London Gateway Port

Sensitivity Analysis for Sediment Plume Modelling

Report EX 4772
April 2003

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HR Wallingford

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Summary

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S.1 In January 2002 HR Wallingford published the results of work undertaken on behalf of P&O Ports Limited and the Port of London Authority to investigate the effects of dispersion of fine material arising from dredging and reclamation activities associated with the proposed London Gateway Port (Reference 1). Further plume modelling results, produced for P&O Ports Limited, were published in March 2003 (References 2 and 3).

S.2 As an aid to understanding the sensitivity of the plume model used for these studies a series of sensitivity tests were undertaken. These sensitivity analysis tests have not been previously published and a selection of test results are presented in this report to provide additional confidence in the results published in References 1, 2 and 3.

Contents

1. INTRODUCTION

1.1 Background

1.1.1 In January 2002 HR Wallingford published the results of work undertaken on behalf of P&O Ports Limited and the Port of London Authority to investigate the effects of dispersion of fine material arising from dredging and reclamation activities associated with the proposed London Gateway Port (Reference 1). Further plume modelling results, produced for P&O Ports Limited, were published in March 2003 (References 2 and 3).

1.1.2 As an aid to understanding the sensitivity of the plume model used for these studies a series of sensitivity tests were undertaken. These sensitivity analysis tests have not been previously published and a selection of test results are presented in this report to provide additional confidence in the results published in References 1, 2 and 3.

1.2 Report structure

1.2.1 The remainder of this report comprises four further chapters. The sensitivity analysis of the far-field impacts arising from plume dispersion are described in Chapter 2. The sensitivity analysis of the near-field dispersion is presented in Chapter 3. The results of the sensitivity analyses are further discussed in Chapter 4 and the conclusions of the report are presented in Chapter 5.

2. FAR-FIELD PREDICTIONS

2.1 Introduction and methodology used

2.1.1 This chapter discusses the results of sensitivity tests of the methodology used to predict the far-field effects of dredging activity.

2.1.2 The methodology used for the predicting the far-field effects of dredging activity has been described in Reference 1. The methodology chosen was to use a constant rate of release to represent the time-averaged rate (allowing for the duration of overflow and of the cycle time) of input of fines to the water column. The simulations were undertaken for a period of fifteen tides which was sufficient to ensure that any build-up in background concentrations has reached a broad equilibrium.

2.1.3 The parameters used in the predictions are as follows:

Table 1 Sediment parameters used in plume dispersion modelling

Critical shear stress for deposition	= 0.1 N/M^2
Critical shear stress for erosion	= 0.5 N/m^2
Erosion constant	= 0.0005 ms
Settling velocity	= 5mm/s

2.1.4 The values of critical shear stress and erosion rate are parameters that are typically used in studies of this type and are derived from the literature. However, the choice of the (constant) settling velocity value, has been made with precaution in mind.

2.1.5 The settling velocity of fine sediment throughout the plume will vary considerably, and, broadly speaking will vary with suspended sediment concentration. In the vicinity of the dredger the settling velocity will be greatest and will range up to several millimetres per second. At the fringes of the plume the settling velocity will return to ambient levels which themselves vary, reducing with distance eastwards. At Southend typical settling velocities, based on the low observed concentrations, will be of the order of a fraction of a millimetre per second.

2.1.6 A precautionary value of 5mm/s has been chosen for the settling velocity for the plumes. This relatively high value reflects the values of settling velocity that might be found near the dredger. Moreover, in the far field where real settling velocities will be significantly lower, this choice ensures that the predicted settling fluxes onto the bed will not be under-predicted even allowing for uncertainty in the parameter values presented in Table 1.

2.1.7 Note that the choice of a relatively high settling velocity will reduce concentrations in the far-field through net deposition in the near and mid-fields to a small extent but the effect of the settling in the far-field is dominated far more strongly by the increased settling velocity. The principal effect of a high settling velocity is therefore to result in more deposition in the far-field, leading to a precautionary estimate of effect.

2.2 Nature of far-field sensitivity test

2.2.1 The sensitivity test was carried out was to undertake the same long-term (fifteen tide) simulation of dredging using the same parameters as presented in Table 1 but with the following differences:

- Instead of a constant, continuous value of release of fines the full dredging cycle was represented in the model.
- A settling velocity dependent on concentration was used. The relationship used was based on recent in situ measurements of settling velocity in the literature and had the form,

$$w_s = 0.005\ C \qquad C > 0.05\ \text{kg/m}^3$$
$$w_s = 0.25\text{mm/s} \qquad C \leq 0.05\ \text{kg/m}^3$$

where C is the suspended sediment concentration (kg/m^3).

2.2.2 The sensitivity test was carried out for the case of dredging at 4km of silty sand. This has been identified as the worst case for far-field effects on intertidal flats, those at Chapman Sands and Southend and Leigh Flats, being of particular interest in this respect (Reference 3).

2.3 Results of far-field sensitivity test

2.3.1 Figure 1 shows the peak concentrations occurring over a fifteen tide period (spring tides) for the "standard" scenario of dredging for silty sand 4km from the upstream end of London Gateway using the methodology presented in Reference 1. The figure also shows time series of depth averaged suspended solids concentrations at six locations around the dredging activity.

2.3.2 The sensitivity test result (with the full detail of the dredging cycle is represented and a concentration dependent parameterisation of the settling velocity) is shown in Figure 2. It can be seen that including the detail of the dredging cycle (and a more accurate representation of settling velocity) significantly increases the peak concentrations in the vicinity of the dredger. This is because the more detailed representation of the dredging cycle introduces fines to the water column at a greater rate during the period of dredging, hence resulting in "peakier" concentration increases.

2.3.3 The prediction of the far-field effects for these two simulations are shown in Figures 3 and 4. Figure 3 shows the peak depth averaged concentrations and a time series at a location on Chapman Sands for the two scenarios. It can be seen in Figure 3 that the more realistic scenario produces higher increases in suspended solids concentrations above background levels. Figure 4 shows the peak deposition for the same area. It can be seen that peak deposition is significantly reduced for the more realistic scenario. The difference between the "standard" and sensitivity test results stems from reduced rates of settling in the more realistic scenario in the sensitivity test. The higher settling rates of the "standard" result reduce the peak concentrations over the intertidal compared to that of the lower settling rates of the sensitivity test.

2.3.4 It is concluded that there is significant uncertainty in the prediction of far-field effects but that the precautionary stance adopted in studies for the Environmental Impact Assessment (EIA) means that any far-field effects in terms of deposition are unlikely to be under-estimated.

3. NEAR-FIELD PREDICTIONS

3.1 Introduction

3.1.1 Further sensitivity tests were undertaken to investigate the sensitivity of near field predictions to tidal range, bathymetry and the representation of the source of the release of fines.

3.1.2 The near field predictions are particularly important because they will be used as the basis for defining the method for control of the dredging operations. The previously published near-field results (Table 5 of Reference 1) are based on the results of realistic representation of the dredge cycle and three day simulation periods. The basic parameters for the test were the same as for the far-field tests presented in Table 1.

3.1.3 All previously published tests used spring tide flow fields, bathymetry as at the start of the dredge programme and an initial source term which had all released material being mixed into the water column (with the released material distributed uniformly through the vertical and in a gaussian distribution lateral to the axis of motion of the dredger, with a standard deviation of 15m).

3.1.4 Two sets of sensitivity tests were undertaken. The first set of sensitivity tests (see Section 3.2) related to the effect of a more accurate representation of dredging and settling velocity (as discussed in Chapter 2). These were designed to demonstrate whether the results presented in the EIA are sufficiently detailed to adequately represent the expected test observations arising from the proposed monitoring regime. The second set of sensitivity undertaken (see Section 3.3) reproduced depth-averaged and near-field concentrations for neap tide conditions, for spring tide conditions with bathymetry as at the end of the dredge programme and for a source term whereby the released material descends towards the bed as a dynamic plume and ⅔ of the released material initially deposits on the bed from where it is entrained by the tidal flows.

3.2 Near-field sensitivity test results – 1

3.2.1 For this sensitivity test detailed representation of dredging of silty sand at 4km with a constant settling velocity of 5mm/s (originally presented in Figure 9 of Reference 3) was compared to the equivalent result using a concentration related settling velocity (as described in Chapter 2).

3.2.2 The original constant settling velocity and sensitivity test results are shown in Figures 5 and 6 respectively. These figures show peak concentration increases over the main area of the dredge and time varying concentrations (depth averaged) at six locations around the dredged area. The figures show that at locations at a lateral distance of approximately 200m from the axis of the dredge path the predicted concentration increases are similar.

3.2.3 The conclusion of this test is that for examination of near-field concentration increases use of a constant (and relatively high) settling velocity produces similar results to use of a more sophisticated concentration-dependent settling velocity.

3.3 Near-field sensitivity test results - 2

3.3.1 For these sensitivity tests the scenario used was the detailed short term (ie 3 tide) simulations of dredging of silty sand at 13km. The results of the original modelling for dredging of silty sand at 13km (originally shown in Figure 14 of Reference 1) are presented in Figure 7. This figure shows peak concentrations over the main area of the dredge and time varying concentrations (depth averaged and near bed) at six locations (roughly at a lateral distance of 200m from the axis of the dredge path) around the dredged area.

3.3.2 All previously published results have presented suspended solids concentrations as depth averaged. The SEDPLUME model represents the vertical profile of the suspended solids in the plume and further processing of the model results has been undertaken to, in addition, predict the average concentration of the plume in the bottom metre of the water column.

3.3.3 Figure 7 shows that the depth-averaged time series have peak concentration increases of up to 250mg/l. Near bed concentrations vary over 1000mg/l at times for some of the time series.

3.3.4 The equivalent results for a neap tide are shown in Figure 8. The far-field dispersion of the resulting plume is less extensive than that for the spring tide results and the predicted near-bed concentration increases on neap tides are up to double those presented in Figure 7.

3.3.5 The results for a spring tide with the dredged channel completed (ie towards the end of the capital works) are shown in Figure 9. The dispersion of the resulting plume is very similar to that of Figure 7, with a small reduction in depth-averaged concentrations.

3.3.6 The results for a spring tide with the alternative source term are shown in Figure 10. The alternative source term produces a marked reduction in concentration increases along the dredge path but a few hundred metres from the dredge path the predicted concentration increases are similar to those presented in Figure 7.

3.3.7 The conclusions resulting from these tests is that the predicted increases in concentration at a lateral distance of approximately 200m from the dredge path are relatively insensitive to both the distribution of the source term used and the degree of deepening of the channel. Neap tides produce significantly greater concentration increases than the spring tide results.

4. DISCUSSION

4.1 The results of the sensitivity tests presented in Chapter 3 include time series of predicted concentration increases at six locations which might be broadly typical of proposed monitoring stations that will be used for the capital dredge monitoring programme. These time series show that concentration increases above background may approach magnitudes of 250mg/l (depth-averaged) and 1000mg/l (within the bottom 1m of the water column) briefly during normal dredging activities on spring tides.

4.2 Previous work (References 1 and 3) and the results of the sensitivity analyses presented in Chapter 2 show these near-field concentrations correspond to far-field effects which are not adversely significant. Moreover, the predicted near-field concentration increases at locations further than 200m laterally from the dredge path produced by representing the detailed dredging cycle are relatively insensitive to the extent of deepening, the choice of sediment model parameters and the nature of the source term. This provides confidence in the use of the model results to establish sensible thresholds for concentration increases arising from the capital dredging.

4.3 On neap tides the predicted near-field concentration increases are significantly greater than on a spring tide (see Chapter 3) but the corresponding far-field affects are significantly lower (Reference 2) than those corresponding to spring tides.

5. CONCLUSIONS

Far-field effects

5.1 The plume studies carried out to support the EIA have taken a precautionary approach in that parameters have been used in the plume dispersion models that over-predict the far-field impacts.

5.2 There is significant uncertainty in the prediction of far-field effects but that the precautionary stance adopted in studies for the EIA means that the predicted far-field effects are unlikely to be exceeded.

Near-field effects

5.3 For examination of near-field concentration increases the use of the constant (and relatively high) settling velocity (in the EIA studies) produces similar results to the use of a more sophisticated concentration-dependent settling velocity.

5.4 The predicted increases in concentration at a lateral distance of 200m from the dredge path are relatively insensitive to both the distribution of the source term used and the degree of deepening of the channel.

5.5 Neap tides produce significantly greater near-field concentration increases than the spring tide results, especially near the bed.

6. REFERENCES

1. London Gateway Development Studies: Dispersion of sediments during dredging activity, HR Wallingford Report EX4489, January 2002.

2. London Gateway Port, Dispersion of sediments during maintenance dredging, HR Wallingford Report EX 4749, March 2003.

3. London Gateway Port, Summary of predicted intertidal sedimentary processes, HR Wallingford Report EX 4750, March 2003.

Figures

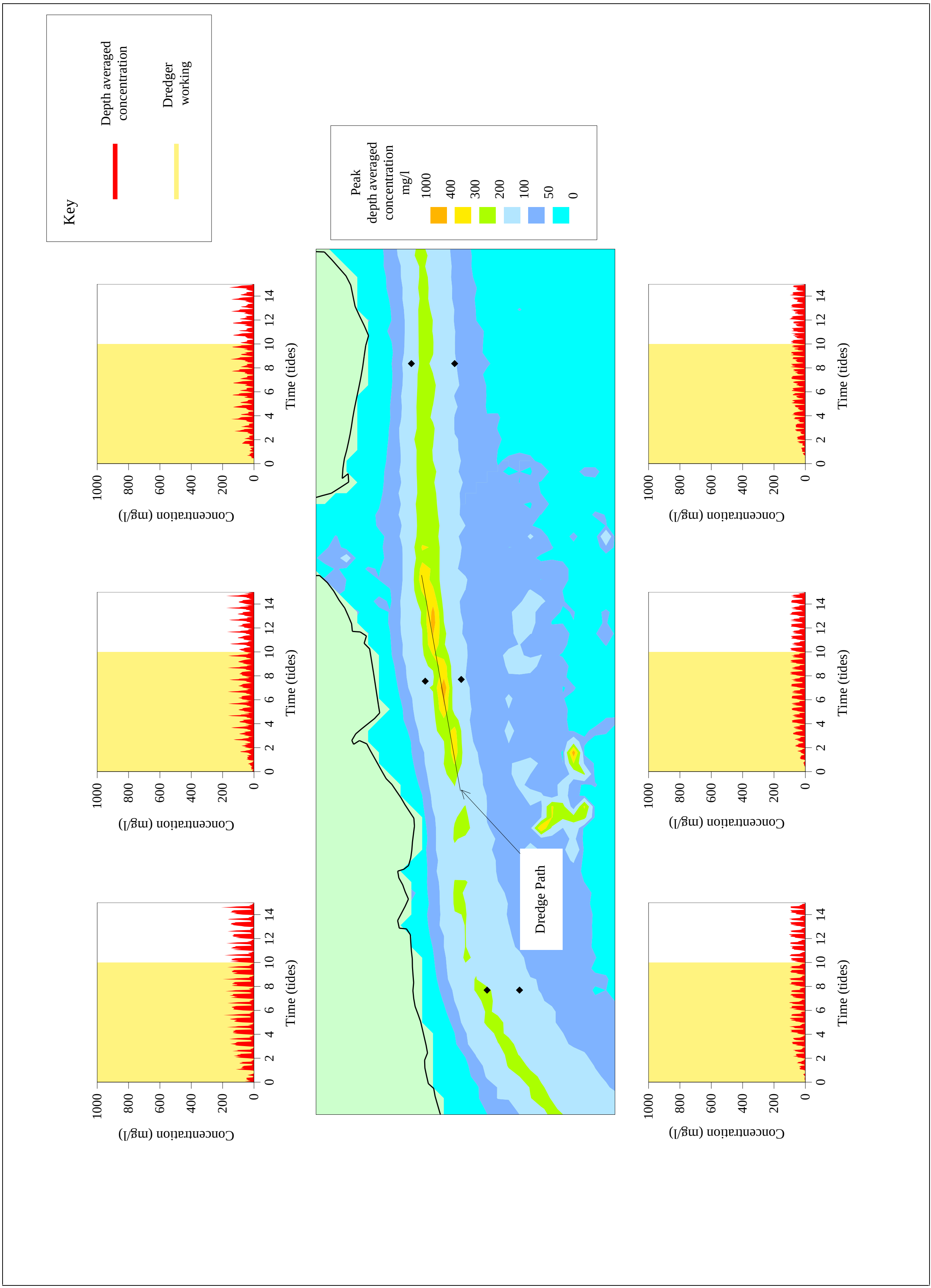

Figure 1 Peak (depth-averaged) concentrations predicted to occur over a fifteen tide period (spring tides) for dredging silty sand at 4km, standard result, near-field

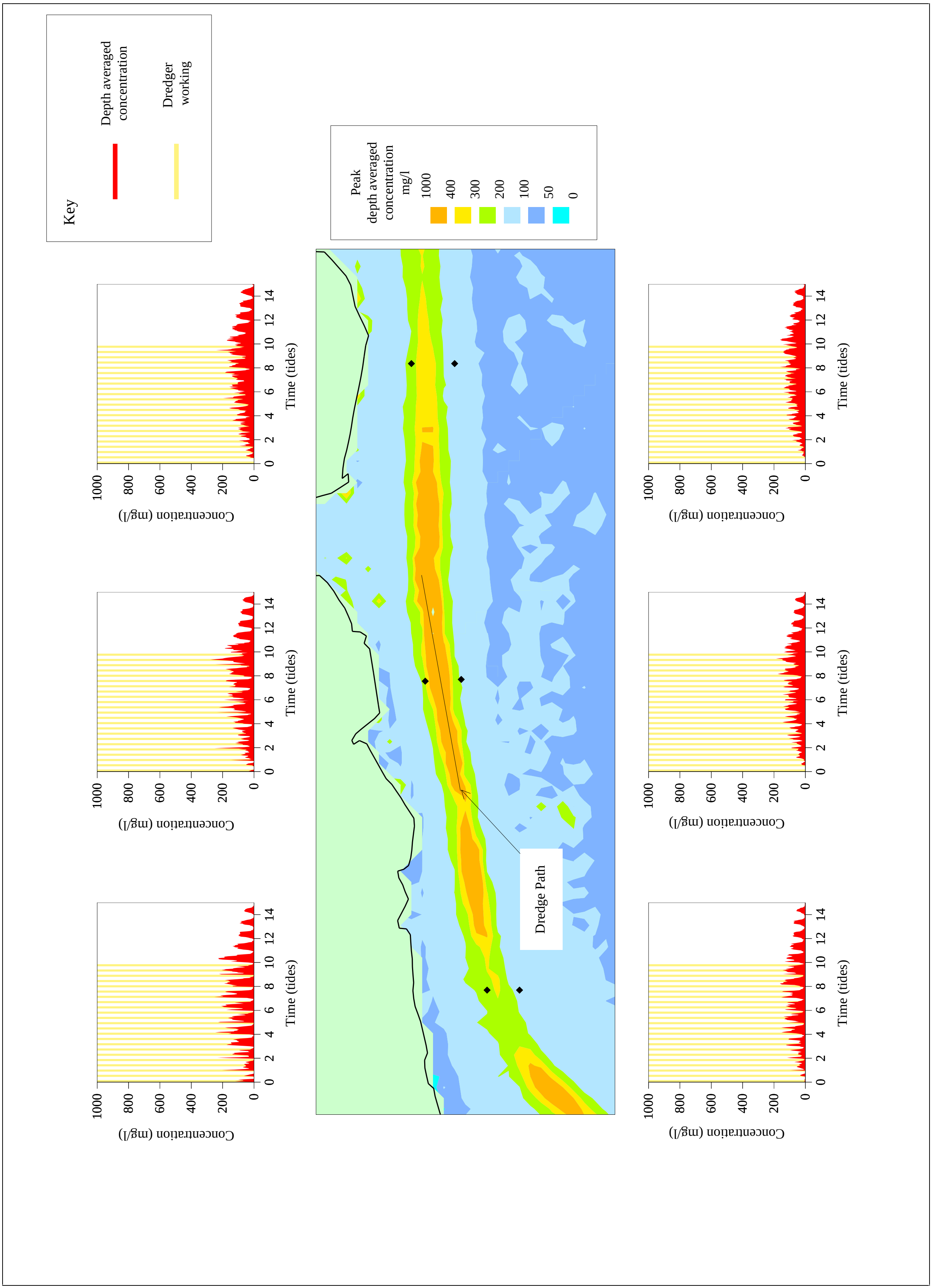

Figure 2 Peak (depth-averaged) concentrations predicted to occur over a fifteen tide period (spring tides) for dredging silty sand at 4km, sensitivity test with full detail of the dredging cycle and concentration dependent settling velocity, near-field

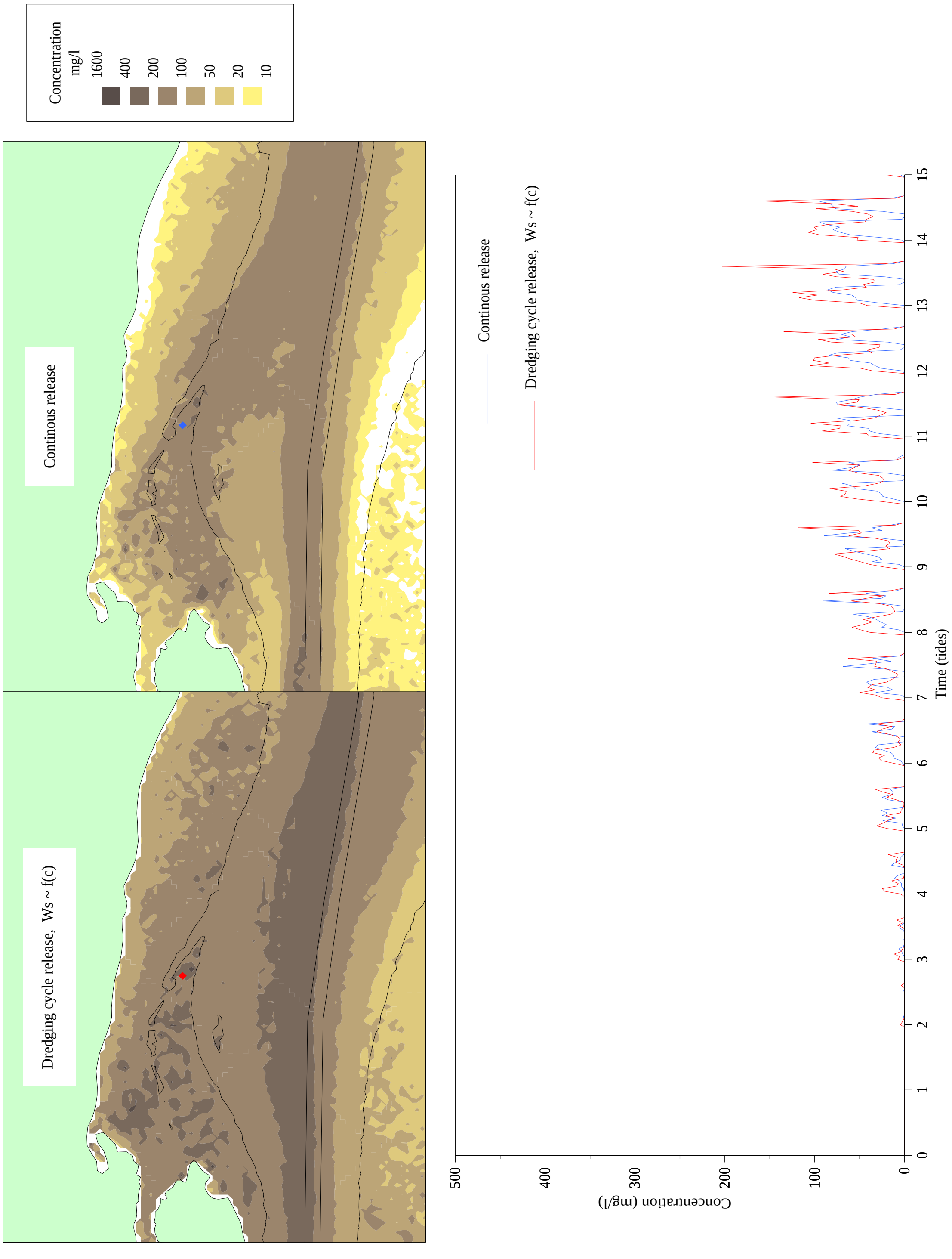

Figure 3 Comparison of standard and sensitivity test predictions for dredging silty sand at 4km, far-field, peak (depth-averaged) concentration increases at Chapman Sands/Leigh Flats/Southend Flats

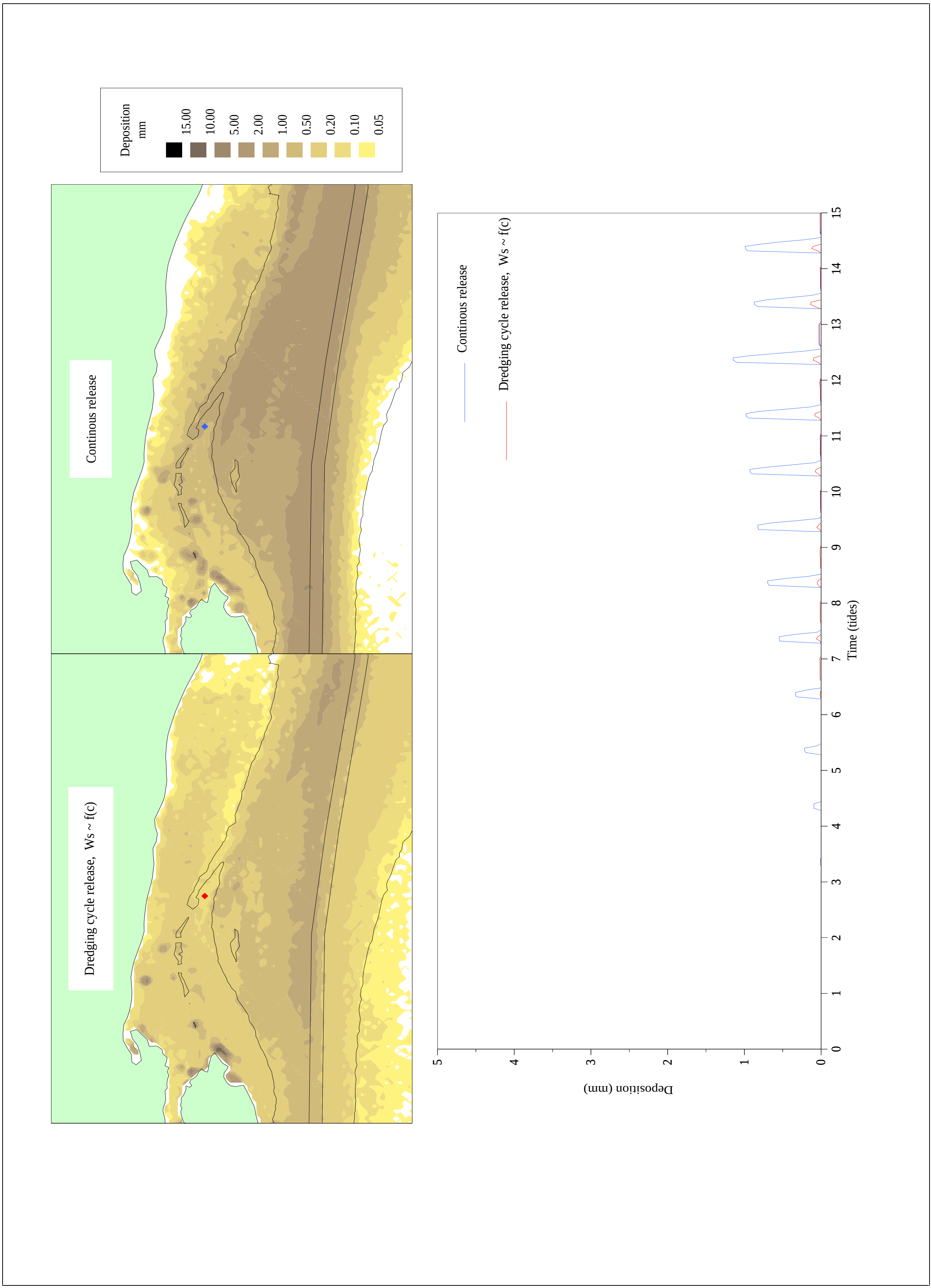

Figure 4 Comparison of standard and sensitivity test predictions for dredging silty sand at 4km, far-field, peak deposition at Chapman Sands/Leigh Flats/Southend Flats

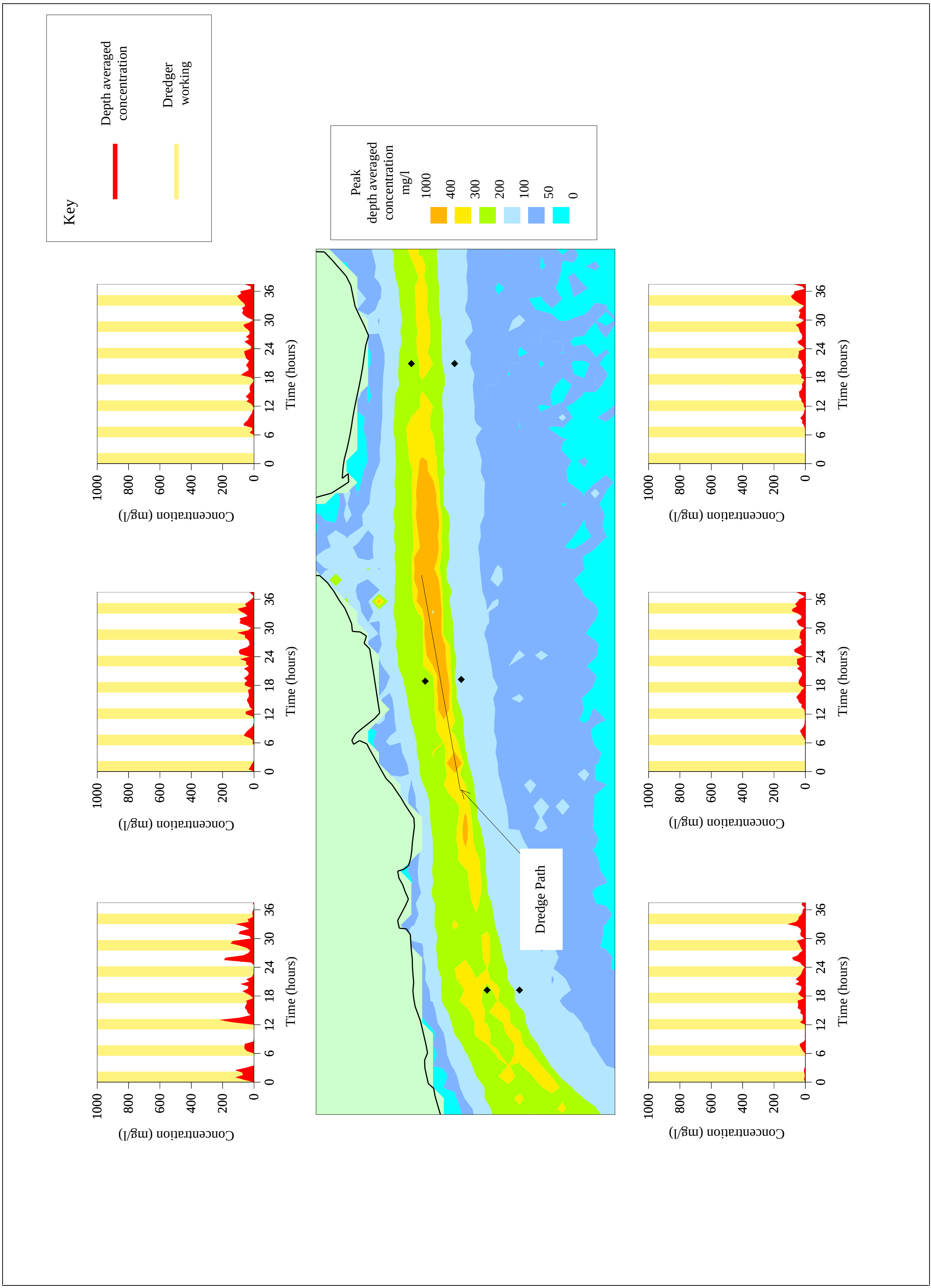

Figure 5 Predicted near-field concentration increases using a constant settling velocity, short-term detailed representation of dredging silty sand at 4km on spring tides

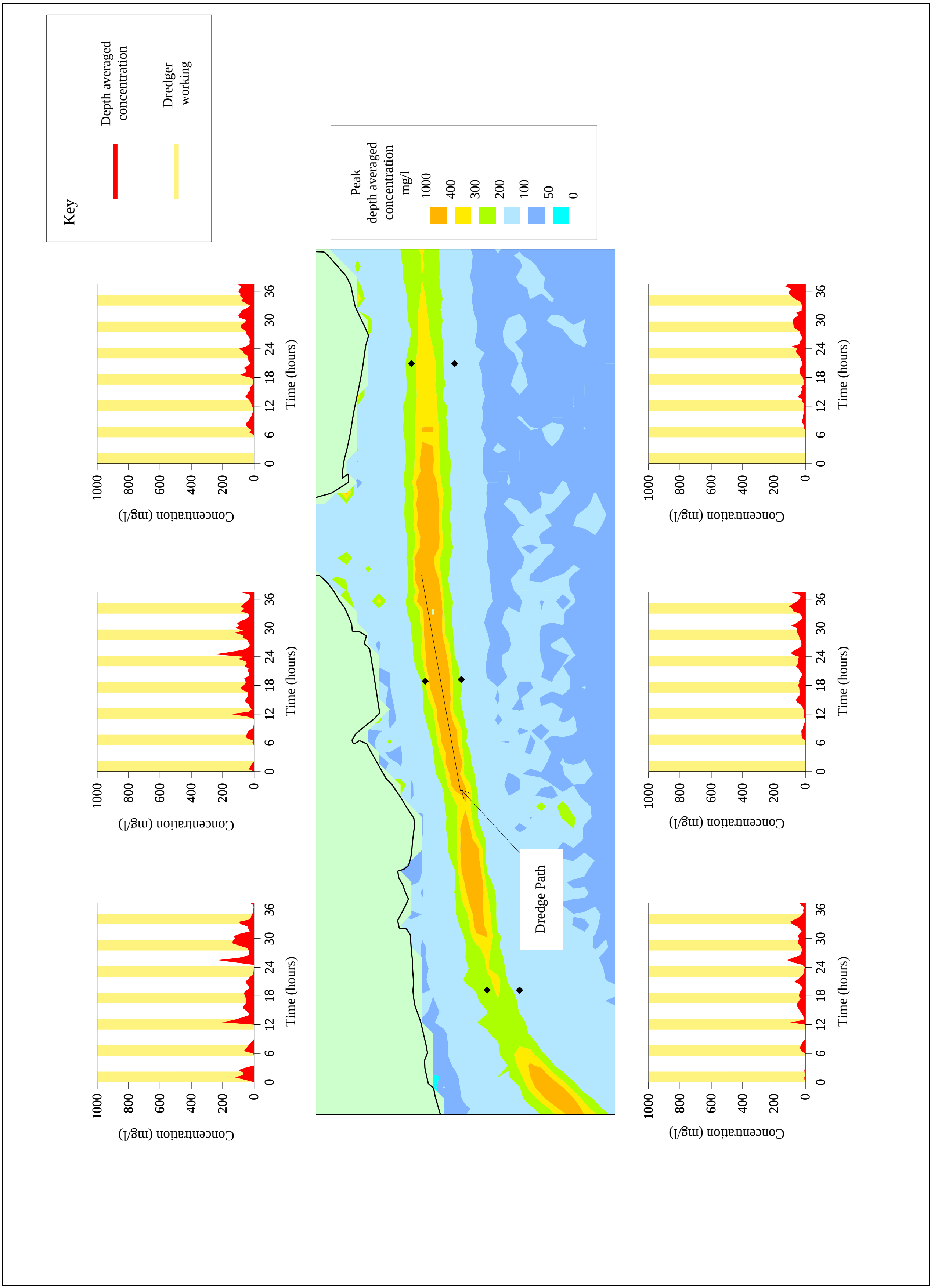

Figure 6 **Predicted near-field concentration increases using concentration dependent settling velocity, short-term detailed representation of dredging silty sand at 4km on spring tides**

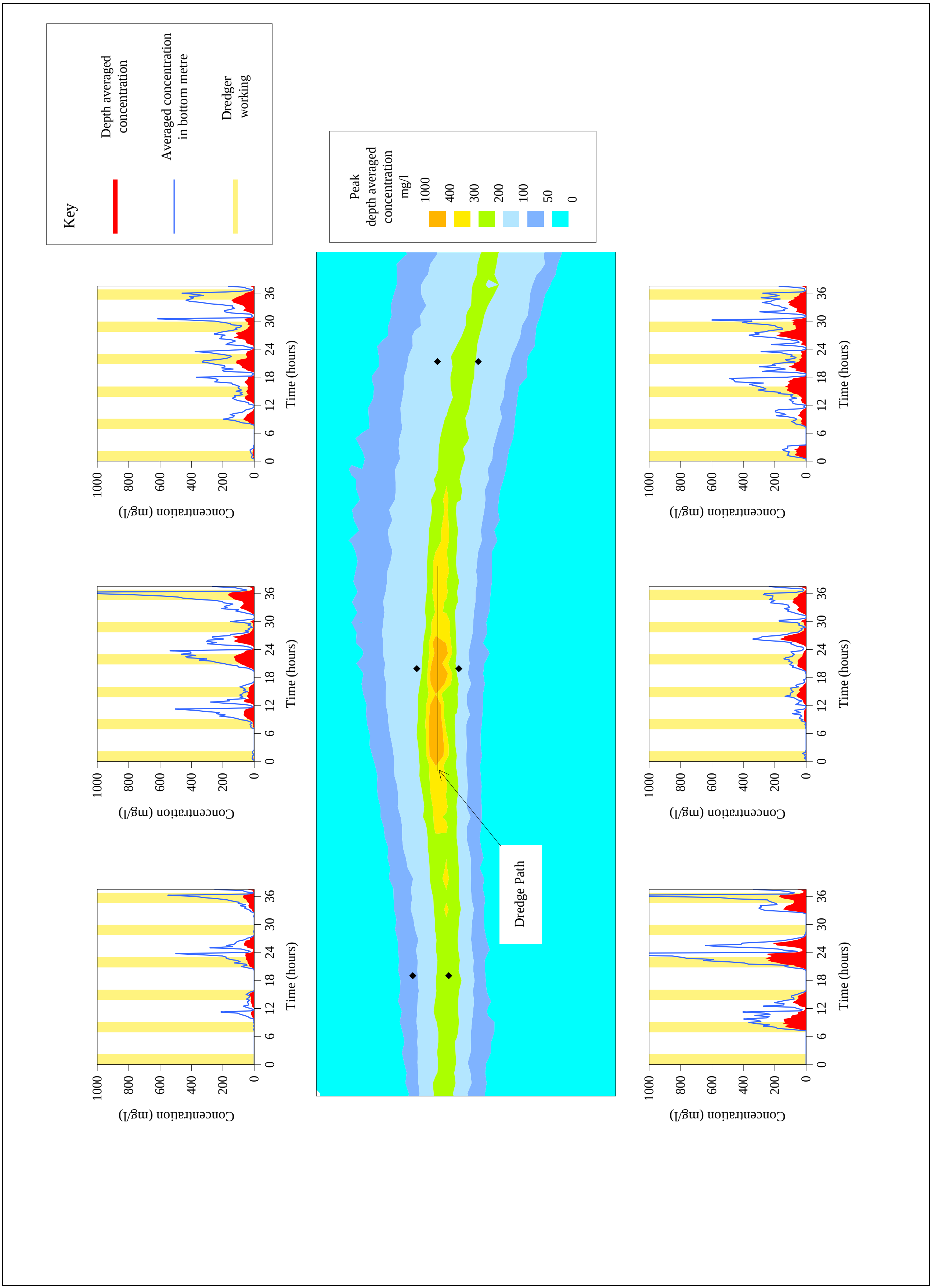

Figure 7 **Predicted near-field depth-averaged and near bed concentration increases arising from short-term detailed representation of dredging silty sand at 13km, spring tides, existing channel, release mixed through water column**

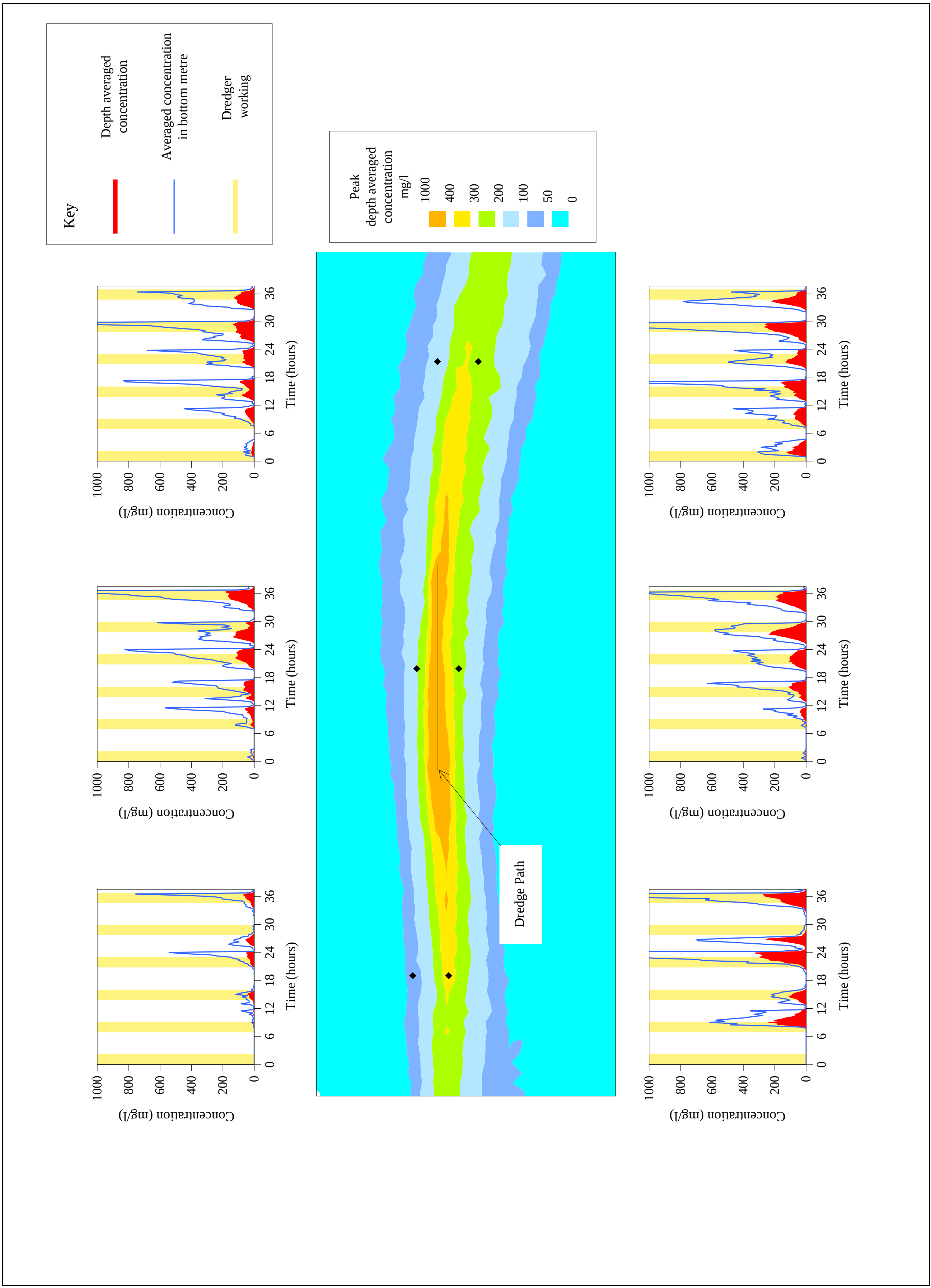

Figure 8 Predicted near-field depth-averaged and near bed concentration increases arising from short-term detailed representation of dredging silty sand at 13km, neap tides, existing channel, release mixed through water column

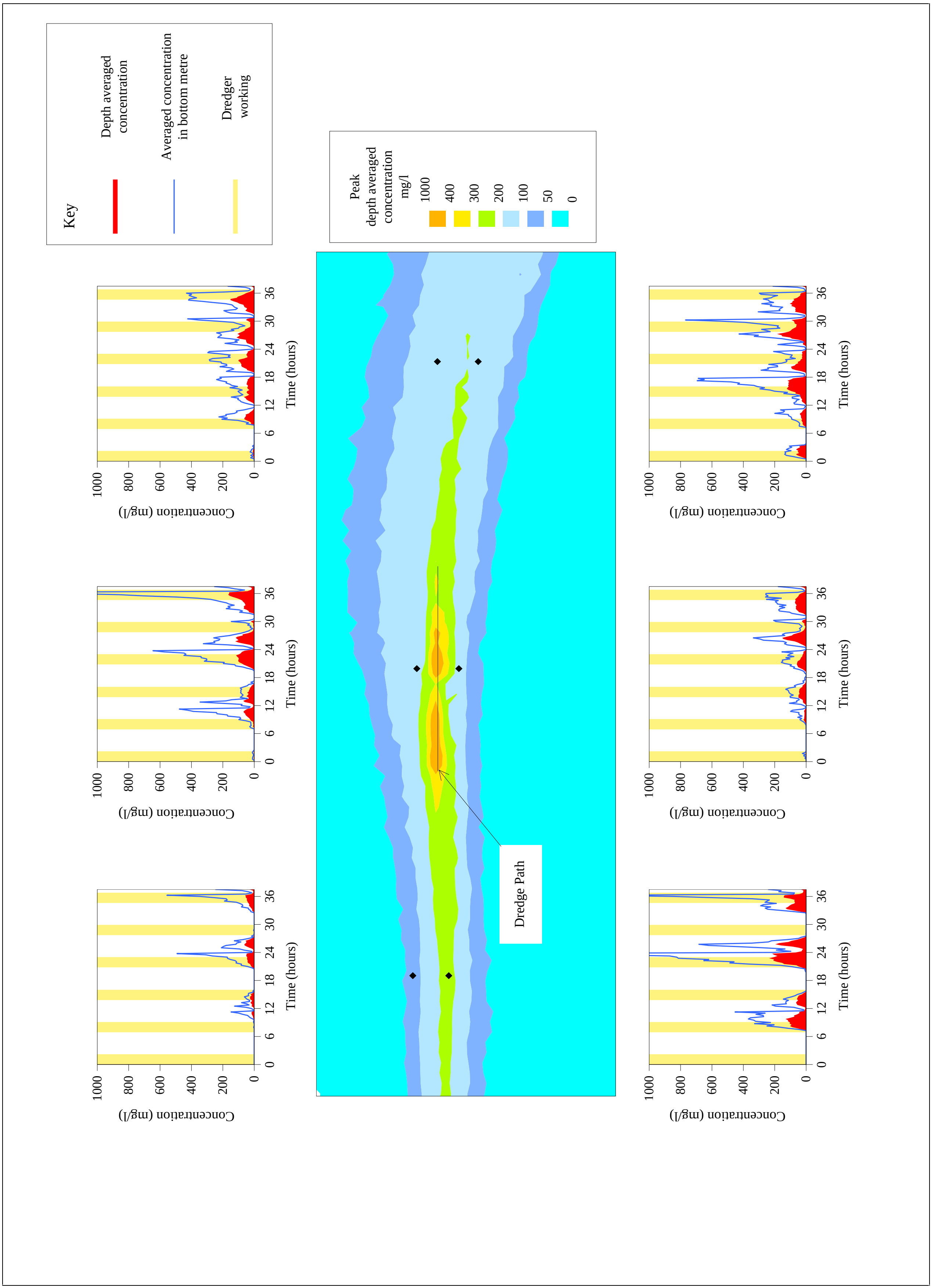

Figure 9 Predicted near-field depth-averaged and near bed concentration increases arising from short-term detailed representation of dredging silty sand at 13km, spring tides, deepened channel, release mixed through water column

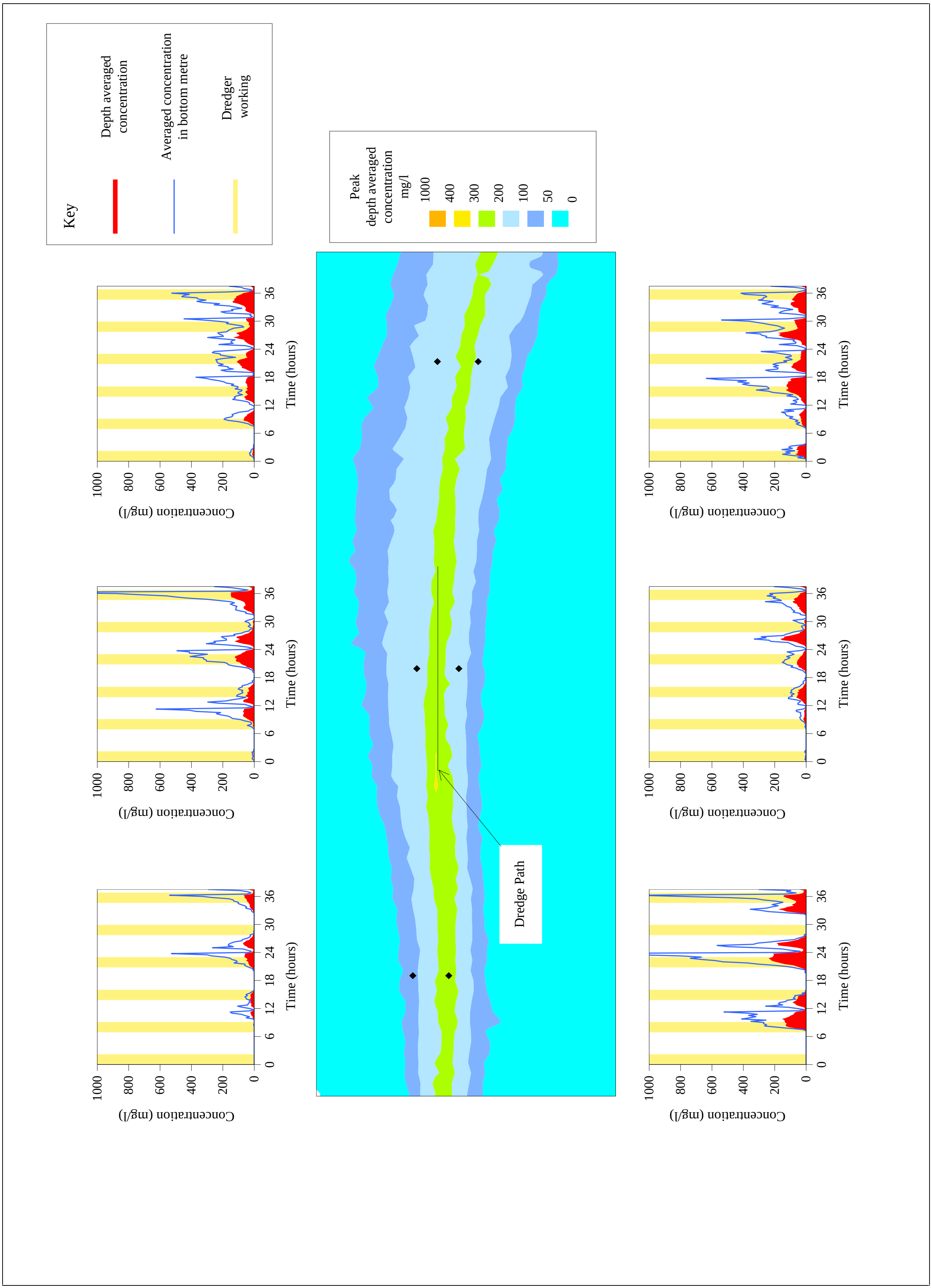

Figure 10 Predicted near-field depth-averaged and near bed concentration increases arising from short-term detailed representation of dredging silty sand at 13km, spring tides, existing channel, release of fines using alternative source term