ANNEX E

WATER QUALITY

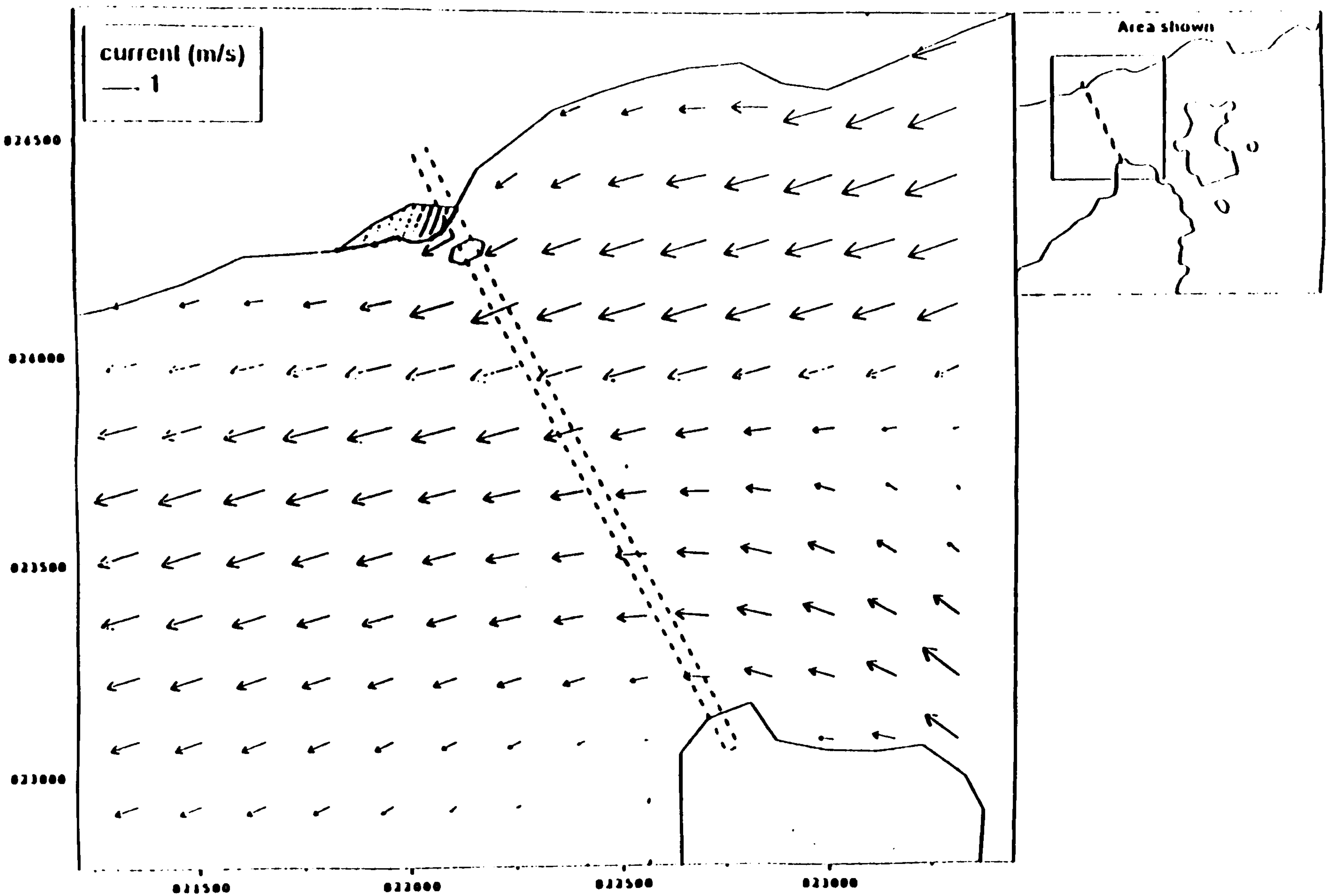
Sections of Reporton Computer Modelling of Tidal Flows and Water Quality

Report HWR 180

Feburary 1997

The contents of this Annex have been extracted from the referenced report; and the results interpolated for the current situation. It is particularly pertinent to note that the reclamation required for ship protection does not extent beyond the 8m contour line, unlike the situation contained herein (refer to Figures A1-A4).

The conclusions of the assessment are that even with intrusion in to the main shipping channel (FSA) and a reduction of 3.5% cross-sectional area, the resulting changes in the volume of water passing through the cross section was 0.6% in the dry season and 0.8% in the wet season which would not adversely affect water quality. With the current proposal the reduction in cross-sectional area is 1.5%, the tower is aligned within a embayment then it may be inferred that this proposal will have even less effect on tidal volumes or flows. The small extent of changes in tidal flows may not be able to be estimated accurately by the model.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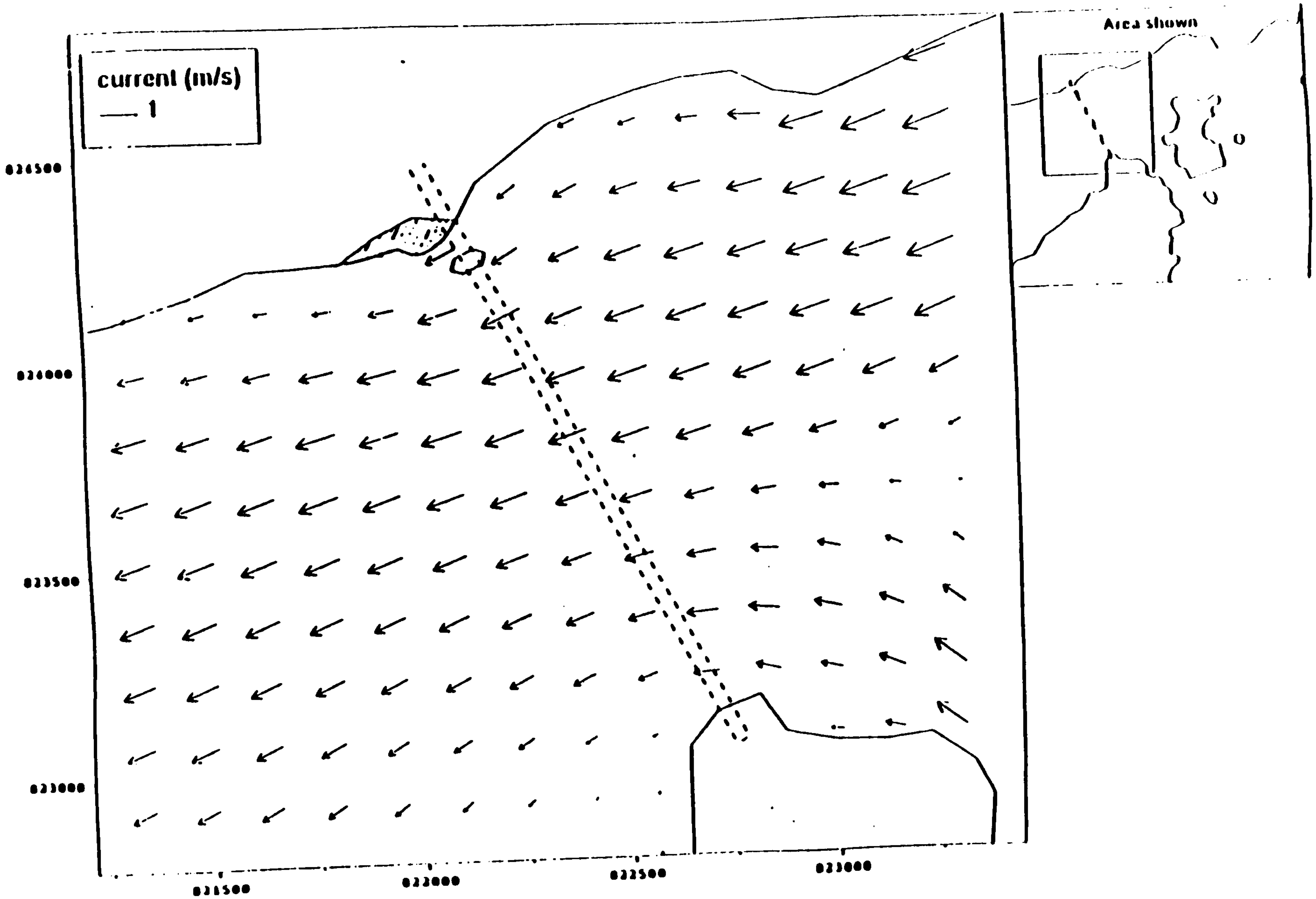


current (m/s)
1
Area shown

CONTENTS

FIGURES (CONTD)

1 INTRODUCTION

The final bridge design being considered under the feasibility studies for the Sham Tseng Link requires a bridge pier with associated ship protection to be built just offshore of the northern landfall.

In January 1997 Hydraulics and Water Research (Asia) Ltd (HWR) were commissioned by Mouchel Asia Ltd to carry out computational modelling to determine the effects of the proposed bridge pier on tidal flows and water quality during and after the construction. The modelling was carried out by HR Wallingford, a joint venture partner in HWR, using the TELEMAC3D suite of flow and water quality models, developed by LNH, Paris.

This report describes the comparison of the flow model with survey data on water levels and currents for 1990 conditions (Chapter 4) and simulation of a 2004 baseline case without the bridge pier (Chapter 5) and simulation with a bridge pier included (Chapter 6). The simulation of sediment plumes is described in Chapter 7.

2 DESCRIPTION OF THE TELEMAC3D MODEL OF TIDAL FLOWS

The TELEMAC 3D free surface flow and transport model has been developed by LNH, Paris. It solves a three-dimensional version of the shallow water equations (ie it is valid for circumstances where vertical fluid accelerations are small compared with the acceleration due to gravity). These three dimensional equations are used in modelling coastal and estuarine flows, where vertical accelerations are small.

The model uses a finite element grid in the horizontal direction made up of unstructured triangles, allowing a very flexible grid to be built that can follow accurately a complex coastline with islands etc. This grid is the same as that also used by TELEMAC 2D, the depth-integrated flow model. In the vertical direction the model grid is developed by division into a number of layers which are specified as sigma coordinate planes with both the surface and bed remaining coordinate planes as the surface moves with the tide. Thus the grid moves, with element sizes in the vertical becoming larger as the water surface rises. The node locations in the vertical take positions at fixed proportions of the distance from surface to bed. Using this method there is always the same number of layers, unlike, for example, the WAHMO models where in shallow areas there may be one layer but in deeper layers there may be two.

The model comprises, at each timestep, the computation of the three-dimensional velocity components at each three-dimensional node and the water surface at each two dimensional location in plan. In addition to these hydrodynamic variables the salinity and/or temperature can also be included, as these variables can have an influence on the water density and therefore can drive flows in three dimensions. In carrying out this modelling it is also necessary to have a description of the way vertical mixing occurs as this redistributes both the horizontal momentum and the salt or heat. A mixing length theory technique is used in TELEMAC 3D to simulate turbulent mixing in the vertical together with damping functions used to decrease the turbulent mixing in the presence of stable stratification.

spring tide are shown in Figure 4.1. The comparison of the modelled water levels and observed dry season spring tide water levels, observed on 8-9 February 1990, is shown in Figure 4.2. The observed tide on this day was very similar to the model and as can be seen the model is well able to represent the differences of tidal range, shape and phase over the modelled area. A further comparison is shown in Figure 4.3 for the observations at the same stations made on 10-11 February 1990. The level of agreement between the model and observed water levels is not as good as for the observations on 8-9 February. Although the observed and model tidal ranges are similar the semi-diurnal phase of the tide is much flatter in the model tide than was measured on 10-11 February and as such the curve for the second, main flood phase of the tide is not as steep in the model as was the case on the day the water levels measurements were made. This is important to consider when evaluating the comparisons for the current speeds because the measurements in the North West New Territories stations were made on this tide.

4.1.2 *Comparisons with Current Meter Data*

The model was compared to current observations made during February 1990. The location of the observation sites is shown in Figure 4.4. The comparisons with the eastern locations (observed simultaneously on 8/2/90) are shown in Figures 4.5 and 4.6 for surface and bed. At these locations there is a very good modelling of the current speeds in the surface and bed layers. The directions are also well predicted by the model. The comparison, especially with the sites E4-6 (closest to Sham Tseng) shows the model results, are very similar to the observations even though the observations differ considerably between these sites.

Comparisons are shown in Figures 4.7 and 4.8 for the surface and bed current speeds and directions for the North West New Territories observation stations W1-6 observed on 10/2/90. The model results are generally very good although there is a tendency for the flood phases of the current to be somewhat underpredicted at most locations. This may be due to the tide on the day of the observations having a steeper flood tide compared with that modelled, as discussed in the previous section. The distribution of the current between the surface and bed layers is also well simulated by the model as are the flow directions.

4.1.3 *Conclusions*

The model results have been compared with field data at the relevant locations for a dry season spring tide and a good agreement found. The model is considered to be wholly adequate for the study of the impact of the Sham Tseng Link works during dry spring tides.

4.2 Wet Season Spring Tide

This Section covers the comparison of the model with field survey data for a wet season spring tide. The water level boundary condition was taken from the dry season spring tide run of the extended WAHMO model because the wet season calibration tide was smaller than the tide during which the 1990 current speeds were measured. The fresh water discharge at the top of the Pearl estuary was also increased compared to the extended WAHMO work in order to account for the fact that August 1992 (for which the extended WAHMO model was run) was an exceptionally dry wet season period. The freshwater flow at the head of the Pearl estuary was set at 16800m³/s which is more representative of typical wet season flows from the Pearl Estuary than was used previously.

is from a survey carried out for BMT during a wet season spring tide of 1986 and the surface and bed layer observations are again compared with the model results. The locations of the current meters are shown in Figure 4.17. The comparisons between the model results and observations for the surface and bed layer currents are shown in Figures 4.18 and 4.19. The ebb tide is of most interest in calrifying the reasons for the difference in the flows at W1 and E6. Here it can be seen that the ebb tide agrees well between the model at all of the locations. This provides extremely good evidence that the model is reproducing correctly the ebb tide in the area of greatest interest. Even at the most southern positions (5CC and 6AA) the current speed in the model is large enough and it is expected to weaken as the flow spreads out to the south so the high current observed at E6 appears to be surprising. The flood tide at these locations is generally well modelled although with some tendency to be a little low.

4.2.3 *Conclusions*

The observations show how varied the flow can be during a wet season spring tide and the model has shown that it can represent this variation well. The currents are generally well represented by the flow model although there is a discrepancy in the ebb tide current at E6. However the ebb tide current is well modelled at a number of alternative locations between the works and position E6 giving confidence that the model is wholly adequate to study the effects of bridge works at Sham Tseng.

5 SIMULATION OF BASELINE SCENARIO

After the comparison with the field data was completed for the 1990 scenario dry and wet season spring tides the model was updated to produce a new baseline case which was intended to simulate the expected coastline in 2004. This was the case against which the simulation including the bridge pier associated with the Sham Tseng Link would be compared.

To update the model bathymetry and coastline the following developments were included (see Figure 5.1):

Developments1990-1996:

West Kowloon Reclamation.
Container Terminal 8.
Central Reclamation Phases I and II.
Hong Kong Convention and Exhibition Centre.
Chep Lap Kok airport platform.
North Lantau reclamations.
Re-aligned fairway south of Tsing Yi.

Developments 1996 - 2004

Container Terminal 9.
Container Terminals 10 and 11.
Ting Kau Bridge pier (Binnie's layout).

dry season spring tide. However the flood tide volumes are reduced by up to 24% leaving the whole area much more dominated by the ebb flow than during the dry season.

6 SIMULATIONS WITH SHAM TSENG LINK BRIDGE PIER

The model mesh and bathymetry were updated to included a representation of the bridge pier and the model was run again using the same 43 hour period to simulate the repeating spring tides. The results from the model simulations with the bridge pier in place were compared with the Baseline runs to determine the effects on tidal flows of the construction of the bridge pier.

6.1 Dry Season Spring Tide

6.1.1 *Effects on Currents*

Current patterns are again plotted for the area of interest for peak ebb and flood currents (Figures 6.1-6.4). Contours of the differences in the magnitude of the surface and mid-depth currents, with and without the bridge pier, are plotted on Figures 6.5-6.6 for peak ebb and Figure 6.7-6.8 for peak flood.

During the flood tide the presence of the pier reduces the total cross-sectional area of the channel by the order of 2%-3% and so some speed increases in the remaining channel width are shown. Comparing the surface current, an area extending 5km west of the bridge experiences a speed increase of 0.02-0.05 m/s with a small central band 3km in extent showing a speed increase of just over 0.05 m/s. Speed decreases are shown along the northern coastline with both the surface and mid-depth currents reduced by at least 0.02 m/s 3km west of the pier. An area extending some 300m west of the pier shows a decrease of 0.3-0.5 m/s in both the surface and mid-depth currents.

During the ebb tide a similar pattern is shown with speed decreases of the range 0.02-0.05 m/s extending 2.5 km east of the pier in both the surface and mid-depth currents. Speed increases are again shown in the remaining cross-section although covering a smaller area than during the flood. The 0.02 m/s increase contour extends to 1.5 km east of the pier. The majority of the speed increases are less than 0.05m/s. There are some speed increases along the northern coastline to the east of the pier during the ebb tide. These changes extend only 500m east from the pier and are of the order of 0.1m/s. These speed increases on the northern shoreline are caused by the bridge pier diverting the ebb flow closer to the coast, whereas previously the majority of the ebb flow was confined to the main, offshore flow channel. The effect is most noticeable on the ebb tide because the flood flow travelled closer to the coastline, prior to the construction of the bridge pier, than the ebb flow and so any re-direction of flow on the flood tide by the bridge pier relative to the original flows in this area are less noticeable.

6.1.2 *Effects on Discharges*

The total volume passing through the set of three cross-sections around the bridge site was again calculated in the same way as for the baseline scenario and the results included in Table 1 together with the percentage changes in the total discharges

The pier reduces the total volume of water passing through the area of interest. Some redistribution of the ebb flow between the Ma Wan and Kap Shui Mun channels is shown causing a slight increase to the volume passing through Kap Shui Mun during that period.

The changes to the total flood and ebb discharge volumes caused by the bridge pier are within 0.6% of the baseline value at the three cross-sections considered. The greatest change being a reduction of 0.53% for the flood discharge through Kap Shui Mun.

Instantaneous discharges through the Ma Wan and Urmston Road channels are reduced by up to 200m³/s with slight increases predicted as the flow direction changes.

Instantaneous discharges through Kap Shui Mun are reduced by up to 60 m³/s during the flood phases of the tide. There are periods of increased discharge of up to 40 m³/s during the ebb phases when the current directions are changing which may result in phase differences between the two simulations.

Model drogues released at the site of the Sham Tseng and Ting Kau outfall demonstrate a slightly reduced tidal excursion when released at LW with the bridge pier in place. HW released drogues have very similar paths with or without the bridge pier. It is concluded that the construction of the bridge pier would not alter significantly the dispersion of pollutants from the outfall.

6.2 Wet Season Spring Tide

6.2.1 *Effects on Currents*

Current patterns are again plotted for the area of interest for peak ebb and flood currents (Figures 6.16-6.19). The differences in the magnitude of the surface and mid-depth currents, with and without the bridge pier are plotted on Figures 6.20-6.21 for peak ebb and Figure 6.22-6.23 for peak flood.

At the time of peak ebb the area of speed decrease shown along the northern coastline is very similar to that predicted by the dry season simulation extending 2.5 km east of the pier site for both the surface and mid-depth currents. Also similar speed increases near to the pier on the northern coast are shown, for the same reasons as on the dry season spring tide. The surface current difference for the wet season simulation shows less current increase across the main width of the section. It also shows some small areas of current change to the east of Ma Wan which may be a result of the redistribution of the flow between the Ma Wan and Kap Shui Mun channels. The mid-depth speed increases cover a very similar area to that predicted by the dry season simulation extending 5 km east of the pier. Contrasting with the dry season result the effect on the mid-depth currents is not obviously a mirror of that on the surface currents, this demonstrates the extra influence of density effects on the complex flows in area of interest.

The general pattern of speed changes shown at the time of peak flood is similar to that shown for the dry season. However, the extent of the changes is less than that shown for the dry season simulation so that the area of 0.02 - 0.05 m/s speed decrease extends 1km west of the pier and the 0.02 m/s increase extends 1.5km west of the pier. More reduction in currents is shown to the east of the pier compared to the dry season and also a small area of speed increase is shown on the ended up in the Rambler Channel with or without the bridge pier in place.

6.2.4 *Summary of Wet Season Results*

The bridge pier is expected to decrease the peak ebb tide current speed by 0.02 -0.1 m/s in an area extending 2.5 km east for both surface and mid-depth currents.

Small ebb tide speed increases occur along the line of the bridge being more pronounced at mid depth than at the surface.

A redistribution of flows benveen Ma Wan and Kap Shui Mun channels occurs causing slight speed changes benveen Ma Wan and Tsing Yi.

Speed increases may occur along the northern coastline near to the pier during both flood and ebb tides.

The changes in the total tidal volumes passing through the three cross-sections surrounding the pier site are all less than 0.8%, with the Urmston Road section showing only marginal reductions of 0.27% and 0.14%.

The pier reduces the total volume passing through the area of interest. The total is redistributed favouring Kap Shui Mun during the ebb and Ma Wan channel during the flood tide periods.

Instantaneous discharges through Urmston Road and Ma Wan channels are reduced by up to 250 m^3/s with slight increases as the flow direction changes and around time of low water.

The reduction in flow through Kap Shui Mun is less marked than that during the dry season, peaking at 50 m^3/s. The flow through Kap Shui Mun is increased during the whole ebb period by up to 80 m^3/s.

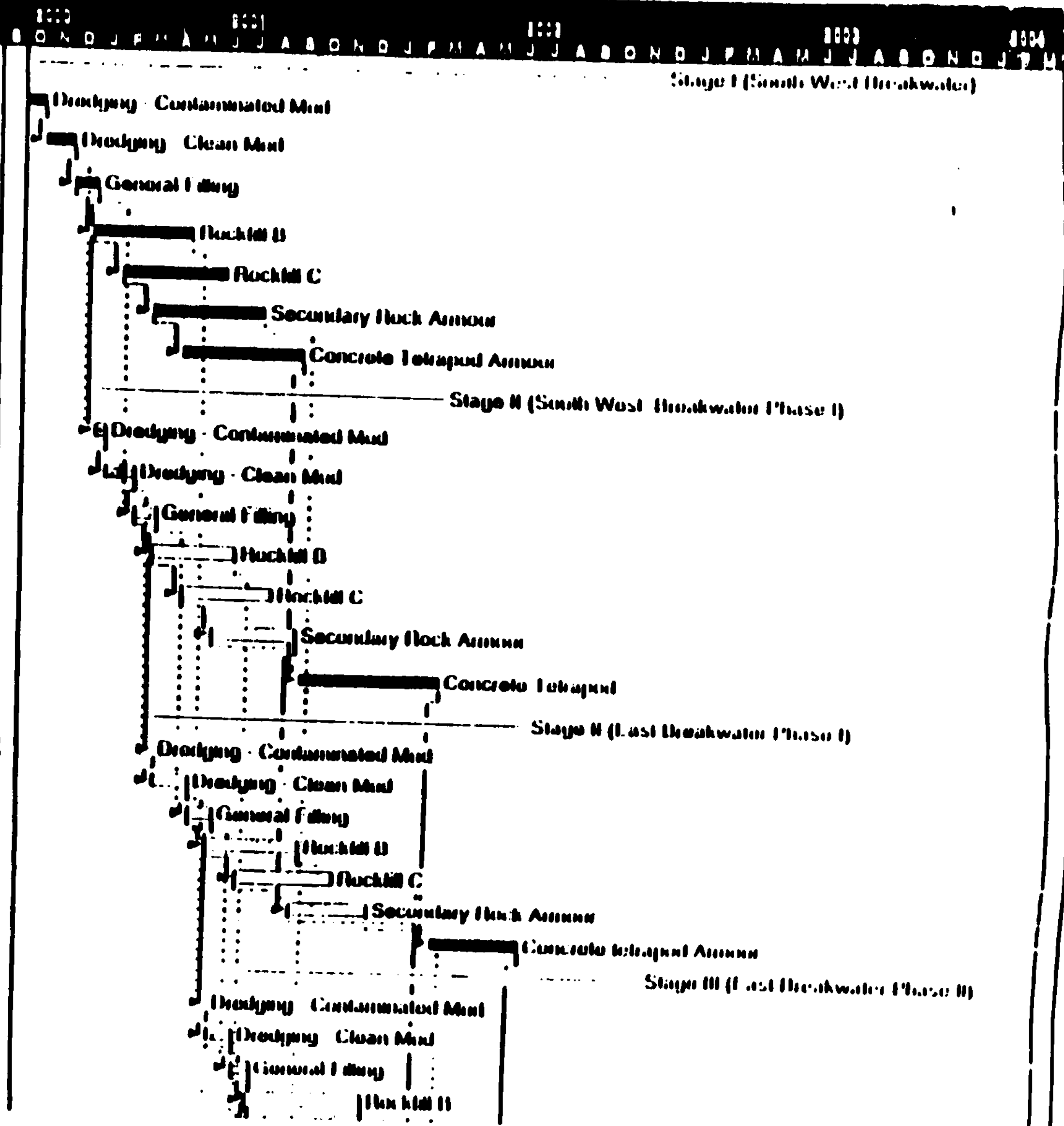
Model drogues released at the site of the nearby Sham Tseng and Ting Kau outfall followed very similar tracks with and without the bridge pier and demonstrate that the construction of the bridge pier will have very little impact upon the dispersion of pollutants from the outfall.

7 SEDIMENT PLUME MODELLING

7.1 Introduction

As part of the construction of the Sham Tseng Link, it is necessary to remove a quantity of bed material from the site of the bridge pier. It is planned to do this by means of grab dredging. This process leads to the loss of a portion of the fine material to suspension which is normally assumed to amount to 5% of the mass of sediment removed. This fine sediment forms a plume which is carried away from the dredging location by the tidal currents and can have an impact on the environment, either by settling onto the bed, possibly smothering benthic organisms if deposition rates are high enough, or by increasing the suspended sediment concentration above background levels at sensitive receivers.

Act ID	Description	Orig Dur	Early Start	Early Finish
1014	Stage I (South West Breakwater)	787	01OCT00	26NOV02
1015	Dredging - Contaminated Mud	25	01OCT00	25OCT00
1016	Dredging - Clean Mud	37	26OCT00	01DEC00
1020	General Filling	30	02DEC00	31DEC00
1030	Rockfill B	124	26DEC00	28APR01
1040	Rockfill C	130	02FEB01	11JUN01
1050	Secondary Rock Armour	139	12MAR01	28JUL01
1060	Concrete Tetrapod Armour	150	19APR01	15SEP01
1160	Stage II (South West Breakwater Phase I)	433 *	01JAN01	09MAR02
1090	Dredging - Contaminated Mud	13	01JAN01	13JAN01
1100	Dredging - Clean Mud	37	14JAN01	19FEB01
1110	General Filling	28	20FEB01	19MAR01
1120	Rockfill B	104	14MAR01	25JUN01
1130	Rockfill C	112	21APR01	10AUG01
1140	Secondary Rock Armour	105	29MAY01	10SEP01
1150	Concrete Tetrapod	175	16SEP01	09MAR02
1180	Stage II (East Breakwater Phase I)	464 *	20MAR01	26JUN02
1200	Dredging - Contaminated Mud	0	20MAR01	19MAR01
1210	Dredging - Clean Mud	45	20MAR01	03MAY01
1220	General Filling	31	04MAY01	03JUN01
1230	Rockfill B	117	27MAY01	20SEP01
1240	Rockfill C	123	04JUL01	03NOV01
1250	Secondary Rock Armour	99	11SEP01	18DEC01
1260	Concrete tetrapod Armour	109	10MAR02	26JUN02
1290	Stage III (East Breakwater Phase II)	541 *	04JUN01	26NOV02
1310	Dredging - Contaminated Mud	0	04JUN01	03JUN01
1320	Dredging - Clean Mud	33	04JUN01	06JUL01
1330	General Filling	23	07JUL01	29JUL01
1340	Rockfill B	148	25JUL01	19DEC01



TSUEN WAN BAY FURTHER RECLAMATION AREA

TANG LUNG CHAU DANGEROUS GOODS ANCHORAGE

TENTATIVE CONSTRUCTION PROGRAMME

FIGURE

8.2 Effects of the Bridge Pier - Wet Season Spring Tide

The results for the wet season spring tide are similar to the dry season tide in that the peak ebb and flood speed decreases occur along the northern coastline. Some speed increases are shown in the main part of the bridge cross-section which are greater at mid-depth than at the surface.

The total volume passing through the cross-sections surrounding the bridge change by less than 0.8%.

Some redistribution of the flow between the Ma Wan and Kap Shui Mun channels shows as slight increases in the total volume passing through the Ma Wan section during the flood tide and Kap Shui Mun during the ebb phase.

Instantaneous discharges through Urmston Road and Ma Wan channels are reduced by up to 280 m^3/s with slight increases as the current changes direction and around low water.

The instantaneous discharge through Kap Shui Mun is reduced through the flood period and increased during the whole ebb period by up to 80 m^3/s.

8.3 Sediment Plume Modelling

The dry season spring tide sediment plume simulation showed that on the ebb tide the majority sediment would be carried along the coast of the New Territories and into the Rambler Channel. On the flood tide the plume was predicted to travel only a short distance. The highest impact at the sensitive receivers was at those in the Rambler Channel with suspended sediment concentrations reaching 15ppm in the lower layer at the northern Oil Depot Pump House but the level of the intake is close to the surface of the sea where the predicted concentrations are much less. Elsewhere in the Rambler Channel suspended sediment concentrations were predicted to be less than 5ppm, while at the other sensitive receivers concentrations were less than 1ppm. Sediment deposition rates were predicted to be low, less than 0.12kg/m² everywhere with the majority of deposition being at much lower rates.

The wet season spring tide simulation showed only small plumes along the coastline in the surface layer and in the lower layer suspended sediment is shown at various times in the tidal cycle in the Western Harbour, off Tsing Yi, at the entrance to the Rambler Channel and to the south of Tuen Mun. Concentrations are shown to be less than 12ppm everywhere. The maximum impact at the sensitive receivers is at Anglers Beach where depth averaged suspended sediment concentrations reach 7ppm. In the Rambler Channel maximum sediment concentrations at the intakes are less than 5ppm and elsewhere concentrations are all less than 1ppm. Maximum sediment deposition rates are shown reach 0.28kg/m² in isolated areas.

Overall the sediment plume modelling has shown that the impacts from the dredging works for the bridge pier construction will not be significant in terms of water quality

ANNEX E

TIDAL EXCHANGE VIA OPENINGS IN THE RECLAMATION AT THE TOLL PLAZA (ALSO REFERRED TO AS "SEA BRIDGES")

An assessment was undertaken to examine whether adequate exchange of water could be maintained between the embayments at Fa Peng and Tso Wan and the main tidal flows via openings provided in the reclamation for the Toll Plaza. The openings are illustrated on Figure 6.5.

Assumptions

The following assumptions were adopted:

- Pollution sources discharged into the embayments are limited to surface runoff especially during the wet season, and the sewage generated currently by the 7 residents and in future by the administration staff at the Toll Plaza. In future this effluent will be collected. treated and disposed of receiving waters of the Western Buffer Water Control Zone.
- The exchange of water between the embayments and the main tidal flows will be driven by hydrostatic pressure which will force the flow system to try to find equilibrium. The difference in level between the main tidal flows and the embayments will be dictated by the hydraulic gradient (ie head losses through the system) which is determined by entry losses, channel losses and exit losses.
- With the large diameter opening proposed (20m) the head losses will be minimal as the velocity within these "channels" will be low (due to low velocities within the system)

Adequate Exchange of Water

To assess whether the exchange of water is acceptable in terms of maintaining water quality a simple approach was adopted. Essentially as the driving force in effecting the exchange of water is the hydrostatic head, then it may be inferred that the tidal prism will be the dominant factor in the exchange process.

If it is assumed that the tidal prism is the product of the tidal amplitude and surface area of the embayment then within Tso Wan the tidal prism is of the order of 7225 cu.m (with a tidal amplitude of 1m on a neap tide and 2m of the spring tide) and within Fa Peng the tidal prism is 4325cu.m.

On average, the volume of water within the embayments at high tide is 14,450cu.m for Tso Wan and 8,650 cu.m for Fa Peng. It may therefore be assumed that 50% of the water within the embayment is replaced each neap tide. If it is further assumed that half of the water exchange replenishes water within the embayment with "external water" then it can be surmised that it could take four neap tides to replenish the water within the embayment. This time would be reduced during the spring tide as the tidal amplitude is greater.

From the foregoing it may be surmised that if complete replenishment takes places over 3-4 tidal cycles, and the pollution load to the embayment is confined to surface runoff, then water quality should be maintained until development is provided seaward of the Toll Plaza.

would replenish waters within the embayment. This implies that, with the very low contribution of pollution to the "system", water quality within the embayments at Tso Wan and Fa Peng should be able to be maintained following construction of the Toll Plaza. During the wet season the inputs from the hinterland drainage will enhance the rate of exchange of waters.