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Able Marine Energy Park 2021

Modelling of sediment plume dispersion from AMEP construction activities

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Executive summary

Able UK Ltd proposes to construct the Able Marine Energy Park (AMEP) located near Immingham on the southern bank of the Humber Estuary. The development was fully consented in 2014. An amendment is proposed to the AMEP consented layout. Able UK Ltd requested HR Wallingford to update assessments and documents that HR Wallingford previously delivered for the consented scheme to support Able UK's material change application. These are reported in HR Wallingford (2021).

A change to the consented construction methodology is proposed with the revetment at the north being built first, and then building the quay from south to north, starting with a revetment at the south. HR Wallingford were commissioned by Able UK Ltd to assess the impacts of this revised construction sequence on plume dispersion.

Two stages of the construction sequence have been simulated in the flow model and the associated plumes arising from reclamation run-off and the BHD that will be going on in parallel. The results of the plume model are found to be comparable with the earlier results of the BHD presented in HR Wallingford (2021) and are insignificant when compared to existing background levels of suspended sediment concentrations in the estuary.

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1 Introduction

1.1 Background

Able UK Ltd proposes to construct the Able Marine Energy Park (AMEP) located near Immingham on the southern bank of the Humber Estuary (Figure 1.1). The development was fully consented in 2014. An amendment is proposed to the AMEP consented layout. Able UK Ltd requested HR Wallingford to update assessments and documents that HR Wallingford previously delivered for the consented scheme to support Able UK's material change application.

A change to the construction methodology is proposed with the revetment at the north being built first, and then building the quay from south to north, starting with a revetment at the south. The reclamation is proposed to be undertaken without cross-berms. HR Wallingford was commissioned by Able UK Ltd to assess the impacts of this revised construction sequence on plume dispersion.

Figure 1.1: Location of AMEP quay

1.2 Objective

The objective of this work was to assess the sediment plume dispersion from reclamation run-off and back hoe dredging during the reclamation of the AMEP facility. Simulations have been carried out to predict the dispersion and deposition patterns of fine sediment from reclamation run-off and backhoe dredging during the early stage of reclamation and during a later stage of reclamation.

2 Plume dispersion model

The plume dispersion modelling uses SEDPLUME-RW. This is the same model as used for the recent modelling work to assess plume dispersion for the amended scheme (HR Wallingford 2021). The plume dispersion work considered in HR Wallingford (2021) examined plume dispersion during construction from a cutter suction dredger (CSD) loading barges, from a trailer suction hopper dredger (TSHD) dredging sand and gravel and from a backhoe dredger (BHD) loading barges. The magnitude of the source terms and the associated plumes from the CSD and TSHD activities simulated previously were much greater than those from the BHD.

In this report the BHD is simulated with the same source terms as considered previously but with the BHD working in different locations. A new source term is developed for the run-off from the reclamation activity.

3 Flow model input

In the previously reported modelling (HR Wallingford, 2021) the flow model input for the plume dispersion modelling was either the baseline condition before any construction had taken place or the final as-built scenario representative of the situation at the end of the construction phase.

For the present study two construction stages are considered. The first scenario is representative of the situation when reclamation will commence. This scenario is shown in drawing form in Figure 3.1 and as represented in the flow model in Figure 3.2. At this early stage in the construction the north and south revetments have been constructed extending across the intertidal at either end of the scheme. The downstream end of the quay wall has commenced construction along with an internal bund behind the quay wall. A BHD dredger dredging to -3.3 mCD is loading barges in the central part of the reclamation area and reclamation of fill material is occurring behind the part constructed bund. The location where the run-off from the reclamation mixes with the estuary waters is taken to be at the inshore edge of the berm behind the quay wall. This layout has been simulated for a full spring-neap cycle in the same way that the baseline and final as built schemes were simulated in the earlier report.

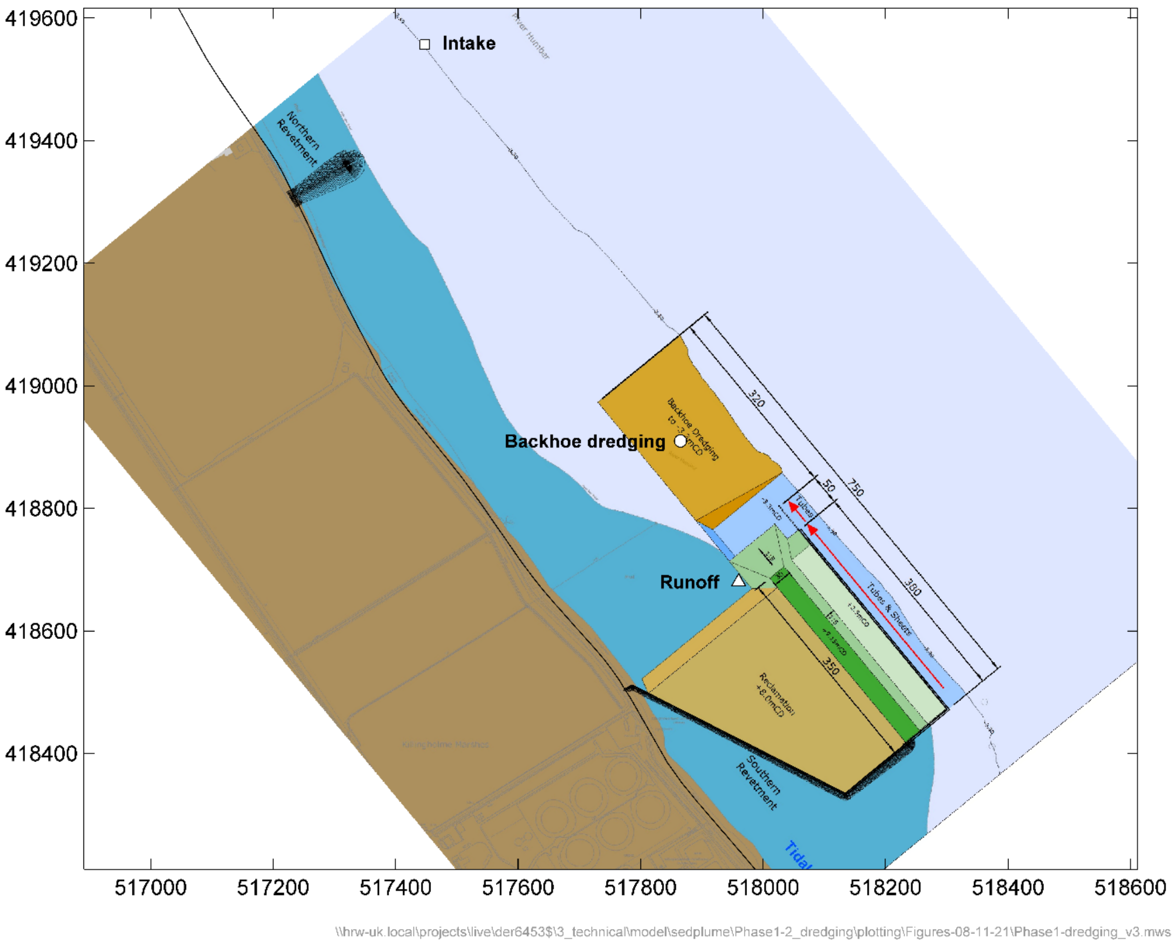

Figure 3.1: Early construction stage with reclamation run-off (drawing)

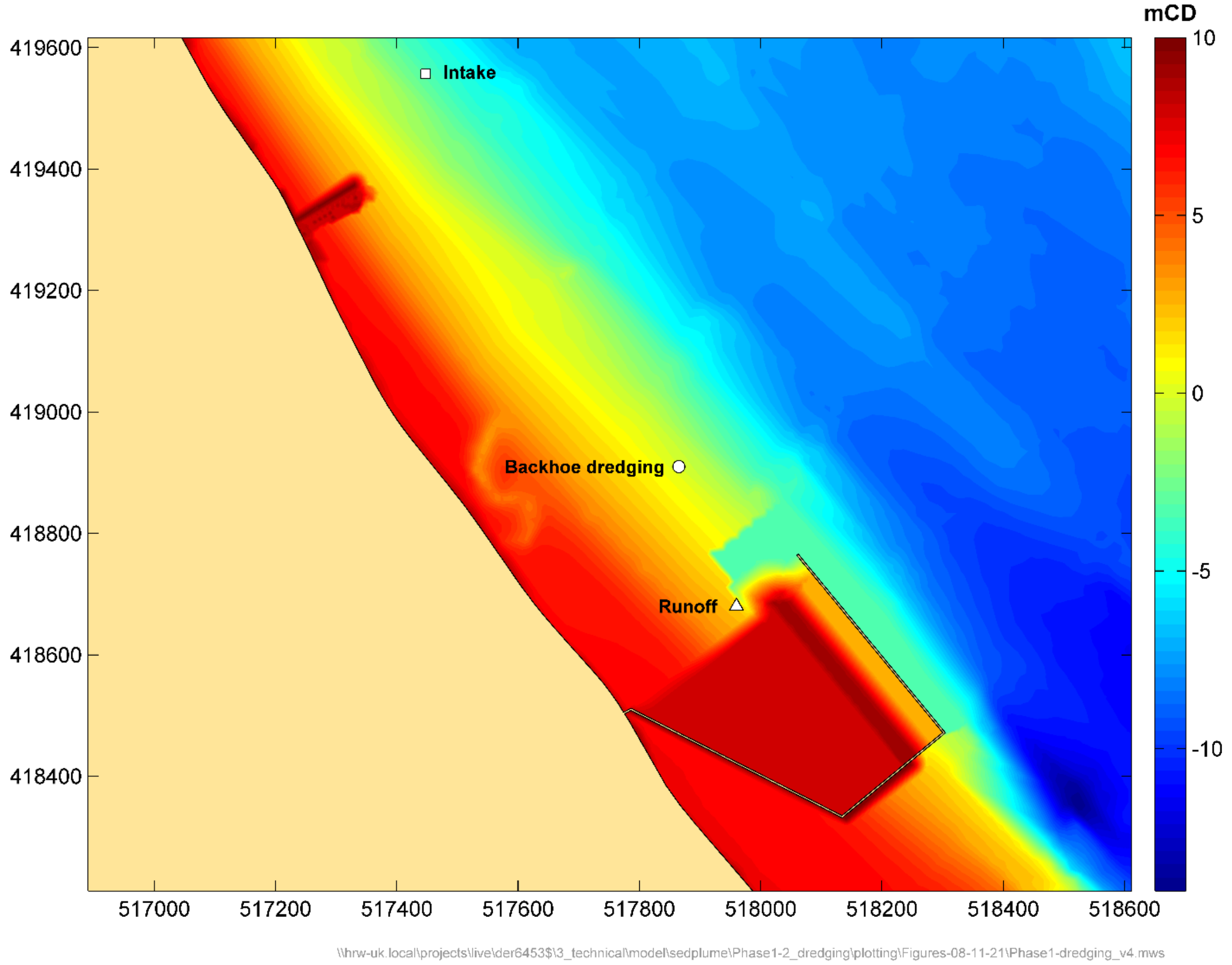

Figure 3.2: Early construction stage with reclamation run-off (model lay-out)

The second scenario that has been simulated is representative of a later stage in the construction when reclamation will be continuing. The scenario is shown in drawing form in Figure 3.3 and as represented in the flow model in Figure 3.4. At this later stage of construction most of the quay wall has been constructed and all of the dredging to -3.3 mCD in the footprint of the reclamation completed. The BHD is now operating at the southern end of the site to deepen the berth pocket and the location of the run-off from the reclamation is in the middle of the site on the inshore edge of the berm behind the quay wall.

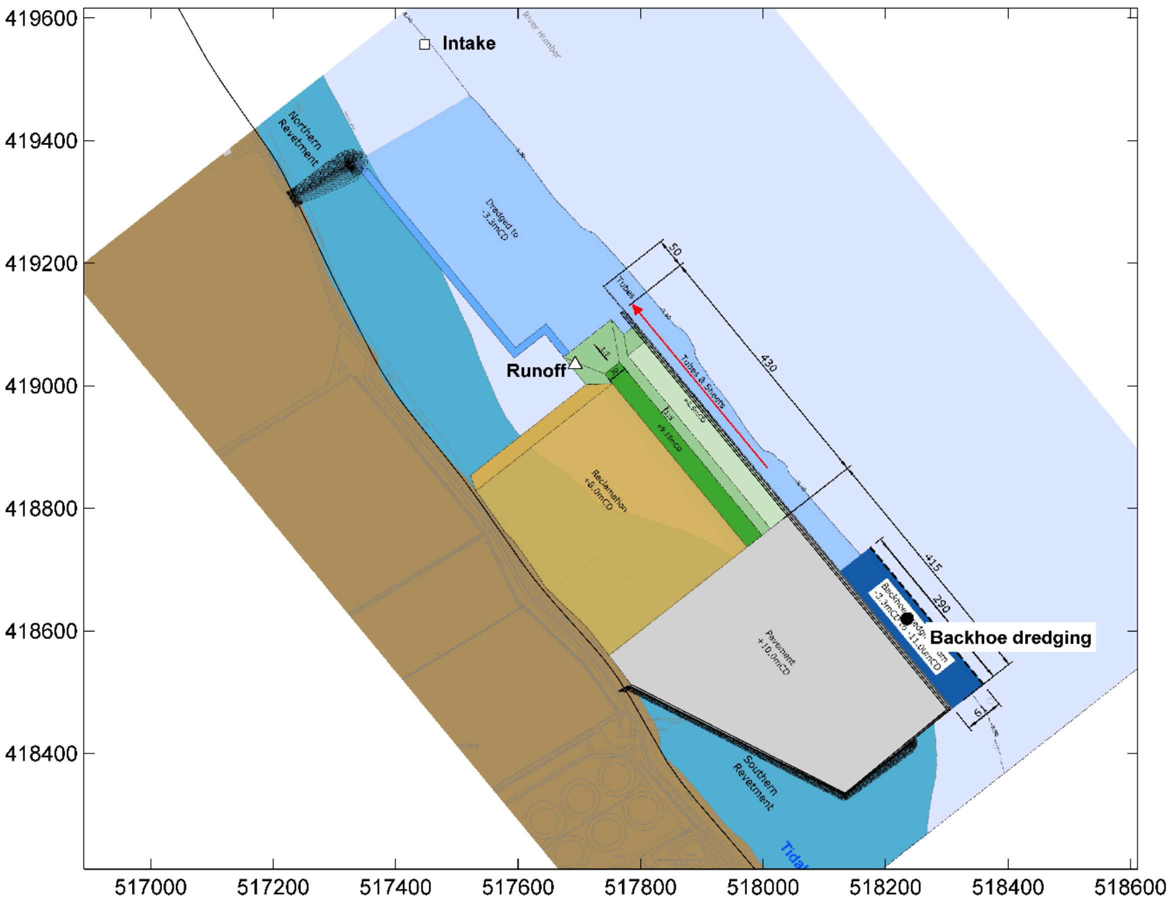

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Figure 3.3: Later construction stage with reclamation run-off (drawing)

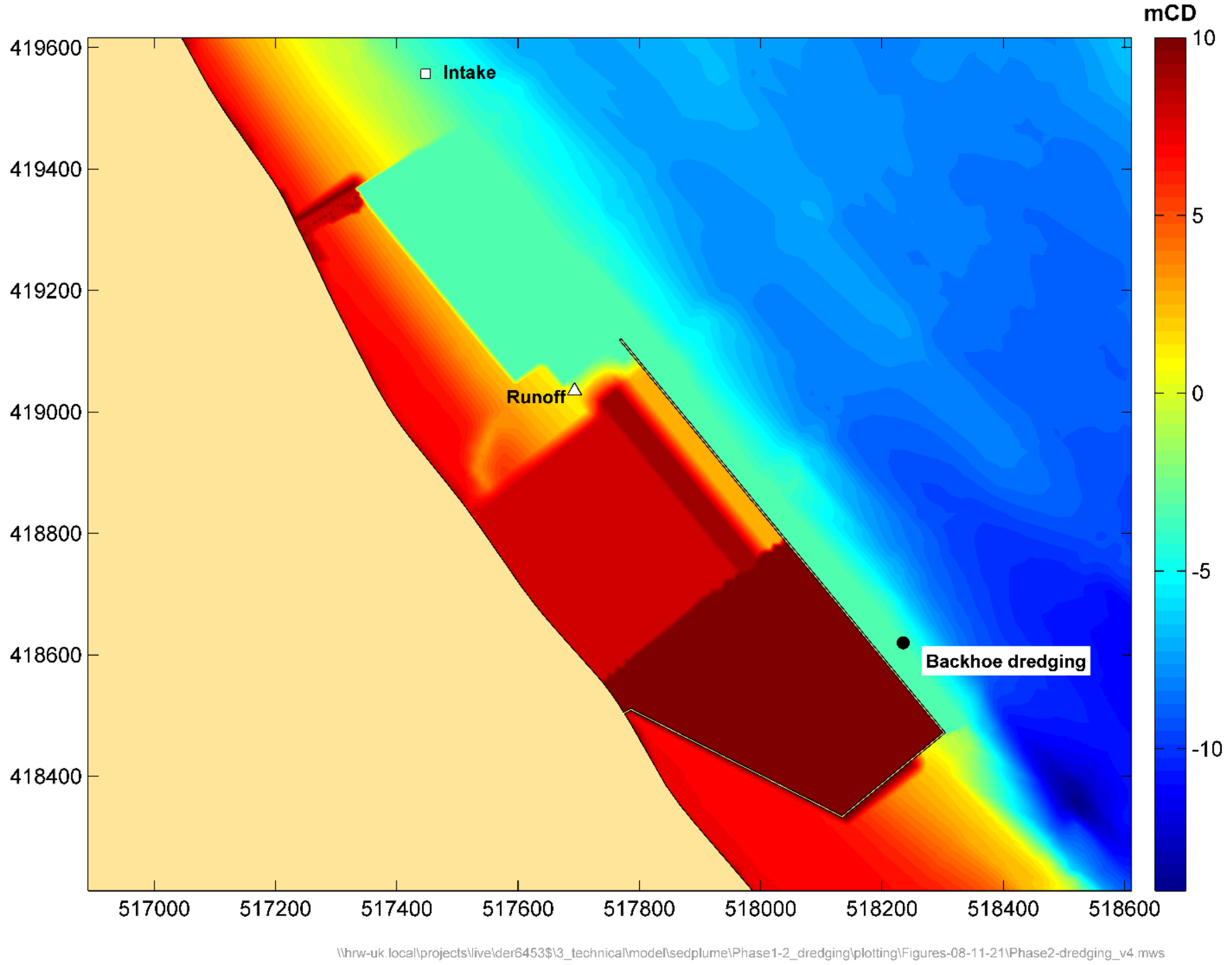

Figure 3.4: Later construction stage with reclamation run-off (model lay-out)

4 Background suspended sediment concentrations

As reported previously (HR Wallingford, 2021) the dispersion modelling does not represent background suspended sediment concentrations in the Humber Estuary but simulates the increase of suspended sediment concentrations generated by the dispersion of the plumes from the dredging and reclamation activity over and above these background concentrations.

As reported previously suspended sediment concentrations within the Humber Estuary vary from several hundred mg/l near the mouth to several thousand mg/l in the upper estuary (Delft Hydraulics, 2004). Measurements of suspended sediment concentrations in the vicinity of the proposed works include:

- Measurements by Partrac (2018) recorded suspended sediment concentrations of up to 3,303 mg/l close to the intake/outfall location, just north of the AMEP site. Spring tide values were consistently in excess of 1,600 mg/l at this location.
- Measurements at the Humber Sea Terminal by IECS (see HR Wallingford, 2011). These recorded peak surface concentrations of 1,600 mg/l (flood) and 900 mg/l (ebb) on a spring tide.
- Measurements at Grimsby by ABPmer (ABP, 2009). These recorded peak surface concentrations of 200 mg/l (ebb) and 150 mg/l (flood) on a neap tide.

- Measurements at Spurn Head (BTDB, 1969) indicated concentrations though depth of several hundred mg/l throughout the ebb tide.

Close to the site at the Humber Sea Terminal (now C.Ro Port Killingholme) there are surface suspended sediment concentrations of up to 1,600 mg/l, and hence potentially larger concentrations lower in the water column. Predicted depth-average increases from the modelling undertaken (see Section 6) are typically less than 50 mg/l which is small compared with the observed range of concentrations that occur on typical tides.

5 Estimation of dredging and reclamation run-off source terms

The source terms used here for the BHD operations are the same as those used in the earlier dredge plume dispersion studies (HR Wallingford 2021). The source-terms for the reclamation run-off use new information provided by Able UK and a contractor.

5.1 Dredging using backhoe

Dredging using backhoe does cause release of fine sediment into the water column but the key feature of dredging using a backhoe is that the productivity (the rate at which material is dredged from the bed) is relatively small compared to other types of plant such as TSHD or CSD loading barges. As the productivity is small, the rate of release of fine material is also small.

Using models developed by HR Wallingford for assessing productivity in dredging operations the weekly productivity of the backhoe dredging was estimated to be 82,000 m^3/wk and the rate of release of fine material was estimated to be 2.9 kg/s. The total loss of fines from BHD over a fortnight is equivalent to about 3,500 tonnes.

5.2 Reclamation run-off

The reclamation has been proposed by the contractor to be undertaken by a larger TSHD (18,000m^3 hopper capacity). The TSHD will dredge fill material from an offshore licensed aggregate site and will then steam to the AMEP site, connect to a pipeline and pump the dredged material ashore into the reclamation area. The fill material will have a low fines content (material less than 63 microns in diameter) because it will have been dredged from an offshore aggregate site. It is assumed that the fines content in the fill material will be 1% when pumped ashore but in reality it could be lower than this. When the TSHD connects to the pipeline to pump the material ashore it will also add water into the hopper to enable the pumping. So the transport water that will be used to convey the dredged material will be local estuary water with some “natural” suspended sediment concentration. The suspended sediment concentration in this transport water are not considered in this assessment as they are at “background” levels. The discharged fill material will settle out close to the end of the discharge pipe. Land based plant will move the discharged material and relocate the discharge point during the reclamation. It will take about 2 hours for the TSHD to discharge the full load of material ashore through the pipeline. The dredger will then sail back to the offshore aggregate site, dredge the next load and return to pump the material ashore. The cycle time has been estimated by a dredgingcontractor to be about 13 hours, with a load being pumped ashore for 2 hours out of every 13 hours. In reality this rate is a maximum rate over a period of time because there will be some operational down-time.

The source term has been calculated on the basis that the TSHD is loaded to about 90% full with material with a bulk density of 1.9 T/m^3. Assuming a dry density for this material of 1.43 T/m^3 gives a dry mass for the dredged cargo of about 23,300 tonnes. 1% of this mass is assumed to be in the fine fraction and 50% of the fines are expected to be washed out of the reclamation, along with the transport water, by the filling process (the remainder residing within the pores between the coarser material). Thus over the 2 hours of discharge 116 tonnes of material are released into the estuary waters. This is equivalent to a source term of 16.1kg/s for 2 hours (or a continuous value of about 2.5kg/s). The total loss of fines over a fortnight of reclamation activity is about 3,000 tonnes, which is a little less than the release from the BHD going on in parallel.

5.3 Comparison of source terms

In the earlier studies (HR Wallingford, 2021) the source term represented when a CSD was loading barges and overflowing had an average value of about 123kg/s. There were time variations in this source term with short peaks of up to about 300kg/s. Over a fortnight the average loss from the CSD and overflowing of barges was about 150,000 tonnes. The present combined sources of fine material from reclamation run-off and losses from BHD loading barges are more than 20 times lower than this CSD scenario and as expected the results show that the plumes and associated deposition are insignificant compared to the CSD scenario previously considered.

6 Results

6.1 Introduction

The results of the plume dispersion modelling are presented in this section. The results are presented in the same format as the earlier results (HR Wallingford, 2021) and include:

- Plots of the increase in suspended sediment concentration at specific moments in time to give an impression of the typical size of the plume.
- Plots of the predicted peak increase in suspended sediment concentration to give an impression of the envelope of effects of the plume. This figure does not represent the plume at any moment in time but is a composite of different parts of the plume at different times.
- Plots of the spatial extent of fine sediment deposition at the end of the 14-day simulation.
- Time series of increases in suspended sediment concentration at the location of the Uniper intake.

6.2 Early stage of reclamation

6.2.1 Spatial distribution of increases in suspended sediment concentration and fine sediment deposition

Typical predicted increases in depth averaged suspended sediment concentration above background arising from the backhoe dredging on spring tides are presented in Figure 6.1 to Figure 6.4. These figures show the typical plume at high water, mid-ebb, low water, and mid-flood on a spring tide. The figures show that the plume typically travels as far upstream as the bend in the Humber where the channel turns westward and as far downstream as Grimsby. Increases in suspended sediment concentration above background levels are less than 50 mg/l.

Figure 6.5 presents the peak increases in (depth-averaged) suspended sediment concentration which occur over the simulation. The figure indicates that peak increases in (depth-average) concentration will be less than 50mg/l but that increases of more than 10mg/l will occur up to 17 km from the point of dredging and reclamation. Some of the elevations in concentration arise from resuspension of temporarily settled material on the flood tide (e.g., the plume to the south of the site). Compared to the results of the BHD shown in HR Wallingford (2021) the plume concentrations are lower. This is because the plume is being generated within the lower flow environment between the north and south revetments of the port under construction and as a result a proportion of the fines being released is depositing locally. In reality some of this deposited fine material will be entrained by construction activity and occasional wave activity and will disperse more widely. However, it can be seen that the plume concentrations and associated deposition are similar to those predicted previously for the BHD operations and are therefore insignificant compared to the background concentrations described in Section 4.

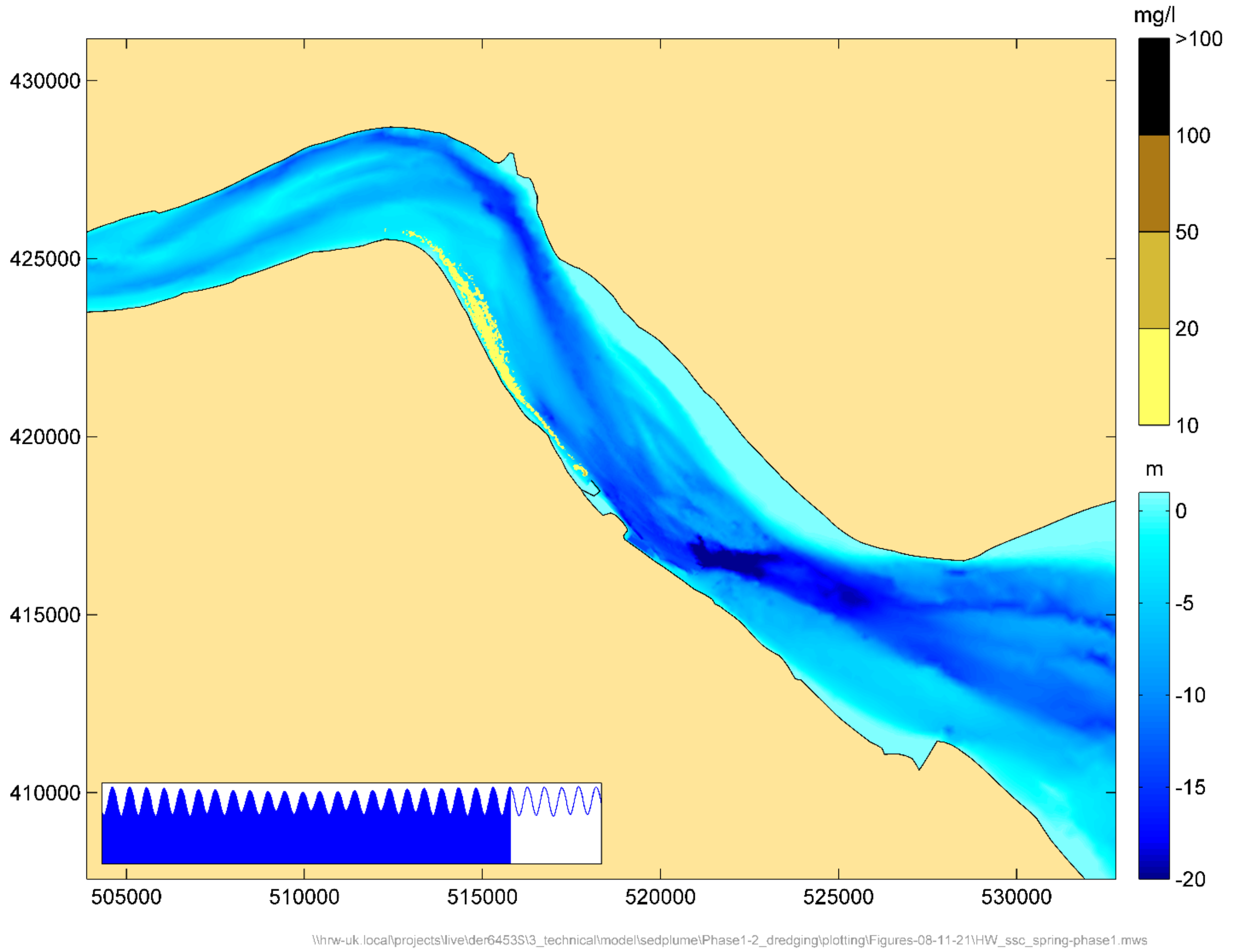

Figure 6.1: Predicted increase in suspended sediment concentration at high water on a spring tide

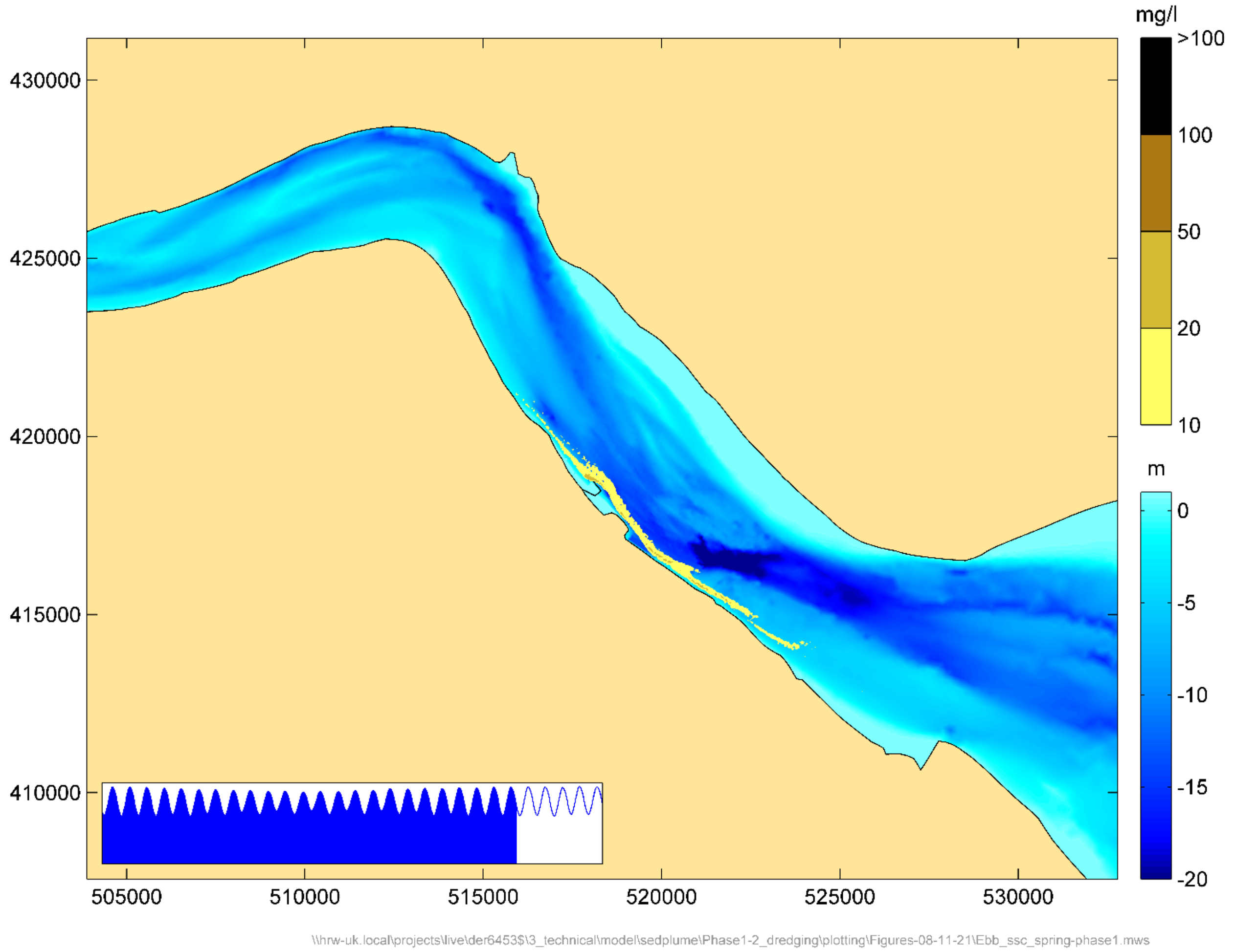

Figure 6.2: Predicted increase in suspended sediment concentration during the ebb phase on a spring tide

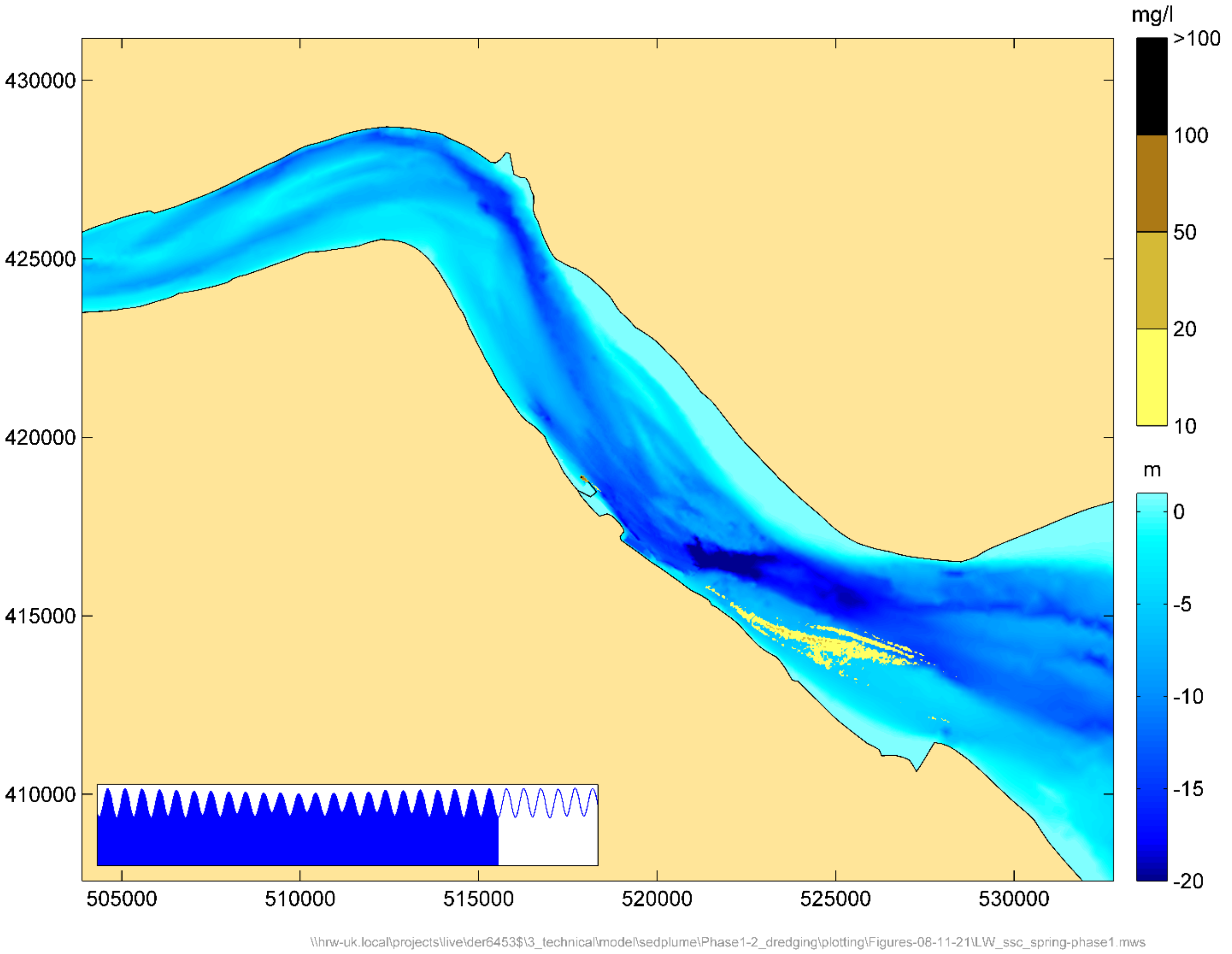

Figure 6.3: Predicted increase in suspended sediment concentration at low water on a spring tide

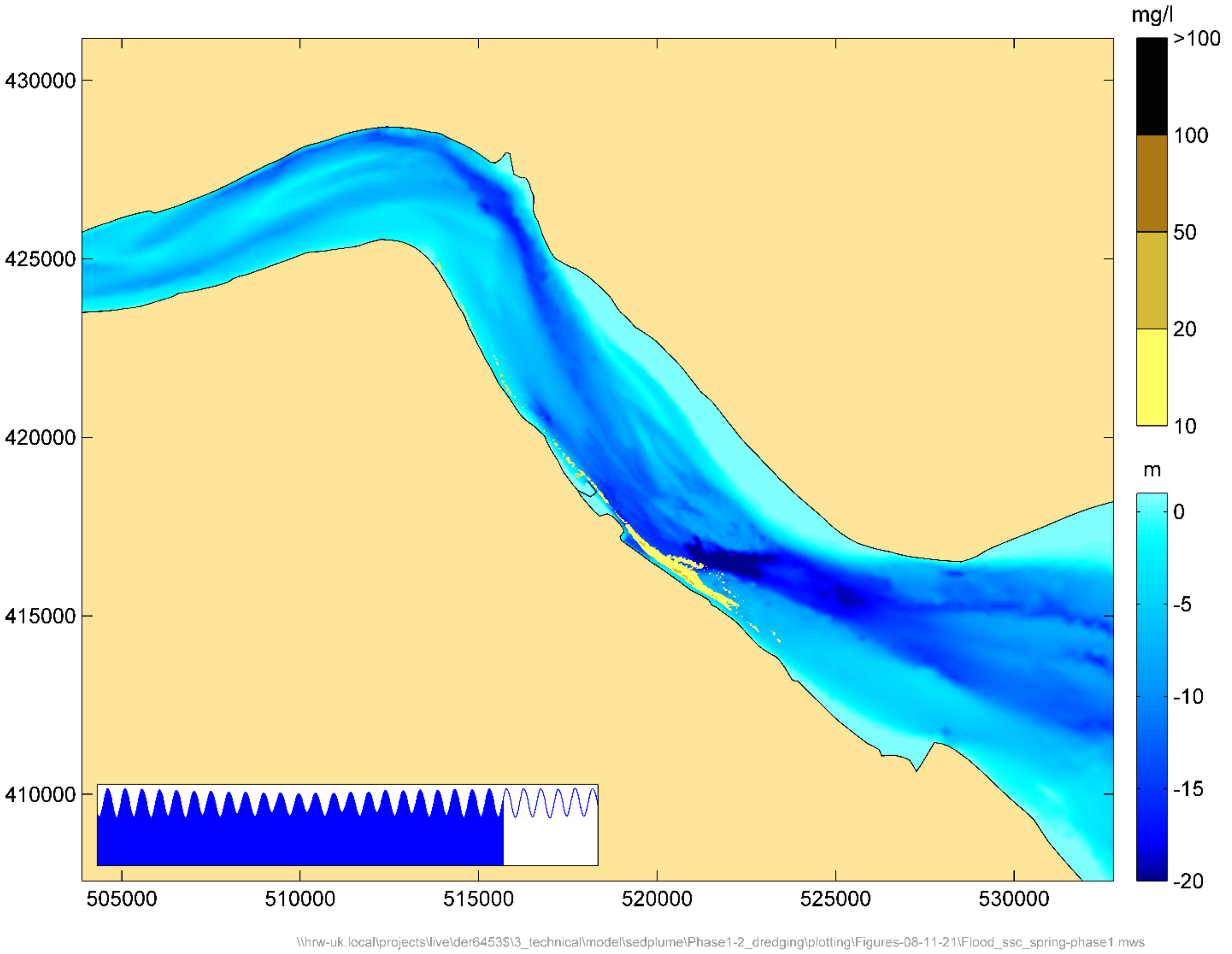

Figure 6.4: Predicted increase in suspended sediment concentration during the flood phase on a spring tide

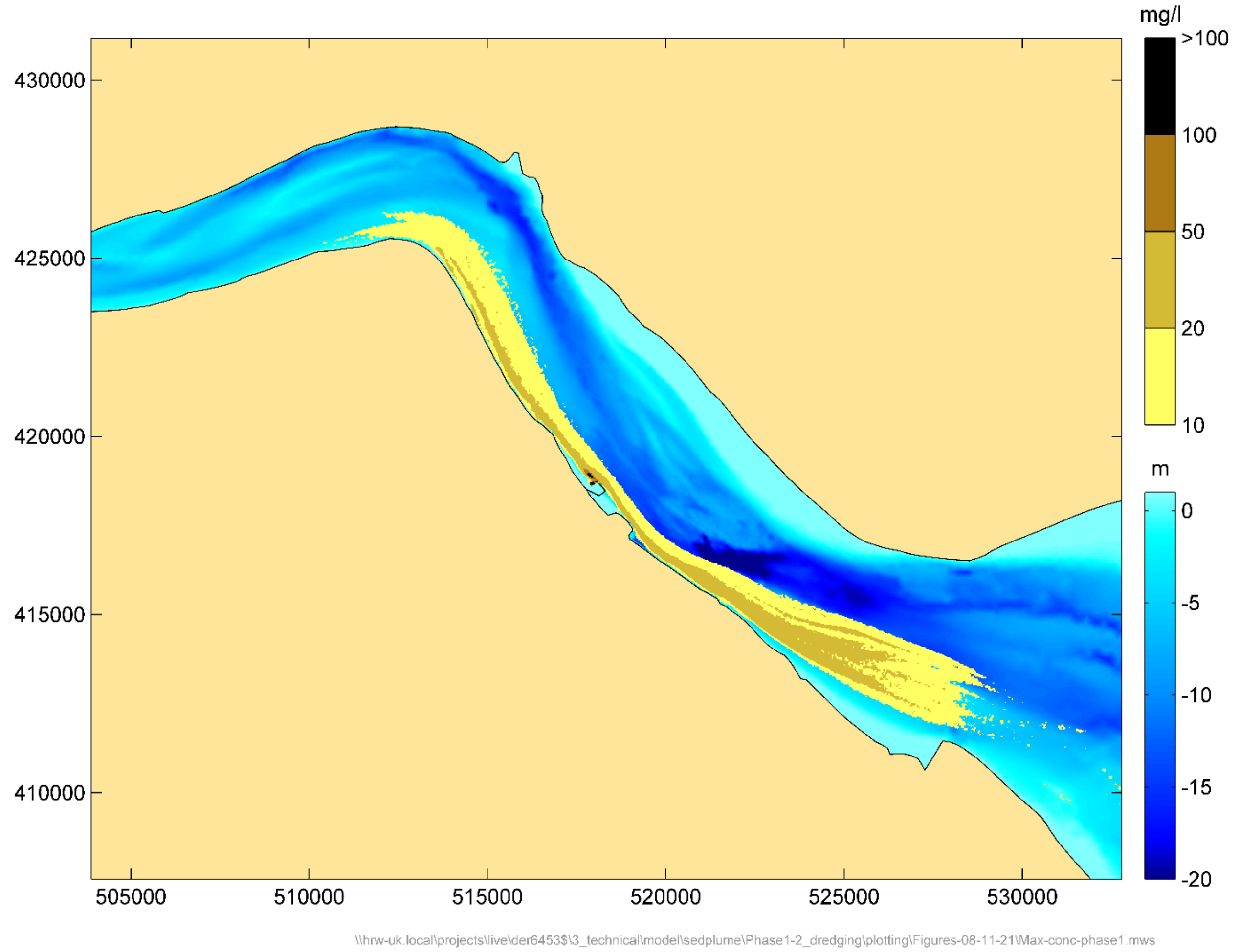

Figure 6.5: Early stage reclamation - Predicted peak increase in depth-averaged suspended sediment concentration above background over a spring-neap cycle

6.2.2 Deposition

Figure 6.6 shows the predicted accretion of fine sediment resulting from the early stage reclamation at the end of the simulated spring neap cycle. The accretion is calculated assuming a dry density for settled fine sediment of 500 kg/m^3. Accretion of only a few millimetres is predicted immediately upstream and downstream of the reclamation and in the berths area. The resulting accretion in nearby berths is quantified in Section 6.2.4.

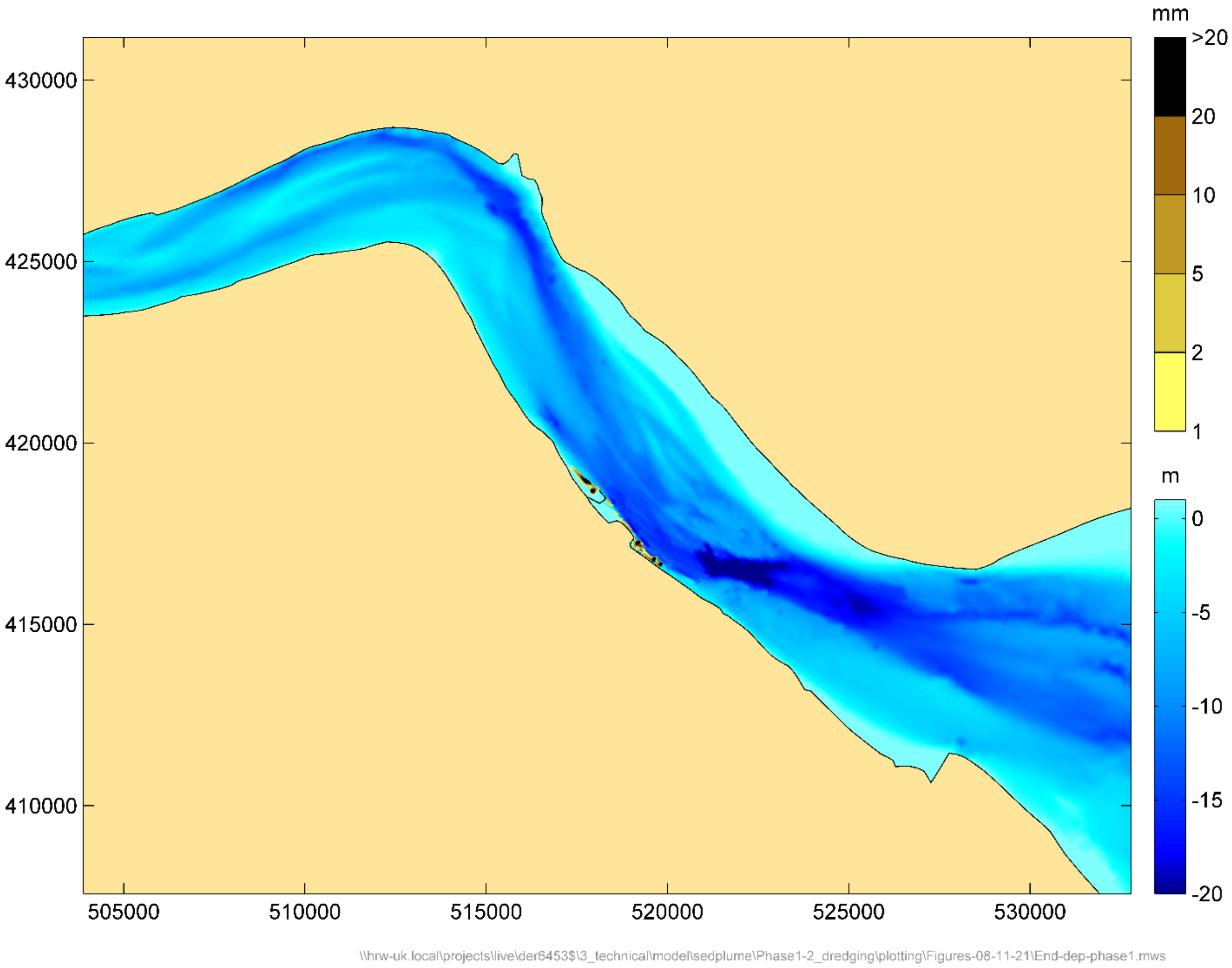

Figure 6.6: Early stage reclamation - Predicted deposition of fine sediment over a spring-neap cycle

6.2.3 Impacts at intake/outfall Locations

Figure 6.7 shows the predicted increases in depth averaged and near bed suspended sediment concentration at the intake location to the north of the proposed works. The predicted increases in depth averaged suspended sediment concentration are less than 25 mg/l and typically in the range 5 to 15 mg/l. The average increase is 4.6 mg/l. Near bed concentrations at the intakes were predicted to be slightly higher, averaging 6.3 mg/l with a peak value of 30 mg/l.

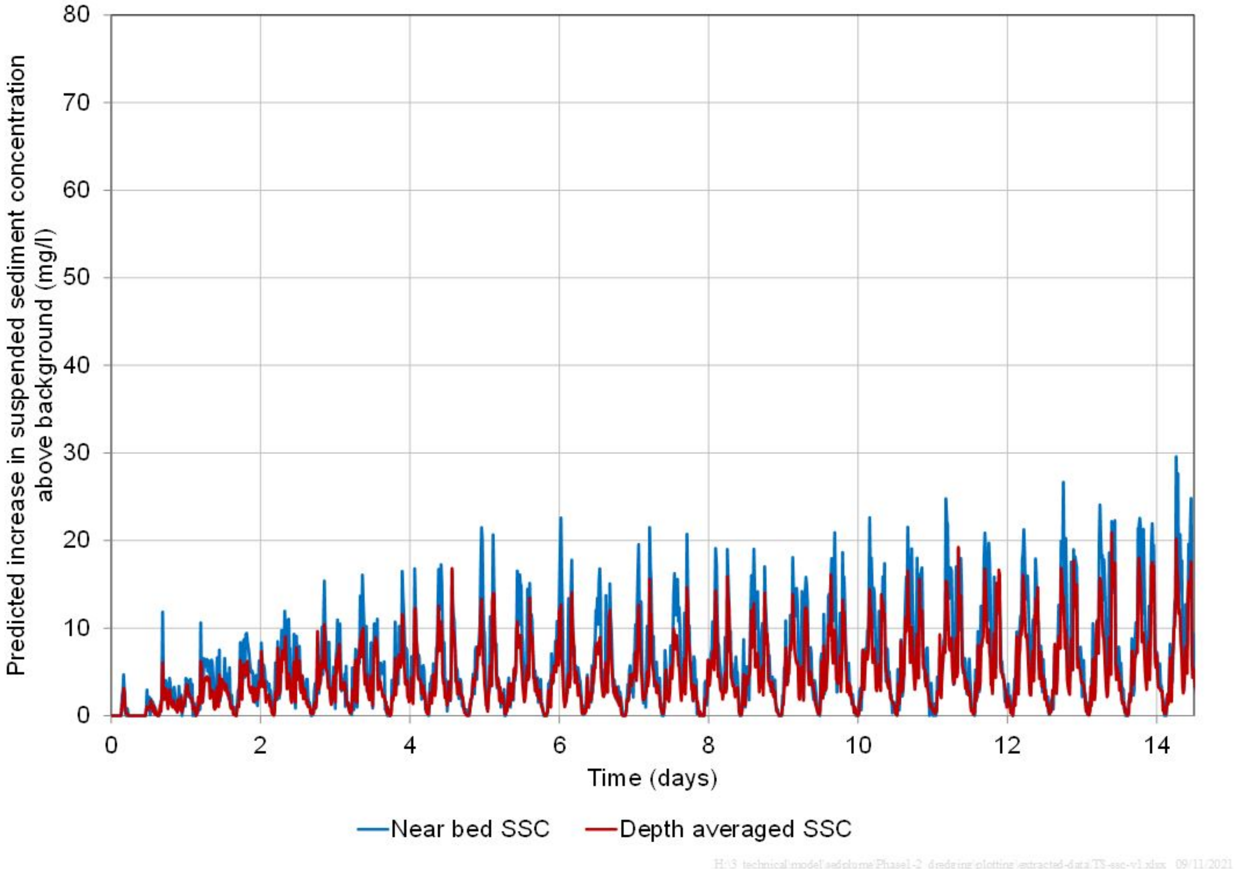

Figure 6.7: Early stage reclamation - Predicted increase in suspended sediment concentration above background over a spring-neap cycle of backhoe dredging at the northern end of the dredging area at the Uniper intake

6.2.4 Accretion at nearby berths

The accretion at nearby berths over the spring-neap cycle resulting from the reclamation run-off and BHD dredging is presented in Table 6.1, together with the accretion presented in HR Wallingford (2021) for BHD alone. The infill at the nearby berths resulting from the combined reclamation run-off and backhoe dredging is similar to that previously assessed for the BHD alone and is relatively insignificant when compared to annual maintenance dredge requirements and the natural variation in those quantities.

Table 6.1: Early stage reclamation - predicted infill arising from reclamation run-off and backhoe operations

Local berth	Predicted infill (m^3) over spring-neap cycle	
	Reclamation run-off and BHD dredging	BHD (HR Wallingford, 2021)
Humber Sea Terminal	0	0
South Killingholme Oil Jetty	38	3
Immingham Gas Terminal	7	2
Humber International Terminal	98	88
Immingham Bulk Terminal	744	736
Western Jetty	0	3
Eastern Jetty	0	1
Immingham Oil Terminal	-	-

6.3 Later stage of reclamation

6.3.1 Spatial distribution of increases in suspended sediment concentration and fine sediment deposition

Typical predicted increases in depth averaged suspended sediment concentration above background arising from the reclamation and backhoe dredging in the later stage of reclamation on spring tides are presented in Figure 6.4. These figures show the typical plume at high water, mid-ebb, low water, and mid-flood on a spring tide. The figures show that the plume typically travels as far upstream as the bend in the Humber where the channel turns westward and as far downstream as Grimsby. Increases in suspended sediment concentration above background levels are less than 50 mg/l.

Figure 6.5 presents the peak increases in (depth-averaged) suspended sediment concentration which occur over the simulation. The figure indicates that peak increases in (depth-average) concentration will be less than 50mg/l but that increases of more than 10mg/l will occur up to 17 km from the point of dredging. Some of the elevations in concentration arise from resuspension of temporarily settled material on the flood tide (e.g., the plume to the south of the site).

In the later stage of reclamation the BHD operations are in deeper water in front of the quay wall at the downstream end of the development. The results are thus more similar to those for the BHD shown in HR Wallingford (2021).

Comparison of these predicted increases in concentration with the background concentrations described in Section 4 indicates that the predicted increases arising from the reclamation run-off and backhoe dredging are insignificant.

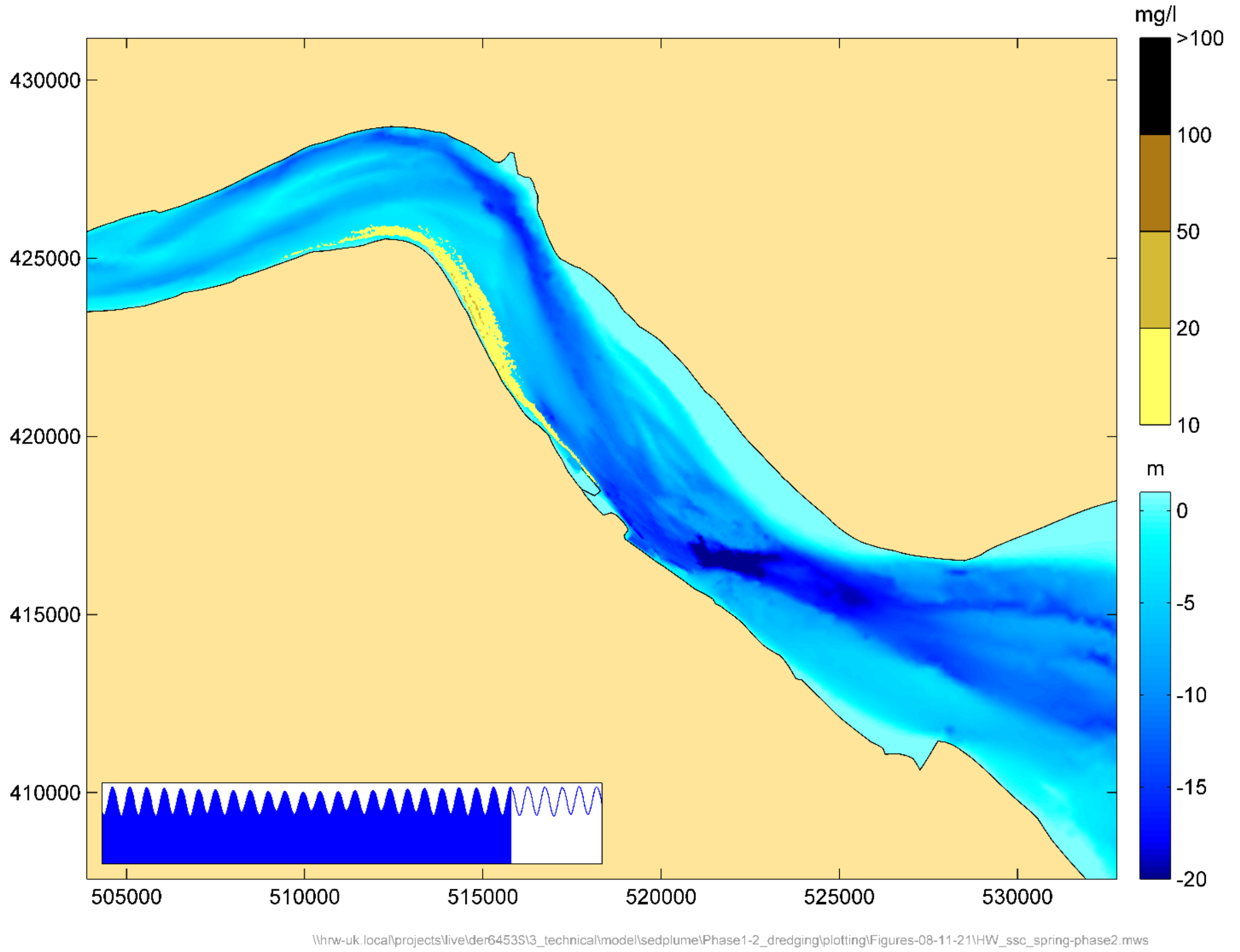

Figure 6.8: Predicted increase in suspended sediment concentration at high water on a spring tide

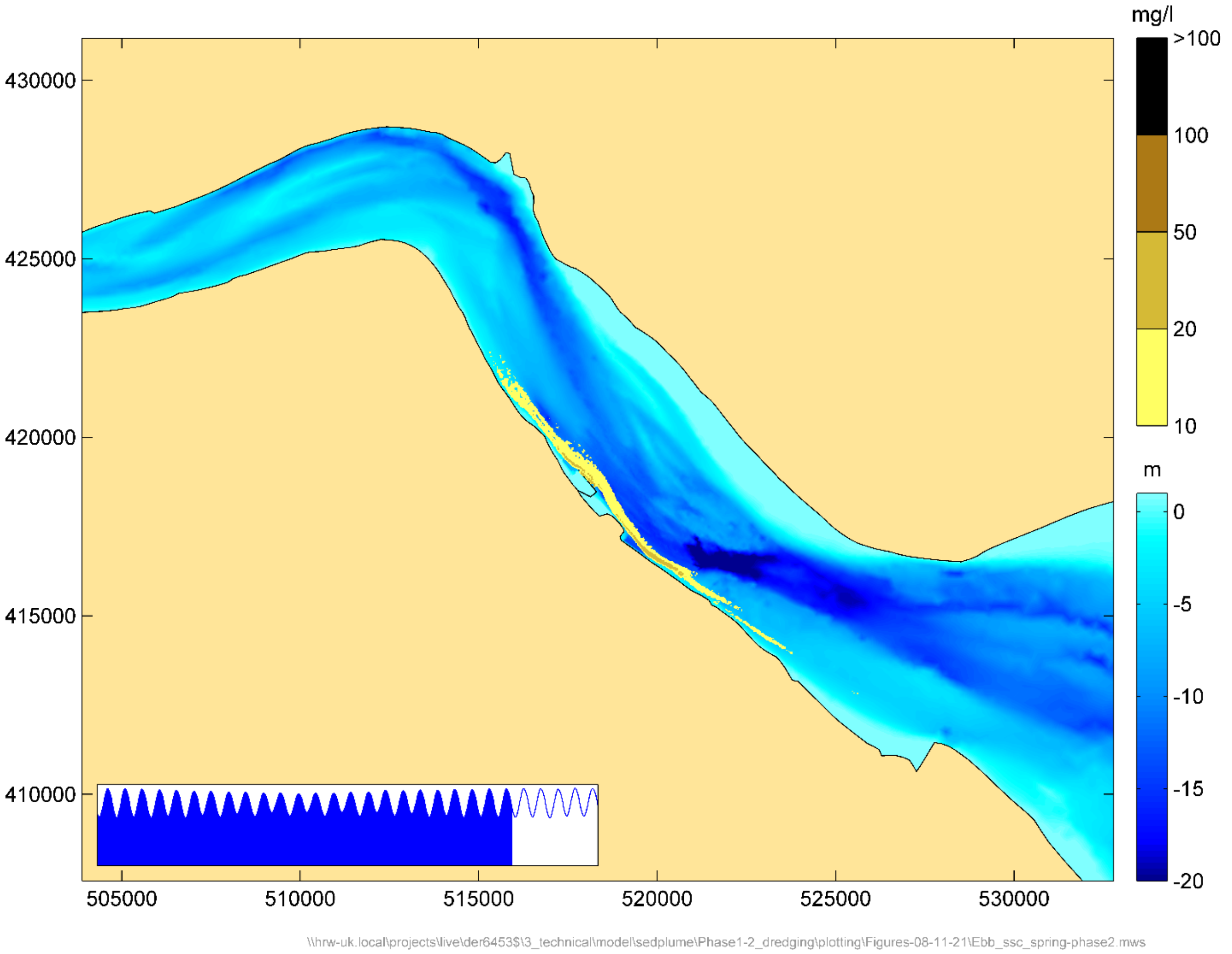

Figure 6.9: Predicted increase in suspended sediment concentration during the ebb phase on a spring tide

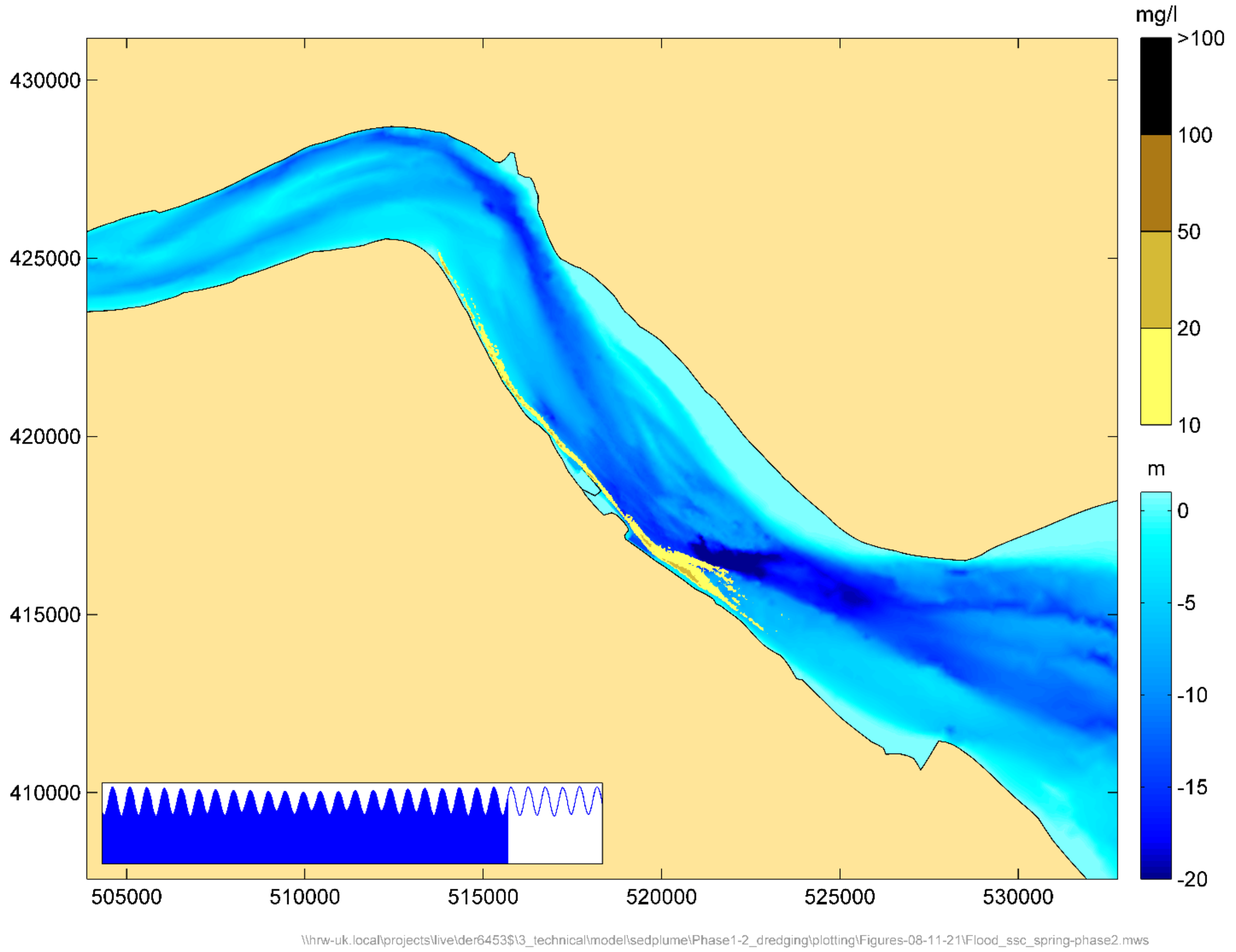

Figure 6.10: Predicted increase in suspended sediment concentration at low water on a spring tide

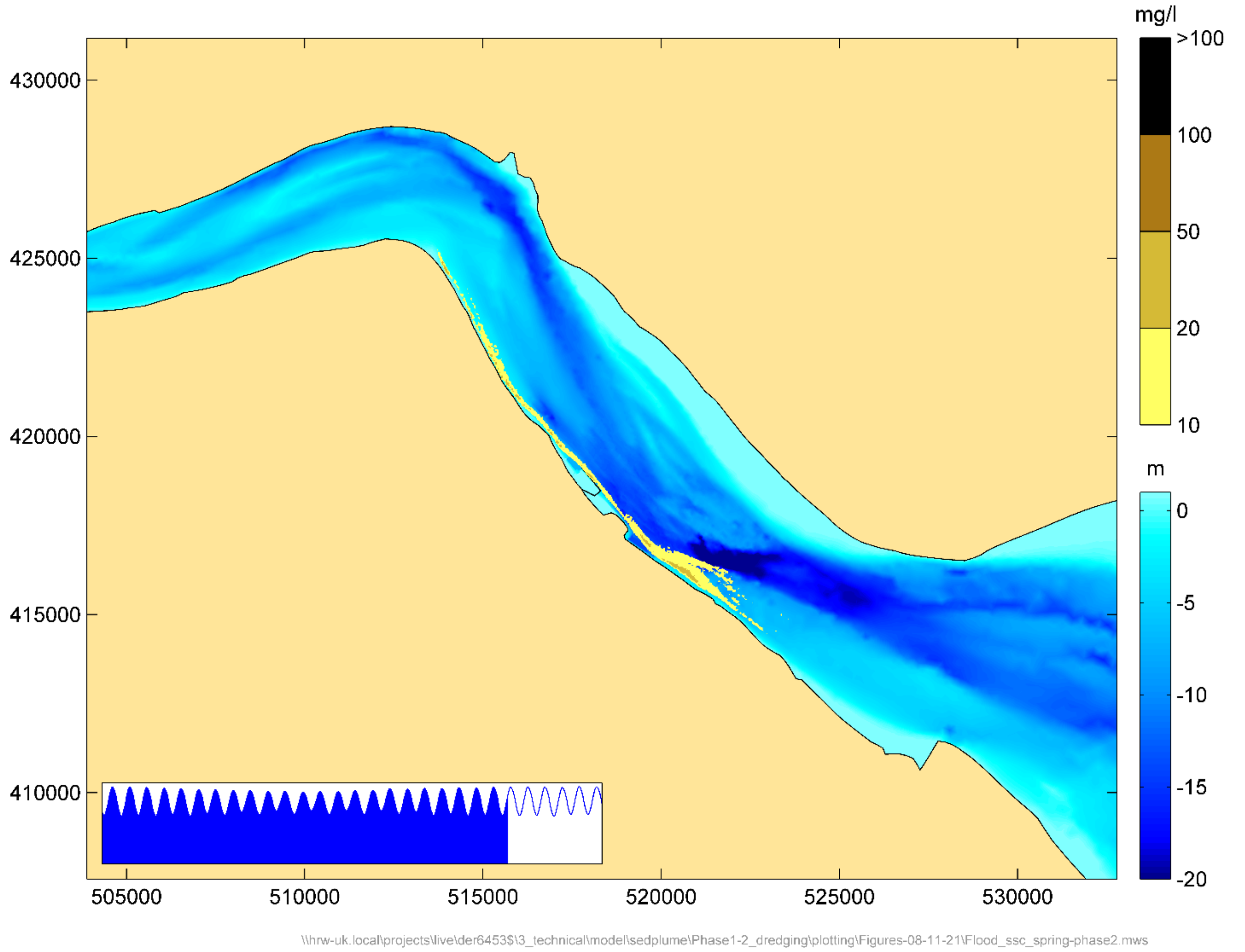

Figure 6.11: Predicted increase in suspended sediment concentration during the flood phase on a spring tide

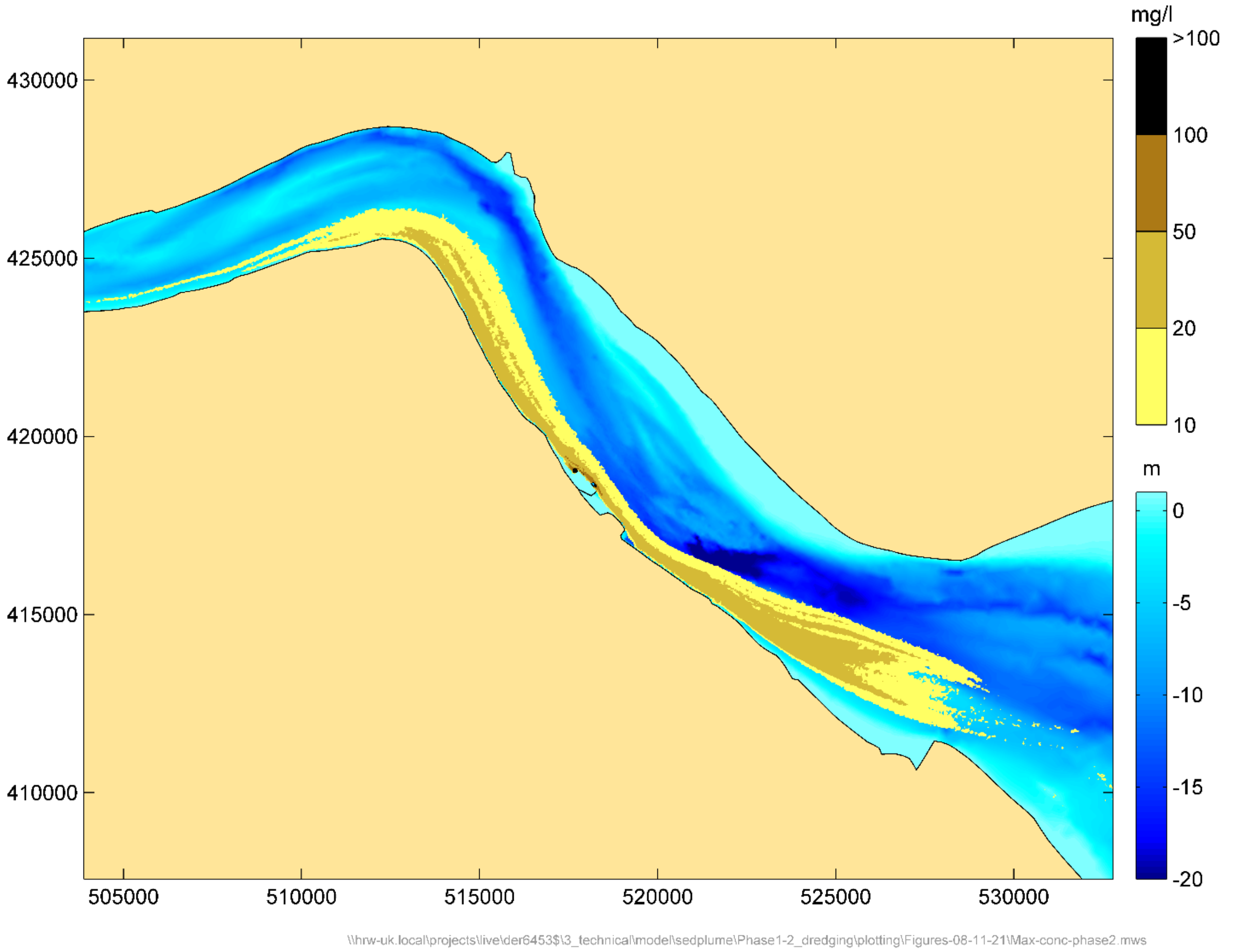

Figure 6.12: Later stage reclamation - Predicted peak increase in depth-averaged suspended sediment concentration above background over a spring-neap cycle

6.3.2 Deposition

Figure 6.6 shows the predicted accretion of fine sediment resulting from the reclamation run-off and backhoe dredging at the end of the simulated spring neap cycle. The accretion is calculated assuming a dry density for settled fine sediment of 500 kg/m^3. Accretion of only a few millimetres is predicted immediately upstream and downstream of the reclamation and in the berths area. The resulting accretion in nearby berths is quantified in Section 6.3.4.

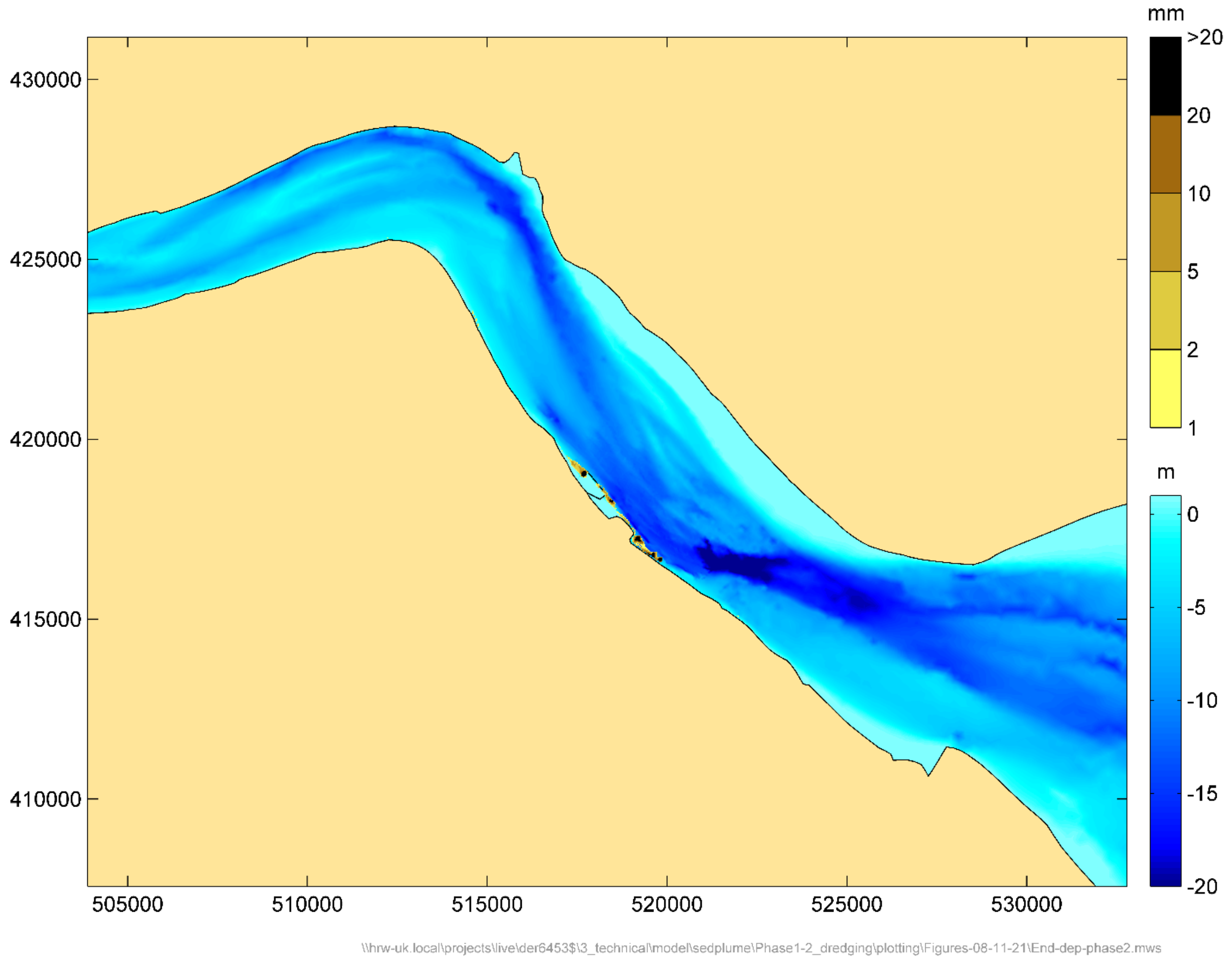

Figure 6.13: Later stage reclamation - Predicted deposition of fine sediment over a spring-neap cycle

6.3.3 Impacts at intake/outfall Locations

Figure 6.7 shows the predicted increases in depth averaged and near bed suspended sediment concentration at the intake location to the north of the proposed works. The predicted increases in depth averaged suspended sediment concentration are less than 25 mg/l and typically in the range 10 to 20 mg/l. The average increase is 7.2 mg/l. Near bed concentrations at the intakes were predicted to be slightly higher, averaging 10.2 mg/l with a peak value of 33 mg/l.

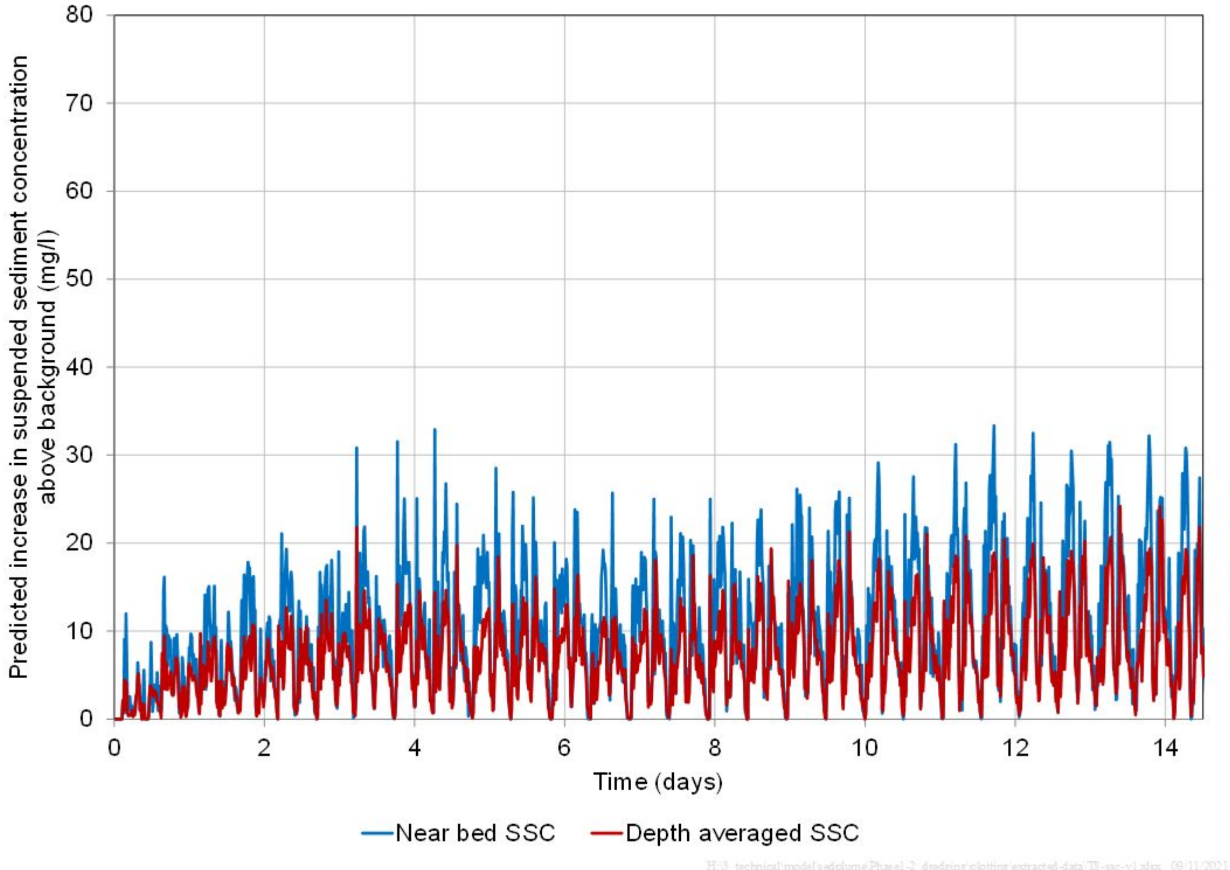

Figure 6.14: Predicted increase in suspended sediment concentration above background over a spring-neap cycle of backhoe dredging at the northern end of the dredging area at the Uniper intake

6.3.4 Accretion at nearby berths

The accretion at nearby berths over the spring-neap cycle resulting from the reclamation run-off and BHD dredging is presented in Table 6.2, together with the accretion presented in HR Wallingford (2021) for BHD alone. The infill at the nearby berths resulting from the combined reclamation run-off and backhoe dredging is similar to that previously assessed for the BHD alone and is relatively insignificant when compared to annual maintenance dredge requirements and the natural variation in those quantities.

Table 6.2: Later stage reclamation - Predicted infill arising from reclamation run-off and backhoe operations

Local berth	Predicted infill (m^3) over spring-neap cycle	
	Reclamation run-off and BHD dredging	BHD alone (HR Wallingford, 2021)
Humber Sea Terminal	0	0
South Killingholme Oil Jetty	219	3
Immingham Gas Terminal	0	2
Humber International Terminal	89	88
Immingham Bulk Terminal	820	736
Western Jetty	0	3
Eastern Jetty	0	1
Immingham Oil Terminal	-	-

7 Conclusions

The plume dispersion modelling for the proposed construction including reclamation run-off shows that suspended sediment concentrations and associated deposition are comparable to that previously assessed for the amended scheme with the BHD loading barges. The impacts are considered insignificant compared to the natural background concentrations in the Humber Estuary and the effects of the reclamation run-off in combination with the BHD that will be undertaken in parallel are shown to be negligible compared to the scenarios of CSD loading and overflowing barges or TSHD dredging sand and gravel previously assessed.

8 References

HR Wallingford (2021) Able Marine Energy Park 2021. Sediment plume dispersion from dredging, Report DER6453-RT002-R04-00, June 2021.

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