— there would be an annual growth of 3.2% in consumption.

5.14 The WSD's report noted that the relaxation on the use of mains water for air-conditioning purposes was on the whole beneficial to the community. However, because of the impact of the predicted additional demand on the stability of water supply and the capacity of treatment works, the report concluded that relaxation of the ban should not be introduced. In January 1997, based on the findings of the report, the WSD's representative objected to the idea of allowing the use of fresh water for WACS at a meeting of the EECSC (see the second inset of paragraph 3.2 above).

Audit observations on the additional consumption of fresh water by WACS

5.15 Audit has examined the basis of the WSD's projection and found that the two assumptions made by the WSD in paragraph 5.13 above are questionable. In projecting the demand, the WSD assumed that there would be an across-the-board adoption of WACS for all the premises and that all the floor areas would be accounted for in estimating the water consumption. This method is inconsistent with the EMSD's assumption that only about 70% of the total floor area was suitable for WACS using fresh water cooling towers. Audit considers that the WSD's assumption overstates the predicted demand for additional fresh water because:

— some buildings have already installed WACS using sea water once-through systems;

— not all buildings are air-conditioned by central air-conditioning systems. Some buildings are air-conditioned by individual air-conditioners installed by the tenants;

— not all the floor areas of the buildings are air-conditioned. Areas like staircases, plant rooms, pantries, toilets and storerooms are usually excluded from the cooling load of central air-conditioning systems; and

— some buildings may not be suitable for conversion from AACS to WACS because of building design or structural problems.

5.16 The WSD had also assumed that the annual growth in consumption rate, due to the increase in floor area, was 3.2%. However, Audit noted that the actual increase in the total floor area of commercial and industrial premises in the past five years from 1993 to 1997 was only 1.4% a year.

5.17 Audit has re-calculated the demand for additional water using the 70% conversion rate and 1.4% growth rate in the total floor area. Details are at Appendix L. **The demand for fresh water based on Audit's projection is much less than that based on the WSD's projection. The demand for fresh water will only increase from 13.3 MCM in 2000 to 56.9 MCM in 2015. Table 1 below illustrates that the additional demand for fresh water by WACS can be fully met by the surplus supply of fresh water.**

Table 1

Comparison of the supply of fresh water and the additional demand arising from the adoption of WACS

Year	Forecasted consumption	Forecasted surplus	Additional demand by WACS	Additional demand by WACS as a percentage of forecasted consumption
	(MCM)	(MCM)	(MCM)	(%)
1999	934	124	—	—
2000	957	111	13.3	1.39%
2001	975	103	16.2	1.66%
2002	995	93	19.1	1.92%
2003	1,007	91	22.0	2.18%
2004	1,039	69	24.9	2.40%
2005	1,023	95	27.8	2.72%
2006	1,017	111	30.7	3.02%
2007	1,011	127	33.6	3.32%
2008	1,010	138	36.6	3.62%
2009	1,004	154	39.5	3.93%
2010	1,007	161	42.4	4.21%
2011	1,014	164	45.3	4.47%
2012	1,024	164	48.2	4.71%

Source: WSD's records and Audit's projection

Capacity of treatment works and distribution network

5.18 Apart from the impact on the overall supply of water, the additional consumption of fresh water due to WACS will also have an impact on the capacity of the treatment works and the distribution network. Audit notes that the WSD has a treatment capacity of 4.3 MCM a day or 1,569.5 MCM a year. This is well above the actual consumption of 916 MCM in 1998 and the forecasted consumption (including additional demand by WACS) of 1,072 MCM in 2012. In addition, two treatment works are under construction in Tai Po and Ngau Tam Mei. The completion of these two treatment works will further increase the treatment capacity on a district as well as a territory-wide basis.

5.19 Audit considers that the impact of the additional demand for fresh water on the distribution network is not significant. According to Audit's projection in Table 1 above, the additional consumption will be about 5% of the forecasted consumption of fresh water upon full conversion to WACS. Furthermore, the additional demand will only increase gradually because the conversion of AACS to WACS will take place over a long period of time. This will give ample

time for making necessary improvements or adjustments to the distribution network. In this connection, Audit notes that the WSD has planned for a water mains upgrading programme to replace 60% of the fresh water mains and 34% of the sea water mains in 20 years at an estimated expenditure of $13 billion. Audit considers that this water mains upgrading programme should take into account the future growth in the demand, including the additional demand by WACS, for fresh water.

5.20 Audit considers that the ultimate goal is to lift the ban entirely on a territory-wide basis. The ban can first be relaxed on a district basis subject to the conditions of the distribution network and the local demand. The starting point should be on those districts which have surplus distribution capacity (e.g. industrial districts that have experienced substantial reduction in water consumption). Approvals for the use of fresh water can initially be granted on a case-by-case basis subject to the supply and demand condition in individual districts before the lifting of the ban.

The recent views of the WSD

5.21 In February 1999, Audit discussed with the WSD about the feasibility of the lifting of the ban. Subsequently, in March 1999, the WSD informed the EMSD that:

— in the short term, in view of the slowdown in the growth of fresh water consumption, the water supply system and treatment capacity were capable of meeting the demand for fresh water by evaporative-type WACS; and

— in the long term, the additional demand for fresh water would be taken into account in the negotiation of the new water purchase agreement from Guangdong Province and in the planning of more treatment works. However, the existing distribution network would need to be substantially upgraded in order to handle the additional demand. Given time and money, the problem of upgrading the existing distribution network should not be insurmountable.

In April 1999, the WSD initiated a study to re-examine the impact on the fresh water supply system upon relaxing the ban on the use of fresh water for air-conditioning purposes.

Audit recommendation

5.22 **Audit has *recommended* that the Secretary for Works and the Director of Water Supplies should consider formulating an action plan to relax the ban on the use of mains water for air-conditioning purposes at an early date.**

Response from the Administration

5.23 The **Director of Water Supplies** has said that:

(a) 1,100 MCM is only the ultimate design capacity of the transfer facilities for the supply of water from Guangdong Province. The reception capacity is actually implemented in phases to match with the demand;

(b) the mean yield of rainfall catchment (288 MCM) may not occur every year. In fact, there is more or less equal chance for the actual yield to exceed or fall below the mean yield. It is therefore necessary to examine the adequacy of water resources in dry years such as during 1 in 10 years droughts (182 MCM) and 1 in 50 years droughts (107 MCM) where deficit may occur. The deficit will have to be met from the storage available at the time (Note 3);

(c) his current assessment is that the additional demand for fresh water by WACS for the period from 2000 to 2014 ranges from 21.8 MCM to 108.1 MCM (Note 4);

(d) the difference between his current assessment and Audit's estimate is due to the following differences in assumptions:

(i) the WSD assumes 100% and Audit assumes 70% of the commercial area will be air-conditioned (Note 5); and

(ii) the WSD forecasts an average 2.9% annual growth rate of air-conditioning water demand attributed to the new non-domestic developments while Audit forecasts a 1.4% annual growth rate (Note 6);

Note 3: *In Audit's view, the mean yield provides a reasonable basis for projecting the rainfall catchment in a particular year. Therefore, it is used in Audit's estimate of the supply of fresh water. Audit noted that in April 1999, the reservoir storage level was 551 MCM, or 94% of the total storage capacity. This high storage level, coupled with the security of water supply from Guangdong Province and the provision of optional increase under the purchase agreement, should provide a good buffer in the event of droughts.*

Note 4: *The WSD's current estimated demand for fresh water by WACS can be catered for by the forecasted surplus supply of fresh water (see Table 1 above), ranging from 69 MCM to 164 MCM from 1999 to 2012.*

Note 5: *For the reasons stated in paragraph 5.15 above, Audit considers that only 70% of the floor area should be taken into account in the calculation of demand for fresh water by WACS. This is consistent with the practice of the EMSD and the Architectural Services Department. Taking into account 100% of the floor area will overestimate the demand for fresh water by WACS. Even if 100% of the floor area is assumed, the estimated demand for fresh water by WACS can still be catered for by the forecasted surplus supply of fresh water (see Note 4 in paragraph 5.23(c) above).*

Note 6: *Audit notes that the 2.9% adopted by the WSD in its calculation is the forecasted growth rate of floor area in non-domestic premises, which has turned out to be overestimated over the past years (see paragraph 5.16 above). Therefore, Audit considers that the actual rate of 1.4% over the period from 1993 to 1997 should be a better estimate of the growth rate in floor area.*

(e) a treatment works must have sufficient capacity to meet the peak demand and not just the mean daily demand of the area it serves. It must also cater for growth in the demand of the area because it takes seven to ten years to commission a new treatment works. As treatment works are not fully integrated, spare capacity at one point cannot meet the forecast deficit of another. It is not right to compare the total plant capacity with the total territorial mean daily demand and conclude that there are surplus capacities; and

(f) the local distribution systems in commercial areas such as Central and Western District, Wan Chai, Causeway Bay and Tsim Sha Tsui are generally inadequate to cope with the additional air-conditioning water demand. Typically, water mains diameters in these distribution systems range from 75 millimetres to 150 millimetres. To cater for the additional water demand, larger mains with diameters from 100 millimetres to 200 millimetres are required. Thus, extensive improvement works to the distribution networks in these areas are anticipated. It cannot be said that the impact of the additional water demand on the distribution network is not significant (Note 7).

5.24 The **Director of Architectural Services** has said that he understands from the audit report that the fresh water supply distribution system in some of the districts may not be capable of catering for the additional demand by WACS. The maximum load of the air-conditioning system lasts from 11:00 a.m. to 4:00 p.m. depending on the orientation and shading of the building. If this period coincides with the peak period of the fresh water demand, the WSD can consider requiring users of WACS to provide water storage tanks with adequate capacity to meet the peak water demand period (Note 8).

5.25 The **Secretary for Works** has said that the audit recommendation to formulate an action plan to relax the ban on the use of mains water will be addressed in the territory-wide study commissioned by the EMSD on WACS.

Note 7: *Audit considers that the impact of the additional demand on the distribution network will not be significant. The additional demand will start from a low level upon relaxing the ban when installation of WACS in new buildings and conversion of AACS into WACS in old buildings take place. Such demand will increase gradually over a long period of time until full conversion to WACS. By then, it will account for only 5% of the total water consumption (see paragraph 5.19 above). In Audit's view, future plans on the distribution network and the scheduled water mains upgrading programme should be able to factor in the gradual increase in demand by WACS.*

Note 8: *The proposal of the Director of Architectural Services on the use of a storage tank can ease the impact of the demand for fresh water by WACS on the distribution network. The idea is to top up the storage tank at night when the demand is low and to use the tank supply for WACS during the peak demand period in the daytime.*

PART 6: HEALTH CONCERN OVER THE OPERATION OF FRESH WATER COOLING TOWERS

Legionnaires' Disease

6.1 In promoting the wider adoption of WACS using fresh water cooling towers, special care has to be taken because the operation of fresh water cooling towers has been found to be associated with LD.

6.2 LD was first recognised in July 1976 when an outbreak occurred among the delegates attending an American Legion Convention in Philadelphia. More than 200 cases were reported and 34 people died. After medical investigations, it was identified that the bacteria of the disease were previously unknown and they were subsequently given the name *Legionella Pneumophila* (LD bacteria). Since the identification of the LD bacteria, sporadic cases of LD and outbreaks were reported in the United States, the United Kingdom, Australia and Singapore. In Hong Kong, a few cases of LD were recorded in recent years. Based on past statistics, it has been found that LD is more active and serious in European countries, the United States and Australia.

6.3 LD is an uncommon infection and some cases of LD may not have been detected or reported. LD typically manifests as severe pneumonia, with patients showing symptoms of malaise, muscle pain, cough, breathlessness, headache and fever, often culminating in respiratory failure. According to some overseas research, the attack rate of LD in an outbreak was found to be less than 5% and the fatality rate of this disease was about 10%. Many antibiotics are highly effective against the LD bacteria. If the patient is treated with appropriate antibiotics near the onset of pneumonia, the outcome is excellent, especially if the patient has no underlying illness that compromises his/her immune system. For patients whose immune systems are compromised, delay of appropriate therapy can result in prolonged hospitalisation, complications or death.

6.4 The LD bacteria are widespread in natural water resources such as rivers, streams, ponds and wet soil. However, an outbreak of LD is mostly associated with man-made water systems. The presence of the LD bacteria usually is not associated with the infection of LD in the absence of favourable conditions for their multiplication and dispersion. Transmission of the bacteria to human bodies is mainly by inhalation of airborne droplets (i.e. aerosols) or particles in fine mist containing the bacteria into the lungs where they are deposited. According to previous reported cases, the sources of aerosols causing an outbreak were mainly traced to building water systems including evaporative cooling towers and humidifiers of air-conditioning systems, hot and cold water services, whirlpool spa, industrial heating and cooling processes. These systems are normally designed to operate at the favourable temperature for the growth of the LD bacteria.

LD and the operation of cooling towers

6.5 During the normal operation of a cooling tower, aerosols are formed and may be carried into the environment through the tower exhaust. If the LD bacteria are present in the cooling water, inhaling the aerosols can result in infection. Poorly maintained cooling towers have been implicated in LD outbreaks overseas. Occurrences of LD have been demonstrated in buildings which have cooling towers as part of their air-conditioning systems, although the disease has also been observed in buildings and circumstances unrelated to air-conditioning systems.

6.6 Contaminated cooling towers pose a public health hazard. Water droplets containing the LD bacteria released from the towers can remain suspended in the air for a long time, especially under humid conditions. These droplets can also travel considerable distances. Large droplets can evaporate to become smaller ones and still contain the same number of bacteria. The smaller droplets can be inhaled and cause LD in susceptible people.

6.7 Infection depends on a number of factors including host immunity, environmental factors, viability and concentration of the LD bacteria. Infection may occur when the LD bacteria are left to develop to large concentrations. As far as is currently known, the only route of infection is by inhalation and not by ingestion or person-to-person contact. It is believed that elderly people, hospital patients and people suffering from deficiency in their immune system are most vulnerable to the disease.

Prevention and control of LD

6.8 Research has found that the LD bacteria can be present anywhere in the environment and complete elimination of them is impossible. Instead, reasonable preventive measures can be instituted to prevent the build-up of a hazardous number of the bacteria. Prevention and control can generally be effected by good housekeeping and regular maintenance of plants and equipment.

6.9 Improper operation and maintenance of water apparatus, such as cooling towers, will help spread LD. However, this potential health hazard can be prevented and minimised by the proper design of the water apparatus and their proper operation and maintenance in accordance with established technical and administrative measures, including the regular treatment of the cooling water by chemicals to prevent the growth of bacteria.

Overseas practices in the prevention and control of LD

6.10 Technical and administrative measures have been developed in overseas countries to prevent and control LD. Some developed countries (e.g. the United Kingdom, Australia and Singapore) require all cooling towers to be registered with regulatory authorities to ensure that cooling tower installations are designed, constructed and maintained properly to prevent the spreading of LD.

6.11 Typical technical and administrative measures include the following:

— dosing of the circulating cooling water with chemicals to inhibit the growth of the bacteria;

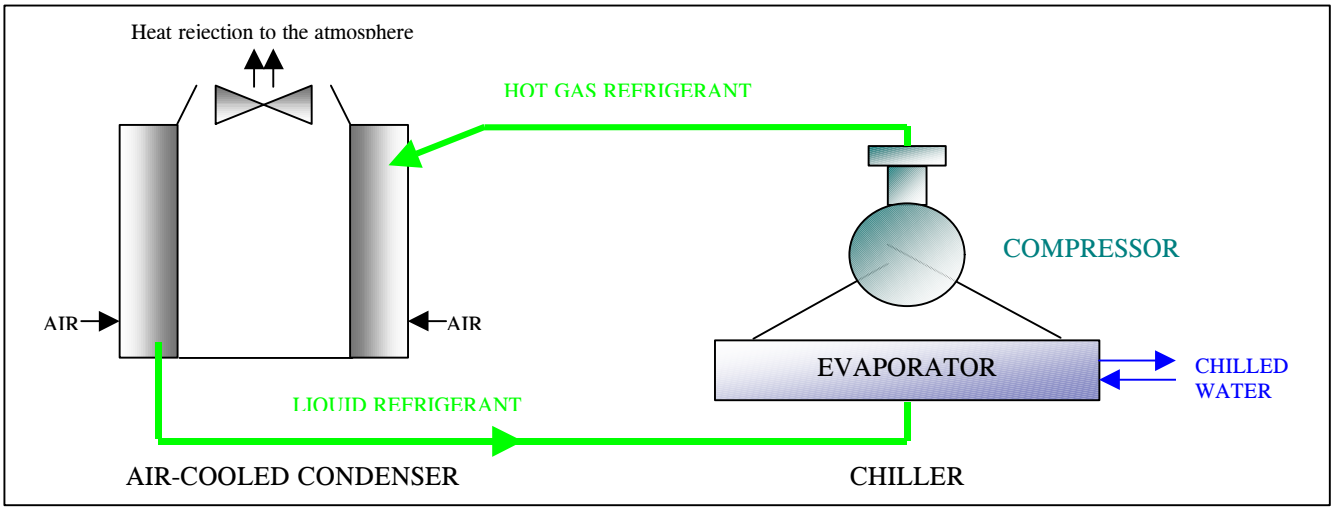
— effective cleaning and maintenance of the cooling towers;

— better location of the cooling towers away from the fresh air intake of the air-conditioning system; and

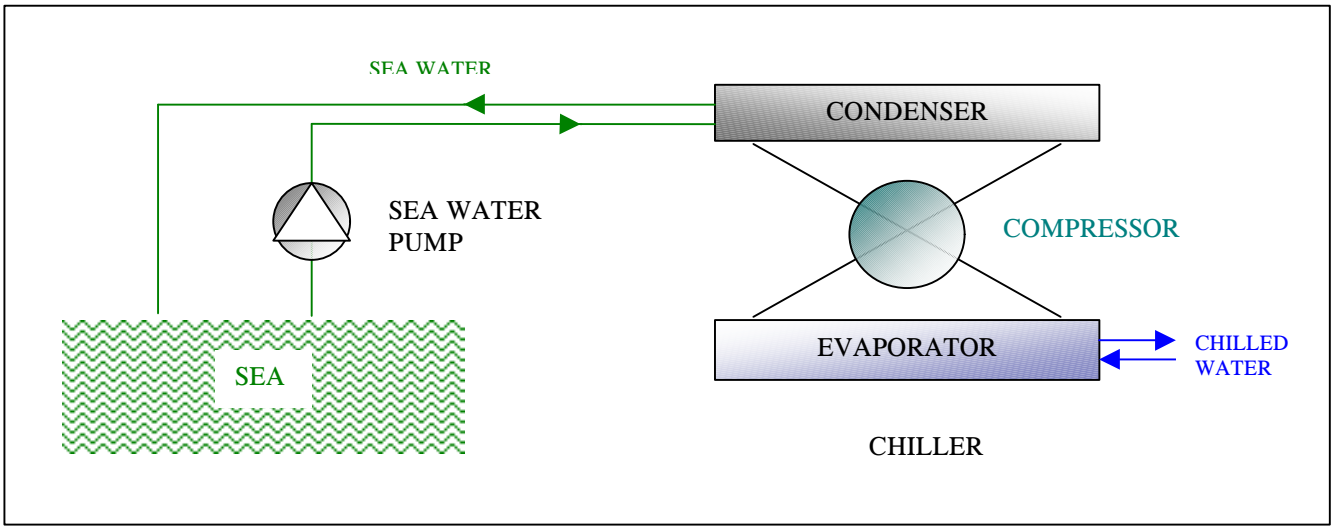
Figure 1

Schematic diagrams of the chillers of typical AACS and WACS
(paragraph 2.3 refers)

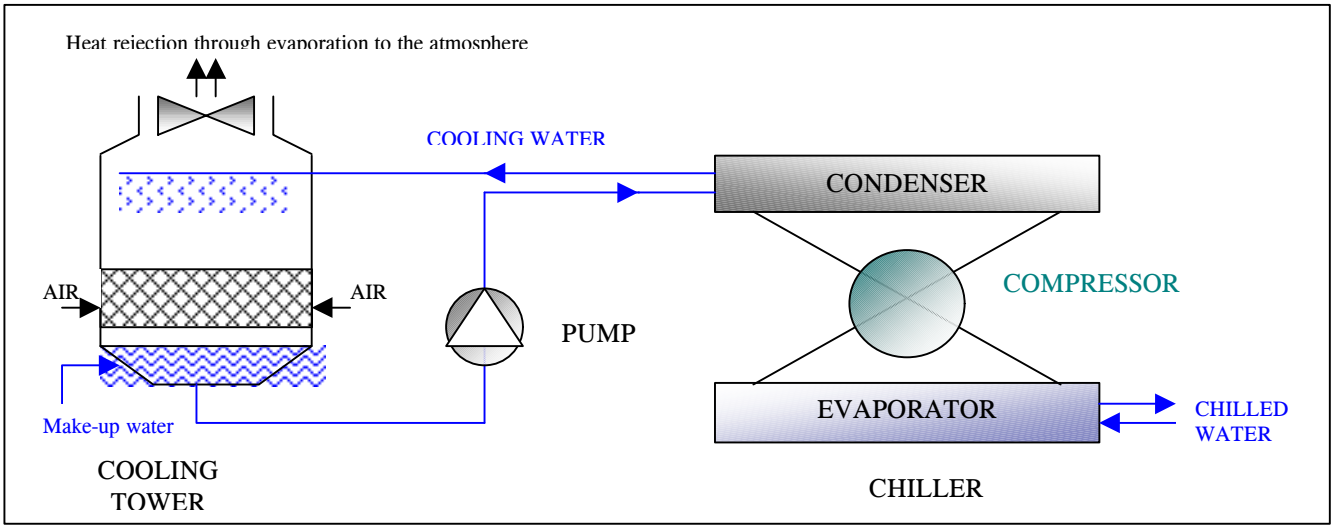
A. AACS



B. WACS (Sea water once-through system)



C. WACS (Evaporative cooling tower system)



Source: Engineering handbooks on air-conditioning systems

Photograph 1
A cluster of cooling towers found in shabby condition at a back alleyway in Mong Kok (paragraph 6.28 refers)

Source: Photograph taken by Audit

Photograph 2
A cooling tower found in shabby condition and located close to windows of nearby premises in Yau Ma Tei (paragraph 6.28 refers)

Source: Photograph taken by Audit

Photograph 3
Old and new cooling towers installed on the podium of a commercial building in Mong Kok (paragraph 6.28 refers)

Source: Photograph taken by Audit

Photograph 4
Two big cooling towers installed on the podium of a public housing estate in Sha Tin (paragraph 6.28 refers)

Source: Photograph taken by Audit

Photograph 5
Cooling towers found in an alleyway between two industrial buildings in Kwun Tong (paragraph 6.28 refers)

Source: Photograph taken by Audit

Photograph 6
Large and small cooling towers installed in industrial buildings in Kwun Tong (paragraph 6.28 refers)

Source: Photograph taken by Audit

— legislative maintenance and monitoring requirements from the Government.

6.12 In the United Kingdom, the Notification of Cooling Towers and Evaporative Condensers Regulations, enacted in 1992, require the registration of all cooling towers with local authorities to ensure that cooling tower installations are designed, constructed and maintained properly to prevent the spreading of LD.

6.13 In Australia, the New South Wales State Government has legislation requiring cooling tower owners to notify the local governments the existence of their cooling towers. It is illegal to own an unregistered cooling tower. The local governments have the responsibility to monitor the database of cooling towers in their areas. The registration mechanism assists in identifying the locations of cooling towers which can be the potential source of an outbreak of LD. Inspections of maintenance records and random sampling of water of cooling towers are also carried out.

6.14 In Singapore, the Ministry of the Environment has published a code of practice to guide those responsible for maintaining cooling towers on a programme to minimise LD risk through proper design and maintenance. Inspectors carry out random sampling of water from the estimated 3,000 cooling towers in Singapore. Although there is no legislation on the control of design, installation and maintenance of cooling towers, it is understood that all the cooling towers in Singapore comply with the government requirements.

6.15 Outbreaks of LD in other developed countries have shown that this disease can be a threat to life. It is known that cooling towers pose risk to the spreading of LD. However, the risk associated with contaminated cooling towers can be minimised by technical and administrative measures. It is generally believed that properly designed, installed, operated and maintained cooling towers do not pose unacceptable health risk.

LD in Hong Kong

6.16 Some developed countries have established technical and administrative measures to prevent and minimise the risk of LD. However, these countries do not ban the use of cooling towers simply because of the risk associated with LD. In Hong Kong, there is also no ban on the use of cooling towers. The WSD's ban is on the use of mains water for WACS on water conservation grounds rather than on the LD risk. Audit does not consider that the Government should forbid the use of cooling towers because of the LD risk. In Audit's view, the key to the prevention and control of LD lies with the proper operation and maintenance of all water apparatus susceptible to the proliferation and spreading of the LD bacteria.

6.17 In Hong Kong, sporadic cases of LD have been reported but no major outbreak has occurred. Problems associated with LD are considered to be more serious in Europe, the United States and Australia than in Hong Kong. However, it is potentially hazardous in Hong Kong because of the warm and humid climate, and the presence of numerous cooling towers and centrally air-conditioned buildings which are ideal for the proliferation of the LD bacteria.

Government action on the prevention of LD

6.18 In 1985, the Government established the Prevention of Legionnaires' Disease Committee (PLDC) to formulate strategies for the prevention and management of the possible outbreak of LD. The Committee is chaired by an Assistant Director of the EMSD with members from the Department of Health, the Works Bureau, the University of Hong Kong, the Chinese University of Hong Kong, the Architectural Services Department and the WSD. The terms of reference of the PLDC are to seek advice and guidance of experts both in Hong Kong and overseas in the fields of public health, microbiology and engineering services with a view to recommending operation, maintenance and design guidelines for minimising the risk of occurrences of LD in Hong Kong.

6.19 In 1987, the PLDC issued its first report on LD and concluded that the disease could be controlled by:

— ensuring good engineering practice in the design of cooling towers, ventilation systems, and the positioning of the cooling towers and ventilation intakes; and

— carrying out a proper preventive programme as part of the normal operation of cooling and ventilation systems, primarily by chemical treatment and periodic maintenance/cleaning of systems to prevent the growth of the LD bacteria.

The Code of Practice

6.20 In November 1994, the PLDC issued the "Code of Practice for the Prevention of Legionnaires' Disease in Hong Kong" (Code of Practice). The Code of Practice was prepared with reference to similar codes in overseas countries such as Australia, the United Kingdom and Singapore. The Code of Practice contains the recommended practices to be followed in the design, installation, operation and maintenance of air-conditioning and water systems, especially cooling towers and centralised hot water supply systems for the effective control and prevention of LD. The recommended practices are as follows:

— under all circumstances, the first option to be examined is to avoid or abandon, where reasonably practicable, the use of equipment which can create a spray of contaminated water. Where the use of such equipment cannot be avoided, the risk should be prevented or controlled by measures to reduce exposure to contaminated water droplets and to prevent conditions which allow the proliferation of the LD bacteria;

— the cooling tower should be sited sufficiently far away from the public thoroughfare, and air intakes of ventilation and air-conditioning systems;

— a comprehensive water treatment programme should be adopted to continuously or intermittently filter and treat the water with corrosion inhibitors, disinfectants, and anti-fouling chemicals;

— the water treatment programme should aim at controlling the fouling of pipework and cooling tower due to silt, scale and microbial growth in order to maintain efficient heat transfer at metal surfaces, and ensure free flow of water through the system; and

— cooling towers should be cleaned, desludged and disinfected regularly. The frequency of cleaning should be based on tower cleanliness and the particular site environment.

6.21 The PLDC considered that when the requirements of the Code of Practice are complied with, the quality of the water circulating in the cooling tower can be maintained and the risk of LD can be minimised. According to the Code of Practice, it should be read and followed by all architects, engineers, building owners, building managers as well as government authorities. The Code of Practice also requires a formal record for every cooling tower with accurate and adequate information to be kept and made available for inspection if demanded by government appointed officials.

Survey of cooling towers

6.22 In 1995, the PLDC commissioned, through the EMSD, a territory-wide survey of cooling towers in Hong Kong. The objectives of the survey were to collect and compile statistics on the location and the number of cooling towers for assessing the risk of LD outbreak and the resources required for the establishment of a registration system. The survey, which was completed in 1996, indicated that:

— there were 11,931 cooling towers in Hong Kong;

— the districts with the highest density of cooling towers were Mong Kok, Yau Tsim, Kwun Tong, Kowloon City, Shum Shui Po, Kwai Tsing, Central and Western, and Wan Chai;

— 1,615 or about 14% of the cooling towers identified were located right next to open windows or fresh air intakes. These cooling towers were not properly installed and would expose the occupants inside the buildings to the risk of LD; and

— 5,604 or about 47% of the cooling towers identified were poorly maintained or dirty.

6.23 At the completion of the survey, a database on the number, type, location and service condition of existing cooling towers was developed. The survey report recommended further investigations in order to analyse and assess the risk of LD in Hong Kong. Up to August 1999, these had not yet been done. Furthermore, the PLDC did not proceed further with its original idea of establishing a registration system of cooling towers.

Investigations of LD cases

6.24 The PLDC is responsible for assisting the Department of Health in investigating the causes of the reported LD cases. Many cooling towers covered by the investigations were found to be poorly maintained and without proper water treatment. In some cases, the LD bacteria were found in water samples collected from contaminated cooling towers. According to the records of the PLDC, so far, 16 LD cases had been reported in Hong Kong as shown in Table 2 below.

Table 2

Number of reported LD cases in Hong Kong

Year	Number of LD cases
1982 – 1991	6
1992	1
1993	0
1994	3 (Note)
1995	1
1996	2
1997	2
1998	1
Total	**16**

Source: PLDC's records

Note: There was one fatal case out of the three cases in 1994.

Audit observations

6.25 Despite the fact that there has been no major outbreak of LD in Hong Kong, Audit considers that the risk of LD should not be ignored. This is evidenced by the sporadic cases reported and the numerous evaporative cooling towers identified by the survey of cooling towers.

6.26 The PLDC has started its work on the prevention and control of LD since 1985 and has issued the Code of Practice for the guidance of the operators and owners of cooling towers. However, Audit notes that the Code of Practice is not issued under any legislation and is only for the general information of the public. **The requirements laid down in the Code of Practice to ensure the proper operation and maintenance of cooling towers are not legally enforceable. The PLDC can only promote voluntary compliance with the Code of Practice by cooling tower owners and operators.**

6.27 The survey of cooling towers conducted in 1996 found that there were nearly 12,000 cooling towers in Hong Kong. This number was more than a hundred times of the 116 cases approved by the WSD (see paragraph 4.4 above). In the absence of other sources of fresh water in Hong Kong, most of these cooling towers must have made unauthorised connections to the mains for the supply of fresh water. **As the unauthorised connections to the mains are illegal in the first place, the willingness of these operators to comply with the requirements laid down in the Code of Practice is questionable.** It should also be noted that even for those cases approved by the WSD, they are only subject to voluntary compliance with the Code of Practice. The WSD's approval relates to the use of water only and does not relate to the operation and maintenance of cooling towers.

6.28 **The 1996 EMSD's survey of cooling towers revealed that 14% of the cooling towers were not properly installed and 47% of them were not properly maintained.** To follow up the findings of the survey, Audit conducted field inspections in selected districts including Mong Kok, Yau Ma Tei, Tsim Sha Tsui, San Po Kong, Kwun Tong, Sha Tin and Central District in April and May 1999. Audit observed that:

— cooling towers could be found quite easily in the back alleyways and podiums of buildings in these areas and many of these cooling towers were in shabby conditions. Photographs of cooling towers taken by Audit during field inspections are at Photographs 1 to 6 on the centre pages; and

— the cooling towers were installed mostly in the premises of restaurants, retail shops and industrial undertakings.

6.29 Based on the results of the 1996 EMSD's survey and Audit's follow-up field inspections, Audit considers that there is an urgent need for the Administration to regulate the operation of illegal water cooling towers for the sake of public health.

Audit recommendations

6.30 **Audit has *recommended* that, in order to minimise the risk of LD, the Secretary for Works and the Director of Electrical and Mechanical Services should consider ways, including the setting up of a registration and licensing system, of requiring operators and owners of cooling towers to comply with the Code of Practice on the proper operation of cooling towers.**

6.31 **Audit has also *recommended* that, in the meantime, the Director of Electrical and Mechanical Services should:**

— **conduct regular surveys of cooling towers to ascertain and monitor the operating conditions of cooling towers, particularly those which are not properly installed or maintained; and**

— **inform owners of the cooling towers of the requirements of the Code of Practice and advise them of the potential risk of LD.**

Response from the Administration

6.32 The **Director of Electrical and Mechanical Services** has said that:

(a) it is worth pointing out that the 1996 survey of cooling towers was basically a street level sight survey only for the purpose of determining the number, type, location and physical condition of the cooling towers, in order to assist locating problematic cooling towers whenever cases of LD were reported. The PLDC and the EMSD did not have the right to assess the maintenance conditions of the cooling towers;

(b) the recommendation in the survey report to conduct a long-term LD risk assessment was not pursued as the risk of LD has been continuously assessed and monitored through the collaboration between the Department of Health and the EMSD, and observed to be low. There have been few suspected LD cases (three cases) since the completion of survey which were later identified as false ones. The cases were also discussed at the PLDC meeting held in May 1999 and members agreed that the number of LD cases was low in Hong Kong when compared with other countries. For reference, there had been 226 LD cases reported in Singapore from 1986 to 1995 and there are about 20 to 40 cases a year in Victoria, Australia. Taking into consideration the small number of notifiable cases (less than two cases a year on average) and the resource implications, the registration of cooling towers was eventually not pursued;

(c) he intended to study the way forward for the registration and licensing system for fresh water cooling towers in Phase 2 of the consultancy study (see the third inset of paragraph 3.7 above). In the meeting held with the PLDC in May 1999, he agreed to consider bringing this issue forward for inclusion in the scope of Phase 1 of the consultancy study. After the review of the WACS Consultancy Study Programme with the Secretary for Planning, Environment and Lands upon the finalisation of the Preliminary Study Report, this part of work would be included in the Phase 2 Study that would commence in mid-2000;

(d) an updating of cooling tower database has commenced since March 1999. The survey will also identify as far as practicable whether or not the cooling towers are obsolete;

(e) without legislative backup, he is not in a position to ascertain whether privately-owned cooling towers are properly installed and maintained;

(f) the Department of Health will take up the role of investigation of reported LD cases while the EMSD will provide technical assistance in collecting water samples for laboratory testing and advice of contamination if so requested. Furthermore, a contingency plan has been in place describing the roles of the Department of Health and the EMSD for handling the outbreak of LD;

(g) in the past nine notified cases since 1994, only two out of about 30 samples (one in 1994 and the other in 1995) were found containing the LD bacteria. These two samples were collected from cooling towers; and

(h) the following actions were initiated at the PLDC meeting held in May 1999:

(i) a review of the Code of Practice to be completed by September 1999; and

(ii) a publicity programme targeting mainly at the owners of cooling towers to be completed by November 1999.

6.33 The **Director of Health** has said that:

— while she supports using more energy-efficient air-conditioning systems, her major concern from the public health point of view is the risk of LD. Given the huge number of air-conditioning systems in this community, the crowded conditions with huge number of inhabitants in most air-conditioned buildings, and the possibility of lack of adequate supervision to ensure proper maintenance of these systems, the use of fresh water for air-conditioning purposes should be discouraged as far as possible, unless vigilant monitoring and enforcement actions on compliance with the Code of Practice are in place;

— she has to commend that the audit report is well written to reflect the present situation regarding LD. The main principle in the prevention and control of LD is good system design, and maintenance of the air-conditioning systems. The audit review has described in detail the existing shortfalls in registration and maintenance of cooling towers and the limitations of voluntary compliance with the PLDC's Code of Practice;

— although the number of LD notified in Hong Kong is not high, there is always the possibility of underreporting. With the wider use of WACS, contaminated cooling towers always pose a public health hazard; and

— she fully supports the recommendations for better and stricter control of the operation and maintenance of cooling towers while considering the wider application of fresh water WACS.

6.34 The **Secretary for Works** has said that the need to set up a registration and licensing system on cooling towers will be addressed in the territory-wide study commissioned by the EMSD on WACS.

6.35 The **Director of Water Supplies** has said that he notes the audit observations and deduction about the existing cooling towers, and the concern over the possible use of mains water without approval.

Appendix A
(paragraph 1.1 refers)

Trend of electricity consumption in Hong Kong

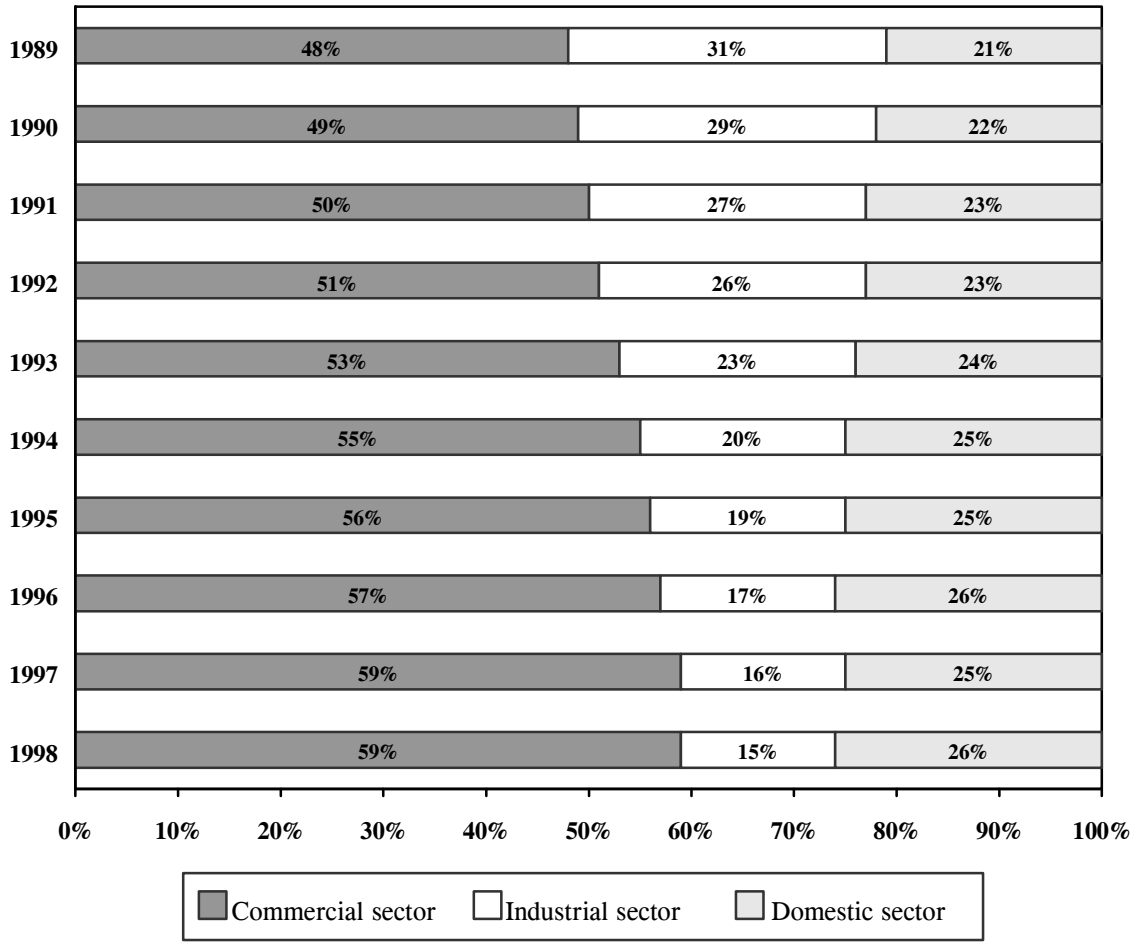
Year	Annual consumption (Note)		Increase over the previous year	Cumulative increase over 1989
	(million kWh)	($ billion)	(%)	(%)
1989	22,386	19.80	—	—
1990	23,834	21.08	6.46%	6.46%
1991	25,317	22.40	6.26%	13.13%
1992	26,153	23.13	3.26%	16.82%
1993	27,725	24.53	6.05%	23.89%
1994	29,182	25.81	5.22%	30.35%
1995	29,855	26.41	2.32%	33.38%
1996	31,633	27.98	5.94%	41.31%
1997	32,243	28.52	1.93%	44.04%
1998	34,846	30.82	8.06%	55.66%

Source: Census and Statistics Department's records

Note: Kilowatt-hour (kWh) is the measurement unit of electricity consumption. The annual expenditure on electricity consumption is calculated at the average electricity charge of $0.8846 per kWh in 1998.

Appendix B
(paragraph 1.1 refers)

Analysis of electricity consumption in Hong Kong by sector



Source: *Census and Statistics Department's records*

Note: *The classification of commercial, industrial and domestic sectors is in accordance with the account type of the two power companies.*

Appendix C
(paragraph 2.8 refers)

EMSD's calculation of saving by using WACS instead of AACS in a typical 40-storey commercial building

	Operating costs ($ million)	**Saving (%)**
Electricity charge for the chiller plant in AACS	4.31	
Electricity charge for the chiller plant in WACS	2.73	
Saving in electricity charge	1.58	37%
Less: Maintenance costs of cooling tower (Note 1)	(0.10)	
Costs of water consumption (Note 2)	(0.35)	
Net saving in operating costs	1.13	26%

Source: EMSD's records

Note 1: The maintenance costs refer to the cost of chemical treatment of the circulating cooling water to prevent bacterial growth, and the cost of routine cleaning and maintenance of the various components of the cooling tower.

Note 2: The costs of water consumption include water charge and sewage charge. The water charge is based on the rate of $4.58 per cubic metre which has not been revised since 16 February 1995. If the full cost of $8.47 per cubic metre of fresh water supply is used, the total costs of water consumption will become $0.59 million and the net saving will be reduced to $0.89 million. The saving in operating costs is still substantial even if the full cost of fresh water supply is taken into account.

Appendix D
(paragraph 2.10 refers)

Calculation of annual saving in electricity consumption in the commercial sector when WACS are widely adopted in Hong Kong

(1)	Total electricity consumption in 1998	34,846 million kWh
(2)	59% of (1) attributed to the commercial sector	20,559 million kWh
(3)	50% of (2) attributed to air-conditioning systems	10,280 million kWh
(4)	70% of (3) suitable for adoption of WACS (Note 1)	7,196 million kWh
(5)	50% of (4) attributed to chiller plants	3,598 million kWh
(6)	37% of (5) as savings from adopting WACS instead of AACS	1,331 million kWh
(7)	Percentage saving in electricity consumption (59% × 50% × 70% × 50% × 37%)	3.82%
(8)	Saving in electricity charge (at $0.8846 per kWh)	**$1,177 million**
(9)	Net saving in operating costs after deducting additional operating costs at about 28% (Note 2) of the electricity saving	**$847 million**

Source: *Census and Statistics Department's records, EMSD's figures and Audit's computations*

Note 1: *According to the EMSD, WACS are suitable for about 70% of the air-conditioning systems.*

Note 2: *As shown in Appendix C, the additional operating costs comprise maintenance costs of cooling towers ($0.1 million) and costs of water consumption ($0.35 million). The sum of $0.45 million is about 28% of the electricity saving of $1.58 million.*

Appendix E
(paragraph 2.14 refers)

Audit survey on the use of WACS in developed countries and Mainland cities

(A) The audit survey concentrated on:

— the extent of use of WACS; and

— the regulations on the use of mains water for air-conditioning purposes.

(B) Developed countries and Mainland cities responding to the audit survey are:

1. Singapore
2. the United Kingdom
3. the United States of America
4. South Korea
5. Japan
6. Sweden
7. Beijing
8. Shanghai
9. Guangzhou
10. Zhongshan
11. Shenzhen

Appendix F
(paragraph 4.4 refers)

Approvals granted by the WSD on the use of mains water for air-conditioning systems from 1979 to 1998

Year	Number of approvals	Year	Number of approvals
		1979-1988	108
1979	12	1989	2
1980	14	1990	1
1981	13	1991	1
1982	6	1992	1
1983	10	1993	-
1984	11	1994	1
1985	21	1995	-
1986	14	1996	1
1987	4	1997	1
1988	3	1998	-
Total	108	**Total**	**116**

Source: WSD's records

Appendix G
(paragraph 5.3 refers)

Supply of water from rainfall catchment and Guangdong Province

Year	Supply from rainfall catchment (MCM)	Supply from Guangdong Province (MCM)	Total (MCM)
1987	317	432	749
1988	173	515	688
1989	247	610	857
1990	221	590	811
1991	180	701	881
1992	364	664	1,028
1993	360	627	987
1994	277	683	960
1995	303	690	993
1996	188	720	908
1997	224	698	922
1998	238	760	998

Source: WSD's records

Appendix H
(paragraph 5.5 refers)

Revision of the planned supply of water from Guangdong Province

Planned supply

Year	Original (with annual increment of 30 MCM)	Revised (with annual increment of 10 MCM)	Difference
	(MCM)	(MCM)	(MCM)
1995	690	—	—
1996	720	—	—
1997	750	—	—
1998	780	760	–20
1999	810	770	–40
2000	840	780	–60
2001	870	790	–80
2002	900	800	–100
2003	930	810	–120
2004	960	820	–140

Source: *WSD's records and Audit's projection*

Note: *The original planned supply increased from 690 MCM in 1995 to 840 MCM in 2000. The figures for 2001 to 2004 are projected by extending the originally planned annual increase of 30 MCM.*

Appendix I
(paragraphs 5.6
and 5.7 refer)

Actual consumption of fresh water in Hong Kong from 1987 to 1998

	Total consumption		
Year	**Actual consumption (MCM)**	**Percentage change (%)**	**Industrial consumption (MCM)**
1987	750	—	161
1988	808	7.73%	170
1989	845	4.58%	182
1990	873	3.31%	179
1991	884	1.26%	174
1992	889	0.57%	161
1993	915	2.92%	145
1994	923	0.87%	117
1995	919	–0.43%	96
1996	928	0.98%	87
1997	913	–1.62%	75
1998	916	0.33%	66

Source: WSD's records

Appendix J
(paragraph 5.8 refers)

WSD's forecast of supply and consumption of fresh water in Hong Kong for the years from 1999 to 2012

Year	Forecasted supply from rainfall catchment (Note)	Forecasted supply from Guangdong Province	Total	Forecasted consumption	Forecasted surplus
	(MCM)	(MCM)	(MCM)	(MCM)	(MCM)
	(a)	(b)	(c) = (a) + (b)	(d)	(e) = (c) – (d)
1999	288	770	1,058	934	124
2000	288	780	1,068	957	111
2001	288	790	1,078	975	103
2002	288	800	1,088	995	93
2003	288	810	1,098	1,007	91
2004	288	820	1,108	1,039	69
2005	288	830	1,118	1,023	95
2006	288	840	1,128	1,017	111
2007	288	850	1,138	1,011	127
2008	288	860	1,148	1,010	138
2009	288	870	1,158	1,004	154
2010	288	880	1,168	1,007	161
2011	288	890	1,178	1,014	164
2012	288	900	1,188	1,024	164

Source: *WSD's records*

Note: *The long-term average rainfall catchment is 288 MCM a year.*

Appendix K
(paragraph 5.12 refers)

WSD's 1995 projection of the demand for fresh water by WACS

Year	Predicted demand (Note) (MCM)
1996	17.9
1997	23.2
1998	28.6
1999	33.9
2000	39.3
2001	44.6
2002	50.0
2003	55.4
2004	60.7
2005	66.1
2006	71.4
2007	76.8
2008	82.1
2009	87.5
2010	92.8
2011	98.2
2012	103.5
2013	108.9
2014	114.2
2015	119.6

Source: *WSD's records*

Note: *WSD's predicted demand assumed that when the ban was lifted in 1996, 30% of the premises suitable for WACS in 1993 would install WACS and full conversion would be completed by 2015. The growth from 1996 to 2015 was based on a linear projection.*

Appendix L
(paragraph 5.17 refers)

Audit's projection of the demand for fresh water arising from the adoption of WACS

Year	Predicted demand based on WSD's 1995 projection	Predicted demand based on Audit's projection (Note)	Difference
	(MCM)	(MCM)	(MCM)
2000	39.3	13.3	26.0
2001	44.6	16.2	28.4
2002	50.0	19.1	30.9
2003	55.4	22.0	33.4
2004	60.7	24.9	35.8
2005	66.1	27.8	38.3
2006	71.4	30.7	40.7
2007	76.8	33.6	43.2
2008	82.1	36.6	45.5
2009	87.5	39.5	48.0
2010	92.8	42.4	50.4
2011	98.2	45.3	52.9
2012	103.5	48.2	55.3
2013	108.9	51.1	57.8
2014	114.2	54.0	60.2
2015	119.6	56.9	62.7

Source: *WSD's records and Audit's projection*

Note: *Audit's predicted demand assumes that the ban will be lifted in 2000, 30% of the premises suitable for WACS in 1997 will install WACS and full conversion will be completed by 2015. The growth from 2000 to 2015 is based on a linear projection.*

Appendix M

Acronyms and abbreviations

AACS	Air-cooled air-conditioning systems
Code of Practice	Code of Practice for the Prevention of Legionnaires' Disease in Hong Kong
EAC	Energy Advisory Committee
EEAC	Energy Efficiency Advisory Committee
EECSC	Energy Efficiency and Conservation Sub-Committee
EMSD	Electrical and Mechanical Services Department
kWh	Kilowatt-hour
LD	Legionnaires' Disease
MCM	Million cubic metres
PLDC	Prevention of Legionnaires' Disease Committee
WACS	Water-cooled air-conditioning systems
WSD	Water Supplies Department