CROSS SOLENT WATER MAIN REPLACEMENT SCHEME

Sediment Transport Modelling
(Draft)

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SUMMARY

1 As part of the 4D Cross Solent Water Main Replacement Scheme, twin water mains pipelines approximately 3 km long will be laid from the coast off Lepe in Hampshire to Gurnard on the Isle of Wight. The shore approach sections will be constructed by directional drilling to emerge approximately 600 to 700 metres offshore from the coastlines on both sides. The central sections approximately 2.12 km long will be constructed by burying a pipeline to a depth of about 1.5 metres using a jetting technique.

2 Sediment transport modelling was required to assess the environmental impact of the bentonite mud discharge from the directional drilling and the sand sediment released from the jetting of the trench for the mains pipelines' mid-section installation.

3 Southern Water's (SW) 125m grid Solent and the Isle of Wight (IOW) MIKE21 tidal hydrodynamic model was used in conjunction with the MIKE21 Particle Tracking Model in the sediment transport modelling. This model has been calibrated and extensively verified and applied in other sediment transport impact assessment studies.

4 The bentonite mud releases at each of the four sites were assumed to be independent given the month interval between each release in the modelling assessment. Therefore a single release from each end of the pipeline would give an estimate of the impact of the releases from each of the two points at each end of the pipelines. The impact of the jetting of the two trenches for the mid-sections of the twin mains was also assumed to be independent given the time period between the laying of the two mains.

5 The model results for the bentonite mud discharge scenarios simulated show that the bentonite mud depth averaged concentrations in the water are predicted to drop well below 0.05 mg/l after one week. The deposition depths of sediment are also predicted not to exceed 0.1 mm in the area of interest approximately one week after the release of the bentonite mud from each release point.

6 The model results shows that depth averaged concentrations of the sand released into the water from the trench mid-section do not exceed 2 mg/l in the vicinity of the discharge. The predicted depth averaged sand concentrations are also shown not to exceed 0.5 mg/l in the nearshore area during the two week simulation period. The simulated sand depth averaged concentrations are shown to fall below 0.5 mg/l a few days after the jetting of the trench has ceased.

7 The deposition depths of the released sand sediment are predicted not to exceed 0.1 mm in the vicinity of the pipeline a few days after the jetting of the pipeline mid-section has ceased.

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1 INTRODUCTION

1.1 As part of the 4D Cross Solent Main Replacement Scheme, twin nominal 300mm diameter pipelines approximately 3 km long will be laid from the coast off Lepe in Hampshire (Hants) to Gurnard on the Isle of Wight (IOW). The shore approach sections will be constructed by directional drilling to emerge approximately 600 to 700 metres offshore from the coastlines on both sides. The central sections approximately 2.12 km long, will be constructed by burying a pipeline to a depth of about 1.5 metres using a jetting technique.

1.2 Sediment transport modelling is required to assess the environmental impact of the bentonite mud discharge from the directional drilling and the sediment released from the jetting technique for the pipe installation. The increase in the suspended sediment (SS) concentration resulting from these construction activities, the transport of the dredging plumes and the settlement of the SS need to be predicted to establish any possible impact on the sites of conservation importance in the vicinity of the area.

1.3 The Cross Solent Water Main pipelines lie within an area covered by Southern Water's (SW) 125m grid Solent and the IOW MIKE21 tidal hydrodynamic model tidal hydrodynamical model. This has been calibrated and extensively verified [1] and applied in other sediment transport impact assessment studies [2].

1.4 The output of the SW Solent and IOW tidal hydrodynamical model has been used in sediment transport modelling to simulate the impact of the release of sediments during the construction of the pipelines. The sediment transport processes have been modelled using a Lagrangian Particle Tracking Model that forms part of the MIKE21 software suite developed by the Danish hydraulics Institute (DHI). This is a pseudo-3D model that can simulate the sediment transport processes of advection, dispersion, deposition, re-suspension, flocculation and consolidation when necessary.

Purpose of the Report

1.5 This report describes the sediment transport modelling undertaken to predict the impact of the sediments discharged during the proposed construction of the Cross Solent Main Replacement pipelines.

2 SEDIMENT TRANSPORT MODELLING

Modelling Approach

2.1 The SW Solent and the IOW tidal hydrodynamical model was used for the prediction of the tidal levels and currents. The sediment transport processes, including advection, dispersion, deposition, re-suspension and flocculation and consolidation where appropriate (cohesive sediment only), were modelled using the MIKE-21 Particle Tracking Model. The accuracy of the Particle Tracking Model is not limited by the grid resolution of the tidal hydrodynamic model. The particle model can precisely represent the positions of sources or distributions of velocities. The model provides output of concentrations over different depth layers (such as surface layer, bottom layer etc). It is particularly advantageous for modelling the sediment transport resulting from dredging activities and for modelling the wastewater plumes of LSO discharges.

2.2 Calibration and verification of the Particle Tracking Model had been carried out in previous studies [2]. In order to isolate the impact of the solids released in the construction activities, a zero background concentration of suspended solids was applied in the modelling.

2.3 The twin 300 mm nominal diameter pipes across the Solent will be installed by a combination of horizontal directional drilling for the shore approach sections and by directly laying the pipes on the seabed followed by embedment using a jetting technique for the central mid-channel section [3]. The shore approach sections extend to a distance of approximately 600 to 700 metres offshore from both coastlines. The central channel mid-section will be approximately 2.12 km long. The twin pipelines will be laid at a separation of around 50 to 100 metres, parallel and to the east of the existing twin 200m diameter Cross Solent water mains. The intention is to embed the pipeline to provide an average 1.2 m cover (trench nominal 1.5 m depth to invert) within the seabed material.

2.4 The estimates of the locations of the directional drilling break out/bentonite mud release points are shown in Table 2.1. It was estimated that for each one of the four shore approach drills that 2450 kg of bentonite mud solids in 82 m^3 of water would be released over a two hour period on 4 occasions each a month apart. The average particle size of bentonite clay and density applied in the modelling were 1 micron and 2650 kg/m^3 respectively [4].

2.5 It was estimated to take around 1.5 weeks to bury each pipeline main mid-section in a trench of approximate average size 0.75 m wide x 1.5 m deep. The sea bed material within this section comprises mainly of cobble and gravel and to a much lesser extent fine to medium sand. It was assumed that the cobble and gravel would settle out very quickly in the vicinity of the trench due to the large particle sizes and subsequent fast settling velocities. The modelling study therefore investigated only the impact of the release of the medium to fine sand in the water column. Analysis of the bed material in this region showed that medium to fine sand comprises of only about 1.24% of the trench solids volume [5]. It was assumed in the model study that the jetting of the trench would begin from the Lepe (Hampshire) end and move towards the Gurnard (IOW) end.

2.6 The moving sand sediment source in the model was approximated by applying the sediment releases at fixed points for a given duration along the pipeline route. These points were the proposed SI survey boreholes and vibrocores shown in Table 2.2 which approximately lie along the mid-section of the pipeline route (i.e. points V2 to V9 and RC2) [6]. It was estimated that the jetting of the trench for each mid-section of the pipeline would take about 1.5 weeks and that the sediment from the trench volume would be released at a constant rate over this period. The approximate trench length was about 2.12 km and the estimated daily volume of solids removed from the trench was about 226.63 m^3/day. The release rate of medium to fine sand based on the ratio of the medium to fine sand in the jetted bed solids would therefore be 2.8125 m^3/day (i.e. 0.086 kg/s assuming a solids density of 2650 kg/m^3). The sediment would be released at this constant rate into the water column for a period determined from the time it took to jet between the fixed point and the previous one along the pipeline route. The average particle size of the medium to fine sand applied in the modelling was 0.25 mm and was based on particle size analysis of the grab samples within the region of the mains mid-section [5].

Table 2.1 Locations of Bentonite Mud Release Points

Release point	Easting	Northing
Hants Lepe Western Pipeline	445770	097640
Hants Lepe Eastern Pipeline	445830	097660
IOW Gurnard Western Pipeline	446700	095880
IOW Gurnard Eastern Pipeline	446750	095920

Table 2.2 Locations of SI Survey Rotary Cored Boreholes and Vibrocores

	Easting	Northing
Rotary Cored Boreholes		
RC1	445830	97670
RC2	445900	96910
RC3	446850	95740
Vibrocores		
V1	445790	97760
V2	445800	97650
V3	445840	97400
V4	445860	97150
V5	446020	96660
V6	446170	96450
V7	446330	96260
V8	446510	96100
V9	446700	95920
V10	446790	95840

2.7 Sediment particles less than 0.06 mm are defined as cohesive sediments. Cohesive sediments have low settling velocities and can be transported much further than sandy particles by tidal currents. At high concentrations, those fine particles can amalgamate and form larger conglomerates due to electrostatic charges carried on each particle, a process called flocculation. The resultant flocs, which effectively act as large particles, settle faster than the individual fine particles from which they are formed. On the other hand the flocculation and settlement process reduces the cohesive sediment concentration, thus slowing down the flocculation process for the fine particles remaining in suspension. Another distinctive feature of the cohesive sediment transport is a process called consolidation. On settling on to the seabed, the settled layer is still in a loose form similar to sewage sludge, which can be easily re-suspended when seabed shear stresses increase as a result of the increase in tidal current velocity. Consolidation can be a very long process before the loose deposition become solid seabed material. There are no flocculation and consolidation processes in the transport of sandy material.

2.8 The bentonite mud release within the MIKE21 Particle Tracking Model was modelled as a cohesive sediment and the fine to medium sand release was modelled as a non-cohesive sediment. For simplicity, the vertical position of the sediment source in the model was fixed at a depth of 1~1.5 m above the sea bed.

2.9 In order to simulate the likely sediment transport resulting from the bentonite mud and fine to medium sand releases, hydrodynamical conditions (tidal levels and currents) were predicted for a continuous fortnight period starting from the spring tide on 00:00 on 07/10/1998 and finishing at the following spring tide at 00:00 on the 21/10/1998. This was carried out using the SW Solent and the IOW hydrodynamical model.

2.10 The bentonite mud releases for each of the four sites were initially assumed to be independent given the month interval between each release. Therefore a single release from each end of the pipeline would give an estimate of the impact of the releases from the each of the two points at each end of the pipelines. The modelling assessment was therefore based on the discharge of bentonite mud from the Eastern directional drilling offshore discharge points shown in Table 2.1.

2.11 The impact of the jetting of the two trenches for the mid-sections of the twin mains was also assumed to be independent given the length of the time period between the laying of the two mains.

2.12 The model scenarios investigated are shown in Table 2.3. The bentonite mud discharges were simulated for a period of about one week from the time of discharge to establish the impact of the transport of the fine mud after the cessation of the discharge.

2.13 The precise dates for the jetting of the trench for the mid-section of the twin mains is as yet unknown but it is approximated that each operation will last about 1.5 weeks (i.e. 10.5 days). The results from the two week long SW tidal hydrodynamical model run described in 2.9 above were used to simulate the transport of released sediments using the MIKE21 Particle Tracking Model. It was assumed that the jetting would coincide with the spring to spring tidal conditions. This is a conservative approach as bed material released under these conditions would be more likely to be transported further than under a two week neap to neap tide tidal period. The two week period would also simulate the impact of the sediment discharges for an additional period of about 3.5 days after the cessation of the jetting operations.

2.14 An overview of all the model simulations carried out in this study is given in Table 2.3.

Table 2.3 Overview of Model Simulations

Run id	**Sediment**	**Release Point**	**Scenario** **HW – High Water** **LW – Low Water**
st-1b	bentonite mud	Hants Lepe East	Spring tide HW release
st-2b	bentonite mud	Hants Lepe East	Spring tide LW release
st-3b	bentonite mud	Hants Lepe East	Neap tide HW release
st-4b	bentonite mud	Hants Lepe East	Neap tide LW release
st-5b	bentonite mud	IOW Gurnard East	Spring tide HW release
st-6b	bentonite mud	IOW Gurnard East	Spring tide LW release
st-7b	bentonite mud	IOW Gurnard East	Neap tide HW release
st-8b	bentonite mud	IOW Gurnard East	Neap tide LW release
st-11s	fine – medium sand	Mid-section route East	Spring to Spring Tide

3 MODEL RESULTS

3.1 Figures 3.1 ~ 3.8 show the maximum predicted depth averaged bentonite mud concentrations over the 1 week simulation period for the bentonite discharge scenarios shown in Table 2.3.

3.2 The model results show that the maximum predicted depth averaged concentrations do not exceed 2 mg/l in the vicinity of the discharge for the Hampshire releases (Figures 3.1 ~ 3.4). The maximum predicted depth averaged concentrations in the near shore zone are also shown to be less than 0.5 mg/l (Figures 3.1 ~ 3.4). The bentonite mud concentrations in the water are predicted to drop below 0.05 mg/l after one week as shown in Figures 3.9 ~ 3.10 for the Hampshire releases.

3.3 The model results show that the maximum predicted depth averaged concentrations do not exceed 0.5 mg/l for the IOW releases. (Figures 3.5 ~ 3.8). The bentonite mud concentrations in the water are predicted to drop well below 0.05 mg/l after one week as shown in Figures 3.11 ~ 3.12 for the IOW releases.

3.4 Figures 3.13 ~ 3.20 show the predicted bentonite mud deposition depth after the one week simulation period for the bentonite discharge scenarios shown in Table 2.3. The deposition depths of sediment are predicted not to exceed 0.1 mm in the area of interest at approximately one week after the release of the bentonite mud.

3.5 Figure 3.21 shows the maximum predicted depth averaged suspended solids concentration for the jetted sand over the two week period of the simulation. It shows that concentrations do not exceed 2 mg/l and 0.5 mg/l in the vicinity of the discharge and the immediate pipeline offshore areas respectively. The depth averaged concentrations are shown to fall below 0.5 mg/l a few days after the jetting of the trench has ceased (Figure 3.22).

3.6 Figures 3.23 shows the predicted sand deposition depth after the two week simulation period for the jetting of the trench for the mains mid-section. The deposition depths of the sand sediment are predicted not to exceed 0.1 mm in the area of interest a few days after the jetting of the pipeline mid-section has ceased.

4 CONCLUSIONS

4.1 This study has been undertaken to assess the impact of the release of sediments from the construction activities of the Twin Cross Solent Main Pipelines.

4.2 The assessment has been based on modelling the impact of the release of bentonite mud from the proposed easterly discharge points at each shore end. This will give an indication of the impact of the discharge from the two bentonite mud discharge points at each shore end given their proximity and the long time interval between each discharge.

4.3 The model results for the bentonite mud discharge scenarios simulated show that the bentonite mud depth averaged concentrations in the water are predicted to drop well below 0.05 mg/l after one week. The deposition depths of sediment are also predicted not to exceed 0.1 mm in the area of interest at approximately one week after the release of the bentonite mud from each release point.

4.4 The impact of the release of sediment from the trench in which the mid-section of the mains pipeline will be laid has also been simulated. The sediments in this area comprise mainly of gravel and cobble and to a much lesser extent fine to medium sand. The modelling study has been based on the release of the sand material as the larger and heavier solids settle quickly in close proximity to the trench.

4.5 The model results shows that depth averaged concentrations of the sand released into the water do not exceed 2 mg/l and 0.5 mg/l in the vicinity of the discharge and the inshore areas respectively during the two week simulation period. The depth averaged concentrations are shown to fall below 0.5 mg/l a few days after the jetting of the trench has ceased.

4.6 The deposition depths of the released sand sediment are predicted not to exceed 0.1 mm in the area of interest a few days after the jetting of the pipeline mid-section has ceased.

5 REFERENCES

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[5] Pers. Comm., Southern Water Services and Halcrow Group, Solent – Grab Samples, Ref. WESOLE/23/274, 07/06/2005.

[6] Pers. Comm., Southern Water Services and Halcrow Group, Cross Solent Main – Jetting Section, Ref. WESOLE/23/243, 23/05/2005.

FIGURES