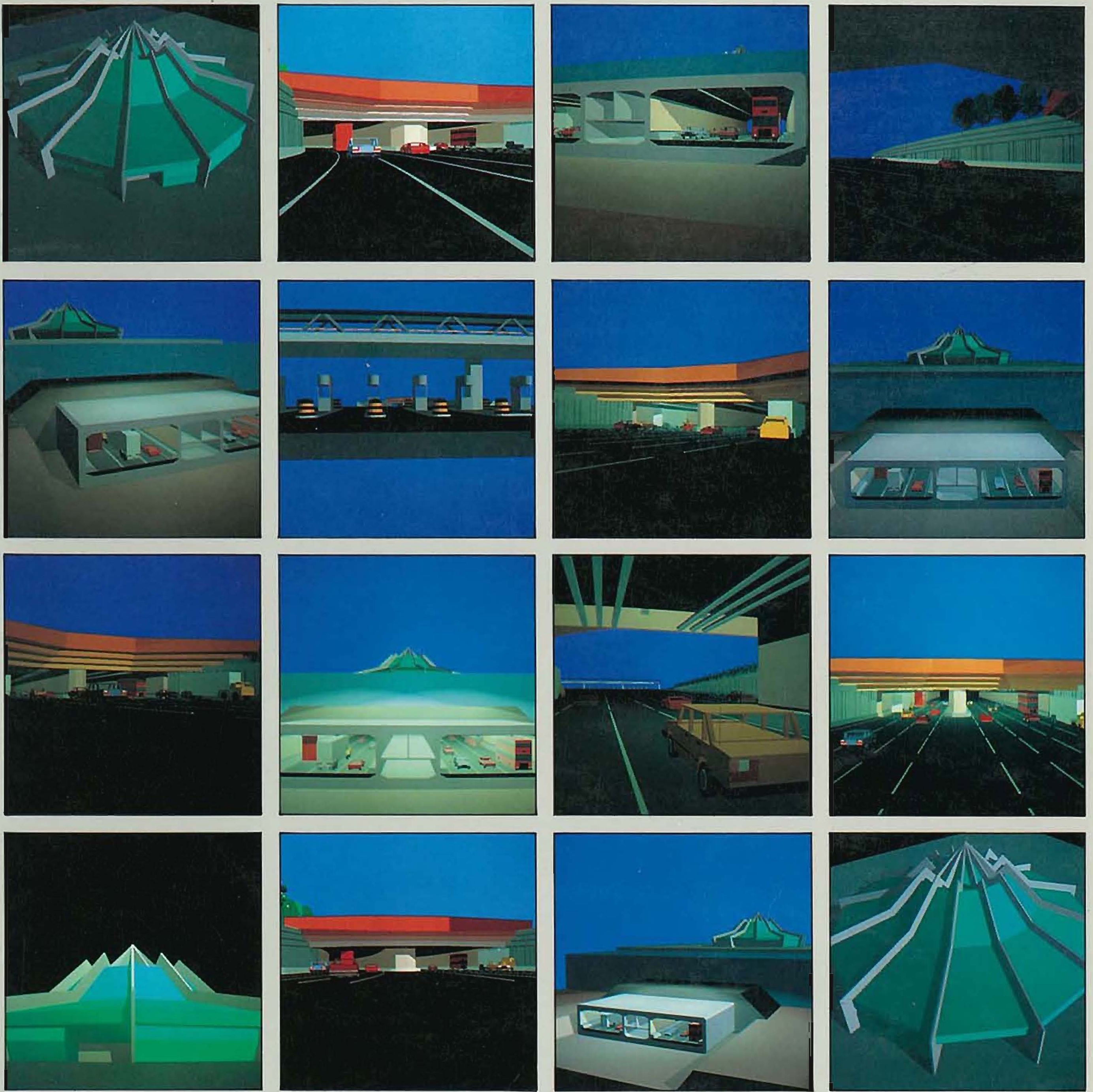


Western Harbour Crossing Study

Highways Department

Western Harbour Crossing Consultants

Final Report

April 1991

EXECUTIVE SUMMARY

WESTERN HARBOUR CROSSING STUDY
EXECUTIVE SUMMARY

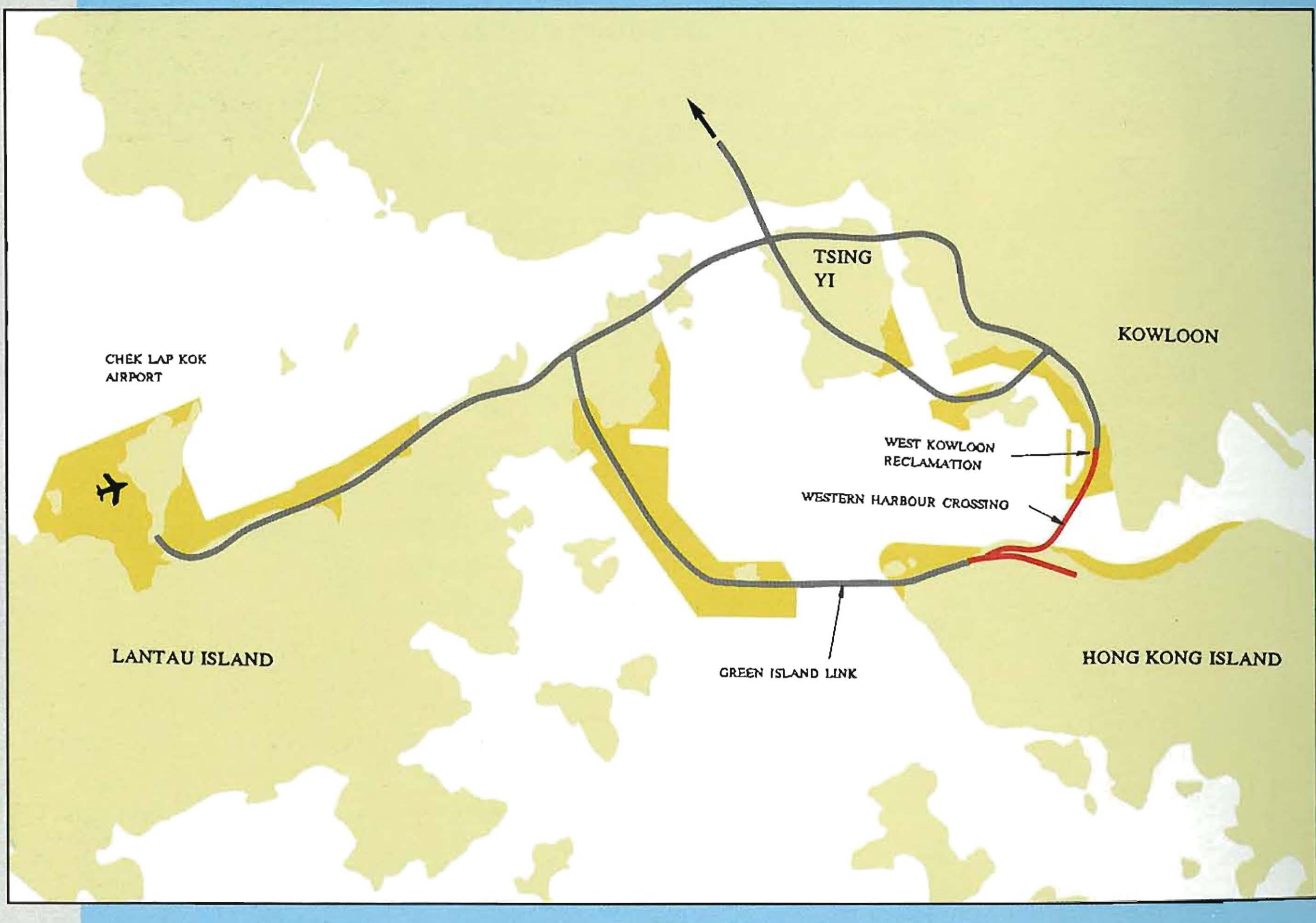
CONTENTS

1 INTRODUCTION

Western Harbour Crossing is one of four sections of the proposed Route 3 between Hong Kong and the PRC border and connecting to the new Airport (Figure 1). A crossing in this part of the Harbour has always been seen as a more direct link between population centres in Kowloon and Hong Kong than the Eastern Harbour Crossing. However, it was only the implementation of the pattern of reclamation recommended in the 1983 Study of Harbour Reclamations and Urban Growth (SHRUG) which enabled a Kowloon landfall for Western Harbour Crossing to be established. Together with another major section of Route 3, the West Kowloon Expressway, Western Harbour Crossing is expected to relieve traffic levels in the Cross Harbour Tunnel and substantially relieve traffic in local streets in Kowloon and West Kowloon.

For these reasons, the Second Comprehensive Transport Study (CTS-2) recommended that Western Harbour Crossing should be accorded the highest priority and should be operational by 1996. Route 3 itself was included in the list of recommended major highway projects in the Green Paper ``Moving into the 21st Century''. The Western Harbour Crossing Study was therefore formulated to undertake a comprehensive review of the crossing, in order to determine its optimium alignment and then to examine that alignment in engineering, transport planning, environmental and financial terms.

Figure 1
Strategic Relationship to PADS



2 THE PROPOSED TUNNEL

The Study has concluded that a Western Harbour Crossing could be constructed as an immersed tube tunnel between Sai Ying Pun and the proposed West Kowloon Reclamation (Figure 2). The tunnel could have either a dual-2-lane or dual 3-lane configuration, the decision between them depending on the view taken of toll level, traffic growth and the requirement for reserve capacity. Either configuration is capable of successful privatisation, subject to certain assurances and safeguards. A private franchise could be tendered, negotiated and awarded in time for construction to commence in January 1993 for completion in December 1996. The findings of the Study in these respects are discussed in more detail below.

Since circulation of the Draft Final Report in November 1990, Government has determined that the tunnel should be of dual 3-lane configuration (Figure 3).

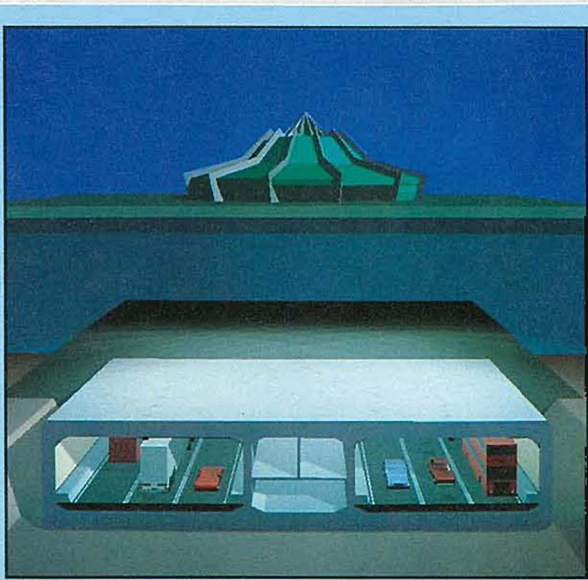
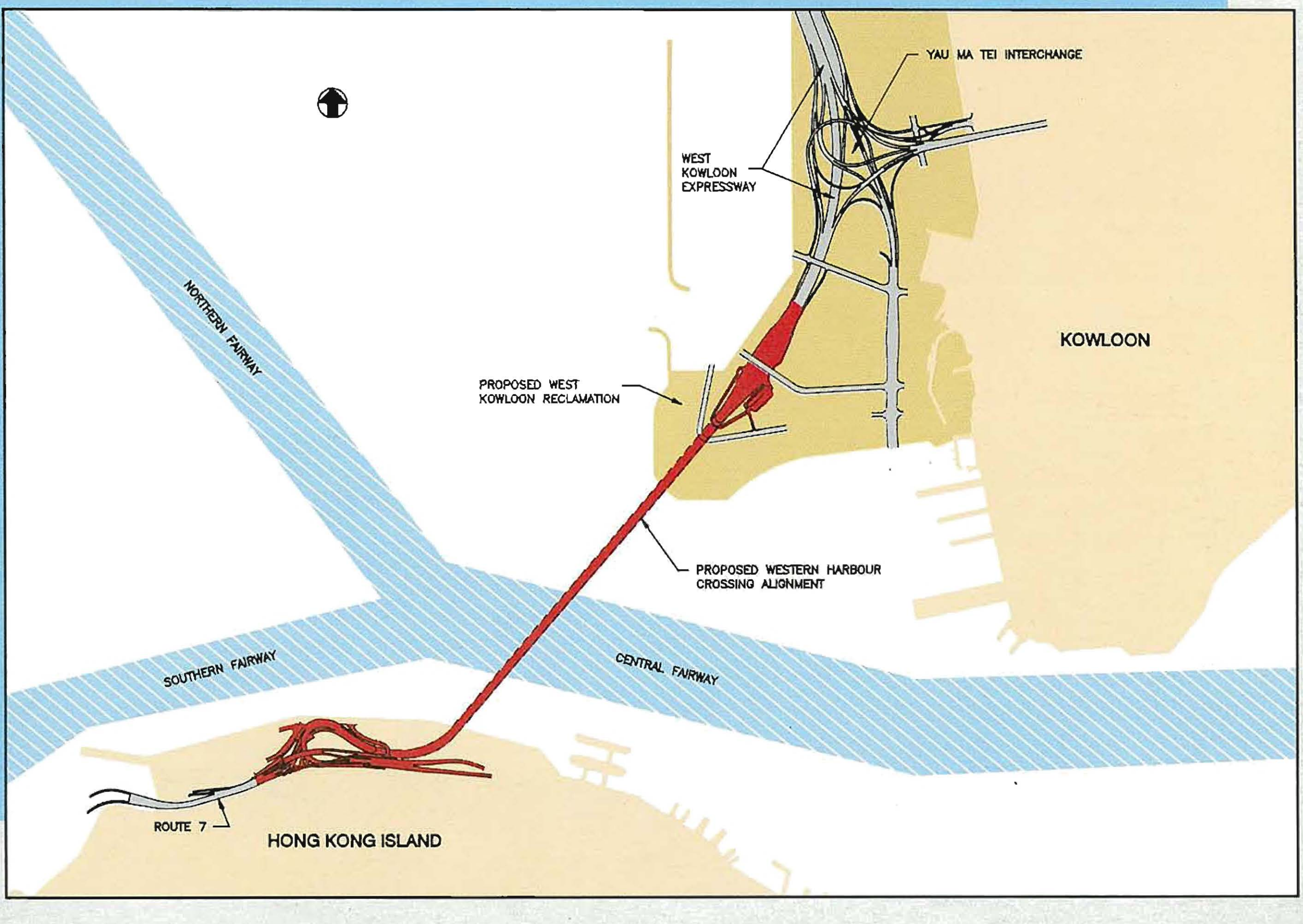


Figure 3
Dual 3-lane Immersed Tube Tunnel

Figure 2
Proposed Western Harbour Crossing



3 TRAFFIC ANALYSIS

Traffic analysis was undertaken to provide inputs into two separate streams of work:-

- toll revenue prediction, leading to financial analysis;
- highway, traffic engineering and environmental design and analysis, both for the completed project and for designing interim arrangements during construction.

Traffic data for this purpose were obtained from Transport Department. Inherent in this data are assumptions concerning land use, population and employment distribution and growth in traffic demand. In the course of the Study, development planning for all elements of the PADS infrastructure was ongoing with considerable uncertainty over land use. The conclusions of the Study are based on data provided by Transport Department between February and April 1990. However, a revised set of land use/trip generation data produced by Planning and Transport Departments in July 1990 was used in a broad analysis to demonstrate little change in level of cross-harbour traffic from that generated by the earlier data.

TOLL REVENUE PREDICTION

The financial analysis required toll revenue prediction over a 30 year or 50 year time horizon. A Territory-wide model which could reflect strategic choices between routes for cross-harbour traffic was used.

All analysis was carried out for the two tunnel configurations (dual 2-lane and dual 3-lane) and for two different relative levels of toll between the three cross-harbour tunnels (Western Harbour Crossing (WHC), Cross Harbour Tunnel (CHT) and Eastern Harbour Crossing (EHC)). This was termed the Base Case analysis. The two toll level sets were termed the equal toll regime in which a toll of $20 was levied at each tunnel (WHC/CHT/EHC : $20/$20/$20) and the unequal toll regime in which a toll of $20 was levied at Western Harbour Crossing and Cross Harbour Tunnel but a reduced toll of $10 was levied at the Eastern Harbour Crossing (WHC/CHT/EHC : $20/$20/$10).

The Base Case traffic analysis found that dual 3-lane capacity was required to cope with demand if the equal toll regime was maintained (Figures 4 and 5). If the unequal toll regime were to be implemented, favouring Eastern Harbour Crossing, then dual 2-lane capacity would be adequate up to the opening of a Green Island Link in 2003 although there would be peak hour queuing and congestion from about 2001 onwards (i.e. within 5 years of opening). The situation would be exacerbated if the low growth in traffic demand between 2001 and 2006 implied by the trip data supplied by Transport Department was not sustained in practice.

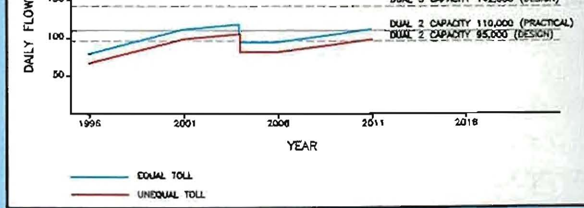


Figure 4
Traffic Flow in Dual 3-lane Tunnel

These results were subjected to sensitivity testing over a wide range of infrastructure and growth scenarios, in particular :

- alternative land use developments, and the phasing of other major interconnected road infrastructure;

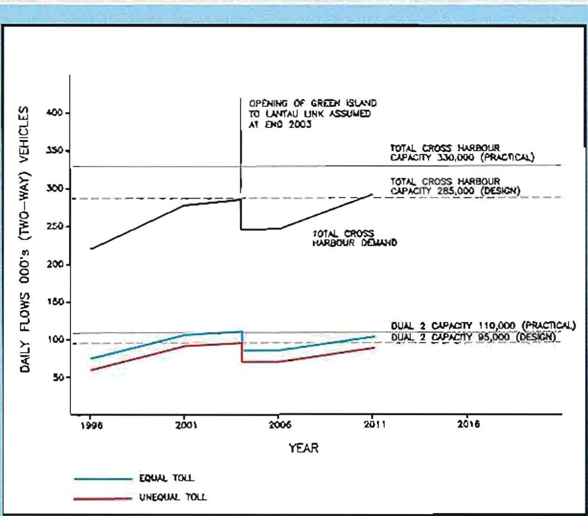


Figure 5
Traffic Flow in Dual 2-lane Tunnel

- alternative toll structures for the WHC and other crossings;

- alternative growth assumptions for cross harbour travel.

It was demonstrated that the Base Case analysis represented the higher side of the ranges of values examined. However, for equal tolls, all tests except low growth produced traffic flows which exceeded dual 2-lane capacity before 2011, and generally exceeded capacity in the period 2001 - 2003, i.e. prior to the opening of Green Island Link. Under two of the unequal toll regimes tested, capacity of a dual 2-lane tunnel would be exceeded before 2011. However, for sensitivity testing under the $20/$20/$10 unequal toll scenario, in no case did the 2011 flow exceed capacity. This emphasised the importance of the toll issue with regard to tunnel configuration.

TRAFFIC ENGINEERING ANALYSIS

To resolve the highway, traffic engineering and environmental issues required the use of a heirarchical traffic forecasting approach progressing from the Territory-wide model via a sub-regional model to, for studies of junctions, a local model. The output from this modelling process was used as input data to :

- interchange capacity (refer Section 4);

- local junction capacities both in the operation phase and during traffic diversion arrangements to enable construction (refer Sections 4 and 8);

- requirements for temporary connections into existing road infrastructure in the event that planned long term connections are delayed (refer Section 8);

- environmental analysis of noise and air pollutions (refer Section 9).

4 TUNNEL ALIGNMENT

The proposed alignment of the tunnel runs between a major interchange with Route 7 at Sai Ying Pun on Hong Kong Island and the interface with West Kowloon Expressway on the proposed West Kowloon Reclamation. The tunnel is approximately 2km between portals.

Figure 7
Sai Ying Pun Interchange

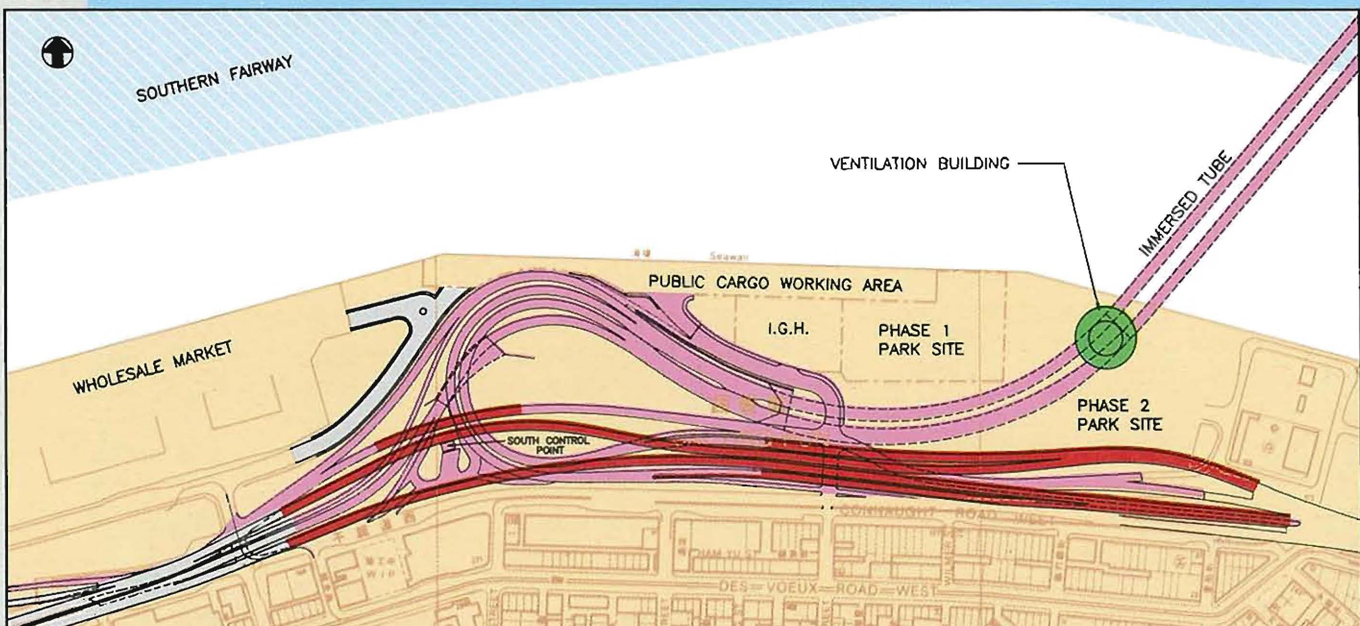
SAI YING PUN INTERCHANGE

The form of the interchange is shown in Figures 6 and 7. It is integral with the proposed Route 7 between Rumsey St Flyover and Belcher Bay Link and provides for all movements between Route 7 and the tunnel and between Connaught Road West and the tunnel.

It is a complex interchange and the final arrangement is the result of a comprehensive evaluation of alternatives. The major physical constraints on the arrangement were :

- the existing Western Reclamation seawall;
- the relocated Wholesale Market Phase I which is currently under construction;
- the tram depot and WSD pumping station adjacent to Connaught Road West;
- the proposed Indoor Games Hall and Park sites;
- the westbound carriageway of Connaught Road West;
- the sewage screening plant and Fire Station adjacent to the Shun Tak Centre.

Figure 6
Sai Ying Pun Interchange and Tunnel Approach



The ``preferred alignment'' for the Interchange, concieved during the Route 7 Study and taken as the point of departure for this Study, was critically re-examined. As a result of this additional work, the interchange has been simplified and improved, resulting in an interchange which is as easy to build as possible, provides the best design standards possible within the available space with adequate spacing of merge/diverge decision points and provides good access to adjacent land use. It also frees more space on the Western Reclamation for the proposed Park; by coordination with USD's architect for the Park, an improved layout of facilities has resulted.

The provision of the Interchange necessitates the relocation northward of the existing eastbound carriageway of Connaught Road West. In the space thus created, an arrangement of looped ramps can be accommodated feeding traffic from the tunnel in both east-and west-bound directions into Route 7 and Connaught Road West. Further ramps cater for traffic to the tunnel.

The form of interchange shown in Figure 6 is strictly appropriate to the dual 3-lane tunnel configuration. The main consequence of adopting a dual 2-lane configuration is that some ramps could be reduced in cross-section, although this itself would give rise to some operational difficulties in merging and diverging traffic. It is therefore considered that the form of interchange for both tunnel configurations would be similar, with only local reductions in ramp cross-section adjacent to the tunnel.

In developing the design, the primary concern has been for safety. Each movement associated with the Interchange has been considered in relation to driver perception, leading to the maximising of stopping sight distances, and an arrangement of decision points so as to minimise the factors to be taken into account by drivers at any one time. Whilst every attempt has been made to achieve 70km/h highway design standards, the physical constraints have inevitably led to some reduction in those standards. A speed limit of 50km/h for the Interchange has therefore been recommended.

The physical constraints have also made it necessary to exceed the desirable maximum gradient of 4%. A maximum gradient of 6% has therefore been adopted as a compromise to ensure that ramps are capable of dealing with expected traffic flows; this figure has generally been achieved.

SAI YING PUN APPROACH TUNNEL

From the Interchange, the tunnel approach road is on a continuous downward gradient throughout the approach tunnel in order to achieve the necessary depth at the seawall. The gradient is either 4.25% or 4.75% depending on the structural form of the immersed tube tunnel (refer Section 5 below). The horizontal alignment consists of a minimum 300m radius. Sightline widening has been provided within the approach tunnel.

IMMERSED TUBE TUNNEL

It has been possible to maintain a straight horizontal alignment for the immersed tube tunnel across the harbour (Figure 2). This simplifies the construction, handling and sinking of the tunnel units, thereby minimising cost. The vertical alignment of the tunnel is determined primarily by the navigational clearance of -13.15mPD set by Marine Department for the Central Fairway (Figure 8). However, the alignment is also constrained by other factors including approach gradients, which ideally should not exceed 4%, a requirement to maximise water depth in the inshore traffic zones and at the `A' class mooring buoys between Central Fairway and the proposed WKR and longitudinal drainage requirements.

By optimising gradients in the approach tunnels, it has been possible to define a vertical alignment which keeps the tunnel and its backfill entirely below the existing seabed, thus ensuring

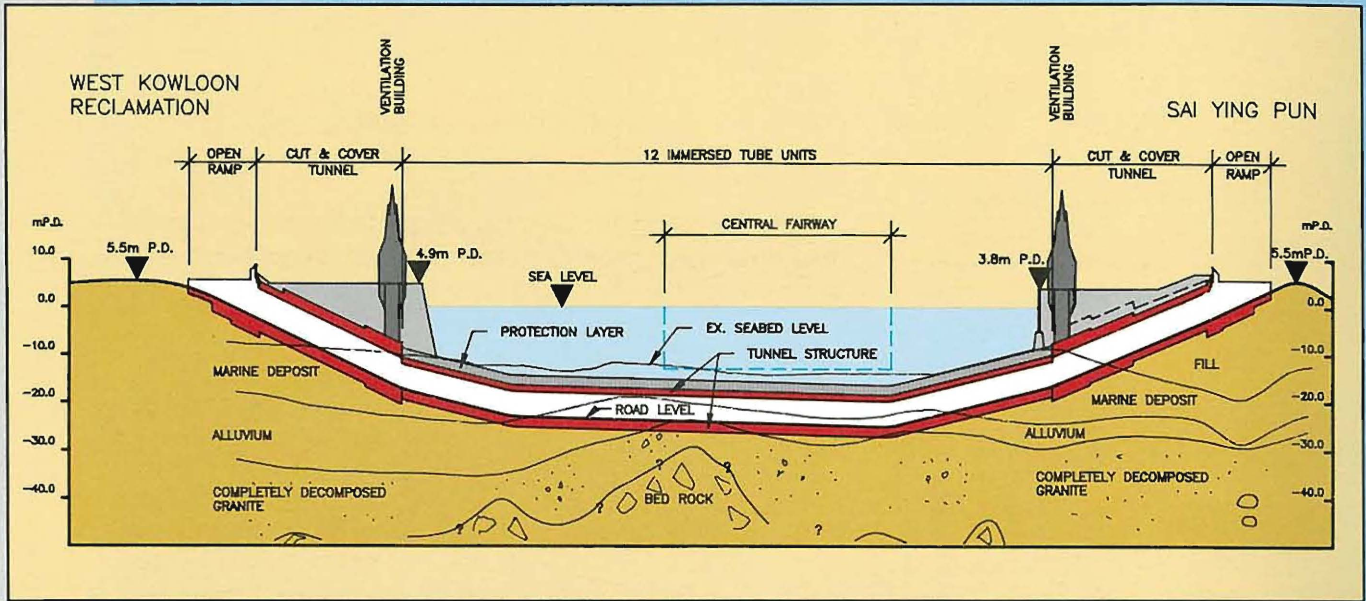


Figure 8
Longitudinal Section

no long term effects on the harbour water regime and minimising navigational hazards. In achieving this alignment it has been necessary to steepen the approach tunnel gradients as described above but this is considered to have minimal effect on capacity.

WEST KOWLOON RECLAMATION APPROACH TUNNEL AND TOLL PLAZA

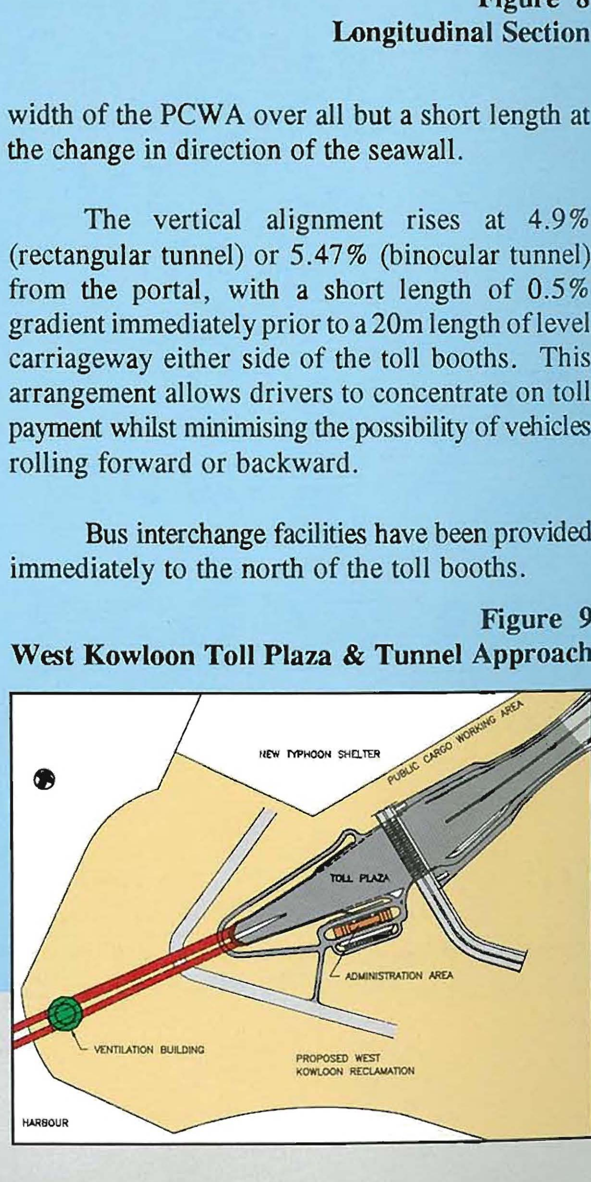
The toll plaza is set on a 2500m horizontal radius curve which links the straight approach alignment extended from the immersed tube with the initial long 1250m radius on to the West Kowloon Expressway (Figure 9). The approach flares at a 1:14 taper to the width required for the toll lanes and then narrows again to a minimum of six lanes before diverging to the West Kowloon Expressway, the Cross-Kowloon Route or to one of three directions on local routes.

The alignment is similar to that developed in the West Kowloon Reclamation Transport Study but it has been optimised to a smoother alignment, which by bringing the road closer to the new seawall, has maximised the site for the Airport Railway Terminus, whilst maintaining the 50m width of the PCWA over all but a short length at the change in direction of the seawall.

The vertical alignment rises at 4.9% (rectangular tunnel) or 5.47% (binocular tunnel) from the portal, with a short length of 0.5% gradient immediately prior to a 20m length of level carriageway either side of the toll booths. This arrangement allows drivers to concentrate on toll payment whilst minimising the possibility of vehicles rolling forward or backward.

Bus interchange facilities have been provided immediately to the north of the toll booths.

Figure 9
West Kowloon Toll Plaza & Tunnel Approach



5 TUNNEL STRUCTURE

IMMERSED TUBE TUNNEL

The cross-harbour section of the tunnel is proposed to be built by the immersed tube method, the same as used for all the existing cross-harbour tunnels (both road and rail) in Hong Kong. The immersed tube tunnel has been determined as 1360m long and for the purposes of this Study, has been assumed to be made up of 12 precast tunnel units each approximately 113.5m long.

There are two typical forms of immersed tube structure in common use; the binocular section comprising a stiffened steel tube lined and surrounded by concrete, and a rectangular reinforced or prestressed concrete section. Both forms have been used previously in Hong Kong. For the purposes of this Study, the principal difference between the two types is the greater vertical height of the binocular cross-section. For any given navigational clearance, this results in the roadway level being lower and the approach tunnel gradient being necessarily steeper in order to reach the same ground level at the landfall.

In the first stage of the Study, over twenty different cross-sections were developed to conceptual design stage to determine comparative costs. Using a database of historical costs, it was found that binocular steel and rectangular concrete cross-sections were competitive for the dual 2-lane tunnel configuration (Figures 10 and 11). For the dual 3-lane configuration, the binocular section was found to be uncompetitive and only the rectangular concrete section was selected for further development (Figure 12).

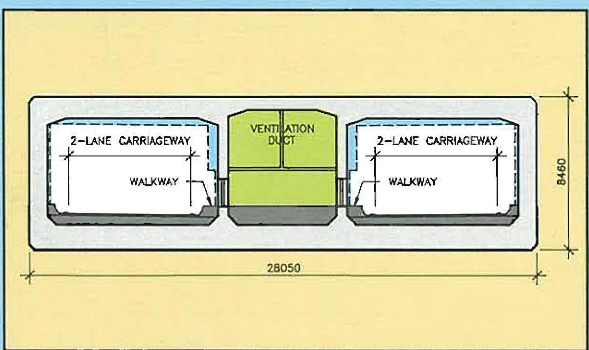


Figure 10
Cross-Section through Dual 2-lane Rectangular Concrete Immersed Tube Tunnel

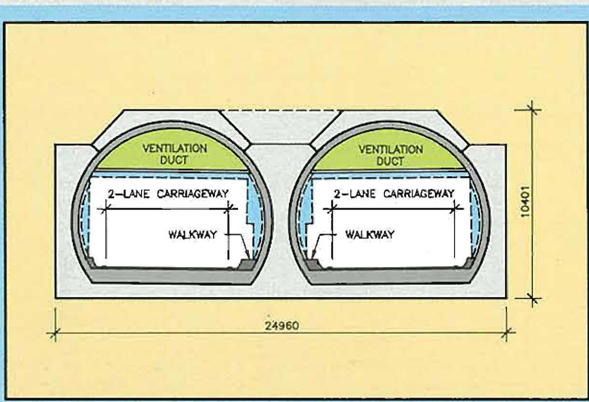


Figure 11
Cross-Section through Dual 2-lane Binocular Steel Immersed Tube Tunnel

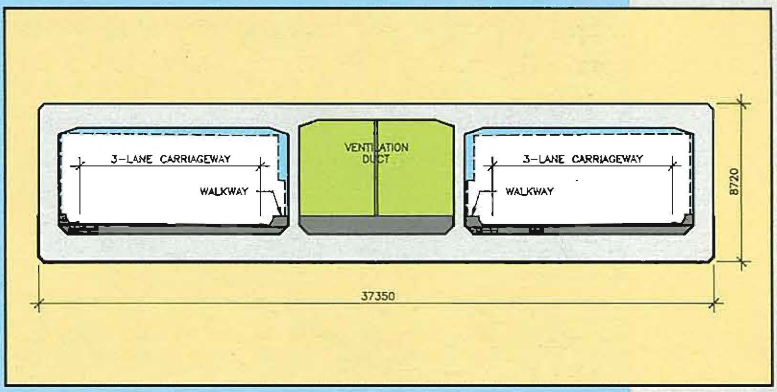


Figure 12
Cross-Section through Dual 3-lane Rectangular Concrete Immersed Tube Tunnel

Each cross section accommodates 2- or 3-lane carriageways in separate ducts, separate ventilation ducts and accommodation for tunnel services (Figure 13). Traffic ducts have been sized to accommodate lane widths and clearances agreed with Transport Department. Analysis of the rectangular reinforced concrete sections was undertaken using a PC-based frame and finite element analysis program. Structural sections were checked to the serviceability and ultimate limit states with particular emphasis on crack width checks to maximise durability. A waterproof membrane is also provided. For the binocular steel cross-section, composite action between the steel plate and the concrete was assumed. The external steel form plate acts as a waterproof membrane.

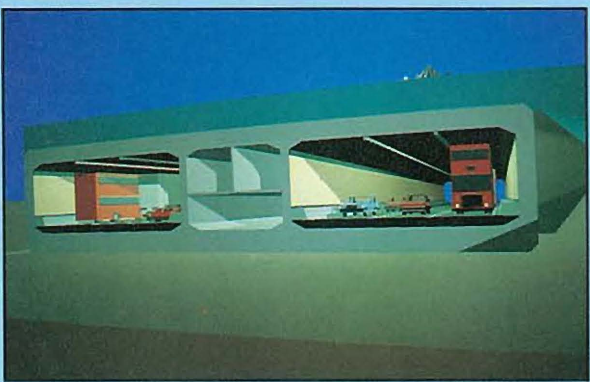


Figure 13
Dual 3-lane Traffic Duct

The tunnel units would be placed in a trench dredged in the seabed (Figure 14). Sideslopes are expected to range between near vertical and 1:4; an average of 1:2 has been assumed. Two forms of foundation are in common use :

- screeded bed foundation in which a mattress of gravel of crushed rock is laid and screeded to fine tolerances before laying the unit;
- sand-placed foundation in which a mixture of sand and water is pumped under the unit after laying, the sand settling out to form a firm foundation.

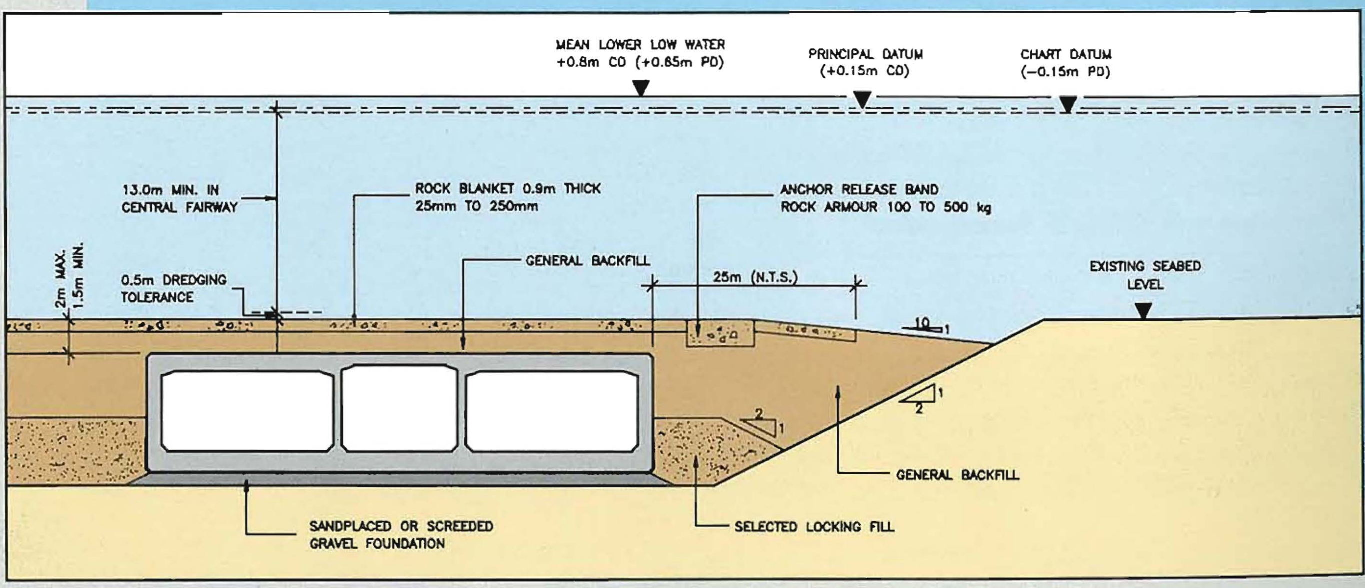
The latter method is expected to be more appropriate to the size of unit to be used for Western Harbour Crossing.

After laying the units, the trench is backfilled. Backfill will be placed to a minimum thickness of 1.5m on top of the tunnel, protected against scour by crushed rock. This layer serves to protect the tunnel against marine hazards such as dropped anchors or stranding ships. Bands of larger rock adjacent to the tunnel (Figure 14) protect the tunnel against anchors dragged along the seabed, by causing the anchor to release.

APPROACH TUNNELS AND RAMPS

Between each tunnel portal and the interface with the immersed tube, is a section of approach tunnel of cast in situ reinforced concrete. Each section is of similar cross-section to the immersed tube and carries separate traffic and ventilation ducts.

Figure 14
Cross-Section of Immersed Tube Tunnel



The approach tunnels might be constructed either in open excavation or by the `top-down' method between diaphragm walls as used in construction of many MTRC stations.

From the portal to near existing ground level, each tunnel approach is contained in an open trough structure constructed of reinforced concrete. The sides of the trough structure form retaining walls whose top height set at +5.5mPD provides flood protection to the tunnel. The full trough structure is expected to be terminated at +4mPD but the retaining walls continue until the road itself reaches the flood barrier height of +5.5mPD, thereby completing the portal flood protection. The flood protection level was calculated based on probable storm surge levels with an allowance for wind generated waves and greenhouse effect.

At Sai Ying Pun, because of the geometric and committed land use constraints on the Interchange, the retaining walls in the open approach structure are almost vertical (Figure 15). The greater availability of space on the West Kowloon Reclamation has made it possible to set back the retaining walls of the ramp trough structure to allow a more open appearance (Figure 16).

Figure 15
Sai Ying Pun Portal

Figure 16
West Kowloon Portal

VENTILATION BUILDINGS

Ventilation buildings are located adjacent to each seawall at the approach tunnel/immersed tube interface and have identical functional requirements. The primary function is to supply and extract air from the tunnel for ventilation purposes (refer Section 6 below) and to house the associated fans, plenums, ducts, power supplies and control equipment. As a secondary function they are a convenient location for plant rooms housing transformers, control centres, telecommunications equipment, uninterruptible power supplies etc., all of which are required for tunnel services.

The two buildings will be dominant and conspicuous and are both expected to be surrounded by land used for promenade or parkland. Buildings intended to be as interesting and as acceptable as possible have been proposed, at the same time ensuring that they are functional and meet the necessary environmental criteria. The buildings are illustrated in Figure 17; they are however only a suggested solution and it would be the responsibility of the franchisee to propose the final form of the structure to the approval of Government.

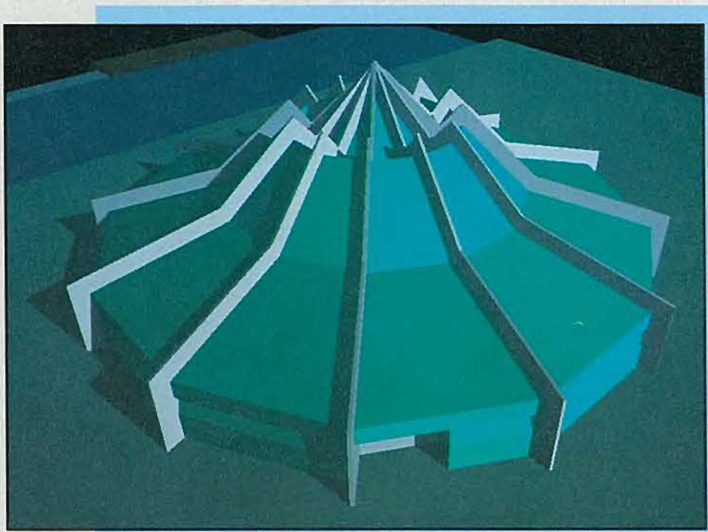


Figure 17
Ventilation Building

GEOTECHNICAL CONDITIONS

The ground conditions to be encountered along the proposed alignment for WHC can be broadly described as a layered sequence of fill, where present, marine deposit, alluvium, decomposed rock and bedrock (Figure 8). This succession has been confirmed by land - and marine - based site investigations.

Under the Western Reclamation, marine deposits were not removed prior to reclamation and boreholes show that the top of the marine deposit is now lower than the original seabed, signifying that mudwaving, consolidation settlement or both has occurred. Consolidation of these deposits will affect the design of interchange structures and embankments as well as the approach tunnel structures. Ground improvement will be required for embankments and it has been assumed for the time being that all structures will be piled to limit differential settlement.

The alluvium will provide a stable foundation for the immersed tube tunnel. Where the tunnel alignment rises towards the seawalls, it will be necessary to dredge out the overlying marine deposits and replace them with suitable granular material. Decomposed granite may outcrop into the deepest portion of the trench and dredging conditions will therefore be variable.

Tests have shown that the marine deposits to be dredged out are not excessively contaminated by heavy metals and can therefore be disposed of in open water at a gazetted dump site.

West Kowloon Reclamation is not yet constructed but it is the intention to remove all marine deposits prior to reclaiming with pumped marine sand. Settlement effects will therefore be limited to consolidation of the hydraulic fill and to a lesser extent the alluvium. In the course of the Study, surcharging of the toll plaza area has been requested in order to accelerate the necessary consolidation. It is anticipated that the approach tunnel structure will not require piling.

6 TUNNEL SERVICES

The tunnel will be provided with electrical and mechanical services including :

- ventilation;
- power supplies;
- lighting;
- drainage;
- fire protection;
- traffic control and surveillance.

VENTILATION

The mechanical ventilation system has been designed to :

- prevent the accumulation of vehicle emitted pollutants such as carbon monoxide (CO) and nitrogen oxides (NO_x);
- maintain visibility within the tunnel by preventing the accumulation of vehicle emitted pollutants that contribute to haze;
- control the spread of smoke and heat when a fire occurs in the tunnel;
- minimize the impact of noise and air pollution to the environment at the portals and around the ventilation building areas.

Air quality standards within the tunnel have been set by EPD in terms of carbon monoxide (CO) content (125 ppm) and oxides of nitrogen (NO_x) (9 ppm). The ventilation system is designed to ensure that these standards are met whilst meeting noise level and tunnel air velocity requirements. Traffic flows are based on the 1987 PIARC Report; vehicle emission factors are PIARC 1987 Standard C.

Longitudinal and semi-transverse systems were reviewed for all tunnel configurations, but in all cases semi-transverse systems were selected as being cheapest in both capital and running cost. Fresh air would be supplied by fans inside ventilation buildings and delivered via ports at intervals into the traffic ducts. The air is pushed along the tunnel by vehicles (piston effect) but then collected and exhausted vertically upwards through the ventilation building to the atmosphere at a sufficient velocity (10m/s) to disperse it. This avoids creating concentrations of polluted air at the tunnel portals.

The fans are controlled automatically by computer software, which is linked to environmental sensors; these measure CO and NO_x concentrations and visibility levels in each of four tunnel zones. On detection of fire, operating fans stop automatically, restarting only after location of the fire. The airflow is then arranged to prevent propogation of smoke onto trapped traffic and to provide a smoke-free environment upstream of the fire for users to escape. The ventilation system is designed to cope with a 100MW fire representing two fuel tankers colliding and catching fire.

POWER SUPPLY

High and low voltage supply and distribution systems are required. For security reasons the high voltage system comprises power supplies from both China Light and Power and Hong Kong Electric. 11kV sub-stations at each portal are connected on a ring system. This enables the entire tunnel to be run from either one supply company. Circuit breaker interlocks are used to prevent accidental paralleling of the two sources.

The low voltage system has reserve transformer capacity and the ability to transfer load among transformers to minimise the effects of plant breakdown.

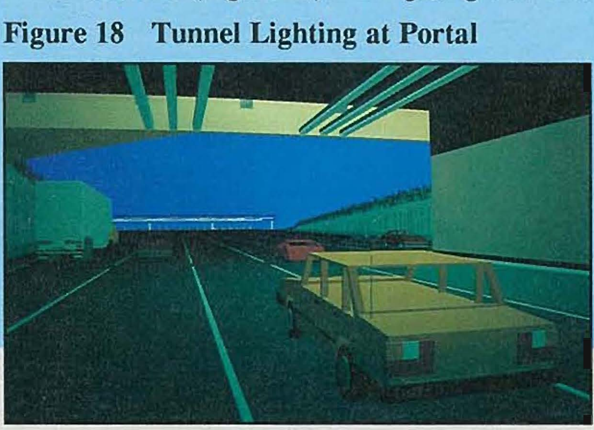
In the unlikely event of total power failure, standby generating plants are provided to supply power to essential services, including lighting, drainage pumps and traffic surveillance and control systems, Uninterruptible power supplies (UPS) are provided to maintain these vital services whilst the generation plant starts and comes on line.

LIGHTING

The tunnel lighting is designed to ensure the flow and safety of traffic in conditions of comfort and speed similar to those on surrounding roads. A high level of lighting must be provided inside the tunnel entrance to minimise the visual task to drivers in adapting to an otherwise abrupt change in lighting. The lighting level must then be reduced in stages, as the human eye adapts, to a constant but lower level of brightness in the tunnel interior.

Lighting design would be based on CIE Publication 26/2 (now ratified as CIE 88) ``Guide to Lighting of Road Tunnels and Underpasses'' (1990). The low level constant lighting in the interior (base lighting) would be provided by continuous or near continuous rows of luminaires containing fluorescent tubes mounted directly above the lane dividing lines (one row for dual 2-lane, two rows for dual 3-lane configuration). This base lighting would be dimmed to a lower level at night. Additional high pressure sodium or fluorescent tubes would be provided in threshold and transition zones; the ceiling-mounted luminaire layout would be arranged to provide stepped reductions in luminance level (Figure 18). All lighting would be automatically regulated by reference to luminance meters at each portal. A certain level of base lighting is backed up by UPS to ensure a minimum level of lighting at all times.

Figure 18 Tunnel Lighting at Portal



High mast and conventional road lighting would be provided at Sai Ying Pun Interchange, the tunnel approaches and the toll plaza area.

DRAINAGE

The drainage system for the tunnel is split into two separate parts;

- a high capacity system to deal with large quantities of storm water arising within the catchment areas of the portal sumps, and discharging to the Government storm water collection system;
- a smaller capacity system to deal with contaminated water arising from the tunnel itself, and discharging to the Government foul sewer.

The incorporation of flood barriers surrounding the tunnel approach areas to prevent inundation means that all stormwater arising in these areas must be collected in the portal sumps. The stormwater will be passed through a petrol interceptor before being pumped up to ground level and discharged, either into a Government trunk system or directly to the sea. The sumps and pumps are sized to cater for extreme rainfall in a 1 in 50 year storm. A standby pump will be provided to back up the duty pumps.

The drainage system within the tunnel itself is designed to deal with surface water not intercepted by the portal sumps, carried in on vehicles etc. The system is also designed to deal with run-off due to tunnel washing, discharge from fire hydrants etc. and this is in fact the critical load.

Foul water will be drained through discrete gratings located on one side of the carriageway into a continuous enclosed channel. Water is collected in a sump at the low point of the tunnel; the sump incorporates a petrol interceptor. Because this water contains higher concentrations of petrol and oil or detergents, it is pumped out, via a transfer sump and grit trap at the SYP portal to the Government foul sewer.

FIRE PROTECTION

The fire protection system consists of a fire alarm system and a fire fighting system.

The alarm system will provide a fast and accurate report to the Fire Services Department Control Centre and to the tunnel Central Control Room. Break-glass alarm units will be provided along both sides of each traffic duct where they can be easily reached by tunnel users. Fire warning signals will also be automatically sent if any fire extinguisher is removed from its position, any hosereel cabinet door is opened or any emergency telephone is lifted. Central Control Room operators can then confirm the fire location via CCTV and adjust the tunnel ventilation system appropriately.

The fire fighting system provides for a multi-stage approach to immediate control of any fire. Portable extinguishers and hosereels can be used by untrained people until the arrival of fire appliances. Hydrants, telecommunication and CCTV systems are provided to enable the operators and Fire Services Department to fight the fire professionally and efficiently to minimise injury and damage.

TRAFFIC CONTROL & SURVEILLANCE

Traffic control and surveillance systems are described in relation to their function in the next section.

7 TUNNEL OPERATION & TOLL COLLECTION

TOLL COLLECTION

As described in Section 4, the tunnel exit/ approach flares at 1 in 14 to accommodate the toll lanes (Figures 9 and 19). Toll lane provision has been based on 2006 design year flows, this date representing a 10 year life of the toll equipment.

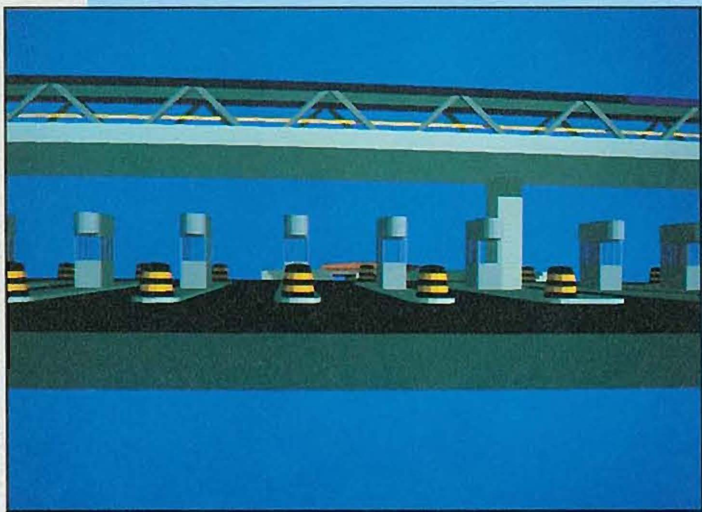


Figure 19
Toll Lane Arrangement

Manual toll collection has been assumed, as on the existing cross-harbour tunnels. In the future it may be possible to replace this with some form of automatic vehicle identification and collection; the increased traffic capacity per lane of such systems will cater for future growth within the same toll plaza width.

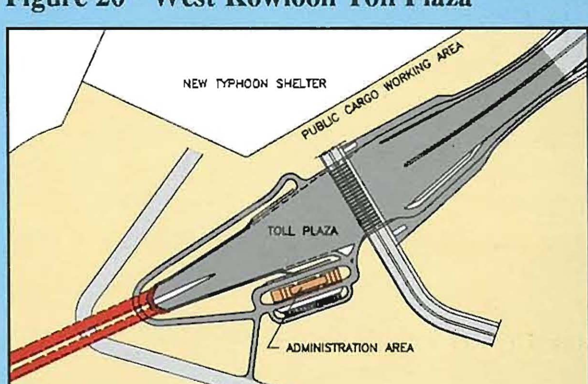
To cater for 2006 traffic flows, 18 toll lanes are required for the dual 3-lane tunnel. The centre two lanes would be reversible to provide a maximum of ten operational lanes in the direction of maximum flow, with eight lanes in the opposite direction. This arrangement allows an extra toll lane to cater for equipment breakdown.

For the dual 2-lane configuration, 14 toll lanes are required, again with the centre two reversible to provide eight operational lanes in the direction of maximum flow and six in the opposite direction.

Each toll booth will be equipped with a collection console and lane processor. The console will enable push-button registration of toll classification. Magnetic card readers enable collectors and maintenance staff to log `on' and `off' for each shift. Each lane processor will be connected `on-line' to a central computer in a Central Control Room to be located in the Toll Plaza Administration Building. The computer will store all toll data to enable high levels of security and statistical information to be maintained. All transactions will be supervised from the Central Control Room via monitoring panels and CCTV.

A 6m wide toll lane is provided on each side of the toll plaza to permit passage of wide loads. A canopy covers the toll booths to protect drivers and collectors in wet weather. A footbridge parallel to the canopy links the bus interchange facilities to adjacent (future) commercial areas and the Administration Building (Figure 19). In the longer term the canopy and footbridge will be replaced by a structure carrying the dual 3-lane Austin Road Extension.

Figure 20 West Kowloon Toll Plaza



The toll plaza area also includes a loop road to enable tunnel patrol vehicles to turn round and access all parts of the tunnel area, facilities to intercept unacceptable (overweight, overheight) vehicles and a weighbridge (Figure 20).

ADMINISTRATION BUILDING

The Administration Building must be located near the toll plaza and for WHC has been located on the east side of the toll plaza, adjacent to the toll booths. This location is ideal since it :

- provides a good view of the toll plaza and toll booth line from the Central Control Room;
- minimises the distance from the building to toll booths for toll collection staff;
- minimises distance to transfer toll booth takings unless these are transferred by conveyor in a tunnel under the toll booths;
- minimises the distance from the overheight vehicle detection equipment and the manned interception point (which have to be located before the toll booths).

The Administration Building contains office accommodation for tunnel staff, messing and locker facilities for operating staff, cash handling facilities and also houses the Central Control Room. The building proposed is integral with stores, workshop and garage facilities although these could be separated as they are at CHT and EHC.

A perimeter road provides access to the building, as well as to the workshops and garages and, under escort, to the weighbridge. There is a restricted gated access to the local road system for use by tunnel staff in certain circumstances.

SOUTH CONTROL POINT

A South Control Point Building has been located at the Sai Ying Pun Interchange as shown as Figure 6. This provides a base for tunnel staff controlling and monitoring tunnel traffic in this area, and also provides a local control centre for the traffic control and surveillance system, albeit interlocked to the Central Control Room in the Administration Building. To enable vehicle weights to be checked at the SYP landfall, axle weighing equipment would be installed adjacent to the Building.

It would be a two storey building to permit a reasonable view. It would have air conditioning and toilet facilities but would otherwise not be elaborate.

TRAFFIC CONTROL & SURVEILLANCE

A computer based traffic control and surveillance system will be provided to allow safe control of traffic by the tunnel operator in all conditions. Control and monitoring will be excercised from the Central Control Room.

The system will be made up of the following elements :

- three aspect lane control signals;
- matrix signals;
- variable aspect signs;
- automatic incident detection;
- overheight detectors;
- closed circuit television system (CCTV);
- radio system;
- emergency telephone system;
- loud address system;
- control of gates/barriers for bi-directional operation.

The system will operate via a two level computer structure, combining a central supervisor processor, with a network of local processors. The central processor will regularly interrogate, or be interrogated by, the local processor. `Hot standby' processors will be provided to back up all duty processors.

Control of all systems and signs will be undertaken from the Central Control Room via the central supervisor processor. The operator will set up any signal aspect via a VDU keyboard; displays will show the requested aspect and those of adjacent signals for confirmation. Preset plans will be available to the operator via menus to deal with common occurences such as the establishment of two-way operation in one duct.

DUAL 3-LANE OPERATIONAL ISSUES

The Study has investigated and presented both dual 2-lane and dual 3-lane tunnel configurations in equal detail. In the course of the Study, concern has been expressed regarding the operating characteristics of a dual 3-lane tunnel under Hong Kong conditions. These concerns relate to :

- portal accidents which are a result of merge/ diverge manoeuvres on entering or exiting the tunnel, particularly at the SYP interchange and particularly involving buses and other heavy vehicles on the upgrade;
- centre lane breakdown/accident where no walkway refuge is immediately available without crossing a lane of moving traffic;
- fire hazards generally.

In addressing these concerns, traffic and accident statistics have been obtained and reviewed for :

- dual 3-lane tunnels in UK and Japan;
- dual 2-lane tunnels in UK and Hong Kong;
- limited access roads in UK and Hong Kong.

It was possible to show a similarity in accident rates between UK and Hong Kong and to confirm that tunnels, especially toll tunnels, are safer than limited access roads. There was no evidence that dual 3-lane tunnels were in anyway less safe than dual 2-lane tunnels.

Hong Kong tunnels are perceived to be different from (particularly) UK tunnels because of the proximity of complex interchanges to the portals, with associated merge/diverge manouvres. However interchanges (not necessarily complex) do exist adjacent to UK motorway tunnels without serious effects. Sai Ying Pun Interchange has been carefully designed to provide well-spaced decision points and the resulting traffic movements from a dual 3-lane tunnel should be no more complex than on the existing dual 2-lane Cross Harbour Tunnel. The Interchange would also provide better visibility and better queuing facilities on the exit, without interfering with other tunnel traffic.

Similarly there was no evidence to show that there would be any significantly greater hazard in the event of fire or to centre-lane users. Indeed there is some evidence to show that a dual 3-lane tunnel may be safer in the event of fire because of the greater availability of space in which to escape and to fight the fire efficiently.

8 CONSTRUCTION ISSUES

INTRODUCTION

A construction methodology was developed for Western Harbour Crossing as a basis for :

- the project programme;
- evaluation of project resource requirements, leading to;
- the project costs, and
- environmental impacts of construction.

The methodology utilises established construction techniques modified where appropriate to minimise environmental impacts. For example, machine bored piles have been preferred to driven piles to minimise noise. For brevity, only the key issues arising from the methodology are reviewed here.

ROUTE 7

The Route 7 alignment between Queen Street (end of the existing Rumsey Street flyover) and the proposed Belcher Bay Link follows the alignment of Connaught Road West. The Sai Ying Pun Interchange contains provision for ramps feeding traffic to and from Route 7 as well as ramps serving the local road system including Connaught Road West. The adjacent section of Route 7 is therefore closely integrated with Sai Ying Pun Interchange to the extent that sections of it will be difficult to build after the Interchange is open to traffic. Whilst precast girder or segmental construction could be used to minimise the extent of disruption, this would still require either night possessions, or work to be carried out over moving traffic. This would restrict the choice of erection schemes and require extraordinary safety precautions.

In the event that such problems could be resolved, sequential construction of Route 7 would effectively double the length of time over which the public would be subject to noise, dust and inconvenience.

Accordingly, Government has determined that the section of Route 7 between Rumsey St Flyover and Water St should be constructed as part of the WHC project. The remaining section between Water St and Belcher Bay Link will be constructed separately but in time to meet WHC opening. This will enable WHC traffic with destinations in Hong Kong Island West and South to make use of Route 7 and the proposed Smithfield Extension and thereby minimise congestion on Western St/Pokfulam Road.

SAI YING PUN INTERCHANGE

The Interchange will be constructed by conventional methods. Ramp B of the Interchange encroaches onto the existing Public Cargo Working Area (PCWA) and the PCWA will be extended eastwards to compensate. The Marine Department PCWA Administration Building will also be reprovided. Access to the Indoor Games Hall and the Phase I Park will be maintained throughout the construction period.

There are two small areas of the required Work Site/Area for the Interchange which it will not be possible to handover immediately. These areas are :

- the site of the temporary poultry market adjacent to the new Wholesale Market Phase I; this market cannot be relocated to its permanent site until the Wholesale Market Phase II is completed;
- the petrol filling station at the corner of Connaught Road West and Eastern St.

It is anticipated that both these sites would be made available by January 1994.

IMMERSED TUBE FABRICATION FACILITIES

During the Study, an extensive review of possible sites for fabrication facilities for tunnel units was conducted. Since the casting basin facilities required for concrete immersed tube units occupy a greater area than the fabrication area and launchway required for steel units, the search concentrated on sites with adequate space for a casting basin. Also, the choice of a dual 3-lane tunnel makes the use of rectangular concrete units the most likely.

Over twenty sites were considered, but, after examination and a preliminary environmental appraisal, only two, at Lamma Quarry and Tseung Kwan O (Junk Bay), were found to be suitable. Further discussion since circulation of the Draft Final Report has established that there are probably too many competing and conflicting land uses, as well as environmental concerns, at Lamma Quarry. Therefore the Tseung Kwan O (Junk Bay) site is now preferred. It is intended to carry out additional development work on a casting basin at this site with a view to offering it to bidders. Bidders would however still be free to nominate their own sites, subject to Government approval.

IMMERSED TUBE MARINE DIVERSIONS

In order to carry out the marine works necessary for dredging the tunnel trench, laying the units, forming the foundation and backfilling, it will be necessary to divert traffic away from the immediate area. In conjunction with Marine Department, a survey of the frequency and routing of marine traffic traversing the area has been made and a pattern of fairway diversions has been recommended.

The diversion of marine traffic will be more complicated if the immersed tube carrying the Airport Railway cross-harbour tunnel goes ahead in the same time frame. Marine Department have expressed concern about this and the issue is being examined as part of the Airport Railway Feasibility Extension Studies. One solution would be for the Airport Railway tunnel across the harbour to be built as part of the Western Harbour Crossing project within a common set of marine diversions, thus eliminating any contractual interfaces.

WEST KOWLOON RECLAMATION

Although construction work is scheduled to commence in January 1993, completion of the southern area of West Kowloon Reclamation is not scheduled until March 1993 at the earliest. It would be necessary to delay handover of this area. Alternatively, the overall start of construction could be delayed until March 1993 to enable handover of the entire crossing site.

Western Harbour Crossing is intended to connect directly with the West Kowloon Expressway and both are currently programmed for completion at December 1996. In the event that West Kowloon Expressway was delayed beyond the opening of Western Harbour Crossing, temporary connections would be required between the northern project limit (just north of the toll plaza) and West Kowloon.

A detailed investigation demonstrated that in order to provide sufficient capacity at junctions, such temporary connections would be required to and from Waterloo Road and Jordan Road. Depending on the level of completion of West Kowloon Expressway, the temporary connections to and from Waterloo Road could utilise elements of the proposed Yau Ma Tei Interchange (which provides permanent connections between the Expressway and West Kowloon). Alternatively, temporary at-grade connections could be constructed. The Jordan Road connections would be via the `bus only' slip roads which join/exit WKE just north of the WHC project limit. The West Kowloon Corridor Yau Ma Tei Section Phase II is also required to be complete in order to permit this connection scheme to operate.

The connection requirements are extensive and could not be implemented on a short-term contingency basis, particularly as construction would have to be undertaken against a backdrop of major reclamation and associated drainage diversion works in West Kowloon. Therefore, if there was any danger of West Kowloon Expressway not meeting the opening date of WHC, it would be necessary to implement design and contract procedures for these connections to enable construction to start as early as mid-1994, with major implications for construction and traffic diversion planning in West Kowloon.

9 ENVIRONMENTAL ASSESSMENT

INTRODUCTION

An environmental assessment of the project was undertaken in two stages. The primary objectives of the first stage were to :

- identify and describe the elements of the community and environment likely to be affected by the proposed development;
- provide an initial assessment and evaluation of the environmental impacts arising from the Project sufficient to identify those issues which are of key concern to the Project or which are likely to influence decisions on the Project;
- identify any monitoring studies necessary to provide a baseline profile of existing environmental quality, particularly for those parameters likely to be affected by the project.

This first stage defined the key environmental issues to be addressed in the second stage but, at least as importantly, enabled mitigation of the identified potential impacts to be incorporated into the preliminary design of the project as it developed. The framework of environmental and legislative controls was also identified.

In the second stage, a detailed investigation programme was undertaken to determine quantitative levels of impact and the means of mitigating those impacts. The detailed investigations included :

For the Construction Phase

- noise impact study;
- air pollution study;
- water quality impact study;
- environmental appraisal of tunnel unit fabrication sites.

For the Operational Phase

- traffic noise impact study;
- air pollution modelling study;
- water quality impact study;
- visual and landuse impact study.

CONSTRUCTION PHASE

The primary impacts during the construction phase are noise and dust.

Noise

Noise impacts on existing residential buildings at Sai Ying Pun are expected to be high, even against a dense urban background. Although there are no statutory controls on construction noise during the daytime, it is recommended that mitigation measures (acoustic screening and shielding, use of silenced and super-silenced plant, operational limitations etc.) should be taken and evening, Sunday and Public Holiday work strictly limited.

At West Kowloon Reclamation, construction noise is subject to significant distance attenuation to existing noise sensitive receivers. Mitigation measures would concentrate on silencing dump trucks and other heavy plant such that acceptable noise levels (ANL) could be met.

Dredging noise would only be a problem at night. Depending on the equipment used, it would be necessary to prohibit dredging within 200-600m of the Sai Ying Pun seawall in order to meet night-time ANL's.

Dust

There are significant dust impacts at Sai Ying Pun, total suspended particulate (TSP) concentrations exceeding the acceptable limit of 500 μgm^{-3} at all receivers. These are worst case conditions but mitigation measures require to be implemented and strictly monitored. At West Kowloon, TSP concentrations comply with acceptable limits but mitigation should be applied nonetheless. Measures include :

- watering of exposed surfaces;
- watering and use of chemical wetting agents on aggregate stockpiles;
- paving and speed controls on site roads;
- enclosure and covering of stockpiles and loads;
- vehicle wheel and body washing.

A monitoring and action programme for construction dust impacts has been recommended.

Water Quality

Construction works in the Harbour are not expected to have significant impacts. Dredging will contribute to a potentially high suspended solids load and mitigation in the form of dredging controls would be required should water quality monitoring show unacceptable turbidity at or near sensitive receivers.

Fabrication Facilities

An environmental appraisal of six shortlisted sites for fabrication facilities was undertaken. On the basis of this appraisal, together with other factors, two sites at Lamma Quarry and Tseung Kwan O (Junk Bay) Phase III were selected for a more detailed assessment, albeit still in broad terms because the exact nature of the work and the exact location of the facility within the chosen site remain uncertain.

Both sites will have noise, air and water quality impacts. However, there are a significant number of competing uses at Lamma Quarry, not least of which are proposals for rehabilitation of the site on expiry of the current licence. On the other hand, the Tseung Kwan O site occupies an area of proposed reclamation which is approved in principle but which is not expected to be developed for housing until at least 1996, by which time Western Harbour Crossing activity would be complete. Accordingly, the Tsuen Kwan O site has been chosen for further study.

OPERATIONAL PHASE

During the operational phase, the primary concerns are traffic and ventilation building noise and vehicle emission impacts, particularly at Sai Ying Pun, and visual impacts. There are no impacts on water quality.

Traffic Noise

The proximity of the Sai Ying Pun Interchange to residential buildings makes it apparent from the outset that received traffic noise level must be high and all possible mitigation measures must be built into the design. Such measures include use of noise absorbent surfacing, minimising of gradients and maximum use of embankments and associated ground contouring to provide shielding. Even with these measures, noise levels are in the range 76.5 - 82.5 dB(A) L10 (1 hour), considerably in excess of Hong Kong Planning Standards and Guidelines allowable levels for buildings using windows as their main source of ventilation, but below the allowable level for normal windows permanently closed.

Noise level within the Phase I Park of 52.1 dB(A) L10 1 hour is not considered excessive but cannot be evaluated against any standard.

At West Kowloon, it is difficult to make predictions in the absence of detailed land use information. Ground level predictions in the vicinity of the Airport Railway Kowloon Terminal are in the range 70.6 to 76.4 dB(A) L10 (1 hour). At Distributor Road D13/D14, noise level is predicted as 55.4 dB(A) L10 (1 hour); this is low because of the screening effect of the portal and because of distance attenuation. The effect of building development along D13/D14 would provide further screening.

Ventilation Building Noise

When all fans are running, noise at 10m from the building is expected to be of the order of 70 dB(A) using normal silencing equipment, or 65 dB(A) using more elaborate silencers.

At Sai Ying Pun, a 26 dB(A) distance attenuation would reduce the noise at sensitive receivers to well below guideline levels.

At West Kowloon Reclamation, it is anticipated that adjacent land use will be commercial. The nearest residential development would be at least 600m away, so that after a distance attenuation of 35.6 dB(A), the noise level at the receiver would be well below guideline levels.

In the Sai Ying Pun Park Phase I, and the proposed Parkland/Promenade on West Kowloon Reclamation, fan noise is expected to exceed background traffic noise (fans 70/65 dB(A), traffic 62.1 dB(A) in Phase I Park, 55.4 dB(A) or less in the Parkland/Promenade). Accordingly, fan noise will be dominant but it must be noted that this noise level only occurs during peak hours (when it will coincide with peak traffic noise). At other times the fans will be operating well below capacity.

Vehicle Emissions

An assessment of air quality at the Sai Ying Pun and Western Reclamation landfalls was undertaken to determine whether the ventilation system as described in Section 6 would meet Air Quality Objectives. 1 hour average worst case pollutant concentrations were modelled using the CALINE 4 model for traffic emission on the Interchange, Route 7 and approach roads and the ISCST model for ventilation building emissions. With the system proposed, only low (i.e. virtually zero) levels of portal emission result.

At Sai Ying Pun, using current vehicle pollutant emission factors, Air Quality Objectives for nitrogen dioxide (NO_2) would be exceeded at the year 2003. However, the emission control legislation now being put in place is expected to result in a 50% reduction in emissions by 2001; such a reduction would enable Air Quality Objectives to be met. Carbon monoxide, total suspended particulates and lead are within Air Quality Objectives using current emission factors without reduction.

Pollutant concentrations from the Ventilation Building increase with increasing height (up to a certain limit) because of the velocity of emission. However, the contribution from Route 7 and Interchange traffic decreases with height and the overall totals reduce.

NO_2 pollutant contours drawn for the Indoor Games Hall and Park show an increasing concentration on the west side adjacent to the portal making this area less suitable for outdoor sports. The Indoor Games Hall will be fully air-conditioned with intakes sited on the seaward side of the Park. There are also tennis courts in this area but other outdoor games pitches are sited further east. After taking account of the 50% emission reduction, NO_2 concentrations even in this area are below the Air Quality Objective.

At West Kowloon Reclamation, the modelling results show compliance with Air Quality Objectives for all pollutants. On the Parkland surrounding the Ventilation Building site, the major pollutant contribution is from traffic on the tunnel toll plaza and approach, the Ventilation Building accounting for only a small percentage of the total. Relocating the Building as discussed under `Visual Impact' below would not therefore lead to a significant change in air pollution. However, the current results have taken no account of any screening by commercial development along Distributor Road D13/D14. The eventual development of this area should lead to significant shielding of the Parkland area.

VISUAL IMPACT

The visual impact of Sai Ying Pun Interchange is unavoidably significant both from ground level and from adjacent high rise buildings. The elevated structures will be prominent from the Harbour, from Connaught Road West, from connecting streets and from the Phase I Park (Figure 21).

Figure 21
Sai Ying Pun Interchange

Mitigation by means of ground contouring, mounding and planting will be required, but will only mitigate ground level impacts and low level impacts from buildings.

The Ventilation Building will tend to dominate the Phase I Park and the solution adopted in the Study has been to make it as interesting and acceptable as possible whilst ensuring functionality. It should be noted that the final form and location of the Building will be determined by the bidder to the approval of Government.

At West Kowloon Reclamation, the toll plaza and associated structures and buildings are expected to have a much less significant impact against a background of major developments (Airport Railway Kowloon Terminal and other commercial areas to the east and PCWA to the west).

Again, the Ventilation Building will be dominant and the same solution as at the Sai Ying Pun Phase I Park has been adopted. It is technically possible, to a cost, to relocate the building further north adjacent to Distributor Road D13/D14 where it would have to be integrated into the commercial development.

Note : There is a separate summary available in English and Chinese describing the Environmental Assessment in more detail.

10 PROGRAMME & COSTS

PROGRAMME

An outline programme for the construction of a dual 3-lane Western Harbour Crossing is shown in Figure 22. The implementation section of the programme assumes that the tunnel would be undertaken as a build-operate-transfer project, enabling documentation to be `fast-tracked' and the design to overlap, and interact with,construction. Under this programme, the project franchise would be awarded in July 1992, enabling a five month design lead to be established prior to the start of construction in January 1993. Programme development from the construction methodology indicates that a 48 month construction programme is adequate, with completion in December 1996. It is probable that this period could be reduced to 45 or 42 months by an efficient franchisee.

COSTS

The capital costs of the dual 2-lane and dual 3-lane tunnel configurations are shown in Table 1. These costs are at September 1990 prices and do not include escalation during the contract period i.e. they are costs for instantaneous construction. They include preliminaries and contingencies. An allowance of 7% is shown external to the estimate to cover design, independent checking and project management. It has been assumed that all land would be made available by Government as part of its agreement with the bidder; land acquisition costs have therefore not been considered.

Maintenance and running costs have been estimated as $50 million per annum (dual 2-lane) and $60 million per annum (dual 3-lane) at 1996 prices.

Figure 22 Programme

Task Name	Start Date	End Date	90	1991	1992	1993	1994	1995	1996	97
Feasibility Study	Nov 1989	Mar 1991								
Prepare Bid Package	Apr 1991	Oct 1991								
Prequalification	Aug 1991	Oct 1991								
Tender and Award	Nov 1991	Jun 1992								
Authorisation and Land	Feb 1991	Sep 1992								
Enabling Legislation	Feb 1992	Oct 1992								
Detailed Design	Jul 1992	Jun 1994								
Construction	Jan 1992	Dec 1996								
- Casting Basin	Jan. 1992	Apr 1994								
- Main Works	Jan 1992	Dec 1996								

Table 1 Capital Costs

Element	Capital Cost (HK$ million) Configuration Dual 2-lane	Dual 3-lane
West Kowloon Toll Plaza	94	115
Sai Ying Pun Interchange	215	215
Approach Tunnels	1077	1284
Immersed Tube	980	1250
Administration and Ancillary Buildings	42	42
Electrical and Mechanical Systems	294	342
Vehicles and Mobile Plant	8	8
Route 7	363	363
Total	**3073**	**3619**

Costs at September 1990 prices, not including escalation.

11 FINANCIAL ANALYSIS

An evaluation of the financial performance of Western Harbour Crossing and its privatisation potential was undertaken, for both tunnel configurations. The evaluation was based on the equal and unequal toll regimes described in Section 3, using a toll of $20 on Western Harbour Crossing at constant 1989 prices. It was determined that the project was financially viable in either configuration and was likely to satisfy the normal public and private sector investment criteria, provided that tolls were permitted to rise with inflation. Project performance was also robust under a wide range of changes to key underlying assumptions.

In view of the relatively high toll level in relation to present cross-harbour tolls, a private investment analysis was undertaken based on a toll of only $11 at constant 1989 prices. In this case, a dual 3-lane tunnel operating under a 30 year franchise was expected to be only moderately attractive to investors, considering the current uncertainty in the investment community.

Consultants

The Western Harbour Crossing Study has been carried out by Western Harbour Crossing Consultants.

Acer Consultants (Far East) Ltd.
Maunsell Consultants Asia Ltd.
Parsons Brinckerhoff (Asia) Ltd.
Pypun-Howard Humphreys Ltd.
The MVA Consultancy

Sub-consultants

CES Consultants in Environmental Sciences (Asia) Ltd.
Coopers & Lybrand Associates Ltd.
Llewelyn-Davies Weeks Hong Kong Ltd.

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