Annex C

Report Describing the Calibration of the Water Quality Model

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1. Introduction

An assessment of the environmental impacts of the Stage III extension of the Sha Tin Sewage Treatment Works (agreement no. CE 90/97) is being carried out. Part of the Environmental Impact Assessment (EIA) involves the consequences of the stage III extension for the marine water quality in Victoria Harbour as effluent from the Sha Tin Treatment Works is pumped to Kai Tak Nullah through the Effluent Export Scheme. Delft hydraulics have been commissioned to examine the impacts of the Stage III extension on water quality in Victoria Harbour using computational modelling techniques.

To assess the marine water quality, a detailed model has been set-up. This Victoria Harbour model is a cut out from the Upgraded model and is locally refined to get a higher grid resolution of the study area. The Upgraded model has been constructed, calibrated and validated under agreement no. CE 48/97 (Delft Hydraulics 1998).

Over the years several large measurement campaigns have been conducted in Hong Kong waters. The measurements of the Victoria Harbour measurement campaign seem most suited for the calibration of the model since they cover the waters surrounding Hong Kong Island in greatest detail. In addition to these measurements, the calibration of the water quality model uses the long-term EPD measurements.

Chapter 2 of this working note deals with the set-up and hydrodynamic calibration of the model. The set up of the water quality model is the subject of Chapter 3. Chapters 4 and 5 deal with the calibration and the verification of the water quality model for the wet and dry seasons respectively.

2. Hydrodynamic Model of Victoria Harbour

2.1 Model Description

2.1.1 General

The model is embedded within the Delft3D modelling suite. Hydrodynamic computations with the Victoria Harbour model are carried out using the Delft3D-FLOW module.

2.1.2 Grid lay-out

The calibration of the model focuses on the 1987 Victoria Harbour measurement campaign. Therefore, the model was set-up to fit within the coast line of 1987. The grid of the Victoria Harbour model, see Figure 2.01, is constructed by local refinement of the Upgraded model grid. Furthermore, the Kai Tak Nullah and the Kwun Tung Typhoon shelter are included in the model.

Within Victoria Harbour, the smallest grid sizes are approximately 50 m whereas at open sea the grid distances increase to 2000 m in the south-east and 700 m in the south-west. In total the computational grid numbers 7200 active computational elements. In the vertical direction, 10 layers of 10% of the water depth each are employed.

2.1.3 Bathymetry schematisation

The bathymetry schematisation as used for the calibration of the model, see Figure 2.02, is based upon the raw depth data supplied to us for the "Update on Cumulative Water Quality and Hydrological Effect of Coastal Developments and Upgrading of Assessment Tool" project (Agreement no. CE 42/97). This data relates to 1987. For areas not covered by the "Update" data set, a data set supplied by the Geotechnical Engineering Office under Agreement No. 48/96 was used.

All data used are relative to Principal Datum (PD) Hong Kong. Hence the reference level of the model is PD.

2.1.4 Simulated period

The simulated period is based upon the availability of measurements. For the wet season the simulations cover the period from the 29*th* of June until the 21*st* of July 1987. The time span for the dry season simulations covers the 15*th* of February until the 7*th* of March 1987. Of these simulated periods, the computed hydrodynamics of the last 15 simulated days, covering a complete spring/neap cycle, are stored for the water quality computations. The model uses a computational time step of 1 minute.

2.1.5 Boundary conditions

The hydrodynamics of the Victoria Harbour model are boundary forced by water levels and velocities generated by the Upgraded model. Each open boundary is divided into several

sections, of which some are defined as water level but most are defined as velocity sections. For instance, the boundary in Ma Wan strait consists of 6 sections of which 5 are defined as velocity sections. The general idea behind this boundary definition is to ensure, as much as possible, a flux through the boundary of the detailed model comparable with the flux through the corresponding section in the overall model. In total, the model has 34 boundary sections. The specification of the boundary conditions is shown in Figure 2.01. It should be noted that the south west boundary is closed to represent Dangan Island. Boundary conditions for salinity are also taken from the Upgraded Model.

The Upgraded model runs used for the generation of boundary conditions apply constant discharges for the major Pearl outlets. Hence, the boundary conditions for salinity, as generated with the Upgraded model, relate to average wet and average dry season conditions.

2.1.6 Initial conditions

The initial conditions for the Victoria Harbour model are chosen to be identical to the initial conditions of the Upgraded model. The initial conditions of the Upgraded model result from previous computations with this model. Hence the initial conditions represent average dry and average wet season conditions.

2.1.7 Wind

For the wet season a constant wind of 5 m/s from the south-west is used. The dry season computations apply a constant wind of 5 m/s from the north-east. These wind conditions represent average dry and average wet season conditions.

2.2 Computational results for the wet season

2.2.1 Water levels

The simulated water levels are compared with measurements in Figure 2.03. From this figure it follows that the water levels as computed with the Victoria Harbour model are almost identical to the water levels as computed with the Upgraded model.

In general, the measurements agree rather well with the computational results of both the Upgraded model and the Victoria Harbour model. The largest differences between the measurements and the observations are observed at the stations located in the most northern model part, i.e. Sham Tseng and Tsing Yi for the neap period between the 16th of July and the 21st of July. However, given the complex character of the tide, the water level reproduction of the model is satisfactory.

2.2.2 Salinity

The computed spatial salinity distribution is compared with the measurements of the Victoria Harbour measurement campaign in Figures 2.04 - 2.07. For the neap period, Figures 2.03 and 2.04, it holds that near the surface the model is slightly fresher than the measurements. However, computation and measurements are in reasonable agreement.

During spring period, Figures 2.03 and 2.04, the resemblance between measurements and computational results is less satisfactory. Near the surface, the model is much more saline than the measurements. Although less pronounced, this also holds for the bed.

The large difference between spring and neap tide salinity measurements is characteristic for the Victoria Harbour measurement campaign. During the SSDS stage II measurements of 1992 The measured salinities within Victoria Harbour (station E5) show much smaller differences between a spring and a neap tide.

The process of building and breaking of stratification is shown in Figures 2.08 - 2.23. The position of the stations are indicated in Figure 2.02

The Upgraded model results are reproduced quite satisfactorily by the Victoria Harbour model. The largest differences between the models are observed within Victoria Harbour. The Victoria Harbour model produces surface salinities which are smaller than salinities computed with the Upgraded model. This probably results from the higher resolution of the Victoria Harbour model within Victoria Harbour. This allows for a more detailed description of the bathymetry.

For both models it holds that during neap the surface is slightly too fresh and the degree of stratification is slightly over predicted. During spring, the computed surface salinity is too saline whereas the degree of stratification is underestimated by the model.

The computational results for the neap period are reasonable. Results for the spring period are less satisfactory. The Upgraded model predicts an amount of fresh water entering the modelled area which is too small compared with the measurements. Sensitivity tests with the Upgraded model described in (Delft Hydraulics, 1998) revealed that twice the model flows for the Pearl outlet should be applied to get these low salinities. Furthermore, the flows should have been dropped immediately after the spring monitoring days to the level of the modelled flows. Only under these assumptions, variability of the Pearl flows could explain the differences between the spring and neap tide measurements. It is much more likely that the changes in salinity result from a shift in the patterns of the wind in this period, whereas the model uses a constant south western wind.

Improvement of the calibration results for the Victoria Harbour model can only be obtained if the Upgraded model is further calibrated to reproduce the difference between the spring and the neap tide measurements. However, this is considered beyond the scope of the present study. Furthermore, the assessment of the water quality impacts of the proposed treatment work should be based upon average dry and wet-season conditions and not on particular 1987 conditions.

2.2.3 Velocities

The computed velocity magnitudes are compared with the measurements in Figures 2.24 - Figure 2.39. Both the Upgraded model and the Victoria Harbour model reproduce the measured velocity profiles quite accurately.

Computed velocity directions are presented in Figures 2.40-2.43. With the exception of the

surface of Station 1 the reproduction of the measured velocity directions by the Victoria Harbour Model is identical, or slightly better, than the direction reproduction of the Upgraded Model. At Station 1 the measurements reveal an anti-clockwise rotation near the surface, whereas the Victoria Harbour model computes a clockwise rotation.

2.3 Computational results for the dry season

2.3.1 Water levels

The computed water levels of both the Victoria Harbour Model and the Upgraded Model for the dry season are shown in Figure 2.44.

With the exception of Tung Lung, the measurements are in good agreement with the computational results of both the Victoria Harbour and Upgraded Models. At station Tung Lung there is a clear mismatch between the mean level of the measurements and the mean level of the computational results. The tidal range, however, is well predicted by the model.

The water level data for Tung Lung was supposed to use Hong Kong PD as the reference datum, the same as is used in the model. However, comparing the measurements at Tung Lung with the other stations and the Tung Lung wet season measurements shows that the reference level of the dry season Tung Lung measurements is not Hong Kong PD.

2.3.2 Salinities

During the dry season, the waters surrounding Hong Kong are well mixed with salinities of approximately 33 ppt. Since almost no horizontal and vertical gradients exist during dry season the computational results for salinity are not presented.

2.3.3 Velocities

The computed dry season velocity magnitudes are presented in Figures 2.45 - 2.60. With exception of station 2, the agreement between the Upgraded model, the Victoria Harbour model and the measurements is satisfactory. For station 2 it holds that it is located on the steep slope of Lei Yue Mun (the eastern entrance of Victoria Harbour). Hence, both measured and computed velocities are very sensitive to the precise location.

The computed velocity directions are presented in Figures 2.61-2.64. The velocity directions, as computed by the Victoria harbour Model, are almost identical to those computed by the Upgraded Model. Both the Victoria Harbour Model and the Upgraded Model reproduce the measured current directions accurately.

2.4 Conclusion with respect to hydrodynamic model performance

The scope of work offered for this project involved a calibration of the hydrodynamic Victoria Harbour model limited to a reproduction of the Upgraded Model. In general the model results are very well comparable.

Both the Upgraded model and the Victoria Harbour model do not reproduce the large difference in salinity between the wet season spring and the wet season neap measurements. Improvements can only be achieved by further calibration of the Upgraded model which is considered beyond the scope of the present project.

3. The Victoria Harbour Water Quality Model

3.1 Flow aggregation

A water quality model for Victoria Harbour has been set up using the Delft3D suite. The basis of the water quality model is formed by a 3D tidal resolving hydrodynamic database for a full spring-neap period for the wet and dry season as calculated by the Delft3D-FLOW module. The model specifications of the hydrodynamic database are presented in Table 3.1.

Table 3.1: Model specification of the hydrodynamic database

Dimension model grid	110 x 129 x 10	
Distribution of layers	equidistant (σ levels)	
Vertical exchange	k-e turbulence model	
	Dry Season	Wet Season
Period (spring-neap)	20 Feb - 5 March 1987	5 - 20 July 1987
Uniform wind condition	NE 5 m/s	SW 5 m/s
River flows	-	-

In order to reduce the computational effort and the data storage, aggregation of the hydrodynamics is performed. The same procedure is applied as in the Upgrade study. In the horizontal a 2x2 flow aggregation is applied in combination with an alternate vertical distribution from top to bottom of 1-2-2-3-2 hydrodynamic layers for the water quality layers. In order to verify the initial aggregation scheme adopted, two experiments with a continuous release of 1000 g/s of conservative matter from Kai Tak Nullah are performed. One with the original hydrodynamics (no aggregation) and one with the 2x2 aggregation. The results are presented in Figure 3.1 and 3.2. Although some minor differences in the pattern and concentration level in the more inner part are observed, the agreement between the results is satisfactory.

3.2 Substances involved

The transport of substances and associated water quality processes are incorporated in the Delft3D-WAQ module. The framework contains suspended sediment, nutrients, phytoplankton growth and bacteria. The applied state variables of the water quality model are listed in Table 3.2.

Table 3.2: List of state variables in modelling suspended sediments, nutrients and algae

State Variable (model name)	Description	Unit
IM1	inorganic matter	gDW/m^3
IM1S1	inorganic matter in the bottom	gDW
NH_4	dissolved ammonium-N	gN/m^3
NO_3	dissolved nitrate and nitrite-N	gN/m^3
DetN	detritus nitrogen (dead algae)	gN/m^3
DetNS1	bottom nitrogen content	gN/m^2
PO_4	dissolved ortho-phosphate-P	gP/m^3
AAP	adsorbed inorganic phosphate	gP/m^3
DetP	detritus phosphorus (dead algae)	gP/m^3
DetPS1	detritus phosphorus in the bottom	gP
AAPS1	adsorbed inorganic phosphorus in the bottom	gP
Si	dissolved silicon	gSi/m^3
DetSi	detritus silicon (dead algae)	gSi/m^3
DetSiS1	silicon at the bottom	gSi
CBOD5	carbaneous BOD (excluding algae and detritus)	gC/m^3
DetC	detritus carbon (dead algae)	gC/m^3
DetCS1	detritus carbon in the bottom	gC
Diat	algae, diatoms	gC/m^3
Green	algae, non-diatoms	gC/m^3
GreenS1	non-diatoms in the bottom	gC
DiatS1	diatoms in the bottom	gC
Ecoli	E-coliform bacteria	MPN/100ml
OXY	dissolved oxygen	g/m^3

3.3 Calibration strategy

The ultimate test of any mathematical model is its ability to reproduce reality. The calibration of the Victoria Harbour model focuses on the reproduction of the long term EPD measurements. The EPD data are obtained regardless of the phase of the tide. These data sets were collected during a long period and cover the complete model area. The EPD monitoring data have been separated in typically dry and wet season values. To filter out randomness, the typical dry and wet season data are averaged over the period 1974-1996 (as far as data were available and monitoring points were operational). Since the EPD data cover the whole model area, they will be used in order to reproduce the spatial concentration patterns for the dry and wet season conditions.

The approach for the determination of the process coefficients is to use a judgement in selecting parameters that are consistent with available field data and local expertise. The

parameters are selected in a sequential manner and the model is finally judged adequate based on a comparison of model outcomes and observations.

In general the procedure for model calibration is to start with the calibration of transport using a conservative tracer (such as salinity). Regarding the relatively small model area, the boundary conditions will have a significant effect on concentrations in the inner part (Victoria Harbour) of the model. In order to analyse the magnitude of the influence, several runs with conservative boundary conditions are performed. As a next step the suspended matter is calibrated, followed by the secchi depth, which can be considered as a estimation of the under water light climate. For the nutrients cycle the total nutrients are verified. Finally, the phytoplankton and related oxygen are calibrated.

3.4 Overview of model input

3.4.1 Initial and boundary conditions

Initial and boundary conditions are constructed using the data of those monitoring points of the EPD routine monitoring programme located in the direct vicinity of the boundaries. Since these data reveal during wet season a significant vertical concentration gradient, 3D boundaries conditions are imposed.

From the initial conditions a spin-up period of two full spring/neap periods is applied. Time-series in the inner part of the model reveal that after this period the concentration levels are not affected by the initial conditions in a significant way.

3.4.2 Meteorological forcing

Water quality processes and associated process coefficients may strongly depend on environmental conditions. For the wet and dry season the following uniform forcing is imposed:

	dry	wet
ambient water temperature(oC):	19	28
Solar surface radiation (W/m2):	171	238

The (monthly averaged) temperature is based on a number of years of EPD routine monitoring data. The average March temperature is used for dry season calculations, while the average August temperature is used for wet season calculations. The solar radiation is taken from Earth Radiation Experiment (ERBE) satellite measurements over the period 1985-1989. The same approach was used in the Upgraded Model.

A uniform solar radiation is used, constant over the day. Due to model limitations, daily fluctuations in, for example, dissolved oxygen (at night respiration of algae lowers oxygen concentrations, while during the day primary production increases oxygen concentrations) cannot be taken into account in this way. The fraction of the solar radiation useful for algae is 0.45.

3.4.3 Loadings

The pollution loads for 1987 of Hong Kong Island and the whole of Kowloon which were used as input for the water quality model are inventoried, analysed and described in Working Paper 5 of the Upgrade Study. From this database the waste load locations covered by the model area were applied.

4. Wet season calibration of the water quality model

4.1 General

Regarding the impact of the boundaries on the inner part of the model area, several preliminary runs were performed prior to the calibration in order to analyse the influence of the boundaries. For the model runs constant boundary conditions of a conservative tracer were applied of 100 mg/l. In figure 4.1 the contributions of the separate boundaries after a period of 14 days are presented. The originating boundary can clearly be seen in each plot as the highest concentration (>70) occurs at this boundary. From this figure it can be seen that the concentration in Victoria Harbour is mainly determined by the Ma Wan Channel boundary and the south-west boundary. The effect of the north-east and south-east boundaries are limited given the imposed wind condition (SW 5 m/s) during wet season.

4.2 Salinity

The averaged wet season salinity contours are presented in Figure 4.2. Examination of this figure shows that spatial salinity distribution at the surface and bottom agrees well with the field observations. Simulated salinity at the surface in the Ma Wan area however, shows somewhat high values. Apparently, too little fresh water is penetrating through the Ma Wan Strait.

4.3 Suspended matter

Stable gradients as induced by strong salinity gradients during the wet season circumstances will reduce the vertical exchange. Therefore, it is expected that steep vertical gradients in suspended matter will occur. This is justified by the EPD field observations which show a significant difference in the suspended matter concentration between the surface and bottom layer of approximately 5 mg/l in the Victoria Harbour region. In the modelling of cohesive suspended matter the following parameter setting is applied in the Patheniades-Krone concept. In this concept the bottom shear stress determines whether sedimentation or erosion will occur or not. Sedimentation takes place when the bottom shear stress drops below a certain critical value. Resuspension occurs when the bottom shear stress exceeds a certain critical value.

Critical shear stress for sedimentation	: 0.05 Pa
Critical shear stress for erosion	: 0.2 Pa
Settling velocity	: 2.5 m/d
Erosion rate	: 0.2 g/m^2s

As the study is focussed mainly on Victoria Harbour, the gradient in suspended sediment concentrations in Victoria Harbour was thought to be of major importance. A somewhat higher settling velocity of 2.5m/day, instead of 2m/day used in earlier models, improved the suspended sediment gradient in the area of interest. A higher settling velocity increases the difference in SS between the surface and bottom layers. The effect is especially prominent in the wet season when stratification prevents mixing of the surface and bottom layers.

A comparison of the averaged modelled spring/neap concentration and the EPD measurements

is presented in Figure 4.3. From this figure it can be seen that the simulated concentrations correspond reasonably well with the measurements. In the south-east region of Hong Kong island the suspended matter concentration is somewhat too high both in the surface and the bottom layer. Near Ma Wan Channel the modelled concentration is somewhat higher than the EPD measurements. However it can be observed that the horizontal concentration gradient in Victoria Harbour is reproduced very well by the model. The deep channel east of Hong Kong Island is reflected by lower concentrations due to a reduced sedimentation-erosion cycle because of higher stream velocities. Thus in general the model results show an acceptable resembles with the field data. It should be noticed that the spatial comparison in the "balloon" plots together with the narrow scale band width of 2 mg/l is very critical, differences between model and measurements are therefore quickly obtained.

4.4 Secchi depth

As a next step in the calibration procedure, the background extinction and the specific extinctions of the particulate matter fractions are tuned. The extinction is directly related to the secchi depth by the Poole & Atkins relation (secchi ~ 1.8/extinction). The extinction plays an essential role in the determination of the underwater light climate and the associated growth conditions of alga. The following extinction coefficients are used:

background extinction	:	0.4 1/m
specific extinction IM1	:	0.05 m2/gDW
specific extinction DetC	:	0.17 m2/gC
specific extinction Diat	:	0.15 m2/gC

In figure 4.5 the simulated secchi depth together with yearly averaged EPD field observations are presented (no seasonal field observation were available). The predicted wet season secchi depth in the Victoria Harbour region is too high compared with the yearly averaged field data. Considering the measured higher algae levels (living and dead) during the wet season it is reasonable to assume that the yearly averaged secchi depths are an overestimation for the light climate in wet season.

4.5 Total nutrients

Total nutrients behave almost conservatively since only net removal from the nutrient cycle will decrease these values (like denitrification). In figures 4.6 and 4.7 the spatial concentration contours are presented for total nitrogen and total phosphorus, respectively. The simulated nitrogen and phosphorus values are in good agreement with the observations, although the modelled vertical distribution of total phosphorus in Victoria Harbour is somewhat too high. This is probably caused by too much sedimentation of the adsorbed inorganic phosphate.

4.6 Ammonia, Nitrate and Phosphate

In Figures 4.8 and 4.9 the spatial predicted and observed phosphate and ammonia concentration are presented. In general the model results and field data are in good agreement

4.7 Chlorophyll-a

In Figure 4.10 the spatial algae biomass is presented as chlorophyll-a concentrations. In the wet season it is expected that higher chlorophyll levels are reached in the surface than near the bottom due to the relatively higher levels of light irradiance at the surface. Together with the settling of algae strong vertical concentration gradients will occur during stratified conditions. Sensitivity analyses reveal that the algae growth is primarily controlled by the interaction of three physical mechanisms: settling of algae, vertical turbulence between the surface and sub-surface layers and the light limitation in the sub-surface layers. From figure 4.10 it can be seen that the modelled chlorophyll is highest in Victoria Harbour in accordance with field data. Also bottom layer Chlorophyll levels are lower than surface layer levels, again in accordance with the measurements. Compared to the Upgraded Model lower Silicon concentrations on the boundaries have been used. This proved to be necessary to induce nutrient limitation and in this way limit algae growth. Silicon concentrations used for this study proved to be more realistic than those used in the Upgraded Model.

4.8 Oxygen/BOD_5

The predicted and observed oxygen levels in the top and bottom layer are presented in figure 4.11. Reaeration proved to be of significant importance. A reaeration calculation was used based on stream velocity: the higher the velocity the higher the rearation flux. The process compares the actual oxygen concentration with the saturation concentration for the ambient temperature and salinity. In the wet season a temperature of 28oC was used. Such a high temperature results in a relatively low oxygen saturation concentration. It is likely that a number of the EPD measurements were taken at lower temperatures and therefore higher oxygen saturation concentrations. In this case reaeration would have been higher. This may explain why the modelled oxygen concentration is somewhat lower than the measured concentration.

In Victoria Harbour oxygen concentrations are lower than the surrounding water due to mineralisation of organic material, disposed at the various waste load locations.

BOD5 values are presented in figure 4.12. BOD5 is an derived variable: it sums the availability of organic carbon and depends mainly on the decay rate of CBOD5 and the fraction of DetC considered to be part of BOD5. The decay rate of CBOD5 is temperature dependent. Given the fact that BOD5 measurements are relatively inaccurate, model results correspond very well with measurements. The most important parameters are:

RcBOD	:	0.25 1/day
BOD5/infPOC:		0.6 (-)
TcBOD	:	1.04 (-)

4.9 Conclusion on the calibration

Given the applied model approach the calibration results are satisfactory, as they represent the main trends for all the observed substances. Given the use of long term measurements to calibrate the model and given the uncertainty in pollution loading, no better match between measurement and calculation should be expected.

5. Dry season calibration of the water quality model

The dry season calibration is described shortly, the same parameter setting have been used as in the wet season calibration unless specified otherwise.

5.1 General

Tracers were released on the boundaries to visualise the water transport in the dry season (figure 5.01). Most important are the north-eastern and south-eastern boundaries transporting water from the open sea area. The boundary north of Lantau Island (Ma Wan Channel) and the boundary between Lantau and Hong Kong Island (west of Lamma) determine transport in the north-western part of the model area. The other two boundaries played only a minor role and are not shown in figure 5.01.

5.2 Salinity

During the dry season a relatively simple salinity pattern exists. This pattern is reproduced well by the model (figure 5.02). As inflow occurs over the boundaries alone, slight changes in boundary conditions were sufficient to reproduce the EPD measurements (for example the eastern boundary was decreased from 33.1 (which was the nearest EPD long term average) to 33.03 g/kg).

5.3 Suspended Solids

The EPD long term measurements represent a rather large difference in suspended solids concentration between surface and bottom layer particularly in the north-eastern part of the model area. The high vertical dispersion which is inherent to the dry season, does however not allow the development of a large gradient in suspended solids.

Thus the calibration results for the surface layer show a reasonable agreement with the measurements (figure 5.03) and the gradient in Victoria Harbour is reproduced well. On the other hand SS in the bottom layer is too low, especially in Victoria Harbour and west of Hong Kong Island. A correct SS concentration seems more important for the surface layer given the growht of algae occurs in the surface layer. Bottom layer concentrations were decreased slightly by increasing the critical shear stress of resuspension to 0.25 Pa.

5.4 Oxygen and BOD_5

The model results for oxygen (figure 5.04) are in good agreement with measurements. Lower concentrations can be found in Victoria Harbour due to loads of organic matter to the Harbour area.

The oxygen concentration in Victoria Harbour depends largely on the BOD5 loads in the Harbour. The BOD5 pattern is reproduced well with the model (figure 5.05): higher levels in Victoria Harbour, lower levels in the rest of the area. However to improve results the decay rate of BOD5 had to be increased (RcBOD=0.45) compared to the wet season. However the resulting decay rate when temperature is taken into account appears to be almost equal for the wet and dry season:

wet season : RcBOD * $TcBOD^{(Temp - 20)}$ $= 0.25 * 1.04^{(28 - 20)} = 0.34$
Dry season : $= 0.45 * 1.04^{(19 - 20)} = 0.36$

The higher BOD loads in Victoria Harbour consume more oxygen and as a result oxygen concentrations are lowered.

5.5 Chlorophyll-a

Chlorophyll concentrations are in reasonable accordance with measurements.

5.6 Nitrogen (Total-N, NH4 and NO3)

Figure 5.07 shows Total-N results corresponded well with EPD measurements. NH4 concentrations are modelled somewhat too high in Victoria Harbour (figure 5.08) but calibration result are satisfactory given the complexity of the substance. Nitrate is modelled too high in Victoria Harbour (figure 5.09). The loads in Victoria Harbour can not be seen in the measurements, but are very important in the Sha Tin model. As nitrate behaves in an almost conservative way under the circumstances (no nitrate is take up by algae, only little is removed through denitrification and formed through nitrification), the concentration is likely to remain high in Victoria Harbour.

5.7 Phosphate (Total-P and PO4)

Figures 5.10 and 5.11 show a good resemblance between model results and measurements for respectively Total-P and phosphate. To change the ratio between particulate phosphate (AAP) and dissolved phosphate (PO4), the distribution coefficient (KdPO4AAP) was set to 0.6, increasing the amount of dissolved PO4 to better match the measurements.

5.8 Conclusion on the calibration

Given the applied model approach the calibration results are satisfactory, as they represent the main trends for all the observed substances. Given the use of long term measurements to calibrate the model and given the uncertainty in pollution loading, no better match between measurement and calculation should be expected.

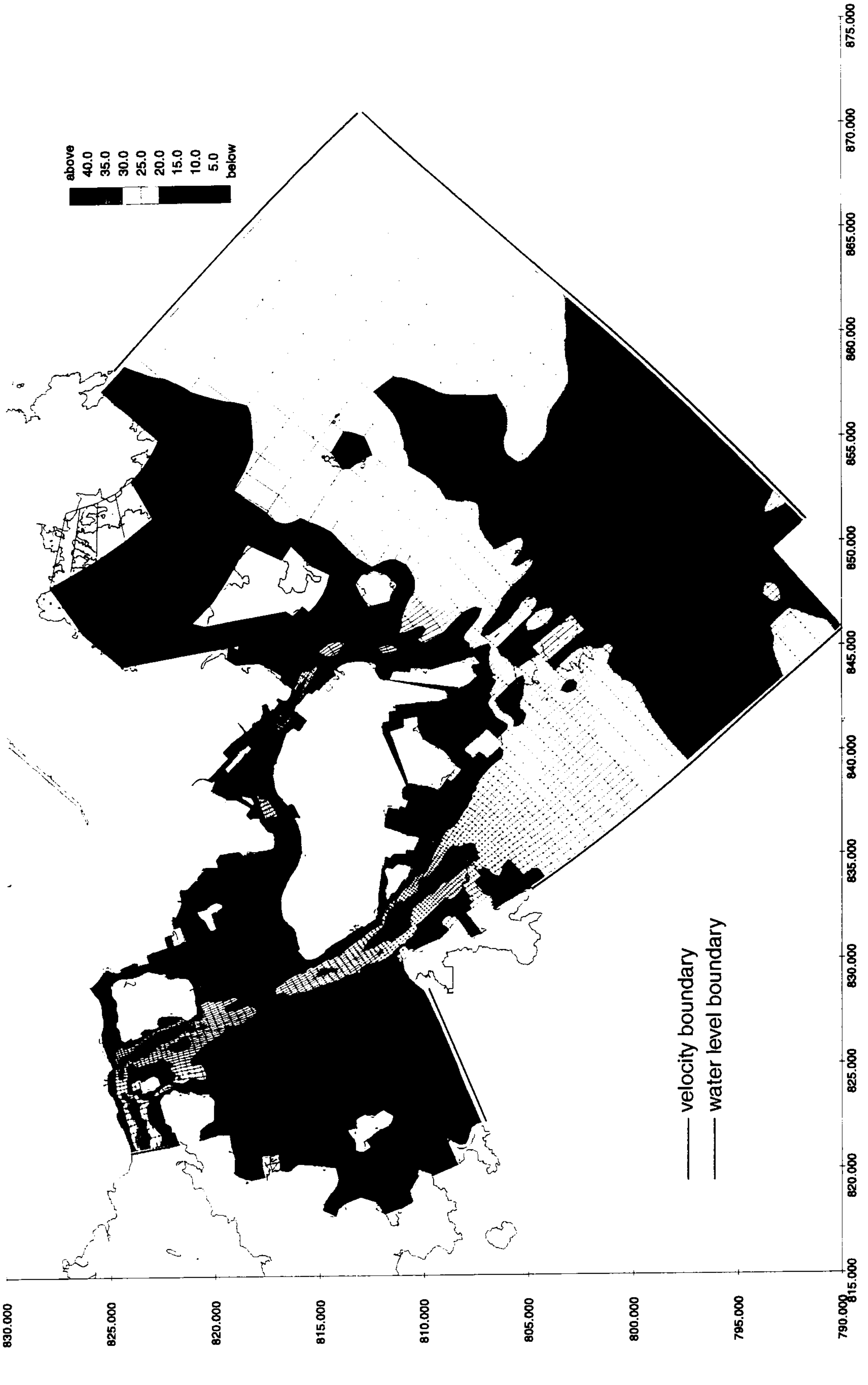
6. References

Delft Hydraulics in association with Hyder Consulting Hong Kong and Origin IT Hong Kong, 1998, Final Model calibration and Validation Report; Part 2, Hydraulic validation and WQ Calibration; January 1998.

Poole, H.H and W.R.G Atkins, 1929
Photoelectric measurements of submarine illumination throughout the Year. J.Mar. Biol. Ass. U.K, 16, 297-324

Upgrading of the water quality and hydraulic mathematical models. Data collection, Analysis, Gaps and modelling approach. Working paper 5, 1997
CED, Hong Kong Government

DELFT HYDRAULICS



Grid layout, bathymetry schematization (overall) and boundary definition
Victoria Harbour Model

DELFT HYDRAULICS

Fig: 2.01

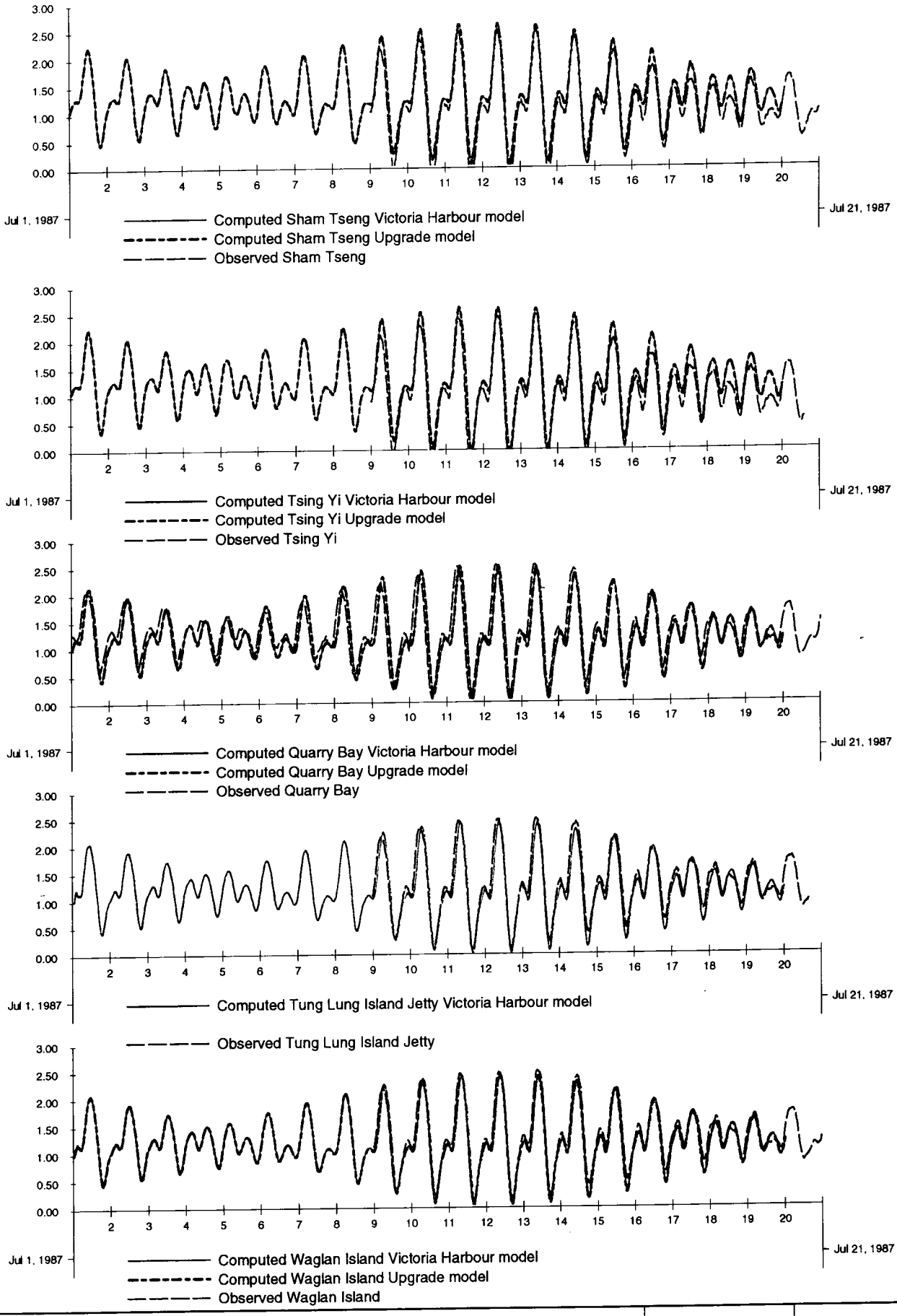
DELFT HYDRAULICS

Bathymetry schematization (detail)
Position of monitoring stations Vict. Harb. measurement campaign (

DELFT HYDRAULICS

Fig: 2.02

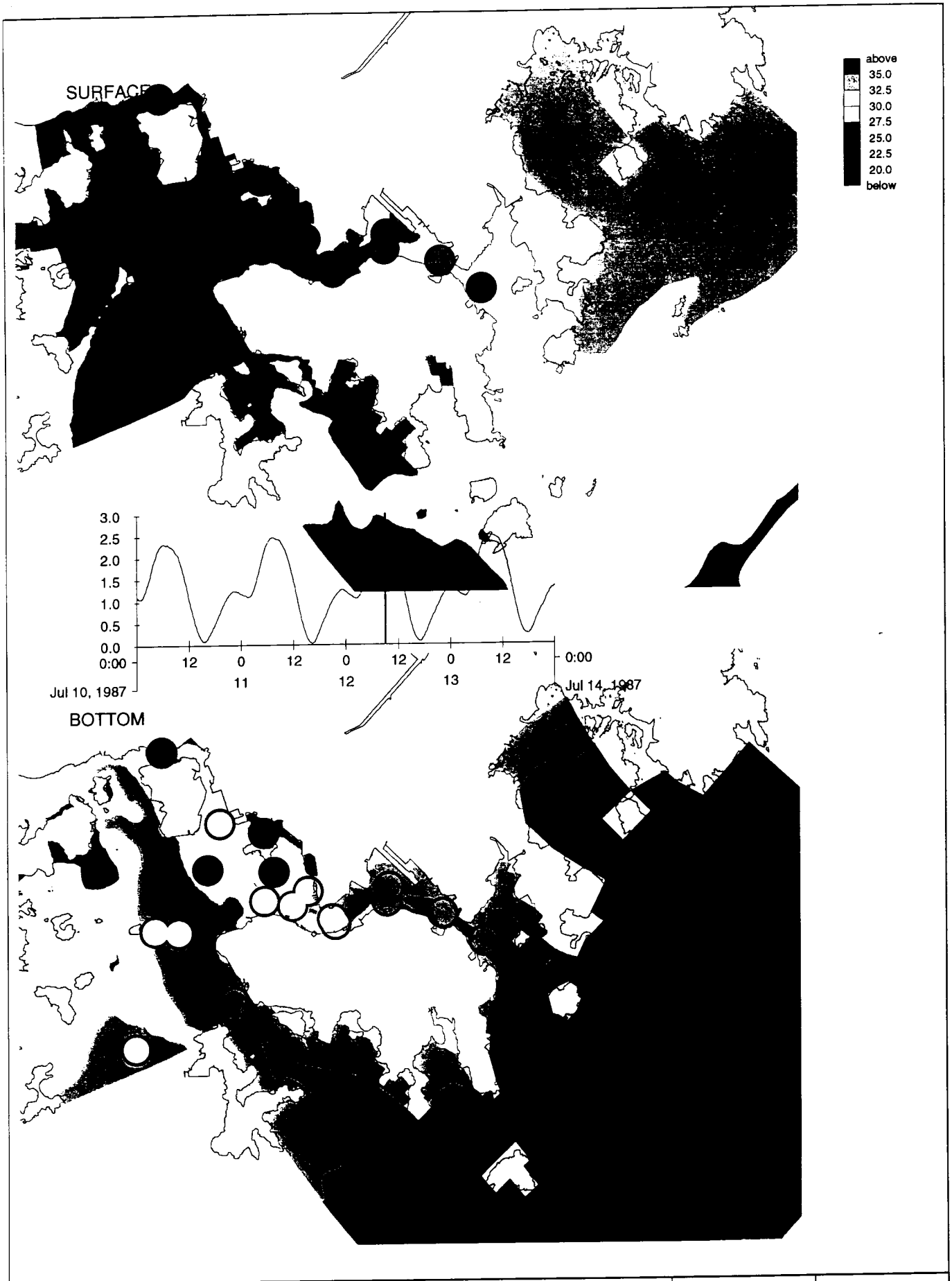
DELFT HYDRAULICS



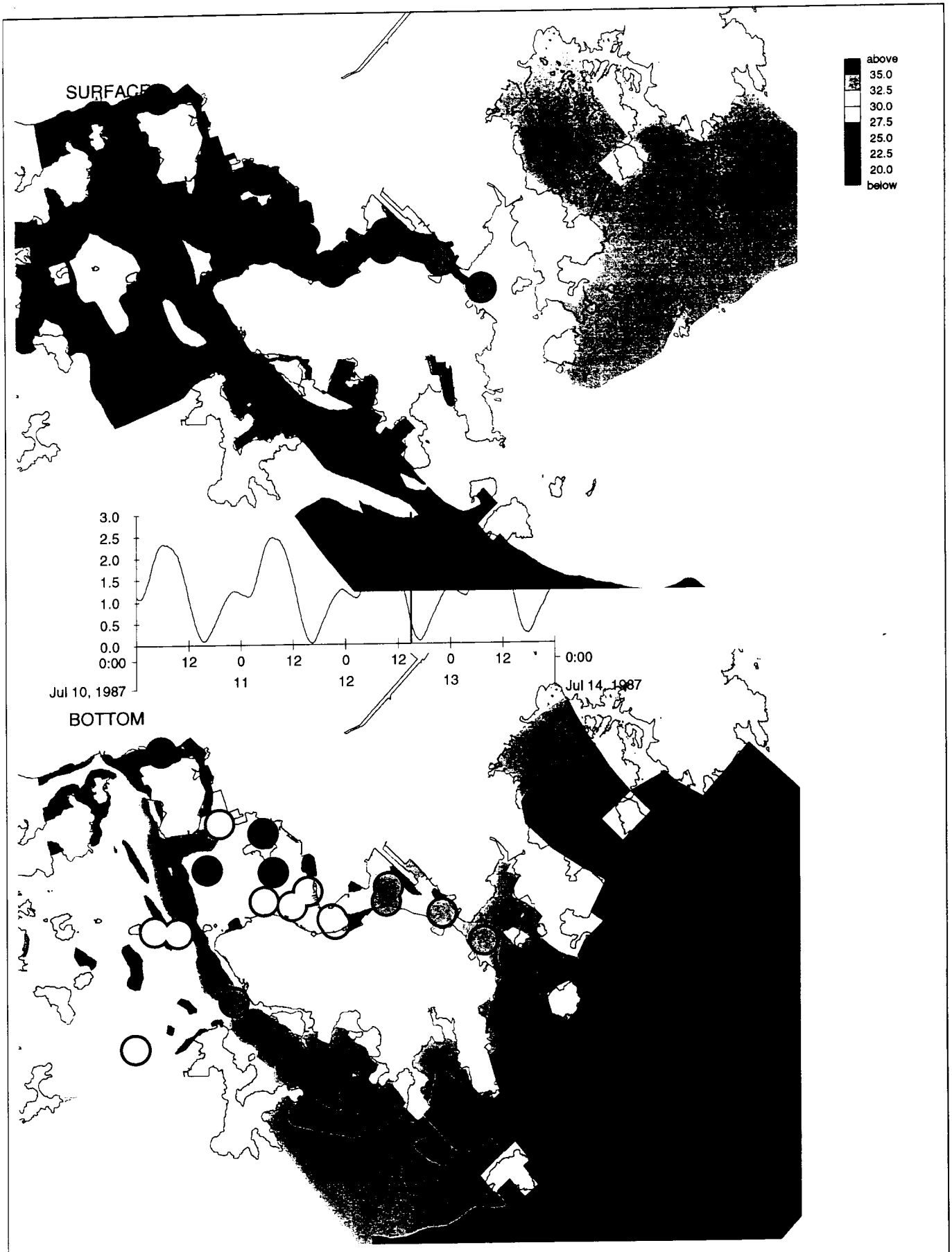
Shatin treatment works stage III extension
Computed and observed water levels, July 1987
Wet Season

DELFT HYDRAULICS

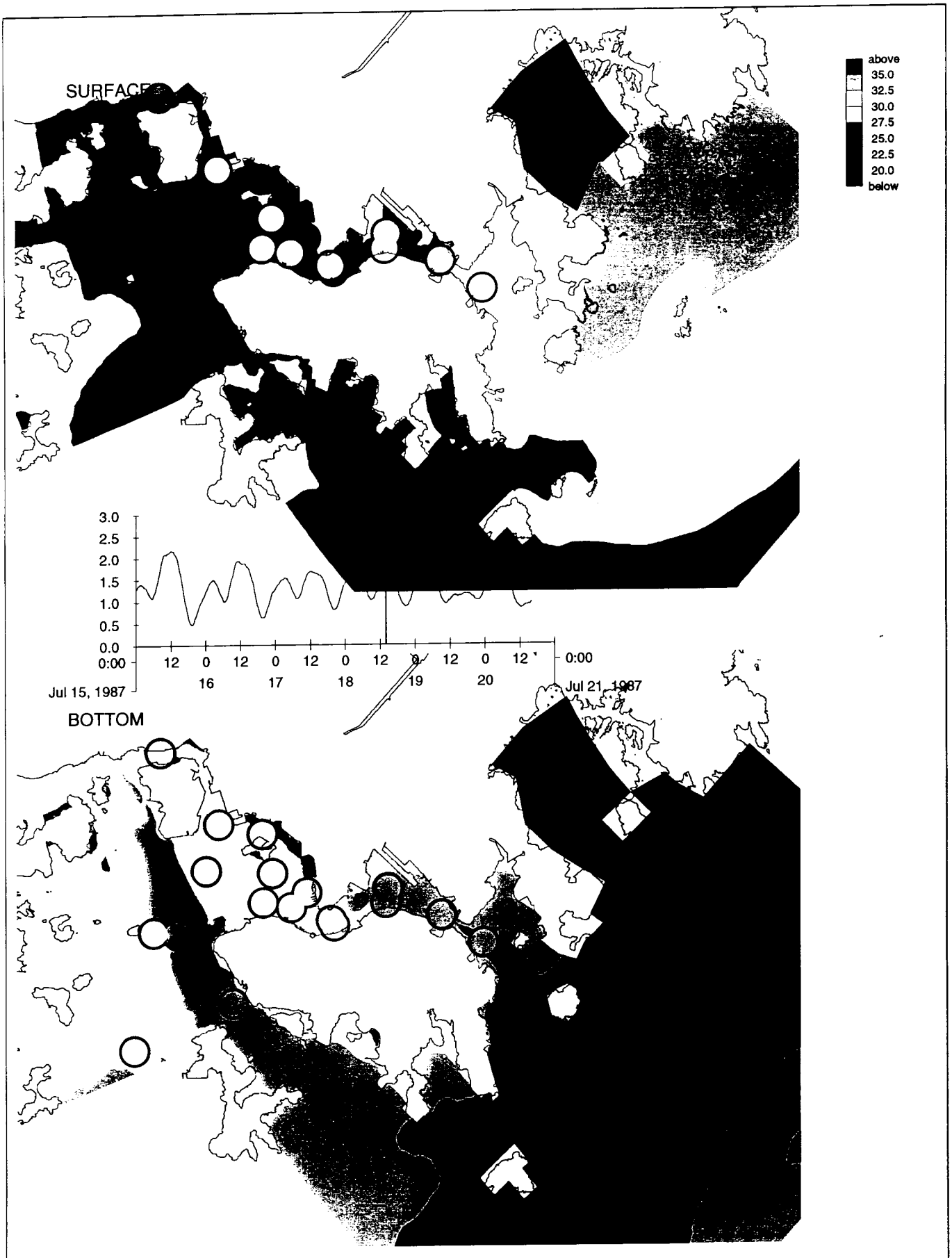
Fig: 2.03



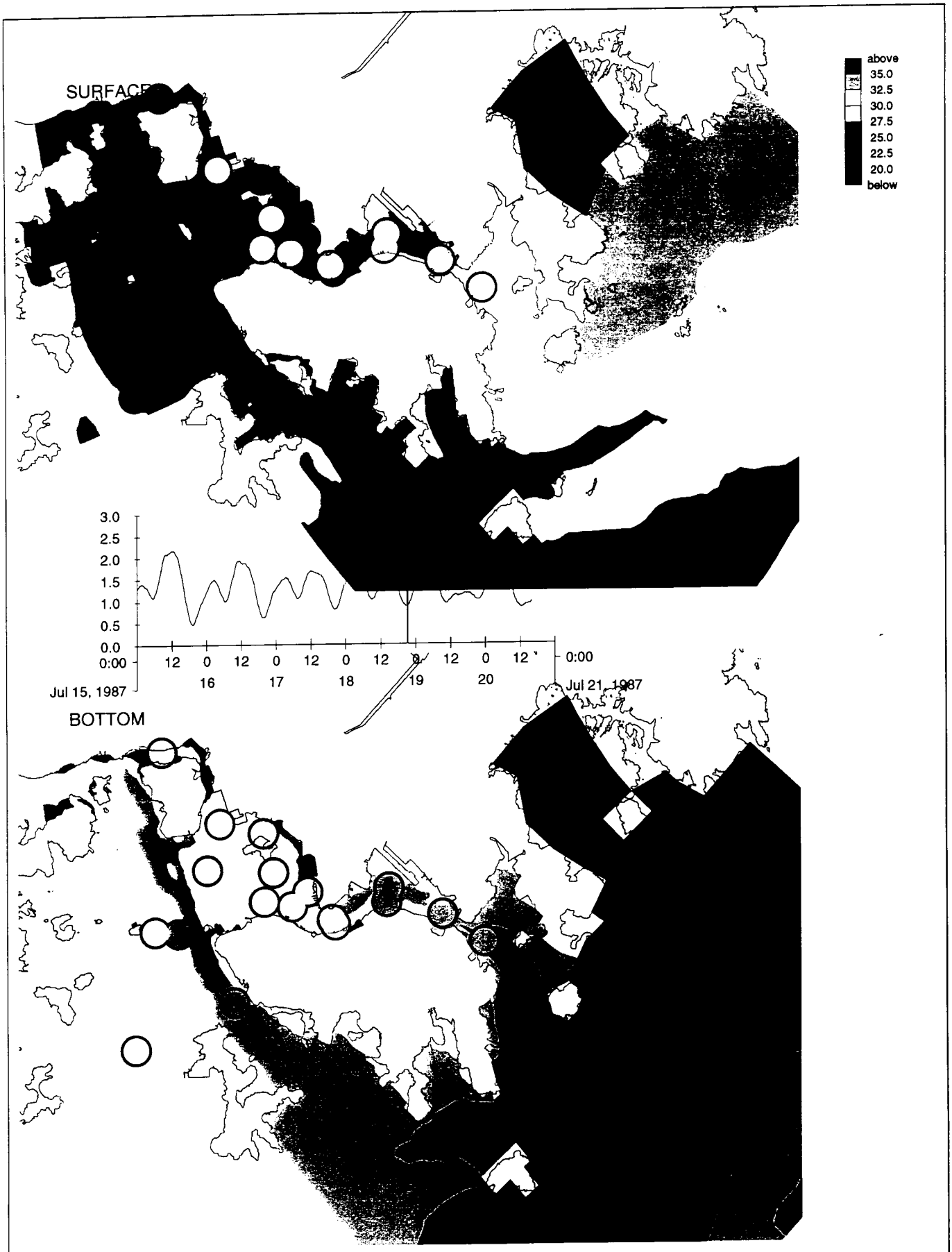
Shatin treatment works stage III extension Computed and obs. salinity in surface and bottom layer, July 1987 High water spring		wind SW 5 m/s
		Delft3D-FLOW
DELFT HYDRAULICS		Fig: 2.04



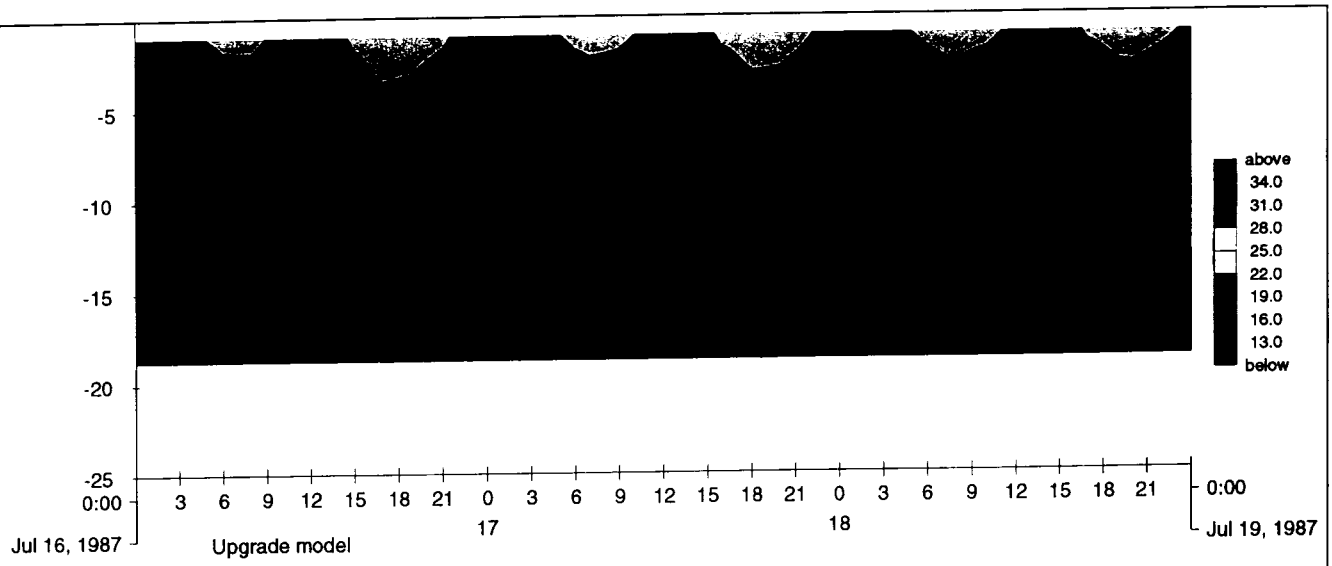
Shatin treatment works stage III extension Computed and obs. salinity in surface and bottom layer, July 1987 Low water spring	RUN :	wind SW 5 m/s
	Delft3D-FLOW	
DELFT HYDRAULICS		Fig: 2.05

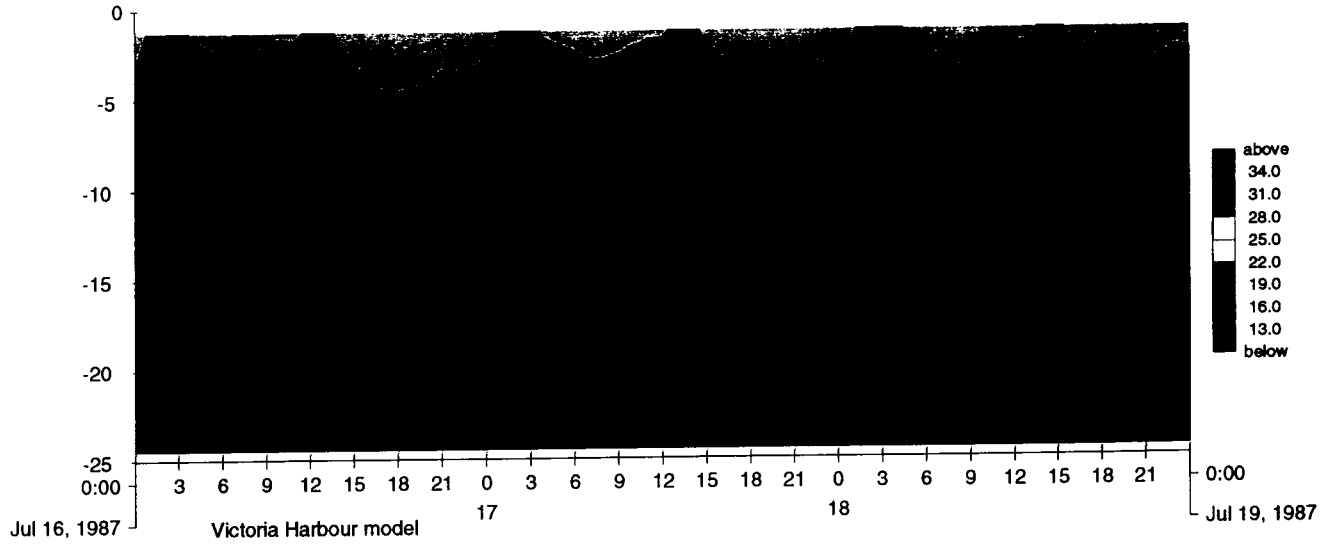


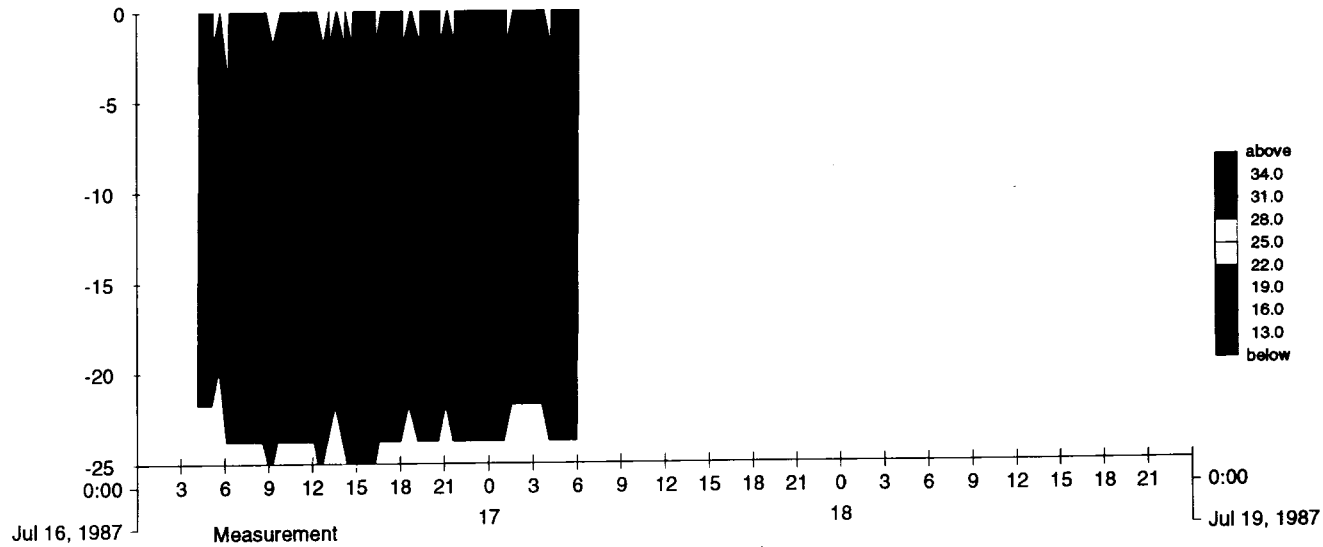
Shatin treatment works stage III extension Computed and obs. salinity in surface and bottom layer, july 1987. High water neap		wind SW 5 m/s
		Delft3D-FLOW
DELFT HYDRAULICS		Fig: 2.06



Shatin treatment works stage III extension Computed and obs. salinity in surface and bottom layer, July 1987 Low water neap		wind SW 5 m/s
		Delft3D-FLOW
DELFT HYDRAULICS		Fig. 2.07

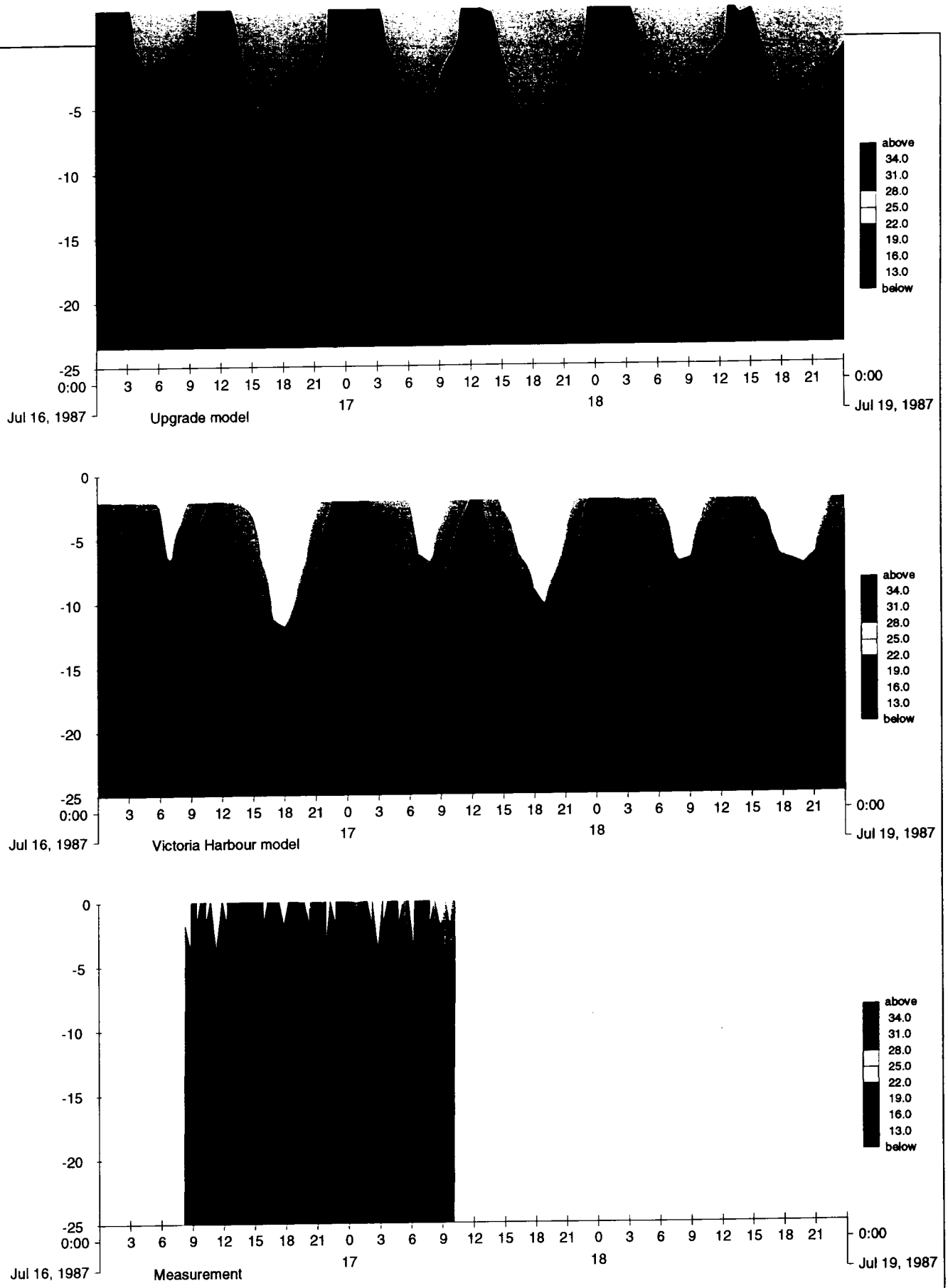






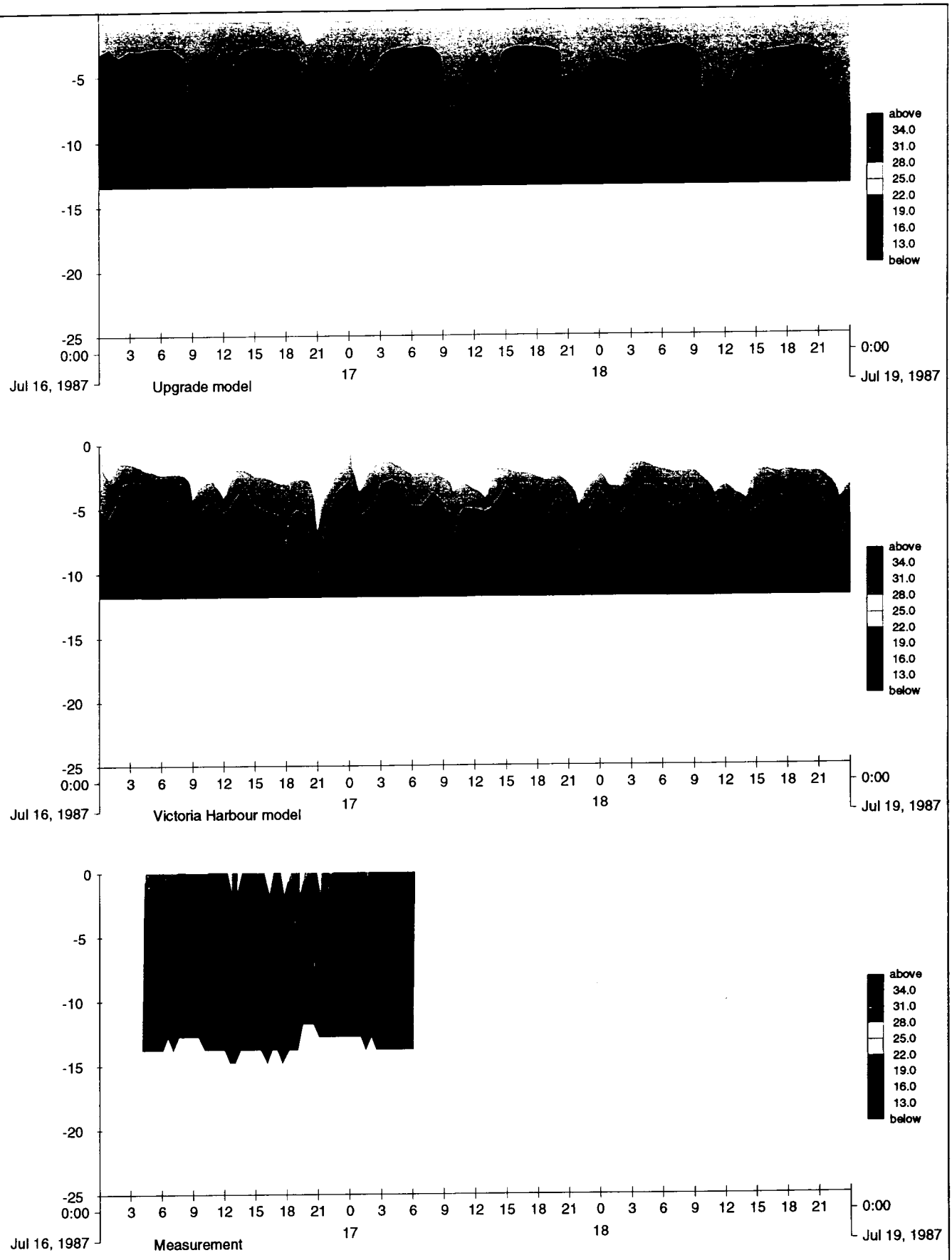
Measured and simulated salinities, Wet season - Neap tide 1987
Station 1; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.08



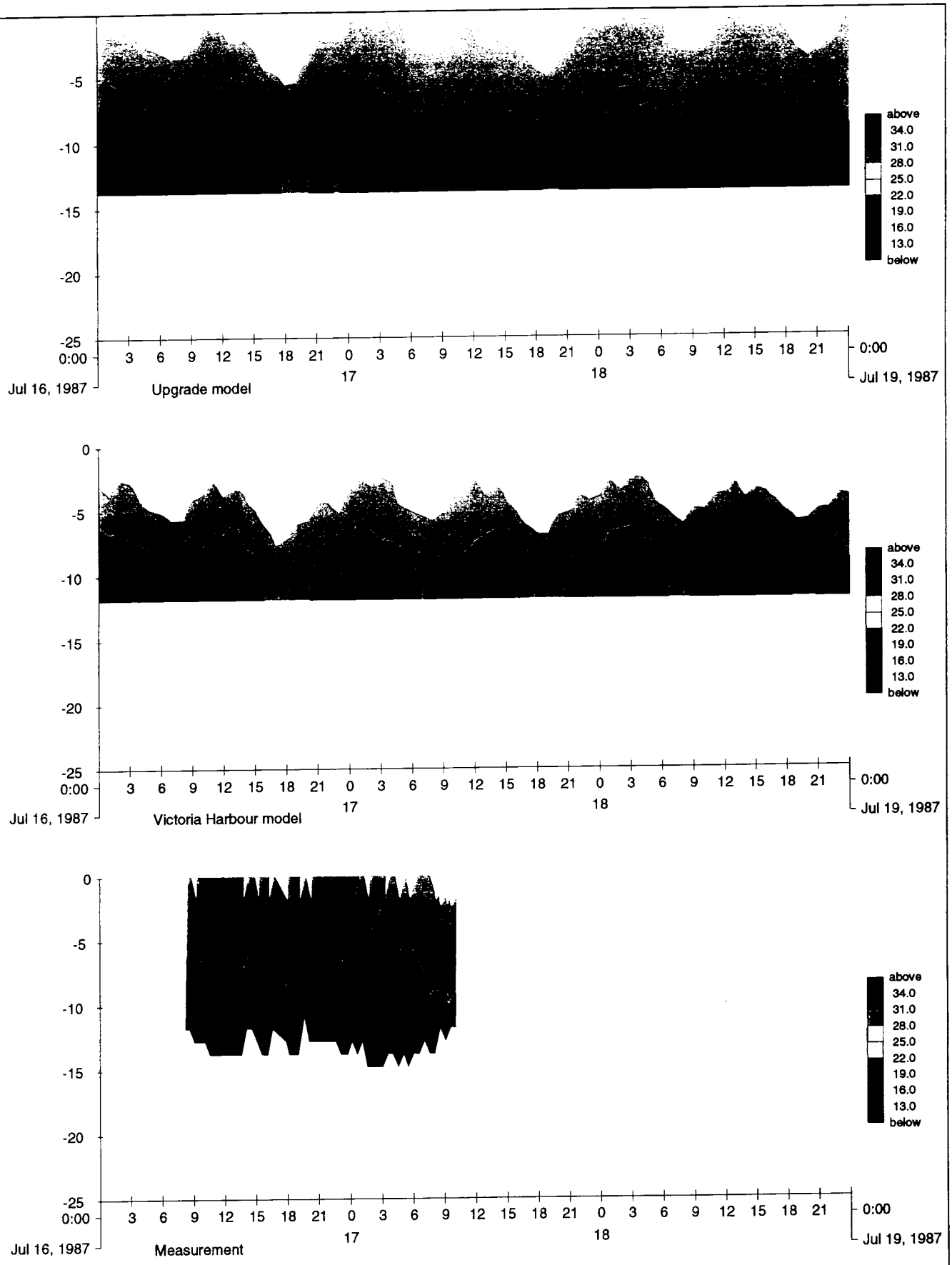
Measured and simulated salinities, Wet season - Neap tide 1987
Station 2; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.09



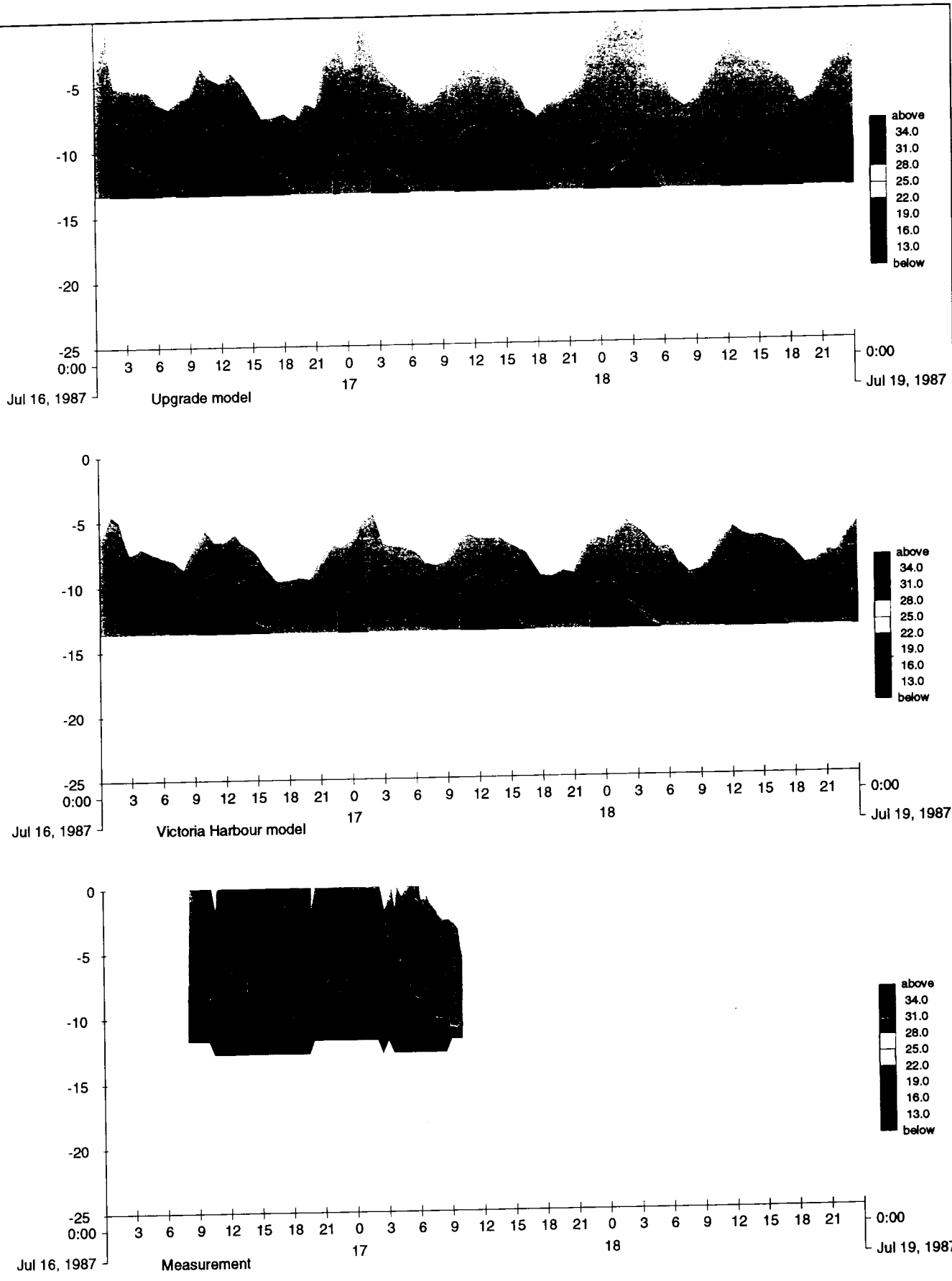
Measured and simulated salinities, Wet season - Neap tide 1987
Station 4; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.10



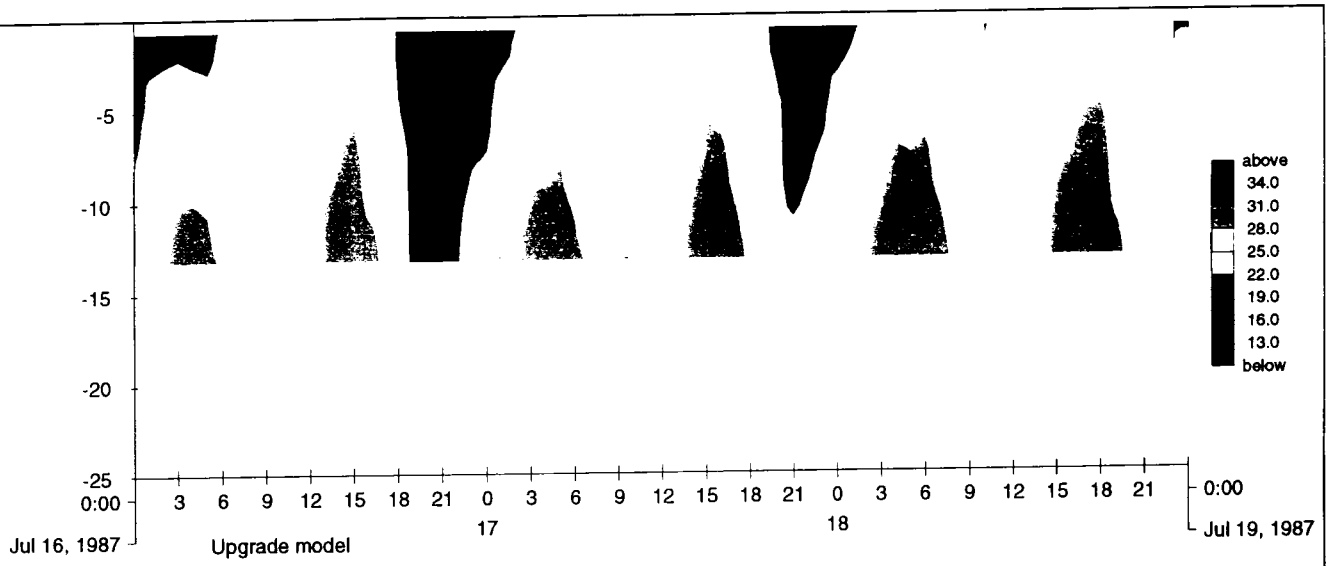
Measured and simulated salinities, Wet season - Neap tide 1987
Station 6; Victoria Harbour measurement campaign

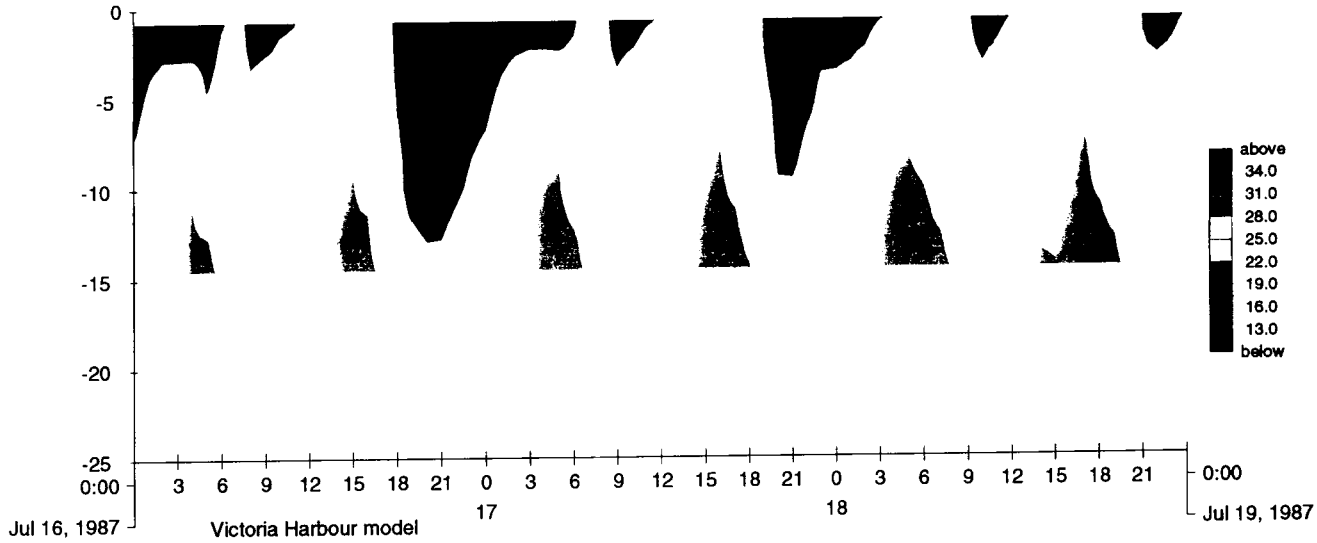
DELFT HYDRAULICS | Z 2455.00 | Fig: 2.11

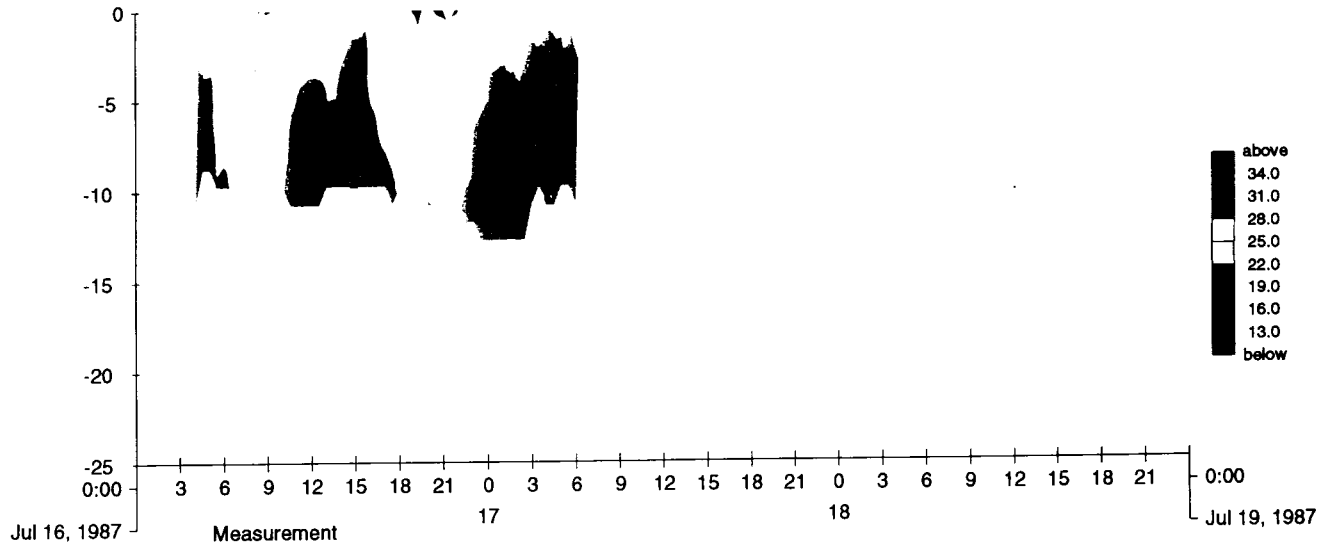


Measured and simulated salinities, Wet season - Neap tide 1987
Station 8; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.12





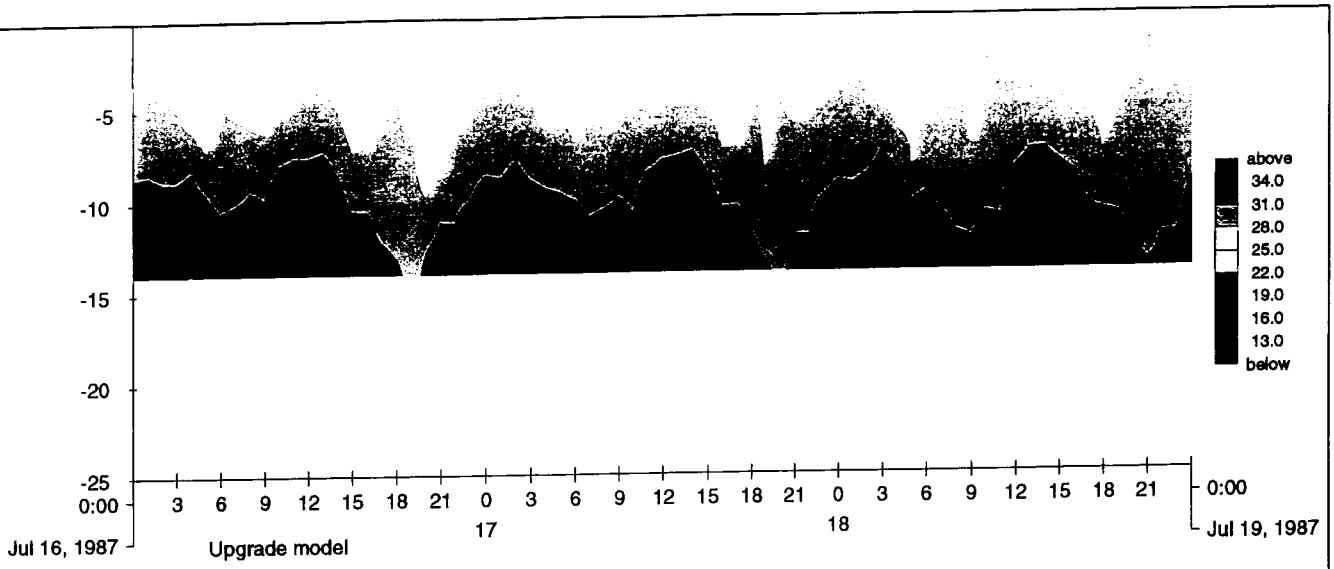


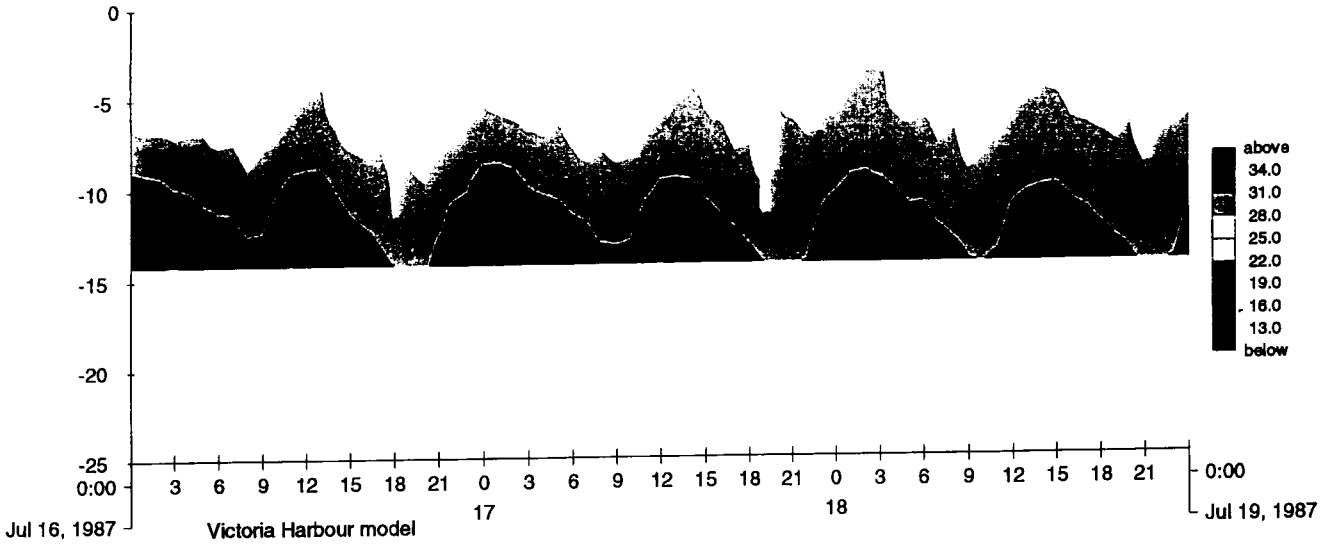
Measured and simulated salinities, Wet season - Neap tide 1987
Station 13; Victoria Harbour measurement campaign

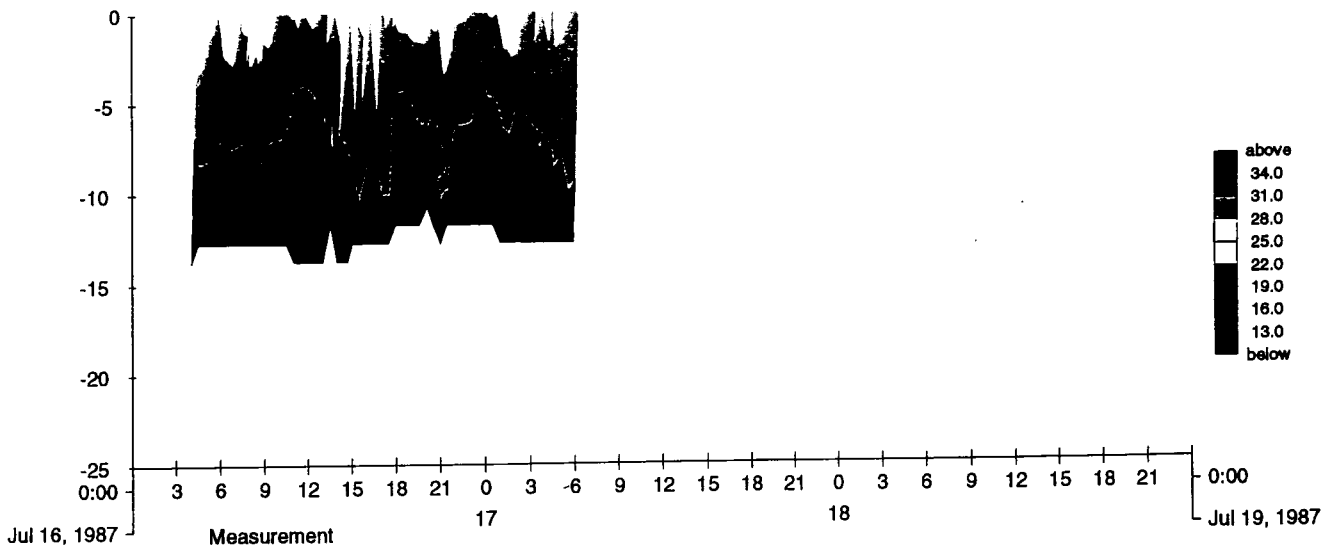
DELFT HYDRAULICS

Z 2455.00

Fig: 2.13

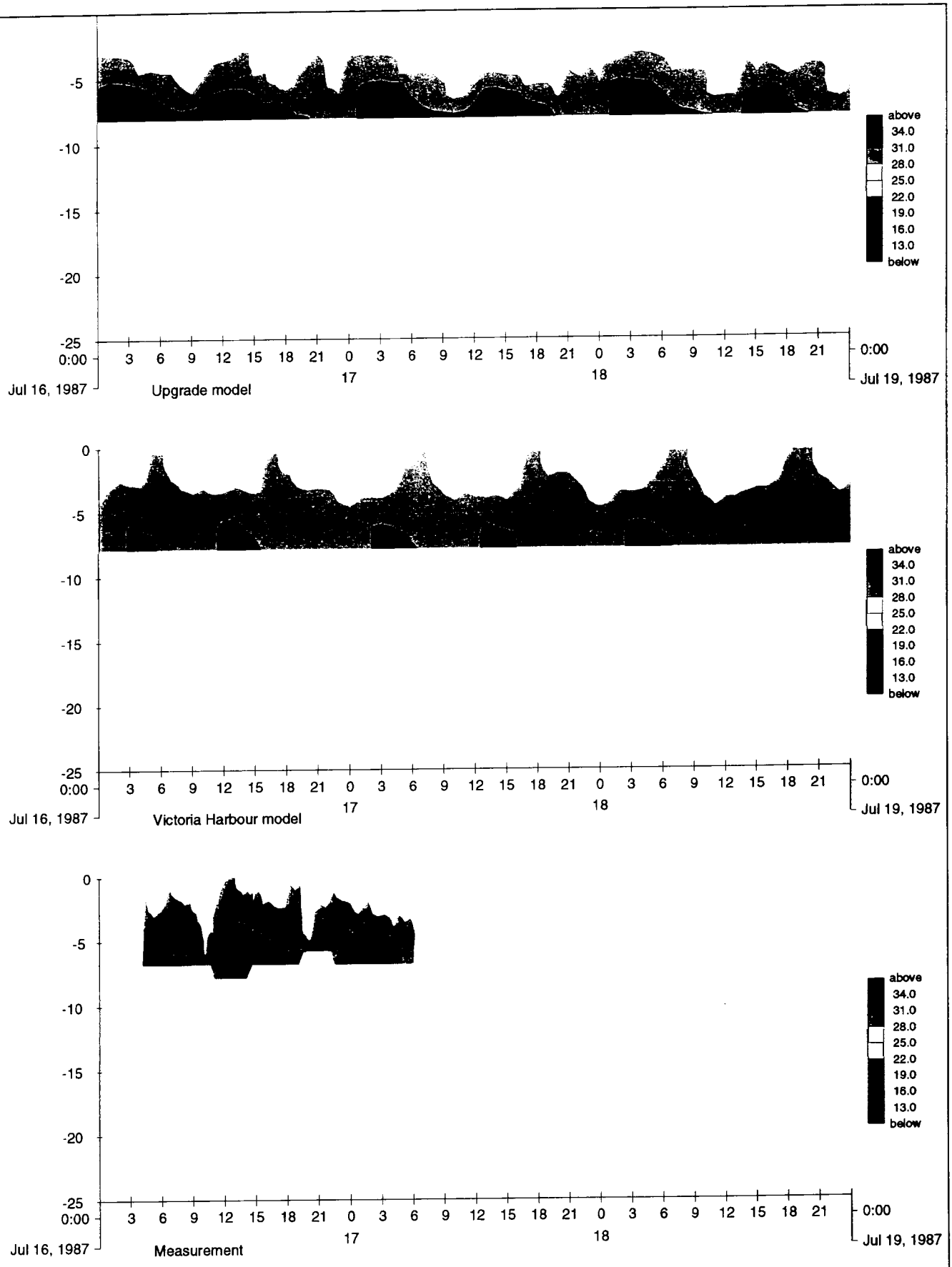






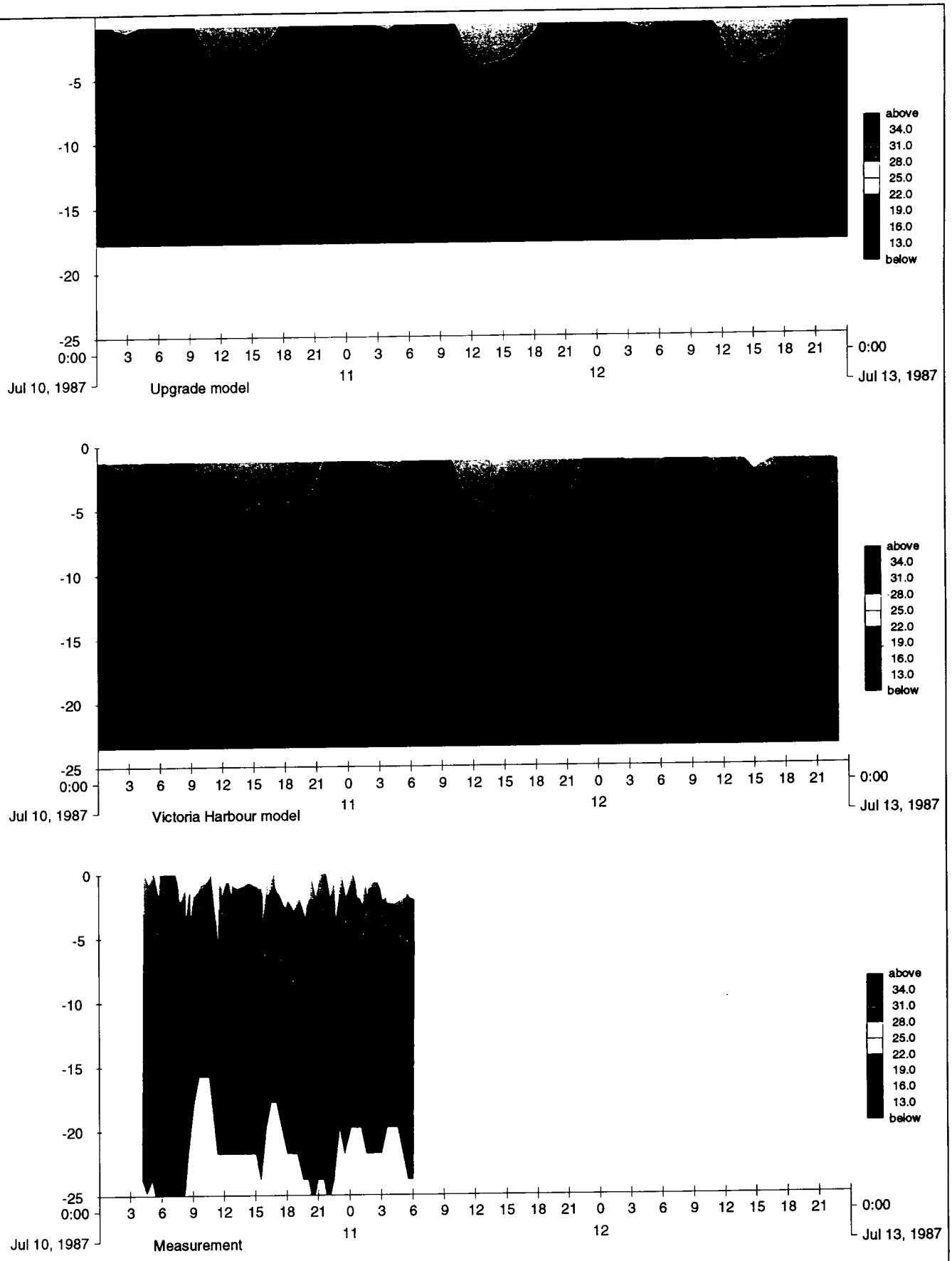
Measured and simulated salinities, Wet season - Neap tide 1987
Station 15; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.14



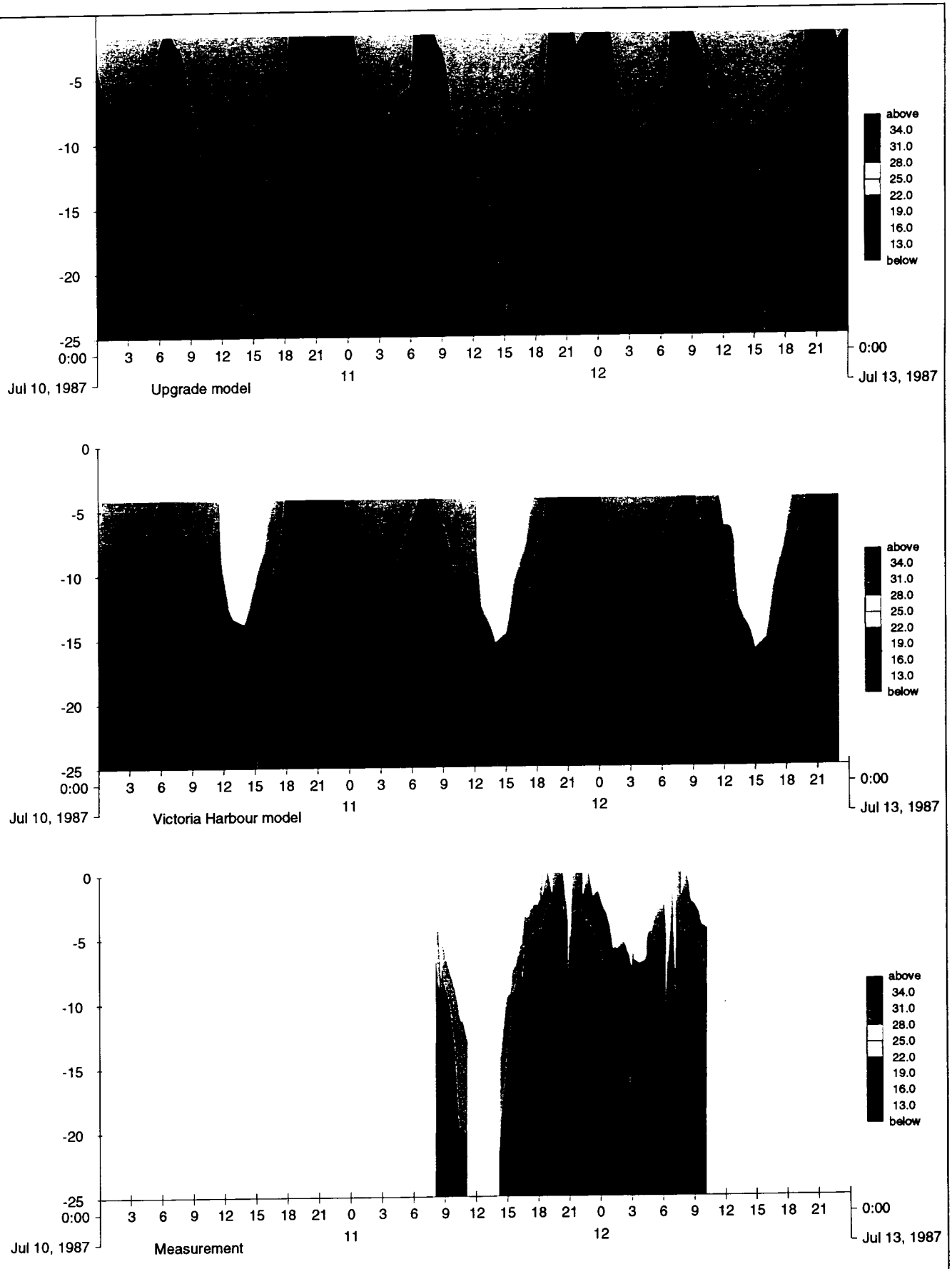
Measured and simulated salinities, Wet season - Neap tide 1987
Station 17; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.15



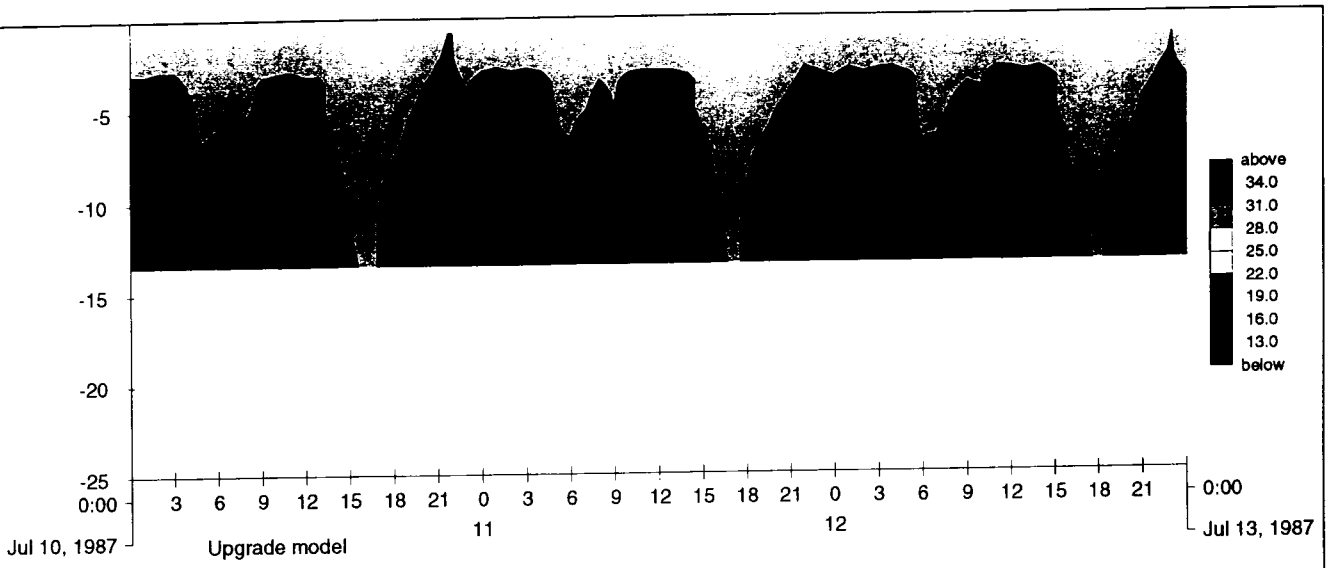
Measured and simulated salinities, Wet season - Spring tide 1987
Station 1; Victoria Harbour measurement campaign

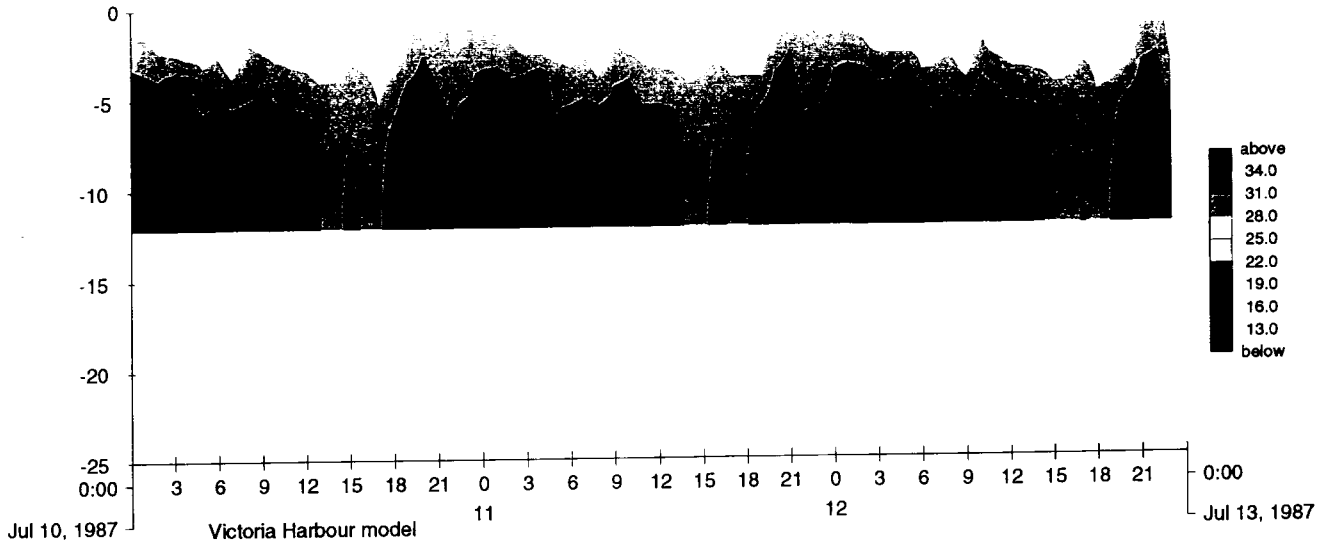
DELFT HYDRAULICS | Z 2455.00 | Fig: 2.16

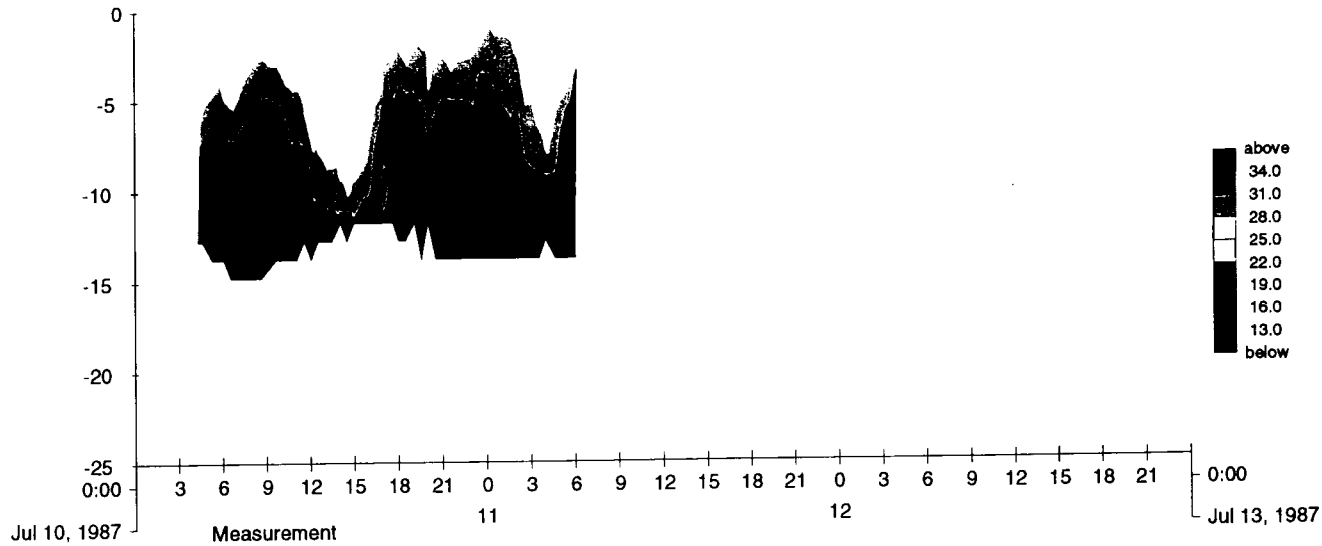


Measured and simulated salinities, Wet season - Spring tide 1987
Station 2; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.17

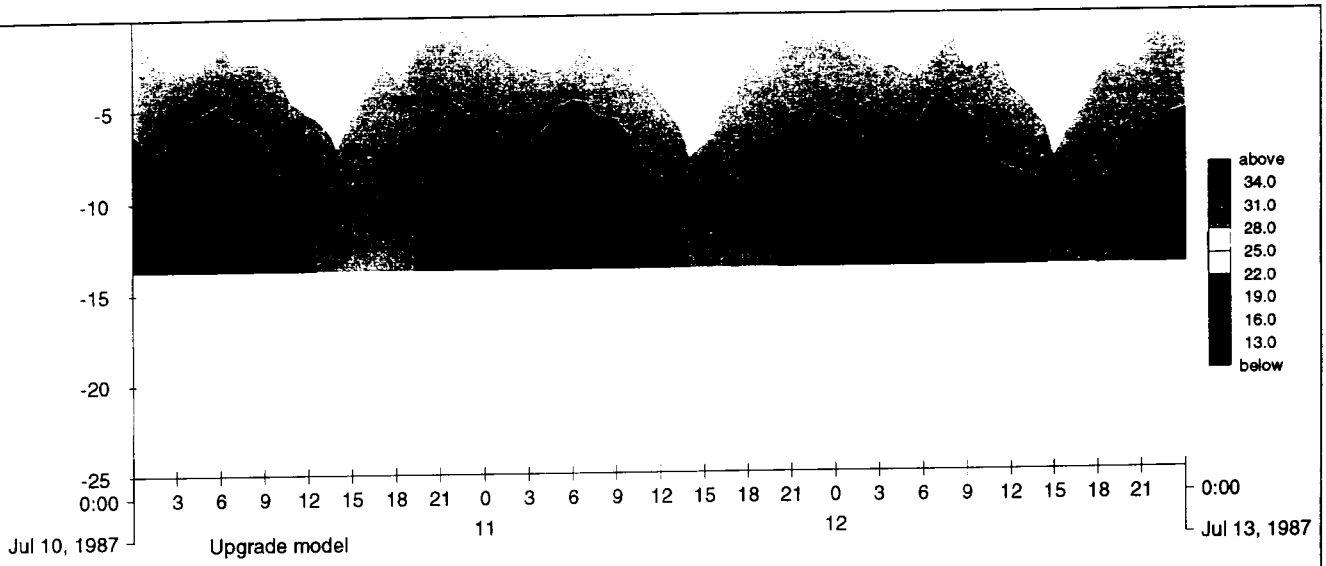


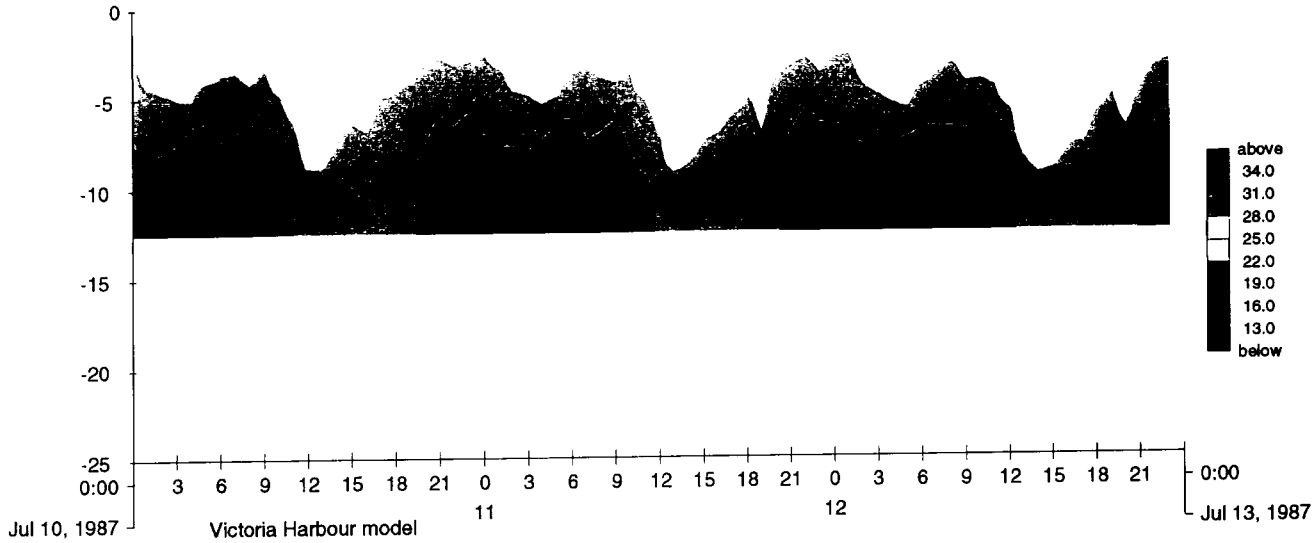


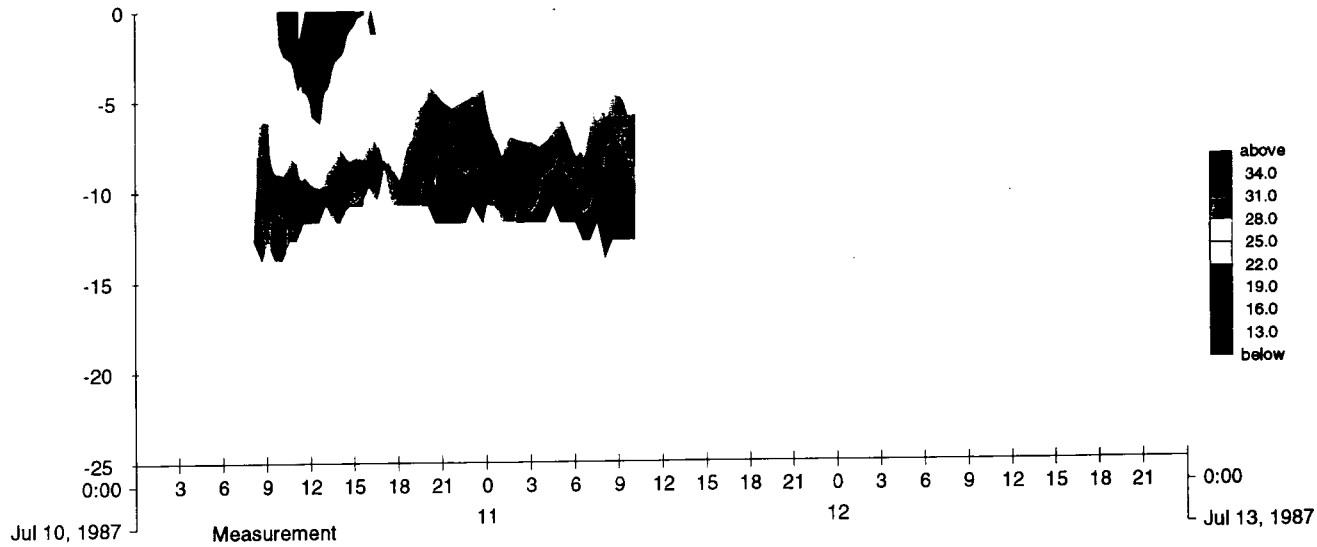


Measured and simulated salinities, Wet season - Spring tide 1987
Station 4; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.18

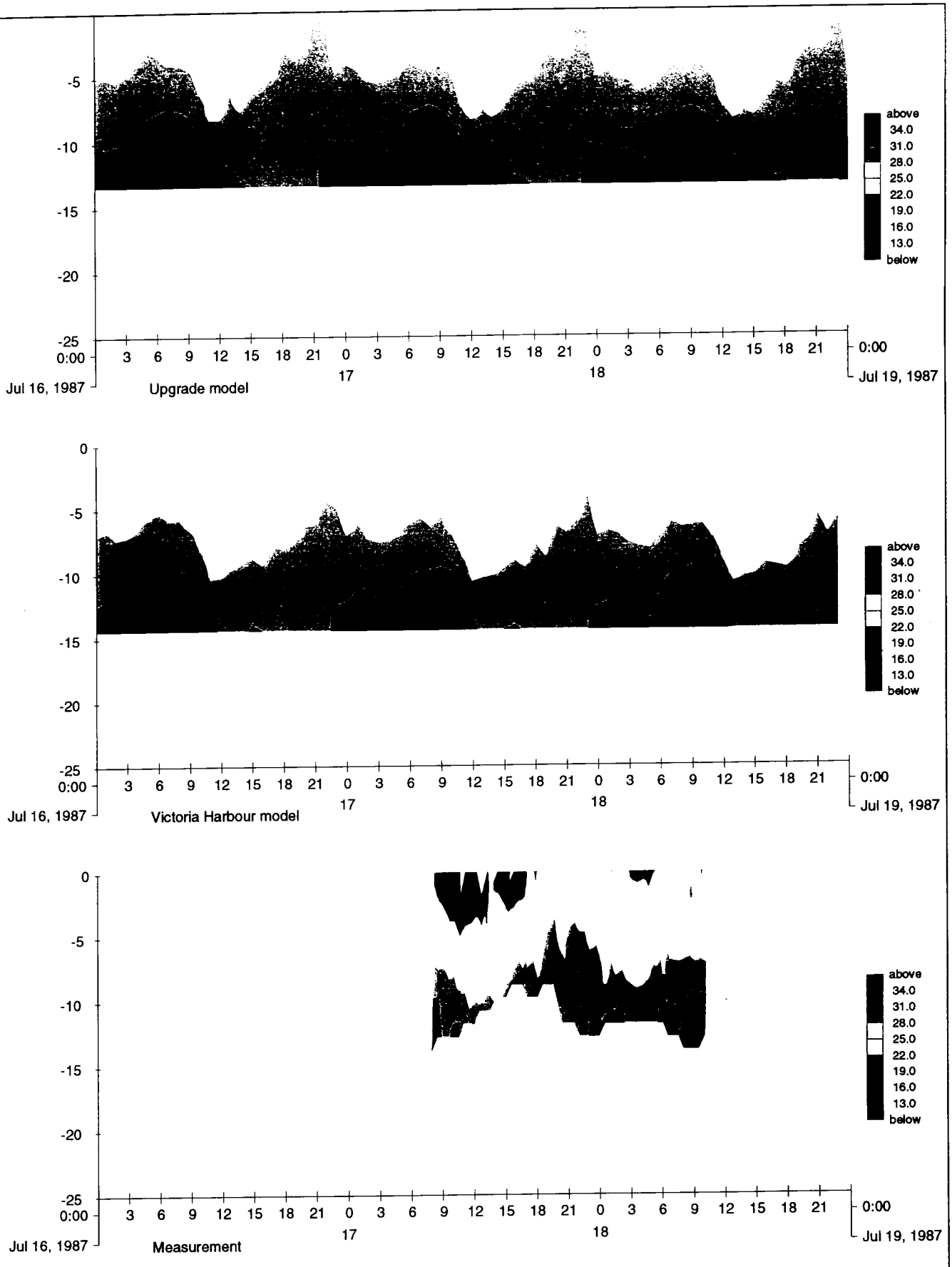






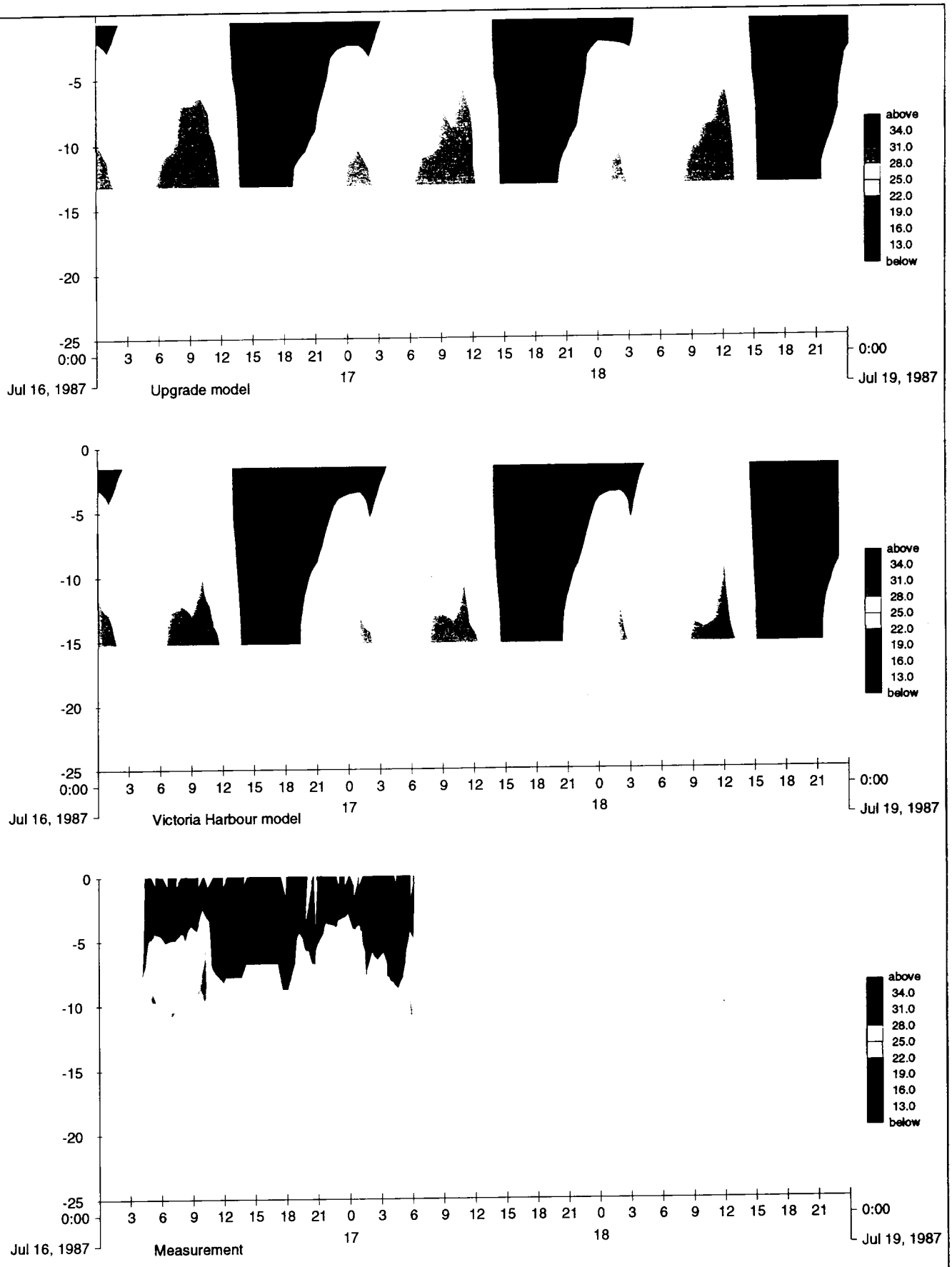
Measured and simulated salinities, Wet season - Spring tide 1987
Station 6; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.19



Measured and simulated salinities, Wet season - Spring tide 1987
Station 8; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.20

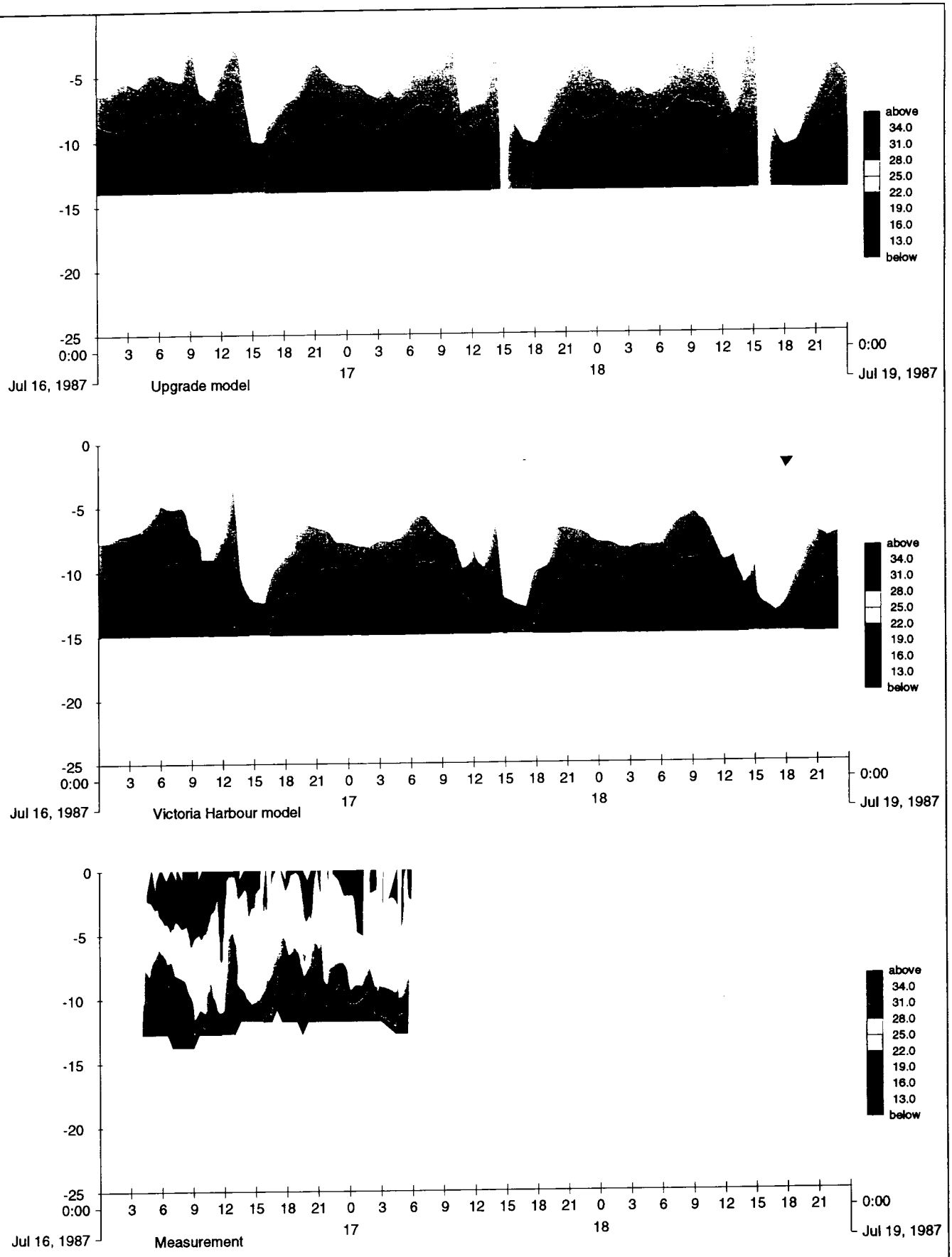


Measured and simulated salinities, Wet season - Spring tide 1987
Station 13; Victoria Harbour measurement campaign

DELFT HYDRAULICS

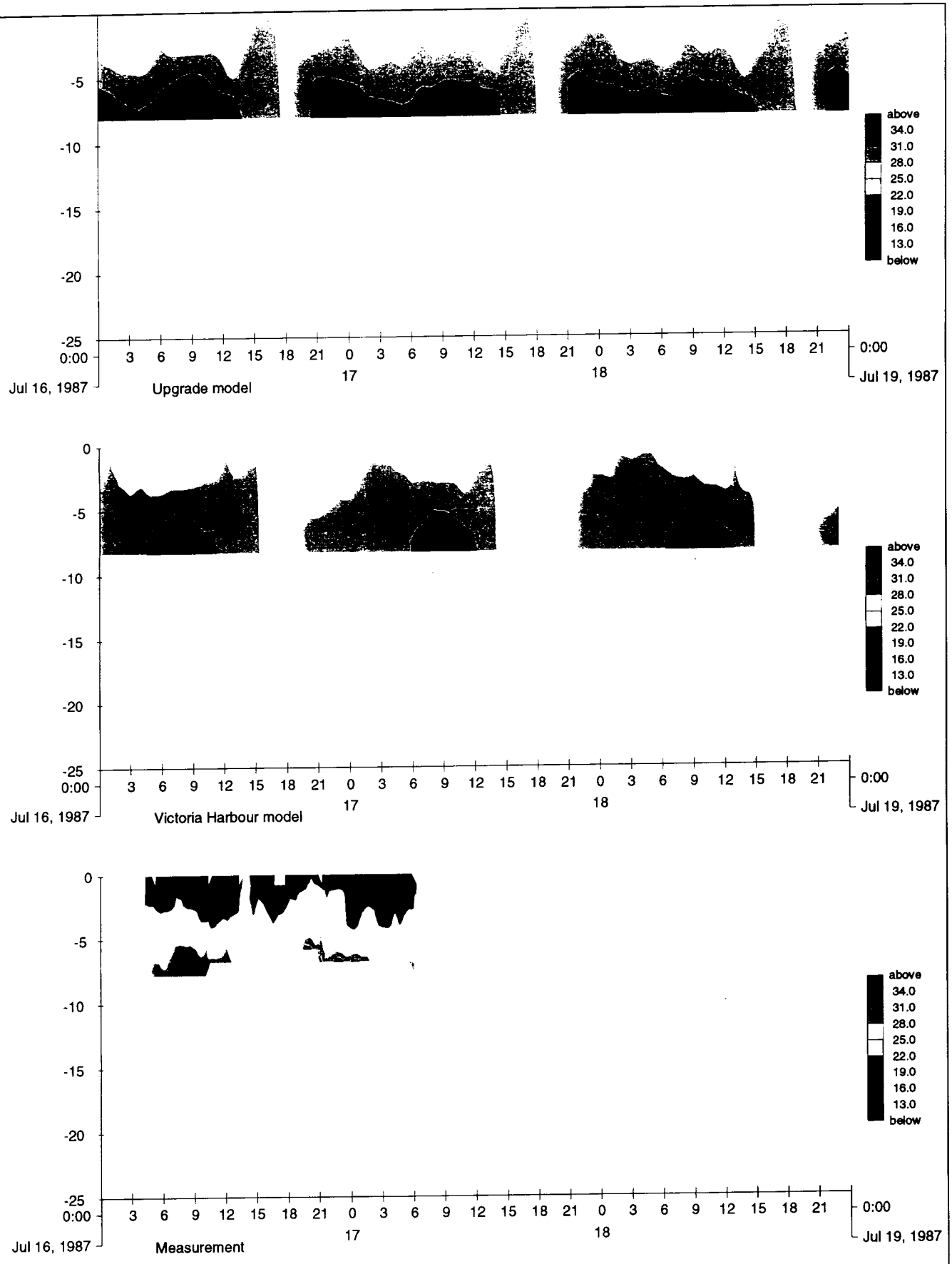
Z 2455.00

Fig: 2.21



Measured and simulated salinities, Wet season - Spring tide 1987
Station 15; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.22

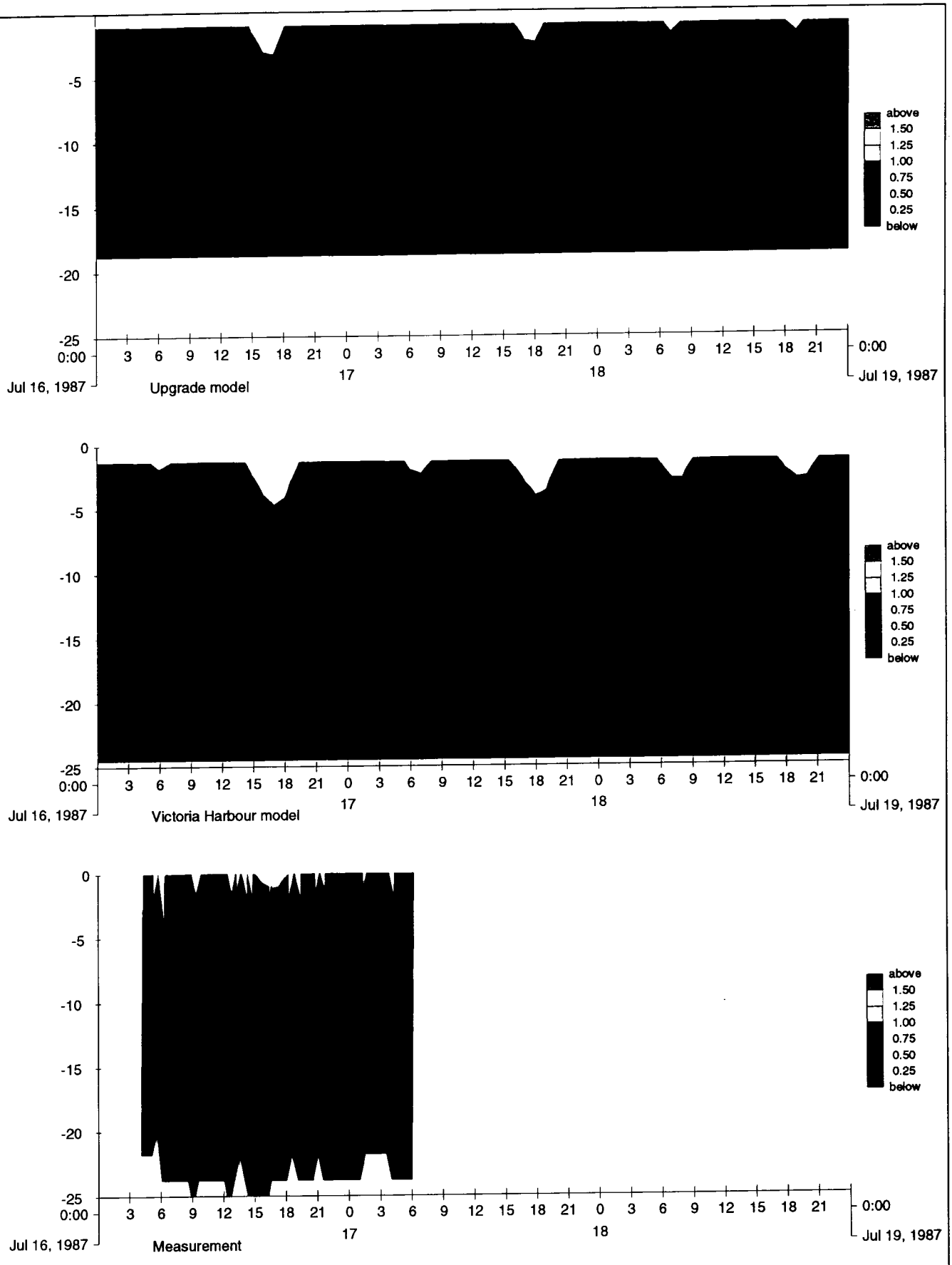


Measured and simulated salinities, Wet season - Spring tide 1987
Station 17; Victoria Harbour measurement campaign

DELFT HYDRAULICS

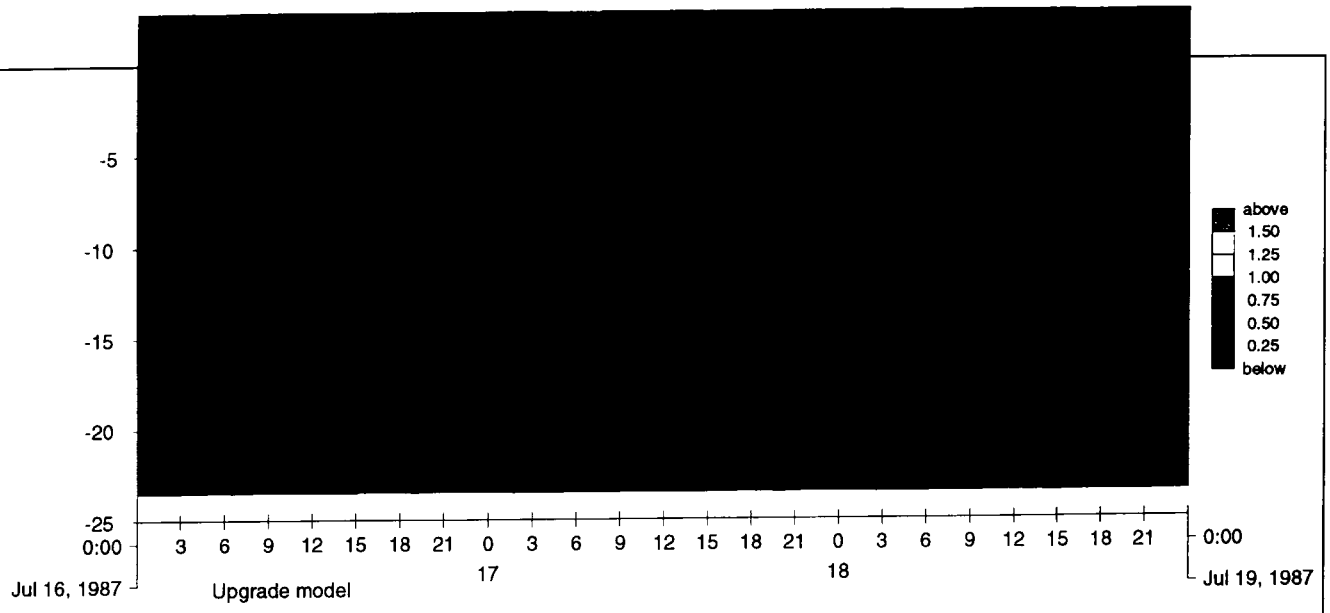
Z 2455.00

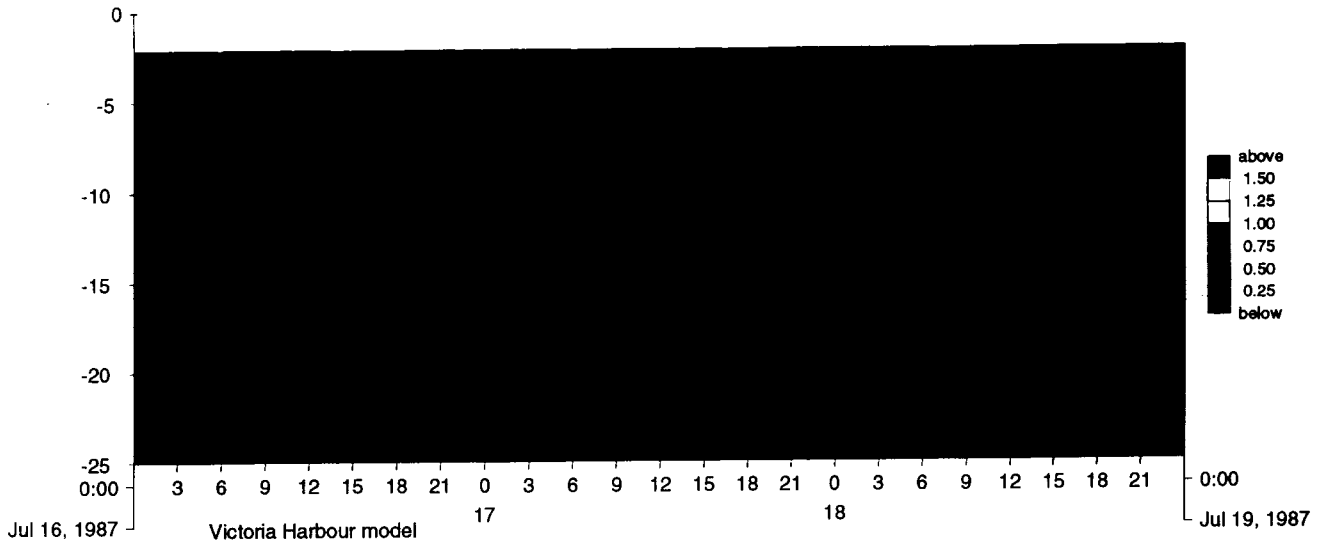
Fig: 2.23

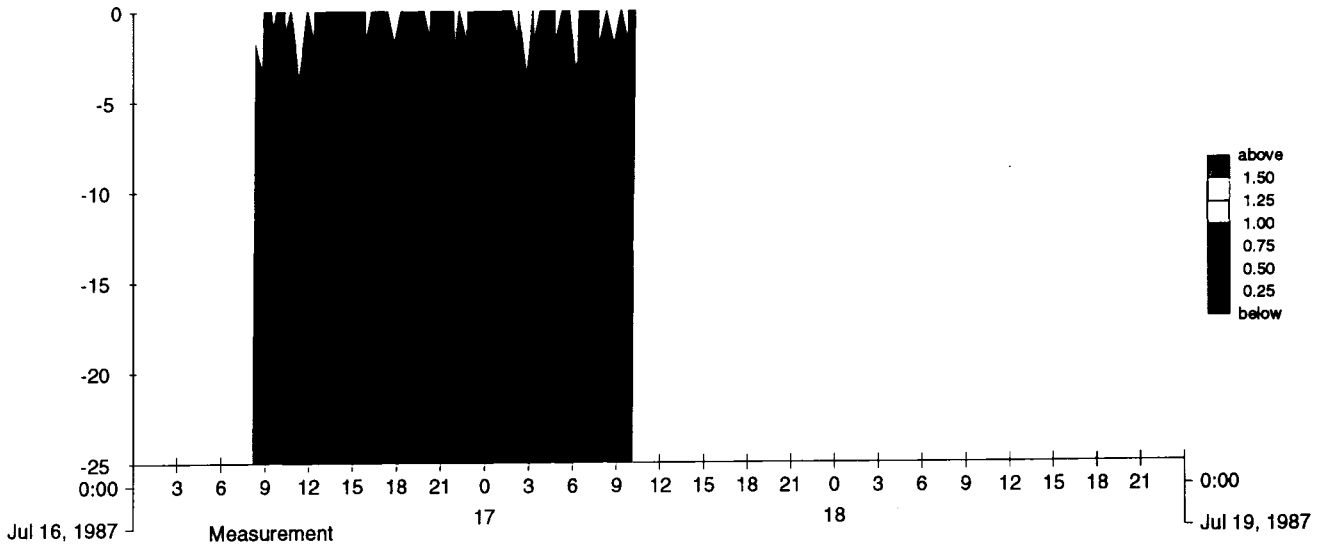


Measured and simulated velocity magnitude, Wet season - Neap tide
Station 1; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.24





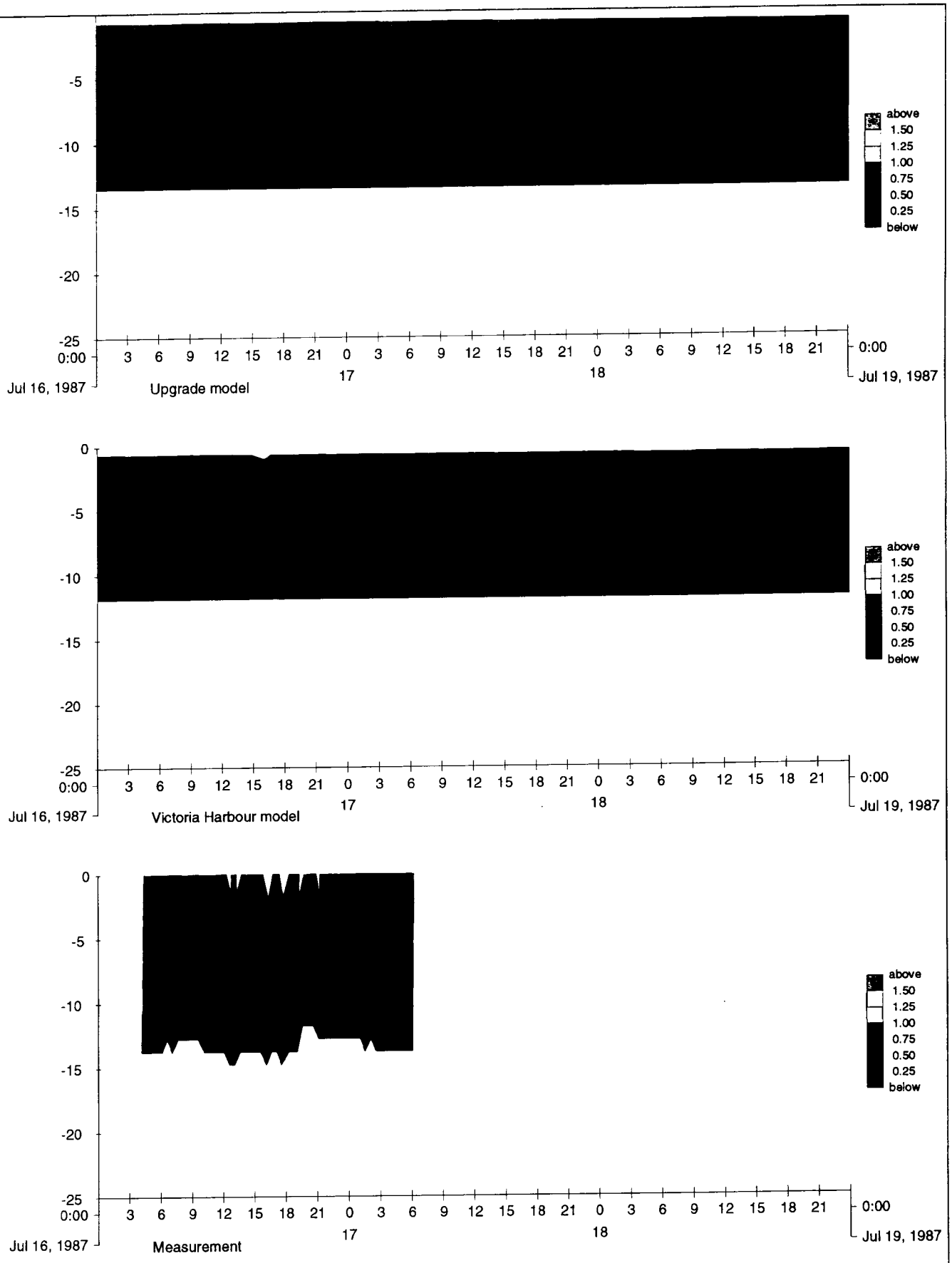


Measured and simulated velocity magnitude, Wet season - Neap tide
Station 2; Victoria Harbour measurement campaign

DELFT HYDRAULICS

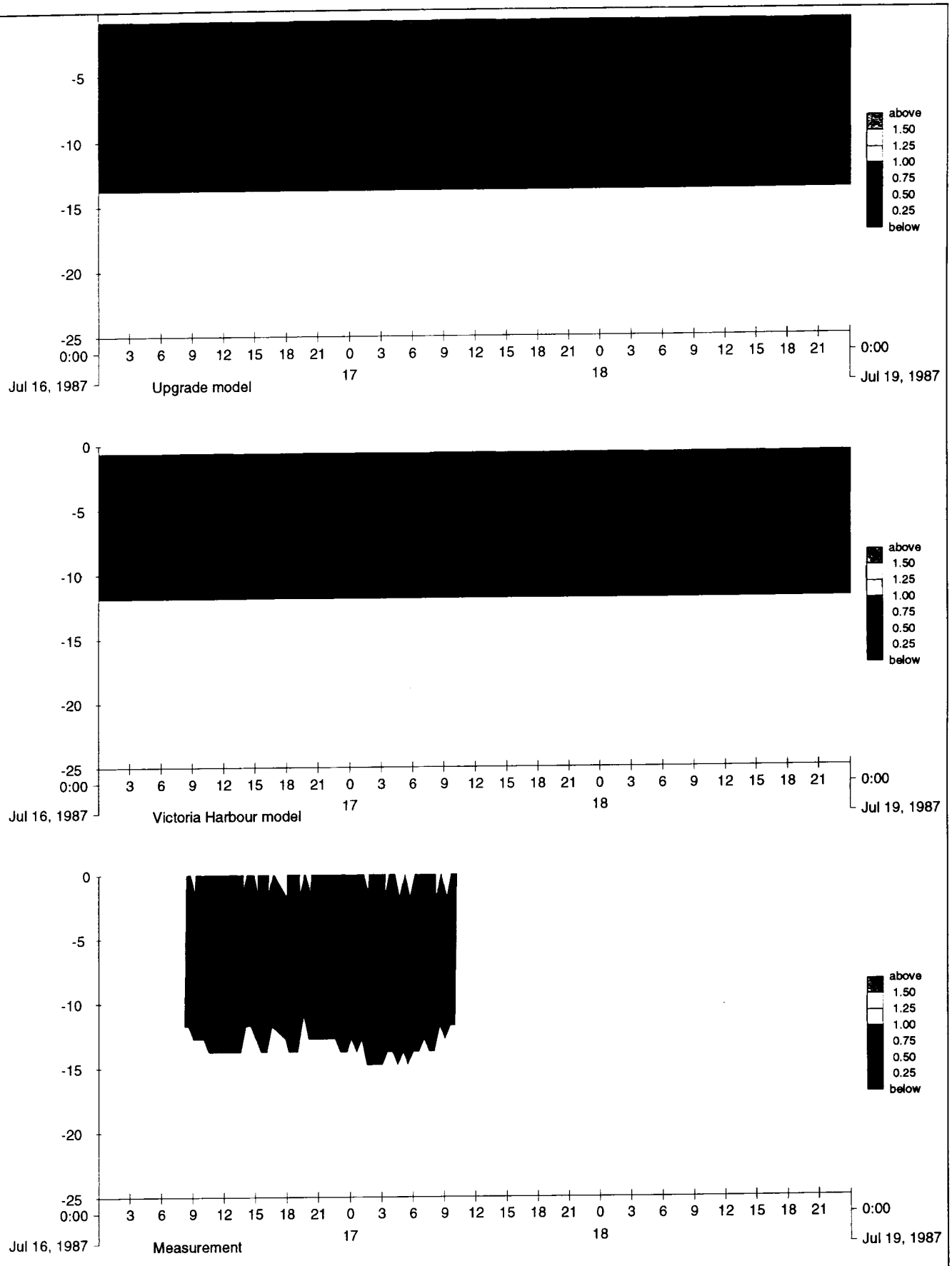
Z 2455.00

Fig: 2.25



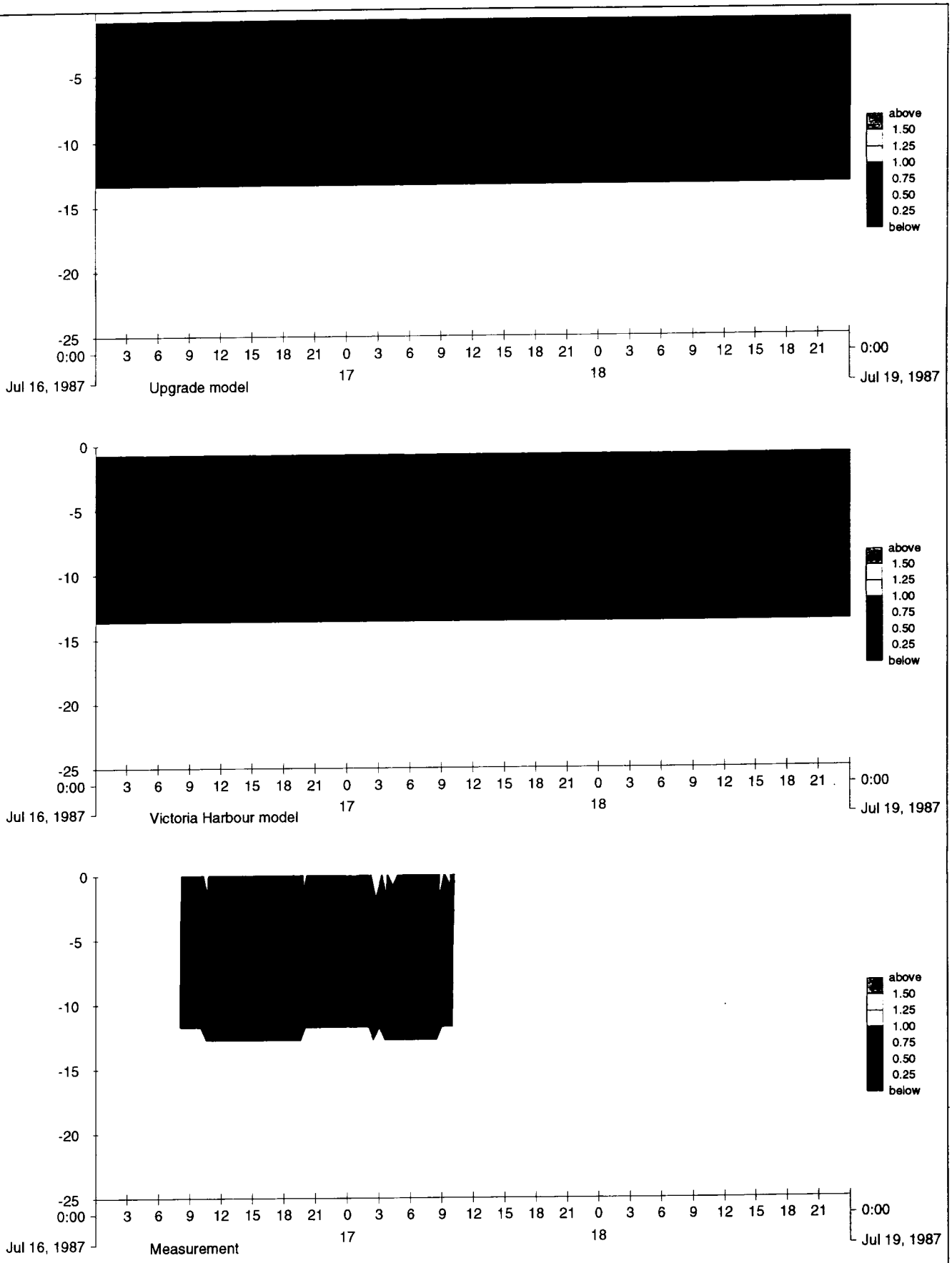
Measured and simulated velocity magnitude, Wet season - Neap tide
Station 4; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.26



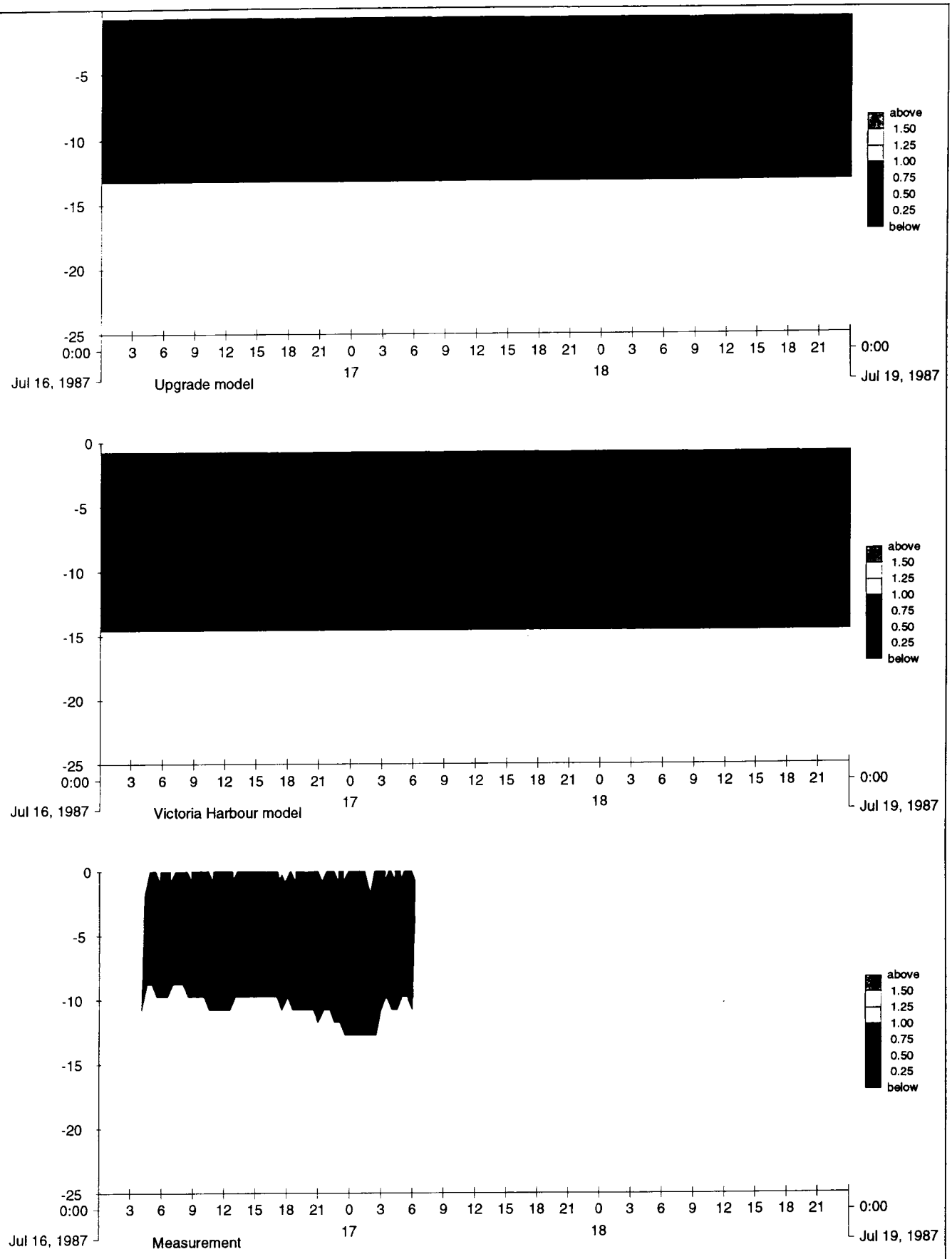
Measured and simulated velocity magnitude, Wet season - Neap tide
Station 6; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.27



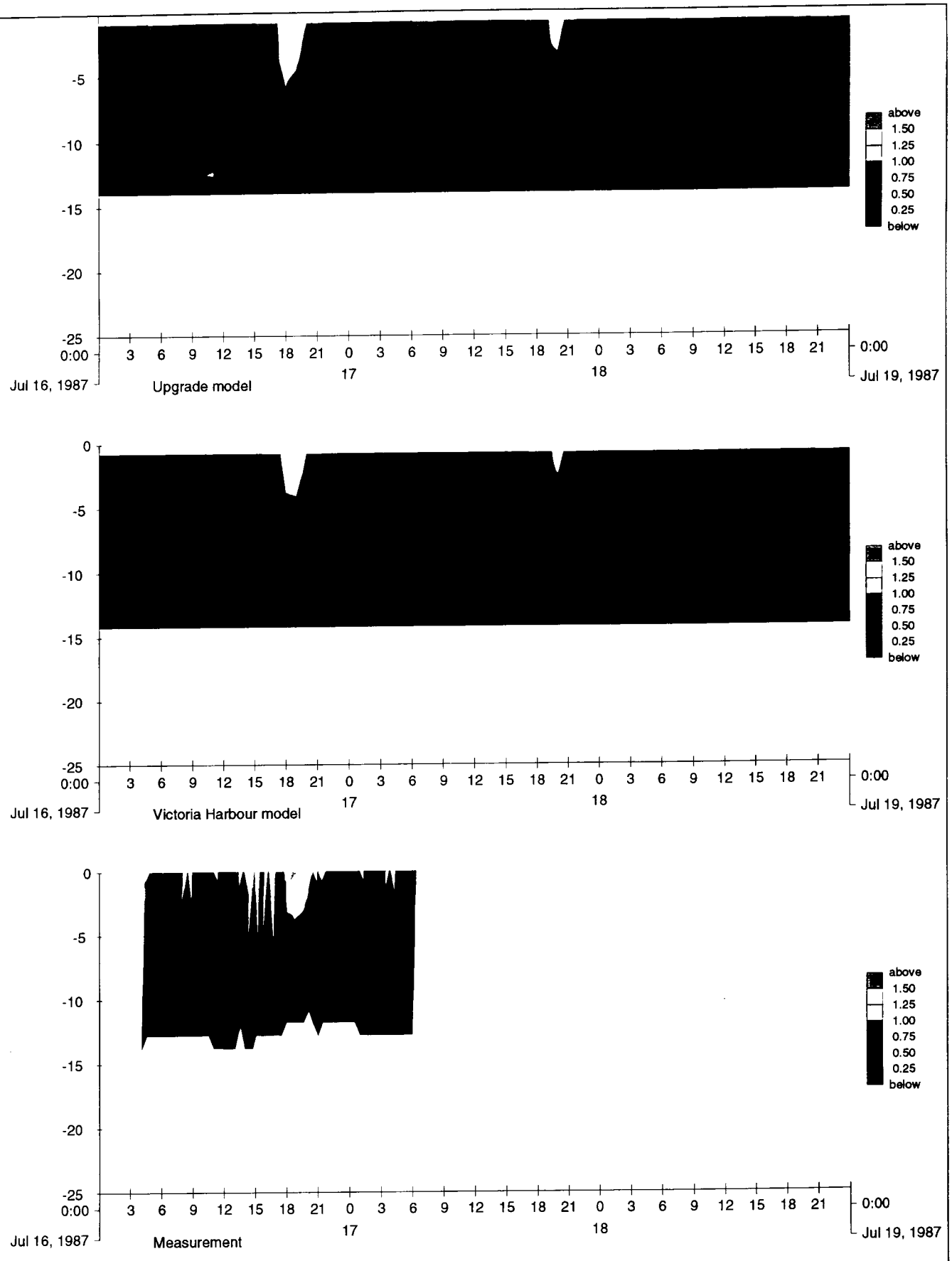
Measured and simulated velocity magnitude, Wet season - Neap tide
Station 8; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.28



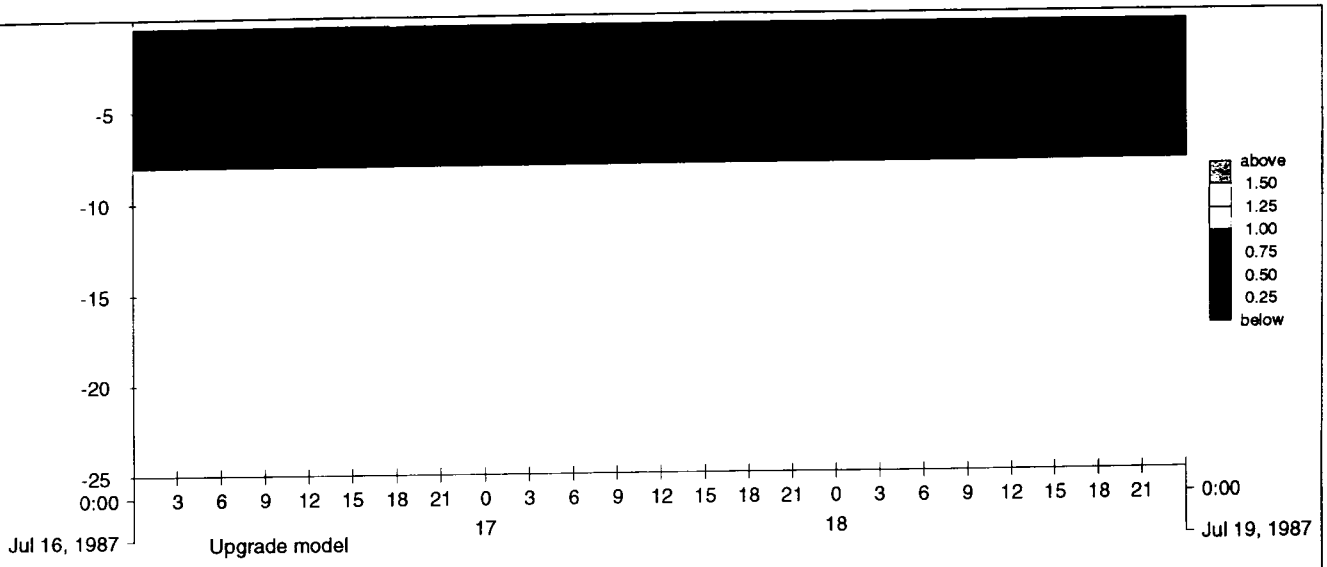
Measured and simulated velocity magnitude, Wet season - Neap tide
Station 13; Victoria Harbour measurement campaign

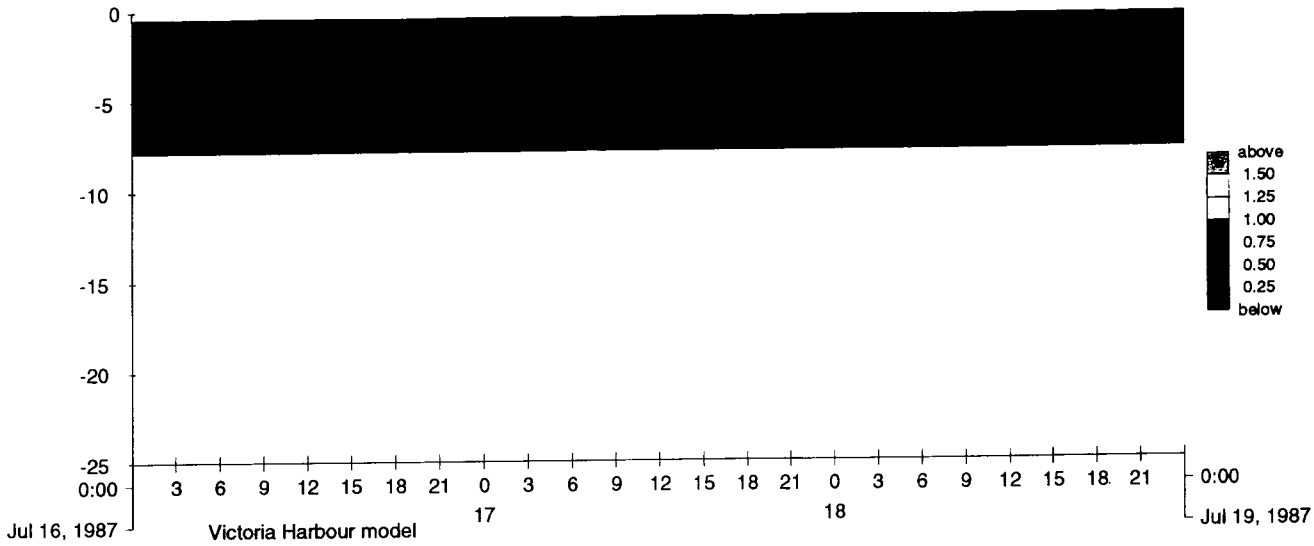
DELFT HYDRAULICS | Z 2455.00 | Fig: 2.29

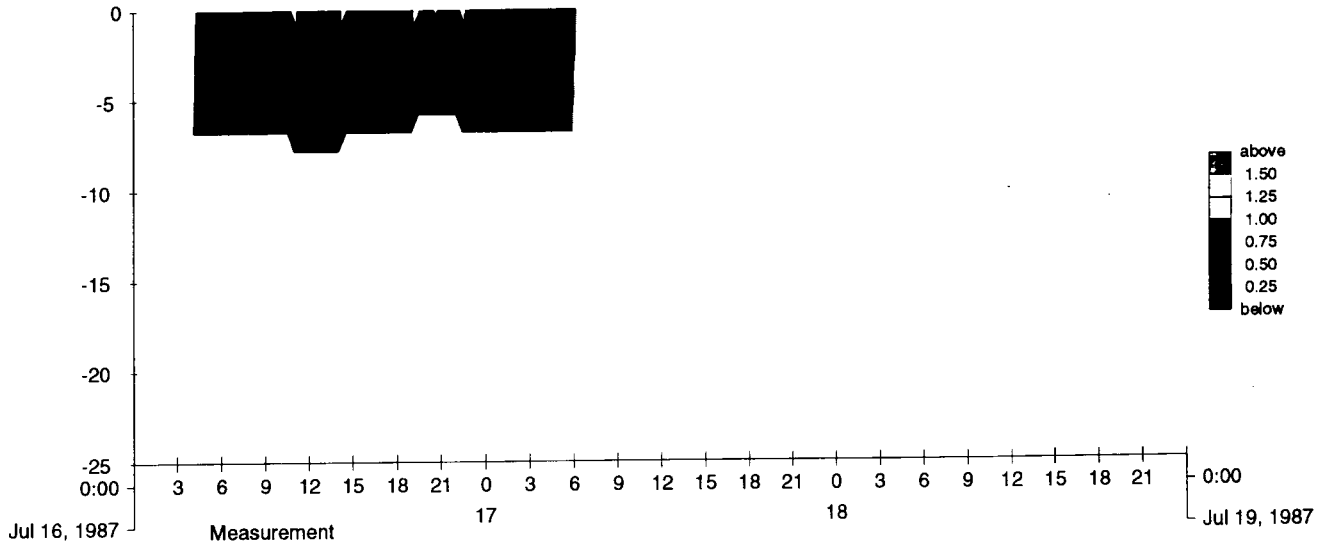


Measured and simulated velocity magnitude, Wet season - Neap tide
Station 15; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.30

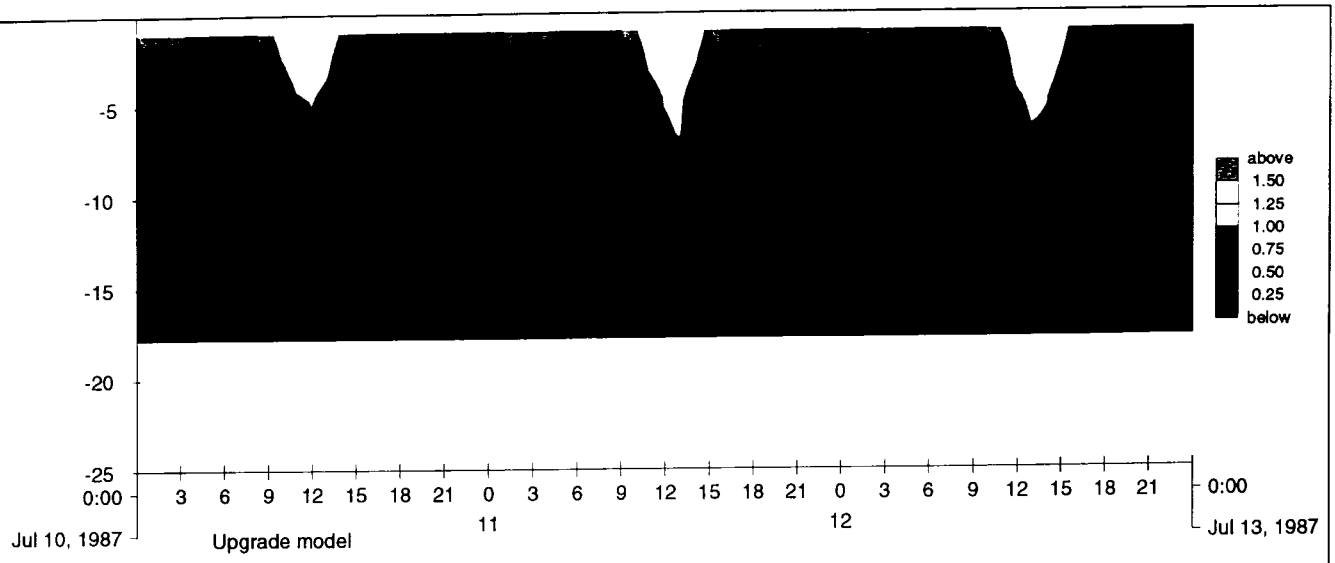


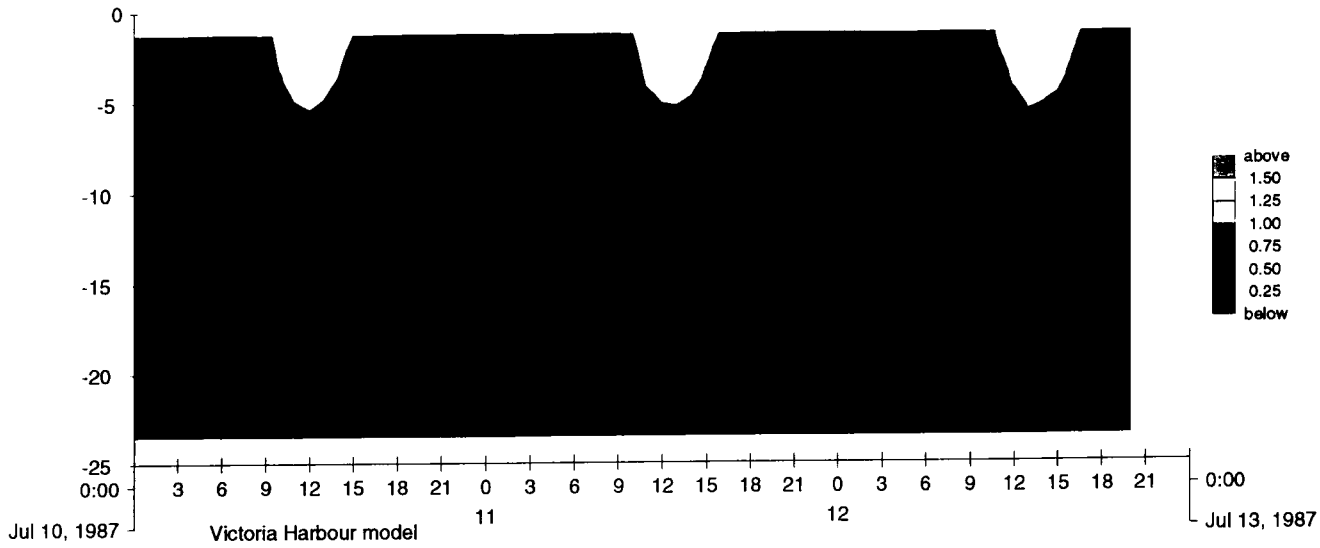


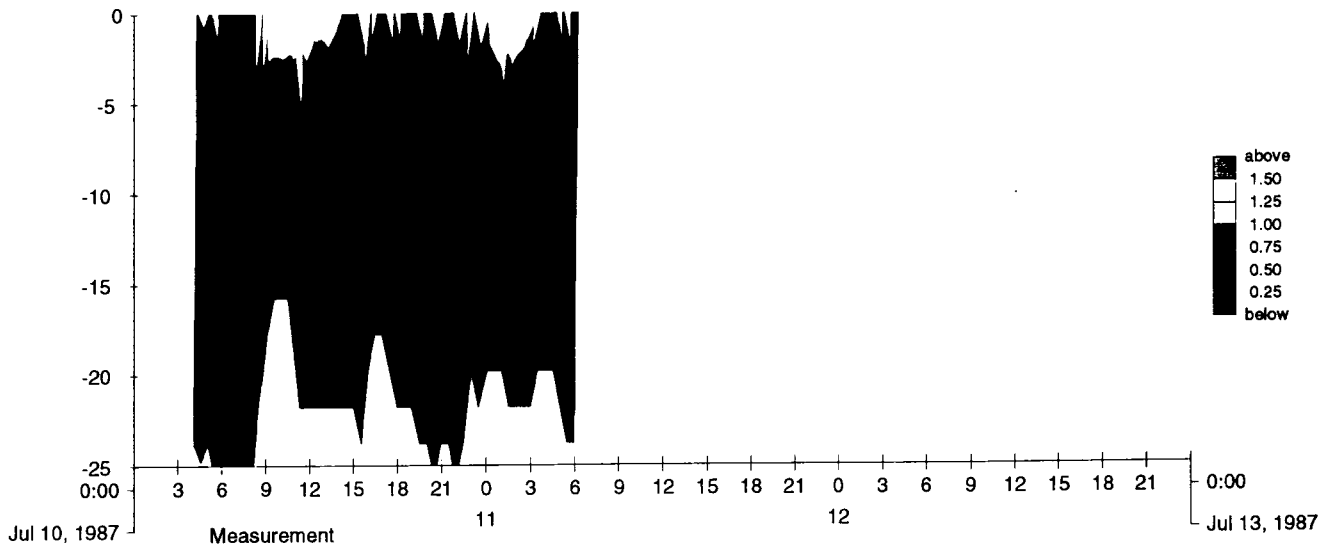


Measured and simulated velocity magnitude, Wet season - Neap tide
Station 17; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.31

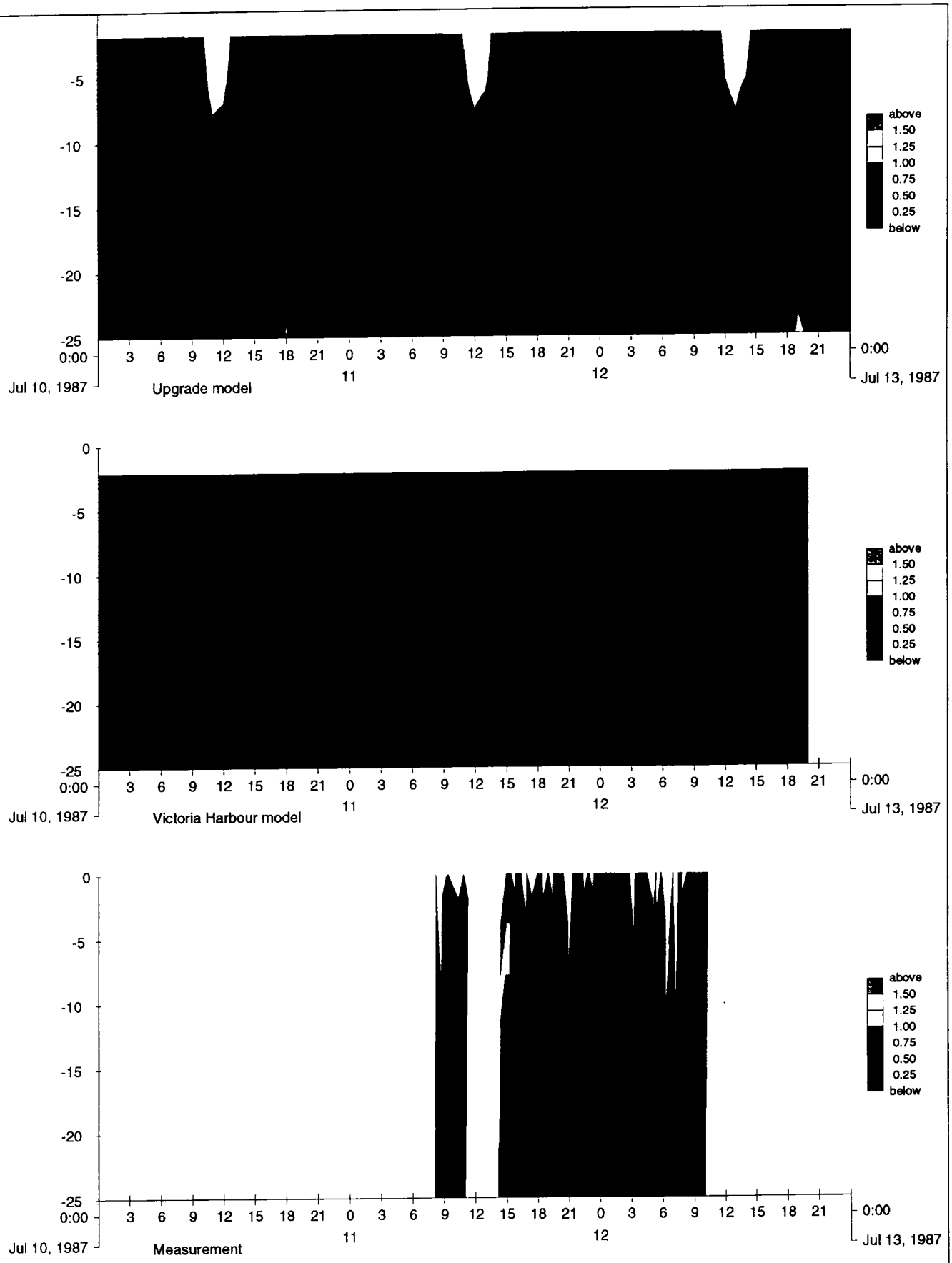






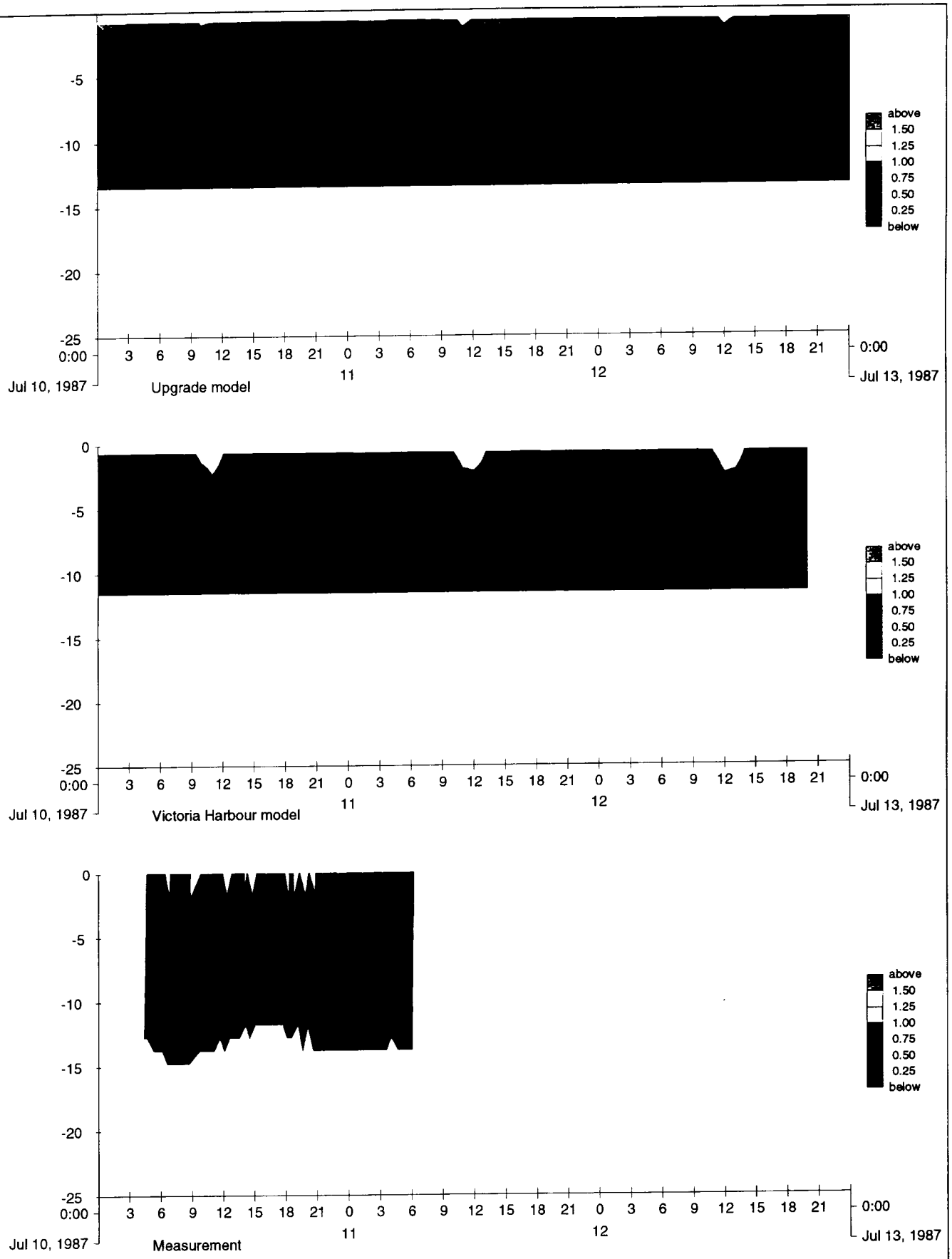
Measured and simulated velocity magnitude, Wet season - Spring tid
Station 1; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.32



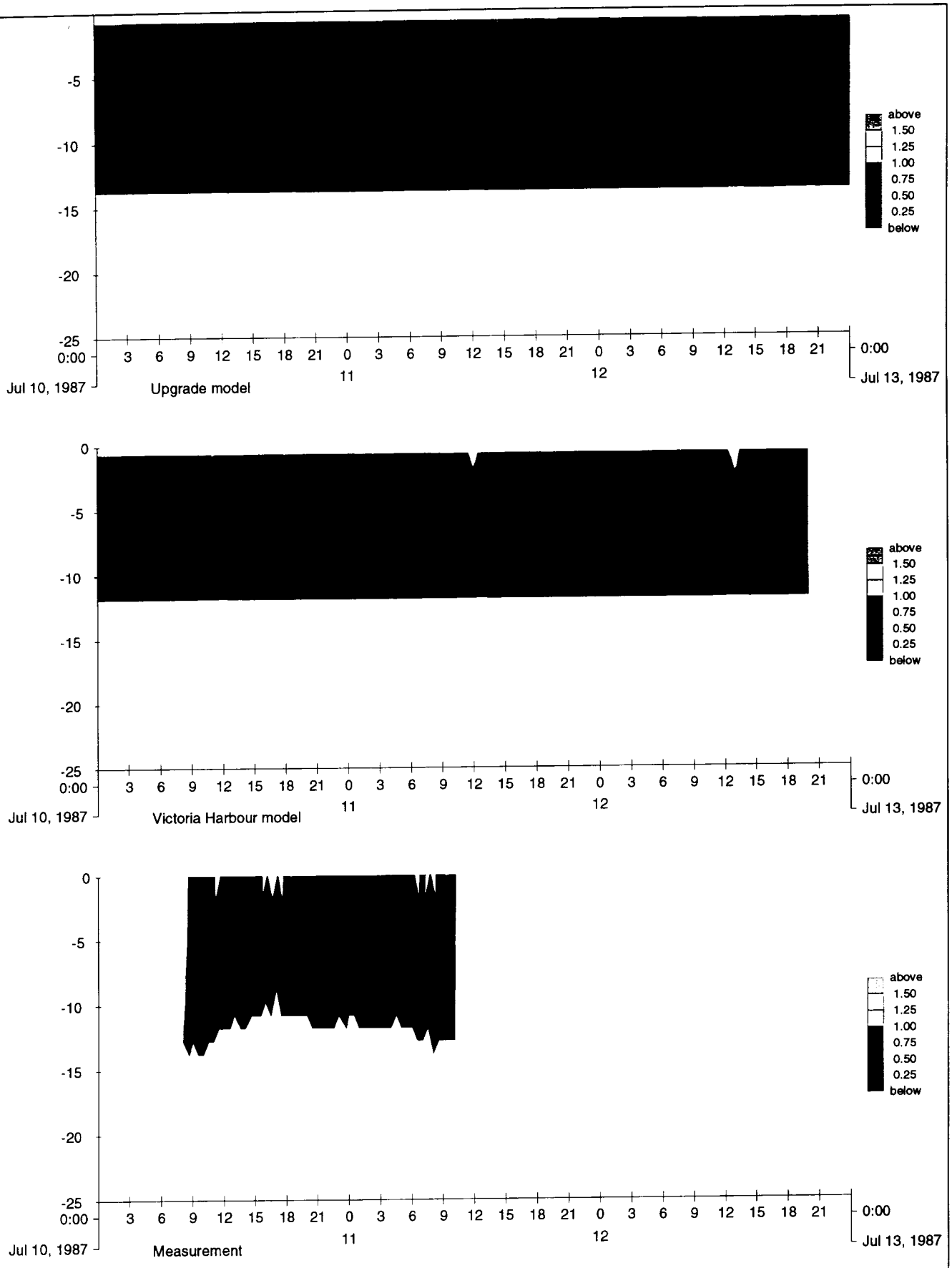
Measured and simulated velocity magnitude, Wet season - Spring tid
Station 2; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.33



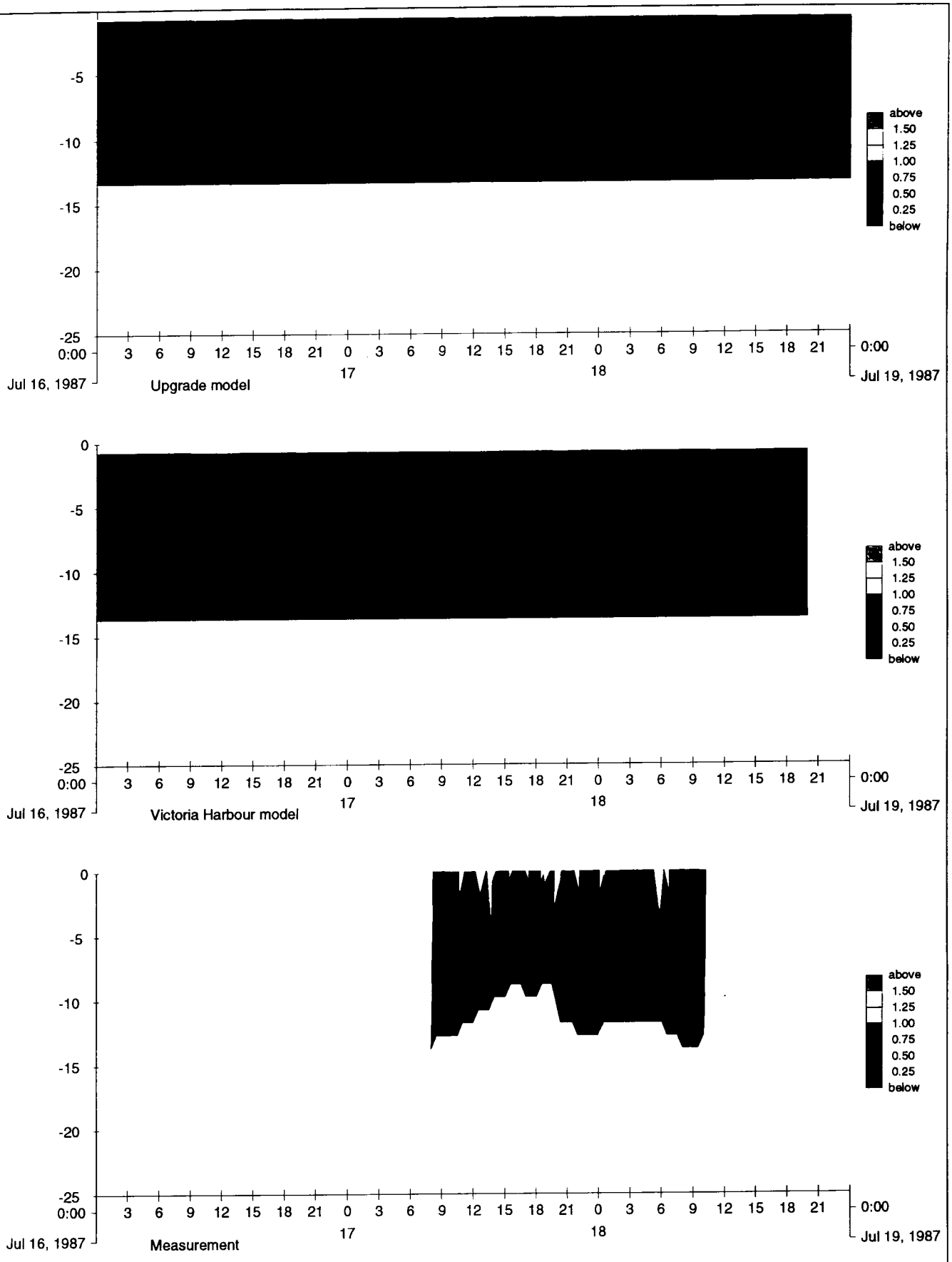
Measured and simulated velocity magnitude, Wet season - Spring tid
Station 4; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.34



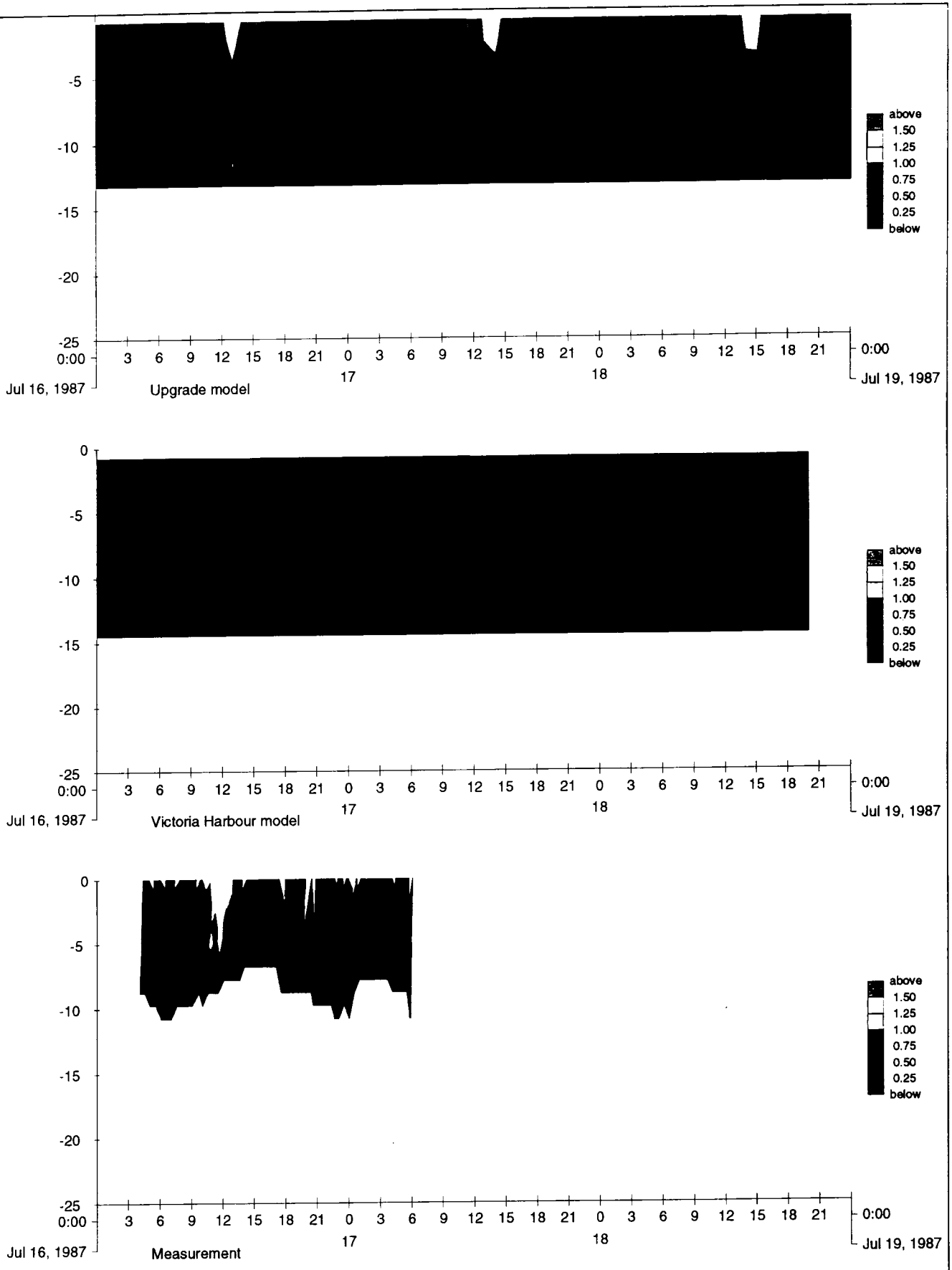
Measured and simulated velocity magnitude, Wet season - Spring tid
Station 6; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.35



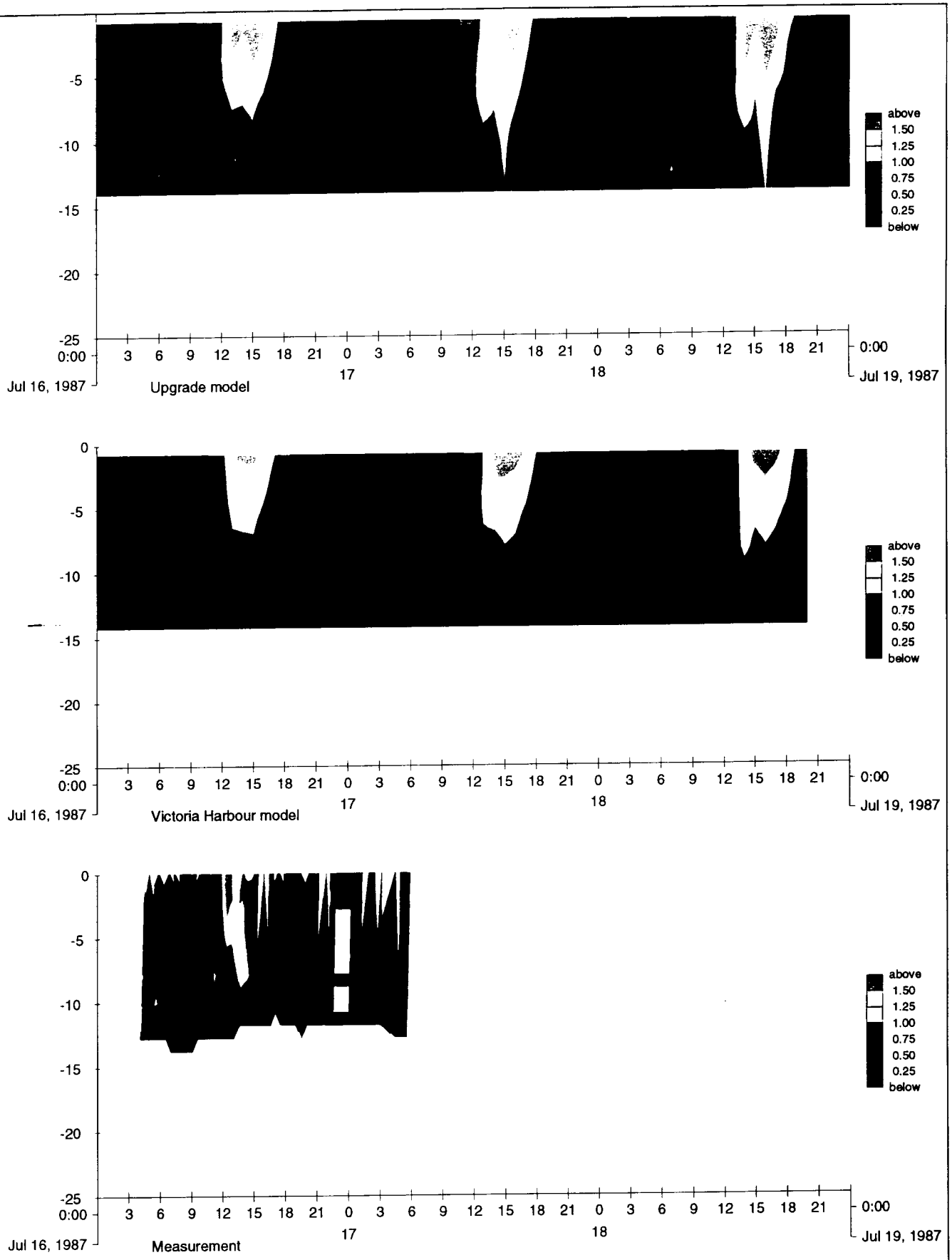
Measured and simulated velocity magnitude, Wet season - Spring tid
Station 8; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.36



Measured and simulated velocity magnitude, Wet season - Spring tid
Station 13; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.37

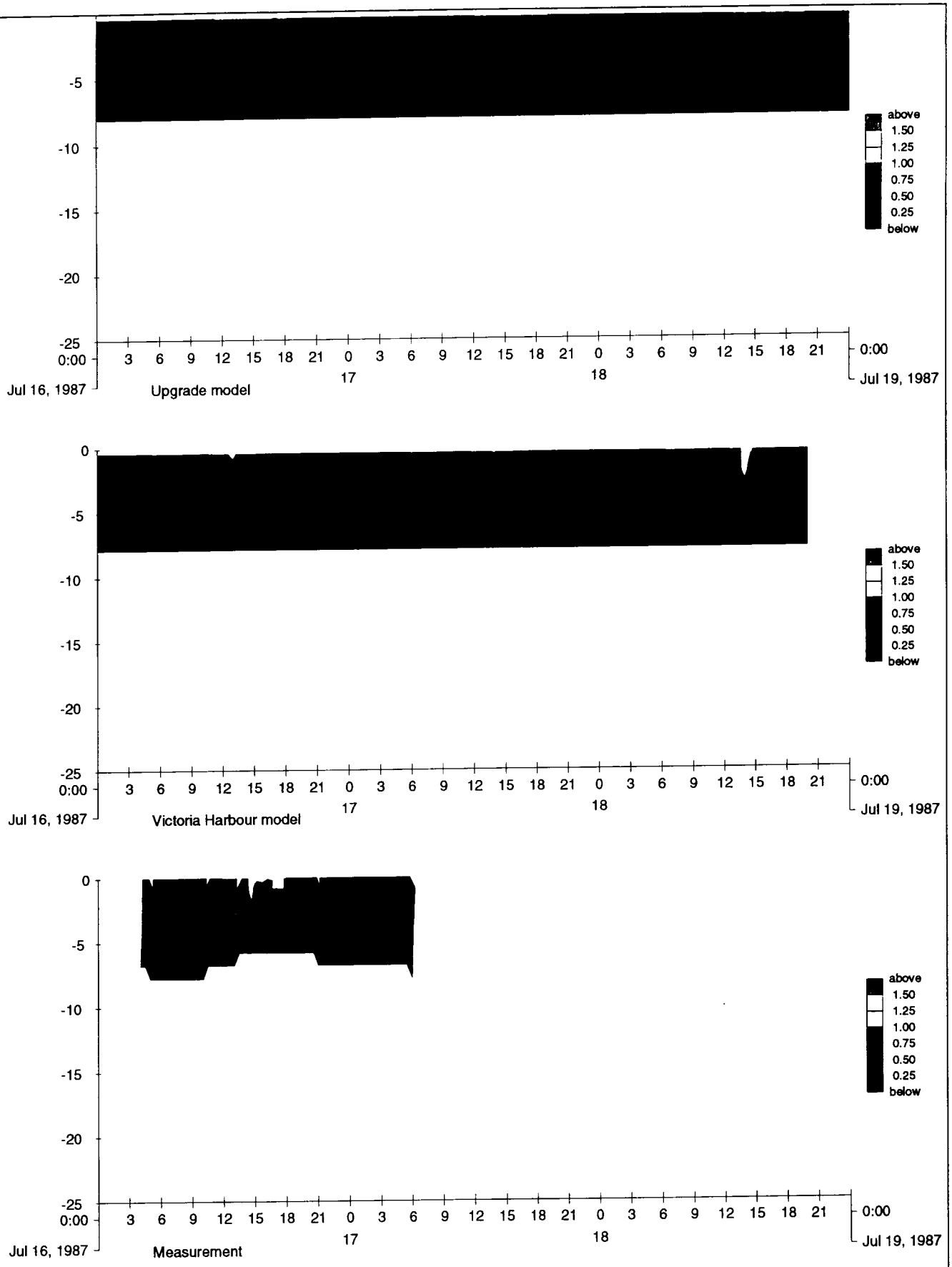


Measured and simulated velocity magnitude, Wet season - Spring tid
Station 15; Victoria Harbour measurement campaign

DELFT HYDRAULICS

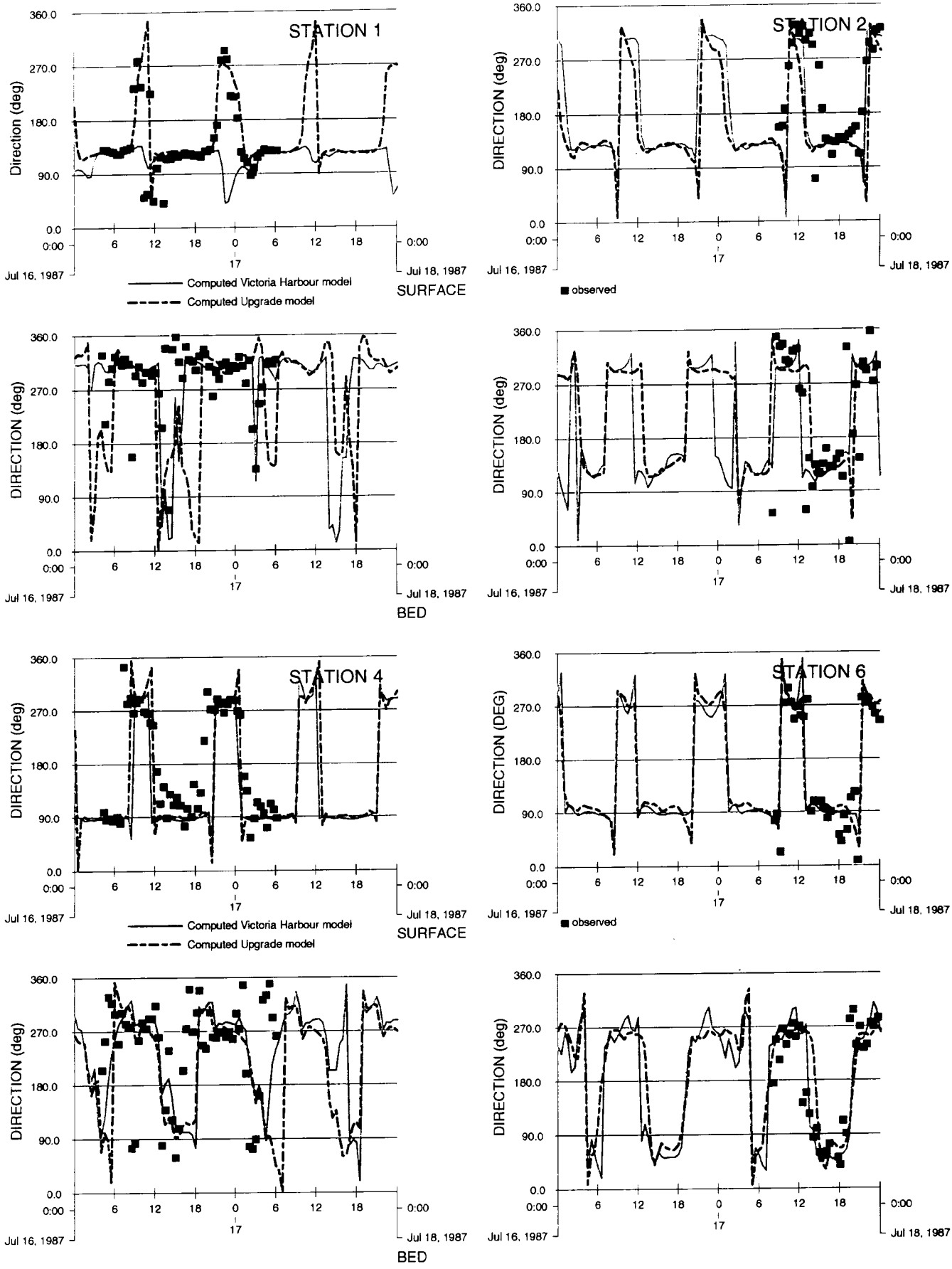
Z 2455.00

Fig: 2.38



Measured and simulated velocity magnitude, Wet season - Spring tid
Station 17; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.39



Shatin treatment works stage III extension

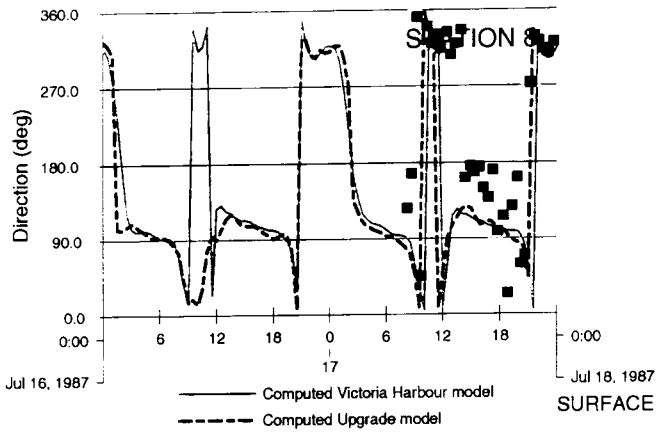
Computed and observed velocity directions; Wet Season Neap Tide

Stations 1, 2, 4 and 6

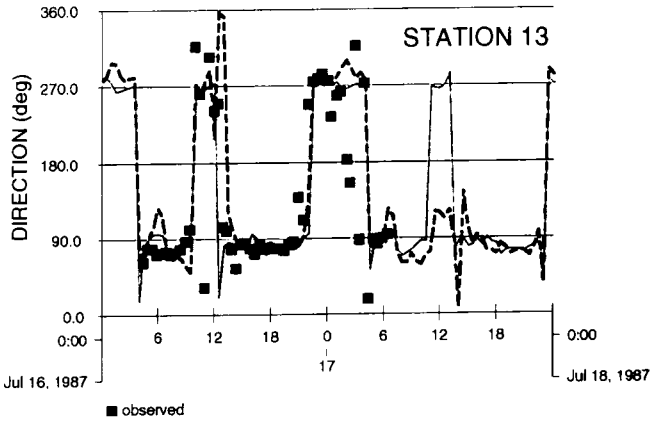
Delft3D-FLOW

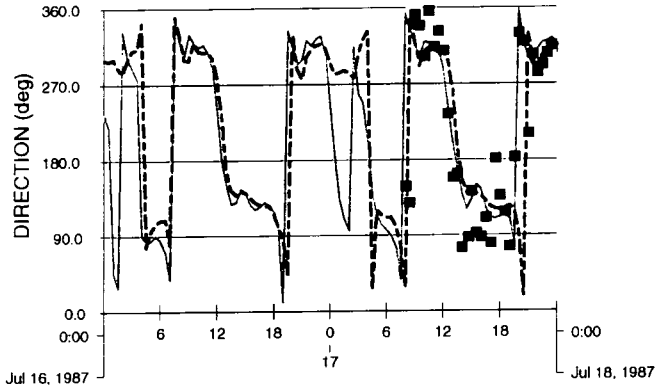
DELFT HYDRAULICS

Fig. 2.40



SURFACE





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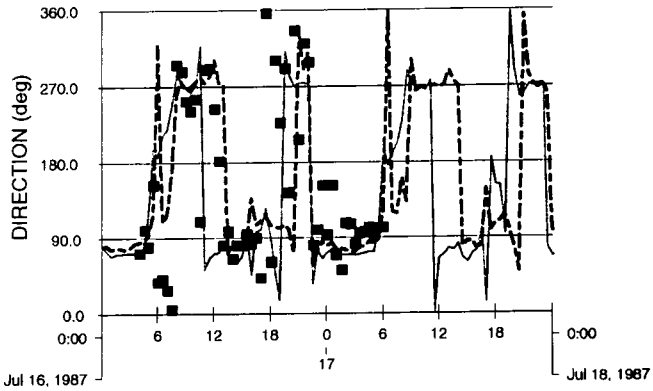
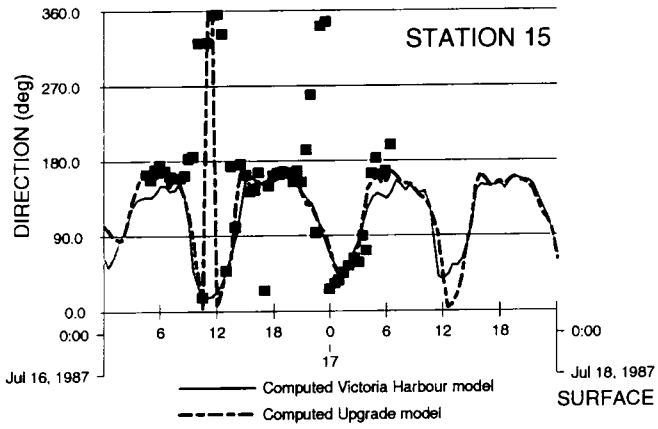
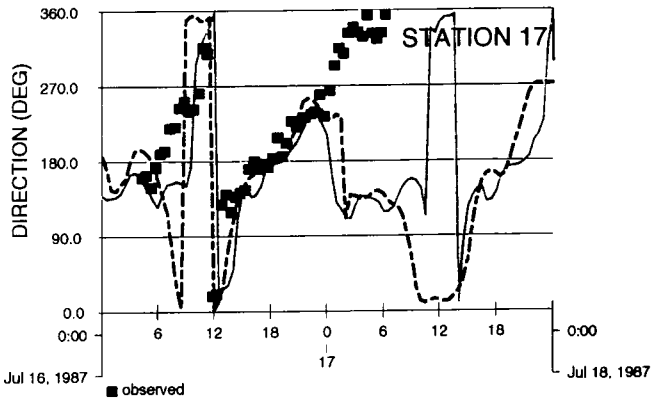
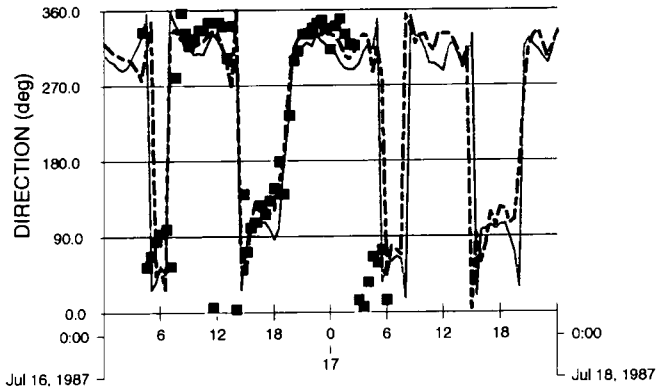


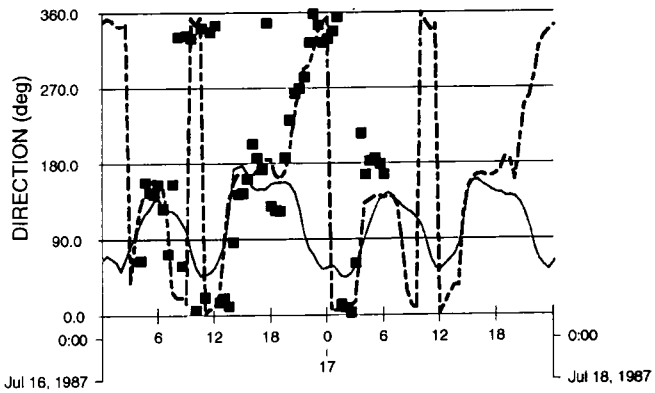


SURFACE





BED

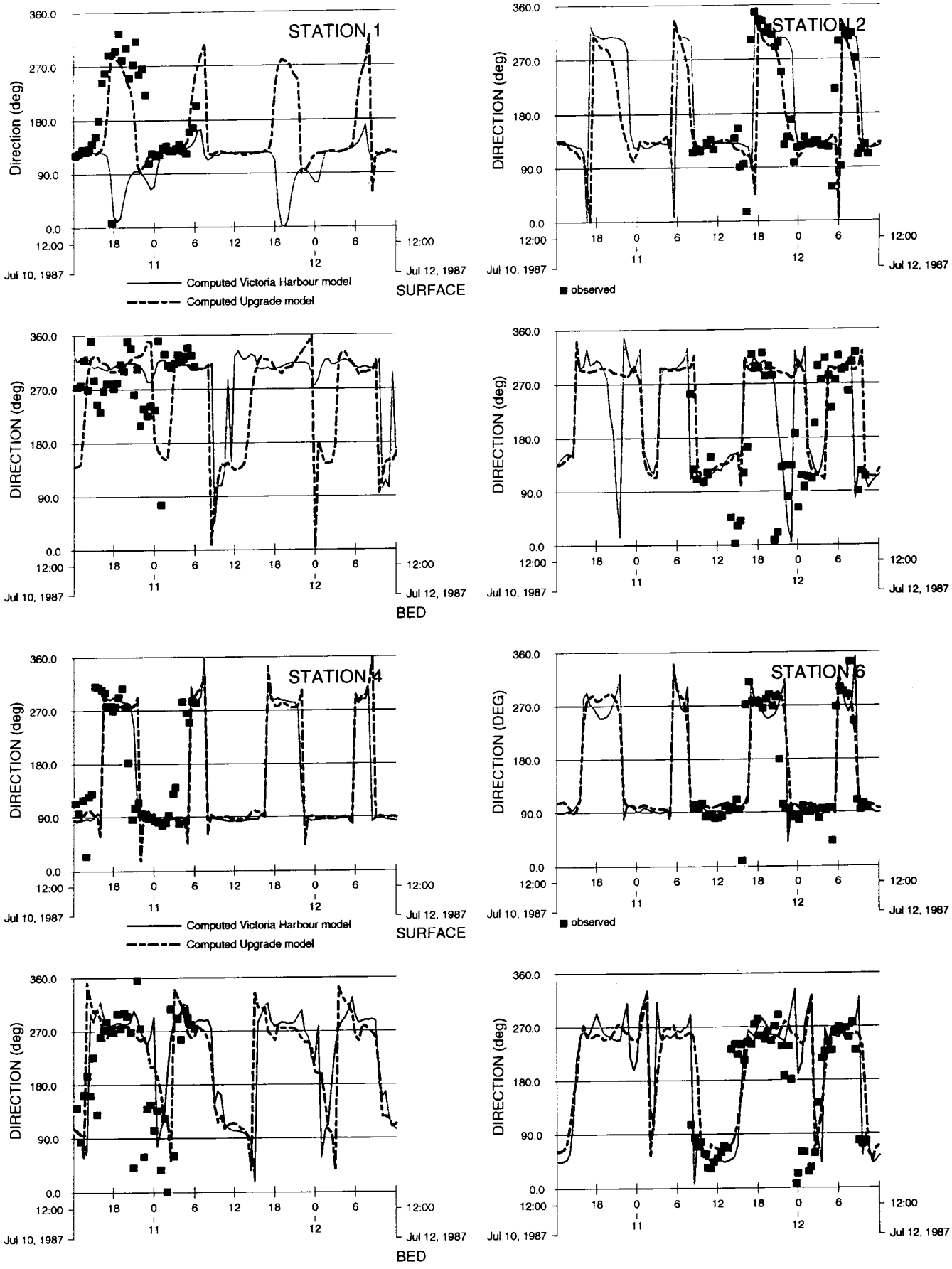


Shatin treatment works stage III extension
Computed and observed velocity directions; Wet Season Neap Tide
Stations 8, 13, 15 and 17

Delft3D-FLOW

DELFT HYDRAULICS

Fig. 2.41

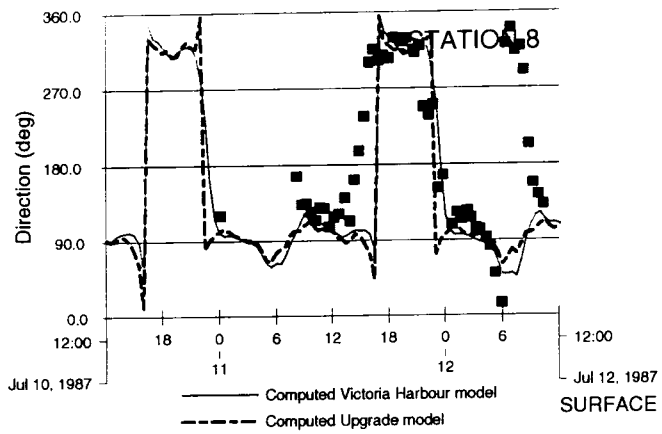


Shatin treatment works stage III extension
Computed and observed velocity directions; Wet Season Spring Tide
Stations 1, 2, 4 and 6

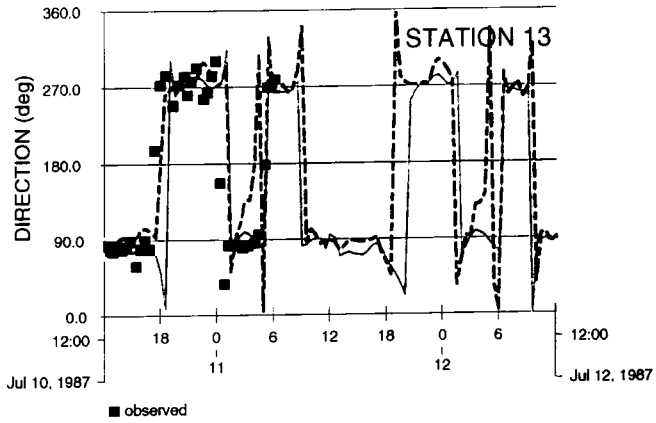
Delft3D-FLOW

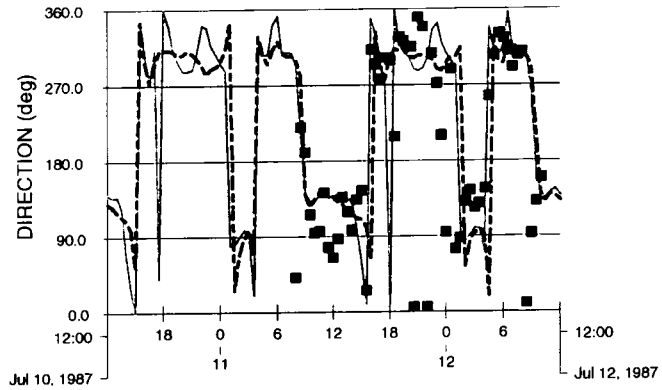
DELFT HYDRAULICS

Fig. 2.42



SURFACE





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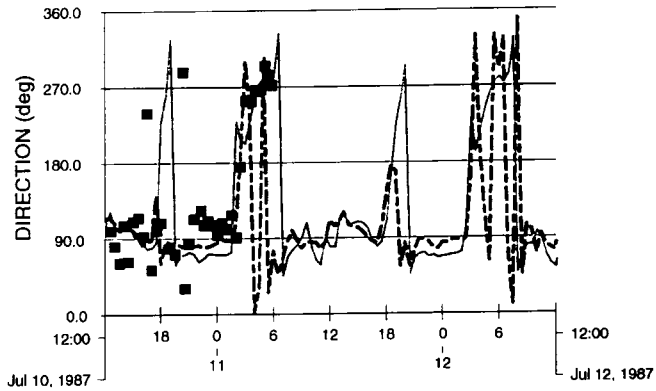
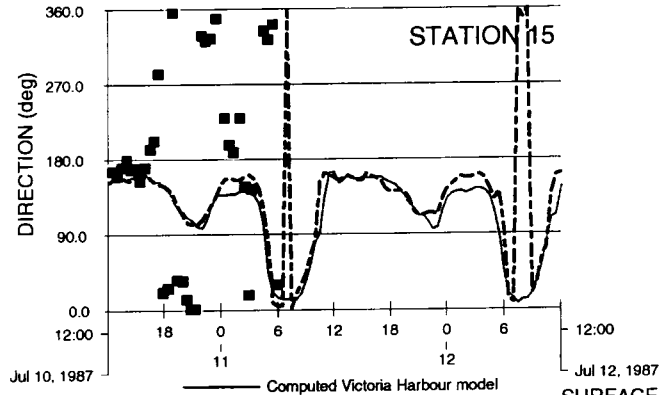
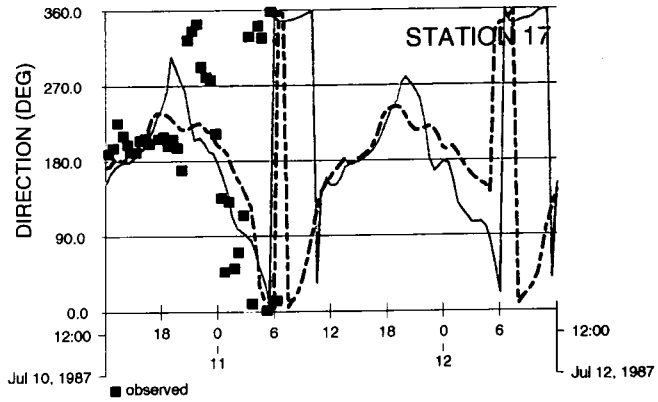
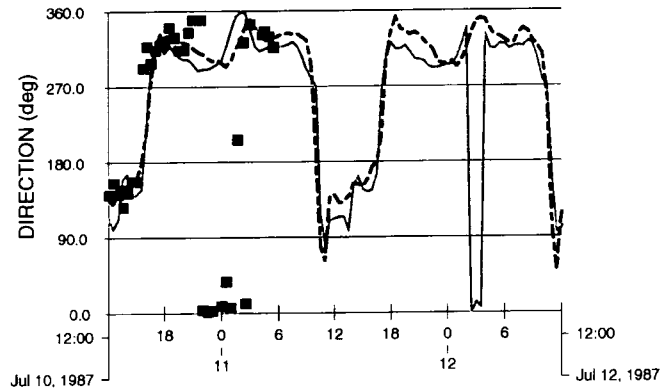


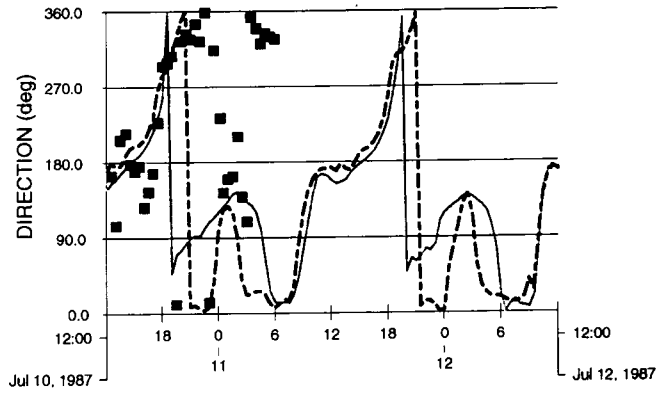


SURFACE





BED



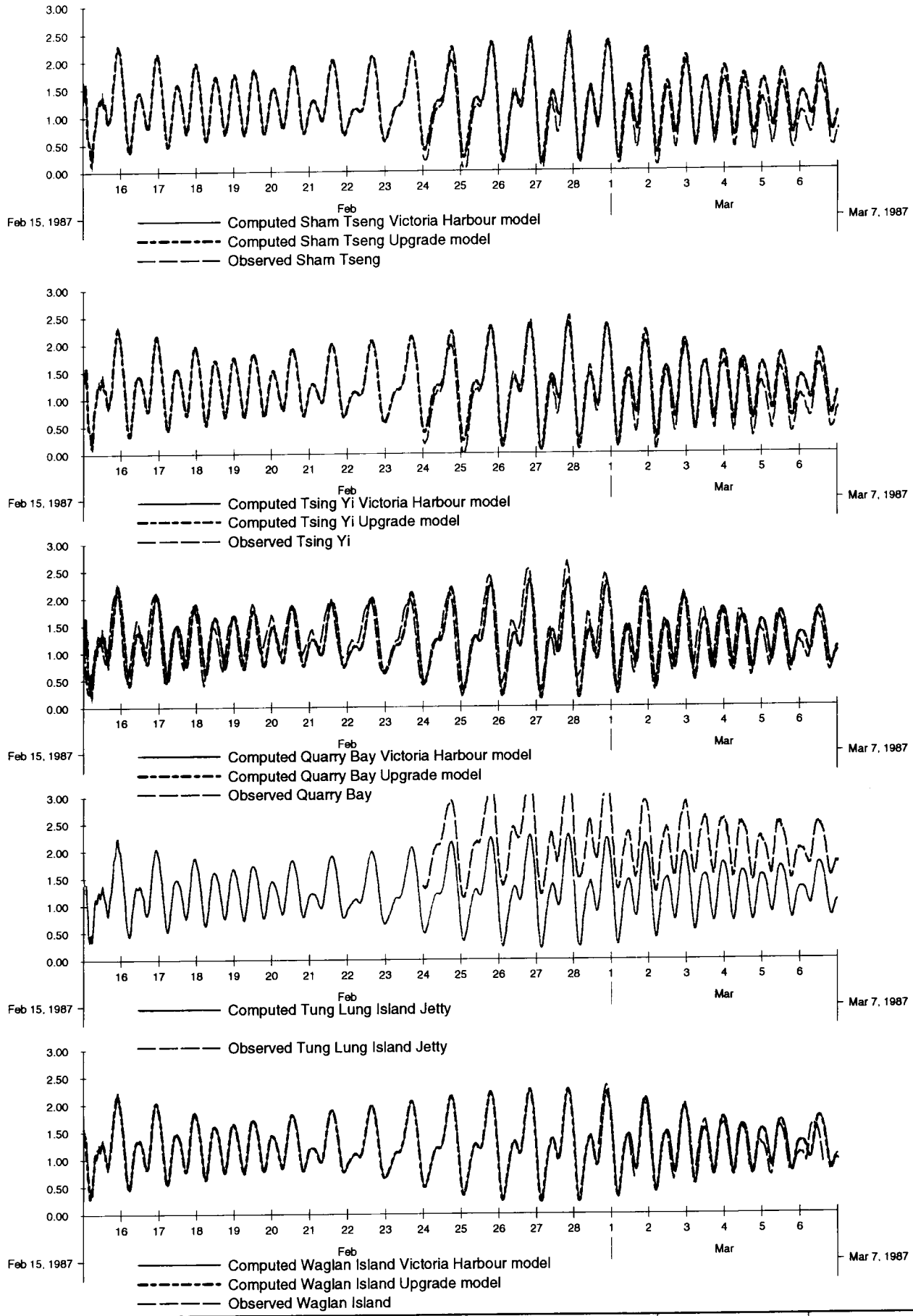
Shatin treatment works stage III extension
Computed and observed velocity directions; Wet Season Spring Tide
Stations 8, 13, 15 and 17

Delft3D-FLOW

DELFT HYDRAULICS

Fig. 2.43

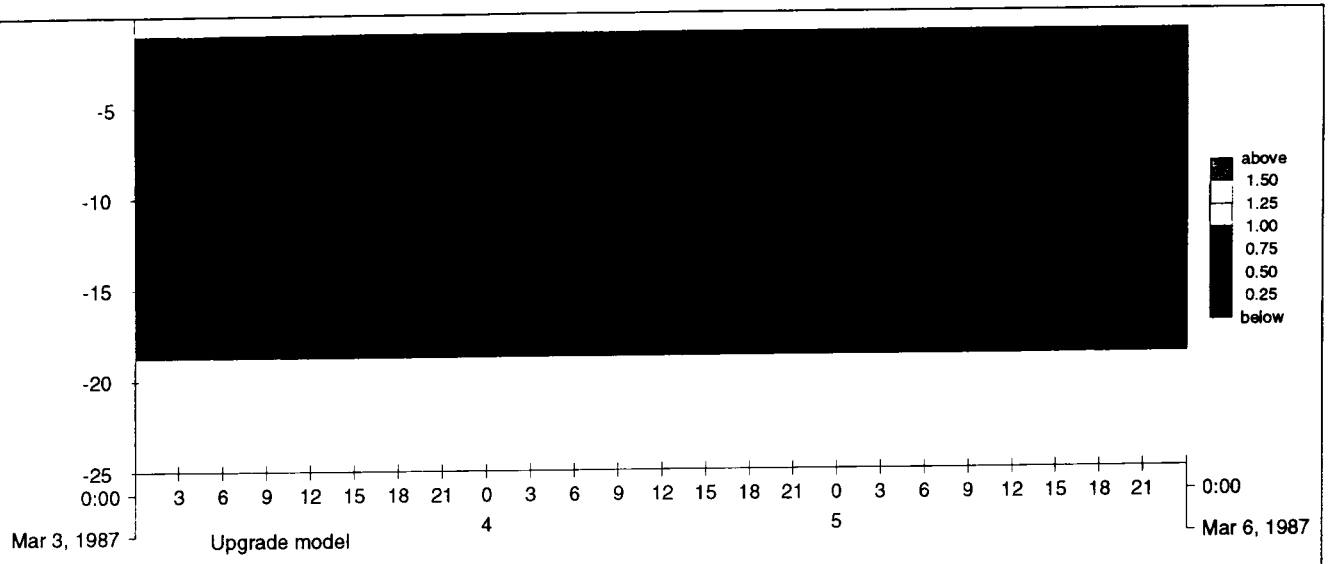
DELFT HYDRAULICS

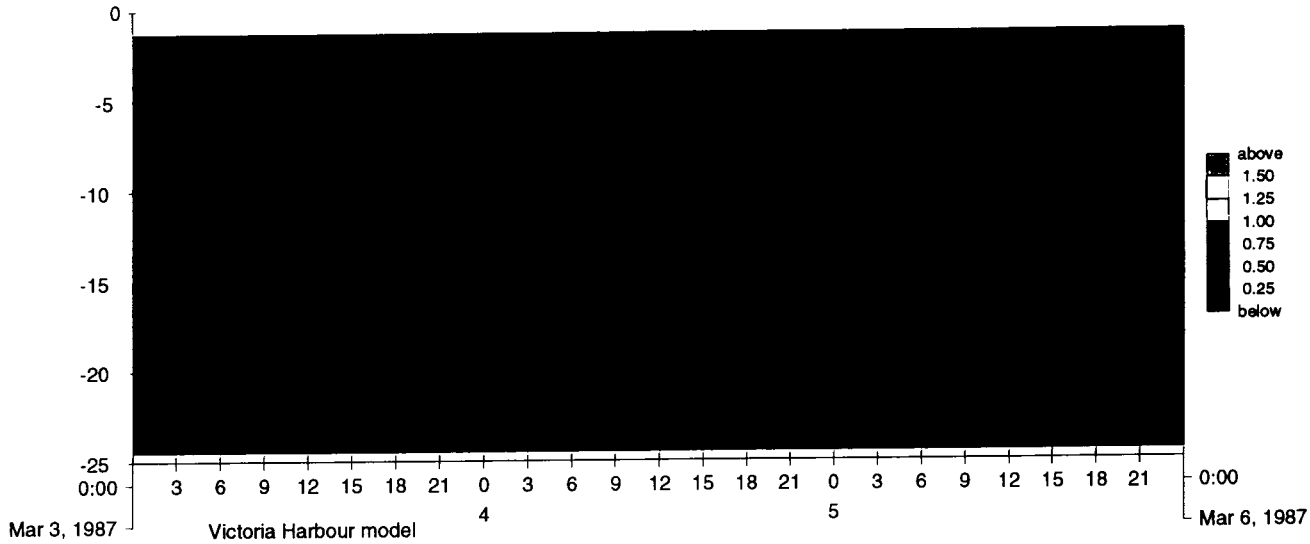


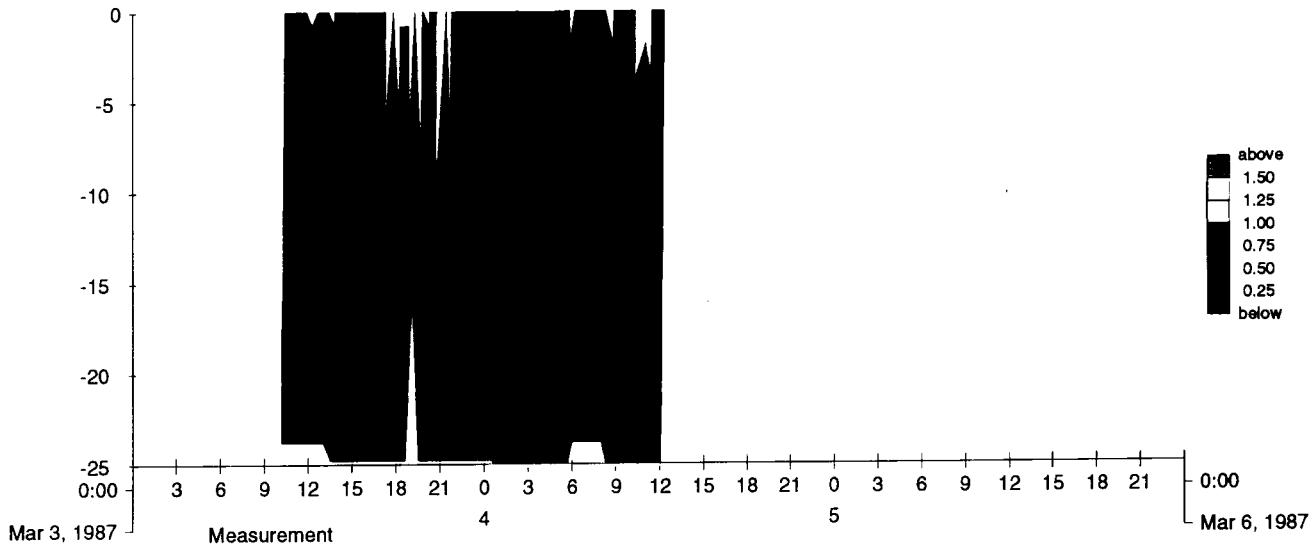
Shatin treatment works stage III extension
Computed and observed water levels, February/March 1987
Dry Season

DELFT HYDRAULICS

Fig: 2.44

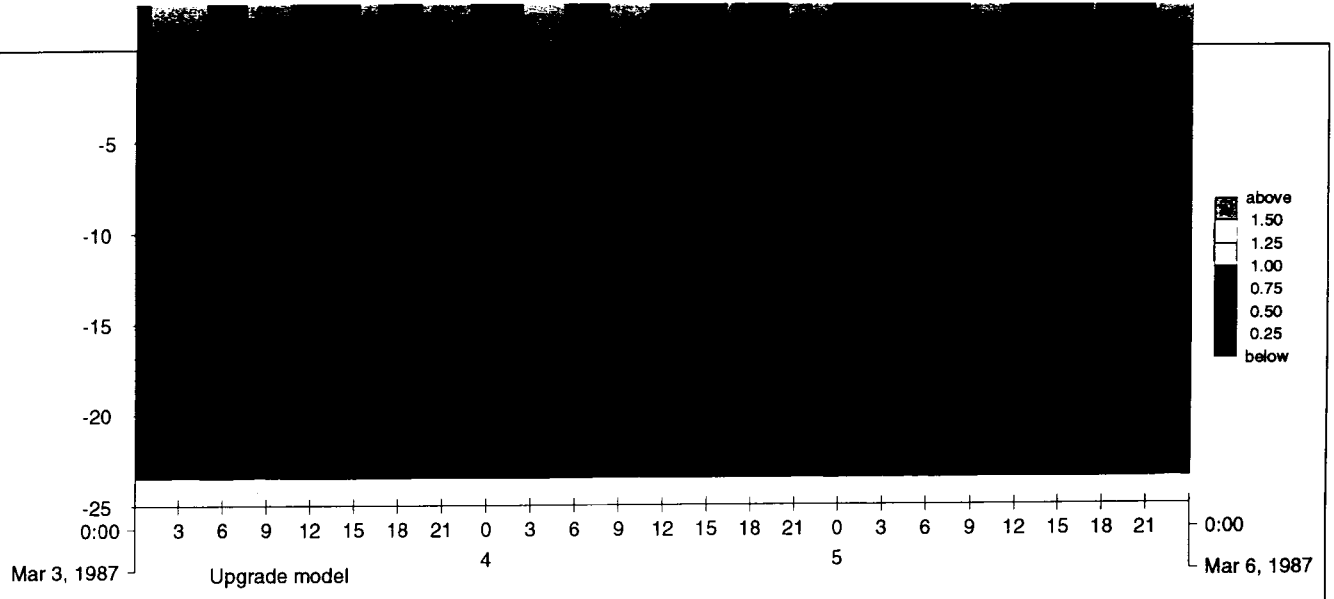


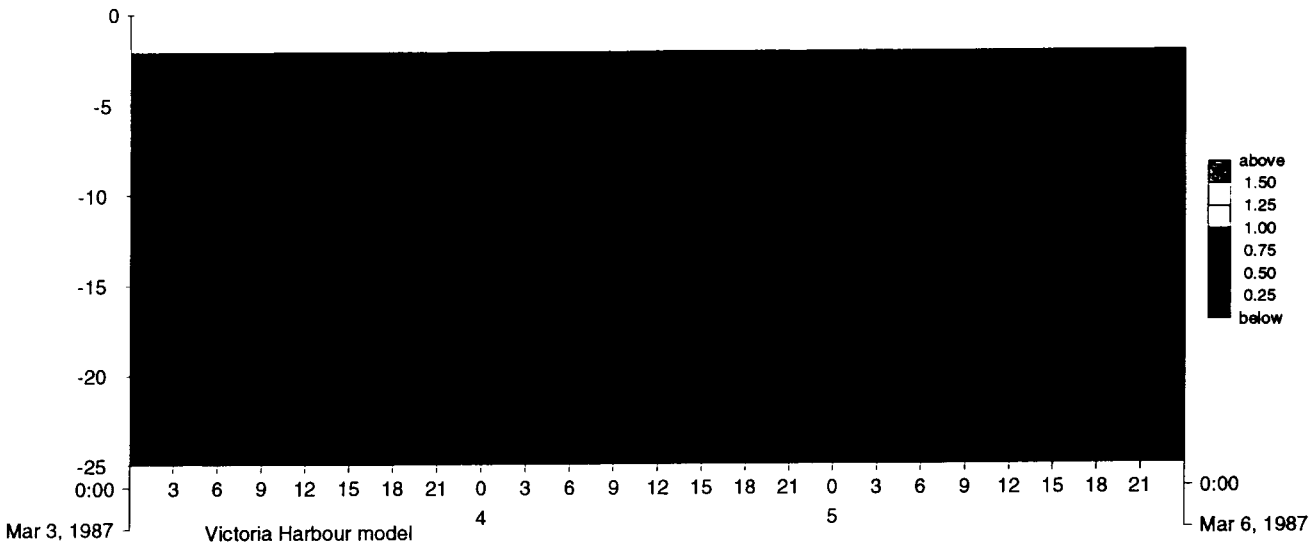


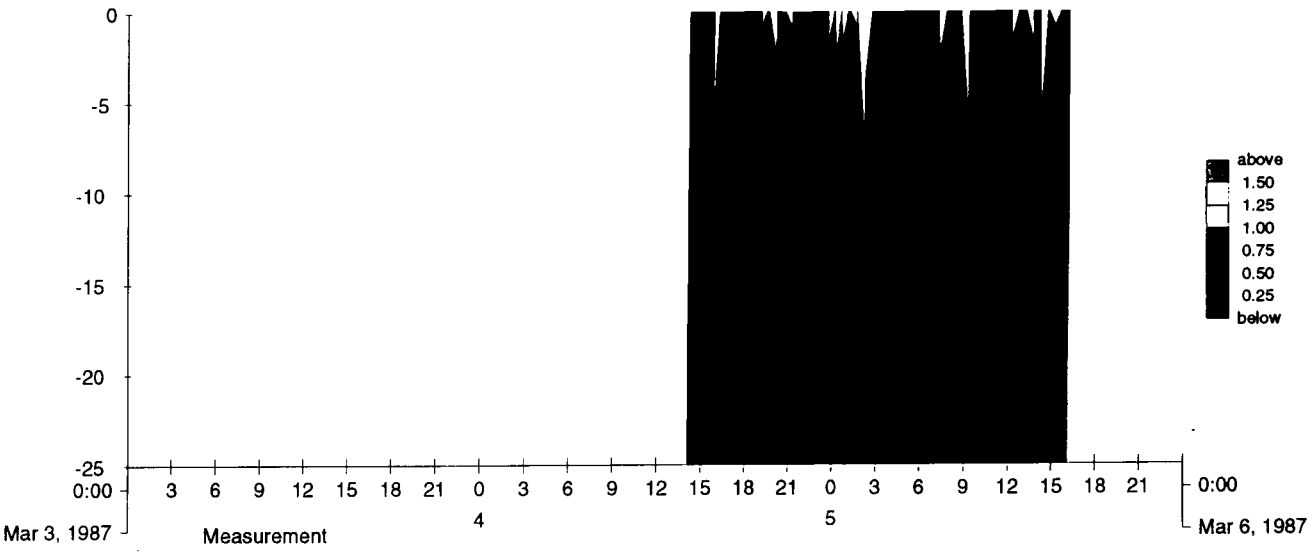


Measured and simulated velocity magnitude, Dry season - Neap tide
Station 1; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.45

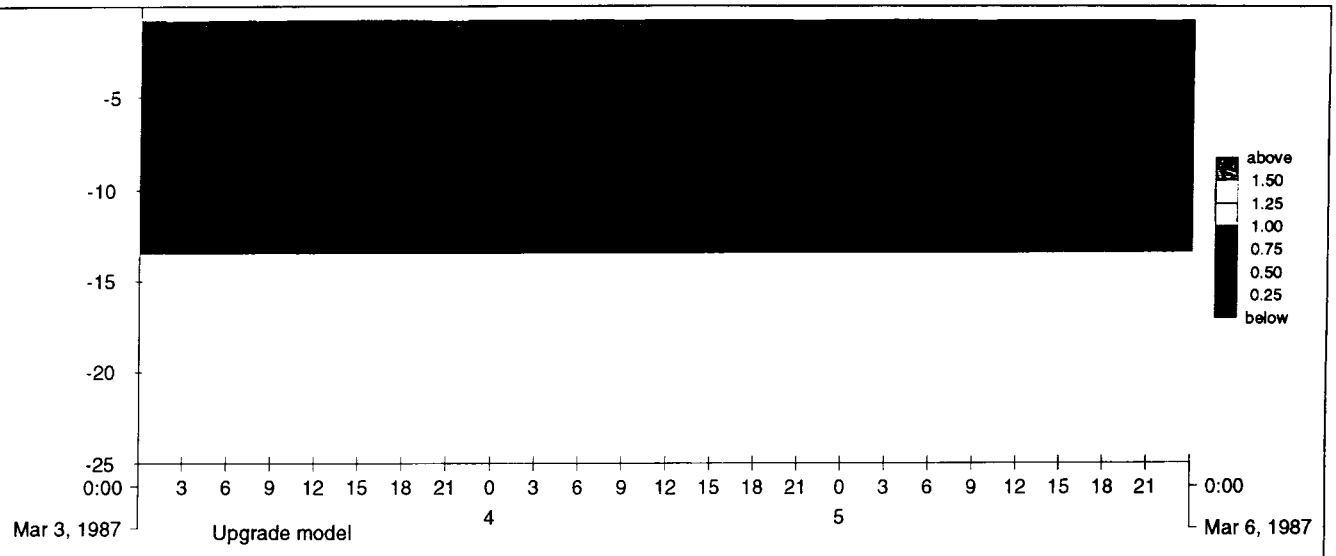


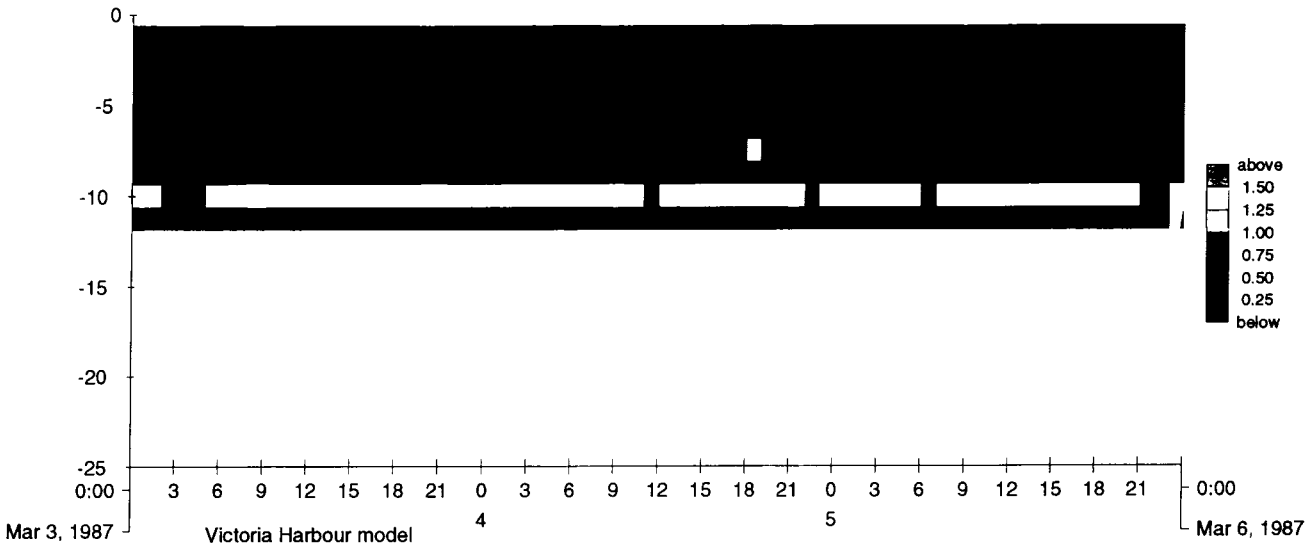


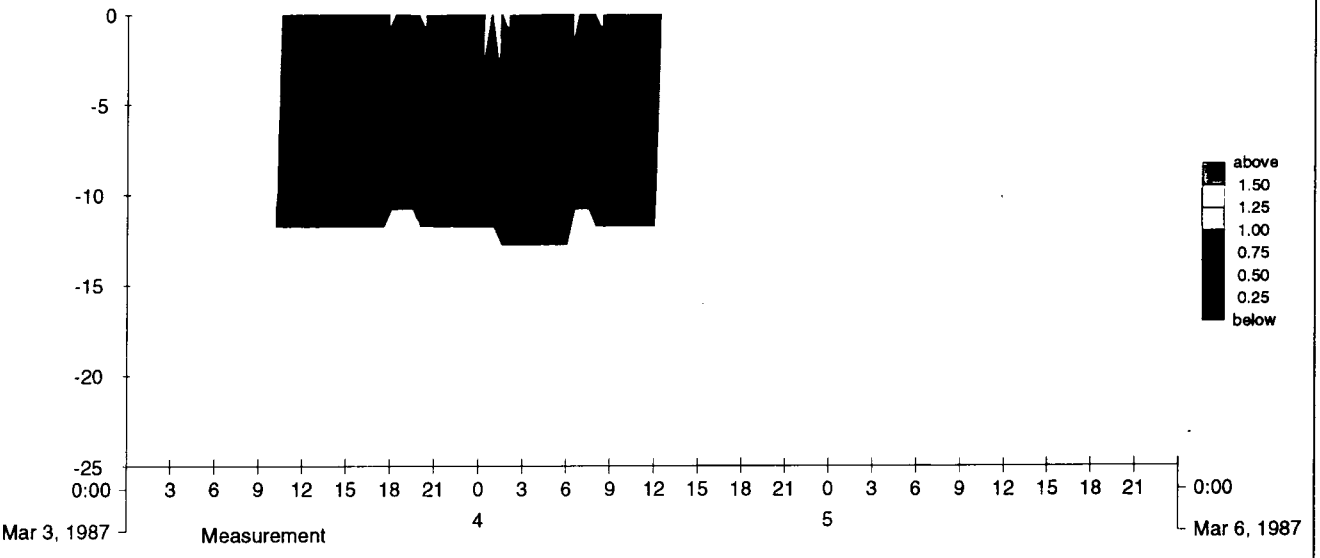


Measured and simulated velocity magnitude, Dry season - Neap tide
Station 2; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.46

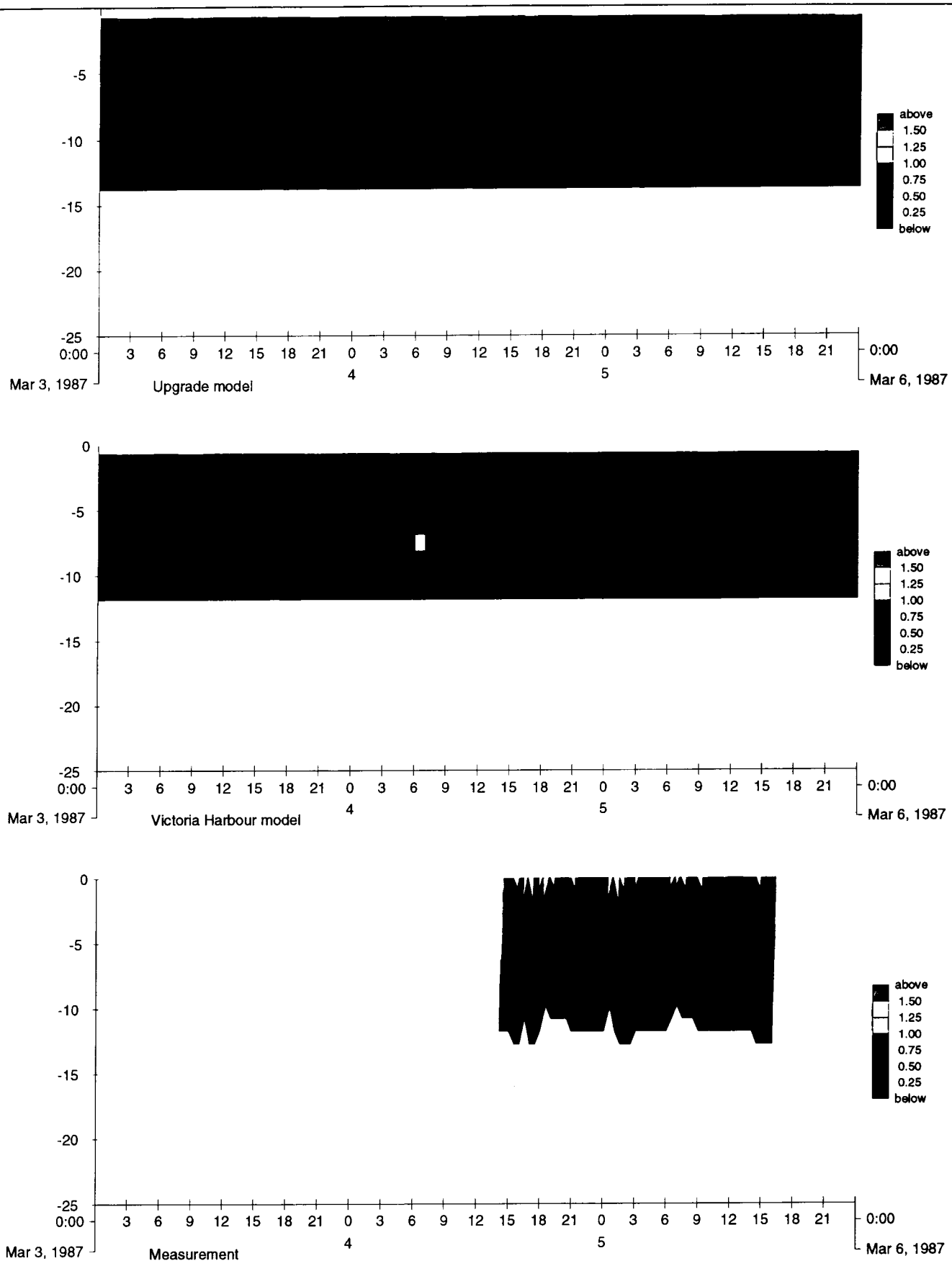






Measured and simulated velocity magnitude, Dry season - Neap tide
Station 4; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.47

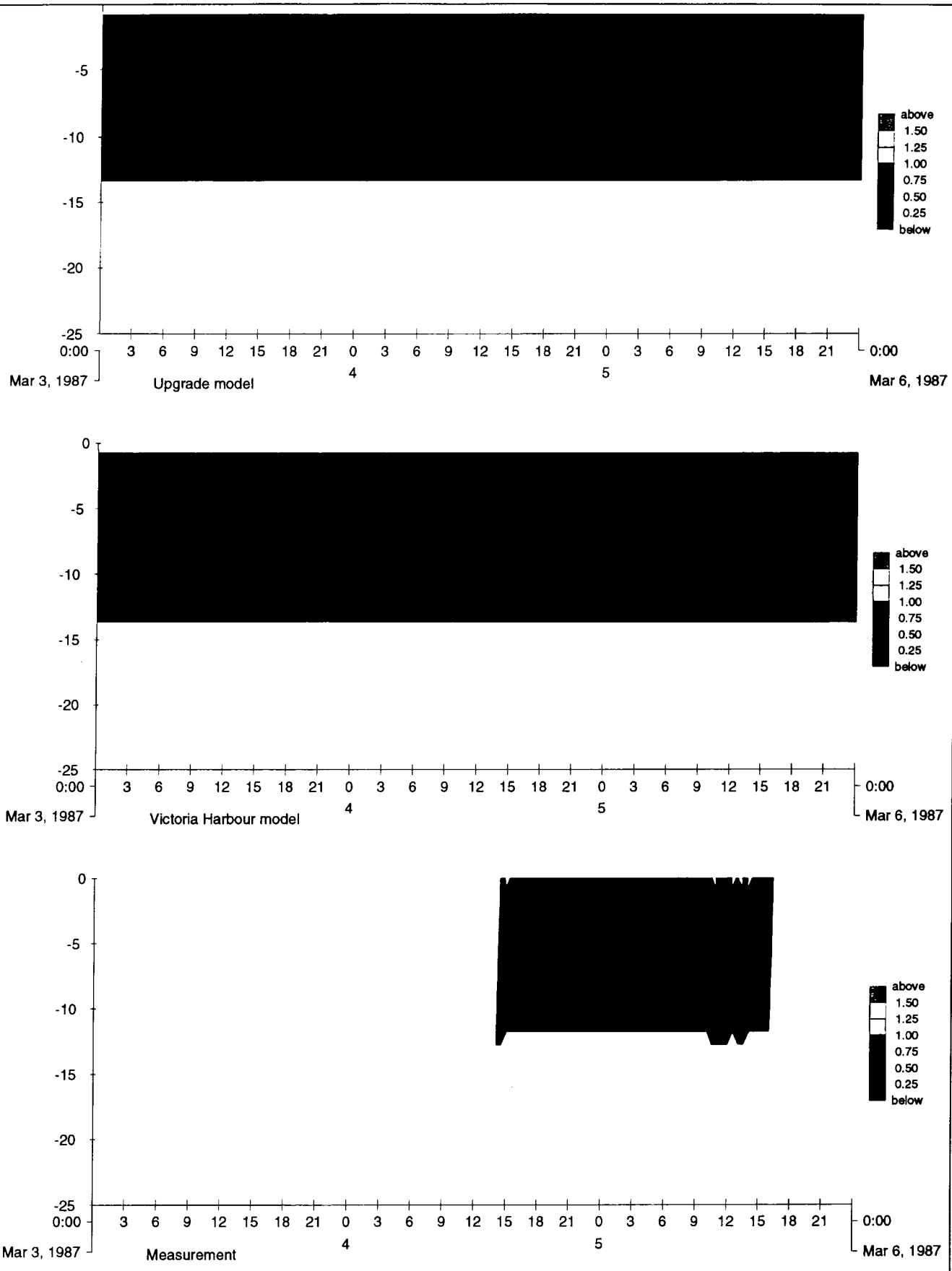


Measured and simulated velocity magnitude, Dry season - Neap tide
Station 6; Victoria Harbour measurement campaign

DELFT HYDRAULICS

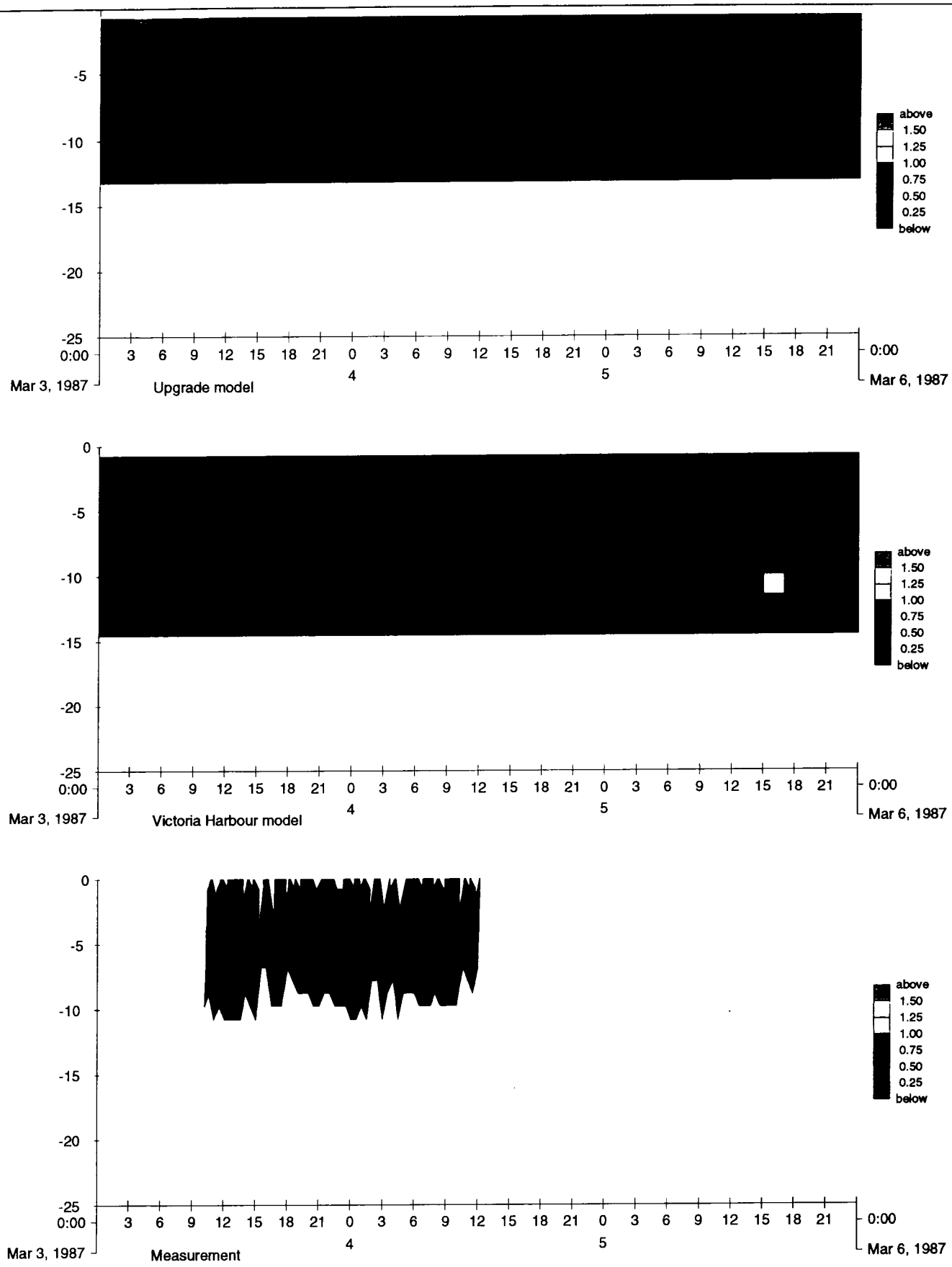
Z 2455.00

Fig: 2.48



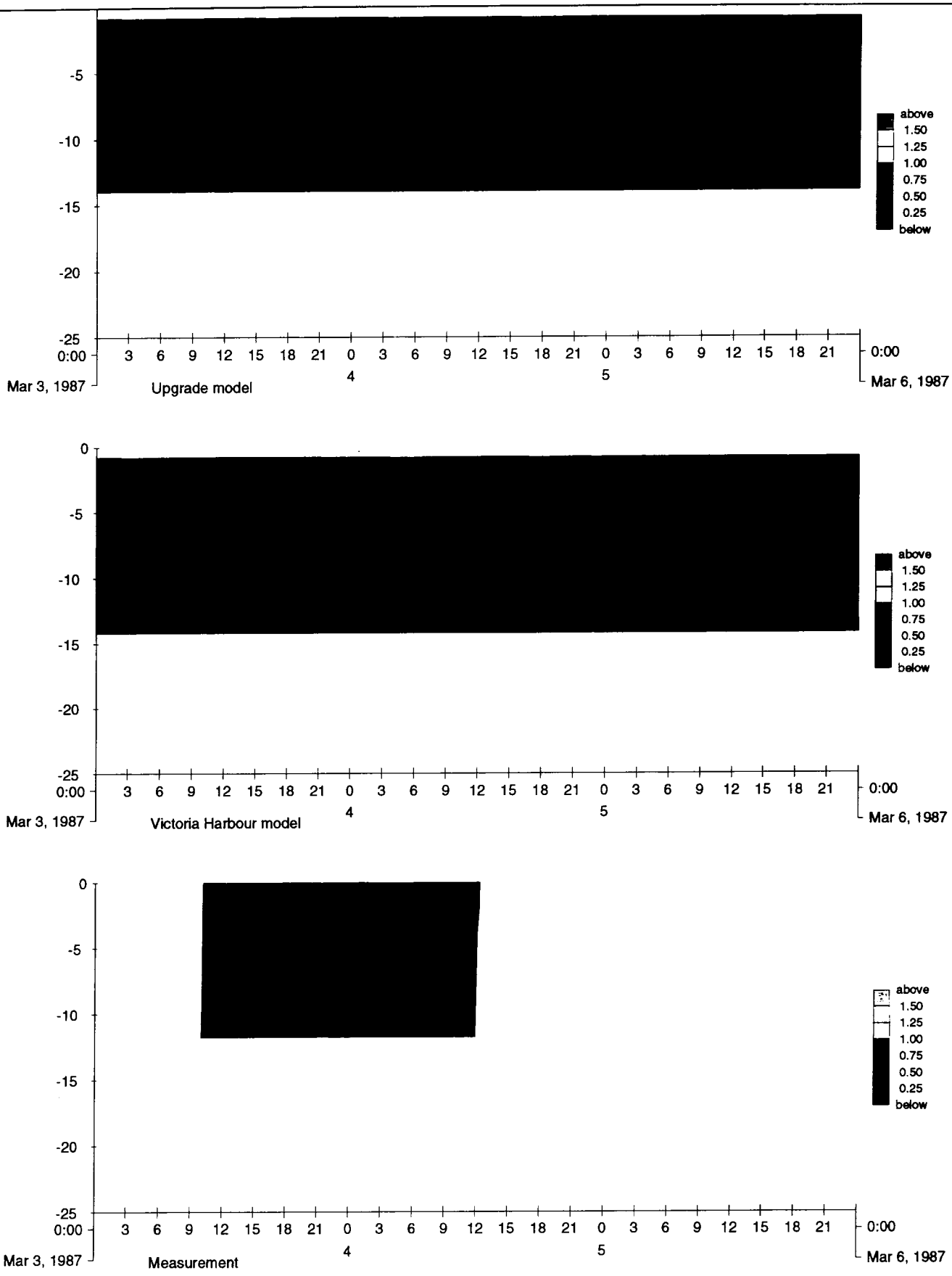
Measured and simulated velocity magnitude, Dry season - Neap tide
Station 8; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.49



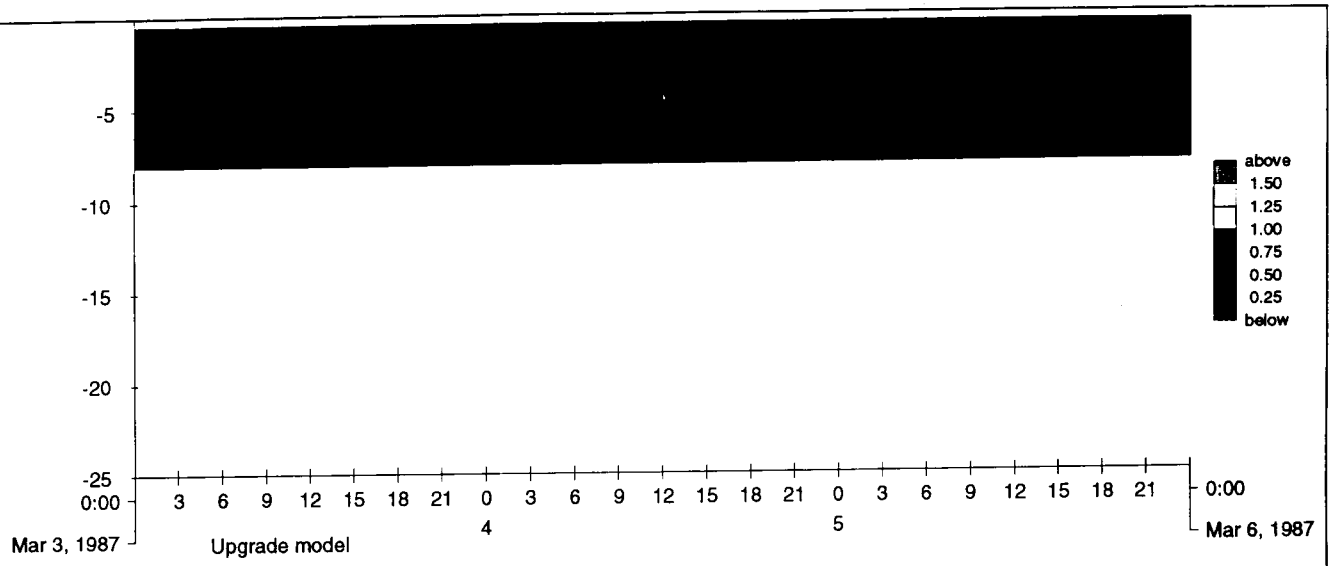
Measured and simulated velocity magnitude, Dry season - Neap tide
Station 13; Victoria Harbour measurement campaign

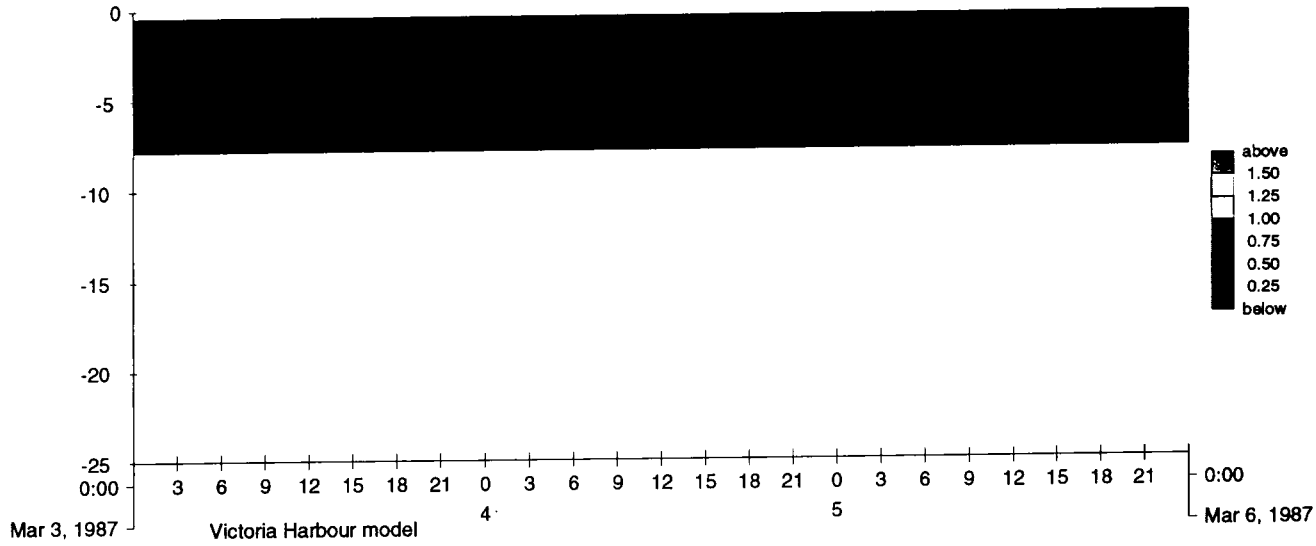
DELFT HYDRAULICS | Z 2455.00 | Fig: 2.50

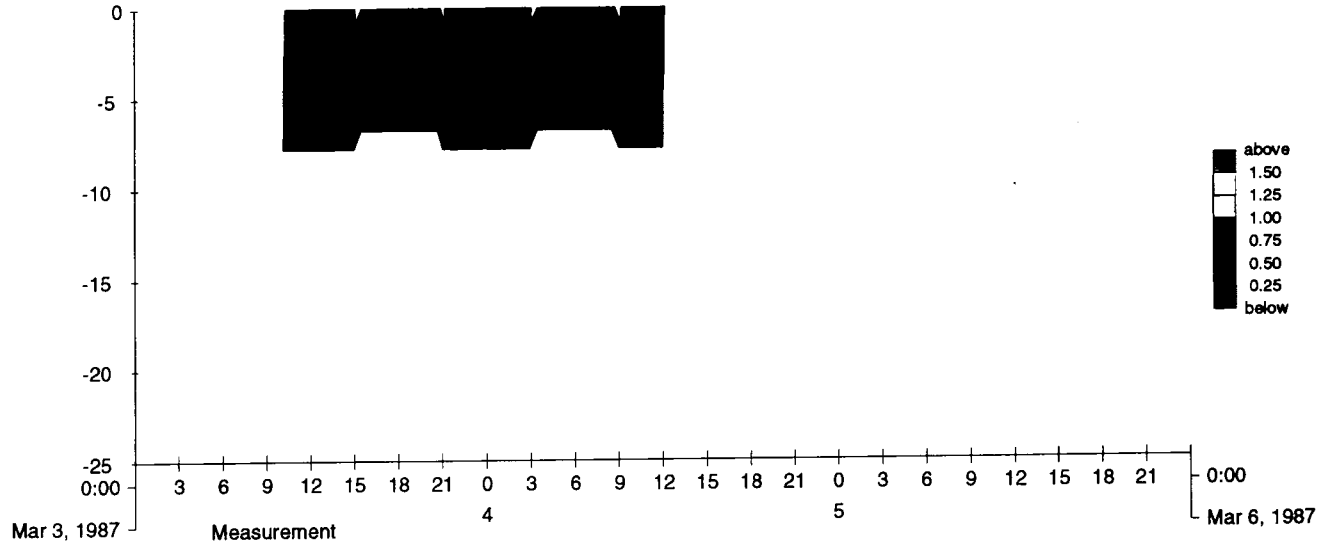


Measured and simulated velocity magnitude, Dry season - Neap tide
Station 15; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.51

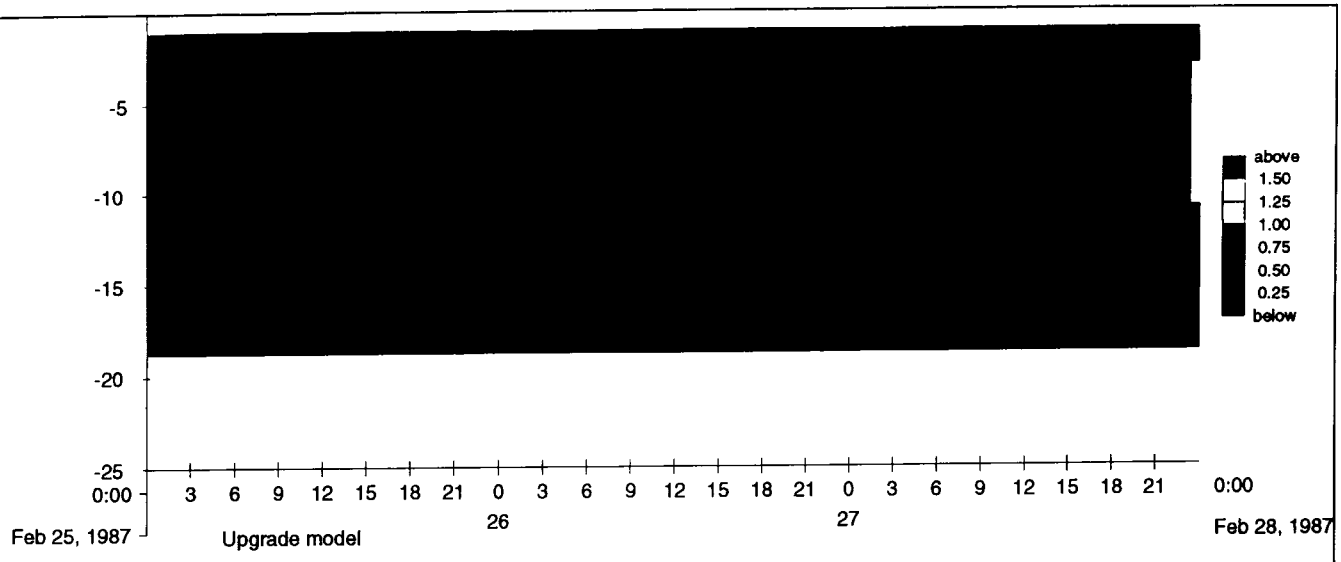


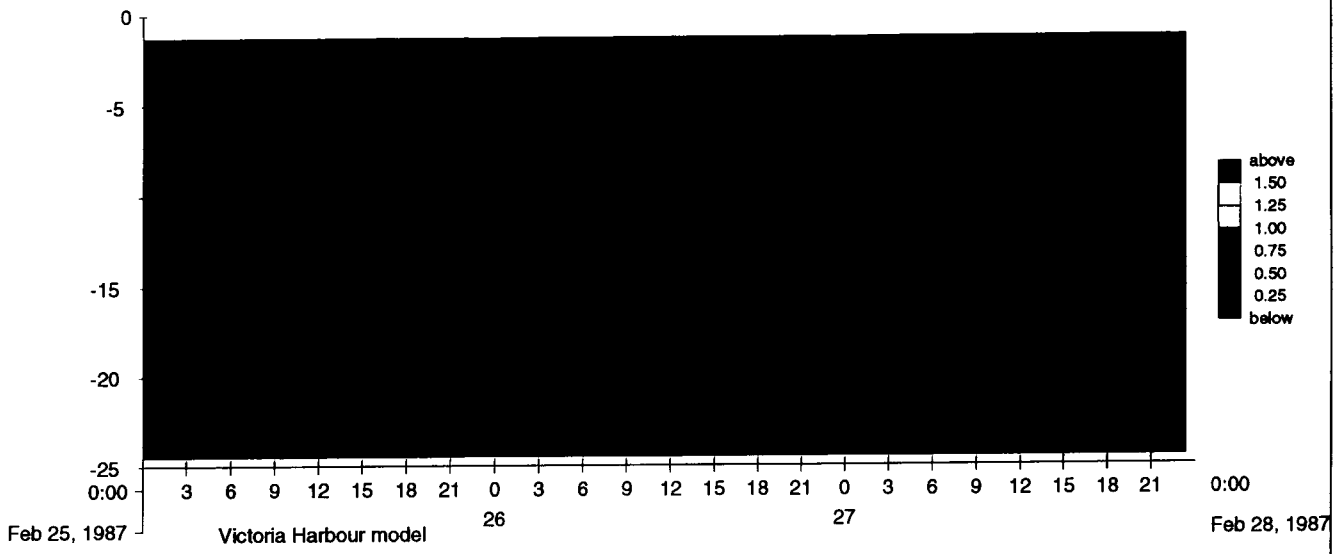


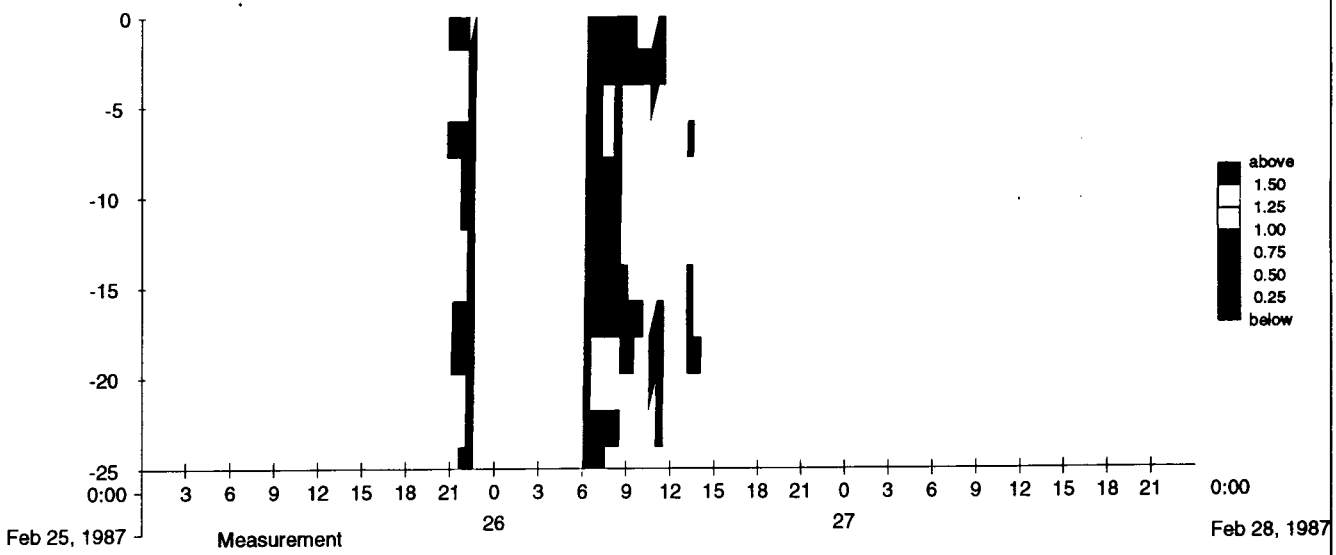


Measured and simulated velocity magnitude, Dry season - Neap tide
Station 17; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.52

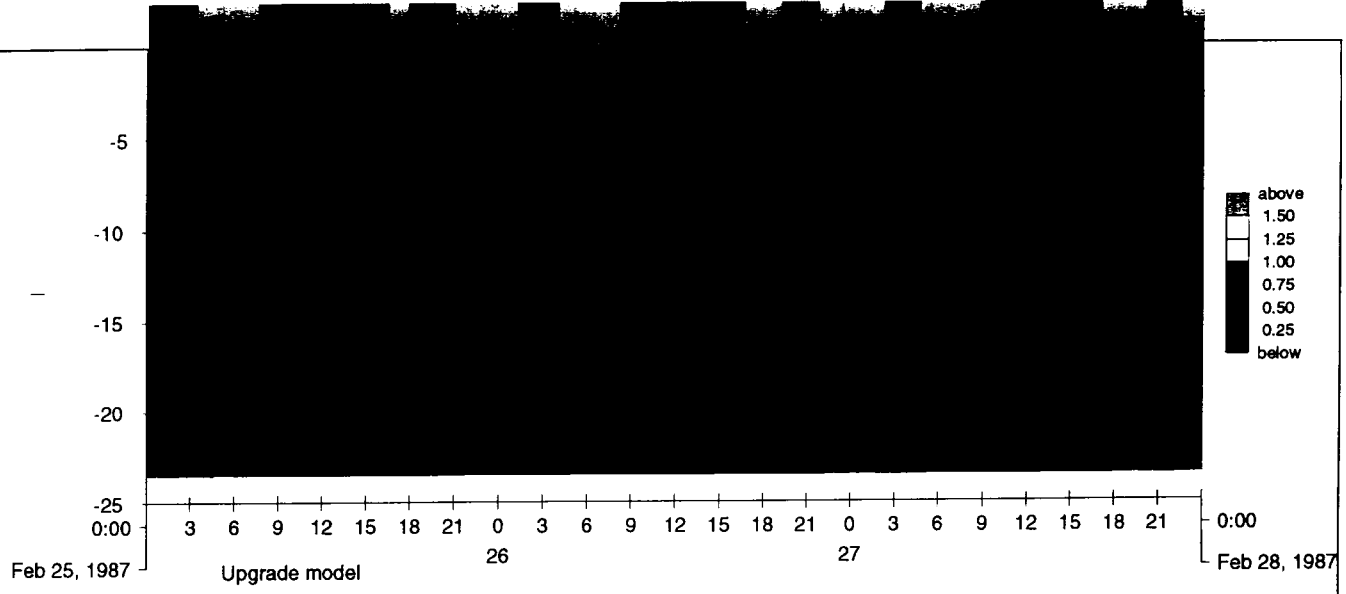


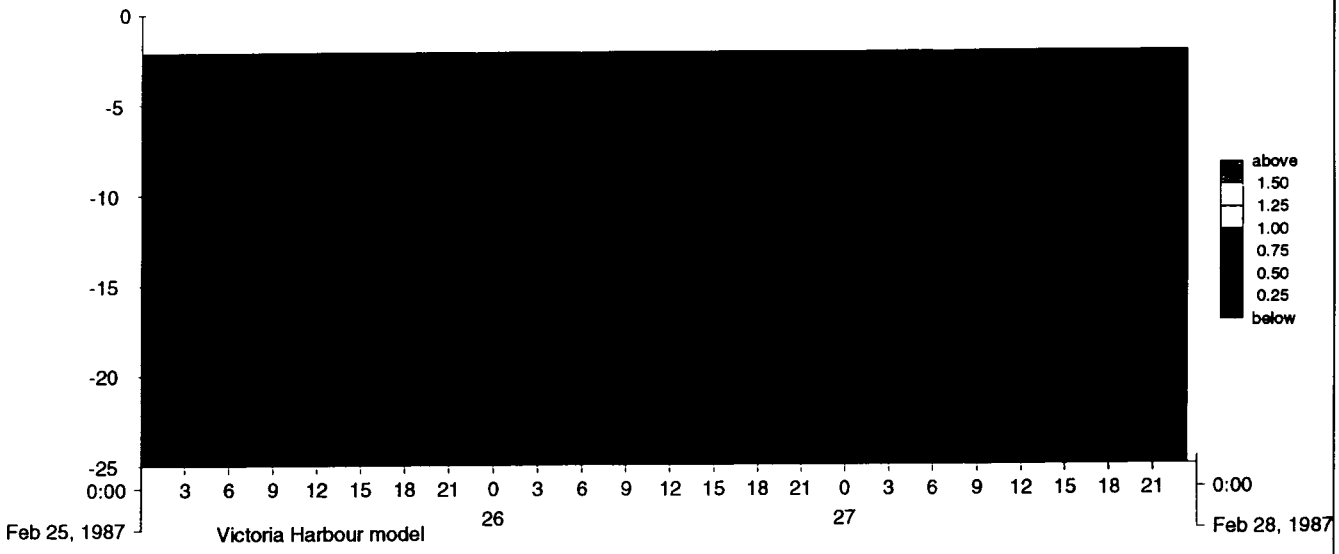


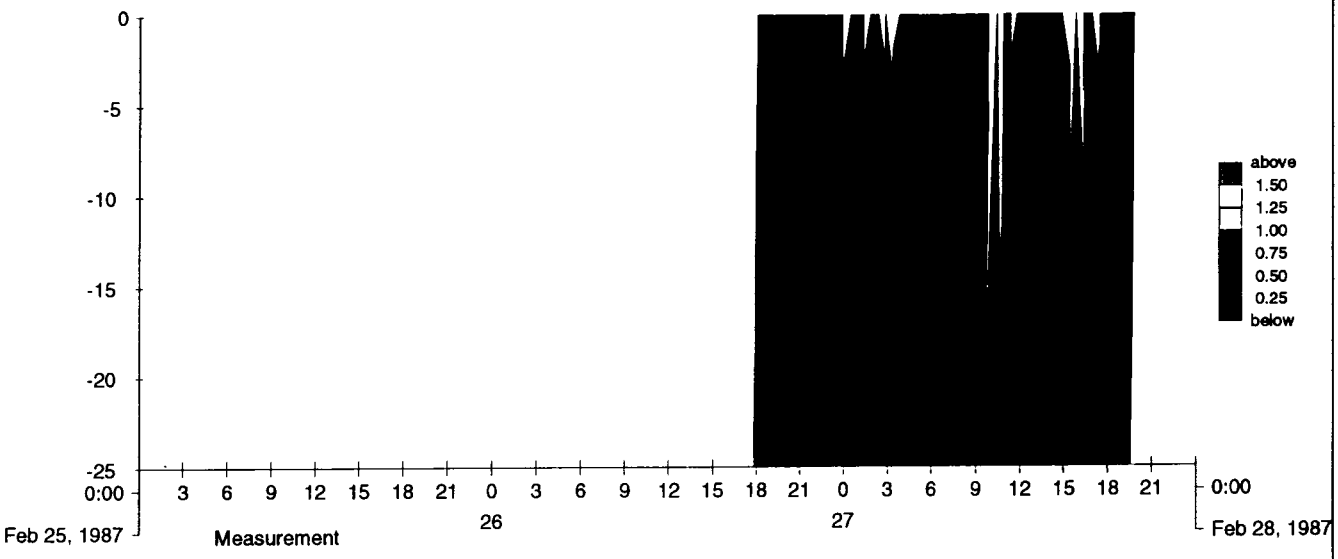


Measured and simulated velocity magnitude, Dry season - Spring tid
Station 1; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.53

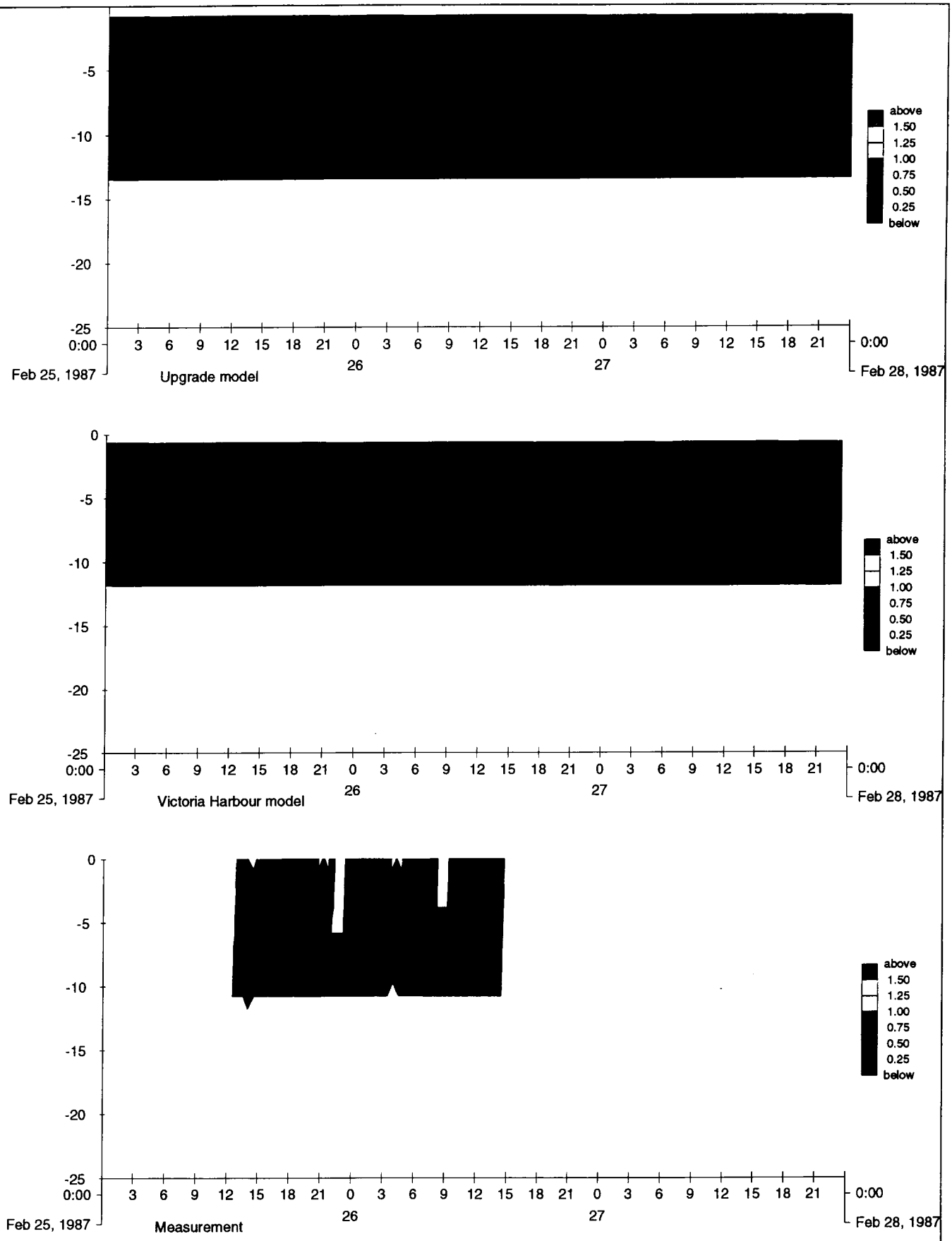






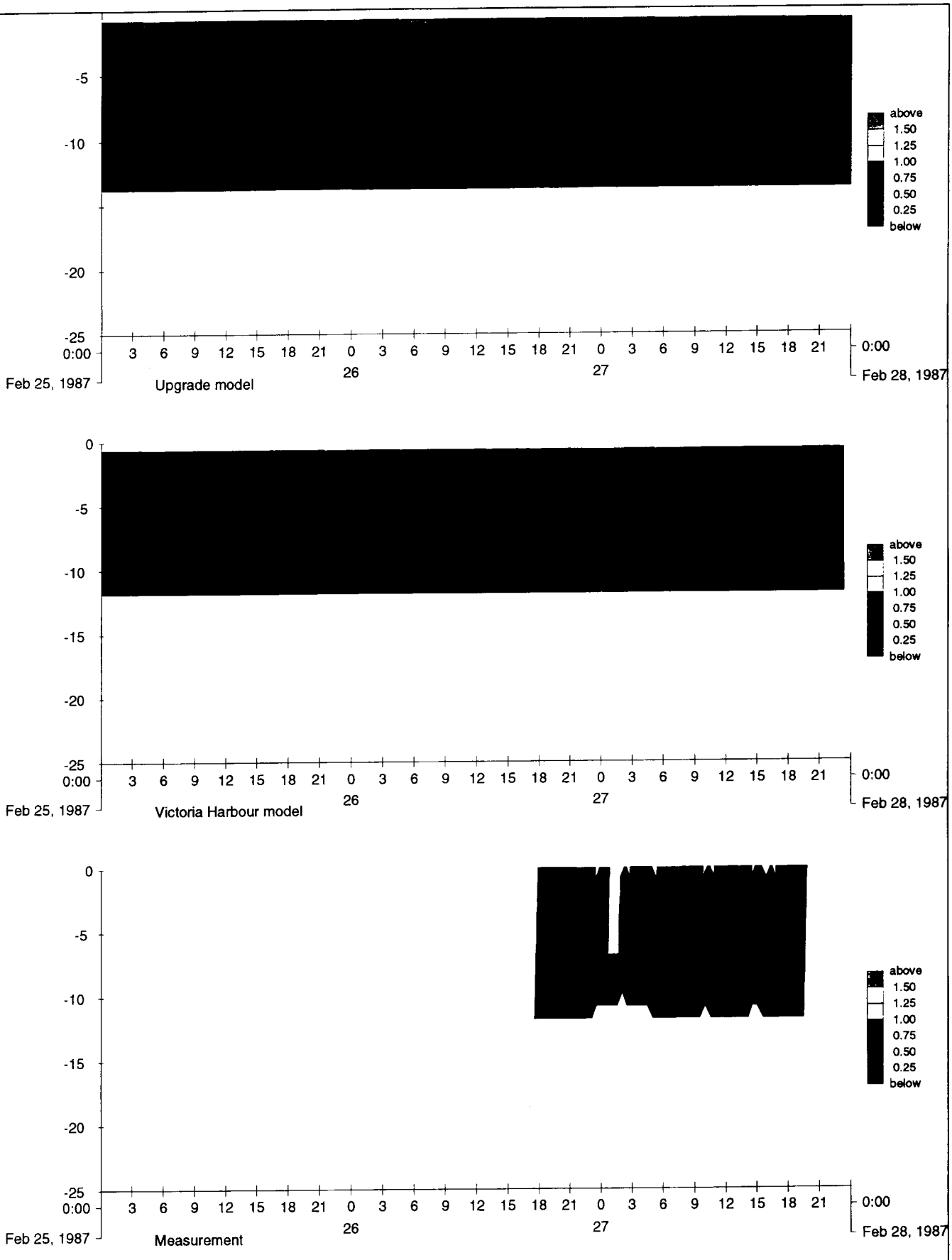
Measured and simulated velocity magnitude, Dry season - Spring tid
Station 2; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.54



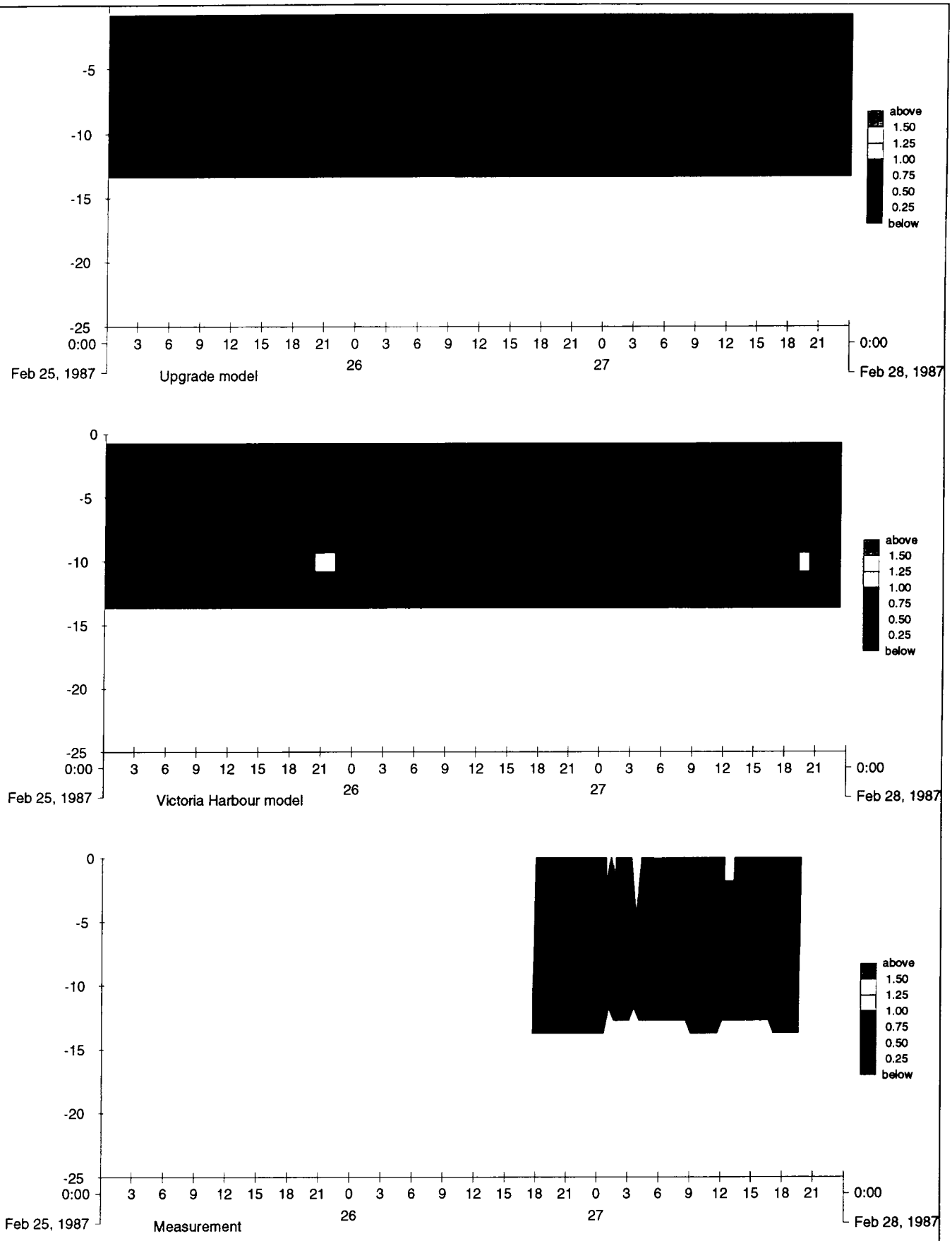
Measured and simulated velocity magnitude, Dry season - Spring tid
Station 4; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.55



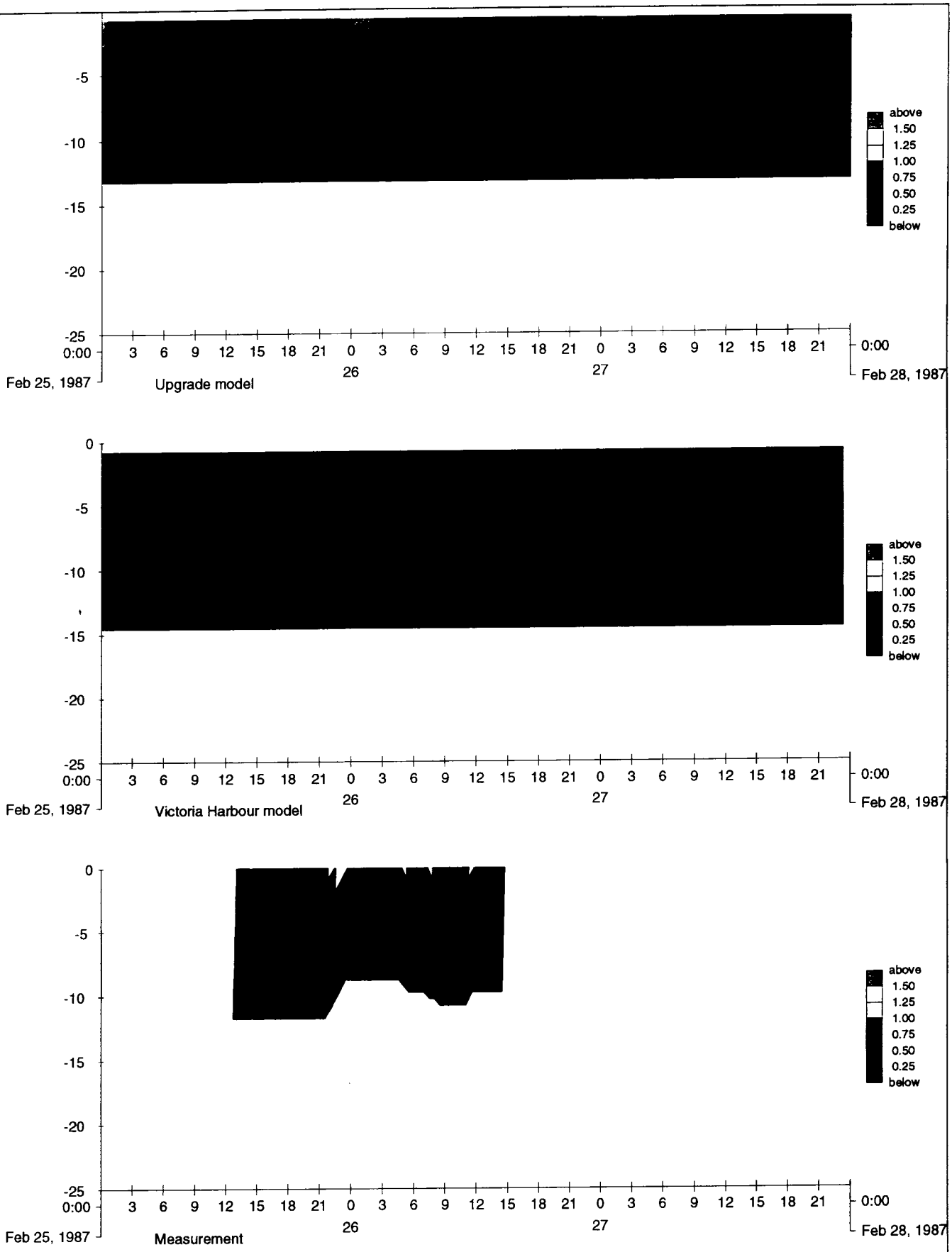
Measured and simulated velocity magnitude, Dry season - Spring tid
Station 6; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.56



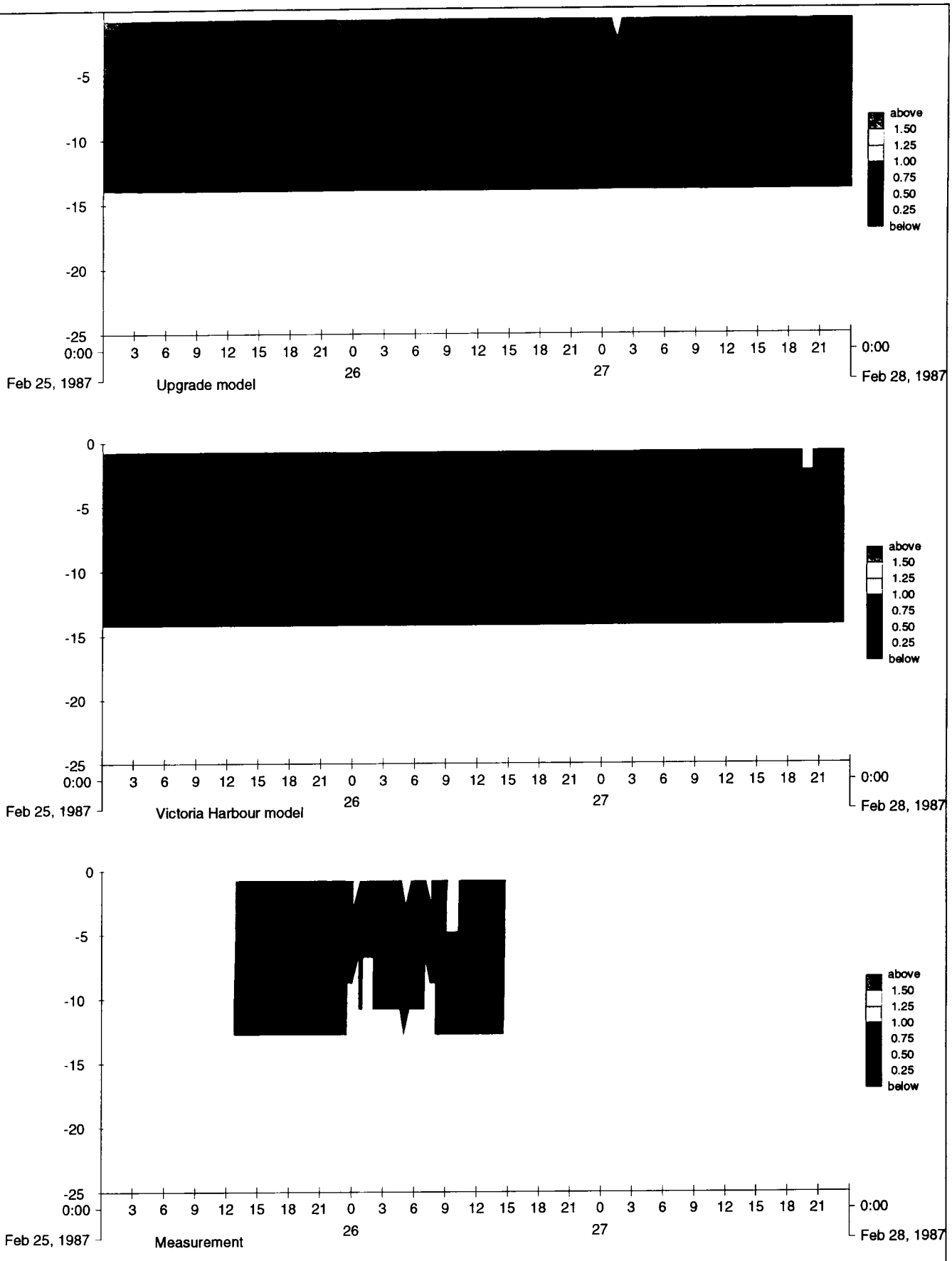
Measured and simulated velocity magnitude, Dry season - Spring tid
Station 8; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.57



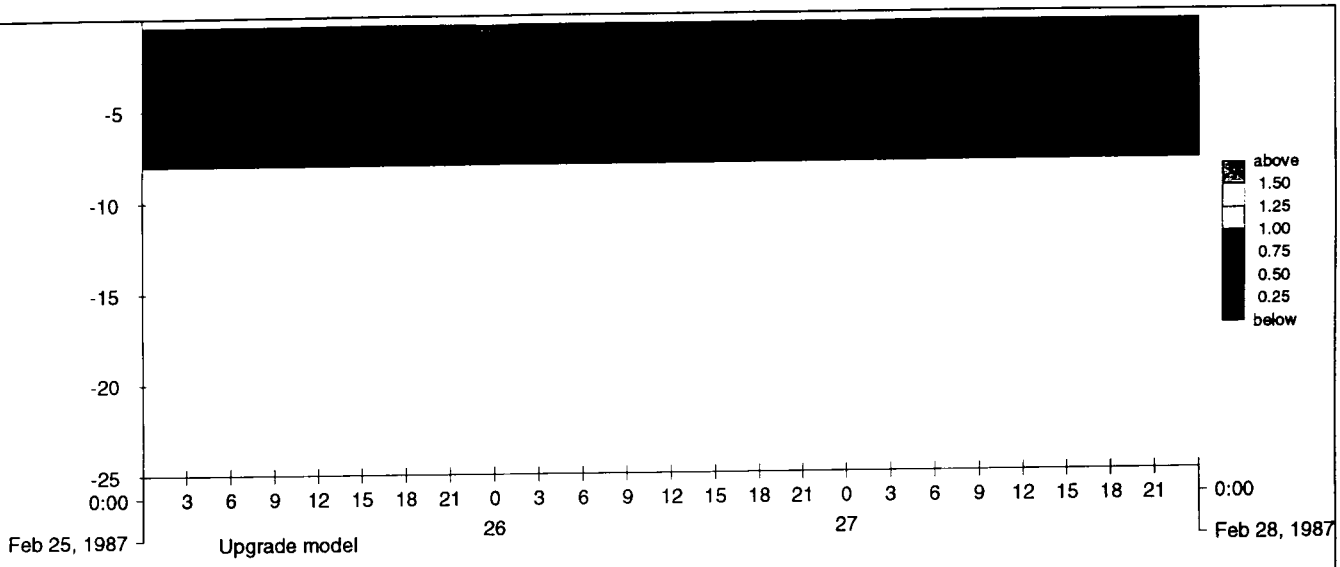
Measured and simulated velocity magnitude, Dry season - Spring tid
Station 13; Victoria Harbour measurement campaign

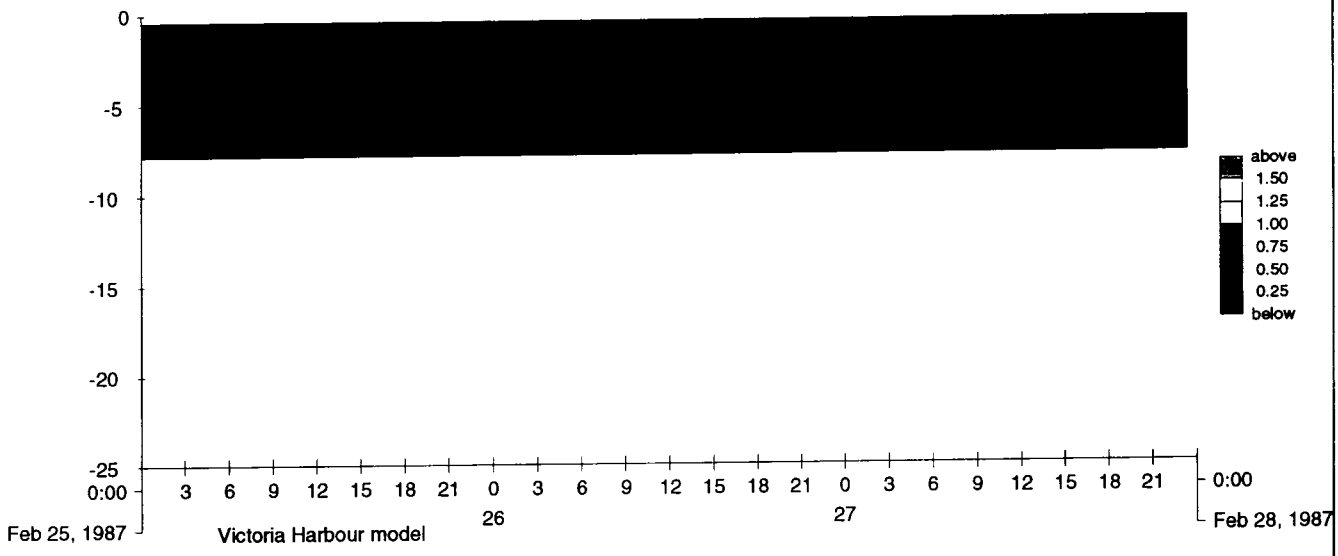
DELFT HYDRAULICS | Z 2455.00 | Fig: 2.58

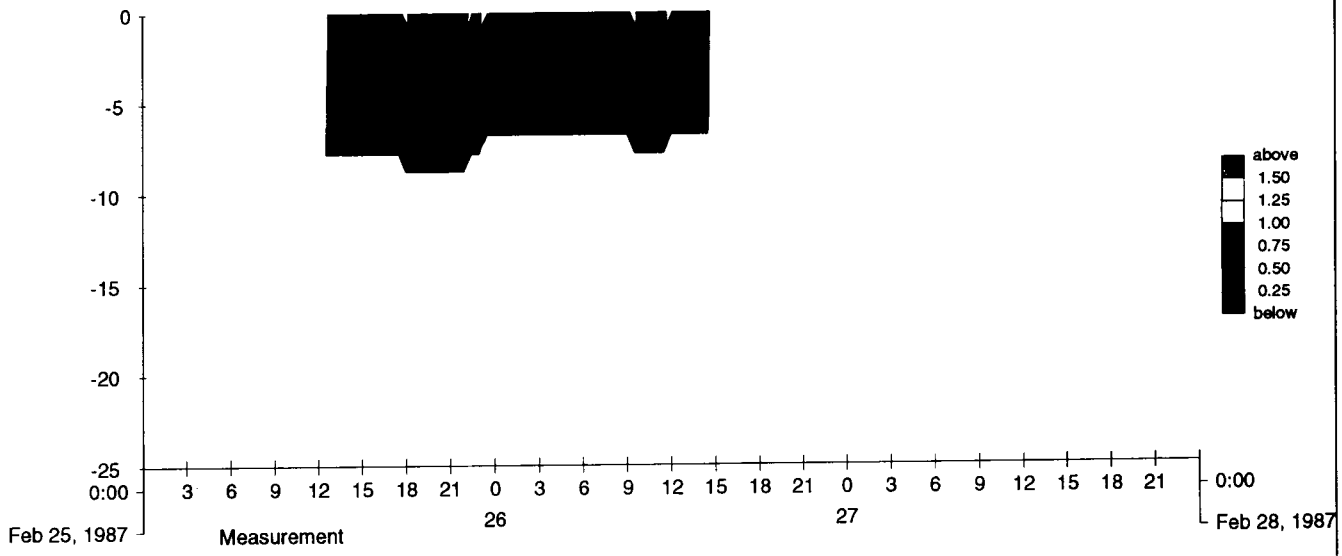


Measured and simulated velocity magnitude, Dry season - Spring tid
Station 15; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2.59.00 | Fig: 2.59

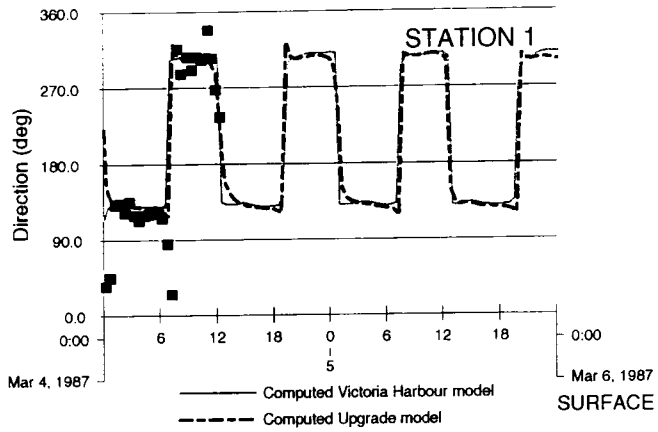




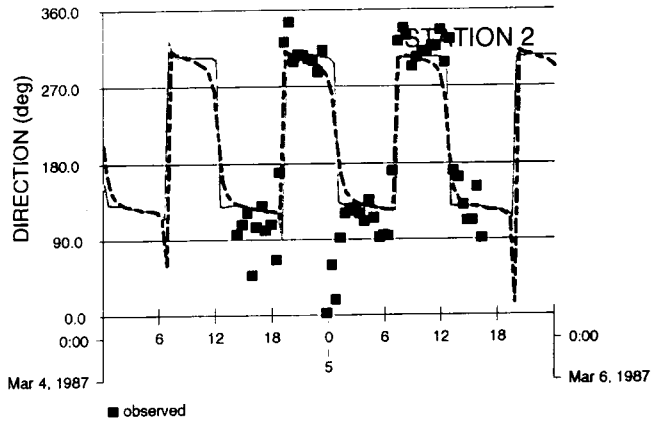


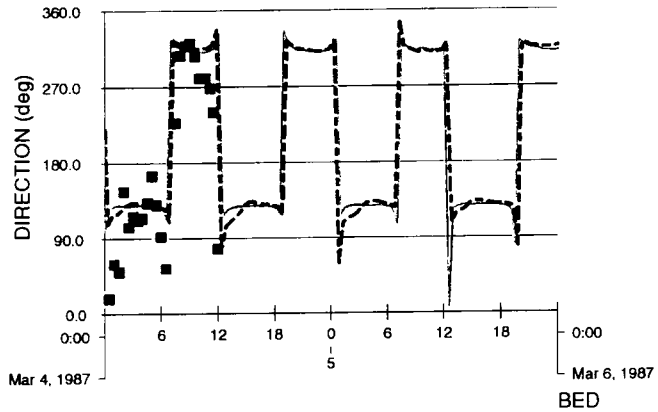
Measured and simulated velocity magnitude, Dry season - Spring tid
Station 17; Victoria Harbour measurement campaign

DELFT HYDRAULICS | Z 2455.00 | Fig: 2.60

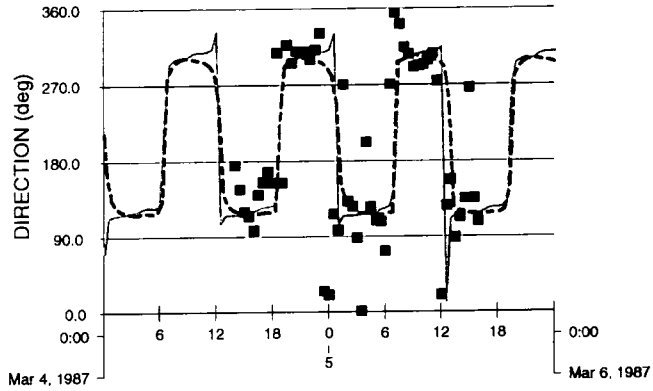


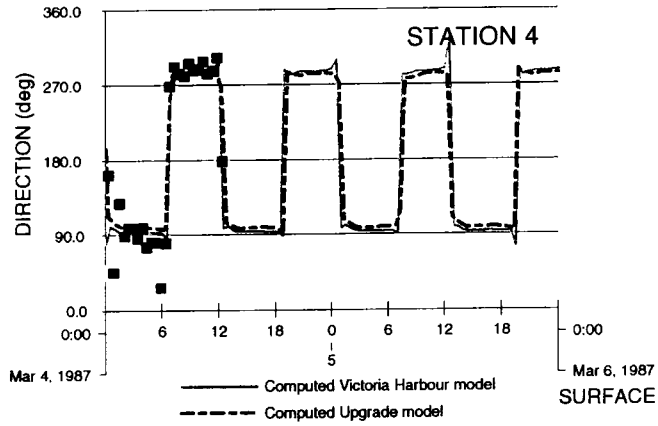
SURFACE



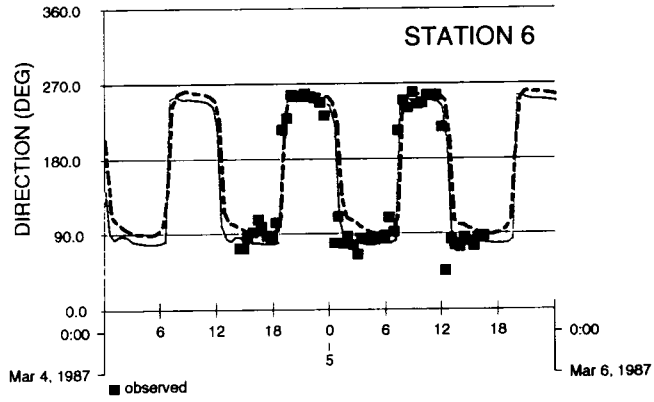


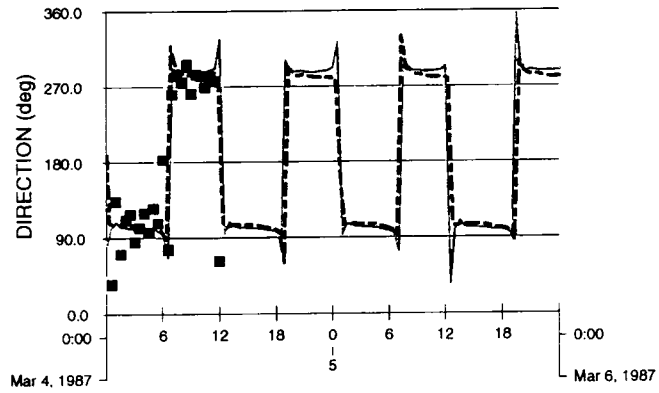
BED



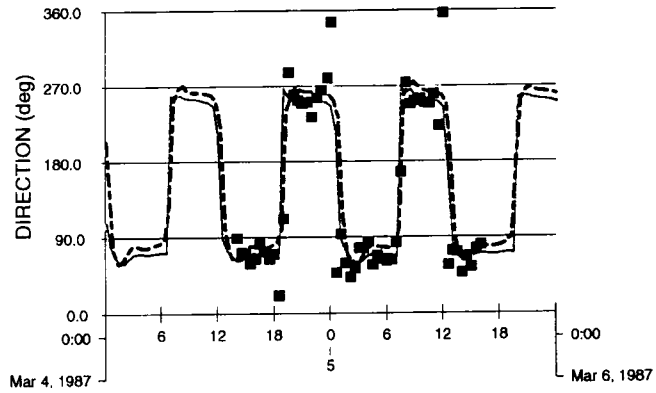


SURFACE





BED

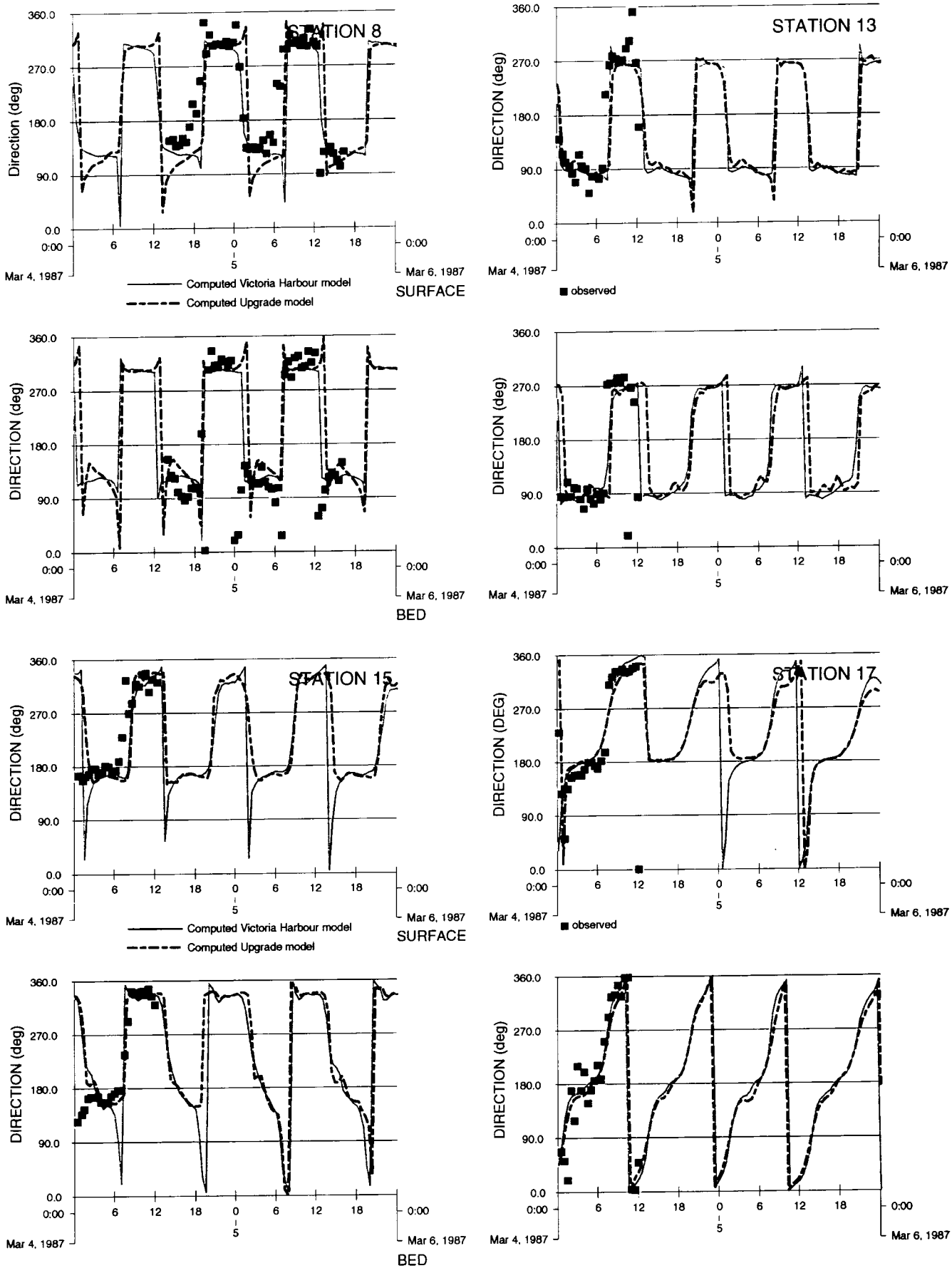


Shatin treatment works stage III extension
Computed and observed velocity directions; Dry Season Neap Tide
Stations 1, 2, 4 and 6

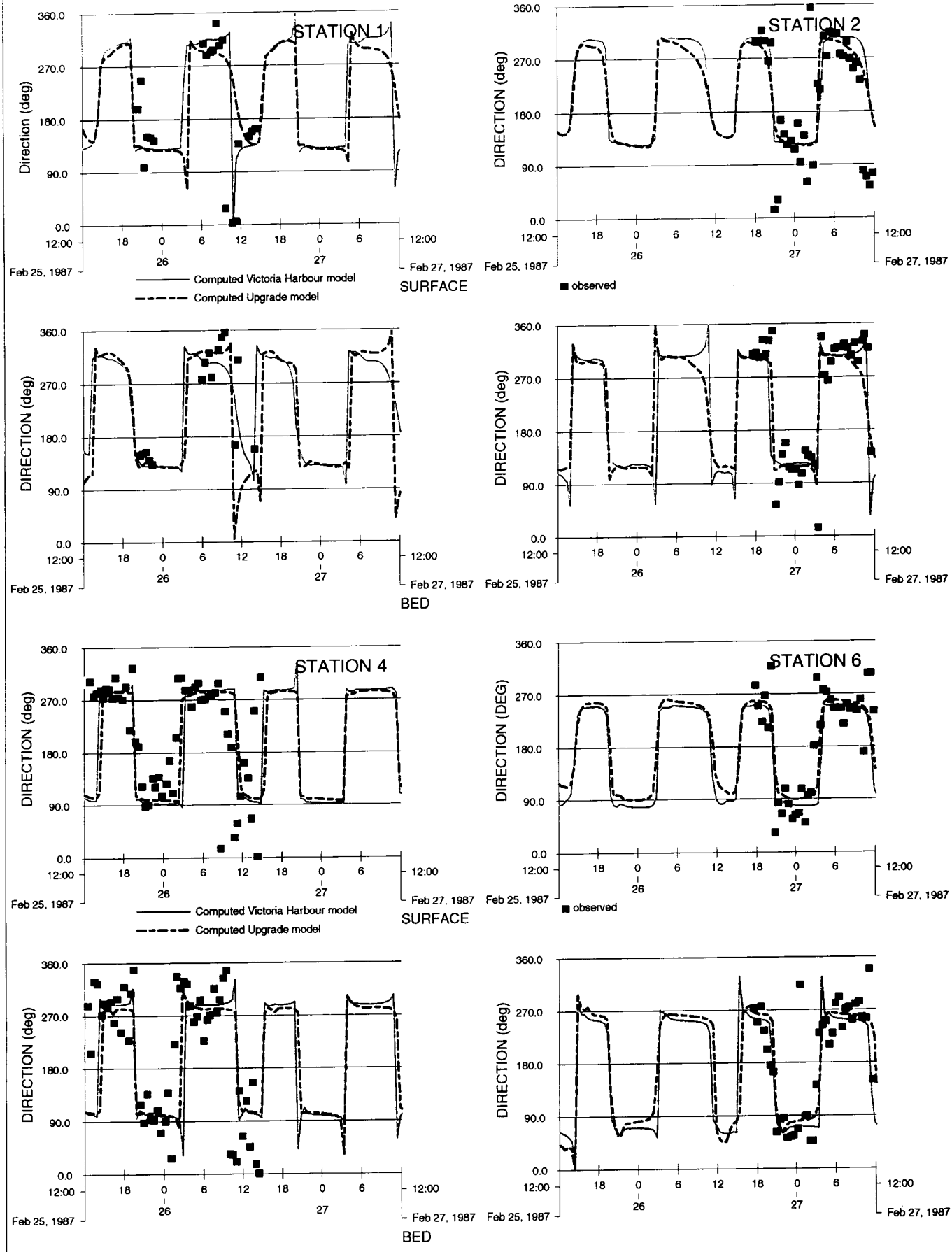
Delft3D-FLOW

DELFT HYDRAULICS

Fig: 2.61



Shatin treatment works stage III extension Computed and observed velocity directions; Dry Season Neap Tide Stations 8, 13, 15 and 17		Delft3D-FLOW
DELFT HYDRAULICS		Fig. 2.62



Shatin treatment works stage III extension

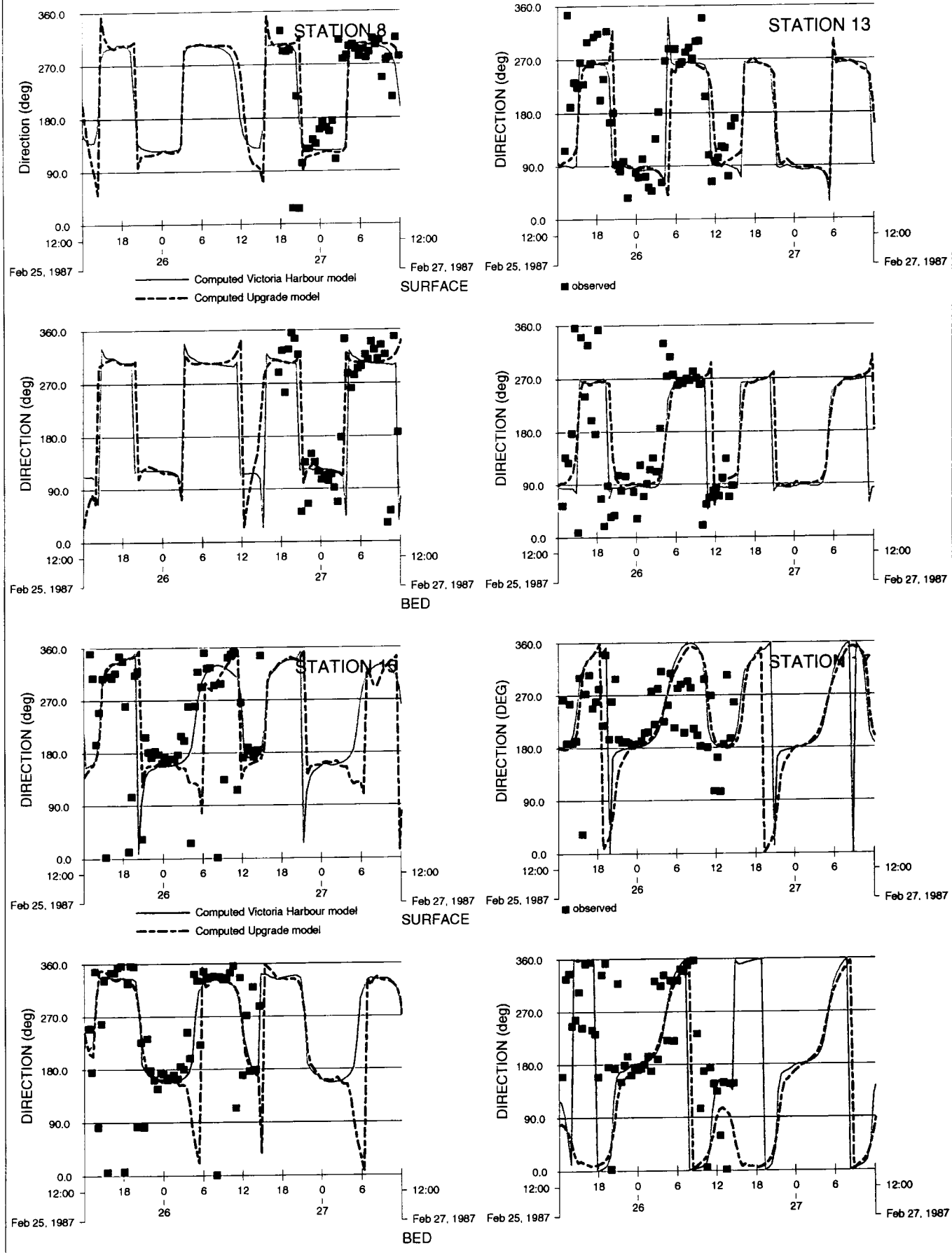
Computed and observed velocity directions; Dry Season Spring Tide

Stations 1, 2, 4 and 6

Delft3D-FLOW

DELFT HYDRAULICS

Fig. 2.63



Shatin treatment works stage III extension

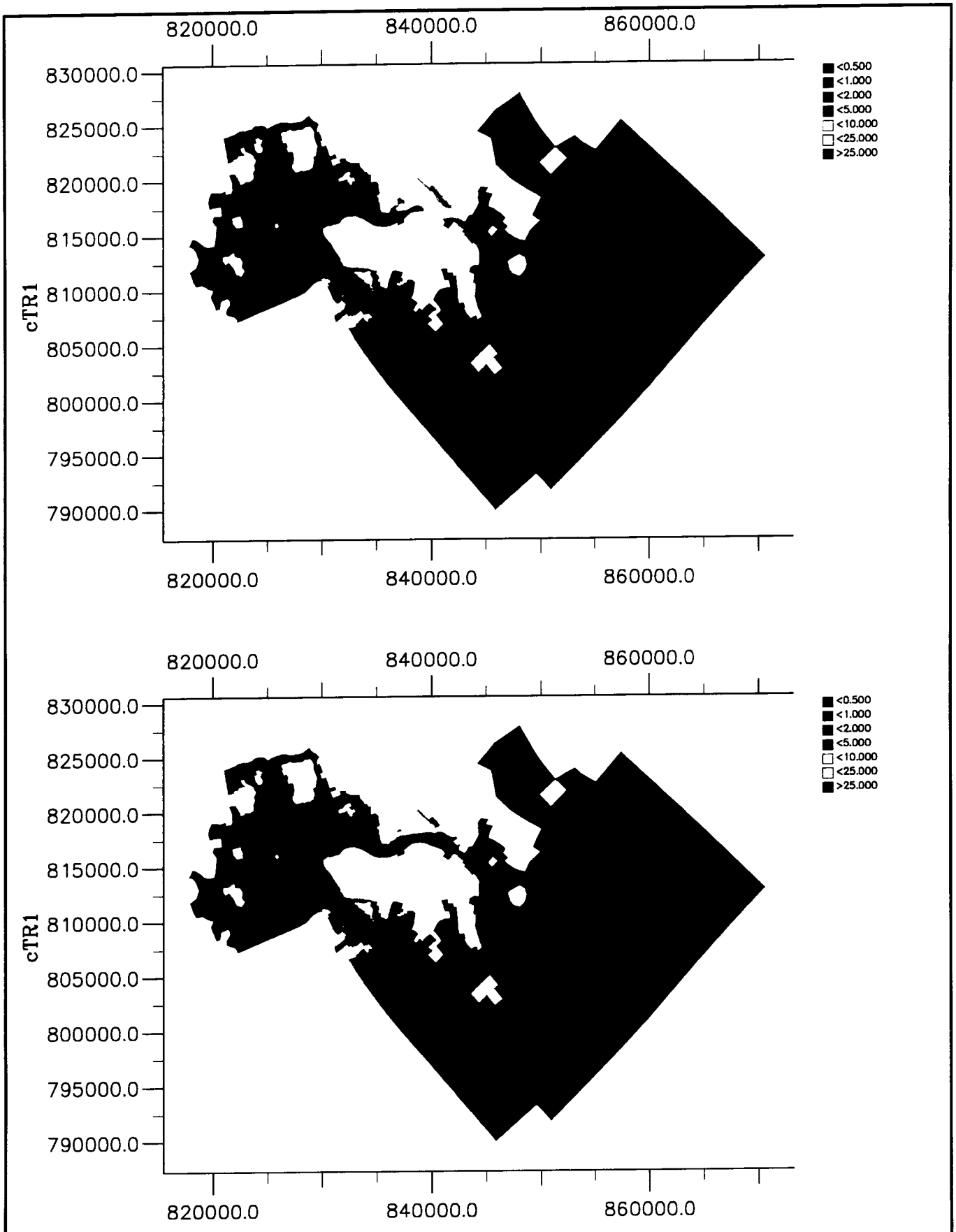
Computed and observed velocity directions; Dry Season Spring Tide

Stations 8, 13, 15 and 17

Delft3D-FLOW

DELFT HYDRAULICS

Fig. 2.64



Tracer Kai Tak Nullah no aggrgation
Upper:surface ; Lower: bottom layer

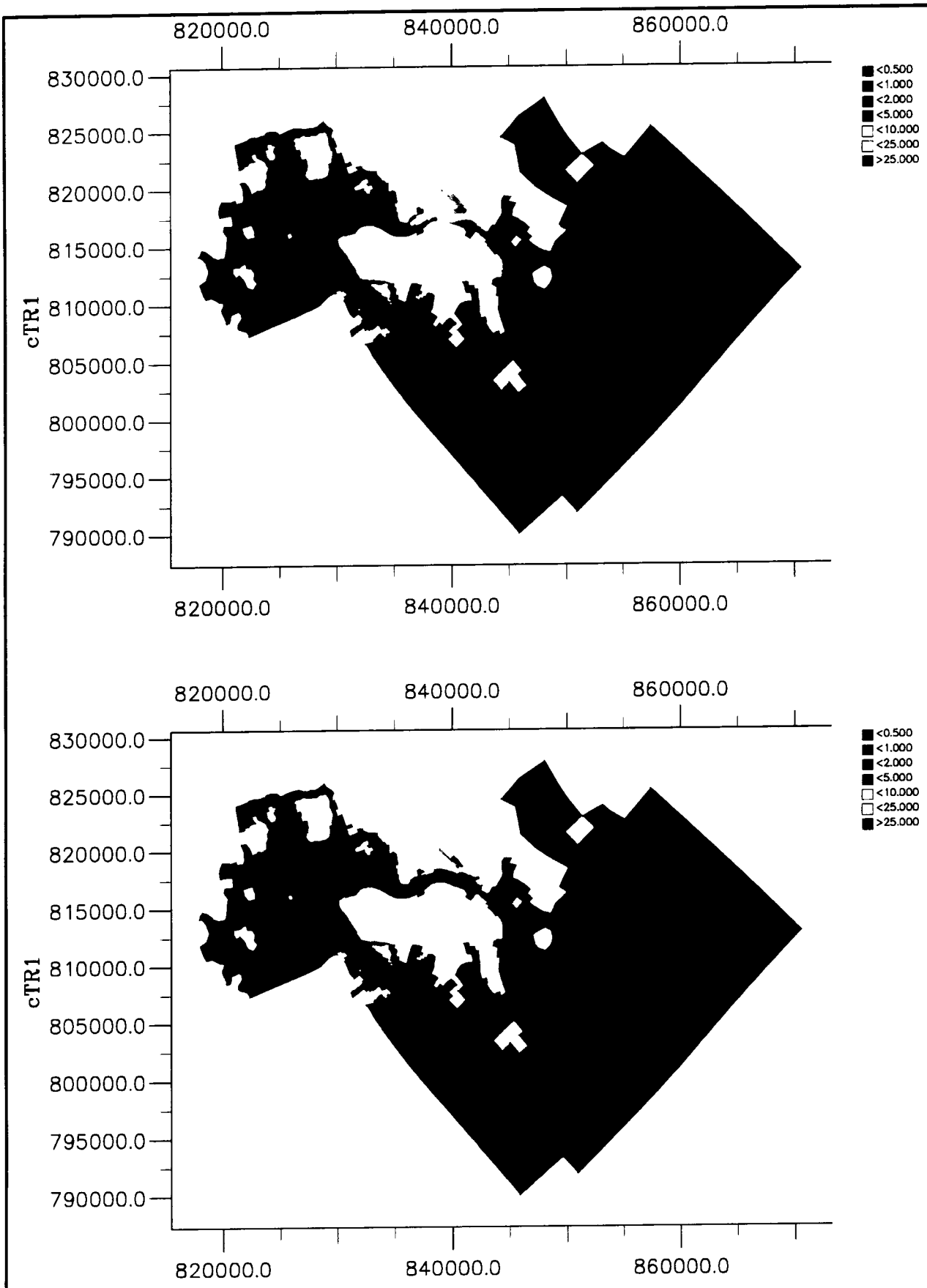
shatintr.ssn

Shatin–HK

WL | DELFT HYDRAULICS

Z2455

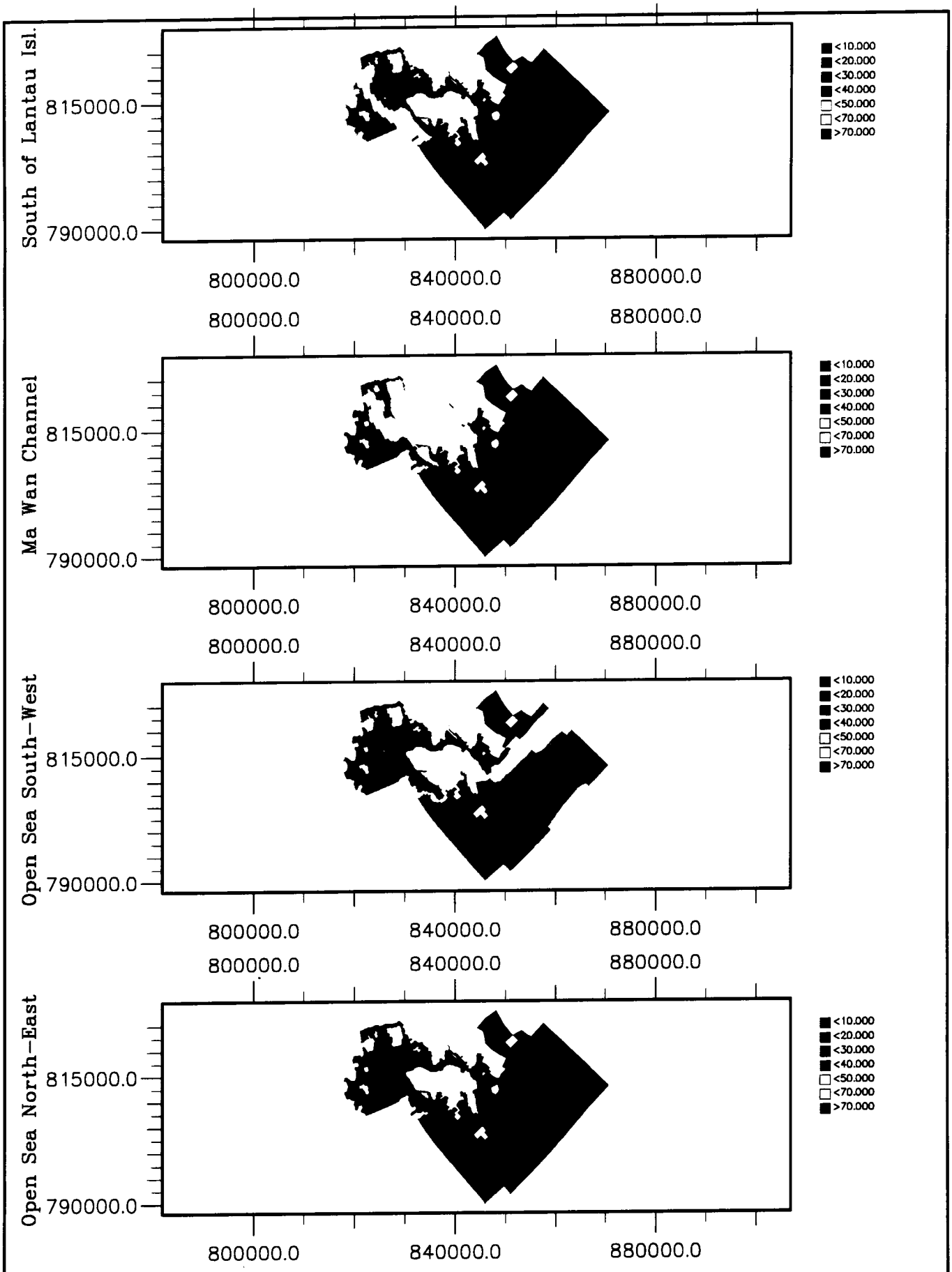
Fig. 3.1



TRacer Kai Tak Nullah 2x2 aggregation
Upper:surface ; Lower: bottom layer

shatintr.ssn	
Shatin–HK	
Z2455	Fig. 3.02

WL | DELFT HYDRAULICS



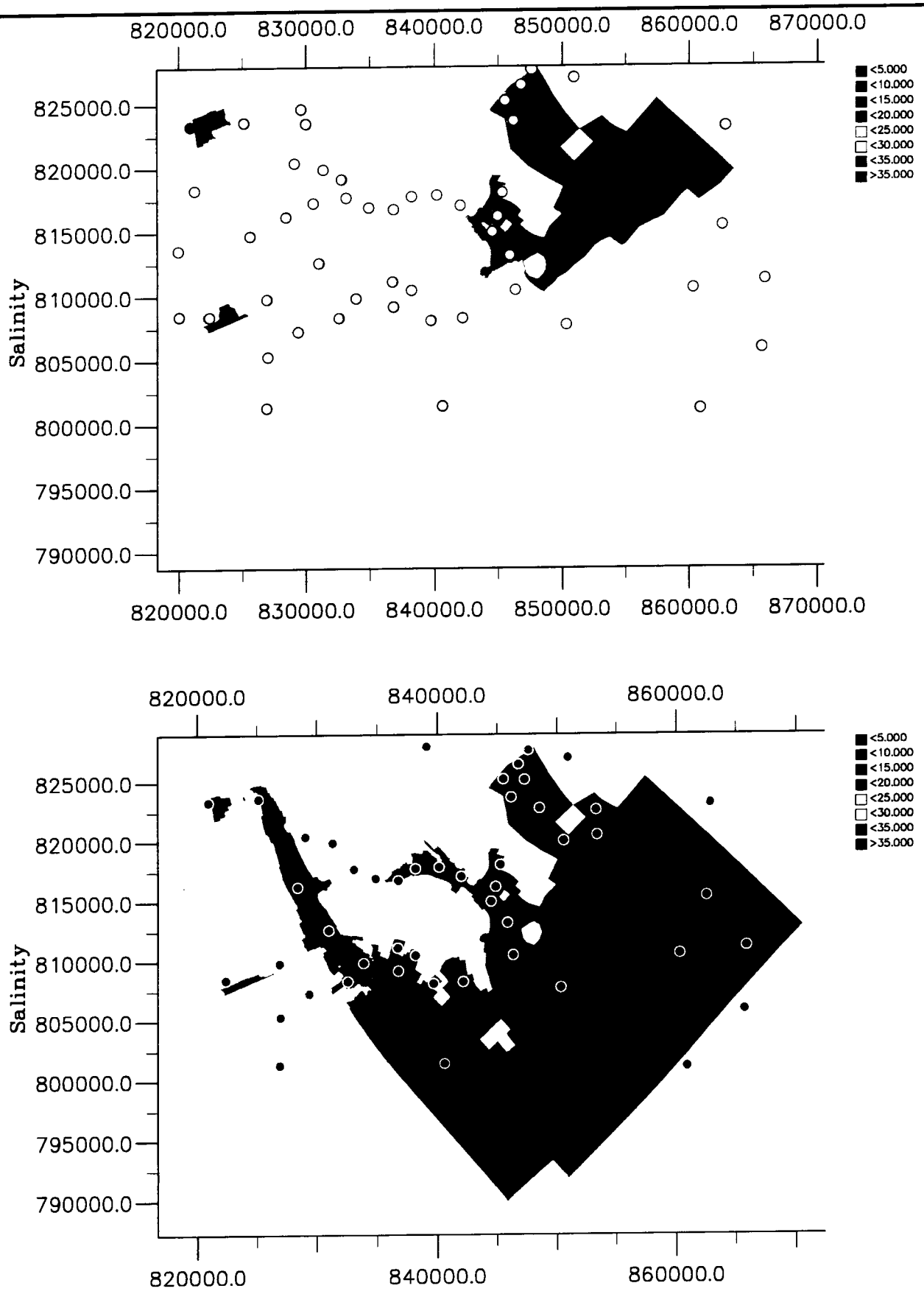
Shatin wet season
Tracers released at boundaries (100 mg/l)
Concentration after 15 days

Shatin–HK

WL | delft hydraulics

Z2455

Fig. 4.01



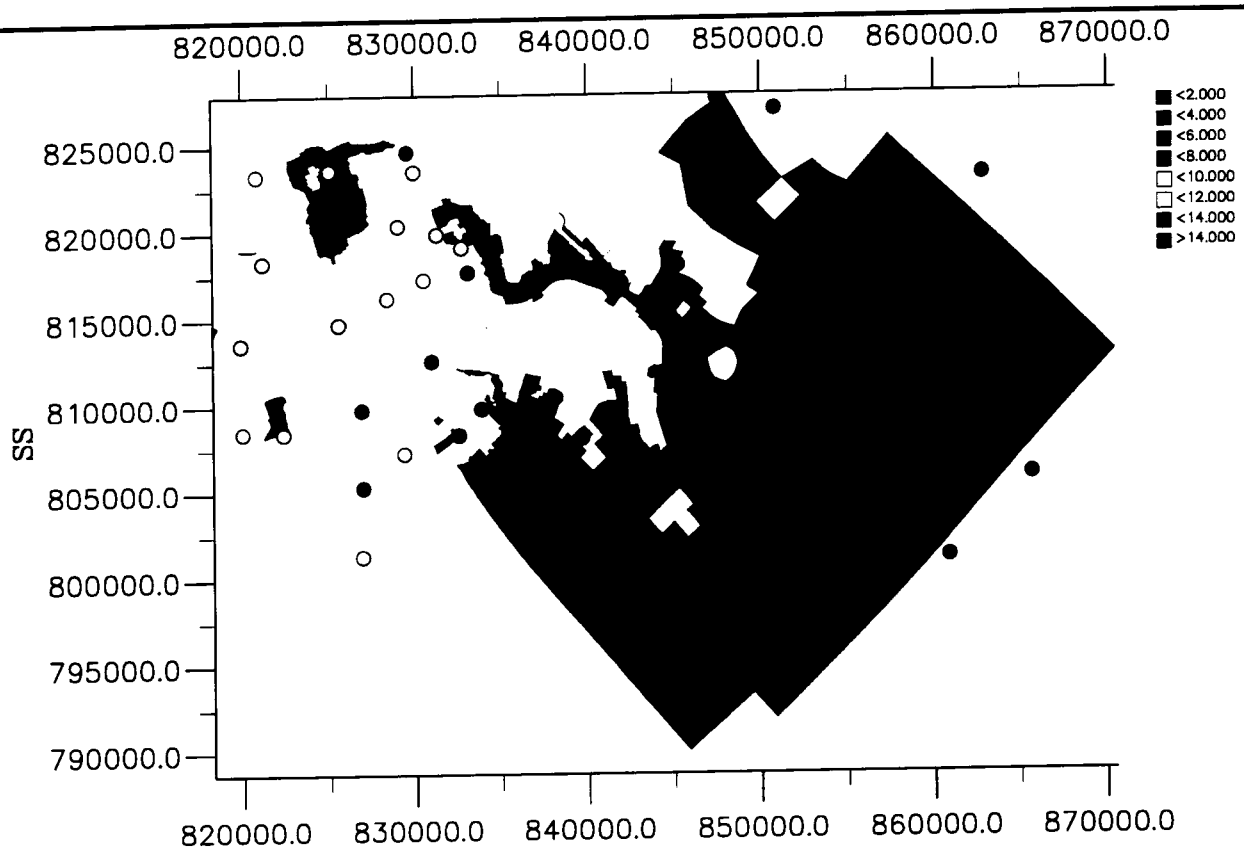
Salinity (ppt) wet season
Upper:surface ; Lower: bottom layer

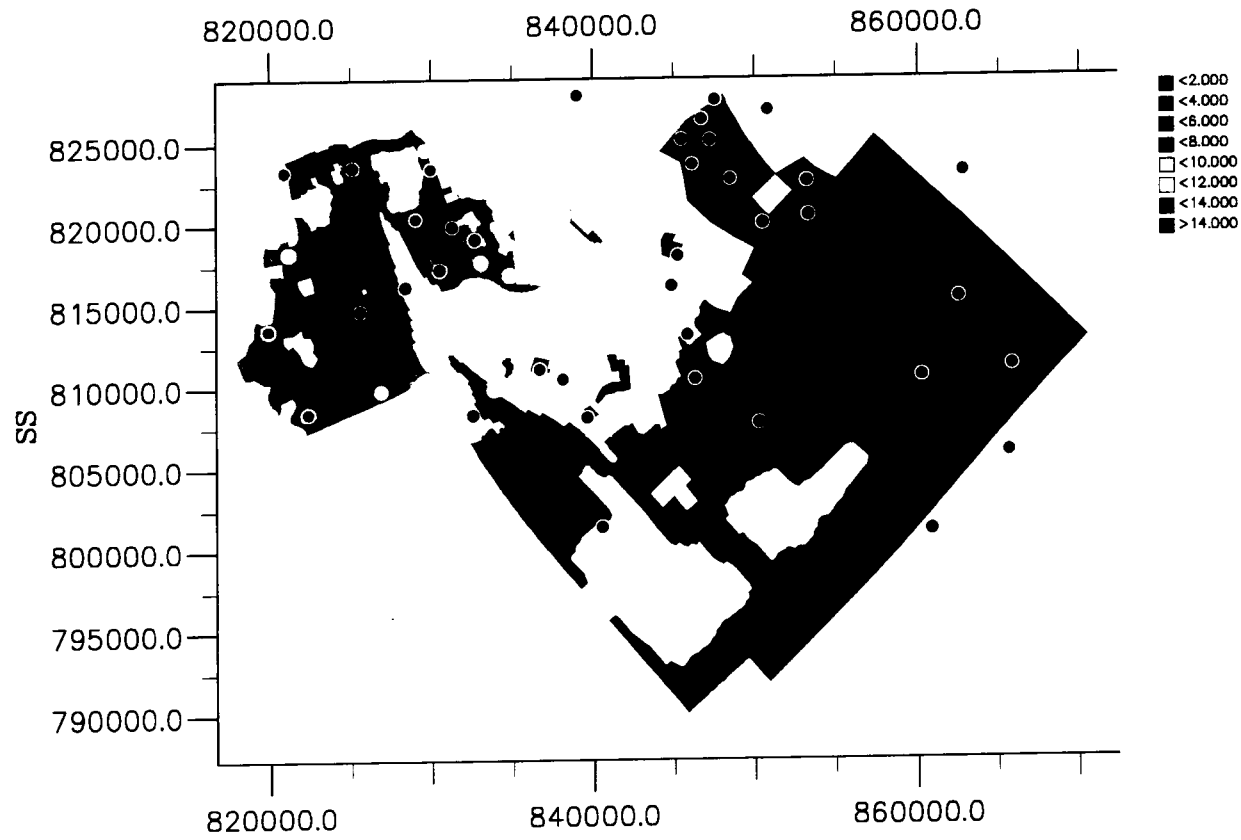
Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.2





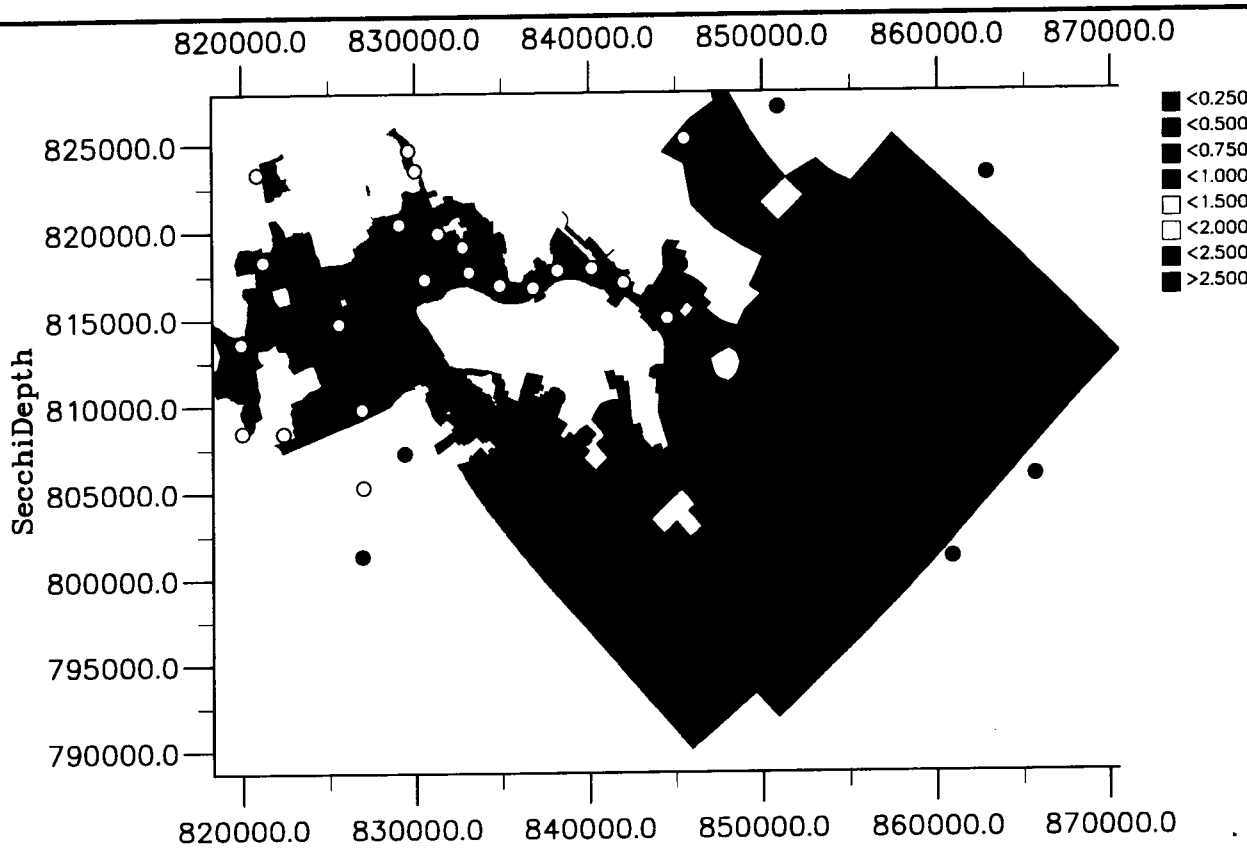
Suspended matter (mg/l) wet season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

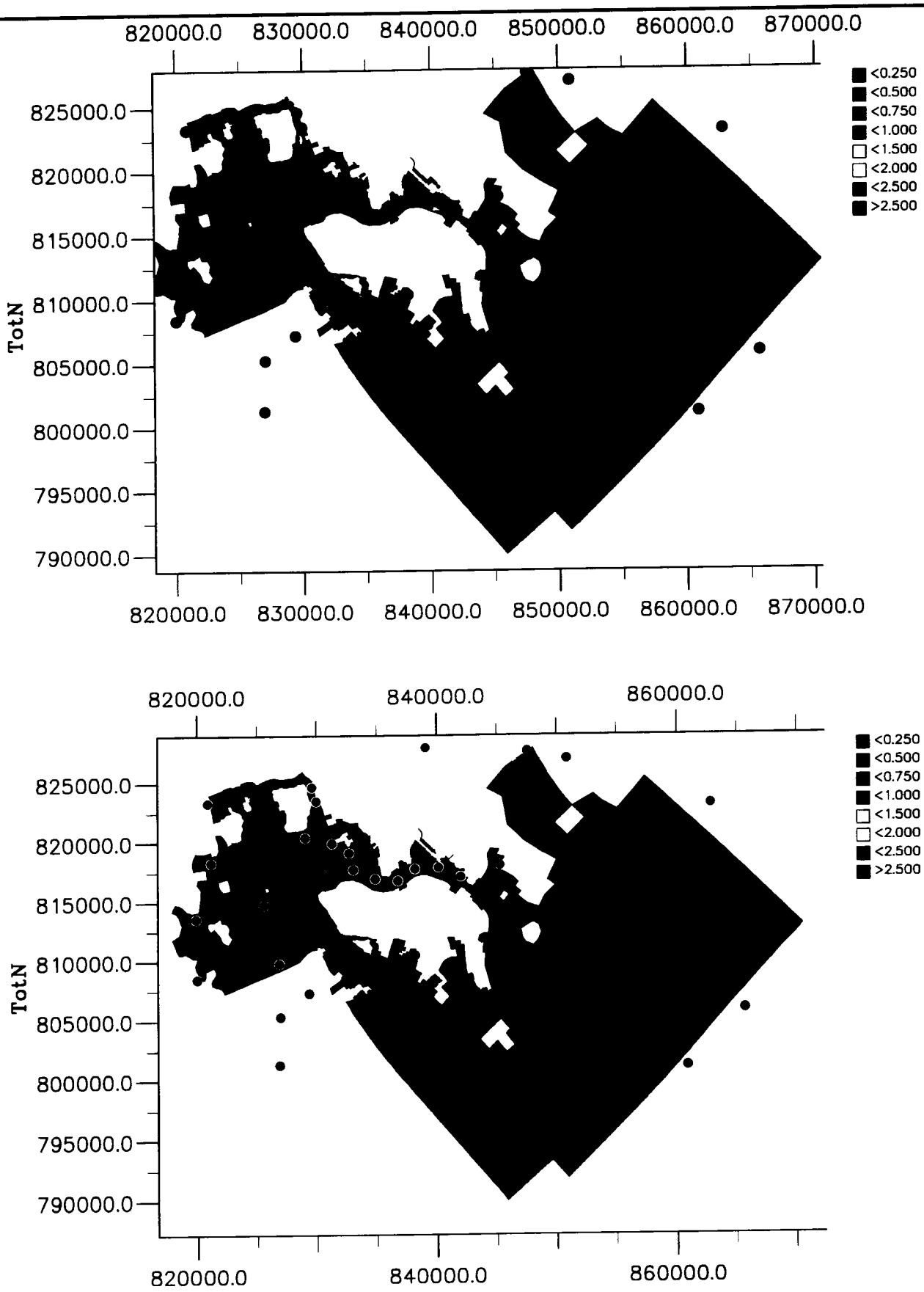
Z2455

Fig. 4.3



Lower plot area

Secchi depth (m) wet season Upper:surface	shat–w02.ssn	
	Shatin	
WL | DELFT HYDRAULICS	Z2455	Fig. 4.5



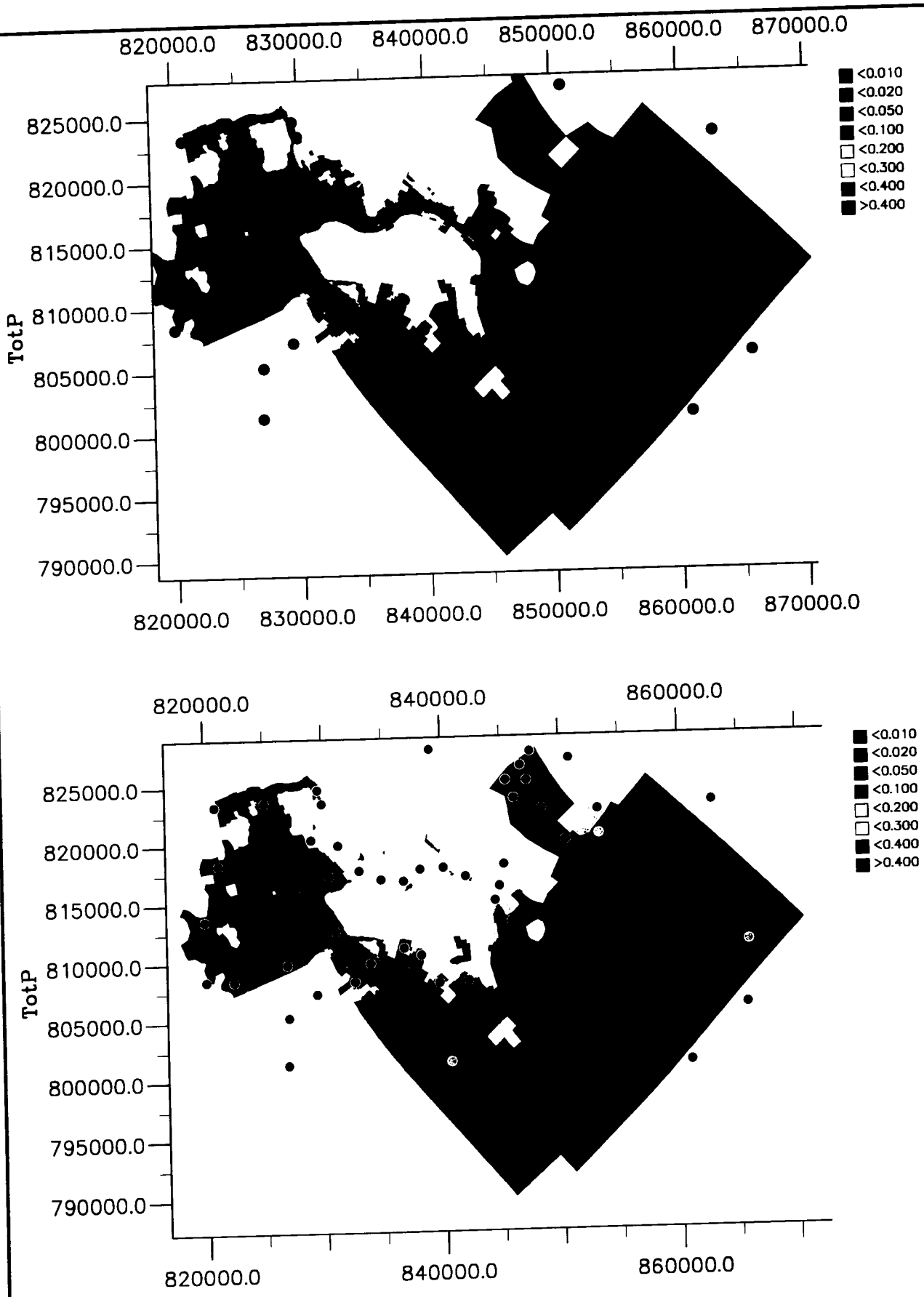
Total N (mg/l) wet season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.6



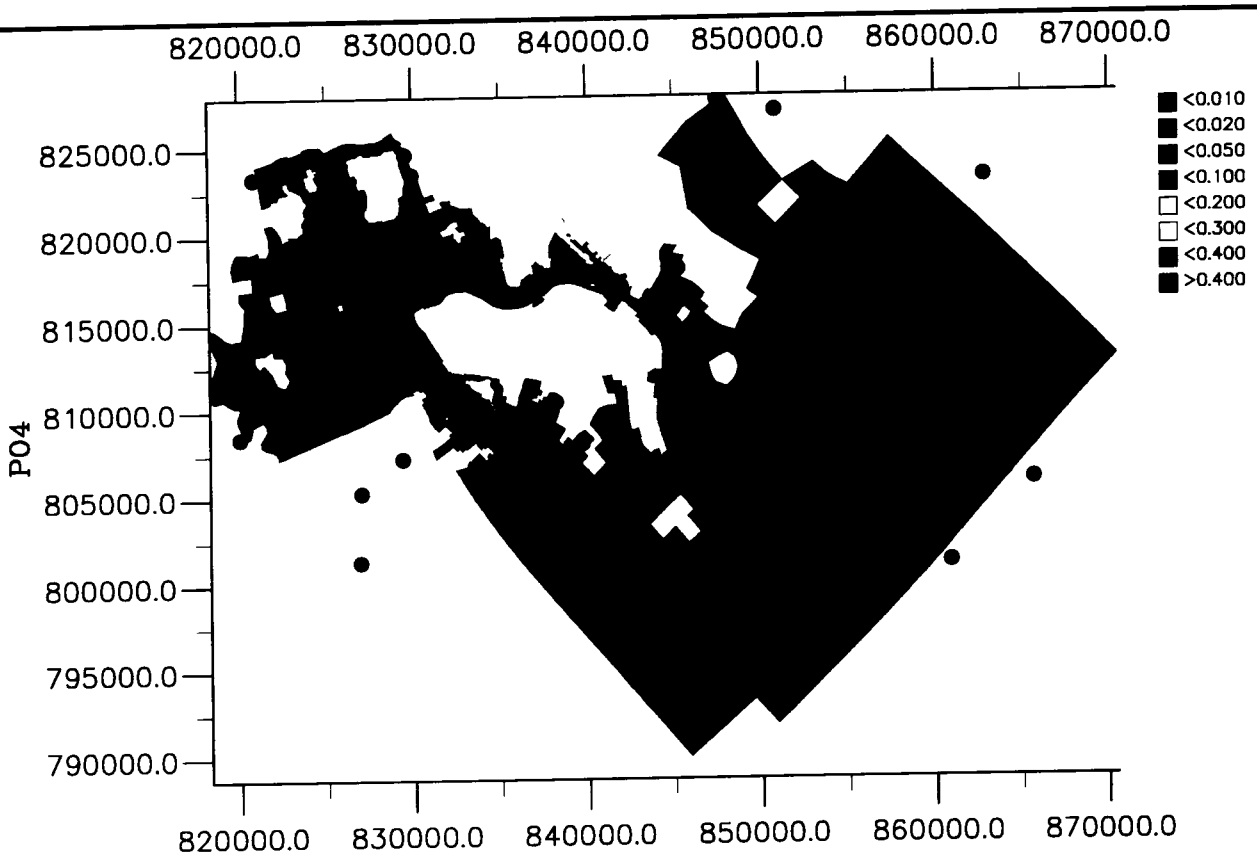
TotalP (mg/l) wet season
Upper:surface ; Lower: bottom layer

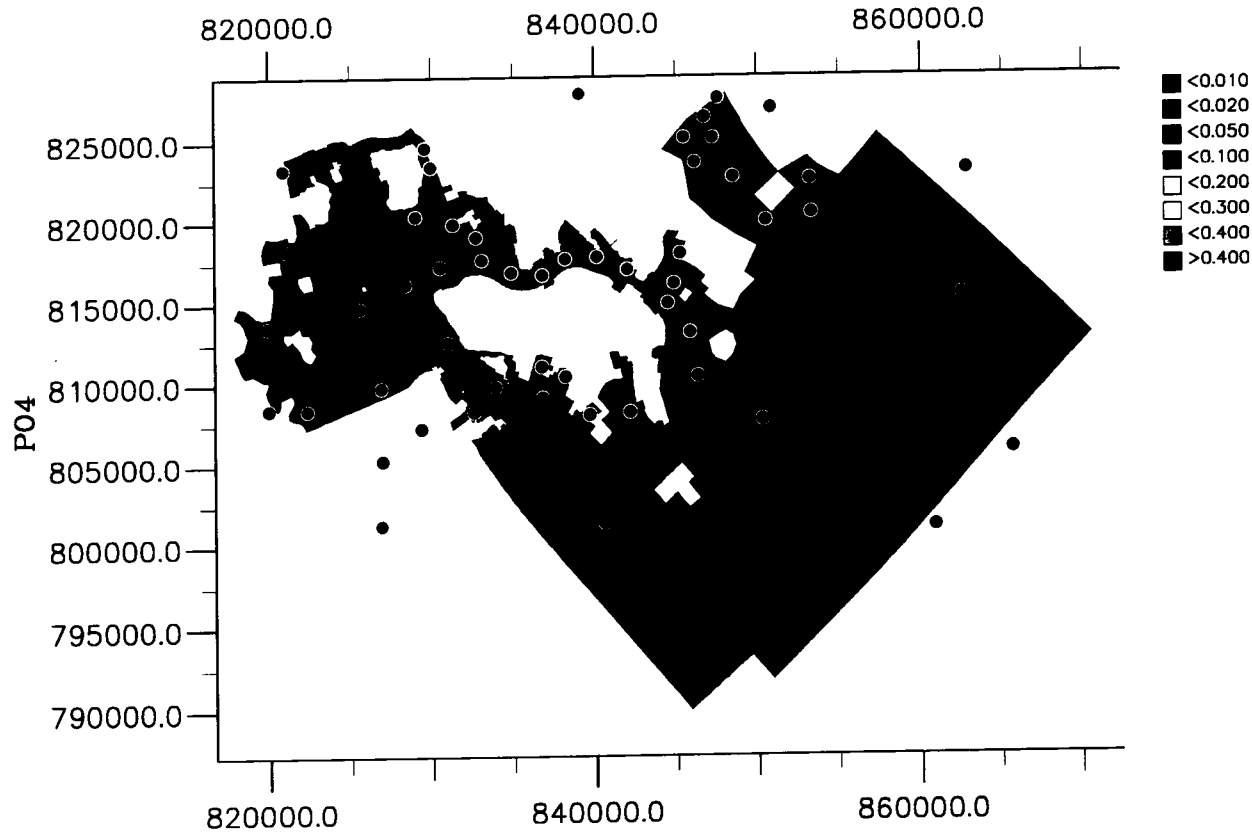
Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.7





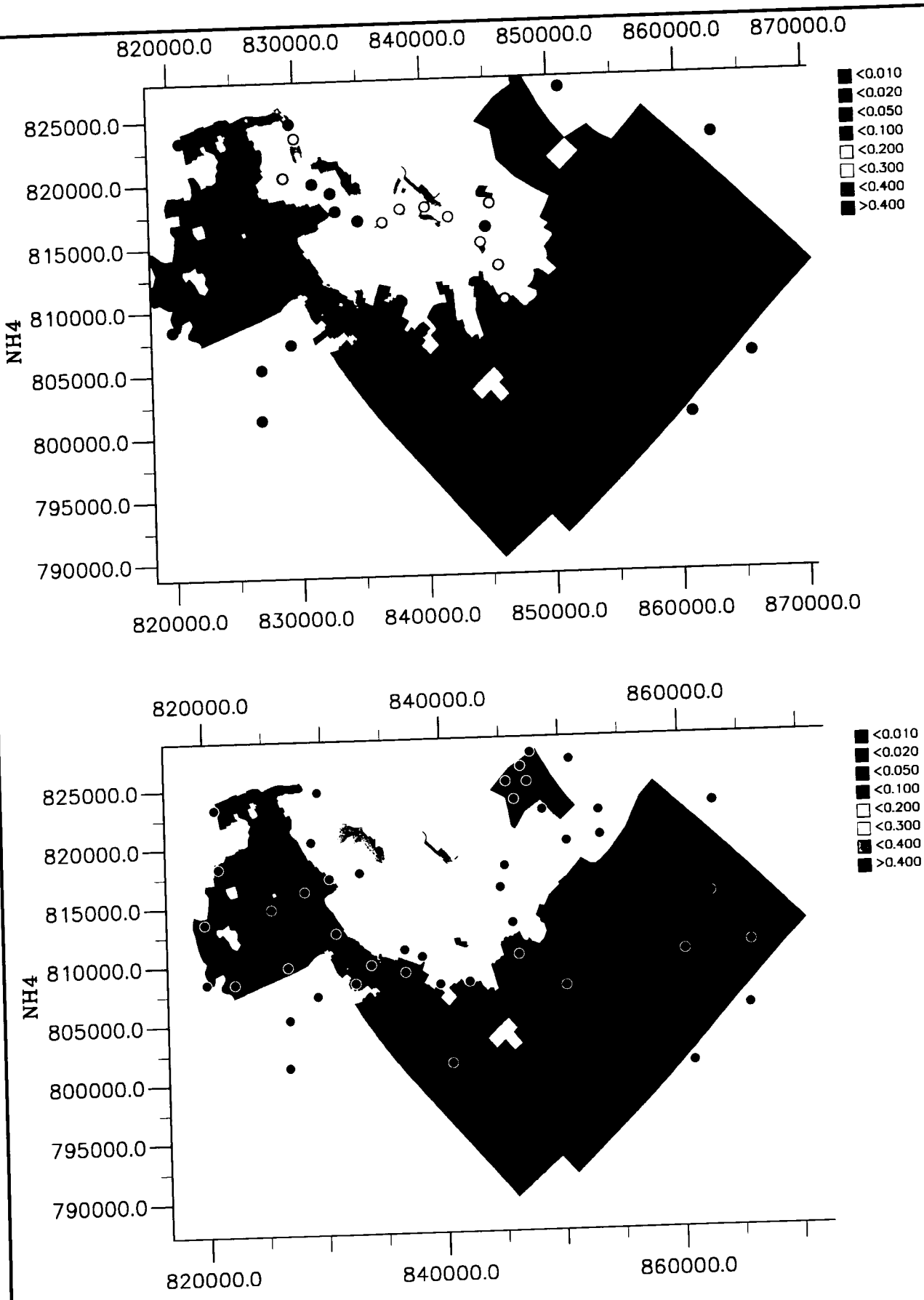
Phosphate (mg/l) wet season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.8



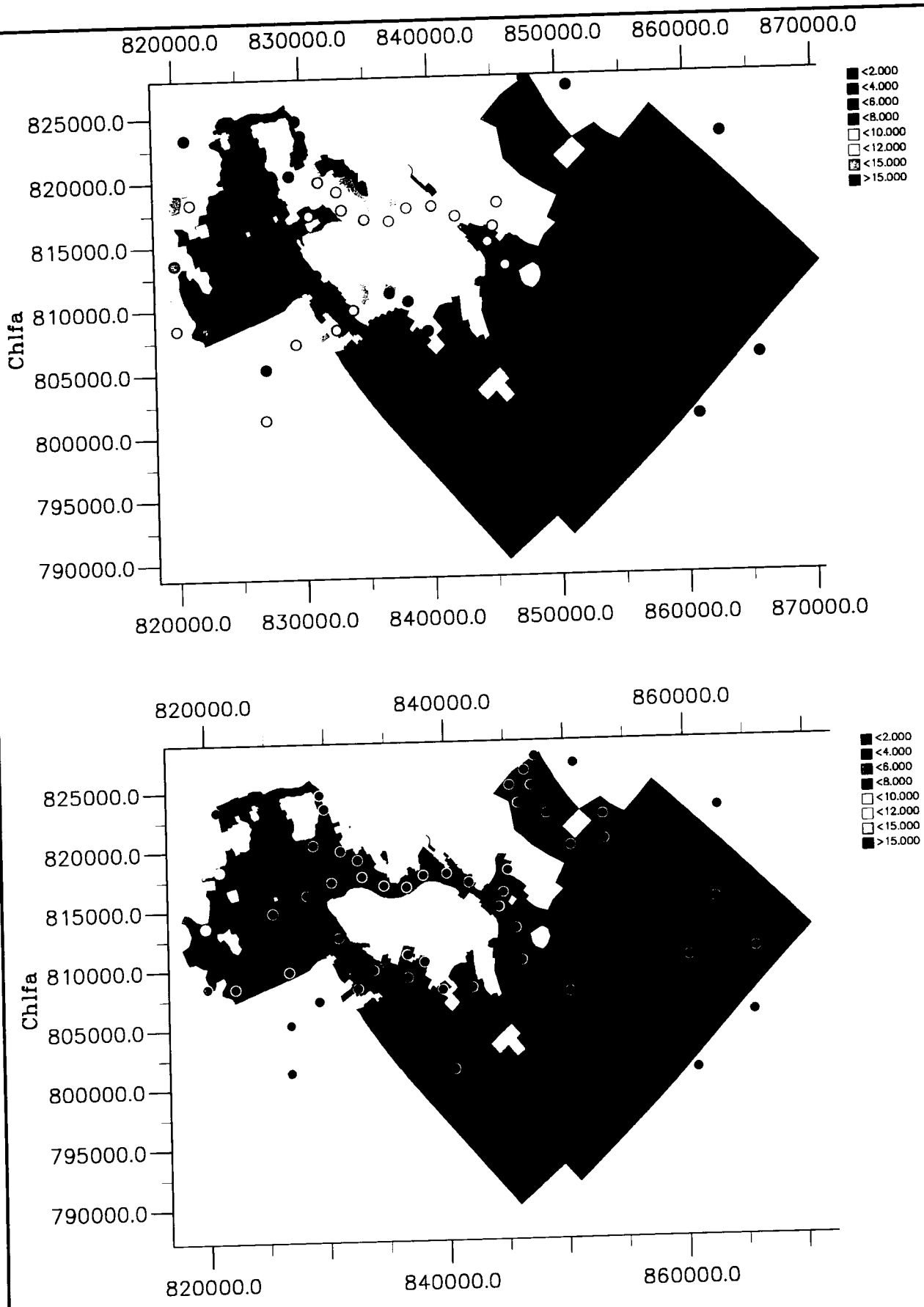
Ammonium (mg/l) wet season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.9



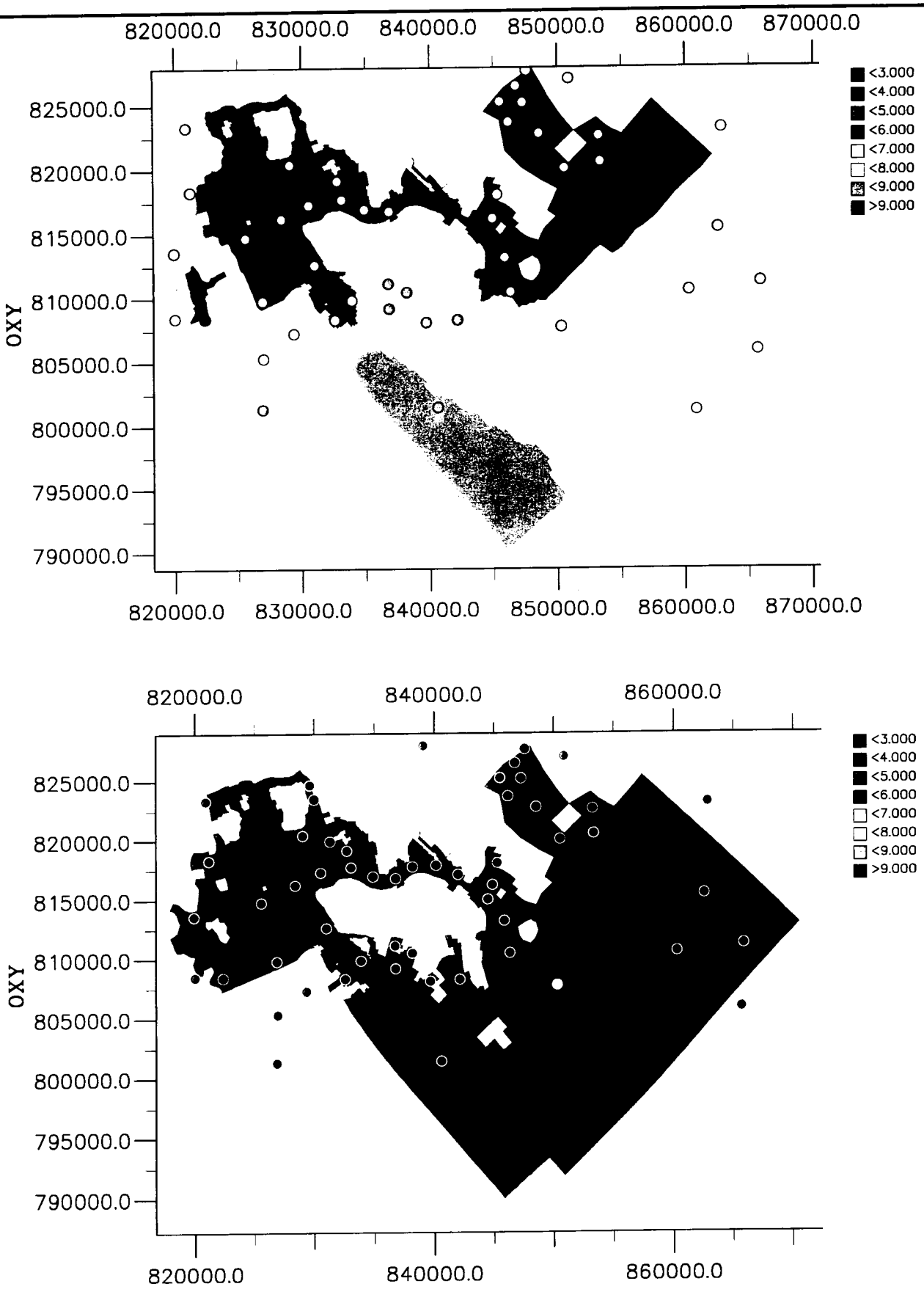
Chlfa (ug/l) wet season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.10



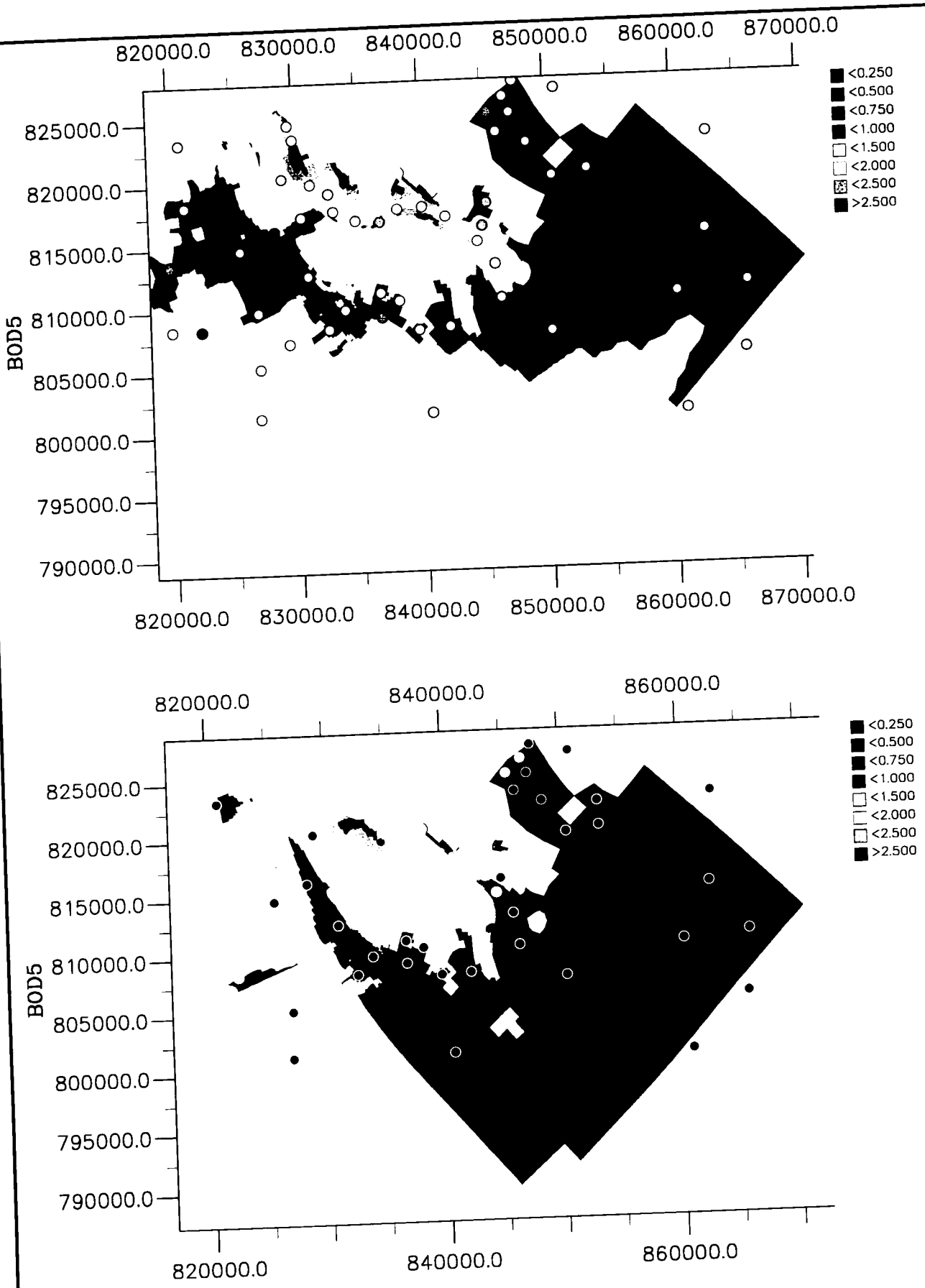
Oxygen (mg/l) wet season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.11



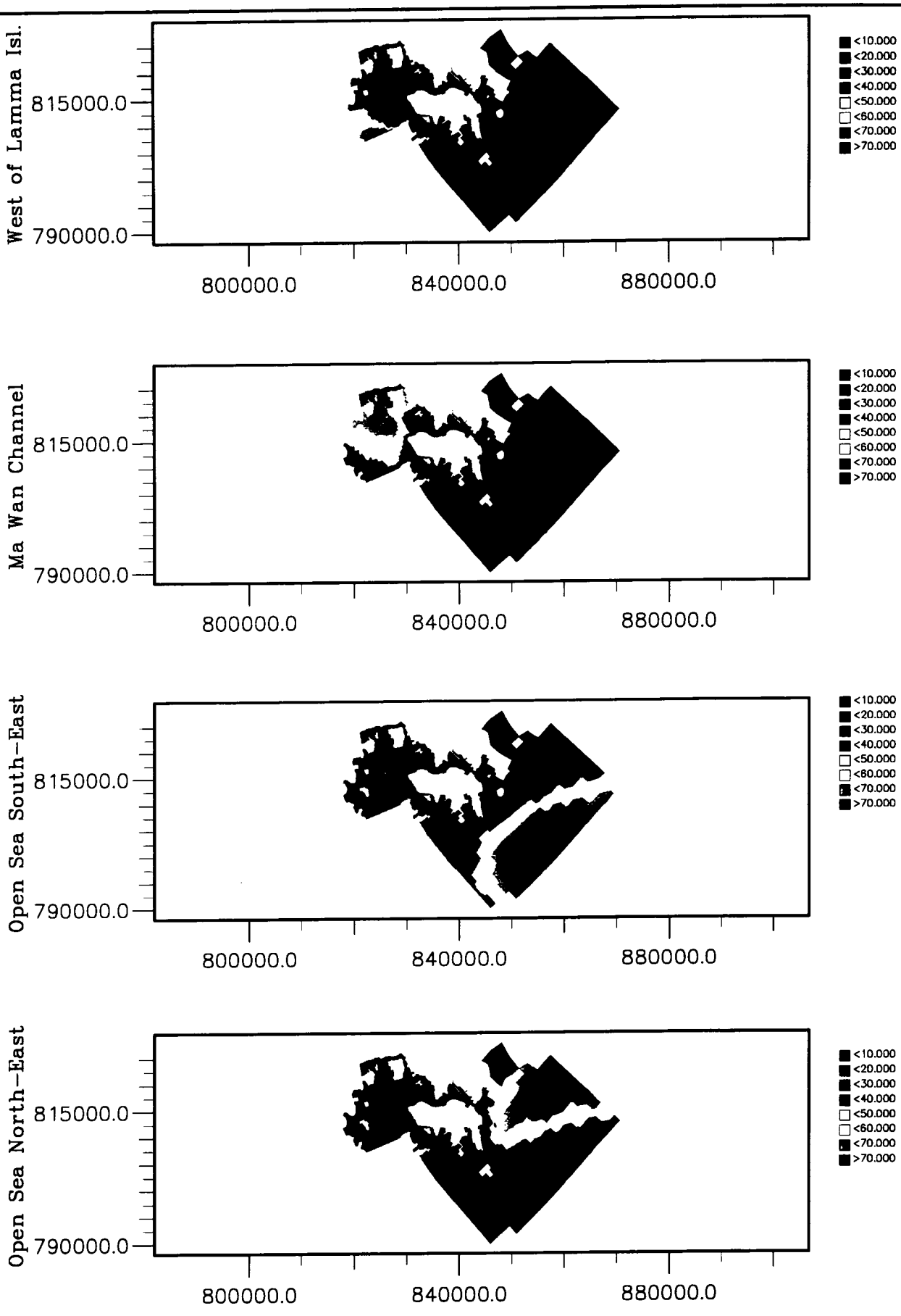
BOD5 (mg/l) wet season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 4.12



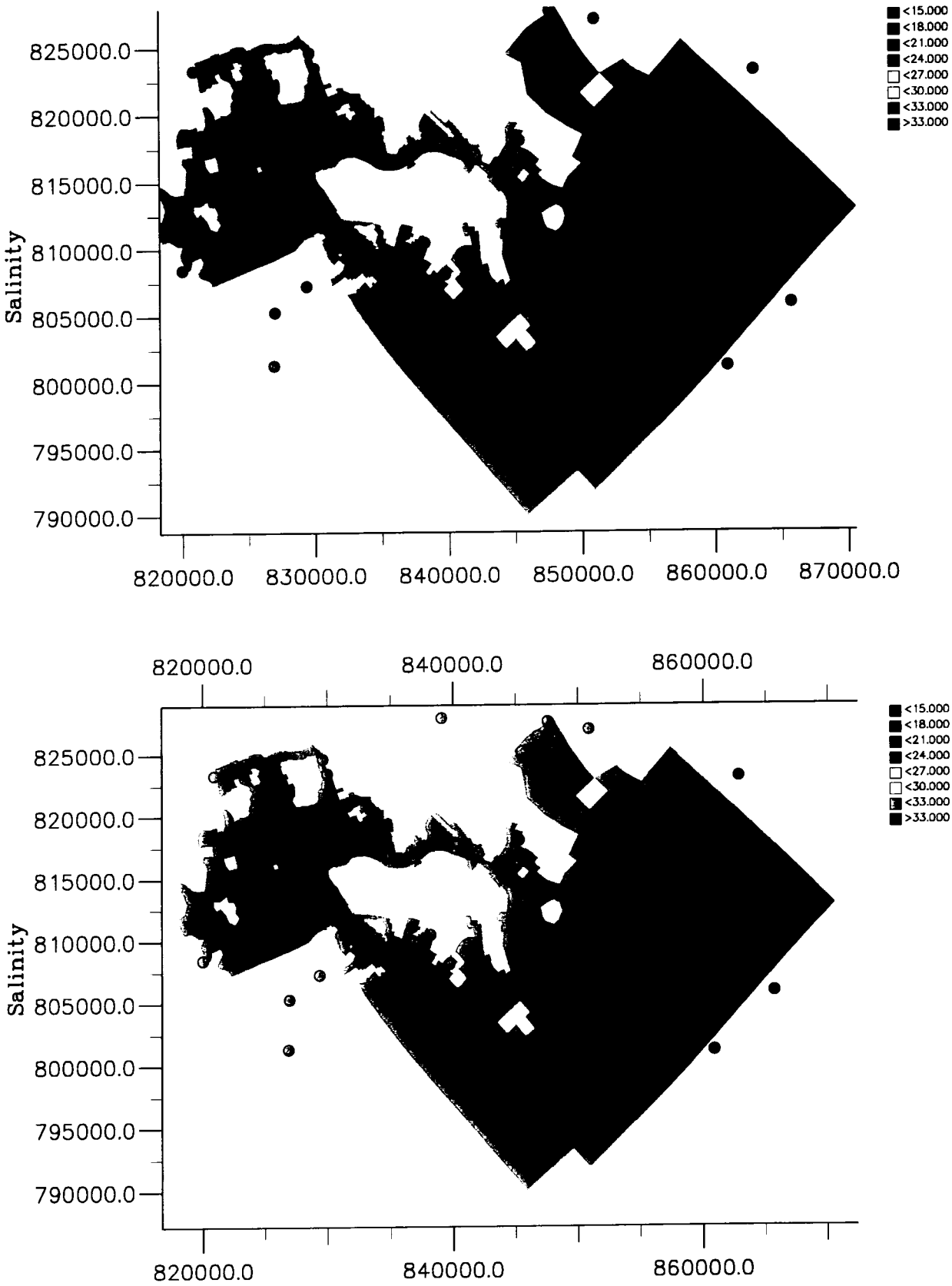
Shatin dry season
Tracers released at boundaries (100 mg/l)
Concentration after 15 days

Shatin

WL | delft hydraulics

Z2455

Fig. 5.01



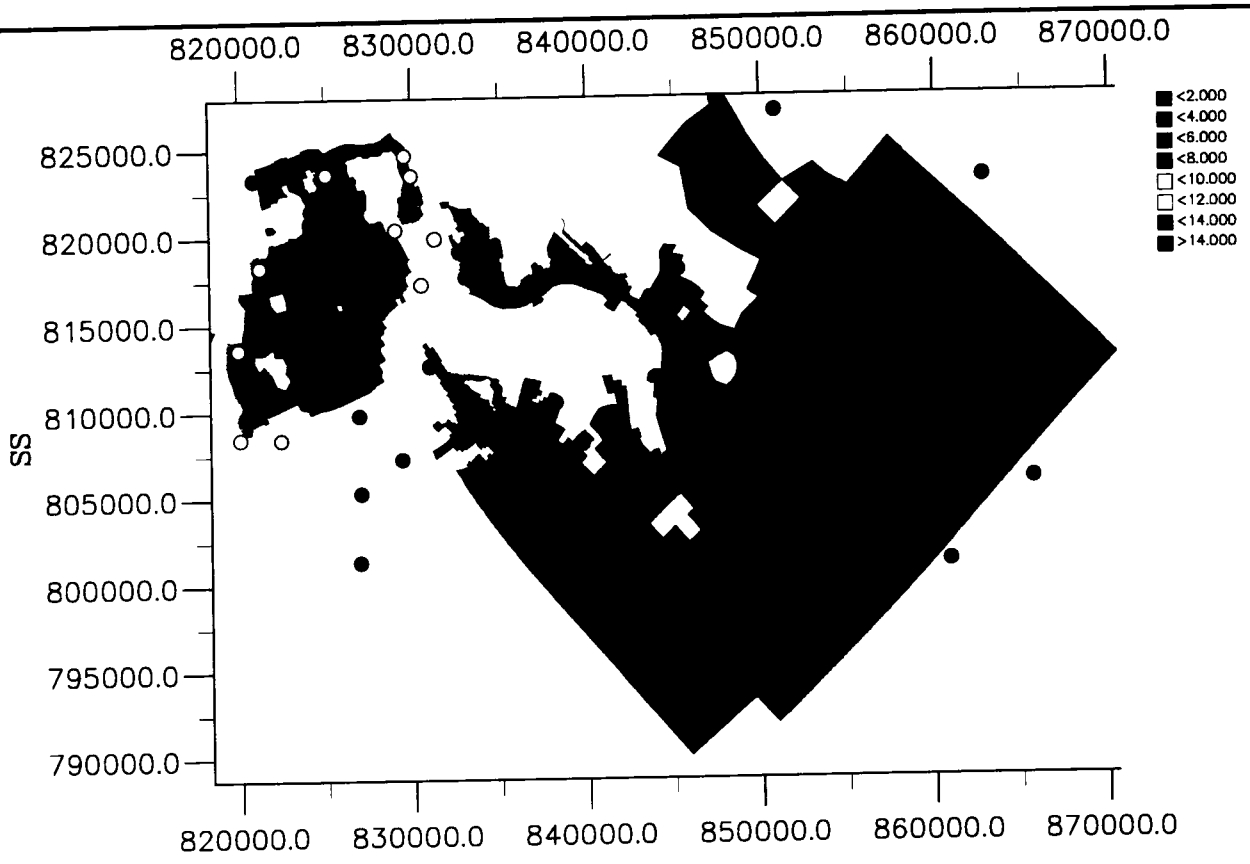
Salinity (ppt) dry season
Upper:surface ; Lower: bottom layer

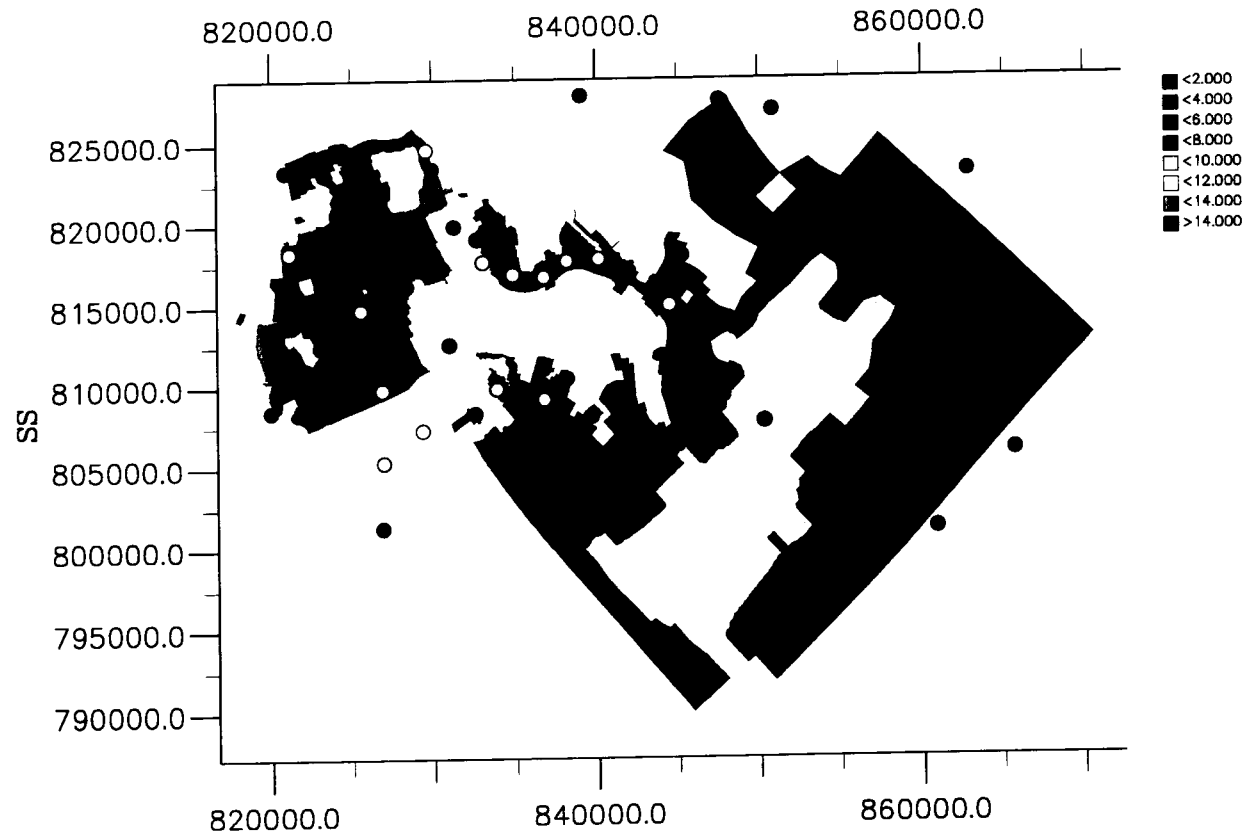
Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.02





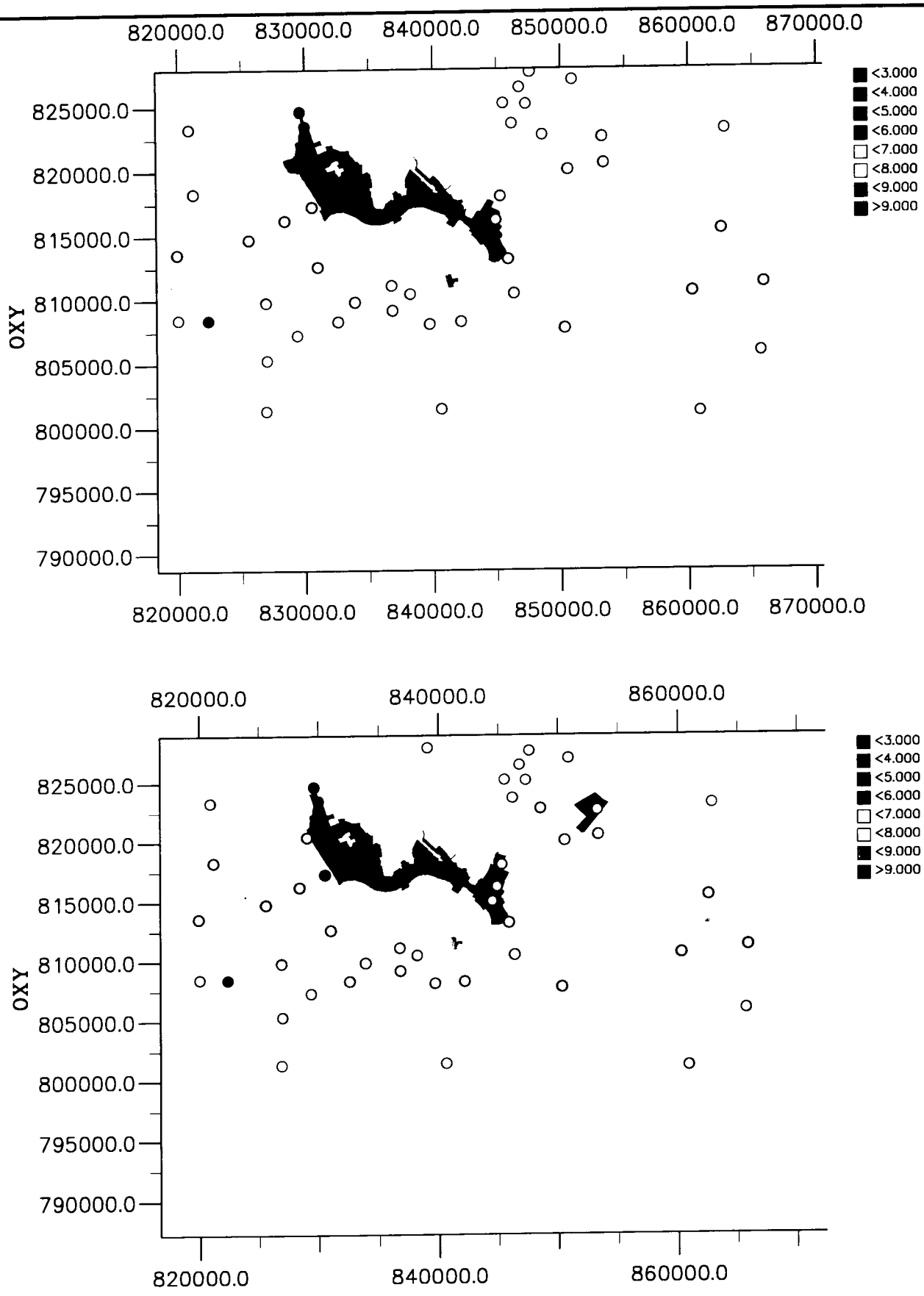
Suspended matter (mg/l) dry season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.03



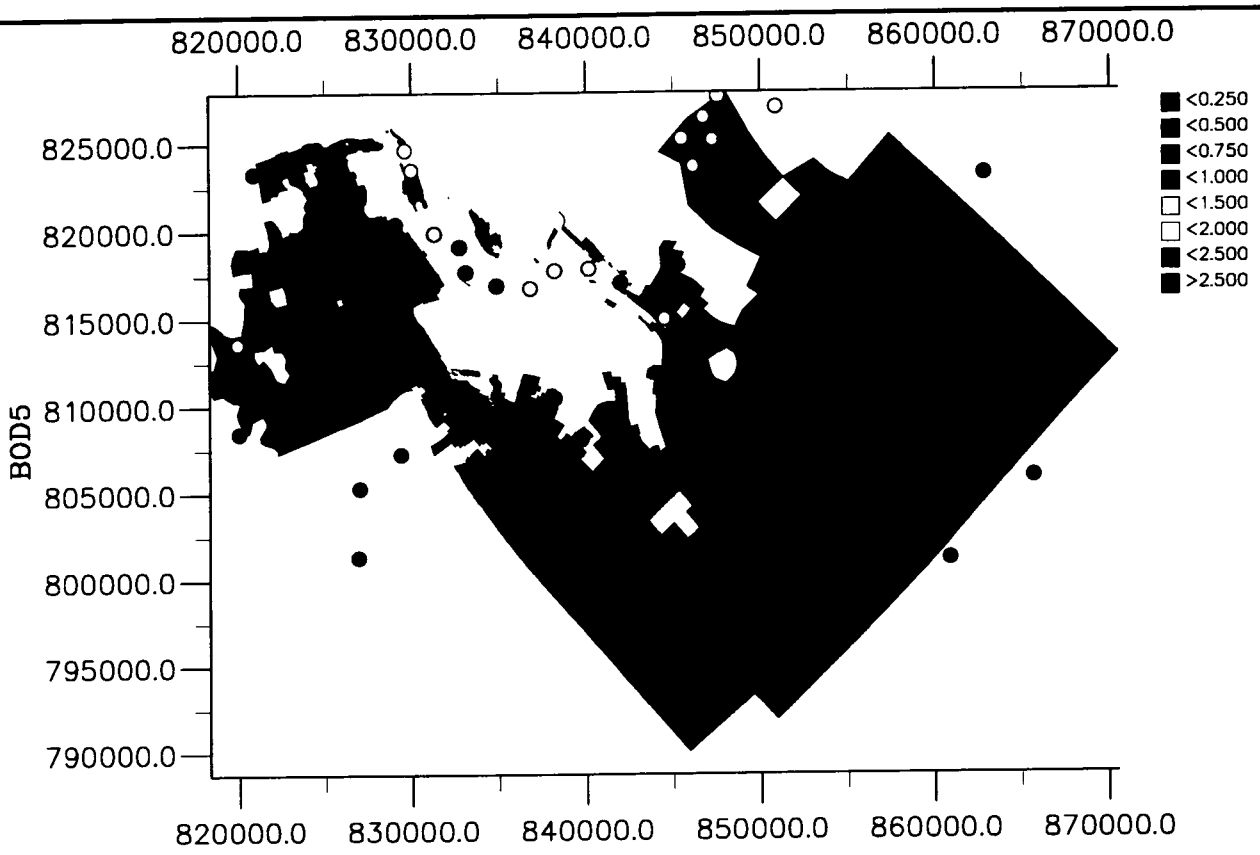
Oxygen (mg/l) dry season
Upper:surface ; Lower: bottom layer

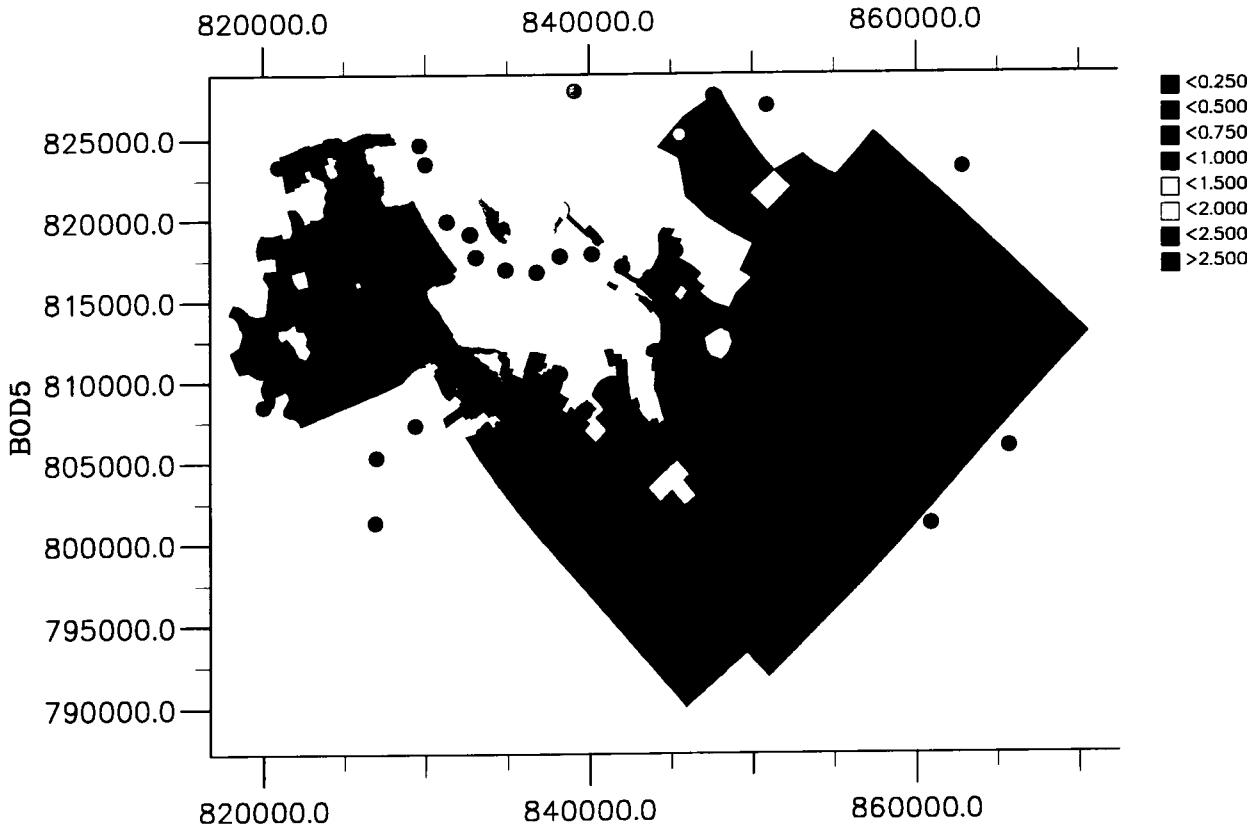
Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.04





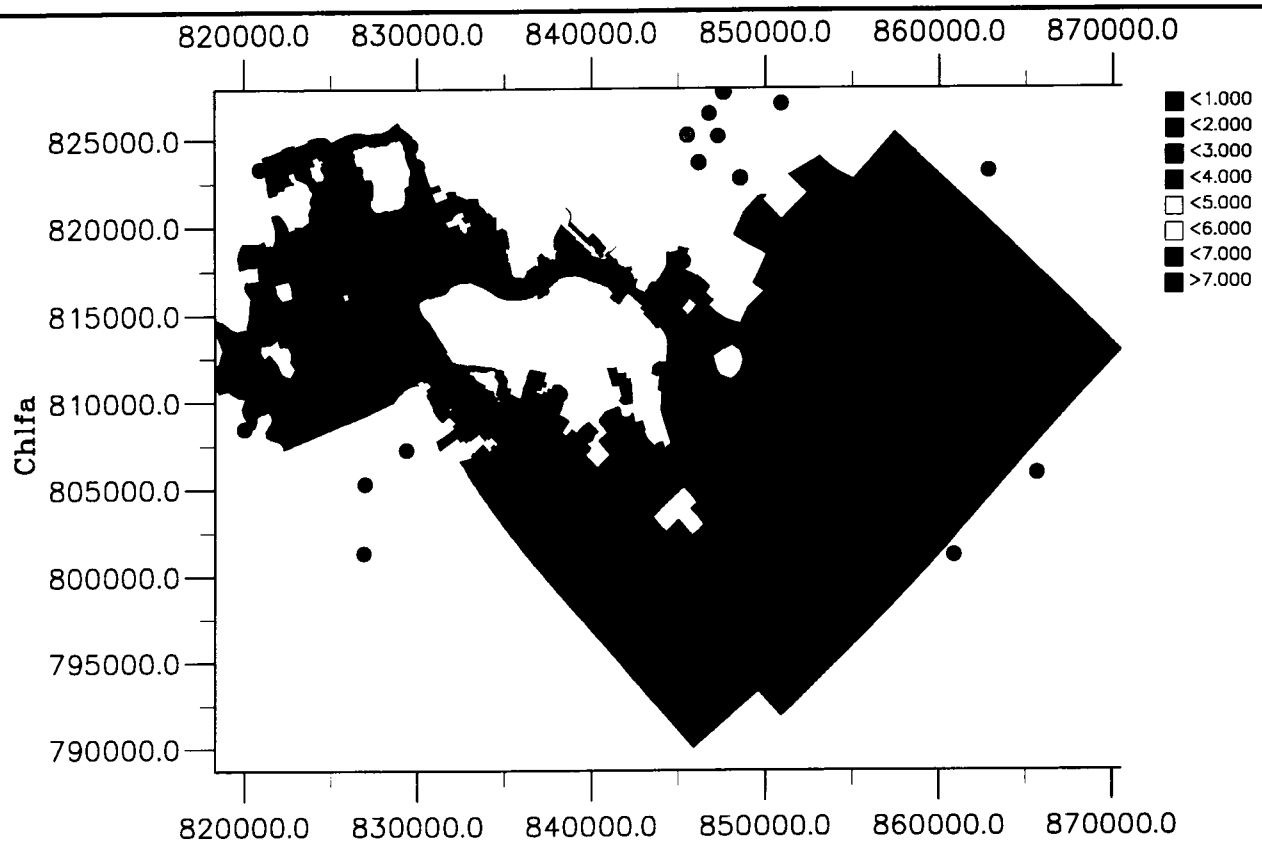
BOD5 (mg/l) dry season
Upper:surface ; Lower: bottom layer

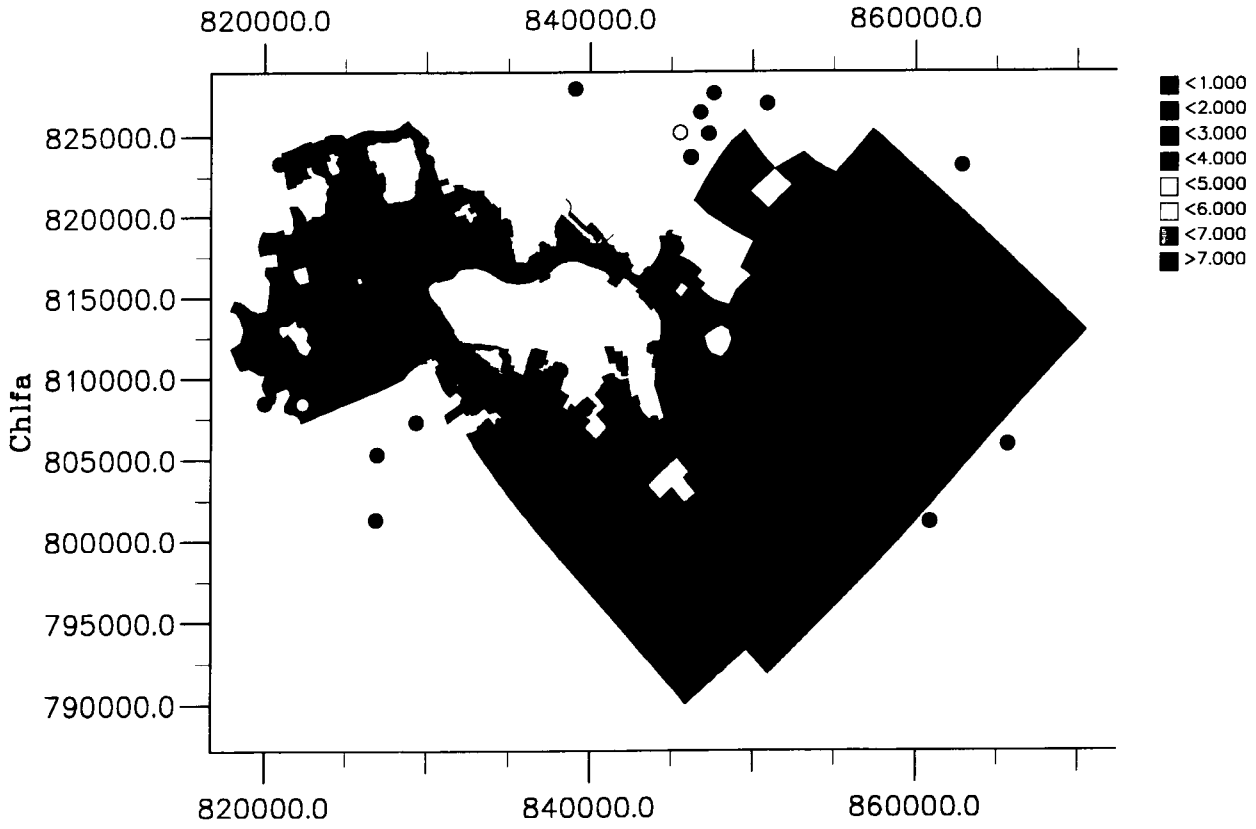
Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.05





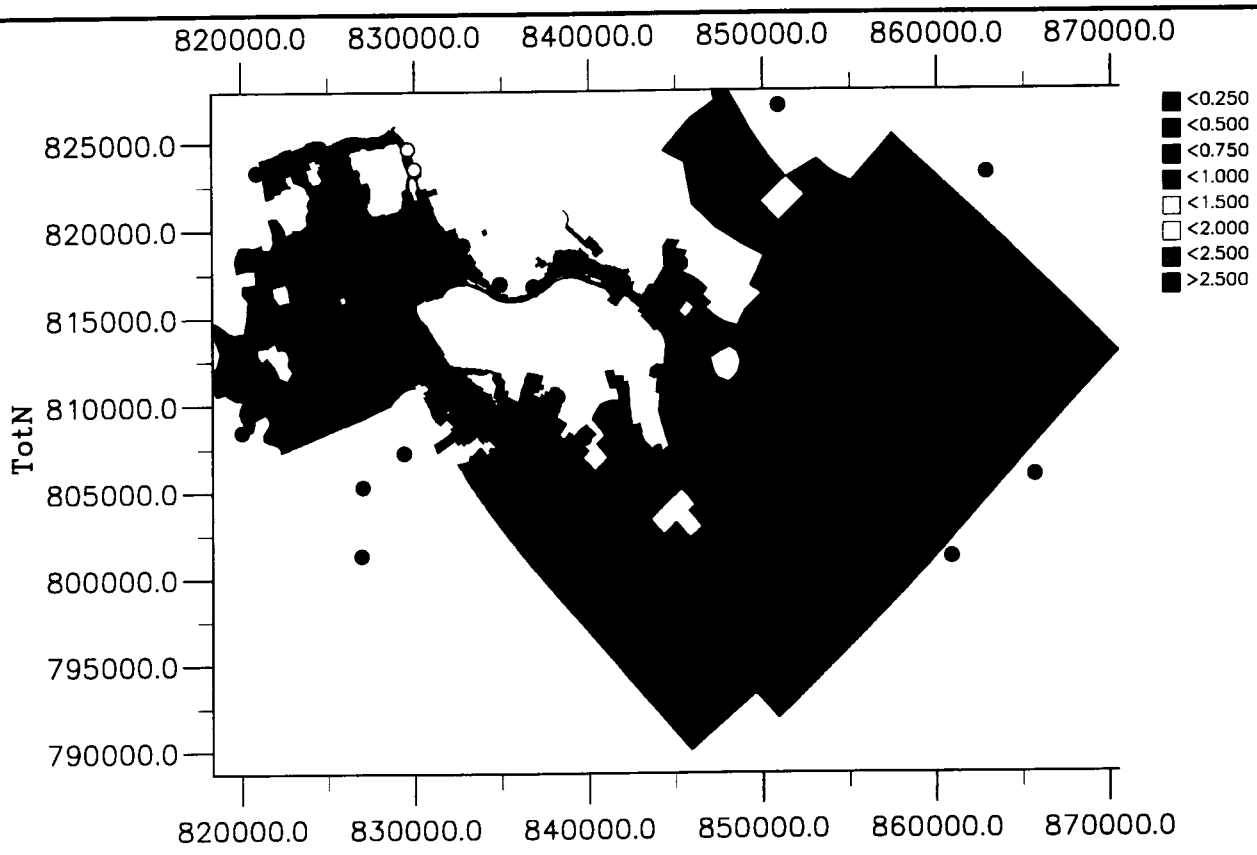
Chlfa (ug/l) dry season
Upper:surface ; Lower: bottom layer

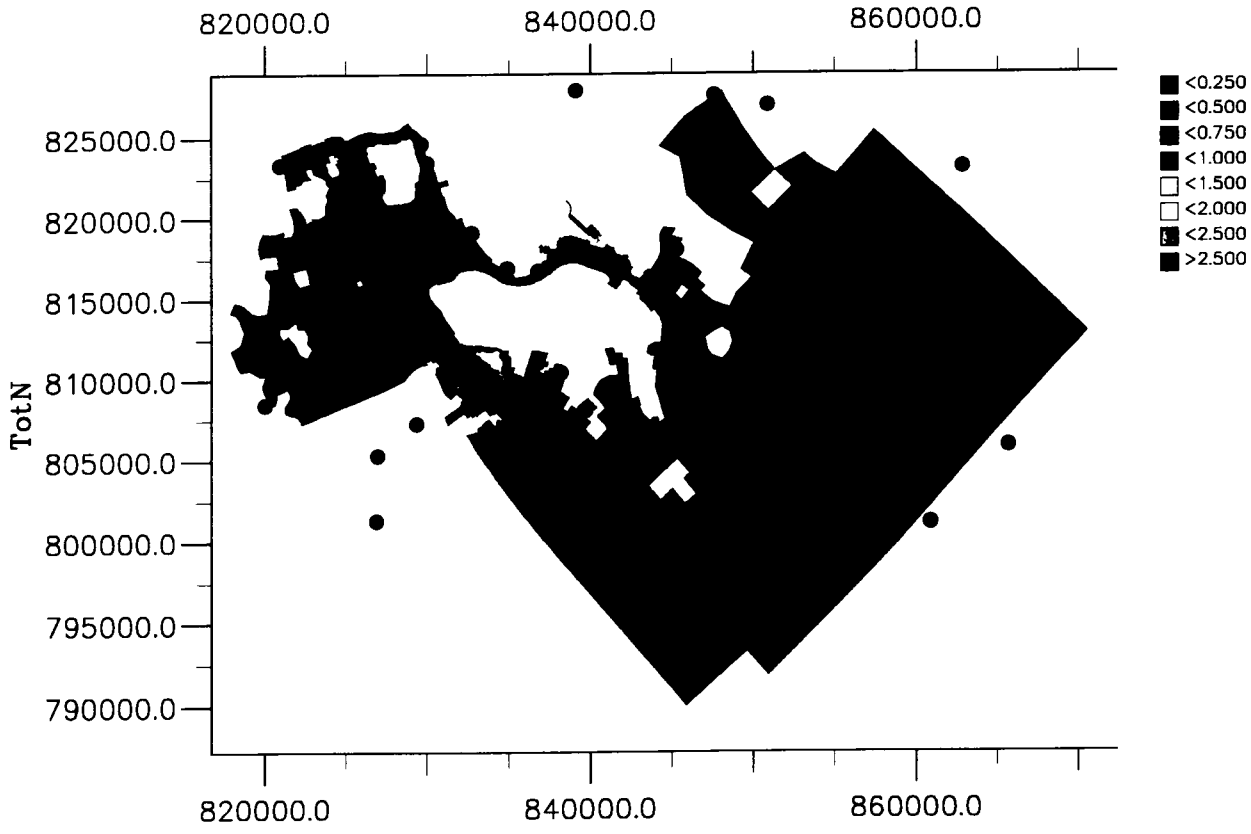
Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.06





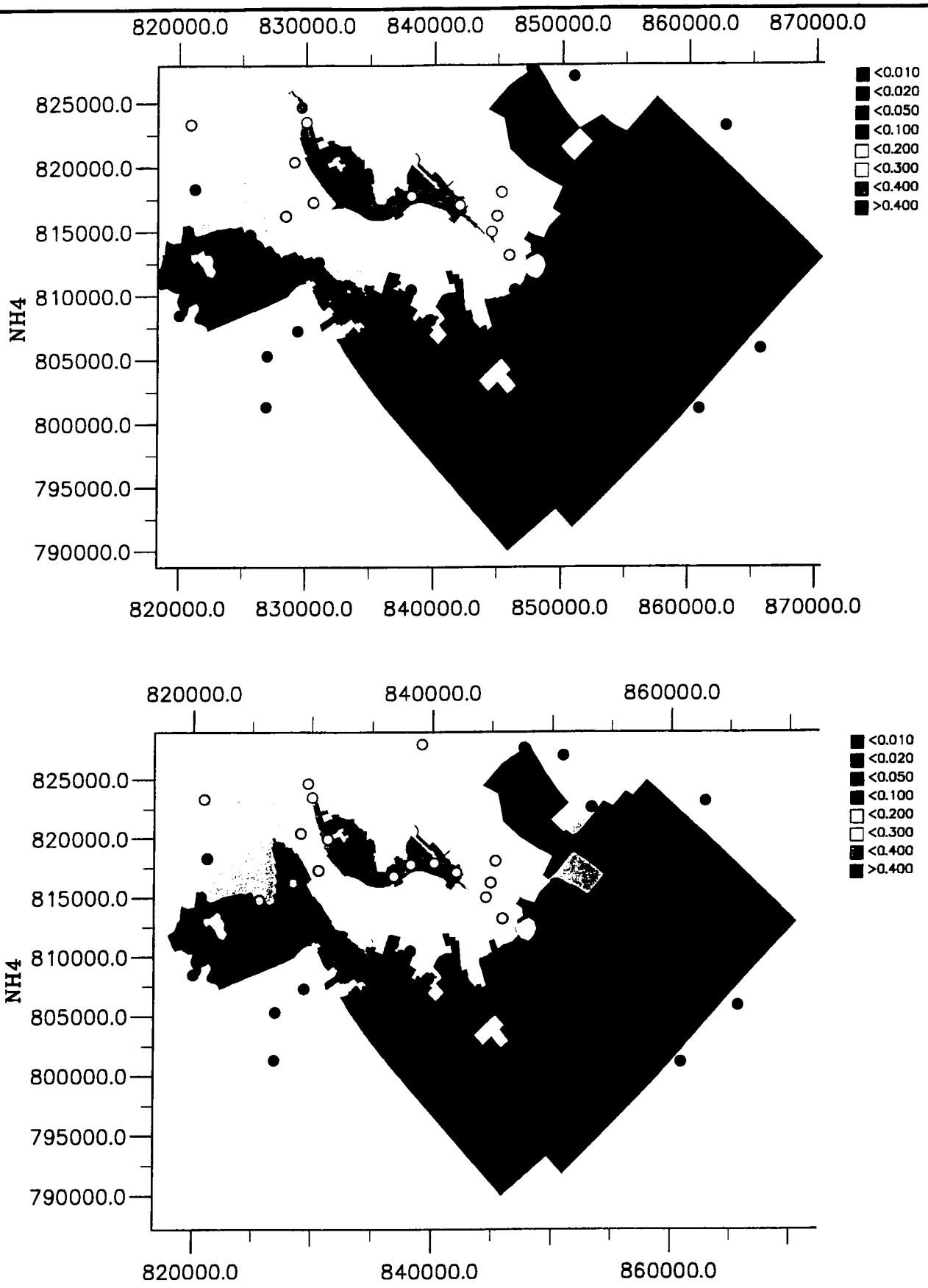
Total N (mg/l) dry season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.07



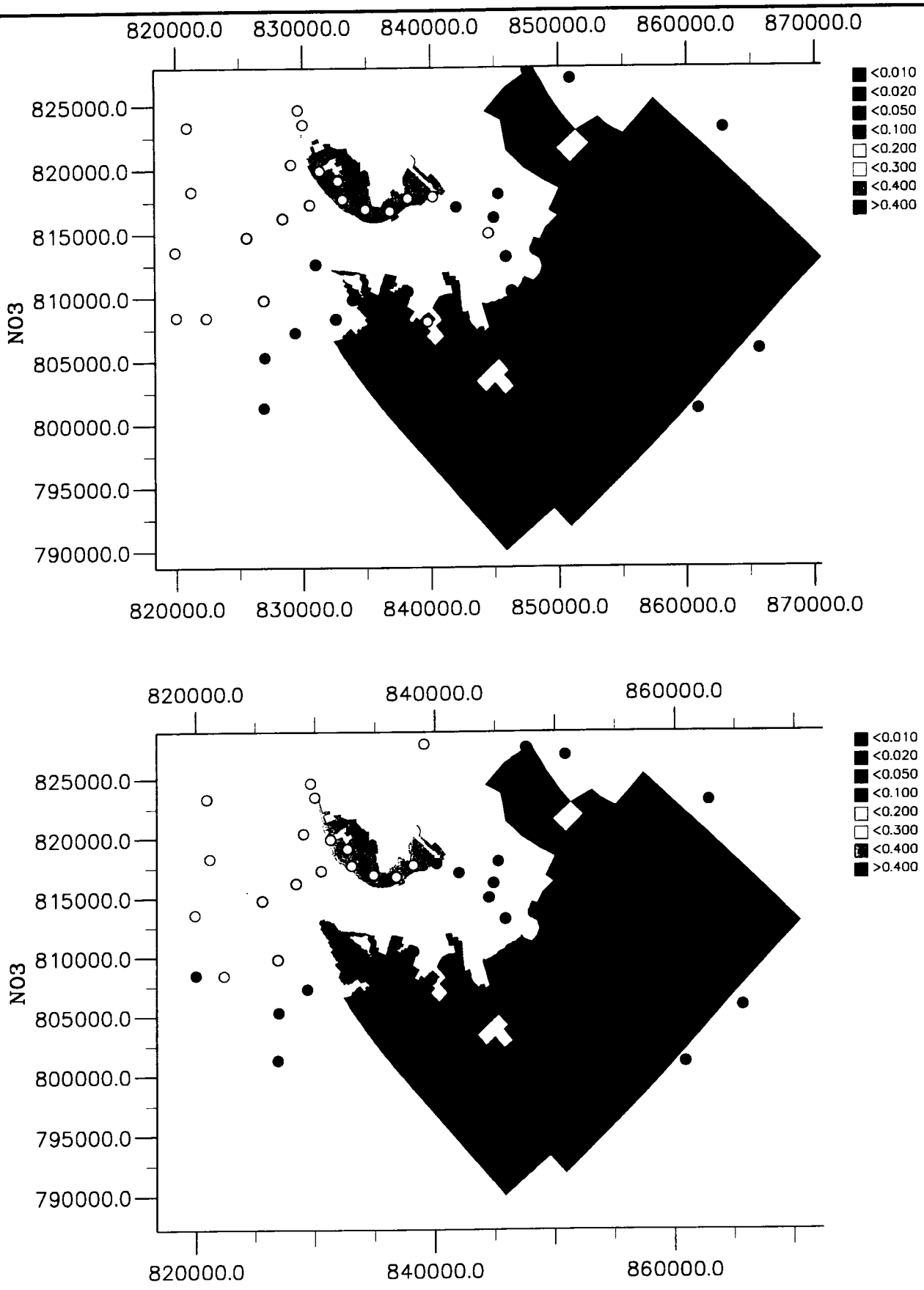
Ammonium (mg/l) dry season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.08



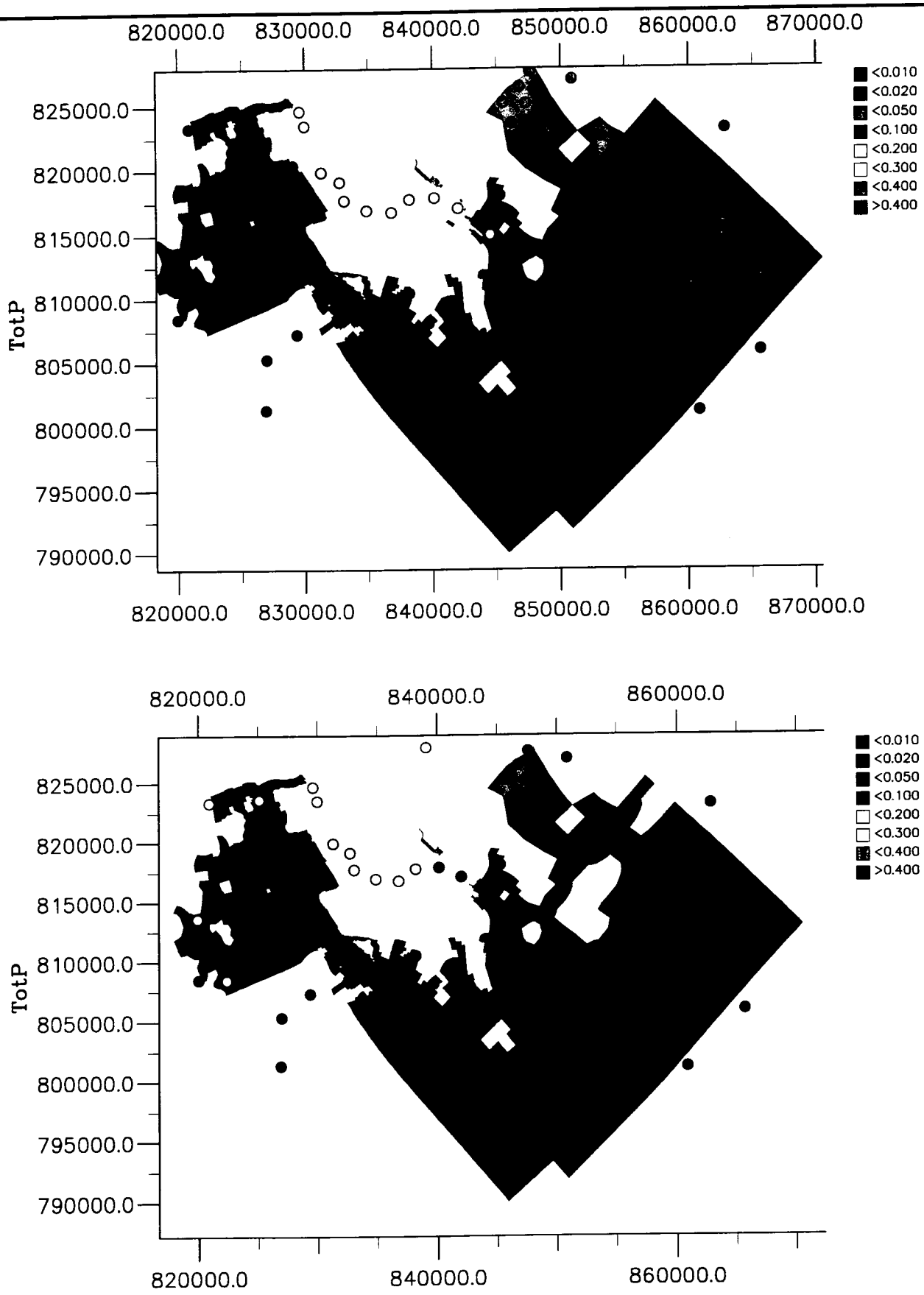
Nitrate (mg/l) dry season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.09



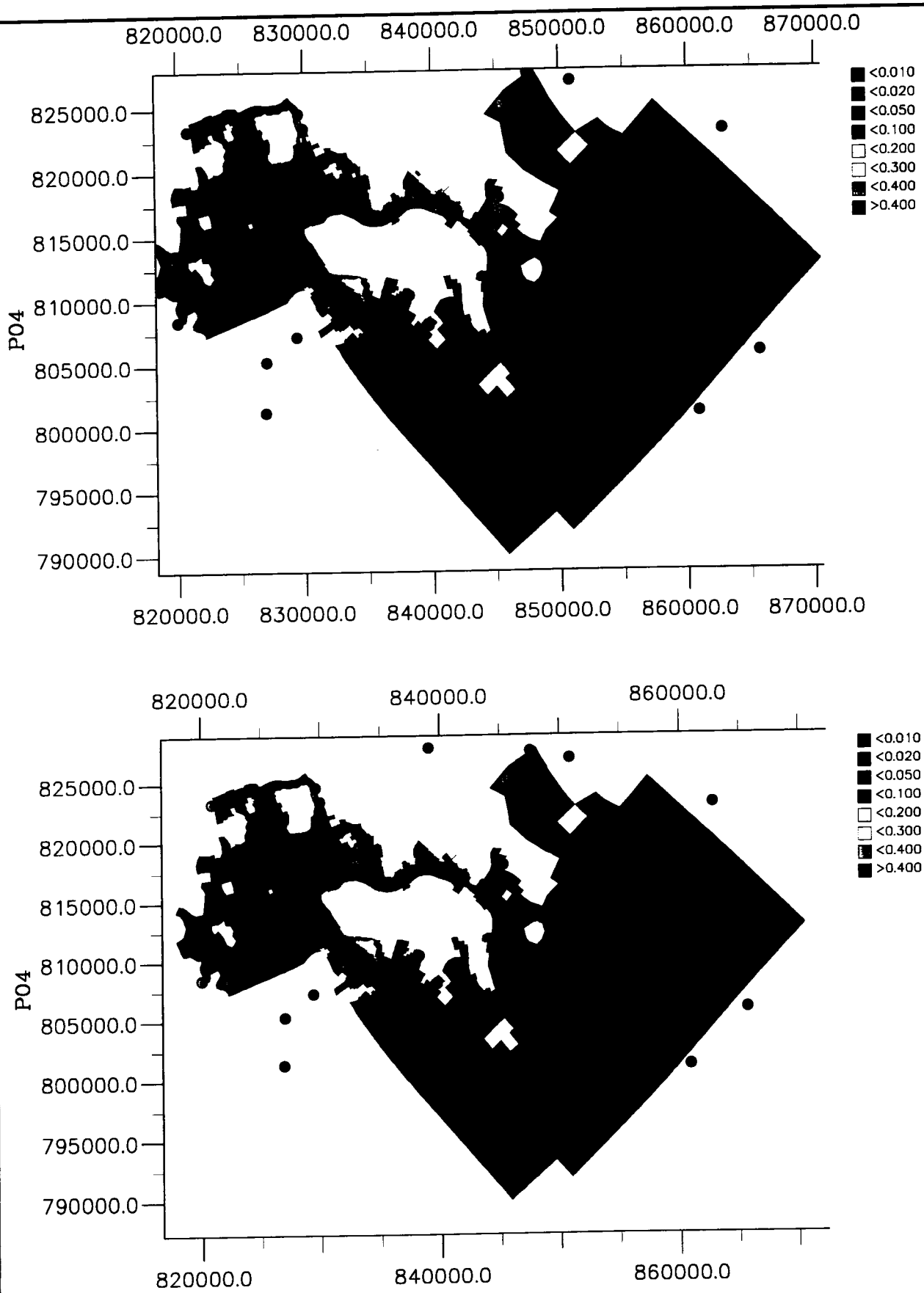
TotalP (mg/l) dry season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.10



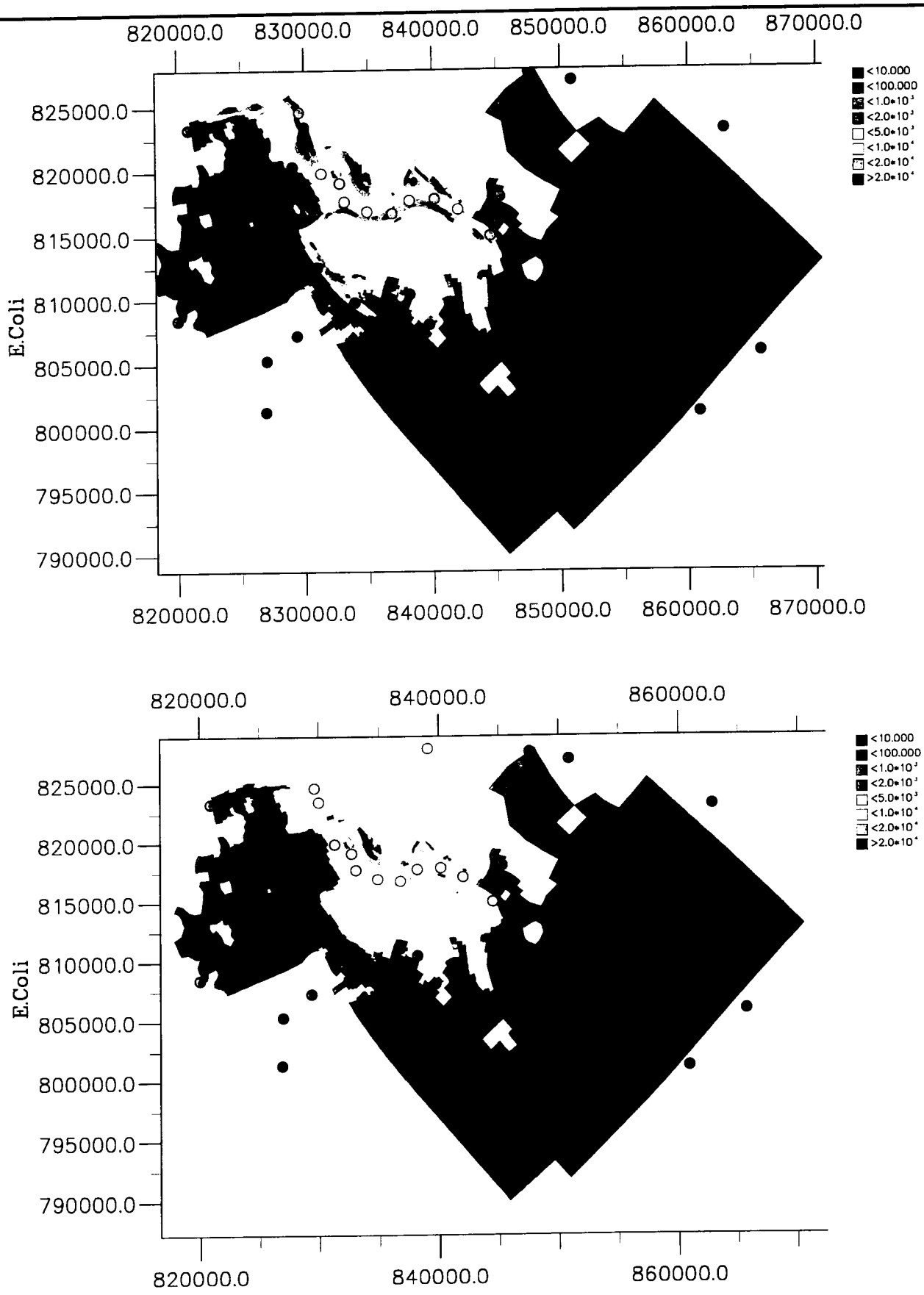
Phosphate (mg/l) dry season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.11



E.Coli (MPN/m3) dry season
Upper:surface ; Lower: bottom layer

Shatin

WL | DELFT HYDRAULICS

Z2455

Fig. 5.12