



Agreement No. CE 47/2001
Implementation Study for
Water-cooled Air-Conditioning Systems at
Wan Chai and Causeway Bay - Investigation

Executive Summary



submitted by

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EXECUTIVE SUMMARY

CONTENTS	Page
1. Introduction	
1.1 Study Background	1
1.2 Objectives	2
2. Baseline Conditions and Identification of Potential DCS/CPSSCC Zones	
2.1 Identification of Potential Customers	3
2.2 Identification of Potential Zones	4
2.3 Cooling Demand Forecast	5
3. Schemes Evaluation and Impact Assessment	
3.1 Basic Design Scheme	8
3.2 Planning and Lands	8
3.3 Energy Saving Potential	13
3.4 Cost Model and Financial Analysis	14
3.5 Preliminary Environmental Review	17
3.6 Traffic Impact Assessment	19
3.7 Operational Risk Assessment	19
3.8 Infrastructure Assessment	20
4. Regulatory Control, and Institutional and Contract Issues	
4.1 Government Policy	22
4.2 Options of Implementation Approaches	22
4.3 Recommended Procurement Options	23

EXECUTIVE SUMMARY

5. Implementation Plan

5.1	Implementation Tasks for Zone 5	26
5.2	Implementation Tasks for Zones 1, 2 and 3	26
5.3	Implementation Structure for Zones 1, 2, 3 and 5	27
5.4	Implementation Programme for Zone 5	27
5.5	Implementation Programme for Zones 1, 2 and 3	28
5.6	Promotion	28

6. Conclusion and Recommendations

6.1	DCS Potential Zones	29
6.2	Planning and Land Issues	29
6.3	Basic Design Scheme	30
6.4	Traffic Impact Assessment and Preliminary Environmental Review	30
6.5	Financial Analysis	30
6.6	Regulatory, Institutional and Contract Issues	30
6.7	Implementation Plan	31

Annex I: Features of DCS and CPSSCC

Annex II: Basic Design Schemes

Annex III: Results of Financial Sensitivity Analysis

Annex IV: Drawings

1. INTRODUCTION

1.1 Study Background

In October 1998, Electrical & Mechanical Services Department (EMSD) commissioned the Preliminary Phase Consultancy Study (PPCS) on Wider Use of Water-cooled Air Conditioning Systems (WACS). The PPCS concluded that the overall economic and environmental benefits would result in the wider use of WACS.

Two studies were further pursued by EMSD, namely:-

- Territory-Wide Implementation Study for WACS in Hong Kong under Consultancy Agreement No. CE 26/2000 and
- Implementation Study for a District Cooling Scheme at South East Kowloon Development (SEKD) under Consultancy Agreement No. CE 51/2000.

The Territory-Wide Study has examined various specific aspects including technical, infrastructure, financial, land issues, environmental, health and regulatory issues for WACS implementation. The SEKD Study was focused on district-wide implementation of District Cooling Scheme (DCS) on the proposed newly developed district of South-East Kowloon.

Wan Chai and Causeway Bay (WCCB) is a well-developed urban district characterized by congested underground utilities, heavy traffic and pedestrian flow. On the other hand, WCCB provides very good potential for the development of WACS as about a third of Hong Kong Island's commercial floor area is located in this district.

To examine the implementation of WACS in WCCB, Parsons Brinckerhoff (Asia) Ltd (the lead consultant) in association with other sub-consultants were appointed by EMSD to undertake this Implementation Study for Water-cooled Air Conditioning System at Wan Chai and Causeway Bay focusing on the following two types of WACS, namely :-

- District Cooling System (DCS)
- Centralized Piped Supply System for Condenser Cooling (CPSSCC)

The basic features of the two types of WACS are at **Annex I**.

All the details and study findings are elaborated separately in the Final Report. This Executive Summary serves to summarize the principal findings, conclusions and recommendations for implementation of WACS in WCCB.

EXECUTIVE SUMMARY

1.2 Objectives

The objectives of this Study are to undertake a district-based implementation study in Wan Chai and Causeway Bay so as to:

- Understand the potentials and constraints of implementing DCS and/or CPSSCC in the study area;
- Evaluate technical viability with respect to technologies, infrastructure, environmental and traffic impact;
- Evaluate financial viability;
- Assess various land issues and constraints;
- Examine and recommend the arrangements for regulatory and institutional frameworks; and
- Compile the implementation plan including different implementation models, approaches, contract strategy, programme, government role and promotion.

2. BASELINE CONDITIONS AND IDENTIFICATION OF POTENTIAL DCS/CPSSCC ZONES

2.1 Identification of Potential Customers

Hong Kong is a free market driven economy with minimum government intervention and so it is expected the DCS service connection in WCCB would be on a non-mandatory basis. Thus, DCS or CPSSCC would unlikely serve all the buildings in WCCB. This leads to the necessity to determine who are the potential customers of the DCS / CPSSCC systems so as to further assess the cooling demand and the financial viability, as well as environmental and traffic implications.

2.1.1 Potential Customers for CPSSCC

The potential customers for CPSSCC in WCCB would be those existing buildings with as-built sea water cooling system, which would likely be affected by Wan Chai Development Phase II (WDII) reclamation. According to the information derived in the WDII Comprehensive Feasibility Study and the past views from the potential customers, if reclamation is to be pursued, building owners of many existing seawater cooled buildings at Wan Chai waterfront will likely to join CPSSCC as a means to serve their as-installed seawater cooled air-conditioning systems.

However, according to the judicial review on WDII, the Government is now undertaking a Planning and Engineering Review for the Wan Chai North area with a view to draw up a minimum reclamation option. The timing and actual extent of reclamation are not clear at present moment. The exact number of potential customers will depend on the following factors:-

- Final WDII scheme and its extent of reclamation;
- Establishment of CPSSCC at the right time to suit the final implementation programme of WDII.

For those inland zones or areas, where the existing buildings have been installed with air-cooled chiller plants, they would unlikely be the potential customers for CPSSCC.

2.1.2 Potential Customers for DCS

In view of low energy consumption of domestic buildings as well as technical and administrative constraints to replace these individual air-conditioning units by DCS, domestic buildings are unlikely to be DCS customers.

Non-domestic buildings with central air distribution systems would have high potential to become customers of DCS. Target buildings include the existing commercial buildings, proposed new developments and redevelopment projects in WCCB. Based on the established selection criteria particularly regarding building usage and cooling demand, only non-domestic buildings with central air-conditioning and with GFA over 10,000 sqm would be considered as potential customers of DCS.

The inventory maps of Figure 2.1 and 2.2 depict the WCCB study boundary, distribution of potential DCS customers forecasted up to Year 2030 and the characteristics of potential buildings for implementing DCS .

Base the above baseline conditions, the total potential DCS customers are estimated to be 135, 138 and 139 by the end of Year 2010, 2020 and 2030 respectively.

2.2 Identification of Potential Zones

It would not be feasible to serve the whole Study area by a single DCS/CPSSCC system taking into account of technical, infrastructure and system reliability considerations. In order to facilitate further assessment, the study area is divided into several regional DCS/CPSSCC zones.

For CPSSCC, as discussed in Section 2.1.1, the potential zone for CPSSCC would be the Wan Chai Waterfront where the existing sea water cooled buildings are situated and may subject to the impact of the future WDII scheme and its reclamation.

For DCS, based on the following criteria, WCCB is divided into five zones as shown in Table 2.1 for further investigation :-

- Distribution of Potential DCS Customers
- Distance from Cooling Load Center/DCS Plant
- Infrastructure and Traffic Constraints

Table 2.1: DCS Zones in WCCB

Zone 1	Buildings mainly located along the Gloucester Road
Zone 2	Buildings mainly located at north side of Wan Chai
Zone 3	Buildings mainly situated within Causeway Bay region
Zone 4	Buildings mainly situated within Fortress Hill region
Zone 5	Buildings mainly situated at the Wanchai waterfront region, i.e. northern side of the Gloucester Road

Figure 2.3 shows the boundary of abovementioned zones in WCCB.

Remark:

- By virtue, the zone area boundary for CPSSCC is same as that for DCS Zone 5.
- For Zone 5, both DCS and CPSSCC are feasible for implementation. Because of higher energy efficiency of DCS as compared with CPSSCC, higher priority should be given to DCS implementation. However, CPSSCC could be an alternative if DCS is not to be pursued in this zone.

2.3 Cooling Demand Forecast

2.3.1 Energy Model

An Energy Model was developed to forecast the cooling demand in the five zones and to project the hourly cooling demands, annual energy consumption, fresh water demands and effluent discharge volume flow rates for DCS using cooling towers for heat rejection, and sea water flow demands for DCS using seawater for heat rejection. The results of the Energy Model also served as input parameters to the Cost Model for financial analysis.

The energy model consists of a database of normalized cooling load profiles for different categories of buildings, Hong Kong weather data, equipment performance data and other engineering data and formulae.

The cooling demand of a potential user building is estimated by feeding the GFA and other relevant data of the building to energy model. The energy consumption is simulated by inputting the appropriate system configuration.

2.3.2 Customer Uptake Consideration

Further to Section 2.1 and 2.2, the potential customer buildings were identified and grouped into different zones. Since DCS connection is not mandatory, not all of these buildings would be connected to DCS. Therefore a prediction of future customer uptake ratio, i.e. the likeliness to subscribe DCS service would be necessary to optimize the plant sizing and to estimate the upfront cost of investment.

The customer uptake ratio would depend on many factors including cost benefits to building owners / operators, customers' confidence on the service provider, and other commercial interests considered by the customers.

The following baseline information and data have been considered to categorize the potential buildings into three groups according to their characteristics and potential for DCS connection.

- Whether the buildings are equipped with a central chiller plant.
- Characteristics of building ownership such as whether the buildings are government owned, private single ownership or private multiple ownership.
- Need for chiller plant replacement in near future. For those buildings with chiller plants near the end of their service life, the building owner would have greater interest to join DCS so as to save their substantial initial investment in the chiller plants replacement.

By analyzing characteristics of the buildings, the estimated customer uptake ratios at ultimate development level are 37%, 40%, 60% and 30% for DCS Zones 1, 2, 3 and 4 respectively.

For Zone 5, the customer uptake ratio is highly dependent on the availability of DCS service at the right time to match with the WDII development program and the timing for chiller replacement of existing buildings in Zone 5. Since the Government are still carrying out engineering review on WDII development and so extent and program for WDII development is still not clear at the moment. If the proposed reclamation of the future WDII scheme requires the removal of the existing seawater pumping stations serving the existing seawater cooled buildings, it is likely that 100% of existing seawater cooled buildings would join DCS and/or CPSSCC so as to save substantial high initial investment cost for relocating individual seawater pumping installations. If the proposed reclamation of the future WDII scheme does not affect the existing seawater pumping stations, these buildings would have less motivation to join DCS/CPSSCC, that is, lower customer uptake ratio for joining DCS/CPSSCC. A sensitivity test on customer uptake ratio has been conducted to assess the impact on the financial viability.

2.3.3 Cooling Demand Forecast

By taking into account the predicted customer uptake ratio for each zone, the peak cooling demand for various DCS zones and CPSSCC are summarized below.

Table 2.2 Summary of Cooling Demand for DCS and CPSSCC

	Phase 1 (2010-2014)	Phase 2 (2015-2019)	Phase 3 (2020-2024)	Phase 4 (2025-2039)
DCS (Zone 1)	28.7 MW	41.8 MW	65.7 MW	65.7 MW
DCS (Zone 2)	27.5 MW	32.0 MW	52.0 MW	52.0 MW
DCS (Zone 3)	37.6 MW	41.8 MW	73.4 MW	78.0 MW
DCS (Zone 4)	10.0 MW	14.4 MW	18.4 MW	18.5 MW
DCS (Zone 5)	148 MW based on 100% customer uptake ratio			
CPSSCC (Zone 5)	138 MW based on 100% customer uptake ratio			

- Note: 1. The above cooling demand figures have included diversity factor due to different usages of buildings in the respective zones.
2. In Zone 5, both DCS and CPSSCC are technically and financially viable. Since when compared with CPSSCC, DCS is more energy efficient and cost effective, therefore DCS should be given higher priority for implementation.

3. SCHEMES EVALUATION AND IMPACT ASSESSMENT

3.1 Basic Design Scheme

The basic design schemes for DCS and CPSSCC outlined in **Annex II** are used for the evaluation and impact assessment in this Section.

3.2 Planning and Lands

3.2.1 Sites Selection Considerations

The key challenge to implement WACS in WCCB is to secure suitable sites in the well-developed and congested urban area for plantrooms for accommodating DCS / CPSSCC plants. The key criteria for the plant site selection are -

- Technical concerns including engineering requirements of heat rejection systems, potential environmental and traffic impacts, and spatial requirements of the proposed facilities;
- Suitability to integrate with other amenities;
- Compatibility with the planning and development intentions, *and*
- Comments from the concerned government user departments on the lands allocation

As WCCB district is a built-up area, there is generally lack of suitable Government unleased land for building DCS/CPSSCC plant. When there is no suitable Government unleased land available for a DCS / CPSSCC plant, the implementation of DCS / CPSSCC will depend on if there is any interested private sector can source and secure suitable private land for DCS / CPSSCC plant.

3.2.2 Land and Spatial Requirements

Without prejudice to the commitment of use of private lands for DCS, the basic design schemes are prepared based on using Government lands for the DCS facilities and thus no resumption of land is required. Numerous sites were evaluated for identification of suitable site for DCS/CPSSCC plant. The general site requirements for the proposed DCS / CPSSCC facilities are summarized in Table 3.1. The sea water and DCS pipelines would be laid in public roads.

In case of implementing CPSSCC, the seawater pumping plant would be installed inside the existing empty pump cells at Phase II of the Hong Kong Convention and Exhibition Centre.

Table 3.1: Site Requirements for the Proposed DCS / CPSSCC Facilities

DCS / CPSSCC Zones /Serving Area	Installed Capacity / Proposed Heat Rejection System	General Site Requirement for DCS / CPSSCC Facilities
DCS Zone 1: Wan Chai North (along Gloucester Road)	84 MW / DCS using seawater for heat rejection	<p><u>DCS Plant</u></p> <ul style="list-style-type: none"> • 2-storey underground plant • Land area: 2,000 m² • Site footprint: 72m x 28m • Site location: The GIC Site of Wan Chai Sports Ground <p><u>Sea water Pumping Station (SWPS)</u></p> <ul style="list-style-type: none"> • 2-storey underground plant • Land area: 1,160 m² • Site footprint: 43m x 27m • Site location: The open space site next to future Wan Chai Ferry Pier
DCS Zone 2: Wan Chai South	74 MW / DCS using cooling tower for heat rejection	<p><u>DCS Plant</u></p> <ul style="list-style-type: none"> • 2-storey underground plant • Land area: 1,960 m² • DCS site footprint: 70m x 28m • Open area for cooling tower plant: 1,720 m² (82m x 21m) • DCS site location: Southorn Playground • Cooling tower plant location: Top of the audience stand
DCS Zone 3: Causeway Bay	105 MW / DCS using cooling tower for heat rejection	<p><u>DCS Plant</u></p> <ul style="list-style-type: none"> • 2-storey underground plant • Land area: 2,400 m² • Site footprint: 86m x 28m • Open area for cooling tower plant: 2,200 m² (79mx28m) • DCS and cooling tower plant location: Existing EMSD Headquarter

EXECUTIVE SUMMARY

DCS / CPSSCC Zones /Serving Area	Installed Capacity / Proposed Heat Rejection System	General Site Requirement for DCS / CPSSCC Facilities
DCS Zone 4: Fortress Hill	31 MW / DCS using seawater for heat rejection	<p><u>DCS Plant</u></p> <ul style="list-style-type: none"> • 2-storey underground plant • Land area: 1,150 m² • Site footprint: 41m x 28m • DCS plant site location: Existing FEHD's vehicle depot <p><u>Sea Water Pumping Station (SWPS)</u></p> <ul style="list-style-type: none"> • 2-storey underground plant • Land area: 945 m² • Site footprint: 35m x 27m • SWPS site location: Existing FEHD's vehicle depot
DCS Zone 5: Wan Chai Waterfront area	168 MW / DCS using seawater for heat rejection	<p><u>DCS Plant</u></p> <ul style="list-style-type: none"> • 3-storey plant with 1 aboveground floor of 4.5m (H) • G/F area: 2,240 m² • Site footprint: 64m x 35m • B1/F and B2/F area: 2,000 m² each floor • DCS plant site location: Existing Wan Chai West Sewage Screening Plant <p><u>Sea Water Pumping Station (SWPS)</u></p> <ul style="list-style-type: none"> • Make use of 5 existing pump cells at waterfront of Phase II of the Hong Kong Convention and Exhibition Centre

EXECUTIVE SUMMARY

DCS / CPSSCC Zones /Serving Area	Installed Capacity / Proposed Heat Rejection System	General Site Requirement for DCS / CPSSCC Facilities
CPSSCC Zone 5: Wan Chai Waterfront area	147 MW/ Centralized seawater heat rejection system	<u>Sea Water Pumping Station (SWPS)</u> <ul style="list-style-type: none"> • Make use of 5 existing pump cells at waterfront of Phase II of the Hong Kong Convention and Exhibition Centre • Site footprint: About 1,800 m²

After comprehensive research and consultation with relevant Government departments, it appears that unleased Government land for DCS plant may only be available for Zone 5 subject to WDII scheme. For the other zones, the availability of Government lands for DCS plant sites are remote given the current planning and lands constraints in these zones.

Figures 3.1 to 3.5 of Annex IV show the piping layout plan for the DCS potential zones (Zones 1, 2, 3 & 5) and CPSSCC potential zone (Zone 5).

3.2.3 Land Disposal Strategy

The prevailing lands policy and land disposal options were examined in detail with respect to the potential impacts/difficulties for implementing DCS. The recommendations are listed as follow:-

- The Government need not to give the DCS operator/investor the title to land but only a right to occupy for the contract period. Thus, the Government would remain in control and be able to repossess any sites should the operator/investor fail to meet his obligations under the terms of the contract.
- For DCS Zone 5, the right timing of implementation is critical for providing DCS service. DCS is a good alternative to re-provisioning seawater pumping facilities due to reclamation and to replacing aged chillers at buildings in Zone 5. If the DCS Zone 5 proposal is endorsed by the Government, it is recommended to reserve the site for DCS plant, i.e. Site E2 (site currently occupied by Wan Chai West Sewage Screening Plant) as shown on Figure 3.1 for building DCS chiller plant and the as-built sea water pumping chambers at HKCEC Phase II waterfront for DCS seawater pumping station. Land for the plant sites could firstly be allocated to a Government department, who would then grant to the successful tenderer through contract arrangement for occupation right for the DCS plant sites.

EXECUTIVE SUMMARY

- For other DCS zones, there is no suitable unallocated Government land available for the time being and hence no imminent programming or implementation timing issue. It is recommended that DCS implementation in these zones should be initiated by the private sector or public joint user development when opportunities arise with future redevelopment in WCCB.
- For CPSSCC, the land disposal strategy is similar to implementing DCS in Zone 5. The existing sea water intake chambers at waterfront of HKCEC Phase II would also be allocated to EMSD, who will then grant to the successful tenderer through contract arrangement for occupation right for CPSSCC operation.

3.2.4 Development Options for DCS Zone 5

With a view to maximize the development potential of the land for plant site for Zone 5, i.e. Site E2, four development options have been considered:

- Option 1: Standalone DCS Plant
- Option 2: DCS plant with roof deck for public open space
- Option 3: DCS plant with top-side commercial development
- Option 4: DCS plant with top-side GIC development

The key advantages and disadvantages of the above four options are summarized below:

- Option 1: This option is simple and straightforward in engineering terms. It is however considered an under-utilization of valuable land resource in the prime area and the land use proposal is not in compliance with the long term planning intention of the site adopted in the Comprehensive Feasibility Study for Wan Chai Development Phase II.
- Option 2: This option is simple and straightforward in engineering terms. The general amenity of the area is enhanced by provision of a roof top open space. It is however still considered an under-utilization of valuable land resource in the prime area. The land use proposed is not in compliance with the long term planning intention of the site adopted in the Comprehensive Feasibility Study for Wan Chai Development Phase II.
- Option 3: This option can maximize the development potential of the plant site and comply with the long term planning intention of the area. Various implementation risks (e.g. uncertainty in the statutory planning process, financial risk to allow enabling works, imposition of unreasonable design constraints) will however be involved under different implementation approaches.

Option 4: This option can maximize the development potential of the plant site but does not comply with the long term planning intention of the site adopted in the Comprehensive Feasibility Study for Wan Chai Development Phase II. No specific G/IC use can be designated at the current stage.

With full respect to the views from the Planning Department and Lands Department regarding the land utilization and long term planning intention of the development site for commercial use, it is still considered that Option 2 is the most viable taking into account the uncertainty in timing of the commercial development and the complexity of the interface between the commercial development and the proposed DCS plantroom and the urgency to establish DCS in order to attract the customers to subscribe DCS due to the anticipated cost saving benefit to them in replacement of their existing old chillers. Government policy coverage to recognize the over-riding programming need of the DCS development, and to reconsider the long term planning intention of the development site, should be sought in due course. With adequate policy directive, land for DCS plant can be allocated to selected Government department, who can then grant an operation license to a service provider through tendering process. The service provider would take occupancy of the land for the installation and operation of DCS system during the contract period. The roof landscape garden can be operated by the service provider or by a relevant Government department, for example LCSD.

If the reconsideration of the long term planning intention turns out unsuccessful, Option 3 can be further pursued.

As mentioned before, the selection of the options and the availability of the site for DCS plant shall subject to review of the WDII project and when EPD can decommission the existing WCW Sewage Screening Plant to return the vacant site for DCS plant. If DCS could not be provided on time, CPSSCC could be pursued.

3.3 Energy Saving Potential

The possible energy savings by using DCS are listed below -

Table 3.2: Energy Saving Potential Comparison

	Dominant Type of AC System	Energy Saving Potential by Substitution of Using DCS
Zone 1 -4	Air-cooled air conditioning (AACS) system	20% (average)
Zone 5	Seawater-cooled air conditioning system	6 % (Sea Water Cooled DCS)

3.4 Cost Model and Financial Analysis

3.4.1 Cost Model

A cost model was custom-built to evaluate the financial viability of different potential DCS schemes and to conduct sensitivity tests under different scenarios.

The cost model adopts the cash flow analysis principle to determine the financial viability of a potential DCS scheme. The input parameters include capital cost, estimated cooling demand, annual energy consumption, tariff rates, etc. The output parameters are Net Present Value (NPV), Internal Rate of Return (IRR) and payback period as reflected from the cash flow diagram.

An investment is considered financially viable when NPV is greater than zero, IRR is greater than the cost of capital, and the payback period is within the contract period of DCS service delivery.

The cost of capital can be interpreted as the discount rate for NPV evaluation. The cost of capital varies from 7.14% to 12.05% depending on certain economic factors. A mean value of 9.3% is adopted for the financial analysis in this study.

3.4.2 Financial Analysis Results

A Base Case scenario is established under the following key assumptions and criteria.

- No government incentive;
- Cost of Capital: 9.3%;
- Land premium: HK\$ 3,500 /m²;
- Pipeline wayleave rental charge: HK\$ 9.5 / 10 mm dia / meter run /year (Remark: The rental charge will be subject to review in each year);
- Customer uptake ratios for different DCS potential zones as predicted in Section 3;
- DCS using seawater for heat rejection is adopted for DCS Zones 1, 4 and 5 and the cooling method is selected based on energy efficiency considerations. DCS using cooling tower for heat rejection is adopted for inland DCS zones, i.e. DCS Zones 2 and 3.
- The tariff for DCS Zones 1 to 4 and Zone 5 should not be greater than the self-generation cost of air-conditioning system using evaporative cooling towers and sea water cooling respectively;
- The abovementioned self-generation costs are estimated to be about HK\$ 0.59 and HK\$ 0.51 per kWhac for evaporative cooling towers A/C scheme and sea water cooling A/C scheme respectively;
- Based on 4 years installation period and 30 years services delivery period for DCS Zones 1 to 5 ;

- At the end of contract period, the DCS operator would transfer the ownership to the Government and would receive a residual value of the DCS facilities; and

For CPSSCC, the key assumptions include cost of capital of 9.3%, self-generation cost for pumping of 0.12 HK\$ per kWhac, service available in 2010 and receipt of a residual value for plant installation upon expiry of the contract period.

The Base Case serves as a reference point for comparing the financial results of other cases under sensitivity tests and incentives evaluation.

With the DCS tariff set to in line with the respective A/C self-generation costs of evaporative cooling and sea water cooling, the results of the financial analysis for different potential DCS schemes are presented in Table 3.3 below.

Table 3.3 Financial Analysis Results of Base Case Scenario

Potential Zone	System Type	Predicted Customer Uptake Ratio	NPV (HK\$ Million)	IRR (%)	Financial Viability
1	DCS-SW	37%	96.8 M	12.1 %	Viable
2	DCS-CT	40%	(31.3 M)	8.1 %	Not viable
3	DCS-CT	60%	10.3 M	9.6 %	Viable
4	DCS-SW	30%	(59 M)	5.5 %	Not viable
5	DCS-SW	100%	95.5 M	10.7 %	Viable

Notes:

- SW denotes using sea water for heat rejection
- CT denotes that using evaporative cooling towers for heat rejection.
- NPV denotes net present value.
- IRR denotes internal rate of return.
- (NPV figure) denotes value of the NPV is negative.

As shown in the above table, DCS Zones 1, 3 and 5 are financially viable - without the need of Government incentives. However, it should also be noted that the financial viability is dependent upon the predicted customer uptake ratio. As there is still uncertainty in market penetration rate, Government's incentives are still considered to be essential to encourage private participation.

For financially viable zones, the minimum tariffs for "zero NPV" are 0.51, 0.58 and 0.48 HK\$ per kWhac for Zones 1, 3 and 5 respectively. For Zones 2 and 4, it is necessary to raise the tariff to 0.63 and 0.76 HK\$ per kWhac respectively in order to make the schemes financially viable.

For CPSSCC, the NPV and IRR are HK\$ 19.1 M and 10.3% respectively and hence this scheme is considered financially viable.

3.4.3 Sensitivity Analysis Results

A series of sensitivity tests have been undertaken. Key factors of the sensitivity analysis include cost of capital, customer uptake ratio, land premium, trenchless pipes laying method, waive of pipeline easement cost and plant site premium, and cost of water consumption and effluent discharge.

The major findings of the sensitivity tests are –

- Under the extreme case scenario when cost of capital reaches 12.05% for every year in the contract period, only DCS Zone 1 is financially viable, whilst Zones 3 and 5 would become financially not viable. However, this scenario is considered remote.
- In spite of the customer uptake ratio rising to 50% for DCS Zones 1, 2 and 4, only DCS Zone 1 is financially viable. It should be noted that 50% customer uptake is considered as an optimistic figure for DCS Zones 1, 2 and 4. It is because most of the existing buildings in WCCB have already installed their individual A/C chiller plants and there is generally lacking of understanding of DCS as DCS is a “first of its kind” business in Hong Kong. This reflects that incentive(s) as a Government support is worthwhile for further consideration in order to promote wider adoption of DCS.

For DCS Zone 5, the DCS Zone 5 scheme will be financially marginal viable when the customer uptake ratio is at 70%. The same ratio of 70% is also required to make the CPSSCC scheme financially marginal viable.

- If the land premium rate is changed from industrial land rate, i.e. HK\$ 3,500/m² to commercial land rate, i.e. HK\$ 13,000/m², it will make DCS Zone 1 the only financially viable zone. For DCS Zone 5, if the existing sea water pumping station is charged under a rental rate of HK\$ 630/m²/year instead of land premium rate, Zone 5 would then become financially viable. Besides, its NPV would be improved by 27% as compared with the NPV in the Base Case. From financial point of view, it is recommended the Government to rent the as-built sea water pumping chambers to future DCS Zone 5 operator, and to use the industrial land premium charge rate rather than the commercial land premium charge rate if required.
- By using the trenchless pipe laying method to all DCS pipelines, only DCS Zones 1 & 5 are financially viable but their NPVs would drop significantly. Pipe route could be properly planned to limit pipeline installation by trenchless method at some critical locations only.

The details and the associated financial results are summarized in **Annex III**.

3.5 Preliminary Environmental Review

3.5.1 Noise

The noise impact due to construction and pipe laying works has been assessed and suitable mitigation measures are proposed. Noise control measures include the use of silencing equipment, erection of movable noise barriers and scheduling the operation of construction tools and equipment. By implementing proper mitigation measures, the noise level could be controlled to meet the construction noise criterion for NSRs at 5m from the site.

As the plant facilities for DCS are mostly installed within underground plant rooms, noise emitted from chillers and pumps would not be a major noise source. The potential noise impact during DCS plant operation has been estimated and the following mitigation measures are recommended for each DCS zone:

- For DCS Zones 2 and 3, an enclosure made of acoustic panels should be provided to house the cooling towers and silencers at cooling tower fan outlets and inlets
- For DCS Zones 1, 4 and 5 and CPSSCC zone, silencers should be incorporated into the mechanical ventilation system serving the underground plantroom.

3.5.2 Air Quality

Dust mitigation measures stipulated in the Air Pollution Control (Construction Dust) Regulation should be incorporated to control dust emission from the work sites. With proper dust control measures, it has been predicted that the air quality impacts during construction would be low and well within the criteria.

3.5.3 Water Quality

The potential water quality impact may arise from the warm sea water discharge from the seawater heat rejection of DCS/CPSSCC and the residual chemicals in the seawater discharge such as chlorine and biocides which are commonly used in chemical dosing to inhibit the marine growth within the sea water pipelines.

Thermal plume modelling was conducted to simulate the dispersion effect of the seawater discharge in Victoria Harbour. The modelling results showed that the thermal plume discharge impact was localized near the outfalls and the temperature rise would be less than 2 °C. Hence, unacceptable temperature rise at the sea water intakes is not anticipated.

The potential impact of residual chlorine was also assessed. Unacceptable impact on marine organism is not expected away from the sea water outfalls. This is attributed to the rapid decay of chlorine in the marine environment.

Unlike chlorine dosing which is continuous in nature, the biocides dosing is a periodic application. It is expected that small amount (less than 2 mgL^{-1}) and intermittent releases of biocides into Victoria Harbour would be readily diluted by the tidal current and hence the associated potential impact would be minimal.

3.5.4 Environmental Benefits

Since the DCS scheme is more energy efficient as compared with the existing air-conditioning systems, implementation of DCS would lead to significant savings in electrical energy consumption and hence the CO_2 emission from the power plant.

Table 3.4 shows the potential annual energy savings and the corresponding reduction of air pollutants emission from the power plant when the existing air-conditioning systems are changed to DCS.

Table 3.4 Potential Energy Savings and Reduction of Air Pollutants Emission in Year 2020 due to Substitution of Existing Air-Conditioning Systems in WCCB

DCS Zone	Estimated Annual Energy Saving (GWh / Yr)	Estimated Reduction of Gas Emission from HEC Power Plant (Ton/Yr)		
		CO_2	NO_2	SO_2
1	16.1	13,800	22.1	38.3
2	12.4	10,600	17.0	29.5
3	20.4	17,500	27.9	48.6
4	2.8	2,400	3.8	6.7
5	7.6	6,500	10.4	18.1
CPSSCC	0.4	343	0.5	1.0

Remarks:

CO_2 denotes carbon dioxide.

Note:

The majority of existing air-conditioning systems for DCS Zones 1 to 4 and DCS Zone 5 are air-cooled and sea water cooled air conditioning systems respectively.

3.6 Traffic Impact Assessment

Traffic impact assessment was conducted on the proposed DCS / CPSSCC pipes routing as shown on Figure 3.1 to 3.5 in **Annex IV**.

In summary, it is concluded that the proposed pipelines could be constructed from a traffic engineering point of view by implementing the following mitigation measures:

- For pipes to be laid under heavy traffic roads such as Fleming Road and Gloucester Road, the works could be carried out during off peak hours, night time or late night period.
- For the few critical locations where pipe laying works by means of open cut method would cause significant disruption to traffic, the pipelines in these locations could be laid by using trenchless method.

3.7 Operational Risk Assessment

The operational risks associated with the equipment failure in the DCS and CPSSCC schemes have been assessed.

Three generic cases were developed in the Operational Risk Assessment and are listed below.

- Failure of seawater heat rejection system of DCS/CPSSCC
- Failure of cooling tower heat rejection system of DCS
- Failure of cooling system of DCS / CPSSCC

A number of faults including external, natural event and functional failures in above generic cases such as power supply failure, sea water intake failure, distribution pipelines and equipment failures have been considered and modelled by using Fault Tree Analysis. The results showed that with proper system design, operation and maintenance, both DCS and CPSSCC could achieve a high level of service reliability exceeding 90%.

3.8 Infrastructure Assessment

3.8.1 Current Utilities Services Review

A review of current utilities services and infrastructure impact assessment was undertaken to identify critical clash locations. Utilities such as telephone and electricity cables are usually laid at shallow depth, it is therefore not expected to be critical constraints to the proposed DCS / CPSSCC pipelines. Where conflicts with existing storm drains or sewers are unavoidable, localized pipe offsets or adjustment of pipe alignments could be made to resolve the clashes since both the DCS / CPSSCC pipelines are working under pressure by pumping system.

3.8.2 DCS Employed with Sea Water Cooling for Heat Rejection

For the above scheme, underground plantrooms are required for DCS chiller plant and the sea water pumping station (SWPS) for Zones 1, 4 and 5. The SWPS should be located close to the sea front for intake of seawater.

Various excavation and construction methods of the underground plant have been proposed and reviewed in this study. It was found that there are no insurmountable issues on civil and structural aspects.

Two distribution piping networks, namely sea water cooling and chilled water cooling, are required to be laid under the public roads. In general, where condition permit, open cut method would be used for pipelines laying. Alternative methods would be used as required to suit the space and traffic constraints. At critical locations, trench less pipeline installation method would also be adopted to minimize impact to traffic.

For CPSSCC for Zone 5, the methodology of pipe laying works could follow the same approach as for DCS.

3.8.3 DCS Employed with Cooling Tower for Heat Rejection

The study indicated the additional demand of fresh water required from operating evaporative cooling towers only accounts for about 3.1% of current fresh water demand. The existing service reservoirs could cater for such additional demand by introducing some interim measures. In the long term, when the salt water pumping station in Wan Chai is commissioned, the fresh water reserved for toilet flushing could be released to satisfy the fresh water demand of the evaporative cooling towers serving heat rejection of DCS.

There is no imminent need of building an entire water supply network for supplying mains fresh water to the cooling towers for the DCS using evaporative cooling tower. Upgrading of existing water mains may be necessary only at some specific locations to cope with an increase in fresh water demand of a specific DCS.

EXECUTIVE SUMMARY

The WSD water mains replacement and rehabilitation program provides a good opportunity to incorporate such upgrading works if necessary.

To minimize the potential impacts to the sewage system discharge, discharge of bleed-off water from cooling towers could be handled by the following ways:

- By using micro filtration technique, about 80% of effluent discharge could be re-used,
- A storage tank could be provided as buffer storage for the remaining 20% of the effluent, and
- The stored effluent could be arranged to be discharged into the existing sewerage system during off-peak period.

A general sewerage impact assessment was conducted to assess the impact on the existing sewerage systems arising from the discharge of bleed-off water from the evaporative cooling towers of DCS. The results showed that the peak flow rates of effluent discharge would be insignificant with respect to the sewerage water carrying capacity of existing sewers when properly handling the discharges as mentioned above.

4. REGULATORY CONTROL, INSTITUTIONAL AND CONTRACT ISSUES

4.1 Government Policy

Unlike electricity and potable water supply that are regarded as essential services to livelihood, the use of district cooling is discretionary as well as being an alternative to conventional decentralized air-conditioning systems. The introduction of a district cooling industry is important if Government wishes to have rapid improvement on the efficient use and conservation of energy, and to arouse active private sector participation in DCS schemes in Hong Kong. The growth and penetration of DCS is dependent on the support of the Government in terms of the following:

- providing the framework and opportunities to attract investment in the district cooling industry,
- providing incentives on land issues for DCS plantroom and distribution pipelines to promote private sector participation in DCS services delivery
- ensuring that the regulatory and institutional frameworks are adequate to protect the subscribers of DCS services; and
- preventing abuse of Government incentives if provided.

4.2 Options of Implementation Approaches

For implementation of DCS in WCCB, six procurement options are identified and are listed below:

Option 1: Government initiated – legislative approach – territory wide ordinance

DCS plant is located in unleased Government land. A new territory wide DCS ordinance would be enacted for land disposal and regulatory control for DCS implementation. Private DCS operator would enter BOT type project agreement with Government for design, build, finance, own and operate the DCS system and transfer the ownership of the systems to Government at expiry of the project agreement.

Option 2: Government initiated – legislative approach – project specific

Similar to Option 1 above. However, instead of enacting a new territory-wide DCS ordinance, a project specific DCS ordinance would be enacted for the DCS implementation in WCCB.

Option 3: Government initiated – contract approach

Similar to Option 1 above except that new legislation would not be enacted for DCS implementation. Land disposal and control mechanisms for DCS implementation would be by contract only.

Option 4: Private initiated – pure private approach

DCS plant is located in land leased to private entities. Private DCS operators have to source and secure land by themselves. No incentives would be provided by Government for DCS implementation. There will be no contract between Government and the DCS operator.

Option 5: Private initiated – Government incentives – service providers regulated by project agreement to prevent abuse

Similar to Option 4 except that incentives would be provided by Government to improve the financial attractiveness of DCS. There could be a joint practice note for Government to exercise control mechanism by Government to prevent abuse of the incentives. Relevant practice note could be included in the project agreement between Government and service providers.

Option 6: Private initiated – Government incentives – service providers regulated by legislation (territory-wide) to prevent abuse

Similar to Option 5 except that a piece of legislation is enacted to regulate DCS operators and prevent abuse of the incentives.

The broad approaches above are also applicable to CPSSCC because they are similar to DCS in nature.

4.3 Recommended Procurement Options

4.3.1 Comparison of the “Contract Approach” and “Legislative Approach”

The Legislative approach provides a more powerful framework for implementing DCS systems than the Contract Approach. For example, legislation may authorize the Government to resume private land for district cooling plant and/or pipe routing, and where necessary impose mandatory subscription to district cooling services.

In the proposed DCS scheme, resumption of private land is not required. Mandatory DCS connection is also not suggested as Hong Kong is governed by free market principle. As such, DCS could be implemented by the Contract Approach without enacting new legislation. Moreover, implementation by contract is generally more flexible and less time consuming.

Since DCS is new to Hong Kong, it is considered more appropriate for a DCS to proceed on a contract basis for the initial district-wide projects in WCCB. Based on the lessons learned from these initial projects, the necessity of legislation for DCS implementation could then be reviewed.

In conclusion, Contract Approach is preferred for the proposed DCS schemes in WCCB.

4.3.2 Comparison of “Government Initiated Approach” and “Private Initiated Approach”

Government initiated approach is recommended when suitable Government land can be made available for DCS plants. Under this approach, Government has more control over DCS implementation particularly regarding implementation timeframe.

However, given that WCCB is a developed urban area, Government unleased land may not be available in most zones. For those zones without suitable Government unleased land, DCS could still be implemented by using the “Private initiated approach”. DCS operators however would have to source and secure private land for DCS plant.

4.3.3 Zone Specific Implementation Approach

Since Government unleased land would only likely be available for Zone 5, the following zone specific implementation approaches are recommended:

- “Government initiated – contract approach” is recommended for Zone 5 where Government land may be made available for the DCS plants
- “Private initiated – government incentives – service provider regulated by project agreement to prevent abuse” is recommended for Zones 1, 2 and 3 where Government land is unlikely to be made available for DCS plant site. Although Government will unlikely provide land for DCS plant site, Government could however consider other incentives to promote DCS. Conditions for granting incentives could be documented in Joint Practice Note, which could be incorporated by reference in a project agreement between Government and the private service provider. Government could exercise control over the service provide to prevent abuse use of the Government incentives.

4.3.4 Incentives

The initial capital investment cost of DCS is considered high and the market penetration rate is uncertain because the potential customers are generally not familiar with DCS, which is the first of its kind in Hong Kong. Therefore, provision of incentives are recommended to be considered by the Government to promote the DCS implementation. Among various incentives, the following key incentives are suggested to be considered :

- Exempt DCS plant room land cost
- Exempt pipework wayleave rental charge
- After joining DCS, buildings’ individual obsolete chiller rooms could be converted to green/commercial area without paying full land premium

4.3.5 Contract Strategies

For Zone 5 where Government unleased land could be made available for DCS plant site, it is recommended that in granting occupation right to private service provider for DCS plant site, the service provider shall be required to enter a “Build-Operate-Transfer” (BOT) or similar type of contracts with Government to enable Government to exercise control through contract on DCS service delivery and to prevent abuse use of Government land. Having been awarded a BOT contract, the private DCS operator would undertake to design, build, fund and operate the DCS facilities and transfer the titles of the facilities to Government at expiry of the contract period. This contract strategy encourages private sector participation in DCS service delivery and provides high flexibility in design, building, operation and capital investment taking into account of uncertainty in customer demand.

Through contract provisions, Government could exercise control mechanisms over service provider regarding quality and tariff of service delivery. The contract should avoid limiting the flexibility of commercial negotiation between the service provider and service purchaser.

5. IMPLEMENTATION PLAN

Following the study on regulatory, institutional and contract issues as presented in the previous section, DCS implementation plans are formulated with respect to implementation tasks, structure and programme.

5.1 Implementation Tasks for Zone 5

The implementation tasks for Zone 5 either for DCS or CPSSCC under the implementation approach of “Government initiated – contract” are as follow:-

- a. Identify DCS / CPSSCC zone and plant site;
- b. Reserve Government unleased land for plant site;
- c. Obtain relevant policy approvals. For example, land for plantroom and pipeline wayleave rental charge, condition for granting relevant incentives;
- d. Invite for Expression of Interest (EOI). Any EOI submission should be completed with a business plan and a technical proposal;
- e. Evaluate EOI submissions to prequalify tenderers;
- f. Prepare tender documents and invite tender for DCS/CPSSCC implementation;
- g. Evaluate tenders and award BOT type contract to the successful tenderer to design, build, fund and operate DCS/CPSSCC. Government can give incentives as appropriate to the successful tenderer through contract to promote DCS/ CPSSCC implementation. In return, the successful tenderer has to comply with all the requirements as stipulated in the contract. Government can exercise control mechanisms over DCS/CPSSCC service delivery by means of contractual provisions; and
- h. Monitor performance and exercise control over service provider according to the contract terms with respect to the following major aspects:
 - Quality of service delivery
 - Tariff of service delivery

5.2 Implementation Tasks for Zones 1, 2 and 3

Implementation Tasks for Zones 1, 2 and 3 under the implementation approach of “Private initiated – Government incentives – service provider regulated by project agreement to prevent abuse” are as follow:

- a. Obtain relevant policy approvals. For example, waive of pipeline wayleave rental charge, conversion of user building obsolete chiller plant room to commercial area after these buildings are connected to DCS ;
- b. Government to announce its policy on incentives. The Government policy could be reflected in relevant practice note;
- c. Upon receipt of application from private sector for DCS/CPSSCC service delivery, Government shall evaluate each individual application. When the application is considered satisfactory and the extent of incentives to the DCS provider is determined by the Government, Government will notify public of

EXECUTIVE SUMMARY

the DCS zone boundary and invite for application within a specified timeframe to let the potential DCS providers to bid for it. Such kind of invitation for application is recommended in order to maintain a fair competition and achieve the best offer.

- d. If only one satisfactory application is received, Government would grant incentives through project agreement to the successful applicant according to the established Government policy and/or practice note. If a practice note is to be applied, it would be incorporated by reference in a separate project agreement between Government and the service provider. If there is more than one satisfactory application, Government would select the best applicant.
- e. Government has to stipulate requirements for granting incentives to service provider. Successful applicant has to enter an agreement with Government to commit compliance with all the stipulated conditions and requirements as required for obtaining Government's incentives.

5.3 Implementation Structure for Zones 1, 2, 3 and 5

For effective implementation of DCS/CPSSCC, it is recommended to establish a Regulator Office to look after DCS/CPSSCC implementation issues. An inter-departmental Steering Committee is also recommended to be set up to give advice and support to the Regulator Office particularly regarding Government policy formulation and cross-department implementation issues.

5.4 Implementation Programme for Zone 5

Based on the proposed technical scheme and implementation approach, the tentative implementation programme for Zone 5 is as follow:-

- a. Administrative works (Total 12 months) including:-
 - Policy formulation and approval (6 months)
 - Resolving land issues (9 months with 3 months overlapping)
 - Formulation of implementation team (2 months without overlapping)
- b. Contract Procedures, Design & Construction (Total 52 months)
 - Preparation of tender (4 months)
 - Tender procedures and award (6 months)
 - Design and construction (42 months)

However, the proposed DCS programme should be subject to further review upon confirmation of WDII implementation programme. It is anticipated that there is a possibility to integrate with future confirmed WDII programme to undertake a fast track implementation programme of DCS.

For CPSSCC, the implementation programme in Part (a) will be shortened by 4 months as it eliminates the time taken for resolving land issues for the plant room. For construction duration in Part (b), as the critical path shall be the installation

of pipeworks irrespective DCS or CPSSCC pipelines, hence the programme in Part (b) is considered also applicable to CPSSCC.

5.5 Implementation Programme for Zones 1, 2 and 3

Under this approach, the timeframe would not be controlled by Government. As soon as the private sector finds suitable private land for DCS plant site and secure sufficient customer demand to justify their investment, they could make application to Government for consideration for granting relevant incentives to support DCS implementation.

5.6 Promotion

In order to promote wider adoption of DCS/CPSSCC in WCCB, Government is recommended to carry out activities to increase the awareness of the public, the prospective service providers and the building owners and operators, of the benefits of adopting DCS/CPSSCC and the Government's policy on DCS/CPSSCC promotion.

6. CONCLUSION AND RECOMMENDATIONS

6.1 DCS Potential Zones

Based on the geographical cooling load distribution and customer demand projection, five high density cooling demand zones are identified as potential DCS zones for detailed evaluation.

The following four zones are further evaluated and found to be technically and financially viable.

Zone 1:	Wan Chai North
Zone 2:	Wan Chai South
Zone 3:	Causeway Bay
Zone 5:	Wan Chai North Waterfront
Remark:	Zone 4 is not financial viable

As Zone 5 is adjacent to the Victoria Harbour, both DCS and CPSSCC are viable subject to the programme and extent of WDII reclamation as well as the availability of Government unleased land for plant site.

DCS is preferred to CPSSCC in Zone 5 because of higher energy efficiency, greater environmental benefit and lower project life cycle cost. Therefore, for Zone 5, focus will be on DCS implementation.

6.2 Planning and Land Issues

Prior to developing the technical analysis of those suitable potential zones, land for DCS plant sites have to be identified. As Wan Chai and Causeway Bay are well developed urban areas, there is generally a lack of unleased Government lands for DCS plant sites. After comprehensive research and consultation with relevant Government departments, it appears that unleased Government land for DCS plant may only be available for Zone 5. For the other zones, the availability of Government lands for DCS plant sites is remote given the current planning and lands constraints in these zones.

For Zone 5, the Wan Chai West Sewage Screening Plant, i.e. Site E2 at existing Wan Chai waterfront is identified as the most suitable site for DCS chiller plantroom. The plant site is now subject to permanent allocation held by DSD. The DCS seawater pumping station can be located in the existing empty seawater pump cells reserved at waterfront of HKCEC Phase II.

With full respect to the views from the Planning Department and Lands Department regarding the land utilization and long term planning intention of the development site, it is considered that Option 2 (DCS plant room with roof deck for public open space) is most viable taking into account of the uncertainty in timing of the commercial development and the complexity of the interface between

EXECUTIVE SUMMARY

the commercial development and the proposed DCS plantroom. Government policy coverage to recognize the over-riding programming need of the DCS development, and to reconsider the long term planning intention of the development site for commercial use, should be sought in due course. With adequate policy directive and no objection from other Government departments, land for DCS plant can be allocated to selected Government department, who can then grant an operation license to a service provider through tendering process. The service provider would take occupancy of the land for the installation and operation of DCS system during the contract period. The roof landscape garden can be operated by the service provider or by a relevant Government department, for example LCSD.

If the reconsideration of the long term planning intention turns out unsuccessful, Option 3 (DCS plant room with top side development) can be further pursued.

6.3 Basic Design Scheme

As Zones 1, 4 and 5 are close to the Victoria Harbour, it is recommended to use seawater cooled DCS system. Both the DCS plant rooms and the DCS pipelines are proposed to be on unleased Government land. Zones 2 and 3 are far away from the sea. It is recommended to use cooling towers for heat rejection in these two zones.

6.4 Traffic Impact Assessment and Preliminary Environmental Review

Technical evaluation with respect to traffic impact and environmental review have been carried out. Results of the evaluation confirmed that DCS schemes implementation in all potential DCS zones are technically viable.

6.5 Financial Analysis

For base case scenario, i.e. without any government incentives, DCS Zones 1, 3 and 5 are financially viable. Subject to the extent of government incentives as evaluated in **Annex III** on financial analysis, Zone 2 could become financially viable for DCS implementation, whilst the financial attractiveness for Zones 1, 3 and 5 could be enhanced by providing the government incentives. For DCS Zone 4, this zone has been evaluated as financially not viable under both base case and the granting of the incentives regarding waiving pipeline wayleave rental charge and plantroom land premium.

6.6 Regulatory, Institutional and Contract Issues

For Zone 5 where government unleased land is available, the “Government initiated – contract approach” is recommended.

EXECUTIVE SUMMARY

For Zones 1, 2 and 3 where government unleased land is not available, the “Private initiated - Government incentives – regulated by project agreement to prevent abuse” is recommended.

2.2

6.7 Implementation Plan

Based on the recommended implementation approach stated in Section 6.6, implementation plans for Zones 1, 2, 3 and 5 are developed. The implementation plans include implementation tasks, structure and programme.

The implementation structure is proposed to include a working department (Regulator office) responsible for DCS implementation and an inter-departmental Steering Committee to give support on policy issues and cross-department implementation issues.

ANNEX I: FEATURES OF DCS AND CPSSCC**1 District Cooling System (DCS)**

DCS distributes chilled water from a central chiller plant of DCS to a number of buildings, whose building owners / operators have subscribed the DCS service. After connection with DCS, these service purchasers would no longer require to keep or use their own existing chiller plants. The absorbed heat from the user buildings is rejected to the sea or atmosphere by employing either sea water cooling or evaporative cooling towers respectively. The below two schematic diagrams show the generic DCS schematic by employing the sea water cooling and evaporative cooling towers for heat rejection purpose.

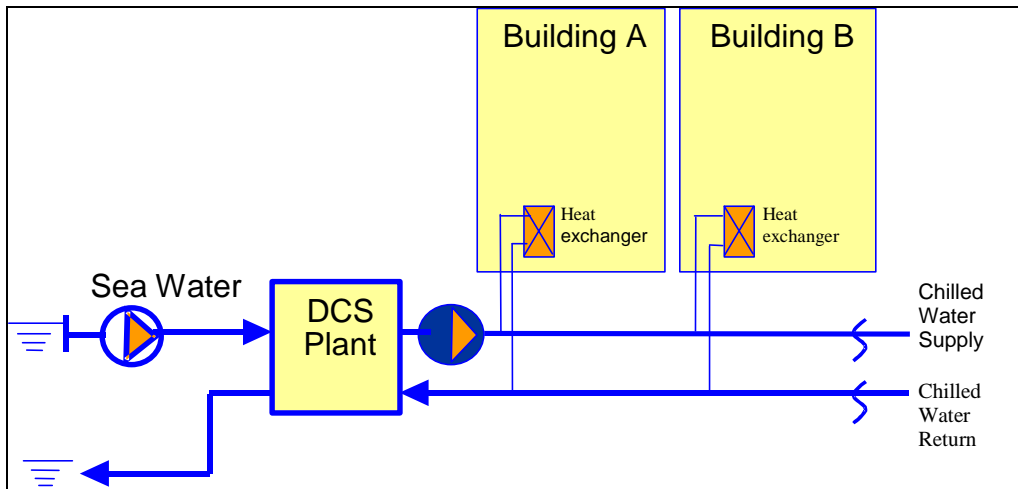


Figure 1.1 Schematic Diagram of DCS with Seawater for Heat Rejection

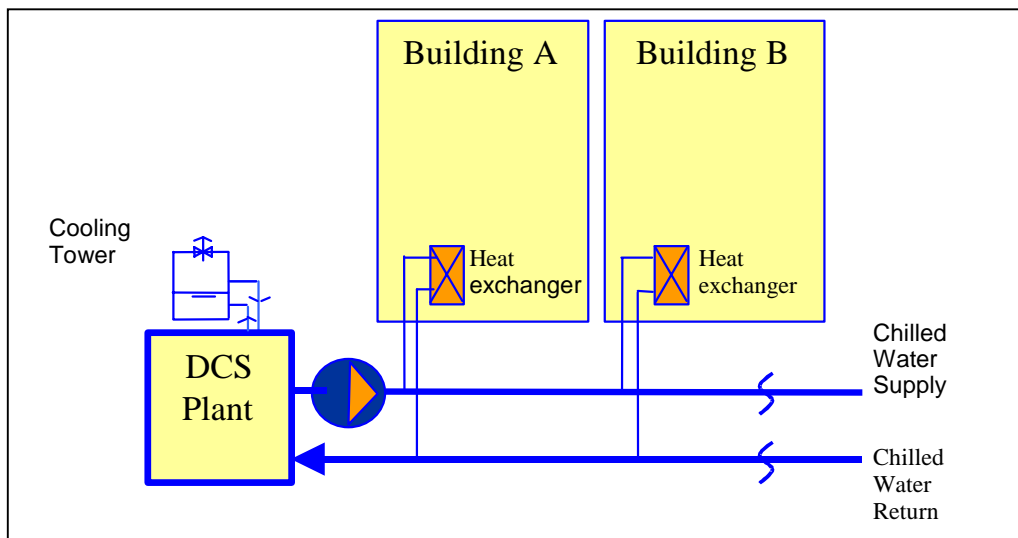


Figure 1.2 Schematic Diagram of DCS with Cooling Tower for Heat Rejection

2 Centralized Piped Supply System for Condenser Cooling (CPSSCC)

The centralized piped supply system for condenser cooling (CPSSCC) is a large scale central sea water pumping system which supplies sea water via the distribution piping network to a number of potential users within the district for heat rejection of their air-conditioning systems.

Figure 1.3 shows the schematic diagram of CPSSCC.

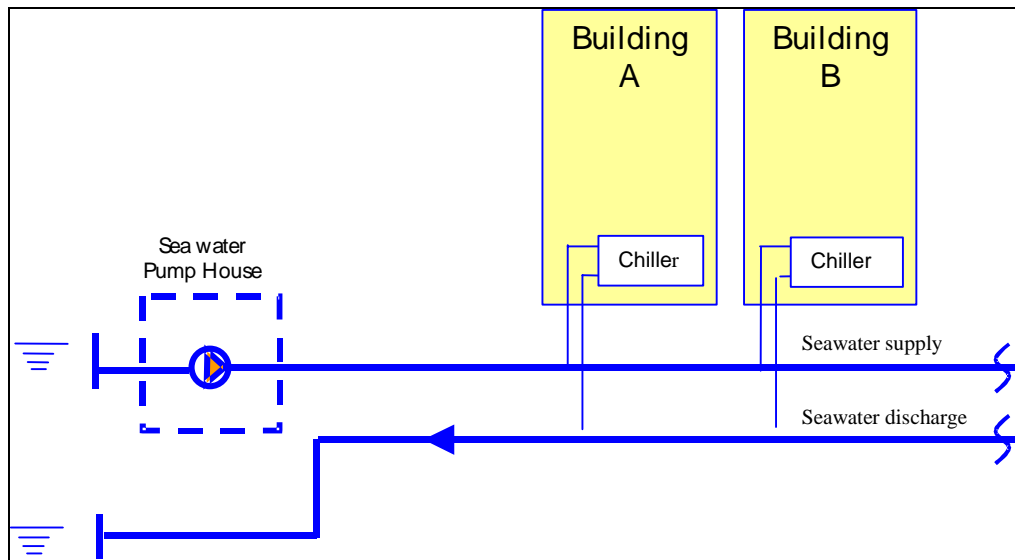


Figure 1.3 Schematic Diagram for CPSSCC

The main difference between DCS and CPSSCC is that the chillers of individual user buildings are required to be kept for operation in CPSSCC scheme. That is, the prerequisite condition for subscription of CPSSCC service is that the customer building must have seawater cooled chiller plant. Given such condition, those owners currently utilizing air-cooled chillers would not be potential customers for CPSSCC.

When compared with CPSSCC, DCS is more energy efficient and environmentally friendly. As both schemes involve substantial capital investment and public road space for pipes laying, it would not be practical to allow two systems to co-exist in the same district. Specific to WCCB, most of the potential buildings have been installed with air-cooled chiller plants. These building owners would likely subscribe for DCS service rather than CPSSCC so as to save upfront cost for converting the air-cooled to sea water cooled chiller plant and to enjoy higher energy saving benefit of DCS. CPSSCC would only be considered under special cases such as reprovision of sea water cooling system for existing seawater cooled buildings when their existing sea water cooling plants become affected by reclamation.

ANNEX II. BASIC DESIGN SCHEMES

1 DCS Basic Design Scheme

As referred to Figure 1.1 and 1.2 in Annex I, DCS is composed of several key components including heat rejection system, DCS plant, pipelines distribution network and heat exchangers installed inside the user buildings. A dedicated DCS plant was designed for each identified potential zone. The basic design scheme is outlined below with reference to the above key components.

a. Heat Rejection System

In view of energy performance, the heat rejection system for DCS would adopt direct sea water cooling when close to sea and evaporative cooling towers for DCS plant when remote from sea.

b. DCS Plant Design

Various types of chilled water generation technologies were evaluated. It is recommended to adopt electrical driven centrifugal type chiller in Hong Kong due to its proven track record and higher overall cost effectiveness as compared with other types of chillers.

The application of ice thermal storage system was also investigated but the financial return is not satisfactory as there is lack of attractive night time electricity tariff in Hong Kong to compensate for the higher energy consumption in ice charging operation in night time period.

Subject to the requirements of user buildings to be served, in general 4.5 °C DCS supply temperature could enhance the cooling carrying capacity of distribution pipelines, lower capital cost of DCS system, and provide high chiller operating efficiency .

Variable flow pumping system would be adopted to cater for the fluctuating district cooling demand so as to conserve the pumping energy.

In general, the DCS plant and sea water pumping stations could be underground while the ventilation shafts, staircases and equipment hoisting chamber(s) could be connected to the floor aboveground.

For DCS plant using cooling towers for heat rejection, open space would be required for accommodating the cooling tower plant as well as the air intakes and discharges.

c. Distribution Network Design

Subject to the geographic locations of DCS plant and the potential customer buildings, two schemes of DCS distribution mains could be utilized. The first scheme is 3-pipes system comprised of 2 chilled water supply pipes and 1 chilled water return pipe. An alternative scheme is 2-pipes ring distribution arrangement where the main distribution pipeline would form a ring circuit with branch-offs connecting to individual DCS user buildings. Both schemes can enable continuous supply of chilled water even when failure of anyone of the main distribution pipes.

The piping material for DCS (fresh water) would be steel pipe with external thermal insulation in order to maintain the DCS supply temperature in case of soil excavation in future road works. For sea water cooling pipes, ductile iron with internal cement lining for corrosion protection would be used.

All the pipelines would be laid under the public roads. Figures 3.1 to 3.4 in **Annex IV** show the proposed DCS piping layout for the potential DCS Zones 1, 2, 3 and 5.

d. Customer Substation Design

Indirect connection between DCS system and user buildings' chilled water system would be made through the customer substation which is a heat exchanger for transfer of cooling energy. The purpose of indirect connection through heat exchangers is to avoid direct contact of DCS chilled water with chilled water of individual building's chilled water systems so as to better safeguard DCS chilled water quality as well as to avoid impact on system temperature and pressure.

e. Phase Development

In order to minimize initial capital investment, DCS installation for each zone is recommended to be divided into 4 phases to in line with the gradual increase of customer cooling demand.

The proposed DCS plant capacities for Zones 1 to 5 and CPSSCC zone are summarized in Table AIII.1. The plant capacities for each DCS Zone could cater for the district cooling demand projected up to Year 2030 with allowance of 7 to 10% spare capacity as a safety margin to cater for any further load growth.

Table AII1.1 Summary of DCS and CPSSCC Plant Capacities

DCS Zone	Chiller Plant Capacities at Ultimate Development Level (Up to Year 2030)
1	84 MW
2	74 MW
3	105 MW
4	31 MW
5	168 MW
CPSSCC	147 MW

2 CPSSCC Basic Design Scheme

The existing five pump chambers at the waterfront in front of the HKCEC Phase II could be utilized for accommodating the CPSSCC facilities. The CPSSCC would comprise several key components including sea water straining system, water treatment, pumping system and distribution network etc. The basic design scheme is outlined below.

a. Sea Water Straining System

At the sea wall, the seawater intake would be fitted with coarse screens to prevent the ingress of both floating and submerged debris.

Automatic backwash strainers (ABS strainer) would be installed inside the plant rooms to protect the distribution pipework. Before being pumped into the distribution pipeworks, the seawater would be filtered by the ABS strainers.

b. Sea Water Treatment System

Electrochlorinators would be installed in the plant rooms for on-site generation of hypochlorite solution, which is then injected into the seawater intake to inhibit the growth of marine organisms.

c. Sea Water Pumping Design

In order to optimize energy efficiency, the selected pump head would suit the general pressure head requirements of the user buildings cluster. For those buildings requiring exceptional higher pump head, these specific buildings would need to install booster pumps to suit the specific needs.

To cater for partial load conditions, seawater pumps would be variable speed pumps. The pumping system would be controlled to meet the changing load conditions.

d. Distribution Networks Design

For CPSSCC, twin sea water intake / outfall mains will be adopted. This arrangement could also improve system reliability such that when one of the main header fails, at least 50% of central seawater supply flow could still be maintained.

Ductile iron pipe with internal cement lining would be used due to its better corrosion resistance to sea water.

Figure 3.5 in **Annex IV** shows the proposed CPSSCC layout plan.

ANNEX III: RESULTS OF FINANCIAL SENSITIVITY ANALYSIS

1. Cost of Capital

The cost of capital would be affected by a number of economic factors, which would vary over 30-years contract for services delivery. This figure is estimated to range from 7.14% to 12.05% and the mean value of 9.3% is adopted in the base case analysis. In order to appreciate the impact of the cost of capital to the financial viability of WCCB, sensitivity tests on cost of capital are carried out and the results are in Table AIII.1 below.

Table AIII.1 Financial Analysis on Cost of Capital Sensitivity Test

	Cost of Capital = 7.14%			Cost of Capital = 12.05%		
Potential Zone	NPV (HK\$ Million)	IRR (%)	Financial Viability	NPV (HK\$ Million)	IRR (%)	Financial Viability
1	233 M	12.1 %	Viable	1.4 M	12.1 %	Viable
2	32.5 M	8.1 %	Viable	(72 M)	8.1 %	Not viable
3	107 M	9.7 %	Viable	(54 M)	9.6 %	Not Viable
4	(32 M)	5.6 %	Not viable	(74 M)	5.5 %	Not viable
5	318.6 M	10.8 %	Viable	(64.1M)	10.7 %	Not Viable

In comparison with the results of the Base Case, the financial viability would be greatly affected when the cost of capital reaches its lower and upper bounds. For example, Zone 2 would be financially viable when the cost of capital drops from 9.3% to 7.14%. However, Zones 3 and 5 would become financially not viable when the cost of capital rises to 12.05%.

According to above findings, the cost of capital is a sensitive parameter; especially for large capacity DCS plant, e.g. DCS Zones 1 and 5. It is because of the higher investment costs for these zones, the corresponding impacts of cost of capital are also greater.

2. Customer Uptake Ratio

Customer uptake ratio directly drives the amount of revenue for a DCS project. However, higher customer uptake ratio means higher cooling demand and greater installation capacity, so the costs outflow and the annual recurrent cost would also increase.

Based on the evaluation results, sensitivity analysis regarding impact of customer uptake ratio on the financial viability is conducted based on 50% customer uptake ratio for the DCS potential zones assuming no government incentives. The results are summarized in Table AIII2.1 below.

Table AIII2.1 Sensitivity Test Results on Customer Uptake Ratio

Potential Zone	System Type	Assumed Customer Uptake Ratio	NPV (HK\$ Million)	IRR (%)	Financial Viability
1	DCS-SW	50%	83.0 M	11.4 %	Viable
2	DCS-CT	50%	(24.6 M)	8.4 %	Not viable
3	DCS-CT	50%	(45.3 M)	7.6 %	Not viable
4	DCS-SW	50%	(33.0 M)	7.6 %	Not viable
5	DCS-SW	50%	(47.6 M)	8.1 %	Not viable

The sensitivity analysis results show the following:

- As compared with Table AIII2.1, when Zone 3's customer uptake ratio drops from 60% to 50% and Zone 5's customer uptake ratio drops from 100% to 50%, DCS in these two zones would become financially not viable.
- Although the predicted customer uptake ratios for DCS Zones 2 and 4 are increased to 50%, these two cases would still remain financially not viable.
- Despite of using 50% customer uptake ratio, which is regarded as optimistic prediction for some zones, most of the schemes are not financially viable without government incentive. This reflects that incentive offer(s) from the Government could effectively promote DCS implementation.

A further financial analysis on different customer uptake ratios for Zone 5 is carried out, it shows that when the customer uptake ratio is dropped to about 70%, the DCS scheme will become marginally financial viable. The financial results under different customer uptake ratios for Zone 5 are summarized in Table AIII2.2.

Table AIII2.2 Sensitivity Test Results on Customer Uptake Ratio for Zone 5

System Type	Assumed Customer Uptake Ratio	NPV (HK\$ Million)	IRR (%)	Financial Viability
DCS Zone 5	50%	(40.2 M)	8.0 %	Not viable
	70%	10 M	9.5 %	Viable
	75%	17.5 M	9.53 %	Viable
	100%	95.5 M	10.7 %	Viable

A similar analysis is also carried out for CPSSCC, the results are summarized in below:

Table AIII2.3 Sensitivity Test Results on Customer Uptake Ratio for CPSSCC

System Type	Assumed Customer Uptake Ratio	NPV (HK\$ Million)	IRR (%)	Financial Viability
CPSSCC	50%	(15.4 M)	7.9 %	Not viable
	70%	(0.4 M)	9.3 %	Not viable
	75%	11.7 M	10.1 %	Viable
	100%	19.1 M	10.3 %	Viable

The above table shows that the project will be marginally financial viable when customer uptake ratio is approaches to 70%.

3. Land Premium

The proposed DCS sites are situated on Unleased government lands, which are currently zoned as GIC. If the government land is granted to a DCS operator, an allowance for the land premium should be included to reflect the market value of the land. For the Base Case, the land premium is assessed based on the industrial land value which is taken to be HK\$ 3,500 / m².

However, if the land premium is calculated based on commercial land use, its estimated value would increase to HK\$ 13,000 / m². The effects of this commercial land premium on the financial viability are shown in the table below:

Table AIII.3.1 Sensitivity Test Results on Land Premium (commercial use)

Potential Zone	System Type	NPV (HK\$ Million)	IRR (%)	Financial Viability
1	DCS-SW	40.0 M	10.3 %	Viable
2	DCS-CT	(89.6 M)	6.4 %	Not viable
3	DCS-CT	(62.2 M)	7.7 %	Not viable
4	DCS-SW	(93.9 M)	4.2 %	Not viable
5	DCS-SW	(16.2 M)	9.1 %	Not viable

According to Base Case findings, Zones 1, 3 and 5 are financially viable based on industrial land use premium. However, if the land premium rate is classified as commercial land use, i.e. 3.7 times of industrial land use, the financial viability would be seriously jeopardized and the NPV would decrease significantly. The result implies that the land premium is a key sensitivity factor. In other words, this is one of the factors the Government could consider as an incentive.

DCS Zone 5 was further evaluated under the basis that the sea water pumping station would be rented by the Government to DCS operator at a rate of HK\$ 630/m²/year and the land premium for DCS plant is calculated based on industrial land use rate. The corresponding NPV and IRR would be improved to HK\$ 121.6 M and 11.3 % respectively. When compared to the Base Case, the NPV will be improved by about 27%. Therefore from the point of promoting DCS implementation, it is recommended the Government to let the existing pumping chambers to the DCS Zone 5 operator at the suggested rental rate instead of charging its full land premium.

If the commercial land premium for DCS plant and the above rental rate for sea water pumping station for DCS Zone 5 are assumed, the NPV and IRR would become HK\$ 40.9 M and 9.9% respectively.

4. Pipe Laying

Potential traffic impacts and major conflicts with existing infrastructure have been assessed with respect to the proposed DCS pipelines. Wherever traditional open cut method could not be applied, for example tram tracks or crossing over shallow box culverts, etc, a more costly trenchless pipe laying method would be required.

The basic design approach utilizes the more cost effective open cut pipe laying method wherever possible. As a contingency consideration, a sensitivity test was conducted to investigate any significant impact on financial viability by using the trenchless pipe laying method.

Table AIII4.1 Sensitivity Test Results on Trenchless Pipe Laying Method

Potential Zone	System Type	NPV (HK\$ Million)	IRR (%)	Financial Viability
1	DCS-SW	52.6 M	10.7 %	Viable
2	DCS-CT	(73.1 M)	6.8 %	Not viable
3	DCS-CT	(14.6 M)	8.9 %	Not viable
4	DCS-SW	(75.9 M)	4.8 %	Not viable
5	DCS-SW	71.4 M	10.3 %	Viable

As revealed from above table, Zones 1 and 5 are financially viable. However its NPV would drop dramatically. DCS Zone 3 becomes financially not viable. According to the above findings, trenchless pipe laying could be regarded as a key sensitivity factor in view of its potential impact on NPV and financial viability. It is therefore the use of trenchless pipe laying method should be limited to only those areas where traditional pipe laying method cannot be applicable.

5. Waive of Pipelines Wayleave Rental Charge and Land Premium

If the land premium and pipelines wayleave rental charge are waived, the overall financial situation for all zones would be improved. The findings are summarized in Table AIII5.1.

Table AIII5.1 Incentive Analysis Results on Waiving Pipelines Wayleave Rental Charge and Land Premium

Potential Zone	System Type	NPV (HK\$ Million)	IRR (%)	Financial Viability
1	DCS-SW	160 M	14.2 %	Viable
2	DCS-CT	18 M	10.1 %	Viable
3	DCS-CT	57 M	11.3 %	Viable
4	DCS-SW	(32.2 M)	7.2 %	Not viable
5	DCS-SW	187.9M	12.2 %	Viable

From these two incentives, the sensitivity analysis results show the following implications:

- The DCS potential zones are financially viable with the exception of DCS Zone 4.
- DCS Zones 1, 3 and 5 are financial viable without government incentives as shown on Table AIII5.1. Nevertheless, the financial performance of these zones would be improved significantly with addition of the two incentives.

For DCS Zone 2, provision of government incentives is needed in order to enable DCS in this zone financially viable.

- The minimum DCS tariff can possibly be lowered to 0.46, 0.57, 0.54 and 0.44 HK\$ / kWhac for Zones 1 to 3 and Zone 5 respectively. This is equivalent to 10% discount from the A/C self-generation cost, which is expected to be able to increase the customer uptake ratios.

6. Discount on Water Consumption and Effluent Discharge Charges (Applicable to DCS Zones 2 & 3 using cooling tower scheme)

In the Base Case analysis, the water consumption and effluent discharge rate are taken as HK\$ 9.69 / m³ and HK\$ 1.2 / m³ respectively. According to the current charge structure, the water consumption charge is subsidized by the Government and the rate is HK\$ 4.58 / m³. For effluent discharge rate, a 30% discount can be applied for industrial applications, i.e. HK\$ 0.84 / m³. The NPV and IRR are evaluated below by using the discounted HK\$ 4.58 / m³ and HK\$ 0.84 / m³ rates.

Table AIII.6.1 Incentive Analysis Results on Discount on Water Consumption and Effluent Discharge Charges

Potential Zone	System Type	NPV (HK\$ Million)	IRR (%)	Financial Viability
2	DCS-CT	(16.2 M)	8.6 %	Not Viable
3	DCS-CT	29 M	10.2 %	Viable

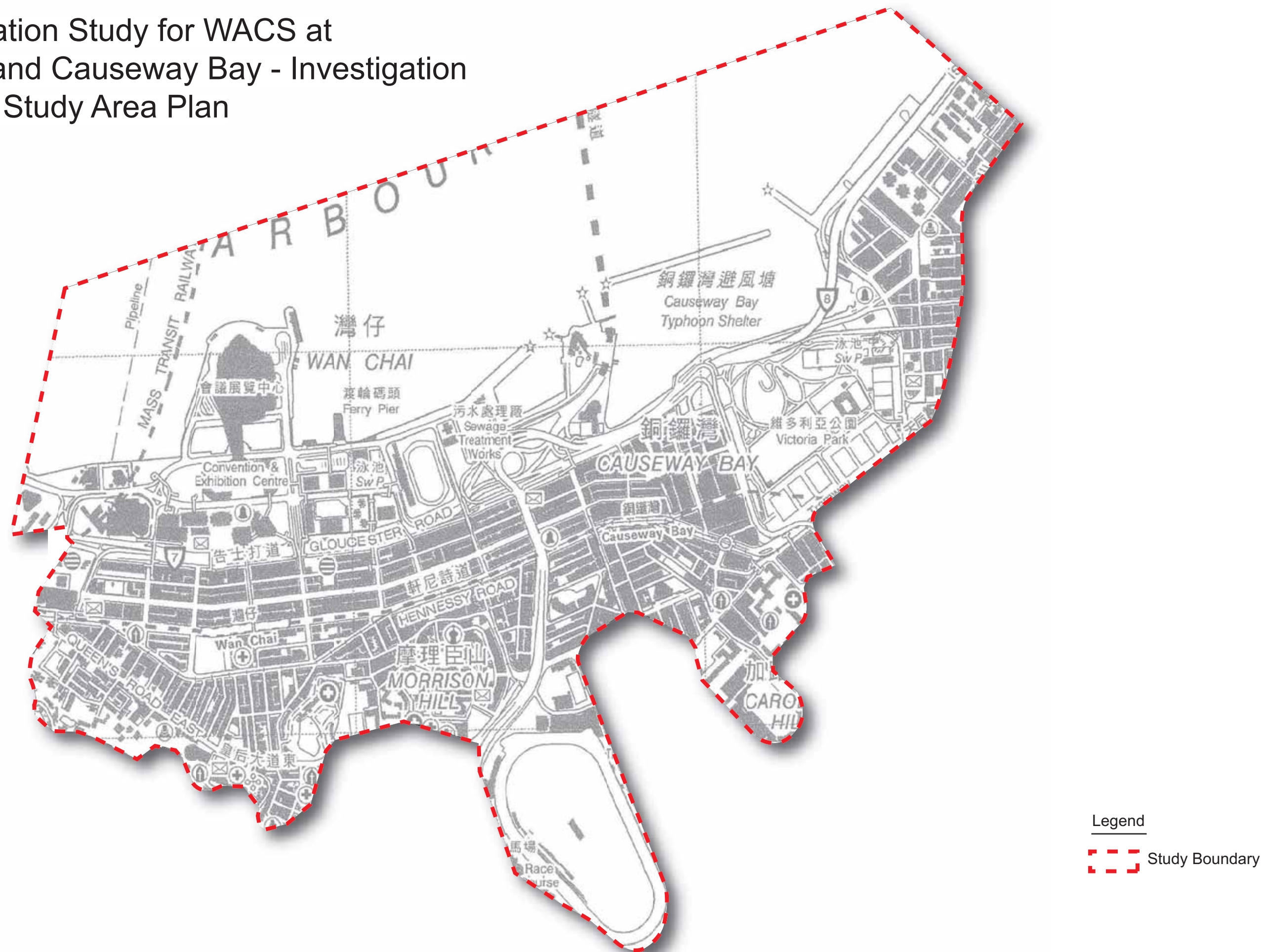
As compared with the results in the Base Case, the financial viability for Zones 2 and 3 would remain unchanged. However, the NPV can be doubled and thus can be improved significantly. Thus, this incentive is considered important to the financial performance and should be evaluated on a case by case basis.

EXECUTIVE SUMMARY

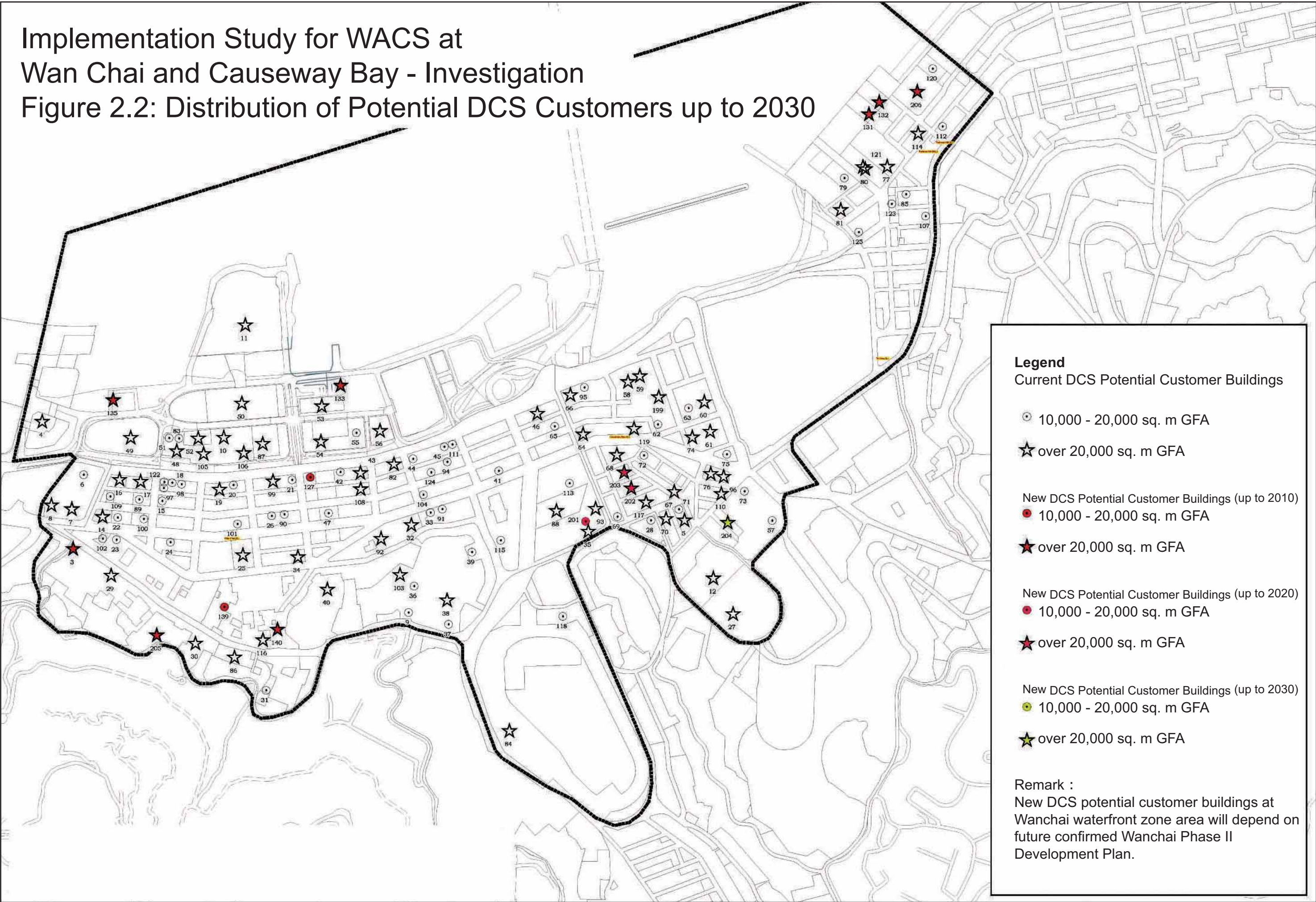
ANNEX IV: DRAWINGS

- Figure 2.1: Study Area Plan
- Figure 2.2: Distribution of Potential DCS Customers up to 2030
- Figure 2.3: Zoning Map for WCCB
- Figure 3.1: Indicative DCS Piping Layout Plan for Wanchai Waterfront Zone (Zone 5)
- Figure 3.2: Indicative DCS Piping Layout Plan for Wan Chai North Zone (Zone 1)
- Figure 3.3: Indicative DCS Piping Layout Plan for Wan Chai South Zone (Zone 2)
- Figure 3.4: Indicative DCS Piping Layout Plan for Causeway Bay Zone (Zone 3)
- Figure 3.5: Indicative CPSSCC Piping Layout Plan for Wanchai Waterfront Zone (Zone 5)

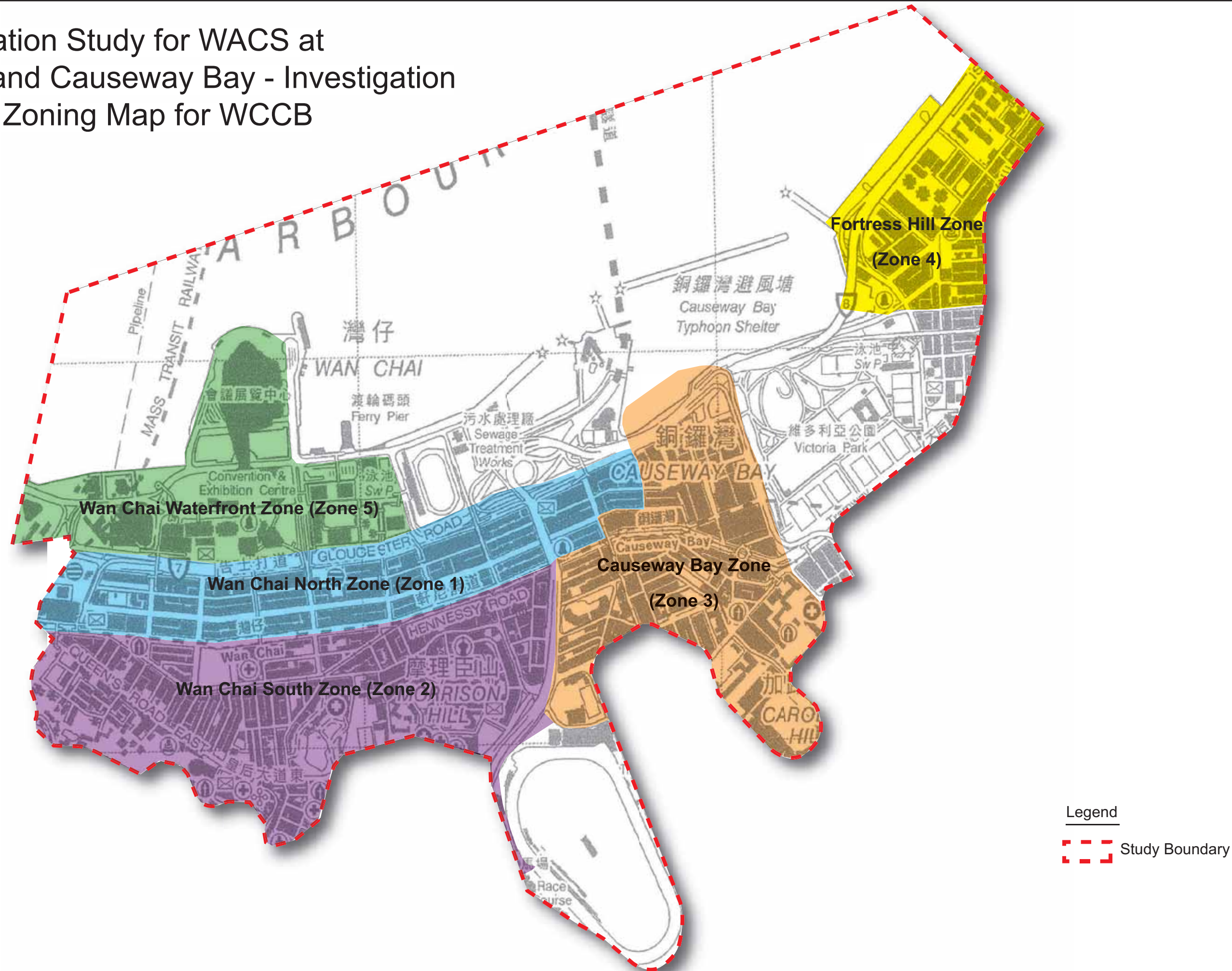
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Figure 2.1: Study Area Plan



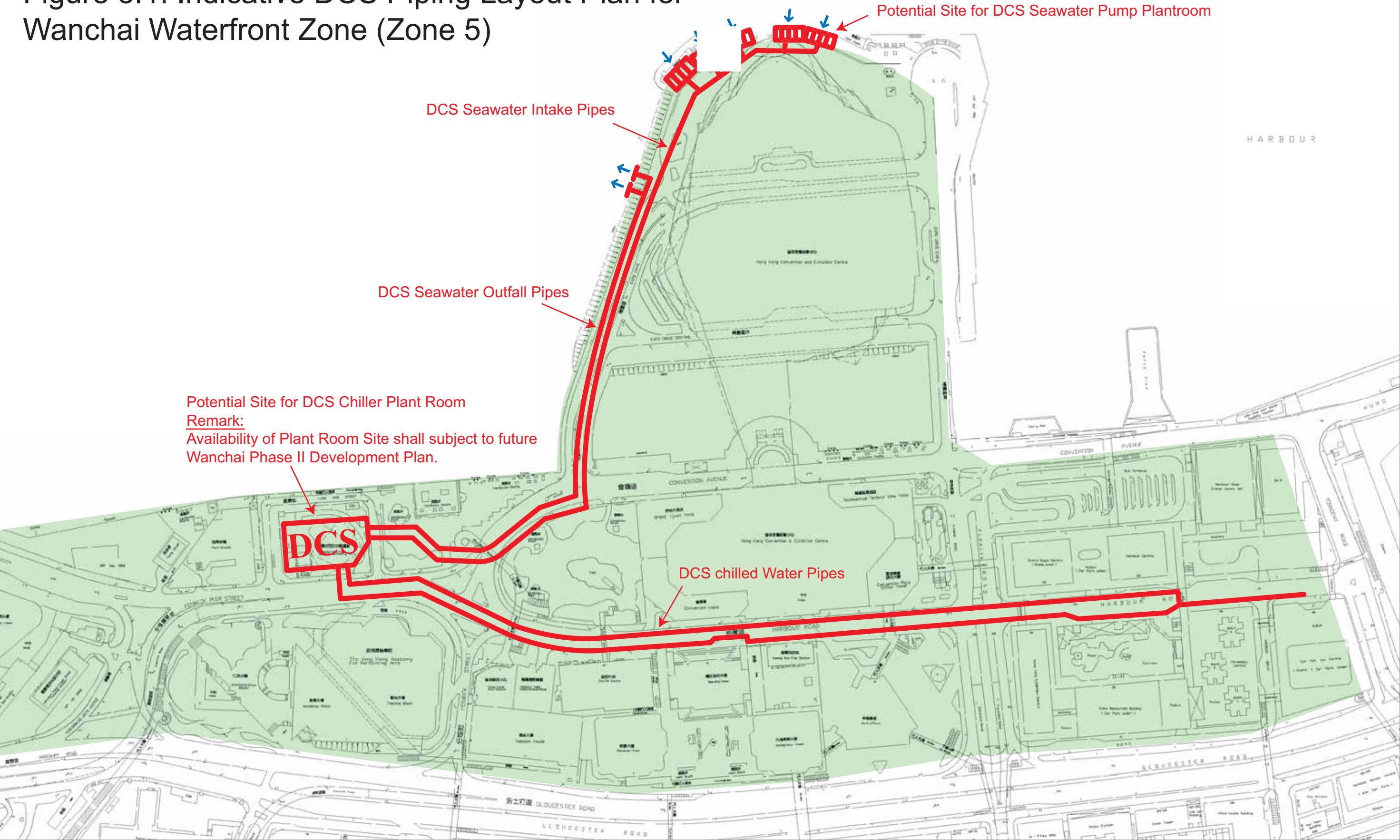
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Figure 2.2: Distribution of Potential DCS Customers up to 2030



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Figure 2.3: Zoning Map for WCCB

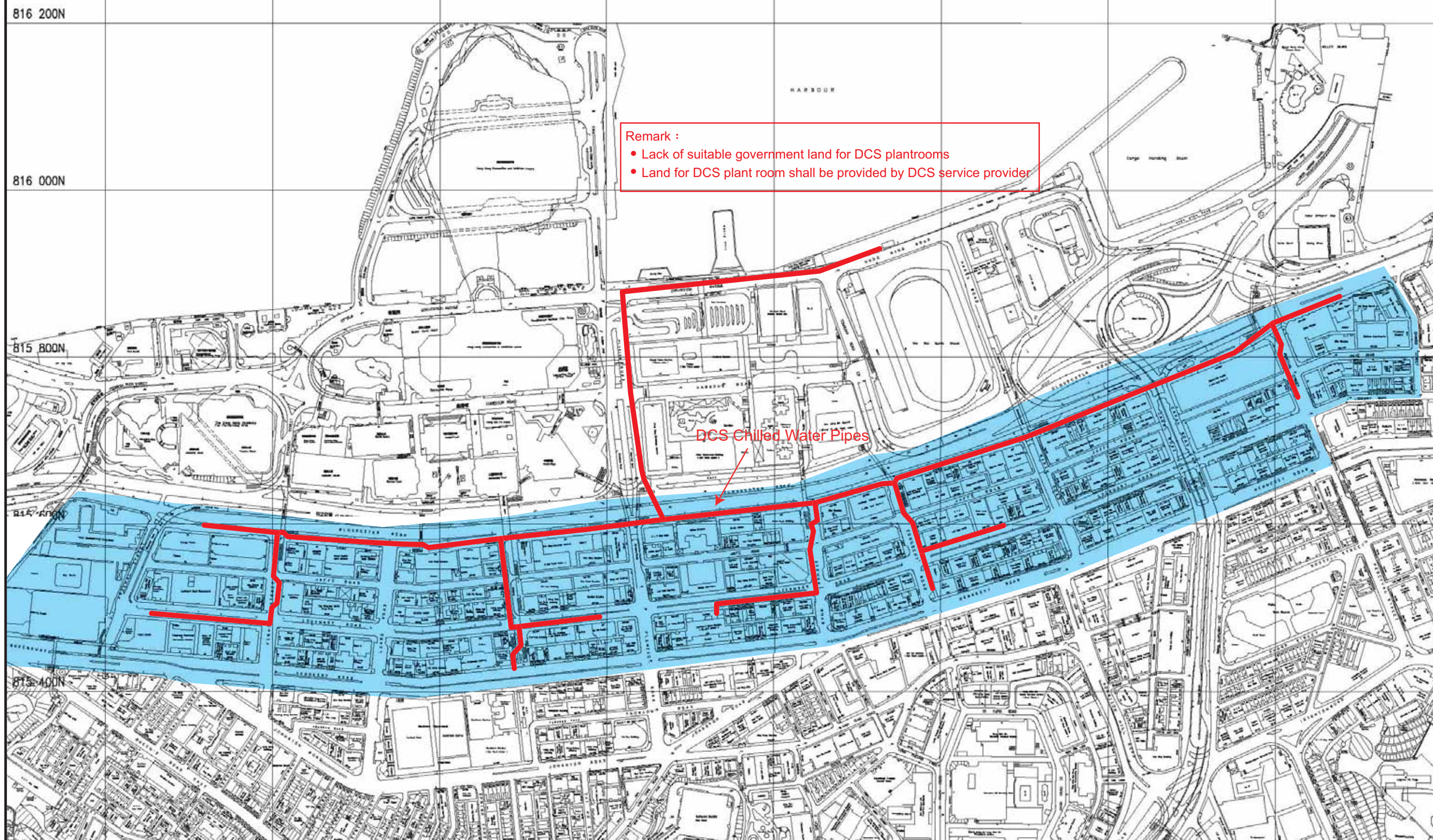


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Figure 3.1: Indicative DCS Piping Layout Plan for
Wanchai Waterfront Zone (Zone 5)



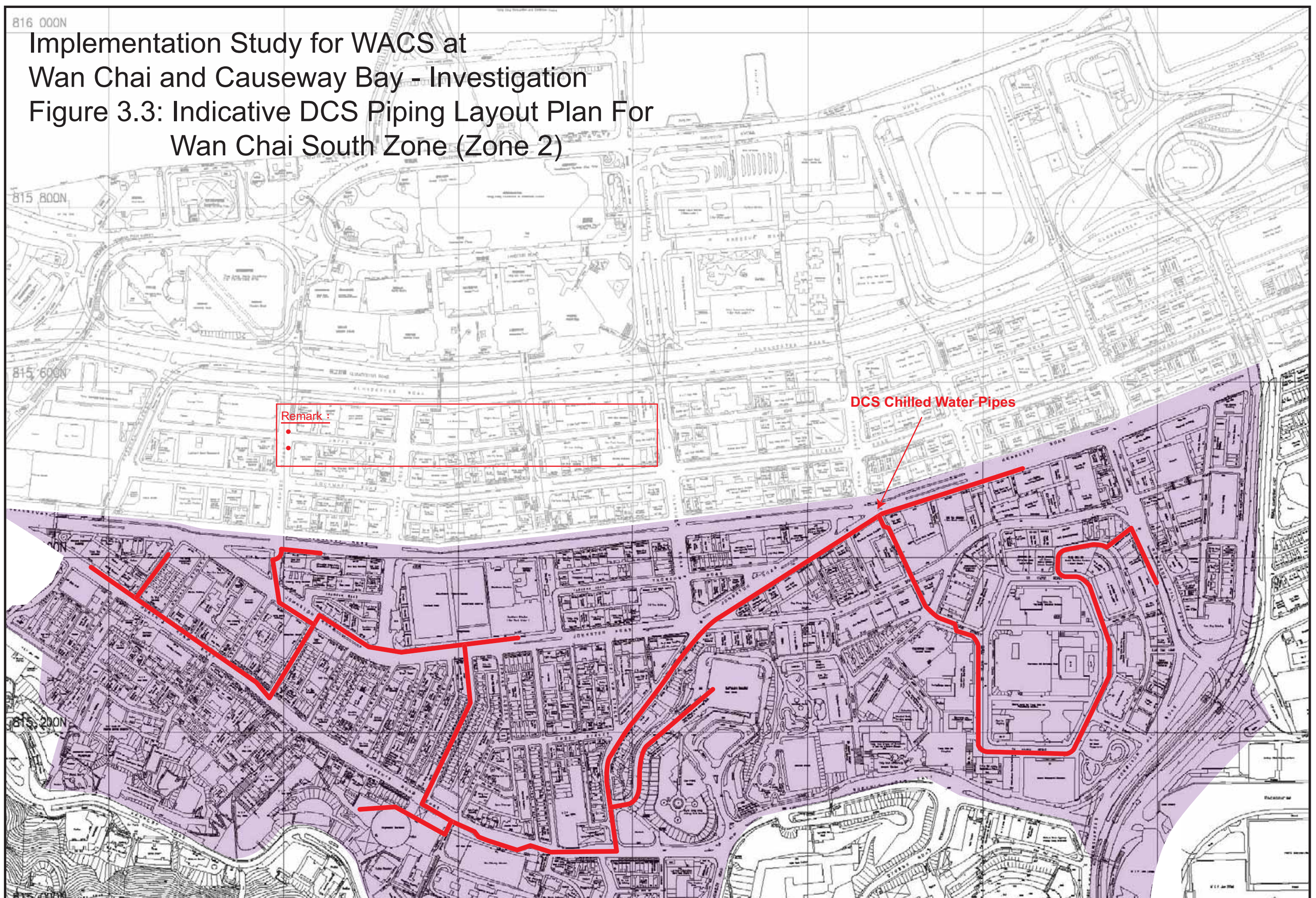
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Figure 3.2: Indicative DCS Piping Layout Plan for Wan Chai North Zone (Zone 1)



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Implementation Study for WACS at Wan Chai and Causeway Bay - Investigation Figure 3.3: Indicative DCS Piping Layout Plan For Wan Chai South Zone (Zone 2)



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Figure 3.4: Indicative DCS Piping Layout Plan For
Causeway Bay Zone (Zone 3)

DCS Chilled Water Pipes

Remark :
• Lack of suitable government land for DCS plantrooms
• Land for DCS plant room shall be provided by DCS service provider

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Figure 3.4: Indicative DCS Piping Layout Plan For Causeway Bay Zone (Zone 3)

DCS Chilled Water Pipes

Remark :

- Lack of suitable government land for DCS plantrooms
- Land for DCS plant room shall be provided by DCS service provider

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Figure 3.4: Indicative DCS Piping Layout Plan For
Causeway Bay Zone (Zone 3)

DCS Chilled Water Pipes

Remark :

- Lack of suitable government land for DCS plantrooms
- Land for DCS plant room shall be provided by DCS service provider

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Figure 3.5: Indicative CPSSCC Piping Layout Plan For
Wanchai Waterfront Zone (Zone 5)

