4. FUEL SPILLAGE

4.1 Introduction

The IEIA study identified that the greatest concern on water quality impacts during the operation phase would be the spillage of fuel or chemicals from vessels using the DGA. As described in Section 3.4, the DG vessels currently registered at the TWDGA would be the potential users of the TLCDGA, which comprise vessels licensed to carry Category 2 and 5 DG. The accidental discharge of chemical wastes from vessels is therefore not an issue of concern. However, the accidental spillage of fuel is identified as a key issue. In addition to affecting water quality, a fuel spill could also potentially impact nearby ecological sensitive receivers such as fisheries nurseries and spawning grounds, marine biota including the Chinese White Dolphin, and beneficial uses such as fish culture zones and bathing beaches.

The objectives of assessing fuel spillage impacts are to:

- determine the chemical fate of spilled fuel in seawater for assessing water quality impacts;
- determine the movement of spilled fuel under various hydrodynamic and meteorological conditions; and
- to identify sensitive receivers which are likely to be at risk in the event of a major fuel spill.

To predict the movement of spilled fuel under the influence of tidal currents and wind-driven flows, a number of fuel spill scenarios have been simulated using the TELEMAC OIL-RW3D model. Fuel spill impacts on marine ecology will be addressed in Chapter 9 under Ecology.

4.2 Environmental Legislation and Standards

Oil and fuel spills to coastal waters are controlled under the Shipping and Port Control Ordinance (Cap. 313) (SPCO) and are the responsibility of the Marine Department. The SPCO prohibits pollution of the sea by oil and fuel from both land-based and marine sources. It is noted that there are no local environmental standards nor guidelines with respect to environmental impacts from oil spillage. The WQO for aesthetic appearance states that objectionable odours or discolouration; visible foam; oil; grease; scum and litter are not to be present in marine waters.

4.3 Assessment Methodology

Impacts on Water Quality

The chemical fate of different types of fuel in seawater will be described through literature review.

Movement of Spilled Fuel - Major Spill Event

Fuel dispersion modelling was undertaken to simulate worst-case fuel spill events and assess the impacts on the nearby beaches and fish culture zone. The fuel dispersion model, OIL-RW(3D) was used to simulate the movement of fuel spilt at a site near the centre of the DGA and at sites near the northern and southern entrances of the DGA (**Figure 4.1**). The northern spill location was chosen to simulate spill movement along the Ma Wan Channel and similarly, the southern spill location was chosen to simulate spill movement along the Kap Shui Mun fairway. The fate of slicks resulting from spills at these three sites were assessed separately. For the two spill locations outside the DGA, fuel slick movement was simulated for spring and neap tides in the dry and wet seasons. For the spill location within the DGA, slick movement was simulated for a wet season spring tide only, as this

4.4 Pollution Incidents at the TWDGA

Records of fuel oil pollution incidents in Hong Kong waters indicate no cases between 1992 to 1997 at the TWDGA. Three minor fuel oil pollution incidents have been reported at the DGA last year (up to 2/9/98) on the 6 February, 31 August and 2 September 1998.

The first incident was reported by a resident of Lai Shing Garden, Tsuen Wan on 6 February 1998. A rainbow colour oil slick about 3m x 5m in size was reported in the DGA. The MD dispatched their oil pollution control craft MD117 to investigate the case and carried out half an hour of anti-pollution operation. The oil slick was dispersed by propeller washes.

The second incident occurred on 31 August 1998. A complaint of oil pollution of about 150 feet in size of rainbow colour was made by a resident of Belvedere Garden, Tsuen Wan, to staff of Albert W. Y. Chan Office. The MD dispatched MD111 to the scene for investigation. However, no oil pollution was observed in the DGA.

The third incident was also informed by a staff of Albert W. Y. Chan Office on 2 September 1998. An oil patch was observed in the TWDGA, near Belvedere Garden. The MD dispatched Sea Cleaner 2 to proceed in the investigation. However, no oil spill was found. There was only a small amount of dirty water found floating on the surface. Later in the day Sea Cleaner 2 was requested to patrol the area again although no oil spill was observed.

4.5 Sensitive Receivers

These are the same sensitive receivers for water quality and ecological impacts described under Chapters 3 and 9 respectively.

4.6 Prediction and Evaluation of Impacts

4.6.1 Impacts on Water Quality

As given in the report "Tsuen Wan DGA: Alternative Site Search Study: Stage 2 Study", the most common cargoes of vessels using the TWDGA are diesel (Fuel oil no. 2-D), diesel oil light (Fuel oil no. 1-D), kerosene (Fuel oil no. 1) and bunker oil (Fuel oil no. 5). The key properties of these fuels are given in Table 4.1 below as extracted from the above ERM report.

Table 4.1 Physical and Chemical Properties of Most Common Cargoes

Parameter	Fuel Oil No. 2-D	Fuel Oil No. 1-D	Fuel Oil No. 1	Fuel Oil No. 5
Synonym	Diesel	Diesel Oil Light	Kerosene	Bunker Fuel
Flash Point (°C)	52	38	38	69 - 169
DG Category and Class	Cat 5 Class 2	Cat 5 Class 2	Cat 5 Class 2	Cat 5 Class 3
Vapour Pressure (mm Hg)	<1	<1	5	<1
Density (g/cc)	0.87 - 0.9	0.81 - 0.85	0.8	0.938
Reference Temperature	20°C	15°C	20°C	(SG) 18°C
LFL (v/v %)	0.6	1.3	0.7	1
UFL (v/v %)	7.5	5	5	5
Burning Rate (mm.min)	4	4	4	4

A spillage of fuel oil would float on the water surface and be dispersed by wave action, evaporation and natural biodegradation. A small quantity (up to 1% of spill volume) will dissolve into the water represents the condition when the spill would most likely escape from the DGA and impact on the nearby sensitive receivers.

OIL-RW(3D) is designed to compute the dispersion of spilled fuel under the influence of tidal currents and wind-driven flows. The model uses flow fields computed by the TELEMAC-3D hydrodynamic model as input data. The TELEMAC-3D model has been verified and used in the Tsuen Wan Bay Further Reclamation Feasibility Study and EIA. OIL-RW(3D) simulates the physical processes affecting spilled fuel such as buoyant spreading, evaporation, emulsification, entrainment, weathering, buoyancy and shoreline stranding.

It was specified that the type of fuel simulated should be kerosene, as this will probably be the lightest fuel cargo of vessels using the DGA, and is therefore likely to spread over the largest area. The largest vessel licensed to use the DGA will have a maximum cargo of 1200 tonnes. An earlier report (ERM's report titled "*Tsuen Wan Dangerous Goods Anchorage: Alternative Site Search Study: Stage 2 Study*") has identified that the most significant spill accident will involve a spillage of 90% of the fuel cargo. Therefore, spills of 1,080 tonnes (1,350m^3) of kerosene were simulated and 20% of the kerosene was spilt instantaneously, with the remaining 80% spilling over the subsequent 24 hours. The spills were assumed to start at two hours after low water when the tide is flooding and would have more immediate impacts to the nearby sensitive receivers, such as the Ma Wan fish culture zone, beaches at Ma Wan and beaches along the southern coastline of the north-west New Territories. The simulations were carried out over approximately three successive diurnal cycles (i.e. 3 days) to ensure the fate of the spills was captured.

Wind would have an effect on the movement of the spill. Historical wind data from 1990 to 1994 for the automatic weather station on Tsing Yi has been used to determine the prevailing wind directions and speeds for the wet and dry seasons. Winds for the fuel spill simulations of 2.58ms^{-1} from 130°N and 2.92ms^{-1} from 170°N were used in the dry and wet seasons respectively. These were applied with a typical drift factor of 0.035, that is, the surface fuel slicks drifted in the direction of the wind at 2.5% of the specified wind speeds.

As limited information was available to define shoreline types in Hong Kong coastal waters, a relatively simple classification was adopted. In each element adjacent to the flow model coastline, the shoreline was defined as beach, which can retain incident fuel, or as rock, which does not retain fuel. In elements defined as beach, it was assumed that the sand's fuel holding capacity was effectively infinite, so that all fuel impinging on the shore there was retained. This assumption was conservative in terms of beach contamination, that is, the quantities of fuel predicted to be stranded on each beach are probably upper limits on what would actually occur there for the conditions simulated. The fuel holding capacities of rock shorelines were assumed to be zero. Full details of the modelling assumptions and approach are presented in a separate Working Paper titled "*TELEMAC 3D Oil Spill and Bacterial Dispersion Modelling for Tang Lung Chau DGA,*" July 1998.

Chronic Fuel Spillage

Seepages or discharges of petroleum products from vessels moored within the DGA would not be permitted under the Merchant Shipping (Prevention of Oil Pollution) Regulation and would be controlled by Marine Department. Therefore such seepage is not considered to be a continuous discharge and will be considered as an accidental spillage with a much smaller volume.

As the volume of chronic seepages cannot be quantified, a range of assumed volumes (such as 0.001% to 0.01% of the major spill) will be used to estimate the seepage plume size. The contour plots of surface fuel slick thickness produced for the major spill event within the DGA were scaled down to indicate the likely extent of the fuel seepage plume. The time of travel to the sensitive receivers has been assumed to be the same as for the major spill event.

not considered likely to occur to a great degree as the ambient suspended solid level in the study area to the south of Ma Wan is 19 mg/L (Section 3.3), and therefore agglomeration will not be promoted.

4.6.2 Movement of Spilled Fuel - Major Spill Event

Each fuel spill simulation was run for approximately three successive diurnal cycles. Model results were presented[1] as contour plots of surface fuel thicknesses at three, six, nine and twelve hours after the start of the spill, and at each subsequent high water (HW) and low water (LW) (in the case of the neap tides, HW and LW plots are for the second tide of each pair of tides occurring during the diurnal cycle). Surface fuel thicknesses were also shown as time-series plots at the identified sensitive receivers and fuel stranded on the shoreline was shown at the end of each three-day simulation. For the two spill locations near the southern and northern entrances of the DGA, additional contour plots were presented of surface fuel thickness at one and two hours after the start of the spill for each tide type.

It should be noted that the assumptions adopted in the fuel spill simulations amount to the selected spill simulations representing the worst-case scenarios, and these fuel spill simulations have been agreed with EPD. As described earlier in Section 4.3, the type of fuel simulated is kerosene as this will probably be the lightest fuel cargo of vessels using the DGA, and is therefore likely to spread over the largest area with the potential to affect a greater number of sensitive receivers. It was assumed that an incident occurs near either one of the entrances and results in damage of the body of the 1200 tonne vessel. It was also assumed that the vessel was fully loaded with fuel and 90% of the cargo was spilled. The surface fuel thicknesses predicted at the sensitive receivers are for the event that no containment actions are implemented at the source of the fuel spill nor mitigation measures implemented at the sensitive receivers. Thus the predicted surface fuel thicknesses represent the maximum values likely to occur at the sensitive receivers.

The likelihood of these worst-case spill scenarios happening was calculated using the event frequencies and spillage probabilities presented in the 1995 Site Search Study[2]. The relevant initiating events leading to an incident outside the DGA and the associated event frequencies were identified from Table A1.a of the report. The probabilities of a fuel spill happening in these incidents were then calculated using data from Appendix 2 of the report. The frequencies of a fuel spill resulting from different initiating events were then added up. The frequency of a spill from a 1200 tonne vessel happening outside the DGA was found to be 3.81×10^{-4} per year (i.e. once in 2,600 years), which is considered to be low. The spreadsheet showing this calculation is given in Appendix C for reference.

Dry Season Spring Tide

The surface fuel thickness time-series simulated at the sensitive receivers for the spill at the southern and northern locations outside the TLCDGA, during dry season spring tide conditions, are shown in **Figures 4.2 and 4.3** respectively. The contour plots of surface fuel thickness at one and two hours after the start of the spill for the southern and northern spill locations are shown in Appendix C (Figure C1 and C2 respectively).

Oil from the southern spill location shows a westward movement before HW, and the drift of the surface slick towards the southern shoreline of the north-west New Territories which occurs under

1 TELEMAC 3D Oil Spill And Bacterial Dispersion Modelling for Tang Lung Chau DGA, MCAL. July 1998. (The additional contour plots of surface fuel thickness at one and two hour intervals were produced in December 1998).

2 Tsuen Wan Dangerous Goods Anchorage: *Alternative Site Search Study – Stage 2 Study Volume 2: Risk assessment* Final Report August 1995

column. In addition, fuel oil will fragment and adhere to suspended solid particles, and subsequently sink as agglomerate particles which may settle on the seabed. Hence, there are several processes involved which have the potential to impact upon water quality as follows:

- dissolution;
- dispersion/emulsification; and
- sinking and sedimentation.

Dissolution

In the event of a spill, low molecular weight aromatics such as benzene, which are present within virtually all petroleum products, partition into the water column. It has been found that the concentrations of lower molecular weight aromatics (including toluene, ethylbenzene, P-xylene, and N-propylbenzene) peak approximately 8 to 12 hours after the initial release of oil to the water column, in the 10 to 100 parts per billion (ppb) range. The concentration then drops off in an exponential manner due to evaporation and the removal of dissolved compounds by advection (water mass transport).

Dispersion/Emulsification

Oil droplets form as a spill fragments and disappears from the water surface, due to wave action and spontaneous emulsification in calm seas. The thinner the slick the more frequently wave breaking occurs, thus dispersion would be a dominant process during fuel spill. In addition, it is thought that emulsification may be a major source of dispersion as the fuel adheres to any suspended solids present within the water column, although this will be dependent upon the suspended solids concentrations present.

Dispersion leads to increased dissolution of the lower molecular weight aromatics, and provides materials which may be ingested by organisms and ultimately deposited in sediments in the form of faecal pellets. The dispersion of oil droplets within the water column may occur for 2 to 3 days. These droplets will return to the surface unless adsorbed onto suspended solids, or be used as a substrate for growth by some marine organisms.

Sinking and Sedimentation

The processes of sinking and sedimentation are considered to be major factors during the decay of high density hydrocarbon fuels, particularly when high levels of suspended solids are present in the water column which the fuel can adhere to. In waters with high suspended solids concentrations, there is the potential for significant impacts on benthos, as fuel adheres to suspended solids and settles on the seabed. Biodegradation of hydrocarbons will take place as micro-organisms within the water use the fuel as a food substrate. This process may lead to reduced dissolved oxygen levels within the water column and associated impacts on marine biota.

The maximum impact upon water quality resulting from the dissolution of aromatics would result approximately 8 to 12 hours after the spill occurred, in the absence of other processes. However, the aromatics would rapidly dissipate, leaving no trace approximately 1 to 2 days after the spill. The effect of these aromatics upon water quality including dissolved oxygen concentrations is not known, although any impact would be temporary due to the rapid dispersion of the aromatics within the water column.

Therefore, the fragmentation and dispersion of the spill will cause temporary water quality impacts as low molecular weight aromatics (such as benzene) dissolve into the water column, although these concentrations will dissipate rapidly. In addition, the process of agglomeration and sedimentation is

Wet Season Spring Tide

The results of the fuel spill simulation for the southern spill location outside the DGA during a wet season spring tide are shown in the surface fuel thickness time-series presented in **Figure 4.6**, and the equivalent results for the northern spill location and for the spill within the DGA are shown in **Figure 4.7** and **Figure 4.8** respectively. The contour plots of surface fuel thickness at one and two hours after the start of the spill for the two spill locations outside the DGA are shown in Appendix C (Figure C5 and C6 respectively).

During the wet season, the freshwater discharge of the Pearl River results in a residual southward drift of surface water in the vicinity of the DGA, which tends to reduce flood tide current speeds and increase ebb tide current speeds relative to the dry season. In the fuel spill simulations for the two locations outside the DGA, this is apparent as reduced westward extents of the surface slick in the wet season relative to the dry season, and as greatly increased southward extents. Oil spilt at the two locations outside the DGA during the wet season spring tide affects the sensitive receivers on the southern shore of the north-west New Territories between Gemini Beaches and Lido Beach, Tung Wan Tsai and Tung Wan on Ma Wan and the Ma Wan fish culture zone.

For the southern spill location (**Figure 4.6**), impacts are first experienced at the beaches within the Tsuen Wan district at approximately 8 hours from the initial spill. The maximum surface fuel thickness (110 microns) is shown at Tung Wan Tsai at around 14 hours from the start of the spill. The fuel slick from the northern spill location (**Figure 4.7**) first reaches these beaches at around 7 hours with lower surface fuel thicknesses than for the fuel slick from the southern spill location, although the impact on the outer part of Tung Wan Tsai is rapid (between 1 to 2 hours) with a higher surface fuel thickness (maximum of 190 microns at around 17 hours from start of spill). The slick is also shown to impact the outer part of the bay of Tung Wan between 1 to 2 hours after the initial spill. For both spill locations outside the DGA, shoreline stranding occurs on beaches as far from the DGA as the southern shore of Lantau.

The fuel slick from the southern spill location reaches the Ma Wan fish culture zone at Kung Tsai Wan within 2 to 3 hours following the initial spill. High quantities of surface fuel thickness are evident at this area of the fish culture zone, with a maximum surface fuel thickness of 2,900 microns at around 8 hours from the start of the spill.. For the northern spill location, the Ma Wan fish culture zone at Kung Tsai Wan is impacted at around 36 hours from the start of the spill with a surface fuel thickness of 5 microns. Small quantities of surface fuel (less than 4 microns) are shown at the Ma Wan fish culture zone at Tam Shui Wan at approximately 58 hours following the spill.

For the fuel spill within the DGA during the wet season spring tide, the drift caused by the imposed wind exceeds the weak tidal currents inside the DGA, and the wind causes fuel to accumulate against the northern breakwater of the DGA. Under these conditions, only a very small quantity of fuel can pass through the northern DGA entrance. The only sensitive receivers affected by the surface slick are Tung Wan Tsai at around 22 hours following the initial spill with a maximum surface fuel thickness of approximately 6 microns, and the Kung Tsai Wan fish culture zone at around 53 hours following the initial spill with a surface fuel thickness of approximately 2.5 microns (**Figure 4.8**). Shoreline stranding of the surface slick occurs on the eastern shore of Ma Wan, and on the southern shore of the north-west New Territories around the North Lantau Strait.

Wet Season Neap Tide

The results of the fuel spill simulation for the southern spill location outside the DGA during a wet season neap tide are shown in the surface fuel thickness time-series presented in **Figure 4.9**, and the equivalent results for the northern spill location are shown in **Figure 4.10**. The contour plots of surface fuel thickness at one and two hours after the start of the spill for the southern and northern the influence of south-easterly wind. After HW, the surface slick moves southwards from the release point directly after release, and some of the fuel which had previously passed westward through the North Lantau Strait returns eastward to the north of Ma Wan and towards the Rambler Channel. Towards the end of the simulation, the only fuel remaining in open water in noticeable quantities is in a small patch about 10 km to the north-west of Chek Lap Kok, and adjacent to some shoreline areas nearer the spill location. As shown in **Figure 4.2**, Anglers, Gemini, Hoi Mei Wan, Casam and Lido beach within the Tsuen Wan district and Butterfly and Cafeteria Beach within the Tuen Mun district are all impacted by the spilt fuel. The first beach to be affected by the fuel slick is Butterfly beach, at approximately 10 hours after the spill. The two beaches on Ma Wan and the Ma Wan fish culture zone at Tam Shui Wan and Shek Tsai Wan are not affected by the fuel slick. However, the Ma Wan fish culture zone at Kung Tsai Wan is impacted by the slick between 1 to 2 hours following the initial spill, with a surface fuel thickness of approximately 20 microns. Most of the shoreline stranding occurs on the beaches along the southern shoreline of the north-west New Territories, with the remainder being on beaches along the eastern shore of Lantau.

Between the start of the spill and HW, fuel spilt near the northern DGA entrance moves north-westward towards the eastern shore of Ma Wan under the influence of both the tidal currents and the prevailing wind. Some fuel also moves into the channel between the south-eastern shore of Ma Wan and the DGA. After HW, some fuel also moves into the Ma Wan Fairway. Towards the end of the simulation, the surface fuel patches near the shore in some areas are very small. The only beaches affected by spilt fuel are the two beaches on the eastern shore of Ma Wan, which is also the area most heavily affected by fuel stranded on the shoreline. As shown on **Figure 4.3**, impacts occur rapidly (within 1 hour) at Tung Wan Tsai and Tung Wan beach following the initial spill. A peak surface fuel thickness of approximately 3,000 microns is predicted at Tung Wan Tsai beach within 1 hour after the spill. A few beaches along the southern coastline of the north-west New Territories and on the eastern shore of Lantau are also affected by stranded fuel. The Ma Wan fish culture zone at Kung Tsai Wan is impacted by the slick at around 26 hours following the initial spill, with a surface fuel thickness of less than 5 microns.

Dry Season Neap Tide

The results of the fuel spill simulation for the southern spill location outside the DGA during a dry season neap tide are shown in the surface fuel thickness time-series presented in **Figure 4.4**, and the equivalent results for the northern spill location are shown in **Figure 4.5**. The contour plots of surface fuel thickness at one and two hours after the start of the spill for the southern and northern spill locations are shown in Appendix C (Figure C3 and C4 respectively).

The simulated fuel slick movements are, in general, qualitatively similar to those during the dry season spring tide, although the slick does not extend as far from the DGA during the neap tide as during the spring tide. For the southern spill location, minimal surface fuel thicknesses (less than 1.5 microns) are predicted at Tung Wan Beach at around 25 hours from the start of the spill **(Figure 4.4)**. The Ma Wan fish culture zone at Kung Tsai Wan is impacted by the slick at approximately 14 hours following the initial spill, with a surface fuel thickness of 800 microns. However, between 1 to 2 hours following the initial spill, the slick is shown to pass Kung Tsai Wan at a distance of approximately 100 m offshore. Beaches within the Tsuen Wan district are shown to be first impacted by the fuel slick at approximately 12 hours following the initial spill. Shoreline stranding only occurs on beaches within 3 km of the DGA.

For the northern spill location, the beaches of Tung Wan Tsai and Tung Wan beach are affected by the fuel slick within 1 hour after the spill. A peak surface fuel thickness of approximately 2,500 microns is predicted at Tung Wan Tsai beach (**Figure 4.5**).

Table 4.3 Spill near Southern Entrance of DGA - Time taken to reach Nearest Sensitive Receivers (in hours)

Sensitive Receiver	Dry spring	Dry neap	Wet spring	Wet neap
Tung Wan Tsai	Not impacted	Not impacted	~ 11	~ 7
Tung Wan	Not impacted	~ 25	Not impacted	Not impacted
Kung Tsai Wan	1-2	1-2*	2-3	2-3
Tam Shui Wan	Not impacted	Not impacted	Not impacted	~ 8
Shek Tsai Wan	Not impacted	Not impacted	Not impacted	Not impacted

* plume would pass Kung Tsai Wan at a distance of approximately 100m offshore

4.6.3 Chronic Fuel Spillage

For the major fuel spill within the DGA (wet season spring tide), the only sensitive receivers affected by the surface slick are Tung Wan Tsai at around 22 hours following the initial spill with a maximum surface fuel thickness of approximately 6 microns, and the Ma Wan fish culture zone at Kung Tsai Wan at around 53 hours following the initial spill with a surface fuel thickness of approximately 2.5 microns. Only a very small quantity of fuel was shown to pass through the northern DGA entrance. By adopting the upper range of 0.01% of the spill plume from the major spill event to represent the volume of chronic seepage, it is found that the surface fuel thickness at both Tung Wan Tsai and Kung Tsai Wan would be less than 0.1 micron. This value is considered to be insignificant. With a spill volume of 0.001% of the spill plume from the major spill event, any fuel seepage plume formed would remain within the DGA due to the weak tidal currents inside the DGA. The impact from this lower range of the spill volume would therefore be minimal.

4.7 Mitigation of Adverse Impacts

The results of the fuel spill modelling generally show that for the northern spill location, impacts at the two nearby beaches on Ma Wan occur rapidly following the initial spill (within 1 hour for dry season spring and neap tides at Tung Wan Tsai and Tung Wan). Higher surface fuel thicknesses are shown under the dry season spring tide, with a peak surface fuel thickness of approximately 3,000 microns at Tung Wan Tsai within 1 hour after the start of the spill. Impacts at the beaches in the Tsuen Wan district occur around 7 hours after the spill (for wet season spring tide). Subsequent impacts are wide ranging, along to Tuen Mun and along the south Lantau coastline. However, these impacts occur over 7 hours after the initial spill and the quantities of fuel involved will be very small, particularly along the south Lantau coastline. The fuel slick is first predicted to reach the Ma Wan fish culture zone at Kung Tsai Wan at around 36 hours from the start of the spill with a surface fuel thickness of 5 microns (wet season spring tide).

For the southern spill location, the fuel is initially transported through the Kap Shui Mun channel and so does not impact on the beaches at Ma Wan. Later, on the ebb tide, the spill impacts on the beaches along the southern coastline of the north-west New Territories and on Ma Wan (the fuel slick was shown to affect Tung Wan Tsai at 7 hours after the start of the spill for wet season neap tide and impacts on Tsuen Wan beaches were shown at 8 hours after the initial spill for the wet season spring and neap tides). Impacts on the Ma Wan fish culture zone at Kung Tsai Wan occur rapidly following the initial spill (between 1 to 2 hours for the dry season spring tide). High surface fuel thicknesses above 2,000 microns are shown for the wet season spring and neap tides at around 4 and 11 hours respectively from the start of the spill. The fuel slick affects the Ma Wan fish culture zone at Tam Shui Wan at around 8 hours following the initial spill for the wet season neap tide with a maximum surface fuel thickness of approximately 30 microns. Shoreline stranding occurs on the south Lantau beaches, although at very low surface thicknesses.

spill locations are shown in Appendix C (Figure C7 and C8 respectively). The wet season neap tide results show relatively short extents of the slick through the North Lantau Strait, and relatively long extents to the south of the DGA, as occurred in the wet season spring tide runs. Shoreline stranding of fuel during the neap tide runs also occurs in similar areas to those affected during the equivalent spring tide runs.

Oil spilt at the southern spill location during the wet season neap tide affects the sensitive receivers between Gemini Beaches and Lido Beach, Tung Wan Tsai and the Ma Wan fish culture zone. Impacts are first experienced at the beaches within the Tsuen Wan district at approximately 8 hours from the initial spill and at Tung Wan Tsai at approximately 7 hours from the start of the spill. The maximum surface fuel thickness (130 microns) is shown at Tung Wan Tsai at around 36 hours from the start of the spill.

The fuel slick from the southern spill location reaches the Ma Wan fish culture zone at Kung Tsai Wan within 2 to 3 hours following the initial spill with a surface fuel thickness in the range of 10 to 100 microns. Higher surface fuel thicknesses are predicted at around 6 hours from the start of the spill (1,900 microns) with a peak surface fuel thickness of approximately 2,100 microns at around 11 hours. The fuel slick is predicted to reach the Ma Wan fish culture zone at Tam Shui Wan at around 8 hours from the start of the spill (**Figure 4.9**) with a surface thickness of approximately 30 microns.

Oil from the northern spill location affects Tung Wan Tsai, Hoi Mei Wan and the Kung Tsai Wan fish culture zone. As shown on **Figure 4.10**, the fuel slick is predicted to reach Tung Wan Tsai between 1 to 2 hours from the initial spill. A peak surface fuel thickness of approximately 800 microns is predicted at Tung Wan Tsai beach at around 25 hours from the start of the spill. The slick is shown to impact the outer part of the bay of Tung Wan between 1 to 2 hours after the initial spill. Minimal surface fuel thickness (less than 1 micron) is predicted at Hoi Mei Wan at around 22 hours from the start of the spill. The slick is predicted to reach the Ma Wan fish culture zone at Kung Tsai Wan at around 41 hours from the start of the spill with a surface thickness of approximately 3 microns.

The results of the fuel spill simulation for the northern and southern spill locations outside the DGA are summarized in Tables 4.2 and 4.3 below.

Table 4.2 Spill near Northern Entrance of DGA - Time taken to reach Nearest Sensitive Receivers (in hours)

Sensitive Receiver	Dry spring	Dry neap	Wet spring	Wet neap
Tung Wan Tsai	<1	<1	1-2*	1-2
Tung Wan	<1	<1	1-2*	1-2*
Kung Tsai Wan	~ 26	Not impacted	~ 36	~ 41
Tam Shui Wan	Not impacted	Not impacted	~ 58	Not impacted
Shek Tsai Wan	Not impacted	Not impacted	Not impacted	Not impacted

* outer part of bay

low probability of a fuel slick reaching the fish culture zone within 2 hours. However, to further protect the Ma Wan fish culture zone from the unlikely event of the fuel plume reaching this sensitive receiver within two hours, provision of oil containment facilities at the DGA or at the fish culture zones has been considered. For government staff to deploy such facilities within 2 hours, permanent and dedicated staff provision will be required. This is considered not justifiable for an event of such a low frequency. This measure is therefore considered not practicable. Thus, the recommended mitigation measure in the event of oil spillage is the implementation of the MD's OPCP.

It is considered important that prompt response action be undertaken in the event of a major fuel spill so as to limit the spread of fuel at the source and to contain the slick. Immediate action will be required in the event of a major spill near the northern and southern entrances of the DGA so as to minimize the potential for adverse environmental impacts at the two beaches on the eastern coastline of Ma Wan and at the Ma Wan fish culture zone at Kung Tsai Wan. The relevant parties should be notified (including Regional Services Department (RSD)) to take precautionary measures to protect the gazetted bathing beaches, and to evacuate bathers if necessary. Anti-oil pollution equipment is available at gazetted bathing beaches and appropriate action should be taken by RSD in accordance with the OPCP in the event of a fuel spill. The use of chemical dispersants is not recommended at the Ma Wan fish culture zone in view of their potential adverse ecological effects. Physical means to combat fuel oil pollution, for example the use of oil booms (for deflection and containment purposes), are therefore preferred to the use of dispersants in the vicinity of fish culture zones. With the immediate implementation of the OPCP, it is considered that the potential for adverse environmental impacts in the event of a fuel spill would be kept to a minimum.

When considering possible spill plumes from chronic vessel seepage, any fuel seepage plume formed is likely to remain within the DGA due to the weak tidal currents inside the DGA. The only sensitive receivers that may possibly be affected are Tung Wan Tsai and Kung Tsai Wan with a surface fuel thickness of less than 0.1 micron. The fuel spill contingency procedures contained in the MD's OPCP are also applicable for minor fuel seepage plumes. It is considered unlikely that any significant impacts would arise due to the very low surface fuel thickness predicted.

4.8 Conclusions

Simulations of the movement and shoreline stranding of kerosene spilt at three locations in and near the Tang Lung Chau DGA have been carried out using the OIL-RW(3D) dispersion model. The input data for the simulations comprised tidal flow fields computed by the fully three-dimensional flow model, TELEMAC-3D, specified wind conditions, and various constants describing the environmental conditions and physical properties of kerosene. The model results correspond to the prevailing environmental conditions (tide type, wind, etc), and have been used to assist in contingency planning.

The fuel slick simulations have been carried out for spring and neap tides in the dry and wet seasons for the defined worst-case spill scenarios. The frequency of the worst-case spill from a 1,200 tonne vessel (loss of 90% of spill cargo) happening outside the DGA was found to be 3.81×10^{-4} per year (i.e. once in 2,600 years). For a smaller typical vessel of 400 tonnes capacity, the frequency of a spill event is estimated to be once in 190 years. These frequencies are considered to be low. The surface fuel thicknesses predicted at the sensitive receivers are for the event that no containment actions are implemented at the source of the spill nor mitigation measures implemented at the sensitive receivers, and thus represent likely maximum values.

The results of the fuel spill modelling indicate that the shortest time in which the fuel slick is shown to impact bathing beaches is within 1 hour for the two beaches on Ma Wan for a spill location near the northern entrance of the DGA (dry season spring and neap tides). For the gazetted beaches along

If the fuel spill occurs within the DGA, it is shown that the fuel slick will not move outside the DGA. The only sensitive receivers affected are Tung Wan Tsai and the fish culture zone at Kung Tsai Wan at around 22 and 53 hours respectively following the initial spill.

From the results of the fuel spill modelling, the shortest time in which the fuel slick is shown to impact bathing beaches is within 1 hour for the two beaches on Ma Wan for a spill location near the northern entrance of the DGA. For the gazetted beaches along the southern coastline of the north-west New Territories, there is a time lag of at least 7 hours until the fuel slick affects the beaches. At the Ma Wan fish culture zone, the fuel slick is shown to first affect the fish culture zone at Kung Tsai Wan between 1 to 2 hours following a spill at the southern entrance of the DGA. MD have advised that their response time to activate the Oil Pollution Contingency Plan (OPCP) is within 2 hours in the harbour limit and that the same time frame shall apply to the DGA. The OPCP sets out the responsibilities, operational procedures and actions for responding to a fuel oil spill in Hong Kong waters. The stated purpose of this Plan is three-fold:

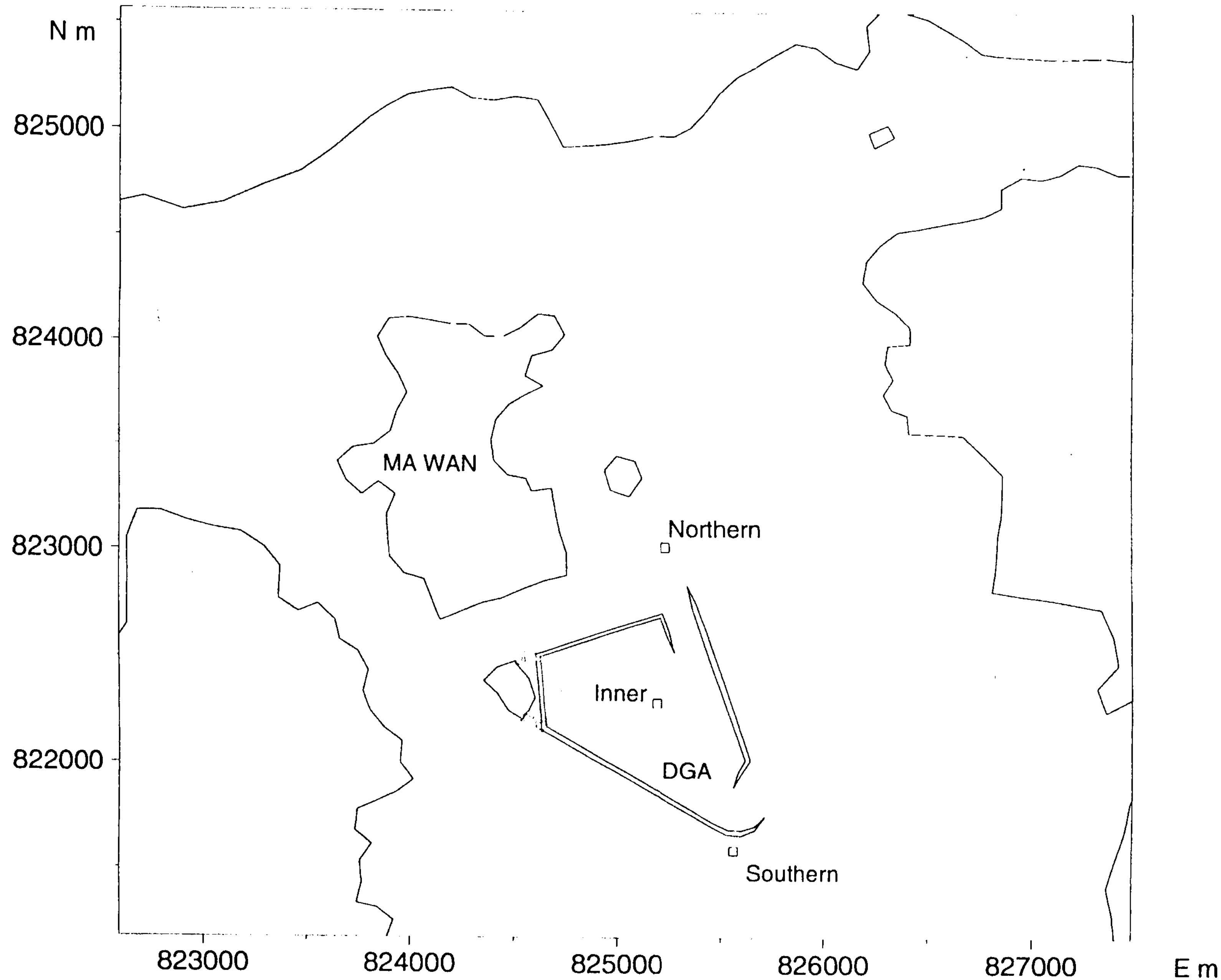
- The co-ordination of Government's response to oil pollution in Hong Kong waters;
- A guide to Marine Department's response – the chain of command, flows of information, available equipment; and
- A guide to the limits of the contingency plan's ability to respond.

As described in Section 4.6.2, the frequency of a spill from a 1200 tonne vessel happening outside the DGA was found to be 3.81 x 10^{-4} per year (i.e. once in 2,600 years), which is considered to be very low. A 1200 tonne vessel was the vessel size adopted in the fuel spill simulations so as to represent a worst-case scenario in terms of the spill size (with the assumption that the vessel was fully loaded with fuel and 90% of the cargo was spilled). On considering the incident event frequency for a smaller typical vessel using the DGA of 400 tonnes capacity, the event frequency was found to be 5.26 x 10^{-3} per year (i.e. once in 190 years), which is considered to be low. (The spreadsheet showing this calculation is given in Appendix C). From the results of the fuel spill modelling it is seen that the worst-case scenario of the slick reaching the fish culture zone at Kung Tsai Wan in less than 2 hours is dependent on certain environmental conditions:

- Season: The fuel spill model predicts that for the wet season, the spill will take more than 2 hours to reach the Ma Wan fish culture zone. For the dry season, the model predicts the spill will reach the fish culture zone between 1 to 2 hours after the initial spill. The probability of wet or dry season is 50% each.
- Wind direction: The fuel spill model assumes a south-easterly wind as this would affect the northern sensitive receivers on Ma Wan most. Based on historic wind data for the automatic weather station at Tsing Yi for the period 1990 to 1994, the probability of a wind direction between 90° and 180° from the north (i.e. between an easterly and southerly wind) is 41% in the dry season.
- Tide conditions: The fuel spill model assumes the spill occurs at flood tide conditions (i.e. 2 hours after low water). During ebb tides, the plume will move south-easterly first before returning with the flood tide approximately 6 hours later. The probability of flood tide conditions is approximately 50%.

The probability of a fuel slick reaching the fish culture zone in more than 2 hours and within the response time of the MD's OPCP is therefore higher than that of a slick reaching the fish culture zone in less than 2 hours. Taking into consideration these necessary environmental variables for a spill near the southern entrance of the DGA to reach the fish culture zone in less than 2 hours, the frequency of this unlikely event will be even lower.

Therefore, the provision of oil pollution mitigation measures in addition to the OPCP are not considered to be warranted given both the low event frequency of a fuel spill near the DGA and the



TANG LUNG CHAU DGA
OIL SPILL LOCATIONS

FIGURE 4.1

the southern coastline of the north-west New Territories, there is a time lag of at least 7 hours until the fuel slick affects the beaches. At the Ma Wan fish culture zone, the fuel slick is shown to first affect the fish culture zone at Kung Tsai Wan between 1 to 2 hours following a spill at the southern entrance of the DGA (dry season spring and neap tides). MD have advised that their response time to activate the OPCP is within 2 hours in the harbour limit and that the same time frame shall apply to the DGA. For a fuel slick reaching the fish culture zone within 2 hours, it would require flood tide conditions in the dry season with an east-south wind direction. Coupled with the low frequency of a fuel spill event near the DGA southern entrance, the frequency of the spill reaching the fish culture zone within 2 hours is even lower. Anti-oil pollution equipment is available at gazetted bathing beaches and appropriate action will be taken in accordance with the OPCP. Therefore, oil pollution mitigation measures in addition to the OPCP are not considered to be warranted.

Prompt response will be required in the event of a major fuel spill near the northern and southern entrances of the TLCDGA so as to limit the spread of fuel at the source and thereby minimize the potential for adverse environmental impacts at the two beaches on eastern Ma Wan and at the Ma Wan fish culture zone at Kung Tsai Wan. Provided that the protocols and operational procedures defined in the MD's OPCP are implemented immediately, it is considered that the potential for adverse environmental impacts would be kept to a minimum.

If the fuel spill occurs within the DGA, it is shown that the majority of the fuel slick is contained by the breakwaters and that only very small quantities of fuel can pass through the northern entrance of the DGA. On examining possible spill plumes from chronic vessel seepage, it is found that the majority of the fuel seepage plume formed is likely to remain within the DGA due to the weak tidal currents inside the DGA. Furthermore, it is considered unlikely that any significant impacts on water quality would arise at the sensitive receivers due to the very low surface fuel thickness predicted.

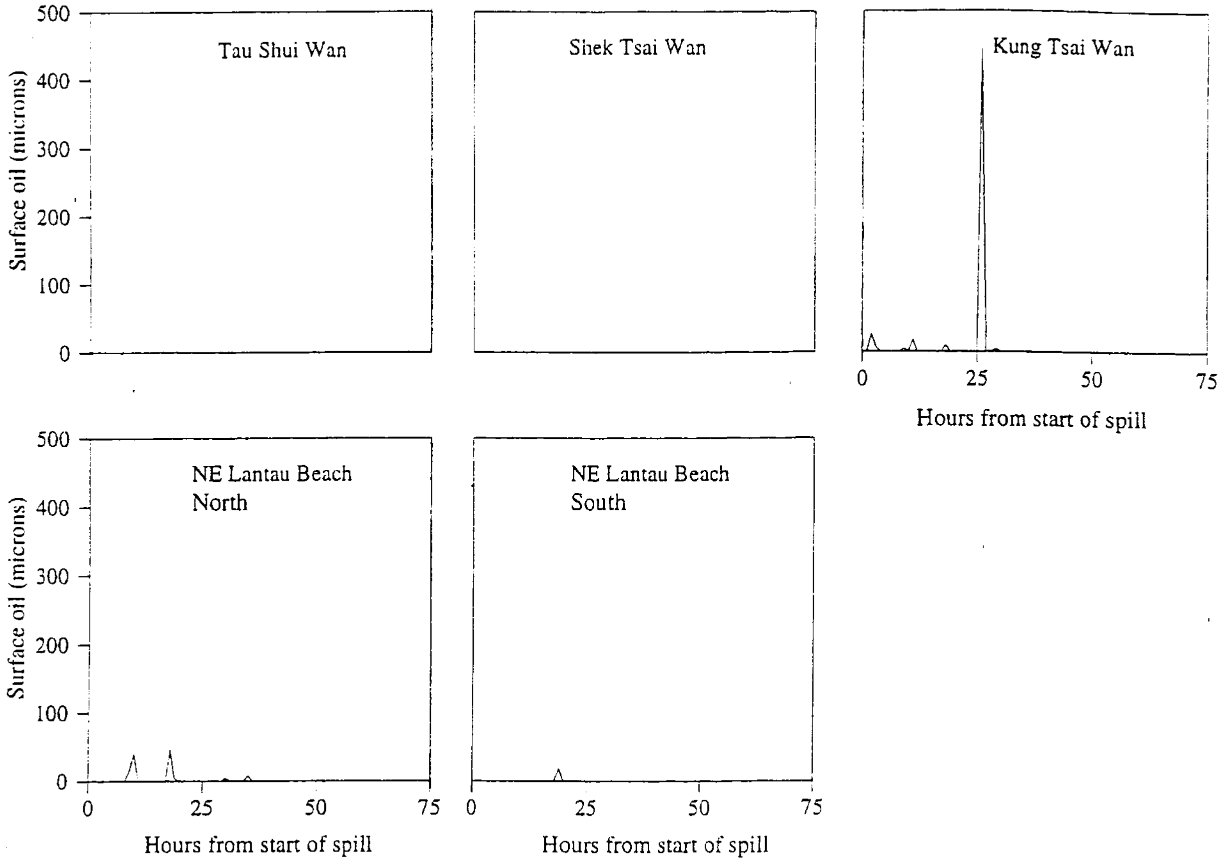


FIGURE 4.2

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, DRY SEASON SPRING TIDE

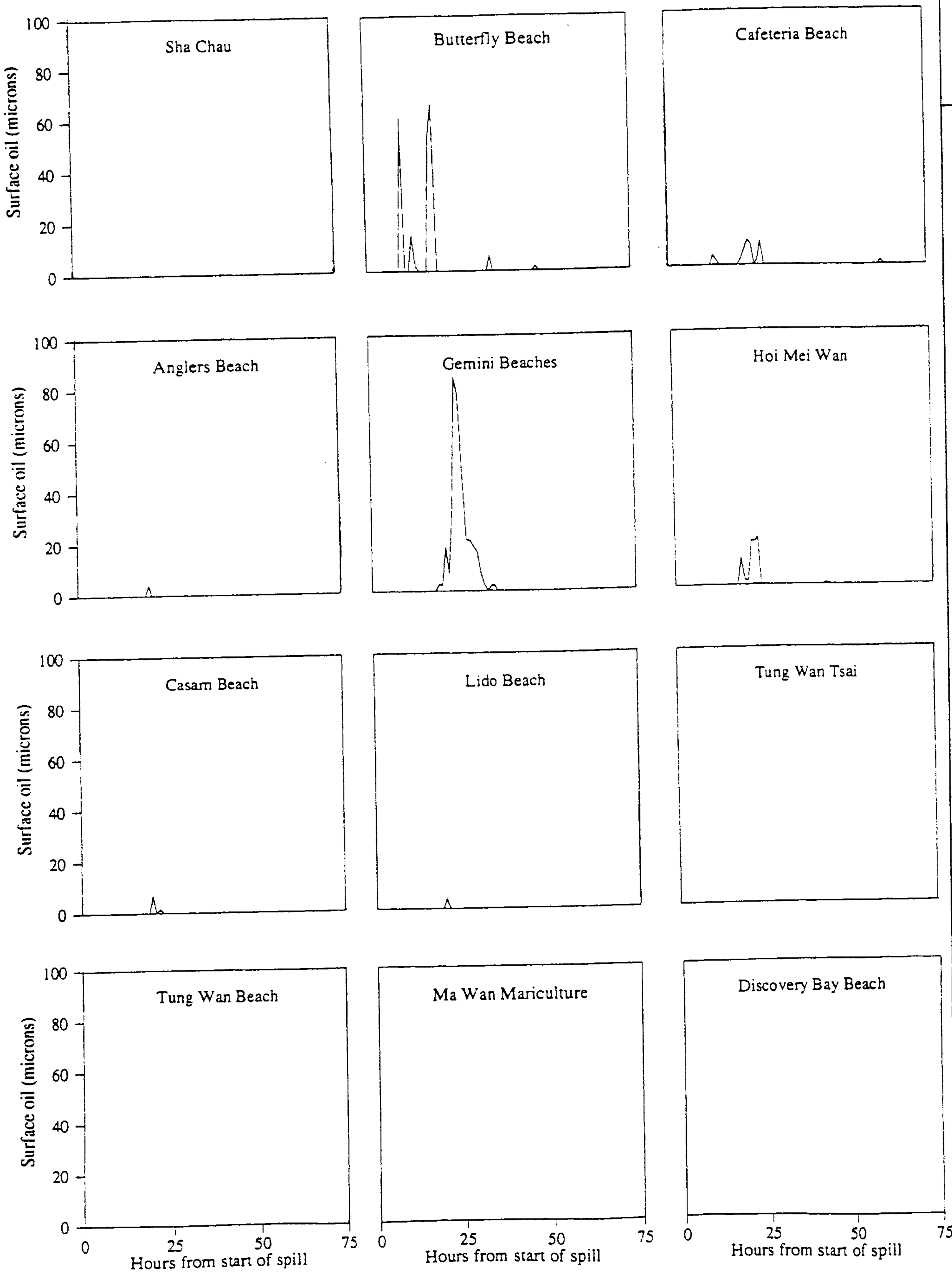


FIGURE 4.2

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, DRY SEASON SPRING TIDE

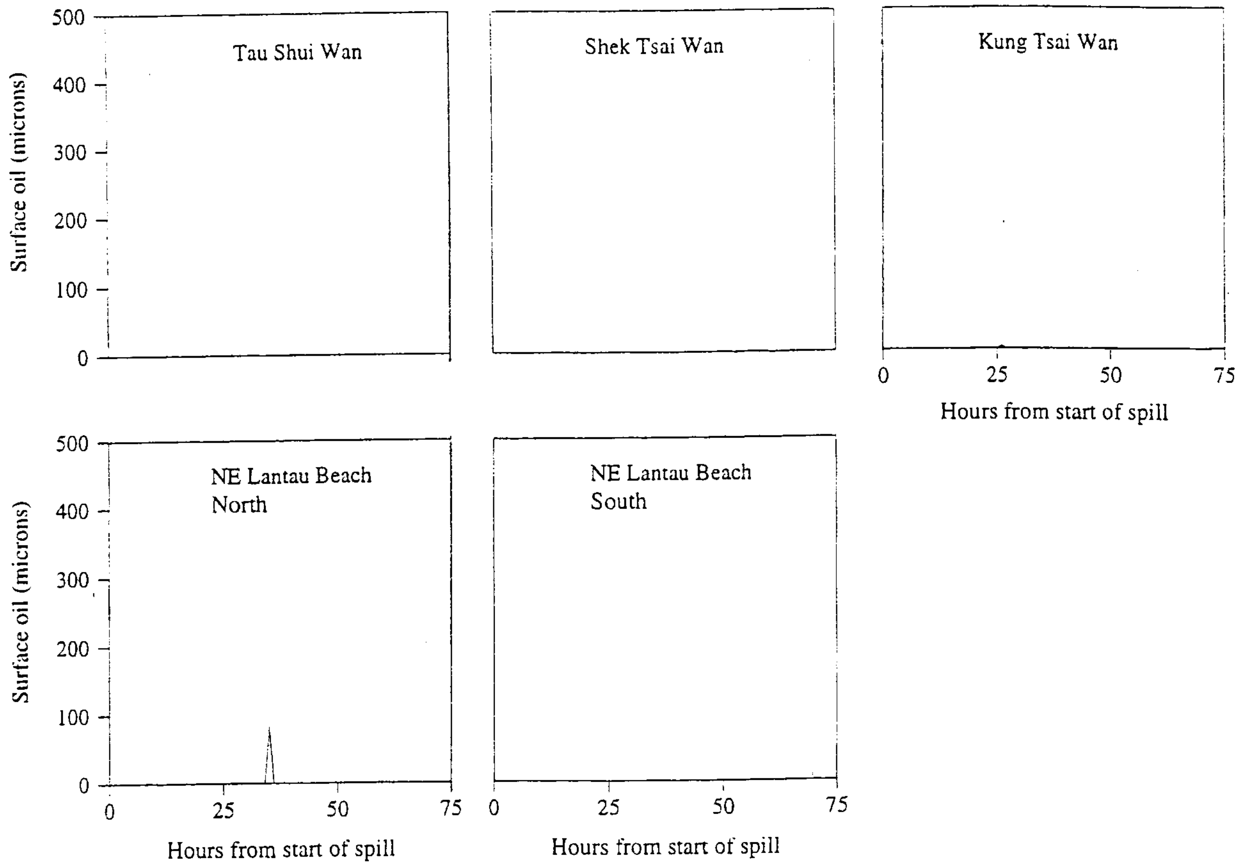


FIGURE 4.3

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, DRY SEASON SPRING TIDE

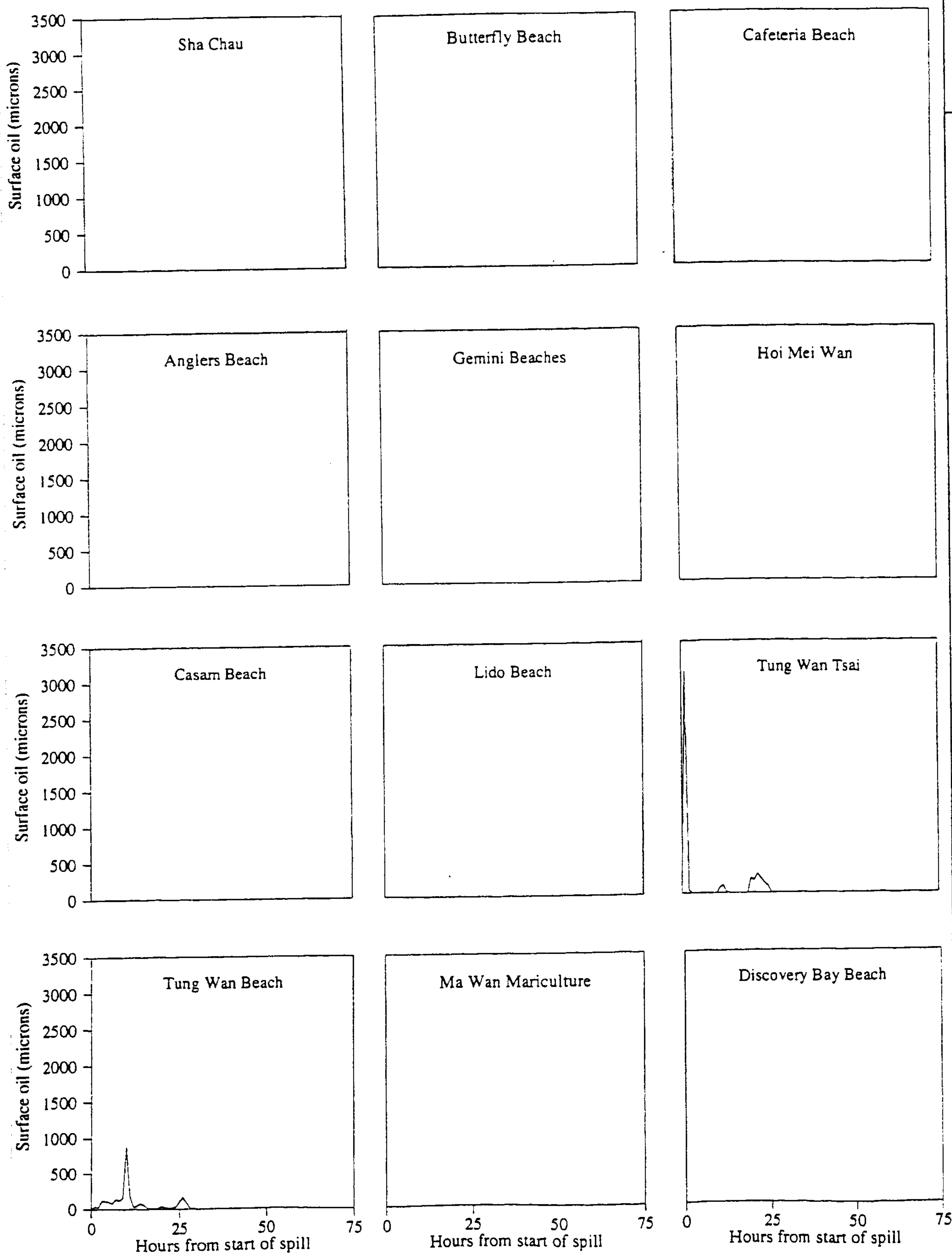


FIGURE 4.3

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, DRY SEASON SPRING TIDE

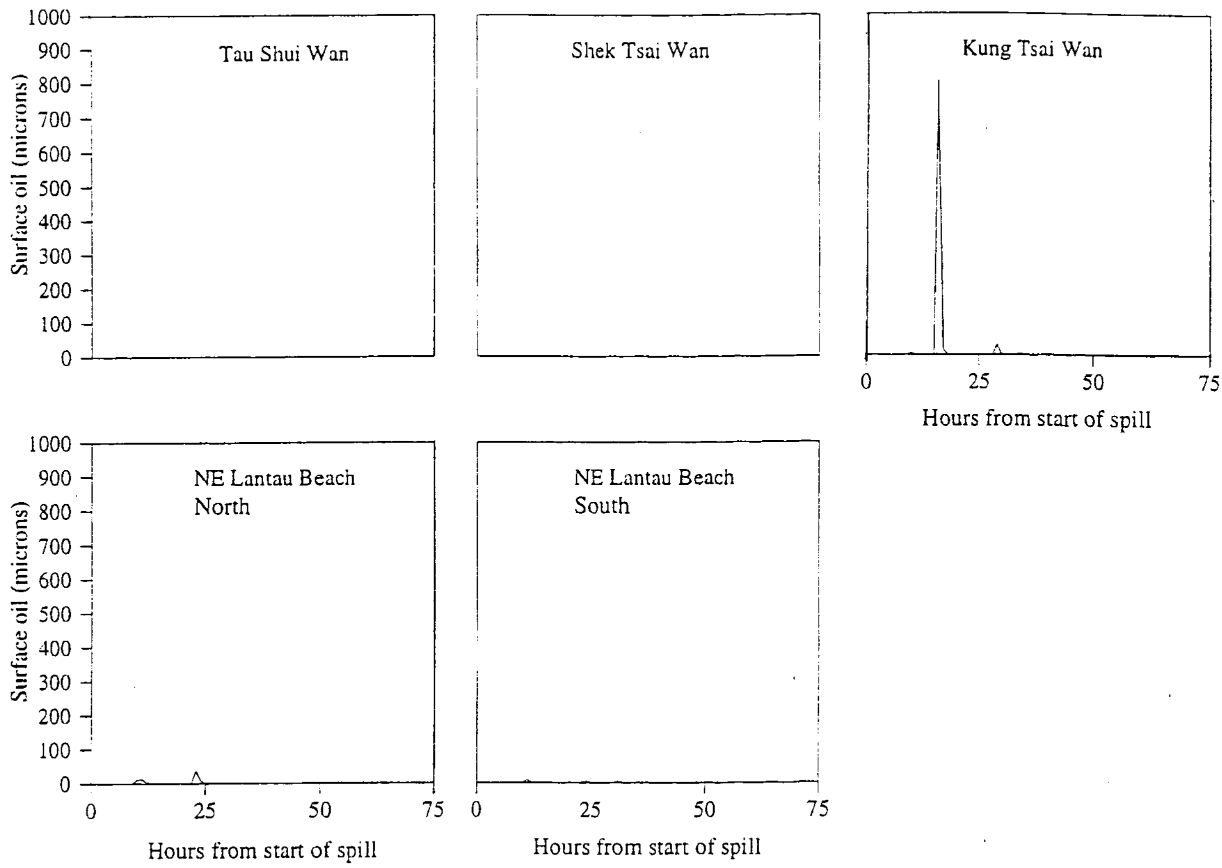


FIGURE 4.4

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, DRY SEASON NEAP TIDE

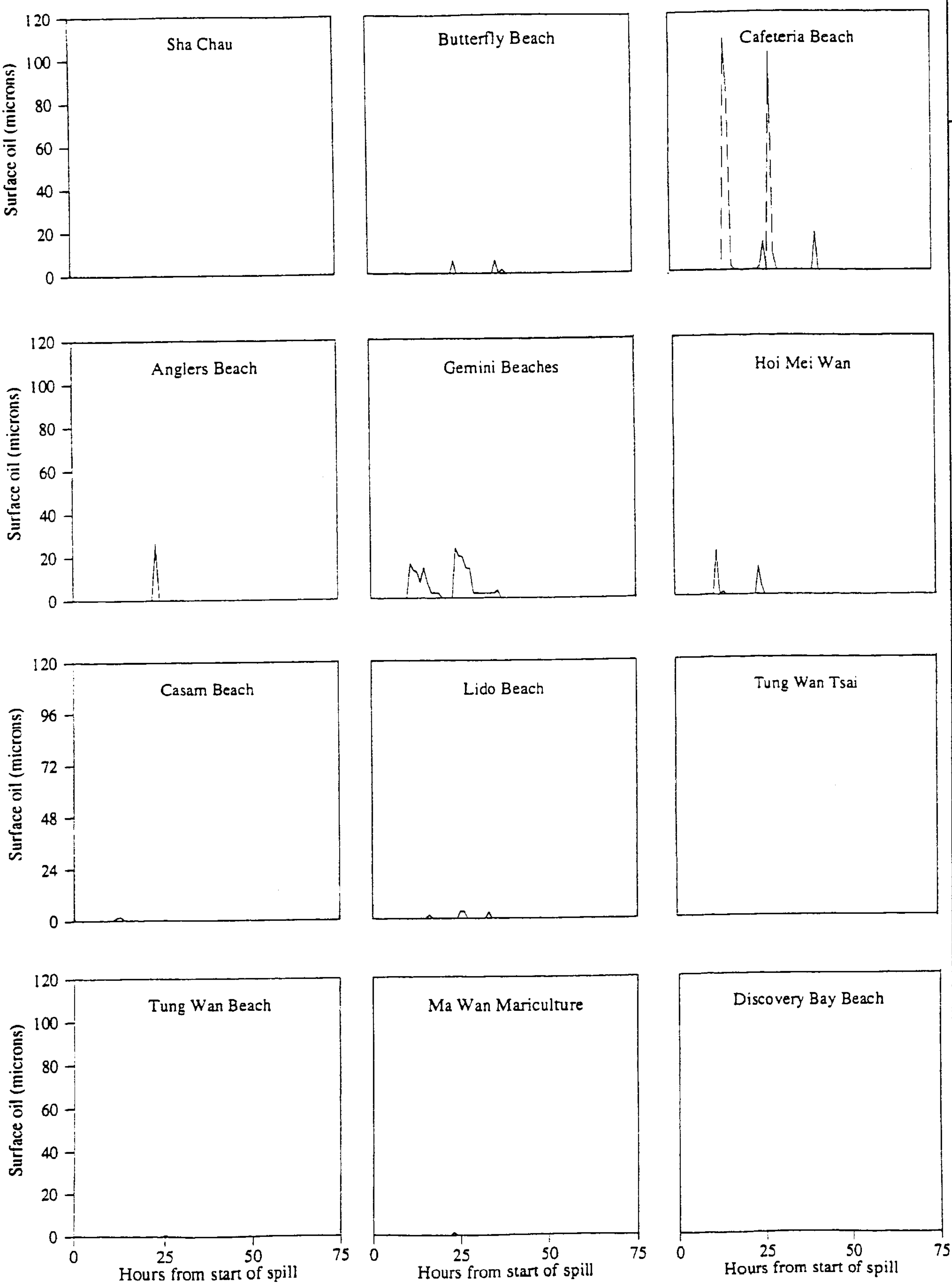


FIGURE 4.4

SHEET 1

TANG LUNG CHAU DGA
OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, DRY SEASON NEAP TIDE

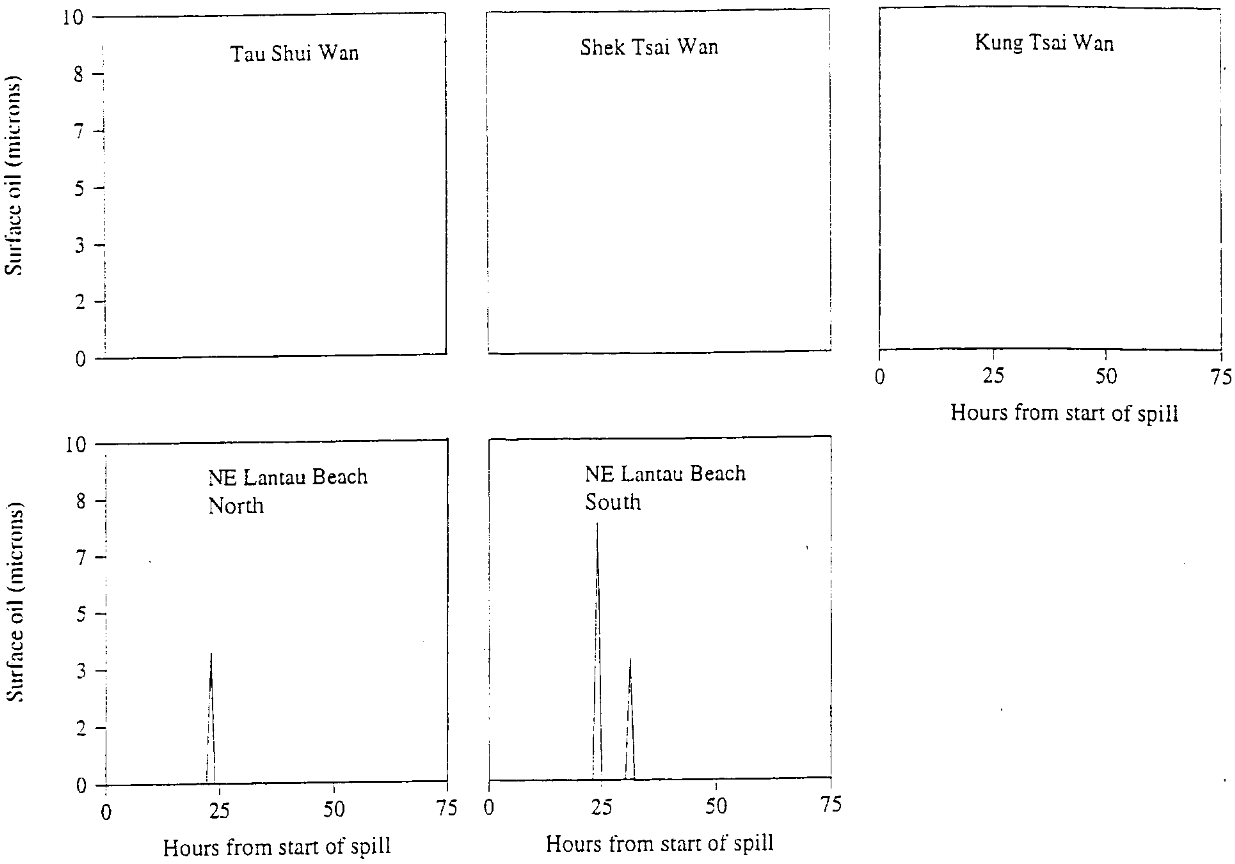


FIGURE 4.5

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, DRY SEASON NEAP TIDE

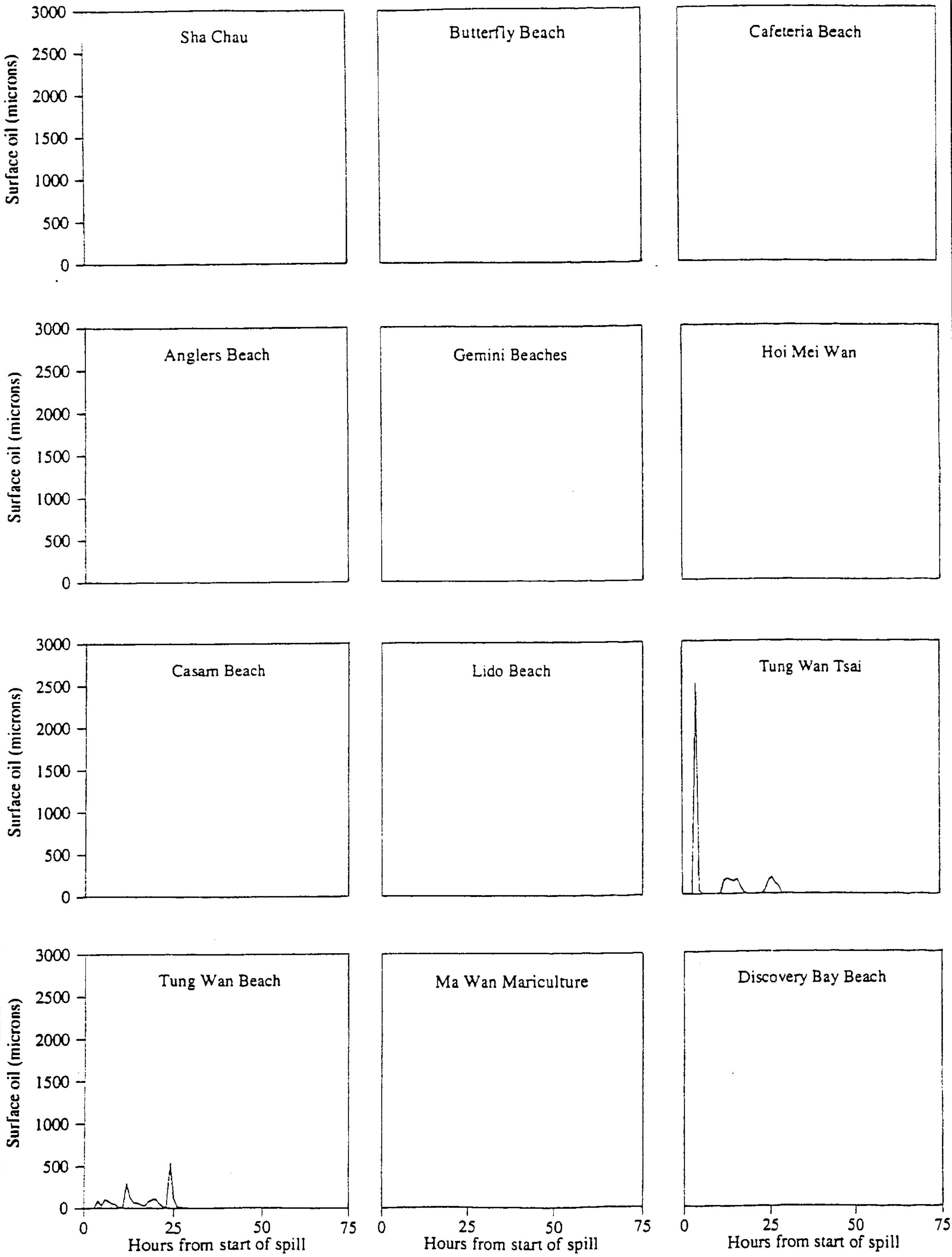


FIGURE 4.5

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, DRY SEASON NEAP TIDE

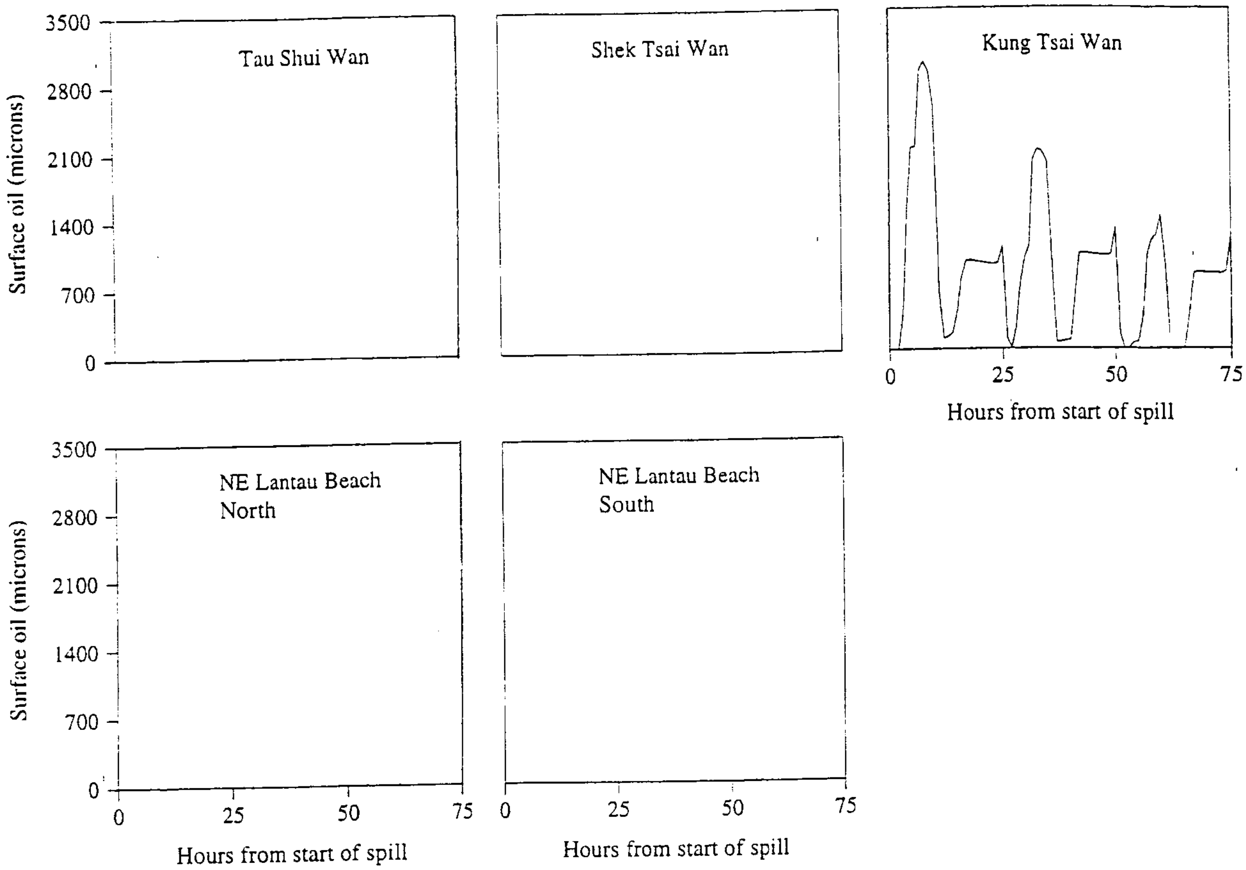


FIGURE 4.6

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, WET SEASON SPRING TIDE

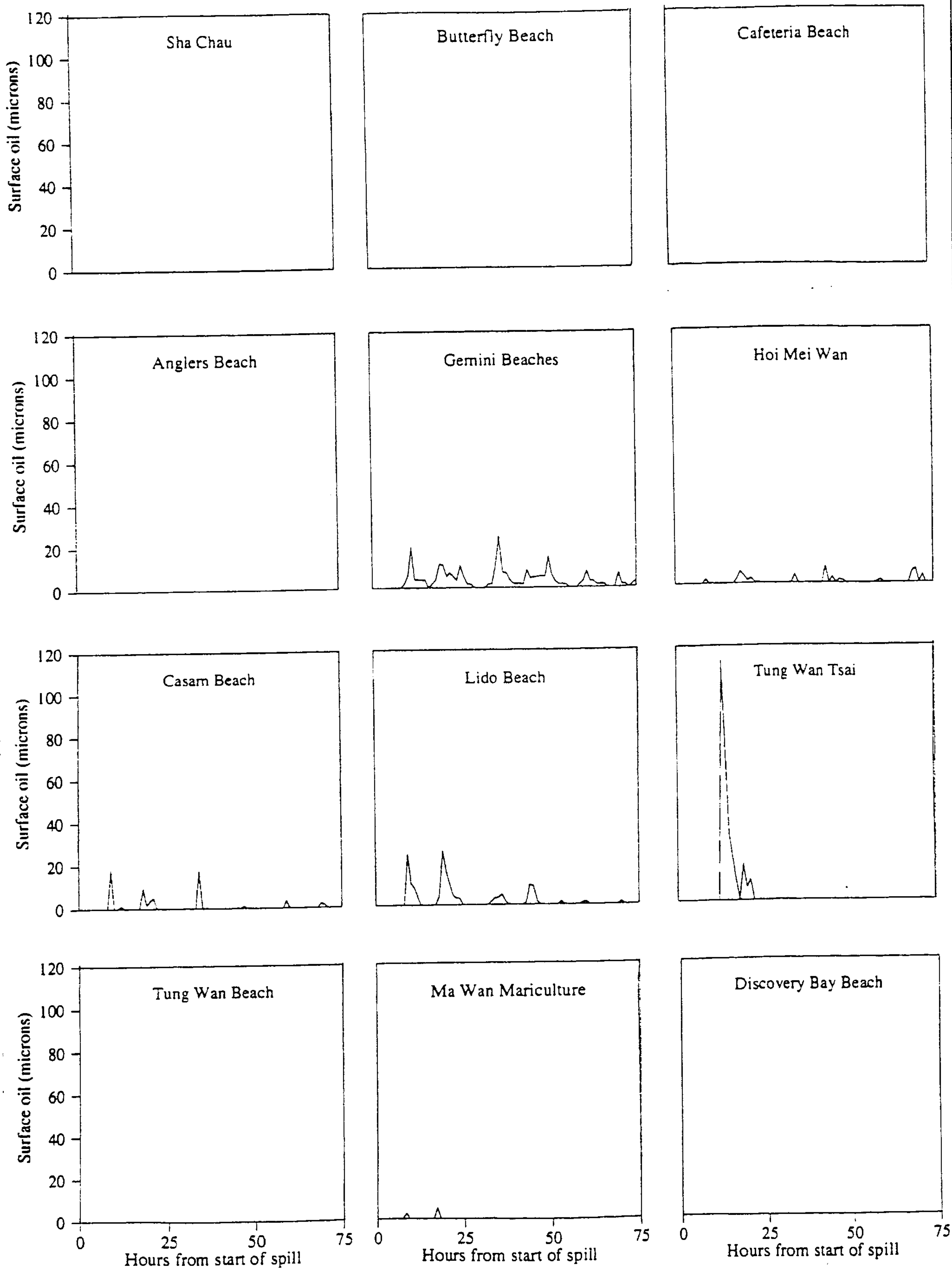


FIGURE 4.6

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, WET SEASON SPRING TIDE

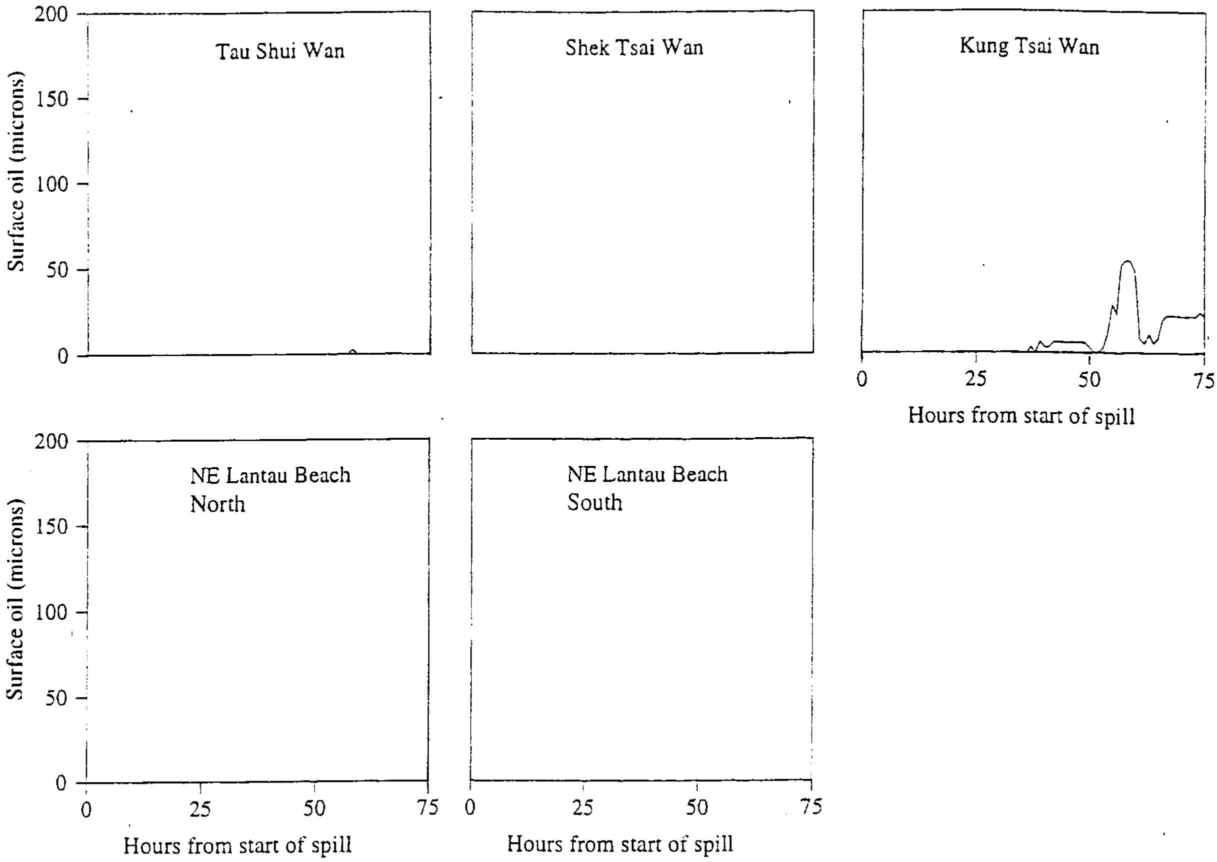


FIGURE 4.7

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, WET SEASON SPRING TIDE

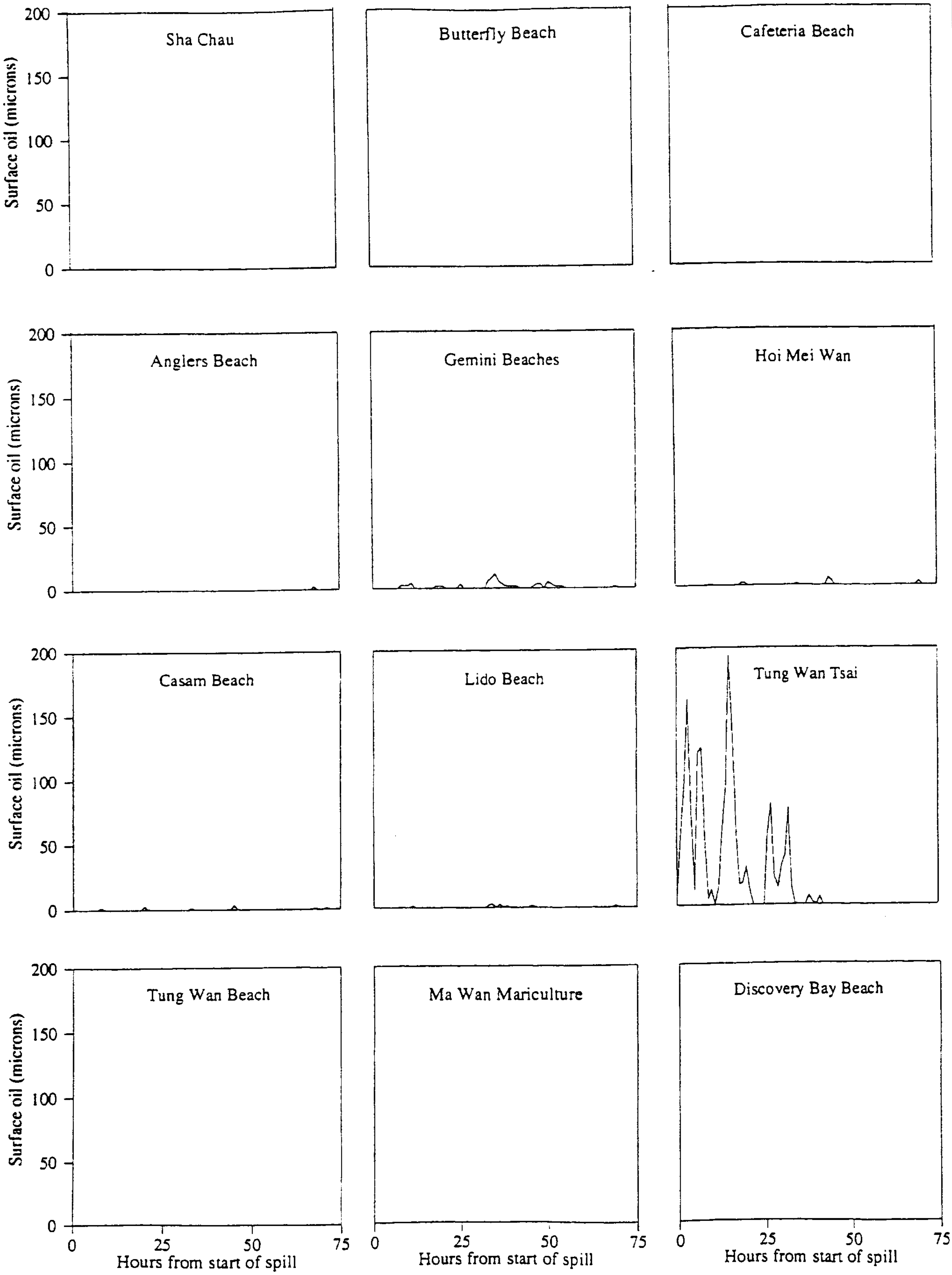


FIGURE 4.7

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, WET SEASON SPRING TIDE

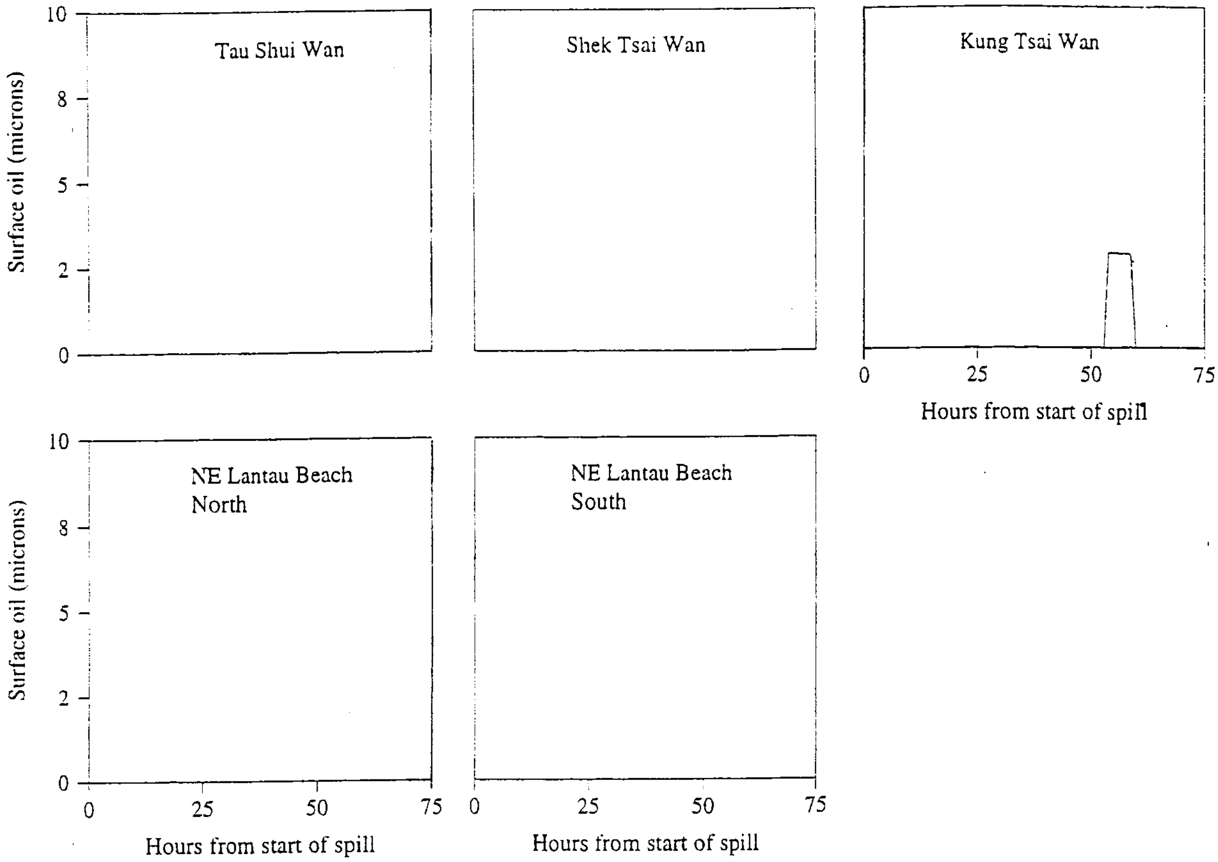


FIGURE 4.8

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SPILL INSIDE THE DGA, WET SEASON SPRING TIDE

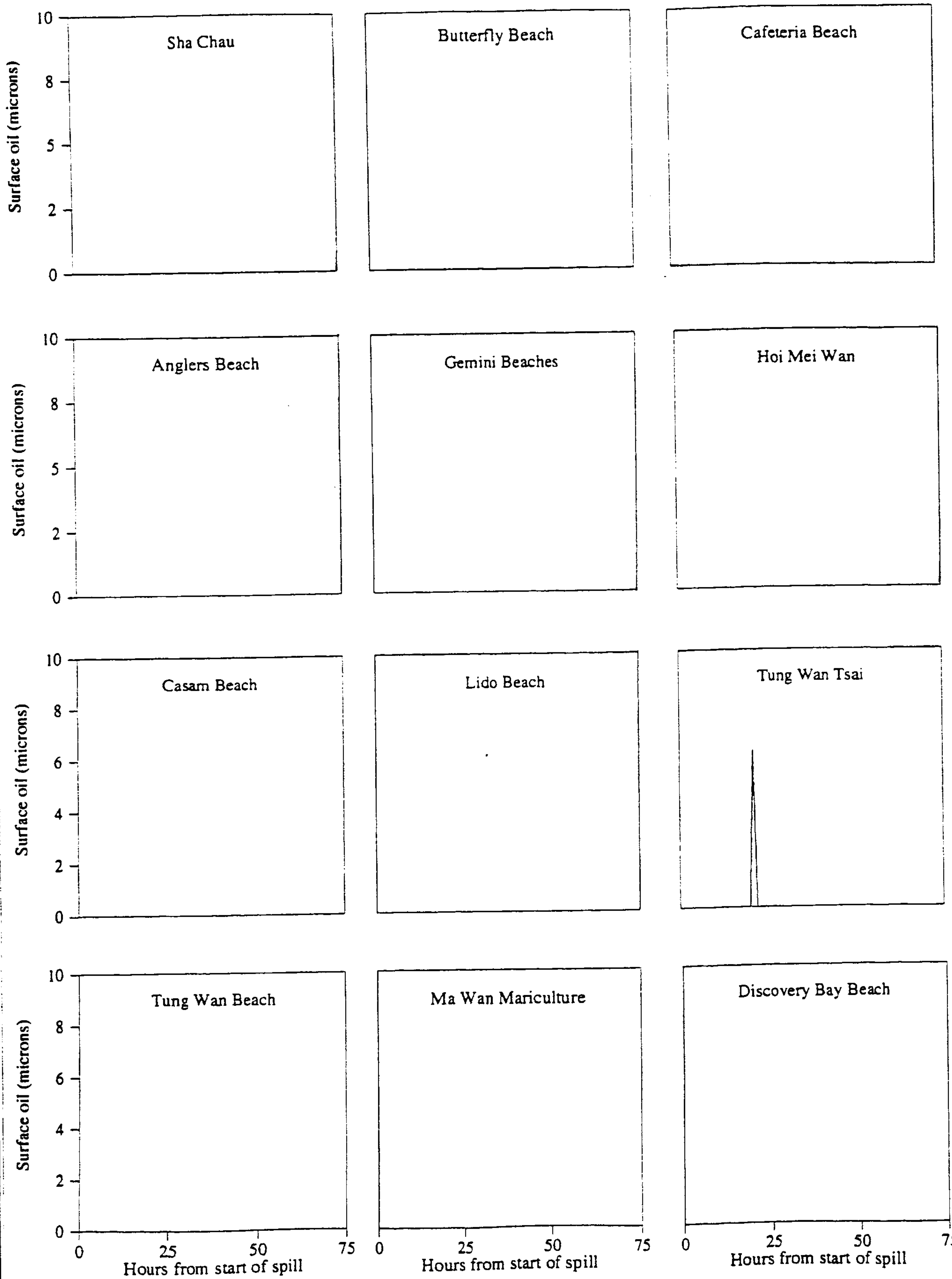


FIGURE 4.8

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SPILL INSIDE THE DGA, WET SEASON SPRING TIDE

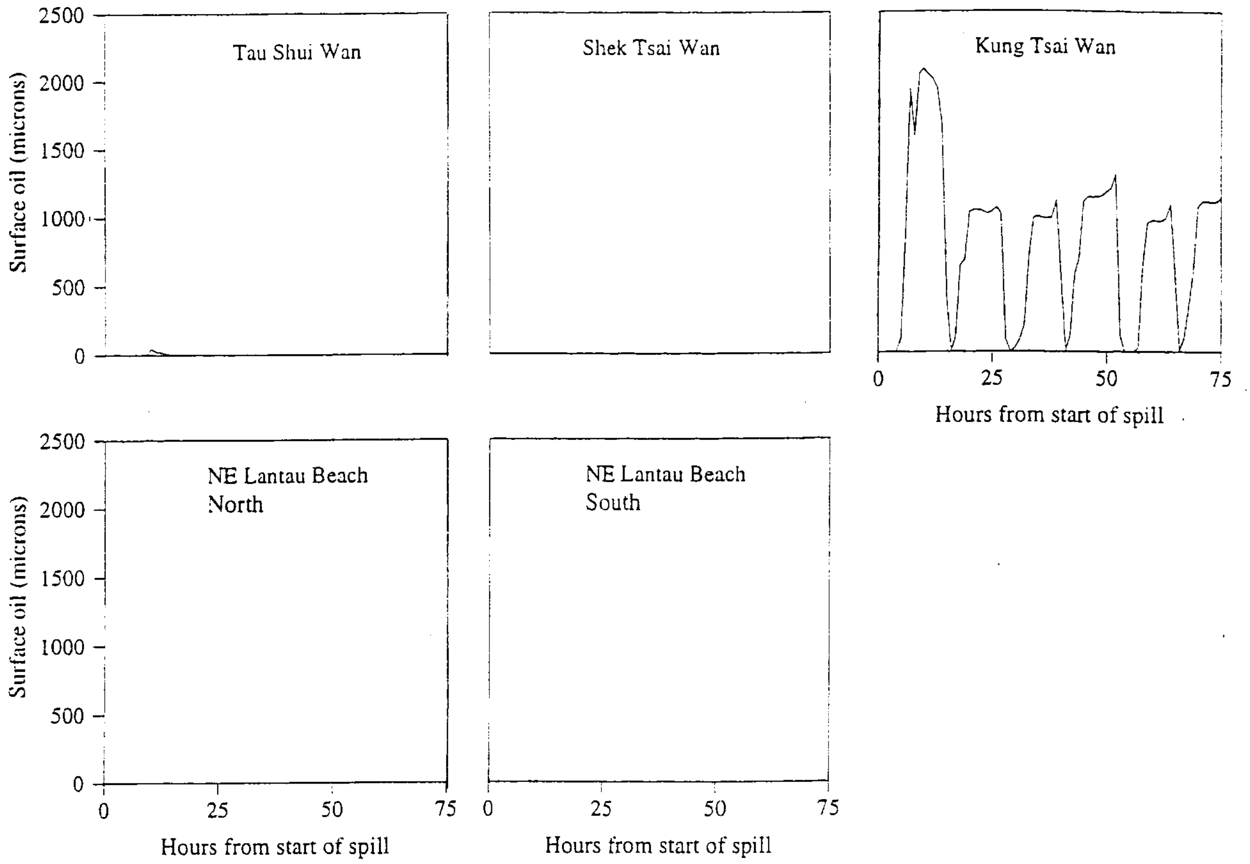


FIGURE 4.9

SHEET 2

TANG LUNG CHAU DGA

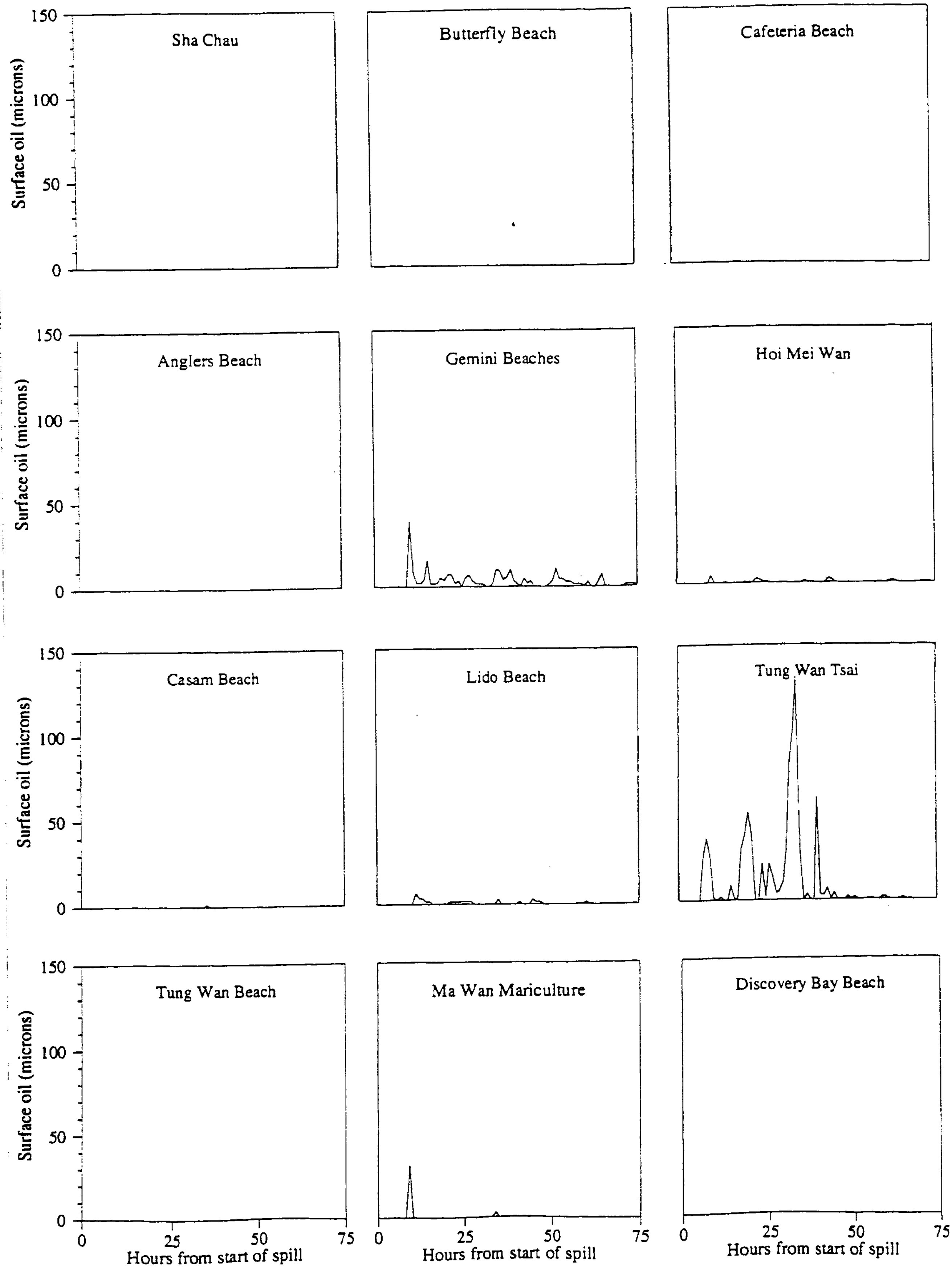
OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, WET SEASON NEAP TIDE

FIGURE 4.9

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, SOUTHERN SPILL LOCATION, WET SEASON NEAP TIDE



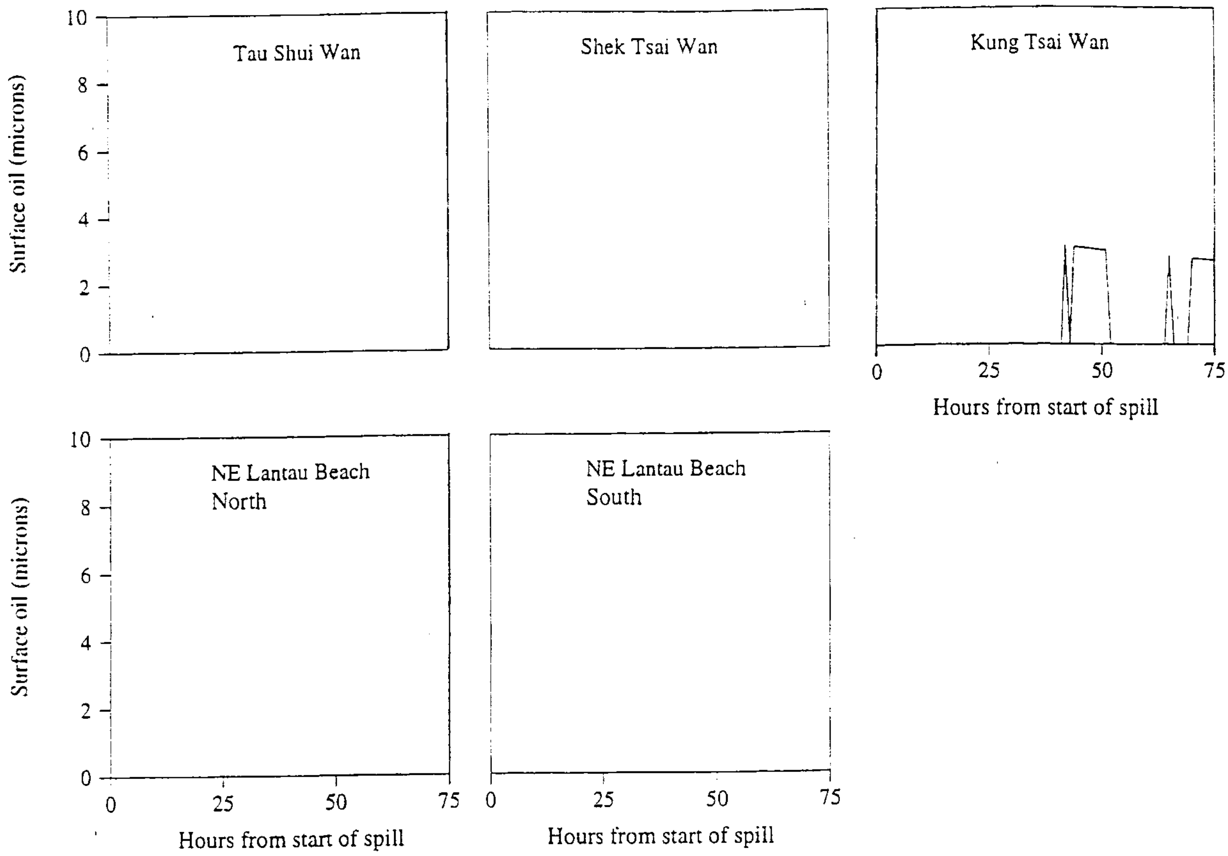


FIGURE 4.10

SHEET 2

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, WET SEASON NEAP TIDE

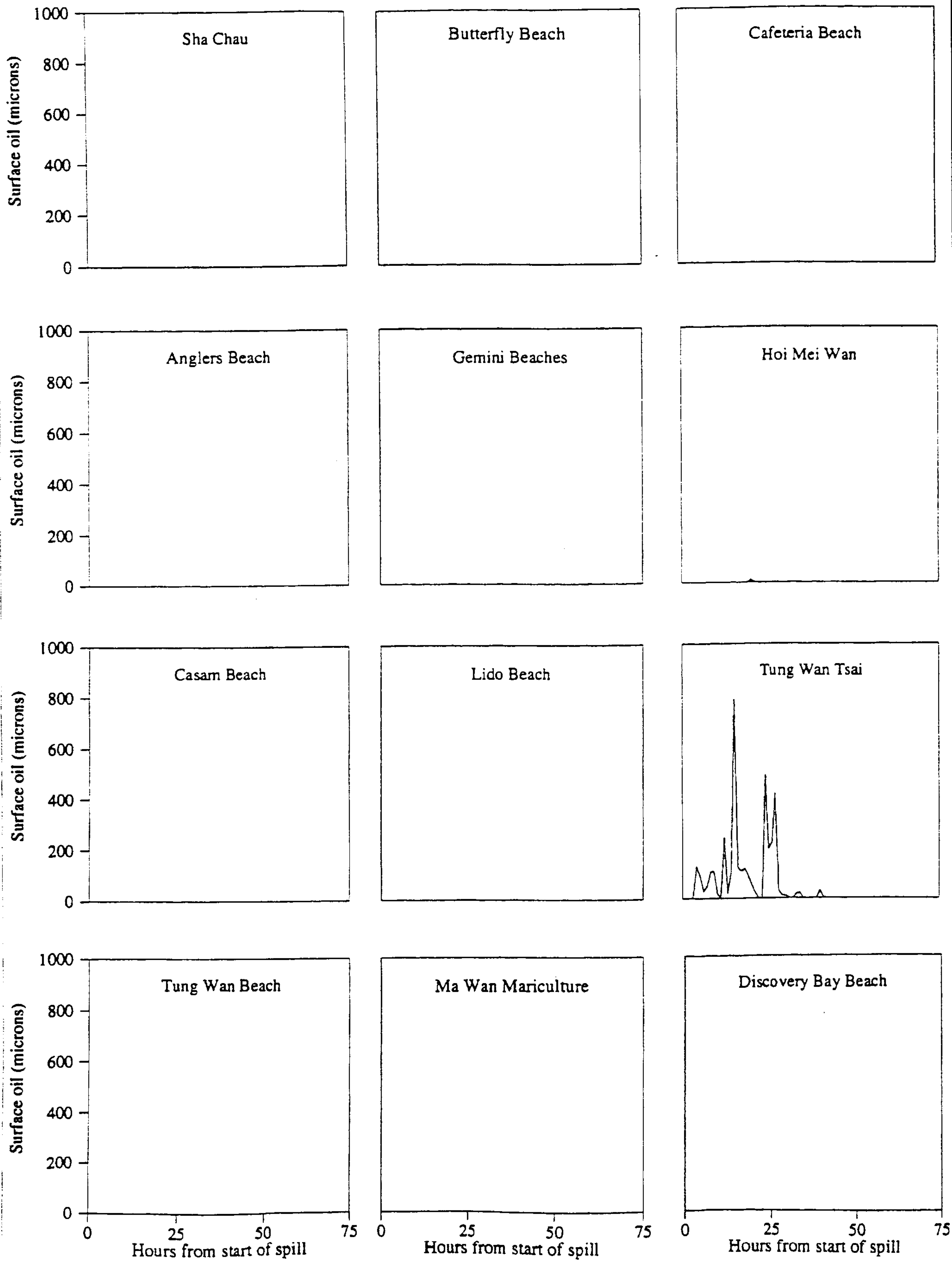


FIGURE 4.10

SHEET 1

TANG LUNG CHAU DGA

OIL THICKNESS TIME-SERIES, NORTHERN SPILL LOCATION, WET SEASON NEAP TIDE