ABERDEEN HARBOUR
EXPANSION PROJECT
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Appendices

APPENDIX 7-D SEDIMENT PLUME MODELLING

FUGRO EMU LIMITED

ABERDEEN HARBOUR EXPANSION PROJECT

SEDIMENT PLUME MODELLING

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SUMMARY

Intertek Energy and Water Consultancy Services (Intertek) has been commissioned by Fugro EMU Limited (Fugro) to support the Environmental Impact Assessment (EIA) they are undertaking on behalf of Aberdeen Harbour Board (AHB) for the proposed harbour expansion in Nigg Bay. Operations at Aberdeen Harbour are constrained by the size and shape of the existing port facilities, and their location within Aberdeen city. As such, AHB is constrained in its ability to provide adequate facilities for current and predicted traffic, requiring an expansion of the facilities at a new location. A scoping report in 2013 identified Nigg Bay as a potential site to be taken forward for investigation, assessment and development.

The particular aspect of the coastal processes assessment considered within this document is the disposal of sediments from the current maintenance dredging in Aberdeen Harbour and the disposal of sediment arising from the dredging activities of the proposed Aberdeen Harbour Expansion Project. The effects of these activities range from the near-field (within 1 km of the development), to the far-field (greater than 1 km from the development). AHB require an understanding of the magnitude and significance of these effects.

The assessment used the existing Aberdeen Coastal Model (ACM), which was calibrated, validated, and accepted as being fit for purpose by SEPA for use in water quality assessments. The ACM was updated using recent data, which provided increased resolution in Nigg Bay. Model performance was reviewed during the upgrade, achieving compliance with the Foundation for Water Research 1993 guidelines. The particle tracking module was used to provide an assessment of the sediment processes for baseline, construction and operational phases of the proposed Aberdeen Harbour Expansion Project. Due to the dredging and disposal methods, and the operational programme not being finalised, this assessment has adopted an extremely conservative approach when considering the effects. As a result, the effects which are discussed represent the worst possible case. The effects from the dredging operations are likely to be less than presented in this assessment, with the effects reduced by one to two orders magnitude depending on the dredging method and programme which are applied.

The key conclusions of this assessment are as follows:

Sediment released at the disposal site during baseline, operational and construction phase scenarios is not predicted to affect the identified sensitive receivers at Aberdeen Ballroom Bathing Water, Nigg Bay Site of Special Scientific Interest (SSSI), Cove SSSI, River Dee Special Area of Conservation and Ythan Estuary and Sands of Forvie draft Special Protection Area (SPA). Sediment sizes of coarse sand and larger are predicted to remain within the disposal area

throughout an average tidal cycle due to the low advection and dispersion of sediment. Sediment smaller than coarse sand is transported outside of the disposal site, due to relatively lower settling velocities resulting in greater advection and dispersion. The area of redeposited sediment produced by these sediment sizes trends north-east to south-west, representing the regional tidal current.

No changes in sediment deposition are predicted during the operational phase. The spatial coverage and thickness of redeposited sediment, and the concentrations of sediment plumes produced by the release of sediment at the disposal location remain unchanged from the baseline condition.

Sediment released as overspill during the dredging operations within the Aberdeen Harbour Expansion, with the exception of mud, will remain within the development area. The partially constructed breakwaters reduce the current speed preventing the transport of material out of Nigg Bay. The effect of the breakwaters on the current speed, and therefore the sediment movement, will increase throughout the construction of the breakwaters resulting in the sediment movement decreasing during the construction phase.

Mud is the only sediment size predicted to leave the development area during the dredging programme. During the duration of the trailing suction hopper dredger operation, sedimented mud thicknesses of up to 2 mm is predicted in the south of the Ythan Estuary and Sands of Forvie draft SPA. During the backhoe dredging operation mud is not predicted to be deposited at any of the identified sensitive receivers. Nigg Bay SSSI is the only other sensitive site to be affected during the dredging operations due to its location within the development area. However, as its SSSI status is as a consequence of its geology, this will not be threatened.

The change in bed level at the disposal site at the end of the construction phase is a combination of the maintenance dredging from Aberdeen Harbour, which will increase the bed level by 2.548 m, and the disposal programme selected. If all of the sediment dredged from Nigg Bay is disposed of at the disposal site, the bed level is predicted to increase by 6.471 m. If the consolidated sediment is used within the harbour construction, the volume of sediment disposed of is reduced, resulting in a predicted bed level increase of 3.840 m. These values represent the worst case scenario and do not account for the resuspension or subsequent movement of sediment.

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TABLES

FIGURES

ABBREVIATIONS

ACM	Aberdeen Coastal Model
AHB	Aberdeen Harbour Board
BW	Bathing Water
DIA	Drainage Impact Assessment
EIA	Environmental Impact Assessment
ES	Environmental Statement
HD	Hydrodynamic
HDM	Hydrodynamic Modelling
PSD	Particle Size Distribution
PT	Particle Tracking
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
SSC	Suspended Sediment Concentration
SSSI	Site of Special Scientific Interest
ST	Sediment Transport
SW	Spectral Wave
TSHD	Trailing Suction Hopper Dredger

1 INTRODUCTION

1.1 PROJECT BACKGROUND

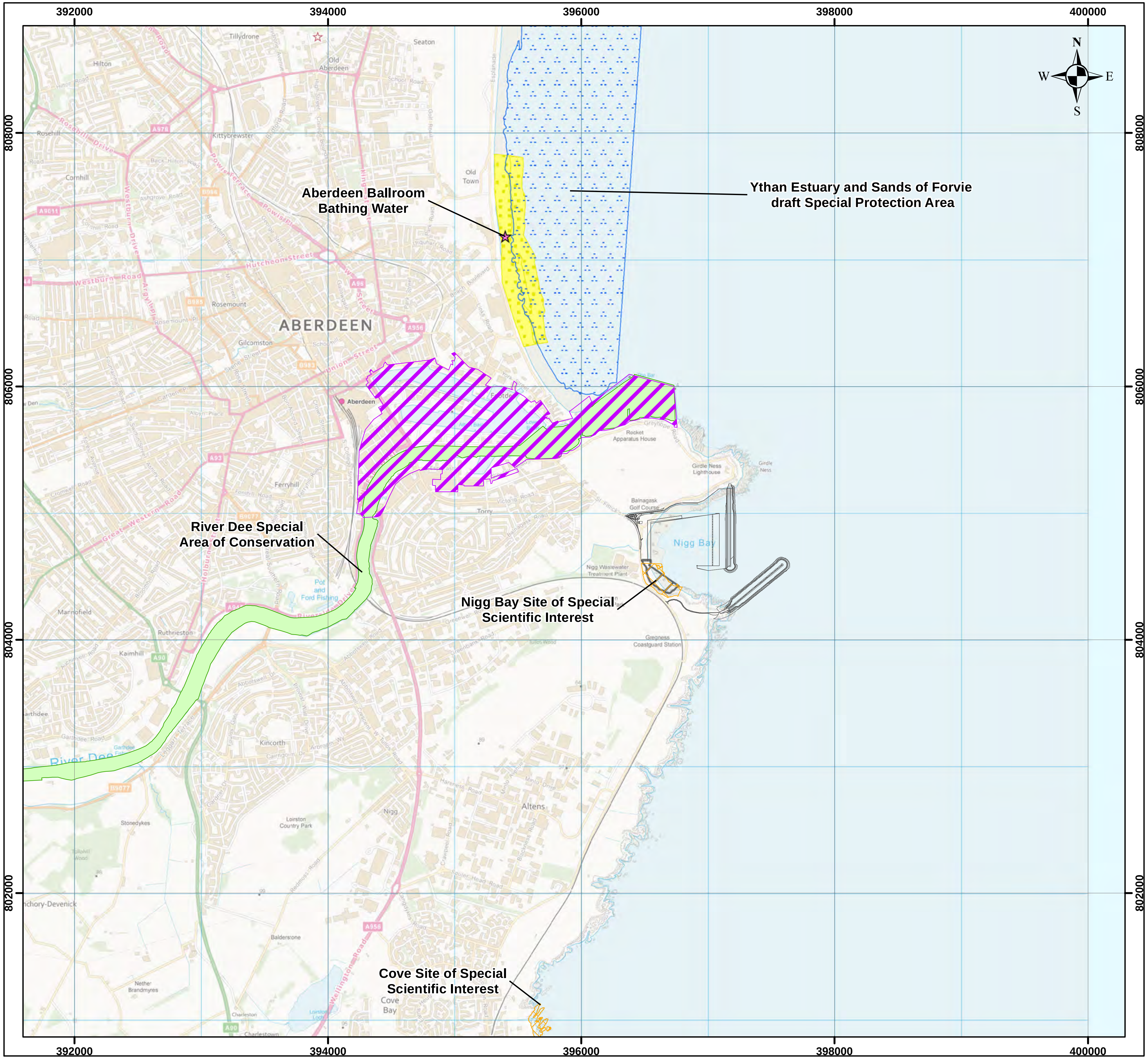
Operations within Aberdeen Harbour are restricted by the size and shape of the existing port facilities and the harbour's location within Aberdeen city. As such, Aberdeen Harbour Board (AHB) is constrained in its ability to provide adequate facilities to meet current and predicted traffic. Due to increased demand, AHB has identified a need to expand port facilities.

A feasibility study, undertaken in 2012, assessed different expansion options for a new or improved harbour. Following consultation, the Nigg Bay option was taken forward for investigation, assessment and development.

A scoping report (RPS, 2013) set out the proposed scope of the Environmental Impact Assessment (EIA). The EIA will inform the Environmental Statement (ES) which will accompany the application for consent for the proposed Aberdeen Harbour Expansion Project. Fugro EMU Limited (Fugro), supported by Waterman Group, have been appointed to undertake the full EIA and prepare the ES in relation to the proposed Aberdeen Harbour expansion. The work reported within this document was undertaken to support the EIA process. Details of this scope of work are provided in Section 1.2.

The geographic setting and the current proposed option for the Aberdeen Harbour Expansion Project is shown in Figure 1-1. The option is considered an indicative plan and may change prior to the final development. For this reason, the technical studies and resulting EIA/ES have adopted a Rochdale Envelope approach for assessing impacts. This approach makes realistic assumptions about the development, but tends towards conservatism (in terms of potential impacts) where there is uncertainty.

The proposed layout is shown in Figure 1-2 with the near-field data extraction locations used in this report indicated. The disposal site and data extraction locations used to assess sediment released at this location are shown in Figure 1-3. The distance of the data extraction locations from the centre of the disposal site are provided in Table 1-1. These locations have been selected to show the variations in suspended sediment concentration and redeposited sediment thickness along the central plume axis, which follows the regional current direction.



ABERDEEN HARBOUR EXPANSION PROJECT

Figure 1-1: Geographic overview of the area of interest

Legend

- Aberdeen Harbour Expansion Project area
- Existing Aberdeen Harbour Area
- Special Area of Conservation
- Site of Special Scientific Interest
- Draft Special Protection Area
- Bathing Water Monitoring Location
- Aberdeen Ballroom Bathing Water

NOTE: Not to be used for Navigation

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File Reference	J:\P1974\Mxd\Method_Statement\ Geographical_Overview.mxd
Created By	Emma Langley
Reviewed By	Ian Charlton
Approved By	Kevin McGovern

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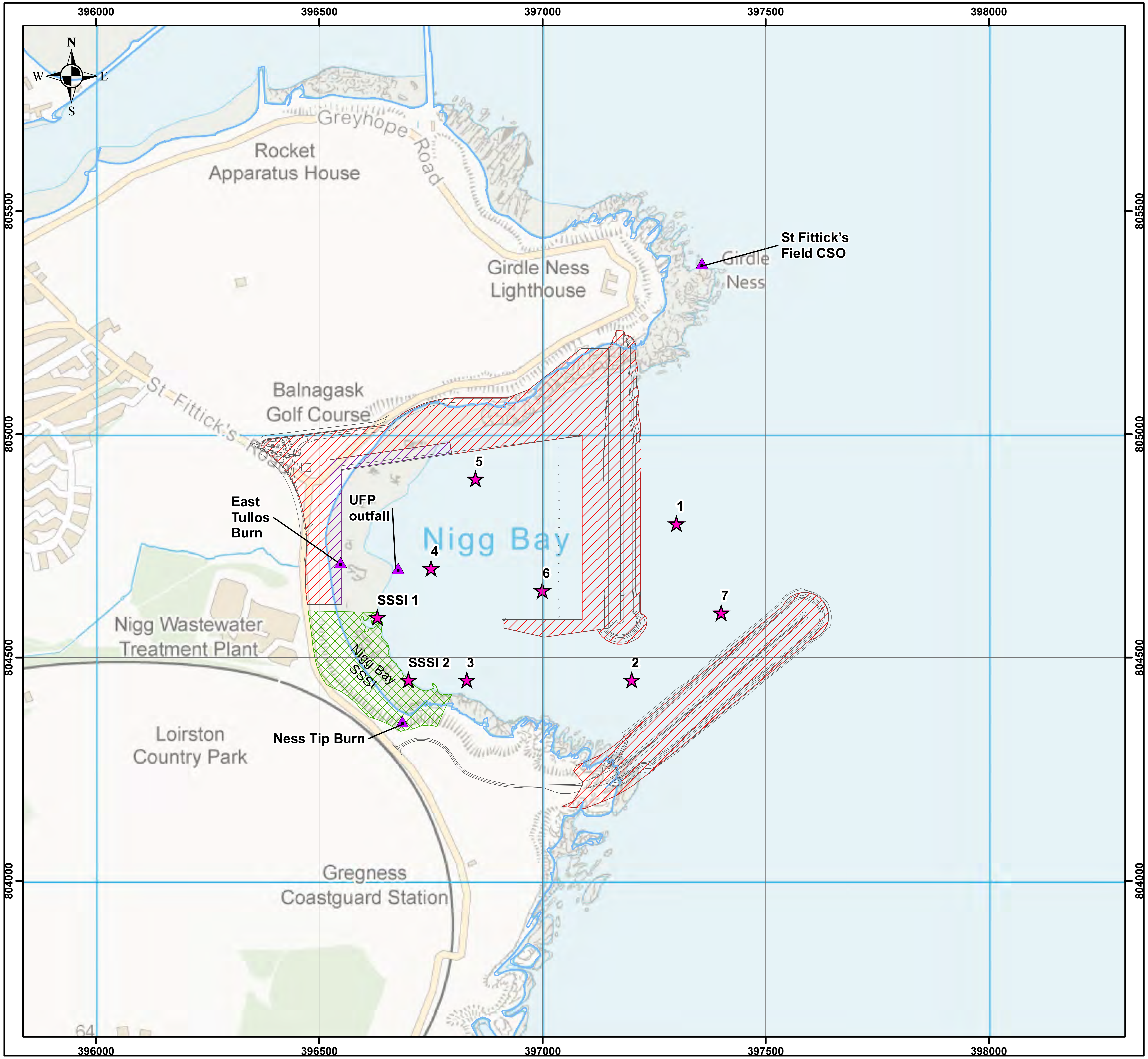

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ABERDEEN HARBOUR EXPANSION PROJECT

Figure 1-2: Extraction Locations

Legend

- Model extraction locations
- Discharge Location
- Aberdeen Harbour Expansion Project
- Suspended Deck Structure
- Site of Special Scientific Interest

NOTE: Not to be used for Navigation

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Created By	Ian Charlton
Reviewed By	Emma Langley
Approved By	Paul Taylor

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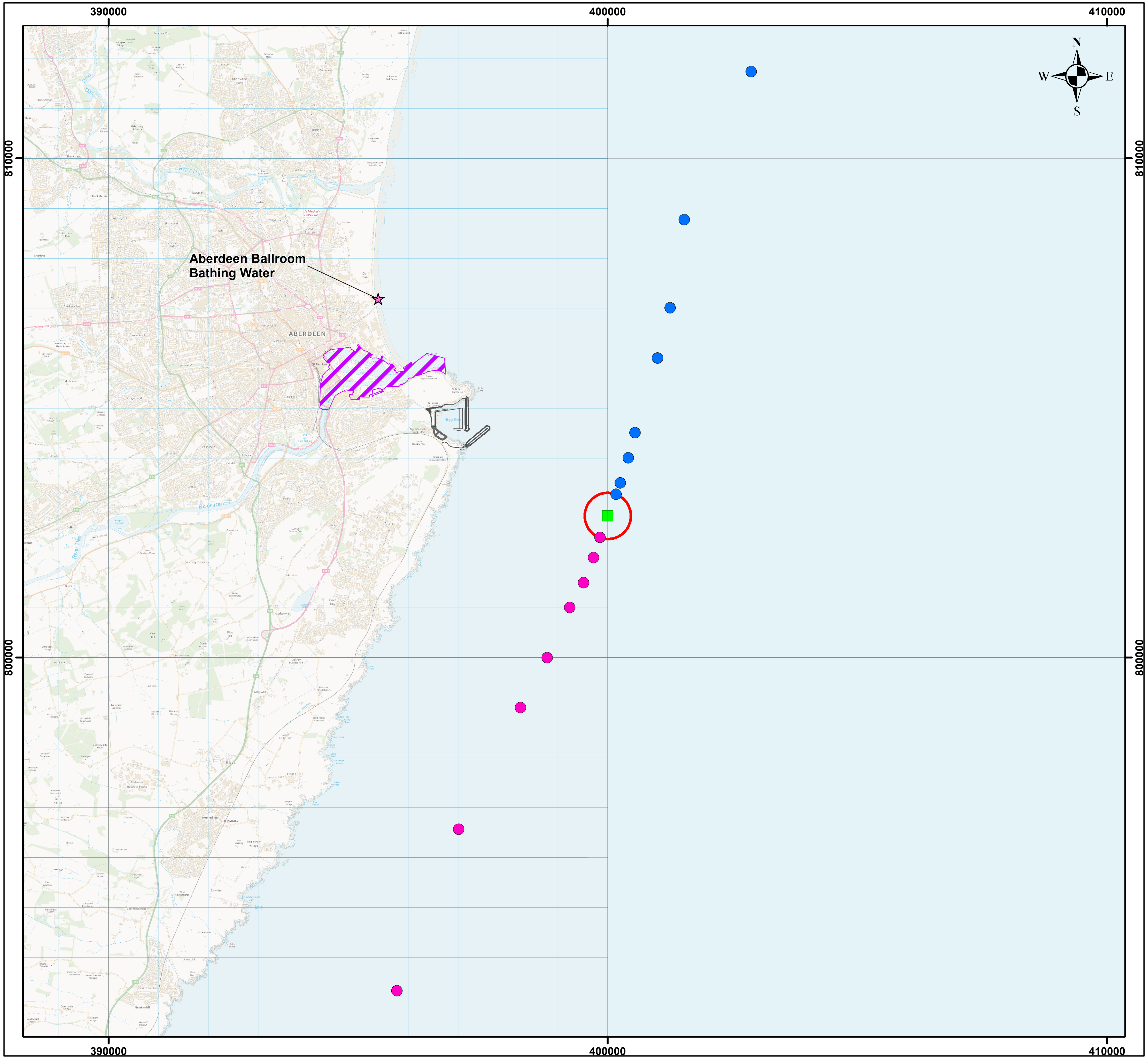

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ABERDEEN HARBOUR EXPANSION PROJECT

Figure 1-3: Model Extraction Locations - Disposal Site and Bathing Water.

Legend

Where

- North
- South
- Disposal Site
- Bathing Water Monitoring Location
- Option 6 - Aberdeen Harbour Expansion
- Disposal Area
- Existing Aberdeen Harbour Area

NOTE: Not to be used for Navigation

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Datum	D_OSGB_1936
Data Source	OSOD, SNH, JNCC, SEPA
File Reference	J:\P1974\Mxd\Method_Statement\ Geographical_Overview_PT_v1.mxd
Created By	Emma Langley
Reviewed By	Ian Charlton
Approved By	Kevin McGovern

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0 1 2 3 4 km

Table 1-1: Distances of data extraction locations from the centre of the disposal site

Data Extraction Location	Distance (m)
North 8	9348
North 7	6122
North 6	4346
North 5	3315
North 4	1749
North 3	1232
North 2	708
North 1	463
South 1	463
South 2	886
South 3	1423
South 4	1991
South 5	3087
South 6	4218
South 7	6952
South 8	10408

1.2 Scope of Work

Fugro appointed Intertek Energy and Water Consultancy Services (Intertek) to undertake a range of technical studies to inform the Aberdeen Harbour expansion ES. The technical studies included by this commission are:

- Hydrodynamic Modelling (HDM). This topic covers currents, waves and sediment dynamics / coastal processes.
- Flood Risk Assessment. This topic includes coastal and river flooding.
- Drainage Impact Assessment (DIA).
- Water Framework Directive Assessment. This topic includes plume dispersion and water quality studies.

The assessment of potential impacts on designated sites will be addressed fully by the EIA and reported in the ES. The EIA process is not detailed in this technical report. However, it is important to be aware of the aims of the project since these have influenced the adopted study methods. With this considered, the following designated sites in the immediate vicinity of the proposed development have been identified:

- Nigg Bay Site of Special Scientific Interest (SSSI);
- Cove SSSI;
- River Dee Special Area of Conservation;
- Ythan Estuary and Sands of Forvie draft Special Protection Area (SPA); and
- Aberdeen Ballroom Bathing Water (BW).

These sites are indicated on Figure 1-1.

1.3 METHOD

A method statement was prepared by Intertek and agreed with Fugro (Intertek, 2015a). This statement was issued as a stand-alone report to Fugro in April 2015 and was then forwarded to relevant stakeholders (Aberdeen City Council, Marine Scotland, the Scottish Environment Protection Agency (SEPA) and Scottish Natural Heritage) for review.

The agreed approach is summarised as follows:

- Existing hydrodynamic (HD) and spectral wave (SW) models covering the development and surrounding area to be updated, calibrated and validated. These models comprise part of the Aberdeen Coastal Model (ACM).
- A bespoke sand transport (ST) model covering the development and surrounding region to be developed. This comprises part of the ACM. This would be constructed using the same software as the HD and SW models.
- The ACM would be used to assess the following:
    - Baseline conditions (an understanding of the hydrodynamic and wave and sedimentological regimes as they are now);
    - Short-term impacts on suspended sediment concentrations during the construction phase (from the dredging operations);
    - Post-construction impacts from the development, and
    - The possible implications of climate change to the impacts predicted by the hydrodynamic and wave assessment.

Following the submission of the method statement and subsequent responses from stakeholders, the scenarios to be included in the assessment were finalised. It was agreed to adopt a realistic 'worst case' scenario for the proposed development, where details were not yet known. This is consistent with the 'Rochdale Envelope' approach outlined by the Infrastructure Planning Commission. The final development is likely to be very similar to the option used in this study, with a large amount of uncertainty focused around dredging operations which will be applied in harbour construction (including the timescale, vessels to be used and volumes disposed of).

The key numerical model that was used in the study was the ACM. This model has been used to assess a range of conditions covering water levels, currents, waves, water quality and sediment transport / coastal processes

1.4 PURPOSE OF REPORT

This report has been prepared by Intertek on behalf of Fugro. It sets out the method and results of the sediment plume modelling assessment for dredging activities and forms part of the coastal processes assessment.

2 MODEL DEVELOPMENT

2.1 BASELINE MODEL

The existing ACM has been updated and refined for the impact assessment of the proposed Aberdeen Harbour Expansion Project. This process is detailed in hydrodynamic modelling and costal processes assessment (Intertek, 2015b) issued by Intertek to Fugro on 31 July 2015. A summary of the model is provided below.

The ACM has been updated using bathymetric data collected in a recent bathymetric survey (undertaken on behalf of Fugro), to better define the sea bed within Nigg Bay. Where new data was unavailable, the original model bathymetry has been used. The unstructured model mesh has been refined within the development area to increase model resolution. Resolution has also been increased around local sites of importance, e.g. Nigg LSO and St. Fitticks' CSO. The original ACM was calibrated and validated with a constant Manning number of 30 $m^{1/3}s^{-1}$, which has also been applied in the updated model.

During the refinement process, the proposed development plans were incorporated into the model mesh generation process, and the model elements were manipulated to enable the development to be added to the baseline model mesh to form the model with the development in place without altering the mesh structure.

The mesh has a spatial resolution varying from approximately 30 m in the area of interest to approximately 3000 m in the offshore part of the model domain. A total of 15,700 triangular elements are used in the model which covers an area of 1,696 km^2 encompassing Nigg Bay, Aberdeen Harbour, and the rivers Dee and Don to their tidal limits. Vertical datum of the model is mean sea level (MSL).

The conclusions of the hydrodynamic modelling and costal processes report on the updated model are:

- Model performance has been retained in the updated Aberdeen Coastal Model to produce the same good degree of fit as the originally approved model which was well calibrated and validated against appropriate field data. The updated model is therefore considered fit for the purpose of undertaking hydrodynamic, wave and coastal processes assessments.
- The ACM has been validated against field data specifically from the development area and has been demonstrated to produce a good fit. The ACM is therefore considered fit for the purpose of undertaking hydrodynamic, wave and coastal processes assessments.

2.2 OPERATIONAL PHASE MODEL

Consistency in the model grid structure between the baseline model and the model with development in place was maintained by constructing the baseline model grid with the outline of the development included in the generation process. This enabled the area occupied by the development to be removed from the baseline grid, thus ensuring that where the two grids coincide, the elements are identical so that any differences that could have resulted from the difference in model grids are removed.

The bathymetry of the operational model was updated to meet the proposed dredging depths as detailed in the development plan. The bathymetry at the breakwaters has been represented as sloping from the top of the breakwaters to the seabed. The gradient of the slope is controlled by the top of the structure and the seabed. The north-west corner of the quay side contains a suspended deck. Under this structure, rock armour will be installed. This has been included using the same method as the breakwaters.

2.3 CONSTRUCTION PHASE MODEL

The construction phase model grid represents the development at the mid-point in the construction. This is required to check environmental impacts during the construction process.

The construction phase grid was produced using the same method as the development grid, with the areas occupied by the partially complete breakwaters removed. Bathymetry has been changed where the breakwaters will be (to represent the completed groundworks) and the slopes detailed in the 'with development' grid have also been applied.

2.4 SEDIMENT PLUME MODELLING

Dispersion of sediment plumes caused by current and proposed dredging operations has been assessed using the particle tracking (PT) module of the ACM. Suspended sediments (sediments in the water column) and settled sediments (sediments deposited on the sea bed) were modelled for a range of scenarios. This enabled the extent of the sediment plume produced by the dredging operations and the effect on water quality to be determined.

The MIKE21 PT model which has been used in this assessment is driven by the HD component of the ACM, which provides the water level and current velocity information. The PT model then tracks the movement and fate of the modelled sediment discharges. The PT modelling takes into account several key processes:

- Advection. This refers to transport by the prevailing currents. Current flows are obtained from the HD model.
- Dispersion. This refers to mixing and spreading of the released sediment due to turbulence within the water column. Appropriate dispersion coefficients (in three dimensions) are specified within the Aberdeen Coastal Model, based on calibration of these coefficients during construction of the model.
- Decay. The sediment being modelled in this assessment will not decay; therefore no decay component has been included in this model.

The PT technique models the movement and decay of a large number of particles (representing a pollutant or other water quality determinand) released into the HD model. Particles are tracked individually in three dimensions, which allows released concentrations to be resolved both horizontally and vertically.

Even if the underlying HD model is 2D, the PT approach allows vertical concentration profiles to be derived. It also allows advection and dispersion to be influenced by processes such as surface wind drift currents and bed friction. The resuspension of sediment is not accounted for in this model, therefore changes in bed level produced by this model will not reflect changes caused by the subsequent movement of sediment.

2.5 MODEL SCENARIOS

Three phases of the Aberdeen Harbour expansion project have been modelled to assess dispersion of sediment plumes under the required conditions. These can be summarised as:

- Baseline – Used to produce an assessment of the area of redeposited sediment and sediment plume resulting from the current maintenance dredging operations in Aberdeen Harbour.
- Operational phase – Used to compare against the baseline results to determine if the development will produce any changes to sediment processes resulting from the on-going maintenance dredging operations in Aberdeen Harbour.
- Construction phase – Used to provide an assessment of the area of redeposited sediment and sediment plumes produced by the dredging programmes required during the construction of the Aberdeen Harbour expansion project.

Sediment plumes were modelled over a mean spring-neap cycle, representing average hydrodynamic conditions. Extreme conditions have not been included as dredging and disposal operations would cease during these times. Within the disposal site, model results have been scaled to represent the change in bed level during the whole construction phase to represent release of sediment across the site. Sediment released within Nigg Bay during the construction phase scenarios will be removed during subsequent dredging, therefore no assessment of the change in bed level at this location will be made. Where sediment is transported out of Nigg Bay an assessment of the effect at the end of the dredging activity will be made.

Assumptions regarding the dredging activities were submitted to Fugro for distribution to project stakeholders and agreement prior to simulations being undertaken (Intertek, 2015c).

2.6 BASELINE SCENARIO

Baseline conditions assess the area of redeposited sediment and sediment plume produced by the current dredging operations at Aberdeen Harbour with sediments released at the designated disposal site CR110. The particle size distribution (PSD) of the sediment within Aberdeen Harbour is generally uniform, comprising predominantly mud grain sizes; the exception to this is the outer channel which has a greater sand component (Macaulay, 2014). Due to the uniformity of the sediment, a single representative distribution was applied to the modelled sediment as shown in Table 2-1.

Table 2-1: Modelled Aberdeen Harbour particle size distribution

Sediment Category	Mean Grain Size (mm)	Settling Velocity (m/s)	Volume (%)
Very Coarse Sand	1.50	0.2030	0.5
Coarse Sand	0.75	0.1031	4.7
Medium Sand	0.38	0.0471	7.7
Fine Sand	0.19	0.0179	9.4
Very Fine Sand	0.09	0.0054	19.0
Mud	0.03	0.0007	58.7

Sediment discharge rates for this scenario were based on the daily dredging logs for the UKD Marlin, which operates in Aberdeen Harbour (Aberdeen Harbour Board, 2015). This provides details of the volume of material collected (and disposed of) in each cycle, dredging duration, release duration and the number of cycles per day. Values used in this assessment are based on the maximum reported daily hopper values in order to produce a conservative estimate of the effects. Table 2-2 provides a summary of this information.

Table 2-2: Aberdeen Harbour (baseline) dredging program

Parameter	Value
Maximum daily volume hopper solids (m^3)	11238
Maximum daily releases	9
Average volume per release (m^3)	1249
Release duration (s)	720
Volume release rate (m^3/s)	1.73
Sediment density (kg/m^3)	2650
Mass release rate (kg/s)	4584

The total volume of solids within the hopper is provided in the UKD Marlins log, which is divided between settled sediment volume and suspended sediment volume. The density value applied represents a worst case scenario as this represents the density of silicon, while the density of the sediment within the hopper will be less than this due to packing of the settled sediment and sediment which is in suspension.

Although the time taken to dispose of the sediment is reported, the method used is not. Sediment disposal is possible from the bottom doors or the dredging hoses (either directly in to the water column or as a 'rainbow' discharge). It has been assumed that the sediment will be discharged via the bottom doors at a depth of 5.6 m (the UKD Marlin's loaded draught) with dispersion of sediment occurring immediately. This will produce a very conservative estimate of the impacts from this dredging activity as sediment released by this method will (usually) descend to the sea floor in a concentrated plume, producing a lower degree of sediment entrainment than has been modelled. This approach has been used a similar dredging method will be applied during the Aberdeen Harbour Expansion Project construction and therefore the effects of the two operations will be comparable. However, as the dredging and disposal methods to be used in the harbour construction have not been finalised a very conservative approach has also been applied to the baseline, and operational phase, assessments.

Deposition of sediment is provided by the model in kg/m^2, this will be converted in to mm depth of sediment to provide an assessment of the change in bed level as a result of the disposal activity. In order to produce the thickness of sediment a representative dry density has been applied to the results. The values used are shown in Table 2-3.

Table 2-3: Representative dry sediment density values

Sediment Size	Dry Sediment Density (kg/m^3)
Very Coarse Gravel	1800
Coarse Gravel	1800
Medium Gravel	1800
Fine Gravel	1800
Very Coarse Gravel	1800
Very Coarse Sand	1920
Coarse Sand	1920
Medium Sand	1920
Fine Sand	1920
Very Fine Sand	1920
Mud	1730

2.7 OPERATIONAL PHASE SCENARIO

The operational phase scenario determined the sediment plume produced by the current dredging operations at Aberdeen Harbour when the Aberdeen Harbour Expansion Project is complete. This will be used to determine if the development will cause any changes to the area of redeposited sediment and sediment plume produced by the current maintenance dredging.

To ensure that changes is only due to the development, the values and set up used in this scenario are the same as those used in the baseline scenario, with the sediment PSD, discharge rates and release location remaining consistent.

2.8 CONSTRUCTION PHASE SCENARIOS

Construction phase scenarios will be used to determine the extent of area of redeposited sediment and sediment plumes produced during the excavation and disposal of the sediment during the construction process. The assessment was made at the mid-point of the construction process, with approximately half of the development completed. During the construction phase, a total volume of 2.3 Mm^3 of sediment is will be removed from Nigg Bay. This sediment can be divided into three categories; unconsolidated, consolidated and rock. Two dredging techniques will be used to remove the sediment: trailing suction hopper dredger (TSHD) for the unconsolidated layer; and backhoe dredging for the consolidated layer, with the rock material removed during these operations.

Dredging operations will be conducted over 17 months, with two disposal programmes being proposed, as shown in Table 2-4. The volume of sediment to be disposed is less than the total to be dredged in both programmes, as in each case excavated rock will be reused in the construction of the harbour expansion.

Table 2-4: Proposed sediment disposal programmes

Parameter	Programme 1	Programme 2
Program duration (months)	17	17
Volume of sediment to be disposed (m^3)	2191000	1020000

Programme 1 assumes that all sediment dredged from Nigg Bay will be disposed of at the designated disposal site. Programme 2 assumes that approximately 55 % of the sediment will be reused in the construction of the Aberdeen Harbour Expansion. The reusable sediment relates to the unconsolidated sediment layer. Both programmes will utilise the two dredging techniques to remove the associated layers.

Dredging operations within Nigg Bay during the construction phase were modelled over four scenarios to assess the impacts of the different dredging techniques, sediment PSD's, and sediment release locations. The modelled scenarios for the construction phase are detailed in Table 2-5.

Table 2-5: Construction phase sediment plume scenarios

Scenario	Sediment Layer	Sediment Release Location	Dredging Method	Programme
1	Unconsolidated	Nigg Bay - losses	TSHD	1 and 2
2	Unconsolidated	Disposal Site	TSHD	1
3	Consolidated	Nigg Bay - losses	Backhoe	1 and 2
4	Consolidated	Disposal Site	Backhoe	1 and 2

Assessments within Nigg Bay (scenarios 1 and 3) will determine the area of redeposited sediment and sediment plume resulting from overspill material during the dredging operations. The impacts from these scenarios will be produced during both disposal programmes.

The area of redeposited sediment and sediment plumes at the disposal site will be dependent on which disposal programme is selected. Programme 1 assumes all sediment will be disposed of, producing impacts from the release of consolidated and unconsolidated sediment (scenarios 2 and 4). Programme 2 will only produce impacts from the release of consolidated sediment (scenario 4), as the unconsolidated sediment will be reused in the harbour construction and not disposed of at the disposal site.

Daily disposal volumes will vary depending on programme, dredging method, and local variations in sediment PSD. Average daily disposal volumes are based on the dredging method and available operational data from the UKD Marlin to produce a worst case scenario for each dredging method.

Sediment disposal and overspill rates that have been modelled in this assessment are greater than the average rates required to complete the dredging operation within the 17 month timescale. While it is not anticipated that these rates will be maintained consistently they represent a realistic maximum rate and present the worst case scenario for suspended sediment concentrations and change in bed level over a mean spring-neap period. The results from the modelled scenarios will be used to determine the effect at the end of the construction phase based on the total volume of sediment to be disposed.

While the construction phase activities are progressing maintenance dredging from the existing Aberdeen Harbour will also be operating. The results from the baseline scenario will be combined with the construction phase results to produce an assessment of the combined changes at the end of the construction period.

2.8.1 Trailing Suction Hopper Dredger

Scenario 1: Nigg Bay TSHD Overspill

TSHD will be used to remove the unconsolidated sediment which is present in the uppermost layers within Nigg Bay. The unconsolidated sediment is approximately 6 m thick across the Nigg Bay area and has a generally uniform PSD based on the data provided by Soil Engineering Geoservices (2013) and the CMACS analysis. As a result, a single representative PSD has been applied, and is shown in Table 2-6 along with the settling velocities.

Table 2-6: Particle size distribution of unconsolidated sediment within Nigg Bay

Sediment Category	Mean Grain Size (mm)	Settling Velocity (m/s)	Volume (%)
Very Coarse Gravel	47.75	1.4171	7.9
Coarse Gravel	24.00	1.0560	4.8
Medium Gravel	11.94	0.7968	4.7
Fine Gravel	5.93	0.5548	3.7
Very Fine Gravel	3.00	0.3494	8.1
Very Coarse Sand	1.50	0.2030	9.2
Coarse Sand	0.75	0.1031	6.1
Medium Sand	0.38	0.0471	27.7
Fine Sand	0.19	0.0179	19.0
Very Fine Sand	0.09	0.0054	5.3
Mud	0.03	0.0007	3.5

TSHD will remove all the material from the sea bed, resulting in the PSD shown in Table 2-6 being collected, however the operator will generally discharge the finest sediment as overspill, which results in the PSD of the sediment plumes produced within Nigg Bay and at the disposal site differing from that shown in Table 2-6. It has been assumed that grain sizes of fine sand and smaller will be included in the overspill material.

The TSHD programme during the construction phase is based on the current Aberdeen Harbour maintenance dredging operations, assuming that the maximum hopper volume and number of daily cycles will be consistent. Overspill has been calculated, using Table 2-6, assuming that 28% of the dredged material will be the ‘fine’ component. Hopper loads of 1249 m^3 will result in 350 m^3 of sediment per cycle being released as overspill. Overspill has been modelled as being released at the surface as this will produce the largest area of redeposited sediment. The PSD of the overspill sediment has been modified to only include the sediment sizes that will be released during the overspill, see Table 2-7.

Table 2-7: Particle size distribution for TSHD spill sediment

Sediment Category	Mean Grain Size (mm)	Settling Velocity (m/s)	Volume (%)
Fine Sand	0.19	0.0179	68.2
Very Fine Sand	0.09	0.0054	19.1
Mud	0.03	0.0007	12.7

The overspill of sediment within Nigg Bay is based on the assumptions that a single dredging unit will be operating, completing nine cycles per day. The average dredging duration (based on logs from the UKD Marlin) is 90 minutes, ranging from 42-120 minutes. A literature review revealed that overspill typically occurs during the final 25% of the loading operation although fine material may be released throughout the dredging operation (Vlasblom & Miedema, 1995). While overspill during this period will be dynamic and increase from a low rate to a peak and then back to a low rate, the nature of these changes will depend on the material characteristics (which vary across Nigg Bay) and operational practices. In situations where there is a high proportion of very fine material overspill may occur throughout the dredging operation. As the operational programme has not been finalised it has been assumed that overspill will occur during the final 25% of the loading operation, 1350 seconds, at an average constant rate. This conservative approach was agreed prior to undertaking the modelling via Intertek Memo ZJUL20 (Intertek, 2015c). The area of redeposited sediment produced will not be affected by a higher release concentration, although it is likely that suspended sediment concentrations and predicted depths of deposits will be.

Scenario 2: Disposal Site TSHD Disposal

Unconsolidated sediment collected during the TSHD will be disposed of at the disposal site if it is not used in the harbour construction. The dredger and operational programme which are to be used during this phase of the construction has not been finalised, and as a result a conservative approach has been used to identify the worst case effects. It has been assumed that disposal of this sediment will be conducted under the same regime as the current Aberdeen Harbour maintenance dredging programme. The maximum hopper volume of 1249 m^3 and nine cycles per day applied in this scenario are the same as applied in overspill scenario. The PSD of sediment has been modified to reflect the removal of the finer material during the overspill within Nigg Bay, with the PSD applied during this scenario shown in Table 2-8.

Table 2-8: Particle size distribution of TSHD disposal site sediment

Sediment Category	Mean Grain Size (mm)	Settling Velocity (m/s)	Volume (%)
Very Coarse Gravel	47.75	1.4171	10.9
Coarse Gravel	24.00	1.0560	6.6
Medium Gravel	11.94	0.7968	6.6
Fine Gravel	5.93	0.5548	5.1
Very Fine Gravel	3.00	0.3494	11.2
Very Coarse Sand	1.50	0.2030	12.8
Coarse Sand	0.75	0.1031	8.4
Medium Sand	0.38	0.0471	38.4

The release of sediment has been modelled at 5.6 m below the water surface, as in the baseline scenario, as the method of sediment disposal has not been finalised. This approach will result in a very conservative estimate of the suspended sediment concentration that will be produced, with the concentrations produced in practice potentially being one to two orders of magnitude less depending on the disposal method applied.

2.8.2 Backhoe Dredging

Scenario 3: Disposal Site Backhoe Dredging Overspill

Backhoe dredging will be used to remove the consolidated sediments within Nigg Bay. This layer is generally uniform throughout the area (Soil Engineering Geoservices, 2013), resulting in the single representative PSD shown in Table 2-9 being applied. This same PSD was assumed for both the dredging bucket losses on excavation and also for the disposal material. Both disposal programmes will utilise this method to remove the consolidated layer.

Table 2-9: Particle size distribution of consolidated sediment in Nigg Bay

Sediment Category	Mean Grain Size (mm)	Settling Velocity (m/s)	Volume (%)
Very Coarse Gravel	47.75	1.4171	9.4
Coarse Gravel	24.00	1.0560	7.6
Medium Gravel	11.94	0.7968	5.1
Fine Gravel	5.93	0.5548	3.5
Very Fine Gravel	3.00	0.3494	6.7
Very Coarse Sand	1.50	0.2030	6.2
Coarse Sand	0.75	0.1031	3.6
Medium Sand	0.38	0.0471	11.0
Fine Sand	0.19	0.0179	12.5
Very Fine Sand	0.09	0.0054	4.7
Mud	0.03	0.0007	29.7

Bucket spill within Nigg Bay during this dredging method will vary according to the bucket size, volume of excess material removed, and the cycle time. Details of the dredging operation are still under consideration; therefore realistic estimates have been made to produce a worst case scenario. These are based on information obtained from International Association of Dredging Companies (2015) and agreed with by Fugro following discussion (Intertek, 2015c). A bucket size of 8.5 m^3 is considered appropriate for a development of this size, with overspill estimated at 20 %, and a cycle time of 30 seconds. This produces an average overspill flux of 150 kg/s. This scenario represents a very conservative estimate of the effects of this dredging activity. The percentage of over-spilled material will vary according to the operational practices applied during the dredging operation, and as a result may be significantly reduced. Reductions in the volume of over-spilled material will reduce the concentrations of the resultant plumes and the redeposited sediment thickness. The area affected by the release of sediment will however remain consistent.

Overspill will be assumed to occur at a constant rate and will not take into account repositioning of the backhoe dredger or for down time when disposal barges are not in position to receive sediment.

The model has assumed that all sediment will be released at the surface. However, in reality sediment will be released throughout the water column (as the bucket moves from the sea bed to the surface). The release of sediment at the surface will produce the largest area of redeposited sediment. As the spatial extent of the redeposited sediment and sediment plume is of key interest, this therefore represents the worst case scenario and will produce a conservative assessment of the impacts of the dredging operation.

Scenario 4: Backhoe Dredging Disposal

The sediment flux at the disposal site has been calculated using the average daily disposal rate from programme 1 as detailed in Table 2-2. Three barges have been assumed to be used during this programme to dispose of material and therefore this will not be considered a limiting factor. Barge capacity has not been finalised. As a result a representative capacity of 467 tonnes has been assumed. To achieve the daily disposal volume, 24.3 releases per day would be required. For conservatism it will be assumed that 25 full barge loads are released at the disposal site per day representing the disposal of 4406 m^3 of sediment.

It is assumed that sediment will be released though the bottom doors on the barges, with the full capacity being released instantaneously at a depth of 3 m below the water surface. As the capacity of the barges has not been finalised this will produce a conservative assessment, with the concentrations produced during the operation unlikely to exceed those produced in this assessment. The distribution of redeposited sediment will be affected by the release of sediment higher in the water column, however as the release method has not been finalised this approach will produce a conservative assessment of the area affected. The area affected by the release of sediment will be unaffected by the release concentration due to the hydrodynamics dominating the dispersion of sediment.

3 ASSESSMENT RESULTS

Results from the modelled scenarios are discussed below with figures and tables for the baseline assessment provided in Appendix A, the operational assessment in Appendix B and the construction phase assessment in Appendix C. The plots demonstrating the extent of the redeposited sediment show the results of the mean spring - neap period which has been modelled, with a minimum value of 1 mm shown. The predicted sediment thickness over the whole dredging programme duration calculated directly from the model results will produce extreme values due to the combination of conservative assumptions made; therefore this total depth should be used with caution. Average suspended sediment concentrations provided in this assessment are from the mean spring period of the modelled tidal cycle. This period has been selected to provide an assessment of the greatest concentrations that will occur. All suspended sediment concentration in the model scenarios originates from the dredging activities therefore the background suspended sediment concentration is zero.

3.1 BASELINE

The baseline scenario has been used to establish the extent of redeposited sediment and plumes produced during current conditions, against which changes due to the Aberdeen Harbour Expansion Project are assessed. Figures and tables for this assessment are provided in Appendix A.

Table A-1 presents the deposited sediment thickness at a number of locations (see Figure 1-3) along the sediment plume produced. The extent of the redeposited sediment is shown in Figure A-1. Results show that very coarse sand remains within the disposal area throughout the modelled mean spring-neap period, producing a small sediment depositional area as a result of the large settling velocity associated with this grain size. Very coarse sand is the only grain size that is sedimented entirely within the disposal area, with finer grain sizes showing greater dispersion, with deposition occurring outside of the area. Coarse sand is deposited outside of the disposal area, with a thickness of 6 mm at point South 1; this represents a small component of the redeposited sediment compared to the thickness of 256 mm at the centre of the disposal site. Deposition of finer grained sediment shows a northeast-southwest trend, representing the tidal current direction. Medium and fine sand show increased transportation in this orientation, producing larger areas of redeposited sediment.

Within the area of redeposited sediment, deposit thicknesses can be seen to vary, with very coarse and coarse sand producing the largest depths at the release location. Finer sediment (medium sand and below) produce a different spatial distribution of sediment, with areas of greater sedimentation to the north and south of the disposal site.

Very fine sand also produces this distribution with the area of redeposited sediment containing two areas of higher sedimentation depths to the north and south of the disposal area, with sediment depths of 18 mm and 25 mm (at points North 5 and South 5 respectively), compared to 9 mm at the disposal site. Figure A-1 demonstrates that the majority of this grain size will be deposited outside of the disposal zone.

Mud produces the largest area of redeposited sediment, with deposition occurring over an area approximately 20 km long and 2.5 km wide. Unlike the other fine grain sizes, sediment thickness generally increases towards the centre of the disposal area, rather than producing two areas of greater sedimentation north and south of the disposal site.

Results shown in Figure A-2 demonstrate that suspended sediment concentrations are greatest at the disposal site for all grain sizes, and decrease to the north and south. Equilibrium is quickly achieved with tidal currents rapidly transporting the sediment from the disposal site or sedimentation occurring. At the disposal site concentrations of medium sand and coarser grain sizes return to background levels within a maximum of 45 minutes, with a minimum duration of 15 minutes. Finer grain sizes require longer to return to background levels, with very fine sand requiring 0.25 to 3.25 hours. This variability is due to releases taking place at different periods within the tidal cycle.

Concentrations of suspended mud show greater variability due to the lower settling velocity of this grain size. This can be seen in mud concentrations achieving background levels within 15 minutes, before increasing in concentration between sediment releases. This is due to multiple releases of mud being present in the water column simultaneously, producing variations in the suspended sediments according to when sediment is released during the tidal stage.

Suspended sediment concentrations at the edge of the disposal area are considerably lower than the centre, with medium sand reduced by 90%, and mud by 51%. Reductions are associated with the dispersion of sediment within the water column as deposited sediment thicknesses do not reflect this pattern.

Table A-2 and Table A-3 show that maximum concentrations are clearly greater than average values. At the disposal site, large maximum concentrations are produced immediately following the release of sediment, creating the large maximum values, followed by rapid sedimentation of coarse material and transportation of fine material away from this location, resulting in significantly lower average concentrations. Away from the disposal site, maximum concentrations of finer grained sediment are similarly higher than the average values due to the currents rapidly transporting the material, resulting in short lived increases in concentrations as sediment plumes move across the data extraction locations. Figure A-2 also demonstrates this, with the large but short lived increases in concentrations. Plots of the average and maximum suspended solids concentrations are shown in Figure A-3 and Figure A-4.

Background concentrations observed during the 2015 ADCP deployment show average values of 24 mg/l and 144 mg/l at the eastern and western survey locations respectively. The average concentration resulting from the baseline disposal scenario at the edge of the disposal site is approximately 84 mg/l, with mud particles representing the largest component of the sediment plume. Outside of the disposal site, mud is the only sediment size with a concentration above the average of the western ADCP survey location.

The areas of redeposited sediment and sediment plumes produced by the disposal of sediment under baseline conditions are restricted to the offshore, with no sediment predicted to reach the coast. Sediment released at the disposal location is not predicted to reach any of the identified sensitive receivers or the Aberdeen Harbour Expansion Project.

3.2 OPERATIONAL PHASE

The operational phase scenario was used to assess the effect of the Aberdeen Harbour Expansion Project on sediment plumes produced at the disposal site. Results from this scenario are shown in Appendix B.

The area and depths of redeposited sediment produced during the operational phase are shown in Figure B-1, with sediment thickness provided in Table B-1. Very coarse sand shows limited transport, remaining within the disposal area during the whole spring - neap period. This results in a small, thick, area of redeposited sediment that is centred on the sediment release location.

Finer grain sizes produce larger areas of redeposited sediment as shown with coarse sand being deposited outside of the disposal area to the south (on ebbing tides) and mud producing a large area of redeposited sediment (approximately 20 km long and 2.5 km wide). Finer gained sediment (with the exception of mud) produce to areas of greater sedimentation to the north and south of the disposal site, as shown in Table B-1, due to their relatively lower settling velocities. Mud produces a regular pattern of redeposited sediment, with the greatest deposition at the disposal site. Areas of redeposited sediment produced during the operational phase replicate the spatial pattern produced during the baseline scenario, with the northeast - southwest trend remaining.

Figure B-2 demonstrates that although results from the baseline and operational scenarios are very similar, small differences exist. South of the disposal site, the operational scenario shows increased sedimentation to the west with decreases to the east, while north of the disposal area increased sedimentation occurs to the east with decreases to the west. Differences shown in the figures are small compared to the total sediment thickness, with maximum changes of approximately ±10 mm. Table B-2 shows the changes at the data extraction locations are slightly less, with a maximum change of -4 mm. The change in total sedimentation thickness of -7 mm at the disposal site is 1.2% of the predicted sediment thickness, representing an unchanged depositional pattern.

Average suspended solids concentrations shown in Figure B-3 demonstrate that maximum concentrations are produced at the disposal location, with dispersion occurring away from this point. Finer grained material produce the largest sediment plumes, with mud present at average concentrations above 1 mg/l at distances of 10 km from the disposal site, as shown in Table B-3. This table also demonstrates that average suspended solids concentrations decrease away from disposal location with mud producing the largest increase in concentration. Predicted suspended solids concentrations in this scenario show the same pattern as during baseline conditions, with medium sand and coarse grain sizes returning to background levels with 45 minutes. Finer grain sizes also show the same variation in concentrations, with multiple mud plumes present simultaneously. Coarse and very coarse sand are not predicted to be deposited out of the disposal area due to their higher settling velocities. Average concentrations shown in Table B-3 and Figure B-4 and maximum concentrations in Table B-4 and Figure B-5 also demonstrate that the same distribution of suspended solids is produced in the operational scenario as during baseline scenario.

Table B-5 presents the differences between the operational and baseline average suspended sediment concentrations at the designated points. The results show that mud experiences the largest absolute changes, with a reduction of -1.1 mg/l at the disposal site and increase of 0.3 mg/l at point south 4 (representing changes of -0.8% and +1.0% respectively). The greatest relative changes are a decrease in mud suspended concentration at point north 8 of -5.6% (a change of -0.1 mg/l) and an increase in very fine sand at point south 5 of 6.3% (a change of 0.1 mg/l). These changes to suspended sediment concentrations are very small and represent an unchanged hydrodynamic regime at the disposal area.

Areas of redeposited sediment and sediment plumes produced during the operational phase at the designated disposal site are generally unchanged from the baseline condition and do not impact on any of the identified sensitive receivers or the Aberdeen Harbour expansion.

3.3 CONSTRUCTION PHASE

Results from the construction phase scenarios are presented in the following section include the sediment plumes produced at the Aberdeen Harbour Expansion Project dredging in Nigg Bay and the disposal location. Sediment plumes produced by the two dredging techniques are discussed separately. Results from the construction phase scenarios are provided in Appendix C.

3.3.1 Trailing Suction Hopper Dredger

Scenario 1: Nigg Bay TSHD Overspill

This scenario has been used to assess the sediment plumes and the area of redeposited sediment produced within Nigg Bay during TSHD overspill. The area of redeposited sediment produced by overspill during TSHD (presented in Figure C-1) shows that fine and very fine sand released as overspill produce small areas of redeposited sediment, centred on the release location. This demonstrates that these sediment sizes will remain entirely within Nigg Bay during a mean spring-neap period, and that this overspill material can be dredged and removed in subsequent dredging operations within Nigg Bay.

Mud is predicted to be transported out of Nigg Bay to the north, producing an area of redeposited sediment 1 mm deep at Girdle Ness point during a mean spring-neap period. North of this location the thickness of redeposited sediment is below 1 mm, due to greater dispersion. Within Nigg Bay, sedimentation occurs in the centre and north of the area, showing the dominant direction of the eddy currents. Table C-1 shows sedimentation thickness at key locations (see Figure 1-2), with only mud present at all locations within Nigg Bay.

No assessment of the change in bed level during the dredging programme within Nigg Bay has been made, as any sediment released as overspill will be removed during subsequent dredging. Mud is predicted to be transported out of Nigg Bay, and therefore an assessment of the change in bed level over the whole TSHD operation has been made and is shown in Figure C-2 and Table C-2. These results predict that the area of redeposited sediment will extend into the Ythan Estuary and Sands of Forvie draft SPA with depositional thickness up to 2 mm predicted in the south of this area. Sediment is not predicted to affect Aberdeen Ballroom bathing water during the whole TSHD period.

The average suspended sediment concentrations shown in Table C-4 and Figure C-5 demonstrate that the movement of sediment within Nigg Bay is limited, with only mud present at all locations. Very fine sand is present at assessment point 6, but the concentration of 0.1 mg/l is significantly less than the mud concentration of 31.5 mg/l. Fine sand is only present points 5 and 6, as shown in Table C-5 due to a relatively higher settling velocity. Time series plots of suspended sediment concentrations are provided in Figure C-4 and show that mud is the most dispersed sediment size and that the suspended solids concentrations quickly achieve equilibrium before returning to background levels. Background concentrations observed at the western ADCP survey location (which is located within Nigg Bay), show average values of 144 mg/l. The sediment plume produced by this dredging operation which extends out of Nigg Bay is subject to greater dispersion, as shown by the lower redeposited thicknesses, and therefore represents a small change to the existing regime.

Figure C-6 indicates that sediment released during this dredging operation will affect a larger spatial area, as reflected in Figure C-2. Outside of Nigg Bay, this area corresponds to the area which will be affected by mud sized sediments, as the coarse grain sizes will remain within the development area. This figure demonstrates that during certain tidal phases mud will transported over a larger area than the other plots, with low maximum concentrations of 10 - 20 mg/l to the east and south of the development. The presence of these concentrations is infrequent as shown by the low sediment depths (less than 1 mm) over the whole dredging programme (Figure C-2).

The maximum concentrations shown in the plot are greater than in the table due to the data extraction points being located around the sediment release location and the rapid sedimentation which occurs within Nigg Bay. This is due to the low current speeds producing a limited dispersion of sediment, resulting in steep sedimentation gradients.

The transport of material out of Nigg Bay during TSHD overspill is limited to mud, which is predicted to impact the Ythan Estuary and Sands of Forvie draft SPA and Nigg Bay SSSI. Sediment is not predicted to affect Aberdeen Ballroom bathing water, Cove SSSI or the River Dee Special Area of Conservation.

Scenario 2: Disposal Site TSHD Disposal

This scenario is used to assess the sediment plumes and redeposited sediment thickness produced by the disposal of sediment at the designated disposal site during TSHD. The predicted sediment thickness from the TSHD disposal scenario (Figure C-3) demonstrate that the coarse grained material released in this scenario is subject to limited convection and dispersion, producing a small area of redeposited sediment. As a consequence of this, a large sediment thickness is produced at the centre of the disposal site which decreases radially from this point. This applies to grain sizes of very coarse gravel to very fine gravel.

Very coarse sand and smaller show increased convection and dispersion in the dominant current direction, producing increasingly elongated areas of redeposited sediment. The depositional thickness within these areas also shows variation, with two areas of greater sedimentation to the north and south of the disposal site. Very coarse gravel to very coarse sand sediment sizes have relatively high settling velocities, which result in these sediment sizes being deposited immediately below the release location. As this point is fixed and there is no further movement of sediment in the model, the sediment thicknesses produced are unrealistically high and should not be used to directly calculate the change in bed level.

Average suspended sediment concentrations are shown in Table C-6 with time series plots in Figure C-7. Locations without suspended sediment concentrations have been excluded from Figure C-7. Results show that medium sand produces the highest concentration, which is due to this grain size being the most common and possessing the lowest settling velocity in this scenario. Time series plots show sediment concentrations are variable, being dependent on the current speed at the time of release, with higher concentrations representing release at lower current speeds.

The values provided are a worst case scenario as all sediment is being released at the same location throughout the model period, and the release rate (which represents the maximum achievable rate) is 2.6 times greater than the daily disposal rate required to achieve the programme timescale. This provides the worst case scenario for the suspended concentrations and the maximum bed level change during a spring-neap period. Average concentrations at the edge of the disposal site are 5.2 mg/l and 6.1 mg/l at the northern and southern edges respectively, which consists solely of the medium sand component. At the surrounding data extraction points, the concentrations have reduced to less than 1 mg/l demonstrating that released sediment will remain within the disposal site.

The assessment of bed level change at the conclusion of the TSHD disposal is based on the model results shown in Figure C-3 indicating that sediment released during TSHD disposal will (largely) remain within the disposal site. Assuming that sediment is released evenly across the disposal site, and remains at this location throughout the disposal period (worst case), TSHD disposal will produce a bed level increase of 2.631 m.

During TSHD disposal, baseline operations from maintenance dredging in Aberdeen Harbour will continue. As a result the change in bed level during the TSHD disposal will be the combined effect of the two activities. Maintenance dredging of Aberdeen Harbour produces a bed level change of 1.401 m, providing a total change during the TSHD disposal of 4.032 m.

Average and maximum concentrations are shown in Figure C-8 and Figure C-9 respectively and demonstrate that large maximum values are limited to the disposal site. This is a result of the limited transport which these grain sizes are subject to. Average concentrations similarly show a small sediment plume resulting from this activity.

The previous notes of caution on the conservative nature of this assessment also apply to this model prediction, and this depth of deposit should very much be seen as a worst case scenario.

Due to the tidal current controlling the subsequent movement of redeposited sediment, sediment released at the disposal site will be dispersed over a wide area but will remain in the offshore area and not affect the coast line following further movement.

3.3.2 Backhoe Dredging

Scenario 3: Nigg Bay Backhoe Dredging Overspill

Bucket spill within Nigg Bay during backhoe dredging generally produces small areas of redeposited sediment, as shown in Figure C-10 and Table C-10. These results indicate that, with the exception of mud, sediment remains at the overspill location showing little to no tidal influence. Mud produces a large sediment area of redeposited during the mean spring-neap period, with deposition occurring across the development area and outside of Nigg Bay at Girdle Ness point. Sedimentation of mud at this location indicates that small eddy currents are still present within Nigg Bay during the construction phase. Average suspended sediment concentrations (Figure C-13 and Table C-13) and maximum suspended sediment concentrations (Table C-14) show that mud is the only sediment size that is subject to dispersion throughout the development area. Suspended sediment concentrations quickly achieve equilibrium, with the maximum time taken for muds to return to background levels of 6.5 hours at point 5. The greatest average concentrations produced at the data extraction points during this scenario is 9.1 mg/l, less than the background value of 143.7 mg/l observed within Nigg Bay.

No assessment of the change in bed level over the dredging programme within Nigg Bay has been made, as any sediment released as spill will be removed during subsequent dredging. The change in bed level due to the release of mud has been assessed, as this is transported out of Nigg Bay. Figure C-11 and Table C-11 show mud released during this dredging operation. Mud is deposited at the eastern Aberdeen Harbour breakwater, with depths of up to 3 mm predicted, and in the Ythan Estuary and Sands of Forvie draft SPA, with depths up to 2 mm.

The maximum suspended sediment concentrations produced by this dredging activity are shown in Table C-14 and Figure C-15. These show that concentrations have a very steep gradient, with the sediment sizes of very fine sand and coarser remaining at the released location. The maximum concentration results show that the areas affected by mud released during this activity cover a similar area to that affected during TSHD. The plots show that mud is transported to the south of Nigg Bay, but the average concentration plot (Figure C-14) and redeposited thickness (Figure C-11) demonstrate that this is an infrequent occurrence.

The maximum concentrations shown in the plot are greater than in the table due to the data extraction points being located around the sediment release location and the rapid sedimentation which occurs within Nigg Bay. This is due to the low current speeds producing a limited dispersion of sediment, resulting in steep sedimentation gradients.

Sediments released as overspill during this scenario, with the exception of mud, are predicted to remain within Nigg Bay. Mud is transported out of Nigg Bay producing an area of redeposited sediment that extends to the north of Aberdeen Harbour into the south of the Ythan Estuary and Sands of Forvie draft SPA. Sediment released as overspill during backhoe dredging is also predicted to impact Nigg Bay SSSI. Aberdeen Ballroom bathing water, Cove SSSI and River Dee Special Area of Conservation are not affected under this scenario.

Scenario 4: Disposal Site Backhoe Dredging Disposal

This scenario presents the sediment plumes and area of redeposited sediment produced by the disposal of sediment during the backhoe dredging operations at the disposal site. The area of redeposited sediment produced by this material (Figure C-12) show that grain sizes of very coarse sand and larger remain within the disposal site during the mean spring-neap period. The area of redeposited sediment produced by these sediment sizes show the largest thickness at the release location (the centre of the disposal site) and decrease away from this point. Coarse sand shows limited deposition outside of the disposal site, with finer sediment producing increasingly larger areas of redeposited sediment.

Table C-12 presents the sediment thicknesses produced during this scenario, and demonstrates that finer sediment sizes (medium sand and below) produce areas of greater sedimentation to the north and south of the disposal site. This is due to a combination of current speed and settling velocity resulting in transportation of these grain sizes out of the disposal site.

Sediment sizes of coarse sand and greater produce small areas of redeposited sediment that remain within the disposal site. Finer sediment sizes (medium sand and below) produce areas of redeposited sediment that extend out of the disposal area. The change in bed level during the backhoe dredging programme at the disposal site has been determined assuming an even disposal of sediment across the area. Predicted sediment thickness has been distributed across the disposal area to produce a bed level increase of 1.292 m. During this period, disposal from the Aberdeen Harbour maintenance dredging will also be present, resulting in a total change at the end of this period of 2.439 m.

The previous notes of caution on the conservative nature of this assessment also apply to this model prediction, and this depth of deposit should very much be seen as a worst case scenario.

Due to the tidal current controlling the subsequent movement of redeposited sediment, sediment released at the disposal site will be dispersed over a wide area but will remain in the offshore area and not affect the coast line following further movement.

Average suspended sediment concentrations are provided in with the time series in Figure C-16. The results demonstrate that sediment plume concentrations reduce with distance from the disposal location and that equilibrium is quickly achieved for all sediment sizes. Concentrations of medium sand grain sizes and coarser return to background levels within 30 minutes. Finer grain sizes require longer to return to background levels, with very fine sand taking up to 2 hours. Mud has the highest concentration at all locations as it has the largest flux during this scenario and the lowest settling velocity, enabling it to remain in the water column for a greater period of time. The average suspended solids concentrations at the edge of the disposal site of 8.3 mg/l and 9.1 mg/l (at the northern and southern points respectively) are dominated by the mud component, which represents approximately 77% of this concentration. Coarse sediment is subject to less transport producing smaller sediment plumes than the mud component.

The very fine sand deposit thickness shown in Figure C-12 shows a depth of less than 1 mm over the mean spring-neap period. This is due to this grain size comprising a small component of the released material and the grain size being subject to a large degree of dispersion, as shown by the low concentrations in Table C-15 and Table C-16.

Figure C-17 and Table C-15 show the average concentrations at the disposal site during backhoe dredging disposal, with Figure C-18 and Table C-16 providing the maximum values. These results indicate the largest concentrations are restricted to the disposal site, due to the relatively large settling velocities of the sediment. The lower values in the average concentrations are due to coarse sediment being rapidly deposited at the disposal location, and finer sediment being subject to transport in the dominant current direction, producing short lived increases in concentrations as the sediment is dispersed in the water column.

The combined suspended solids concentrations for all particle sizes from the backhoe disposal and the Aberdeen Harbour maintenance dredging are shown in Table C-17. This demonstrates that the Aberdeen Harbour maintenance dredging has a greater effect on suspended concentrations, with an average contribution of 87% at all the results extraction locations

4 CONCLUSIONS

The existing ACM has been updated and refined for the impact assessment of the proposed Aberdeen Harbour expansion. The refined model has been applied to scenarios representing baseline, operation and construction phases to assess the relative changes in sediment behaviour. Both near-field and far-field changes due to the development have been assessed along with the long term fate of redeposited sediment.

A number of conservative assumptions have been made in estimating potential inputs to the sediment plume modelling. The combined effect of these assumptions is likely to mean that the modelled outputs are greater than would be expected during real operations.

Conclusions from this assessment are presented in the following sections below.

4.1 OPERATIONAL PHASE

Disposal sediment plumes produced during the operational phase are the same as those during the baseline scenario, with negligible differences between the two. Changes to the hydrodynamic regime due to the Aberdeen Harbour expansion are limited to the immediate vicinity of Nigg Bay, and as a result do not affect the regional tidal currents which control the formation of sediment plumes at the disposal location.

Areas of redeposited sediment produced at the disposal location are demonstrated to be dependent on the settling velocity. Large settling velocities associated with coarse sand and larger sediment sizes show minimal impact from currents, producing small, concentrated areas of redeposited sediment with the greatest sediment depth below the release location (the centre of the disposal site). Sediment sizes of medium sand and finer have lower settling velocities and are subject to greater current influence, producing elongated sediment areas of redeposited material in the dominant (north-east to south-west) tidal direction. The lower settling velocities of these sediment sizes result in the greatest sedimentation occurring outside of the disposal site, to the north and south, as sedimentation occurs following transportation by the dominant currents.

The modelling shows that the coarse sediment will descend as a plume to the seabed. However, the PT module is not capable of modelling entrainment processes which would occur in this situation and reduce the immediate dispersion of other (finer) sediments following release. As a result of this, the redeposited sediment footprints would be reduced in size, and suspended solids concentrations lower, limiting the area affected by the disposal activity.

The suspended sediment concentrations which have been presented within this report represent a conservative assessment, assuming that sediment will be subject to advection and dispersion processes immediately following release. In practice, sediment released via this method is likely to form a sediment plume as it descends to the sea bed. Sediment (including the fine mud component) will remain entrained in this plume. This will result in a lower proportion of sediment becoming entrained, and subsequently dispersed, in the water column. Despite this conservatism, the results demonstrate that the majority of sediment will remain within the disposal site, with suspended concentrations outside of this area dominated by mud. In practice, it is likely that the concentrations produced by normal operations will be up to an order of magnitude lower than those predicted in the worst case scenario modelling.

Sediment released at the disposal site during the operational phase is not predicted to affect the identified sensitive receivers or the Aberdeen Harbour expansion.

4.2 CONSTRUCTION PHASE

Two dredging methods have been modelled during the construction phase, TSHD and backhoe dredging. Despite the differences in the dredging methods, the areas of redeposited sediment and sediment plumes produced within Nigg Bay and at the disposal location show similar spatial distributions. The construction phase results are discussed below both in terms of disposal location and disposal programme.

4.2.1 Nigg Bay

Sediment released within Nigg Bay as a result of spill during the construction phase is largely predicted to remain within the development area, with the exception of mud. This is due to low current speeds created by the partially constructed breakwaters. The greatest sedimentation is predicted to occur at the sediment spill location, demonstrating the low current speed and low dispersion within Nigg Bay. Sedimentation of spill material is therefore strongly dependent on the release location, with only very fine sand and mud showing the effects of local eddy currents. Dispersion of sediment is expected to decrease throughout the construction programme as the breakwaters are extended, with the area affected by overspill being larger during the beginning of the construction programme due to greater current speeds.

Mud shows a larger degree of dispersion with sedimentation occurring outside of the development area to the north for both dredging methods. Overall sediment thicknesses of up to 4 mm are predicted at the Ythan Estuary and Sands of Forvie draft SPA at the end of dredging programme. Nigg Bay SSSI will be impacted by sediments during the dredging programme due to its location within the development area. However, due to its designation under its geology, its SSSI status will be unaffected. Aberdeen Ballroom bathing water, Cove SSSI and the River Dee Special Area of Conservation are not affected by the spill of sediment within Nigg Bay.

Sediment concentrations outside Nigg Bay are similarly dominated by the mud component of the released sediment. Average concentrations produced by mud at the data extraction locations within Nigg Bay show a maximum value of 35.6 mg/l and 9.8 mg/l for the TSHD and backhoe dredging respectively, less than the background level of 143.7 mg/l which was observed. At St Fittick's point the average concentrations are 0.5 mg/l and 0.3 mg/l for TSHD and backhoe dredging respectively, showing that the effects from the dredging are largely limited to the construction area. The conservative assumptions of dredging overspill used in this analysis have produced low suspended solids concentrations outside of Nigg Bay. It is therefore likely that these will be even smaller in reality.

Redeposited sediment thicknesses and suspended solids concentrations produced by the dredging activities within Nigg Bay will vary according to the location of the dredging and the timing during the construction phase. As the breakwaters are constructed, current speeds will be reduced and calm conditions produced. This will result in any sediment released due to dredging within the harbour area being redeposited within the harbour area, and not affecting the Ythan Estuary and Sands of Forvie draft SPA or St Fittick's point. While the retention of sediment within the harbour will increase the redeposited thickness at this location, any sediment redeposited will be removed during subsequent dredging.

The maximum concentrations shown at some points in the plots are greater than in the tables due to the data extraction points being located around the sediment release location and the rapid sedimentation which occurs within Nigg Bay. This is due to the low current speeds producing a limited dispersion of sediment, resulting in steep sedimentation gradients. In addition to this hydrodynamic effect, interpolation of values between cells within the model can produce lower values when results are extracted than is shown in the plots. This does not affect the dispersion of sediment within the model or the results shown in the figures.

4.2.2 Disposal Location

The area of redeposited sediment produced at the disposal site is controlled by the sediment settling velocity, with the spatial coverage remaining constant in both disposal scenarios. Sediment sizes of coarse sand and greater are predicted to largely remain within the disposal site, showing little to no tidal influence. The area of redeposited sediment produced by sediment sizes of medium sand and smaller show greater dispersion, with areas of redeposited sediment elongated in the regional north-east to south-west current direction.

Variations in sedimentation thickness can be seen in the area of redeposited sediment. Sediment sizes of coarse sand and greater produce the greatest sediment thickness at the centre of the area of redeposited sediment (the disposal location), whereas medium sand sediment sizes and finer produce two areas of higher sedimentation to the north and south of the development area. These areas are created due to the lower settling velocities, enabling the flooding and ebbing tides to transport sediment out of the disposal site before being deposited.

During the backhoe disposal very fine sand produces a redeposited sediment thickness of less than 1 mm during the mean spring-neap period, and therefore is not shown in Figure C-12. This is due to the low volume of this grain size which is present in this sediment, combined with the relatively high dispersion of this particle producing a thin deposited thickness. Table C-15 and Table C-16 show that this grain size is present in the model and also demonstrate that it is only present in low concentrations.

Suspended sediment concentrations quickly achieve equilibrium at the disposal site, with maximum concentrations being reached immediately following the release of sediment, and a return to background concentrations for all grain sizes of medium sand and coarser within 45 minutes. Fine sand and very fine sand require longer to return to background levels, but these are achieved before the next release of sediment. Mud requires the greatest length of time to be removed from the water column, but background concentrations are produced between releases. Time series plots at the specified locations also demonstrate that increases in suspended solids are short lived and quickly return to background levels, showing that there will be no long term effect from the disposal of sediment following the cessation of disposal activities.

Suspended solids concentrations during TSHD and backhoe disposal will also be a combined impact from the capital and maintenance dredging operations shown in Table C-8 and Table C-17. In both scenarios the resulting suspended solids at the edge of the disposal site are dominated by the maintenance dredging operations, with the effects from the capital dredging largely limited to the disposal site. The results presented for the TSHD capital dredging (Table C-8) have assumed that the releases of sediment from both capital and maintenance dredging have occurred at the same time and the same location, presenting the worst case for suspended solids concentrations.

Disposal of material during backhoe dredging will also be affected by the maintenance dredging programme, with the resulting average suspended solids concentrations shown in Figure C-17 and maximum values shown in Figure C-18. . These demonstrate that (as with the TSHD) backhoe dredging represents a small component of the suspended solids when combined with the maintenance disposal, with approximately 12% of the concentrations outside of the disposal area coming from the backhoe dredging activities.

Results from the PT scenarios demonstrate that coarse sediment released at the disposal site will be deposited immediately below the release location, even when subject to dispersion immediately following release, and will therefore form a plume as it descends to the seabed. This process will entrain finer sediment within it, reducing the area affected by the redeposited sediment and reducing the SSC outside of the disposal site. As a consequence of this the change in sediment thickness within the disposal site would be increased due to the additional material remaining within this location.

4.2.3 Disposal Programmes

The change in bed level at the end of the construction phase will depend on which sediment disposal programme is applied. During both programmes the change in bed level due to the maintenance dredging at Aberdeen Harbour will be consistent, with a total increase in bed level over the whole construction phase of 2.548 m due to this activity. The PT model does not account for resuspension or subsequent movement of sediment deposited at the disposal site; therefore the values presented here represent the worst case scenario with the likely real-world depths less than the values presented.

Disposal Programme 1

Disposal programme 1 assumes that all of the dredged sediment will be disposed of at the disposal site; therefore the change in bed level will be produced by the effects of the baseline, TSHD and backhoe dredging disposals. This results in an increase of bed level at the end of the construction phase of 6.471 m. The maintenance dredging during this disposal programme represents 39% of this change. Due to the conservative assumptions used in this assessment due to the number of unknowns, it is likely that the actual sediment depth increases will be substantially less than this.

Disposal Programme 2

Disposal programme 2 assumes that only sediment from the backhoe dredging will be disposed of at the disposal site, along with the maintenance (baseline) dredging. This results in change in bed level at the disposal site of 3.840 m. The maintenance dredging during this disposal programme represents 66% of this change.

The change in bed level at the disposal site in this scenario is less than during programme one due to the lower amount of material which is to be disposed of.

4.2.4 Long Term Fate of Deposited Sediment

The long term fate of sediment following being deposited at the disposal site will be controlled by the tidal conditions present at this location. Current speeds of 0.66 m/s and 0.37 m/s on mean spring and neap tides are present at the disposal site, with movement of sediment trending north-east to south-west as shown in the deposited sediment plots. The water depth at this location (and offshore along the length of redeposited sediment) is great enough that wave action will have a relatively small effect on the movement of the deposited sediment, except under the most extreme conditions.

The bed shear stress present at this location is responsible for the subsequent resuspension and movement of the redeposited sediment. Sediment sizes of coarse sand and finer will be subject to transport under mean spring-neap conditions, with coarse sand being moved during peak currents. Due to the tidal current controlling the subsequent movement of deposited sediment, material released at the disposal site will likely be dispersed over a wide area but will remain in the offshore area and not affect the coast line following further movement. It therefore poses little risk in terms of accumulation.

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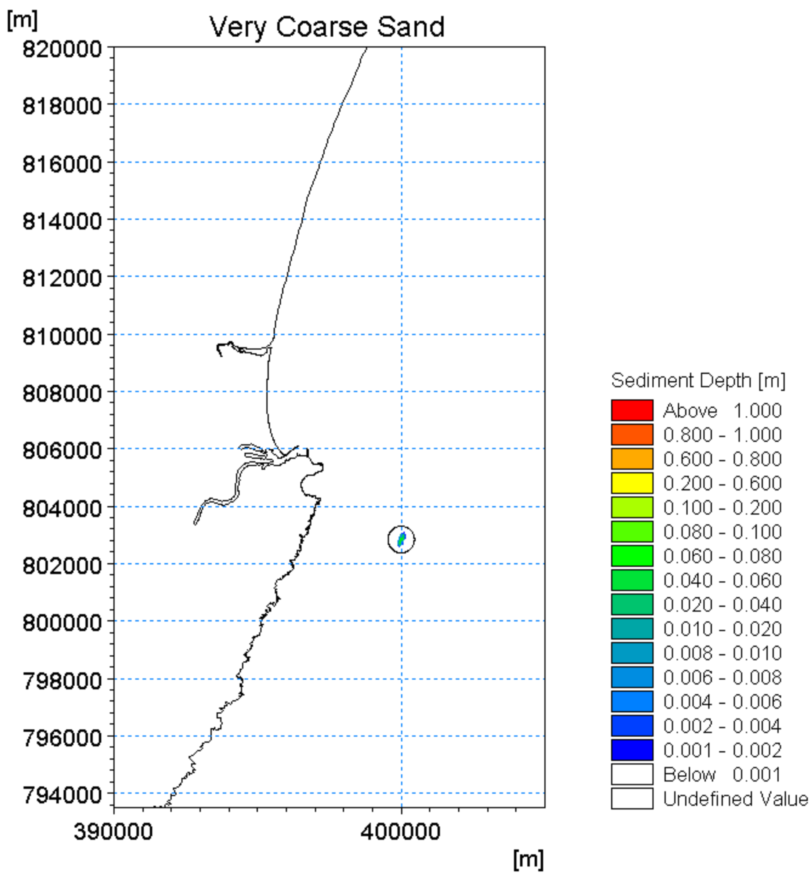
Appendix A Baseline Results

Figure A-1: Baseline area and depth of redeposited sediment

Over a Large Extent



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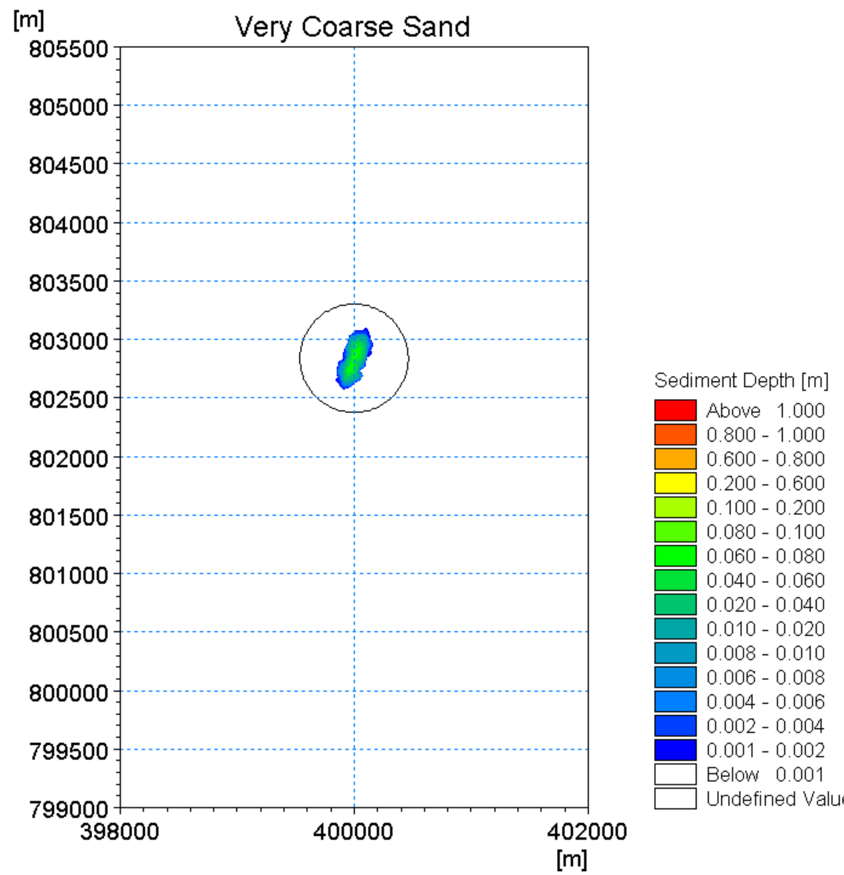

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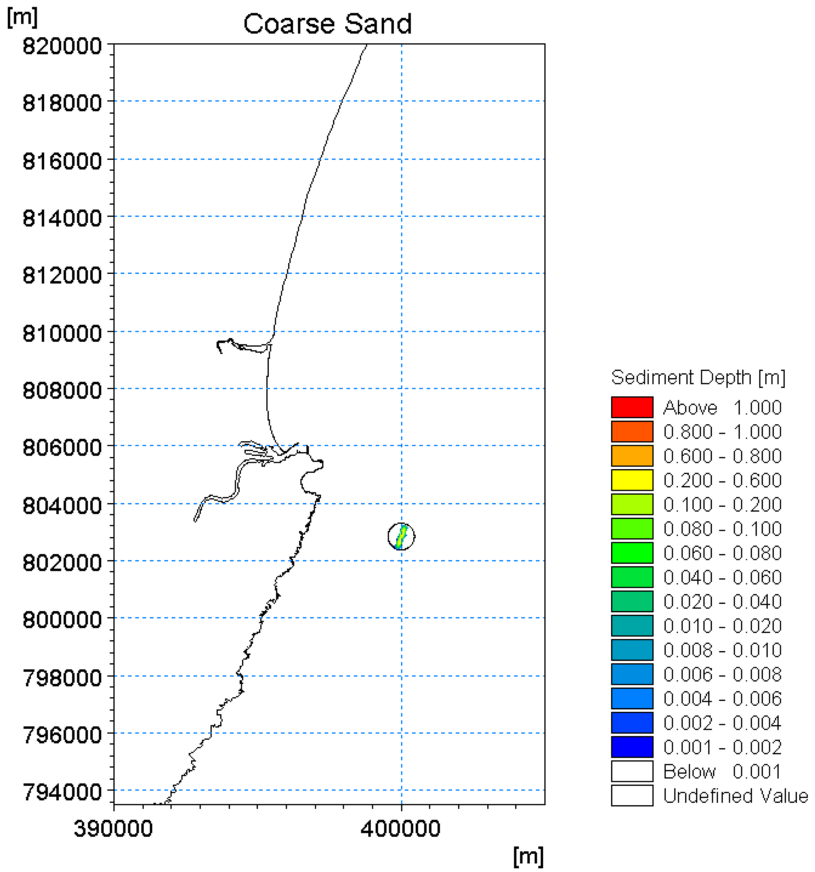

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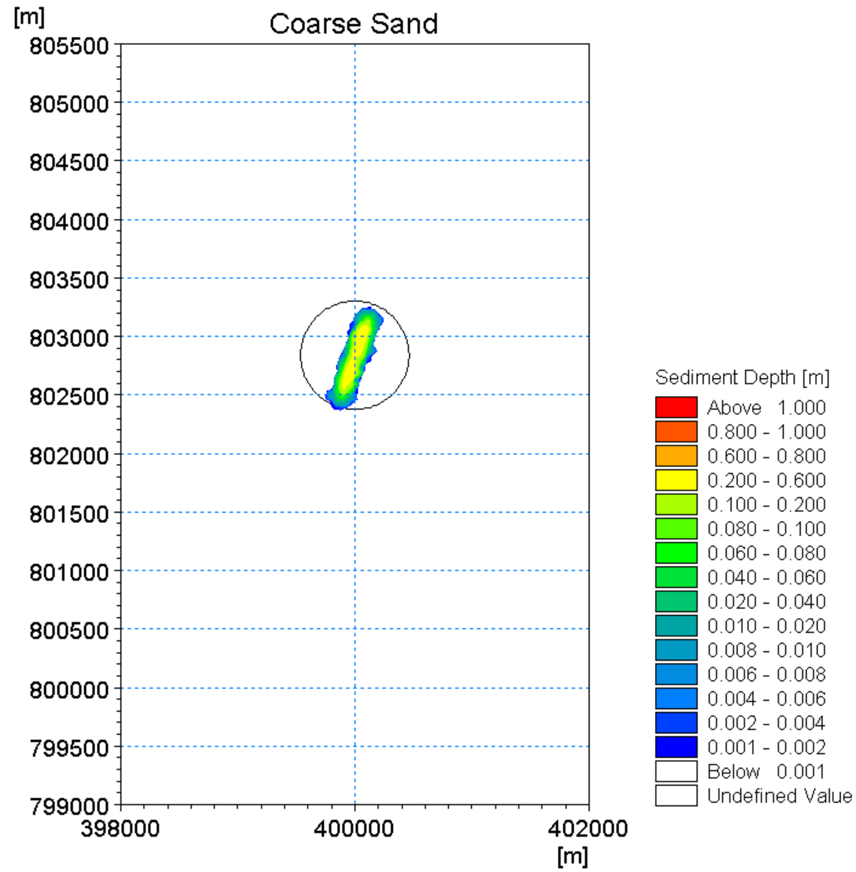

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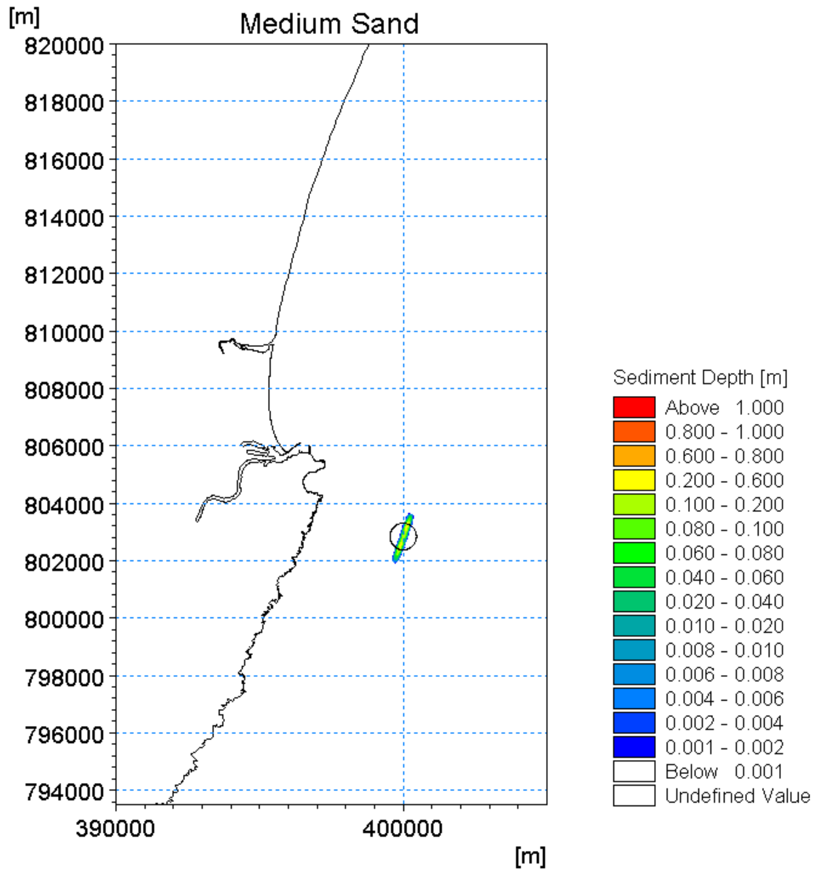

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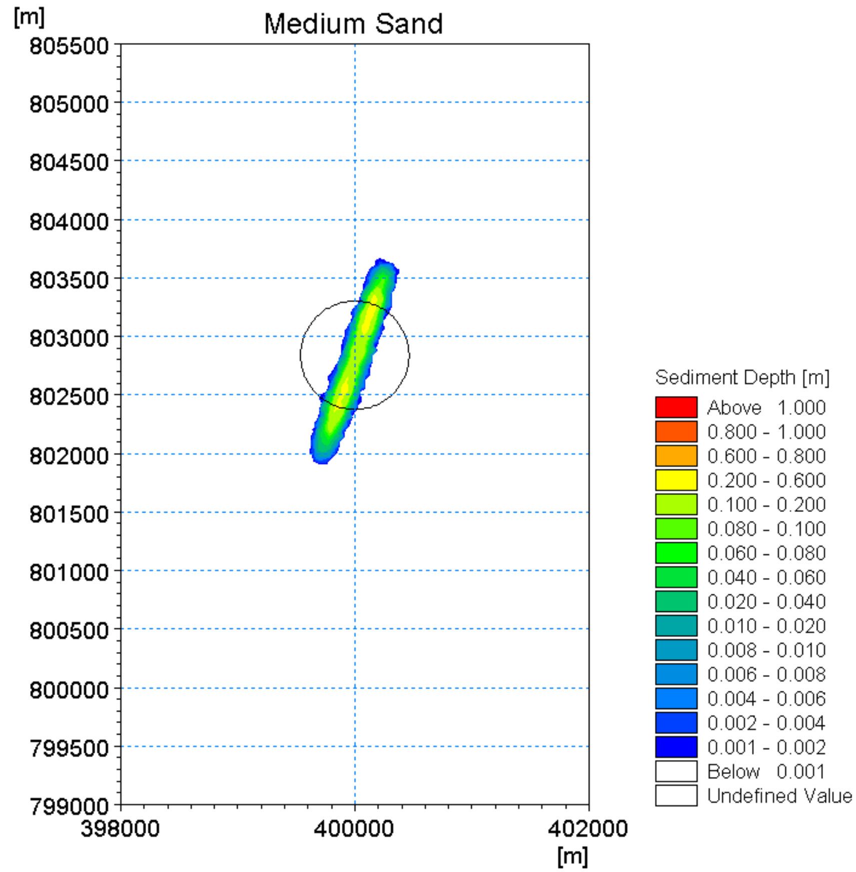

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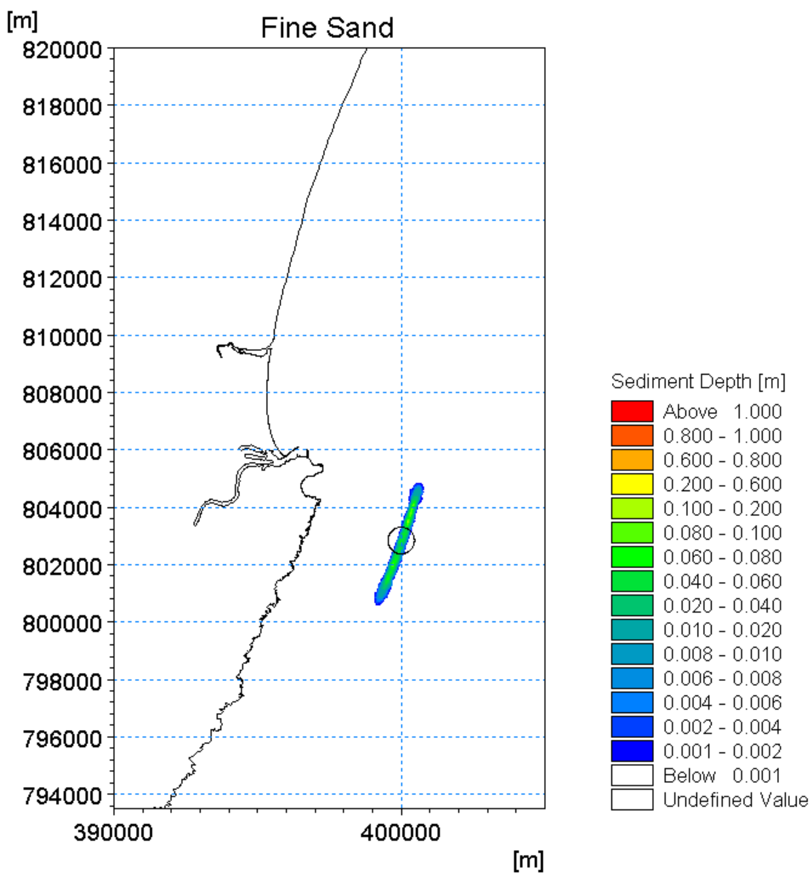

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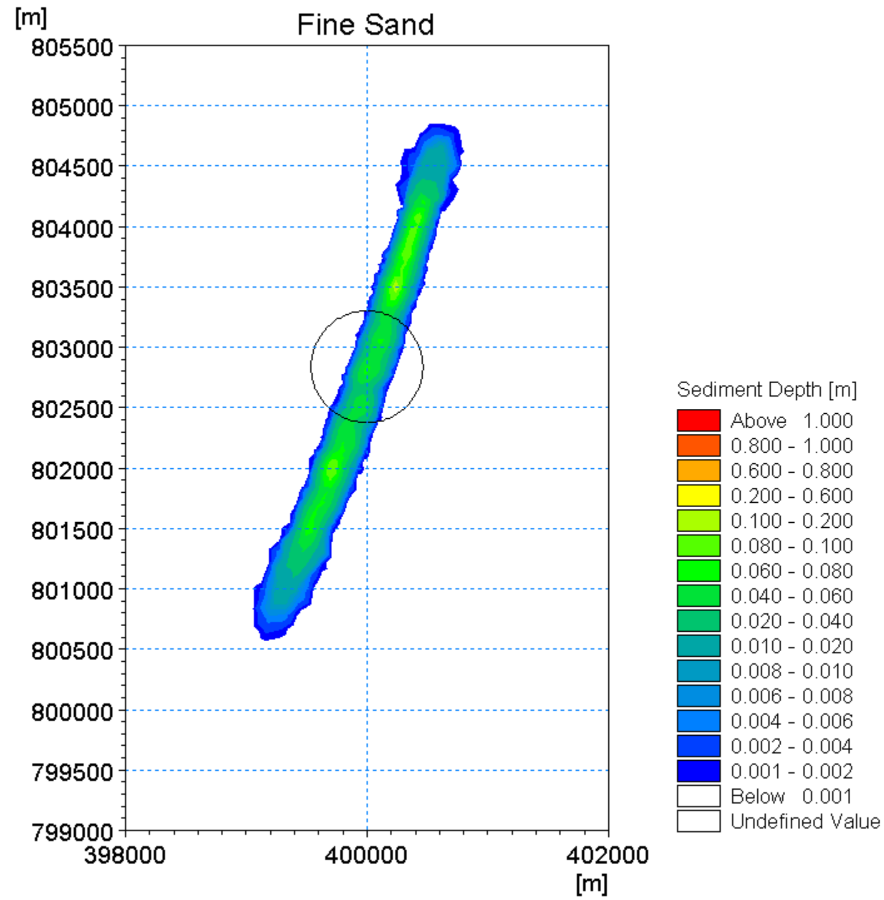

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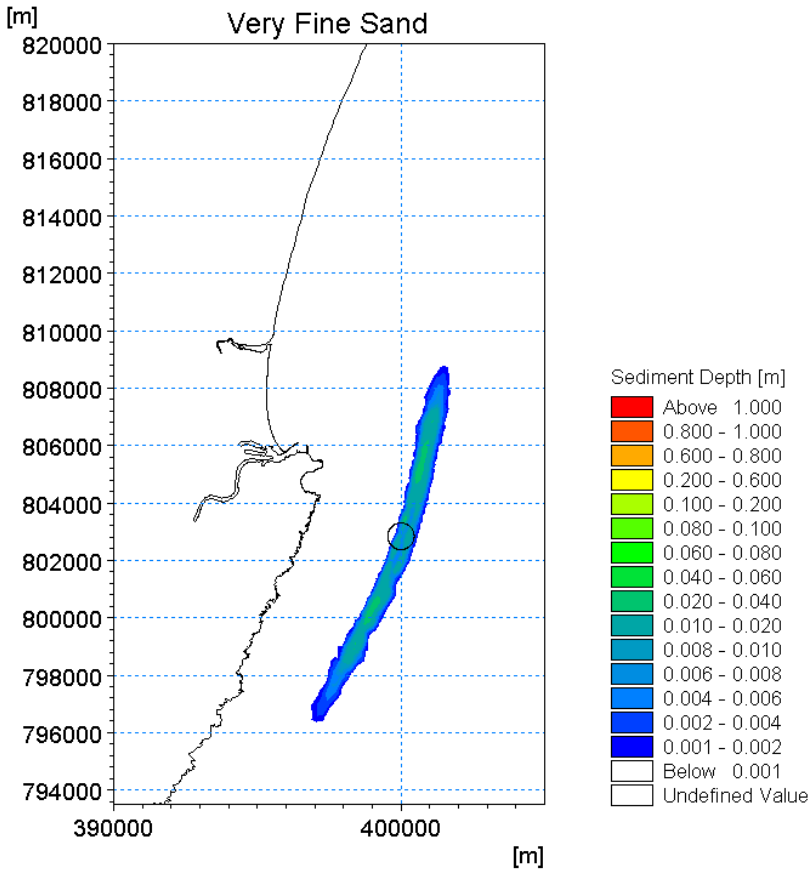

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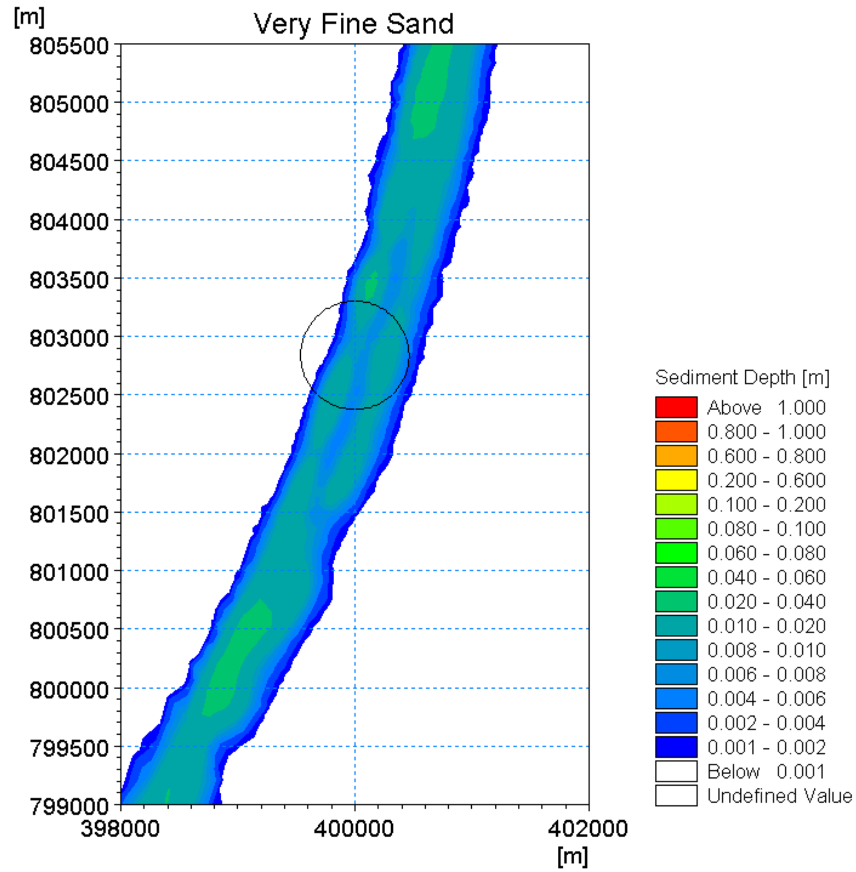
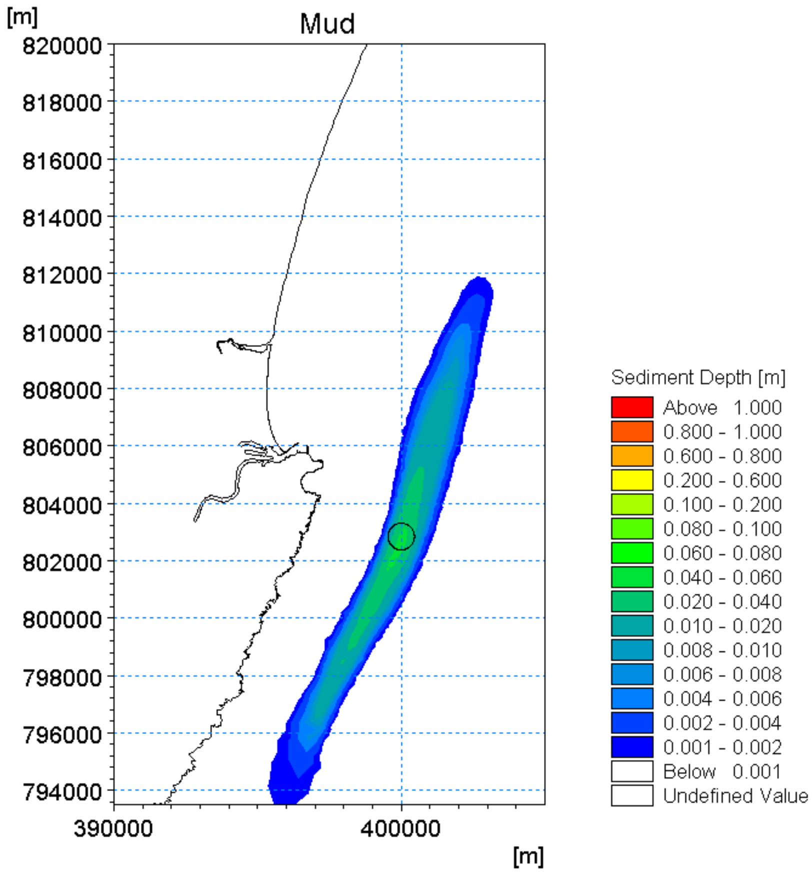


Over a Large Extent



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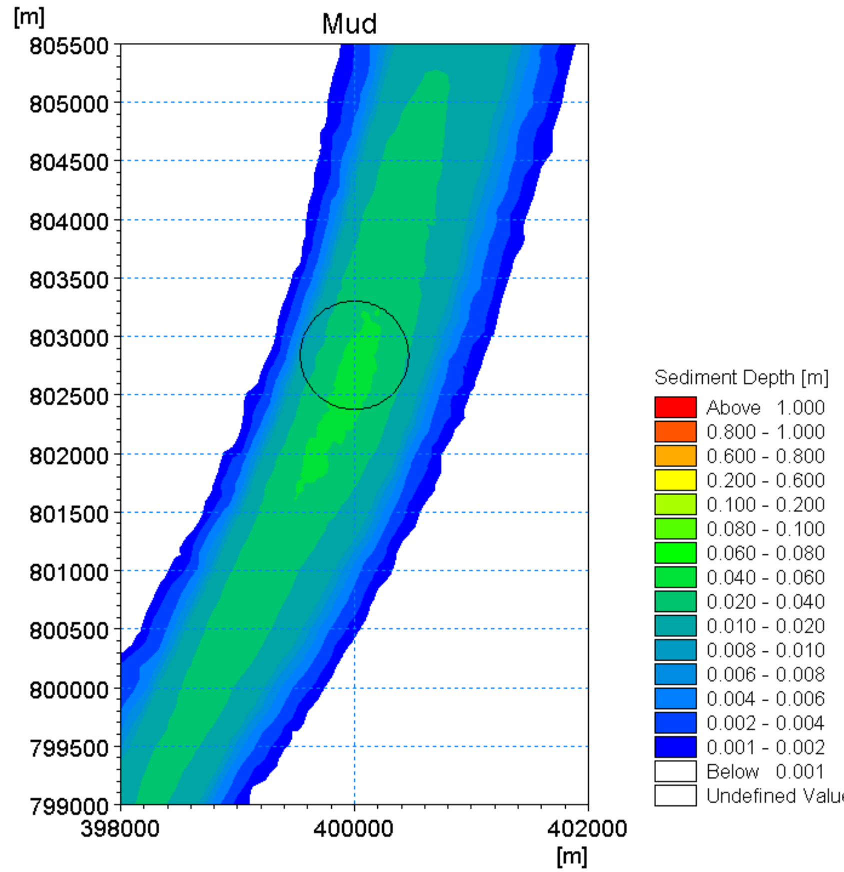
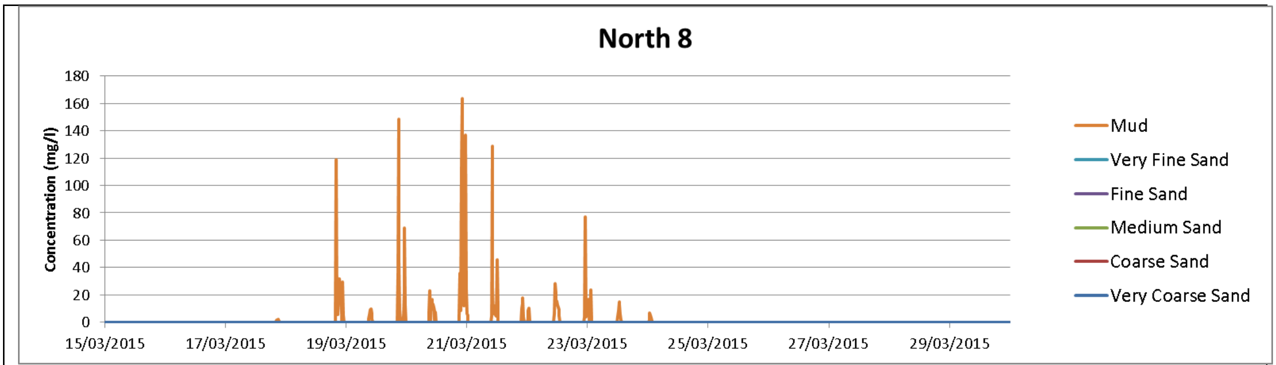
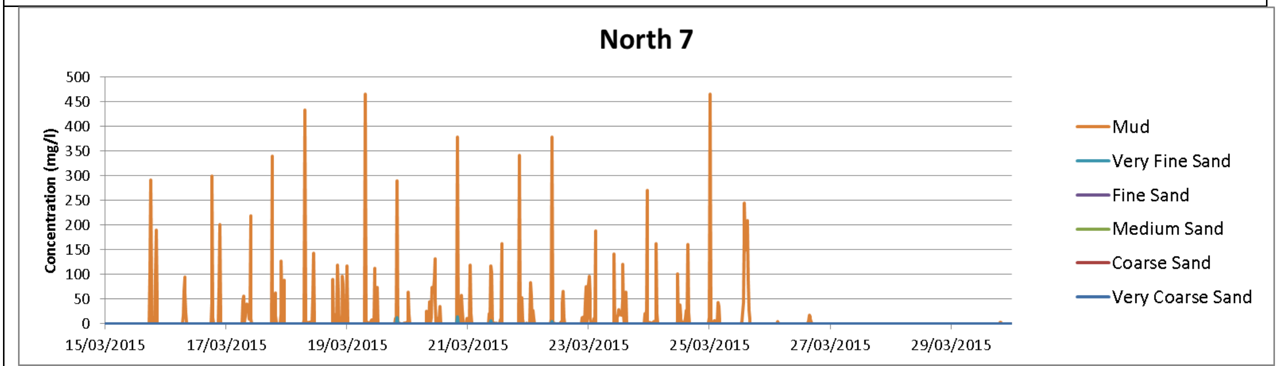


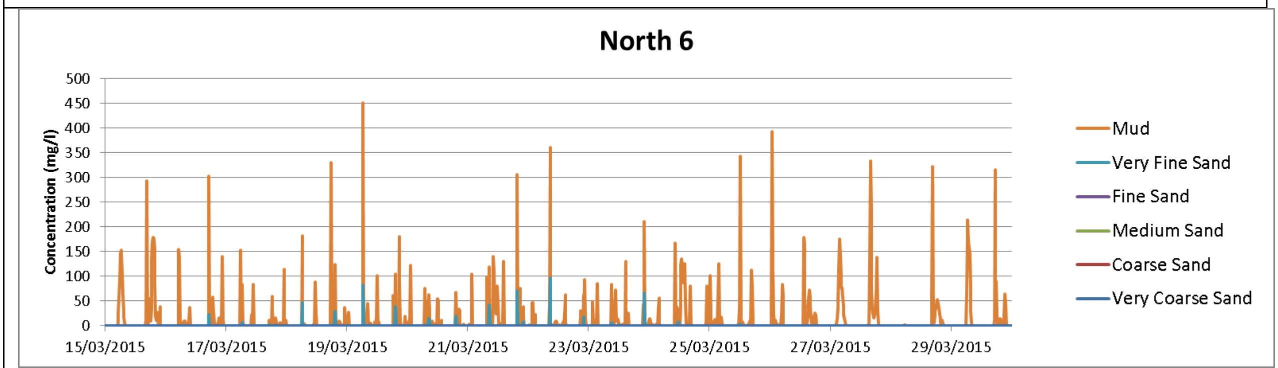
Table A-1: Baseline depth of redeposited sediment

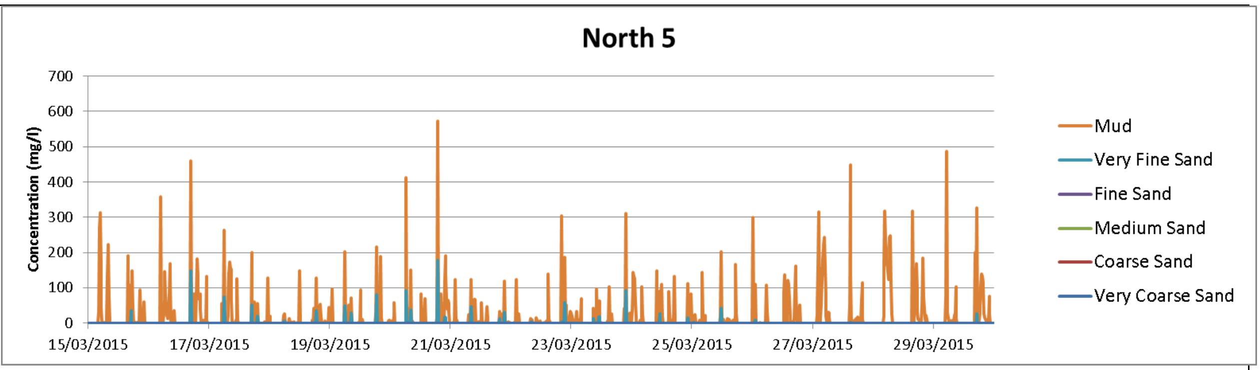
Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mm)	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0	0	0
Coarse sand (mm)	0	0	0	0	0	0	0	0	256	6	0	0	0	0	0	0	0
Medium sand (mm)	0	0	0	0	0	0	86	236	167	222	15	0	0	0	0	0	0
Fine sand (mm)	0	0	0	0	18	83	108	50	60	45	91	67	10	0	0	0	0
Very fine sand (mm)	0	1	13	18	14	12	13	14	9	14	8	16	13	25	14	1	0
Mud (mm)	1	7	14	17	27	30	39	39	45	42	42	38	32	26	21	10	1
Total (mm)	1	8	27	35	59	125	246	339	601	329	156	121	55	51	35	11	1

Figure A-2: Baseline suspended sediment concentration








North 5
Concentration (mg/l)
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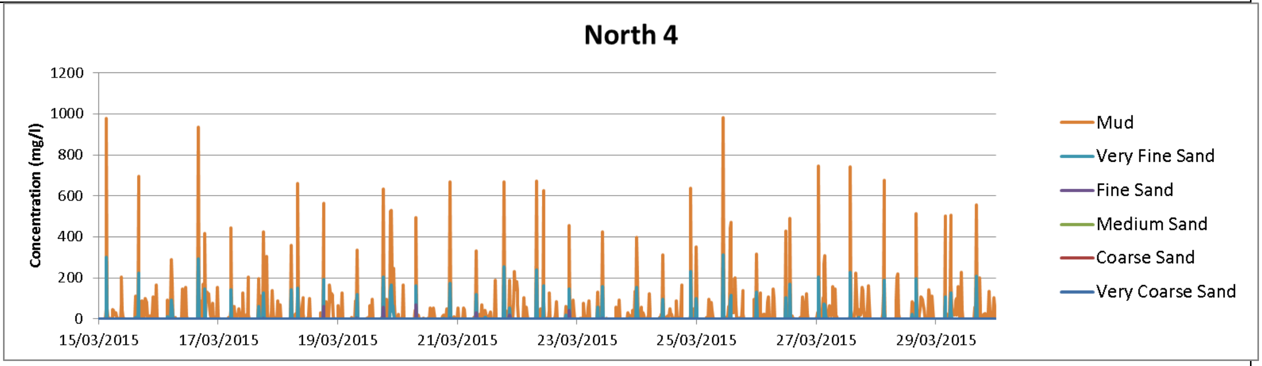
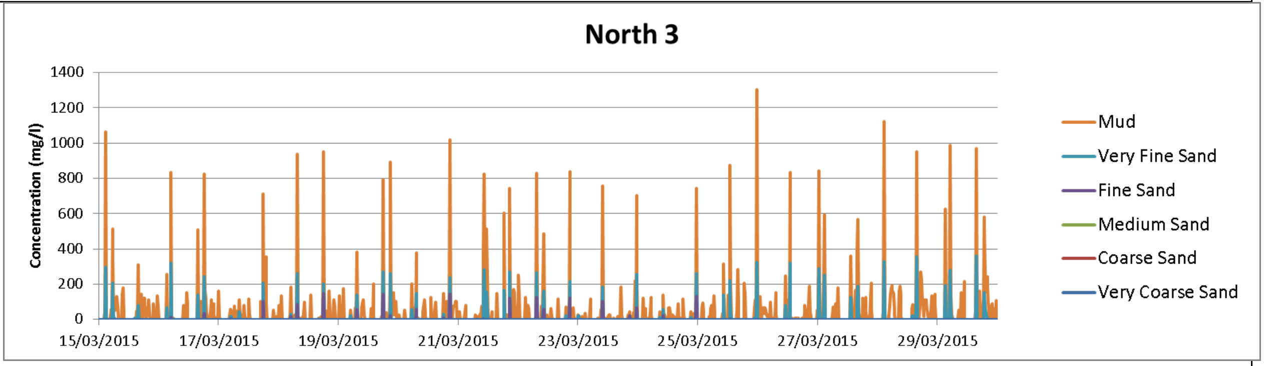
600
500
400
300
200
100
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


North 4
Concentration (mg/l)
1200
1000
800
600
400
200
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand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Concentration (mg/l)
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600
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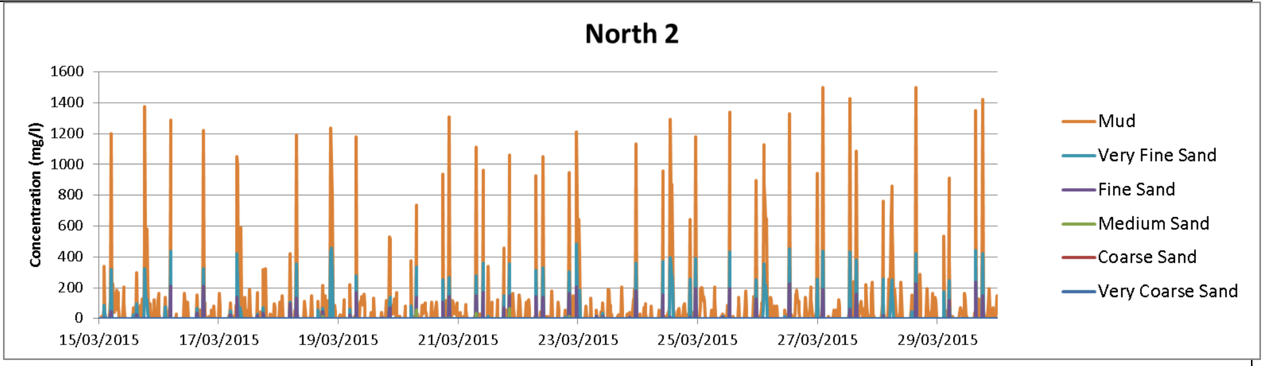
200
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand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800
600
400
200
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17/03/2015
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27/03/2015
29/03/2015
Mud
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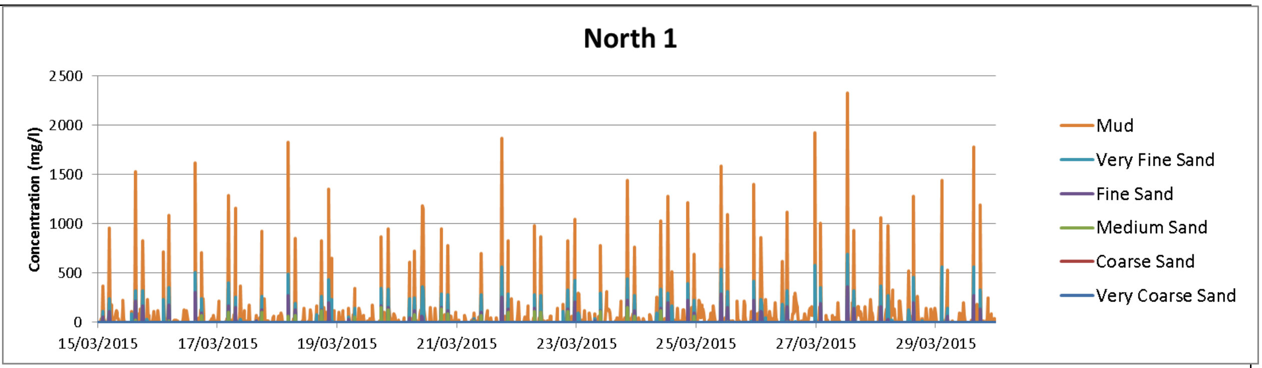
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand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1500
1000
500
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17/03/2015
19/03/2015
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25/03/2015
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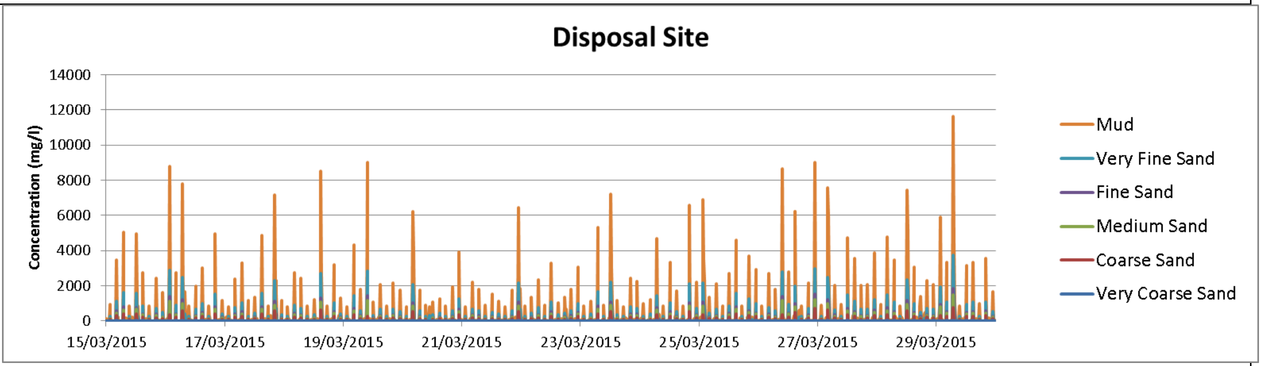
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


Disposal Site
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17/03/2015
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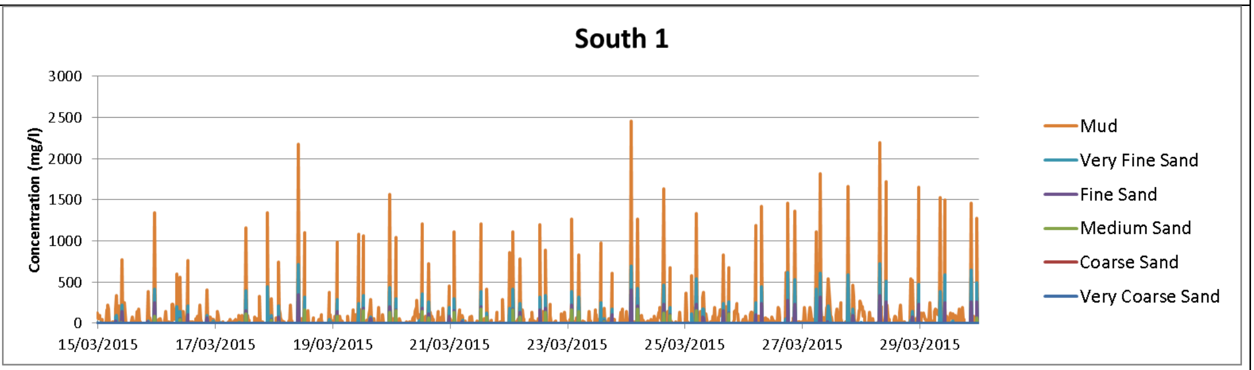
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand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Concentration (mg/l)
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2500
2000
1500
1000
500
0
15/03/2015
17/03/2015
19/03/2015
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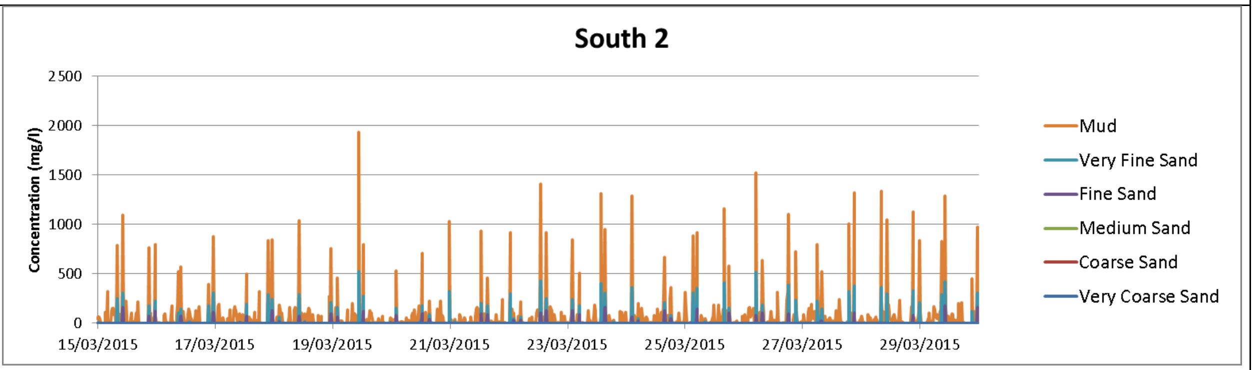
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand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Concentration (mg/l)
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1500
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500
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17/03/2015
19/03/2015
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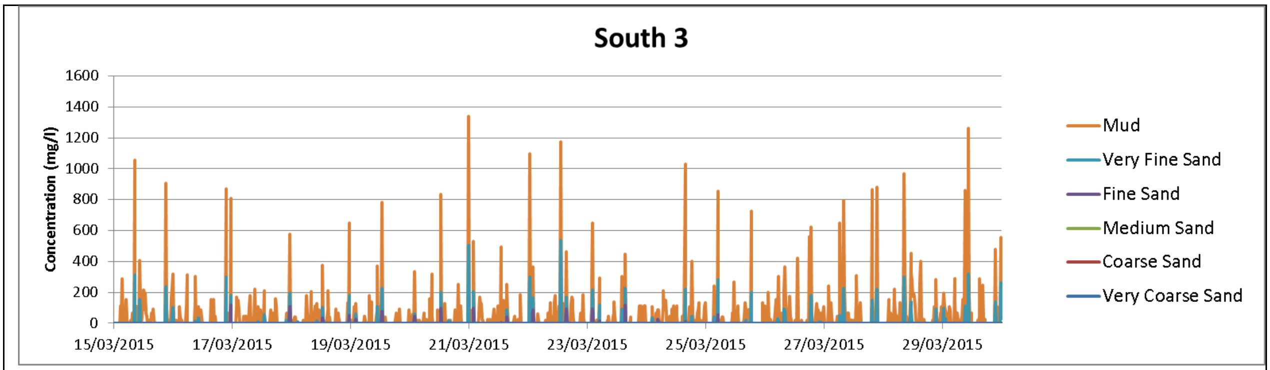
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand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Concentration (mg/l)
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1400
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1000
800
600
400
200
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17/03/2015
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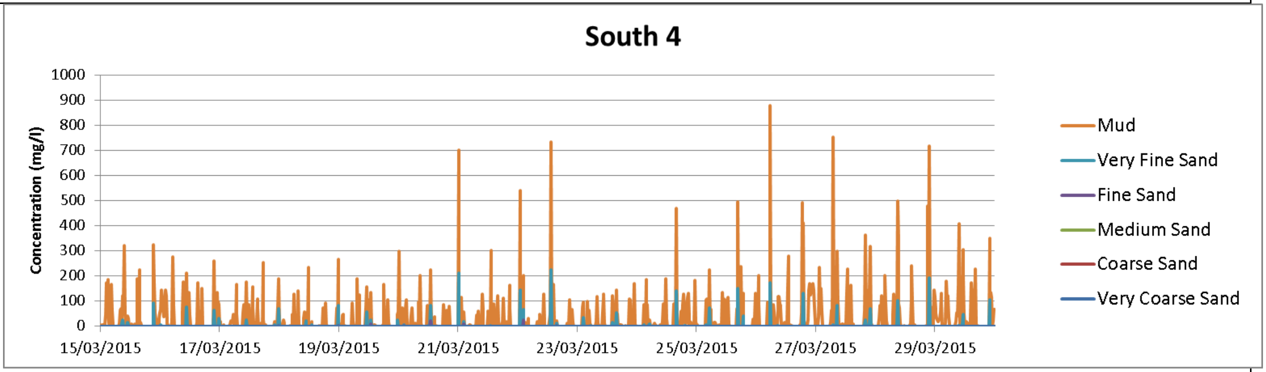
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand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Concentration (mg/l)
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300
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19/03/2015
21/03/2015
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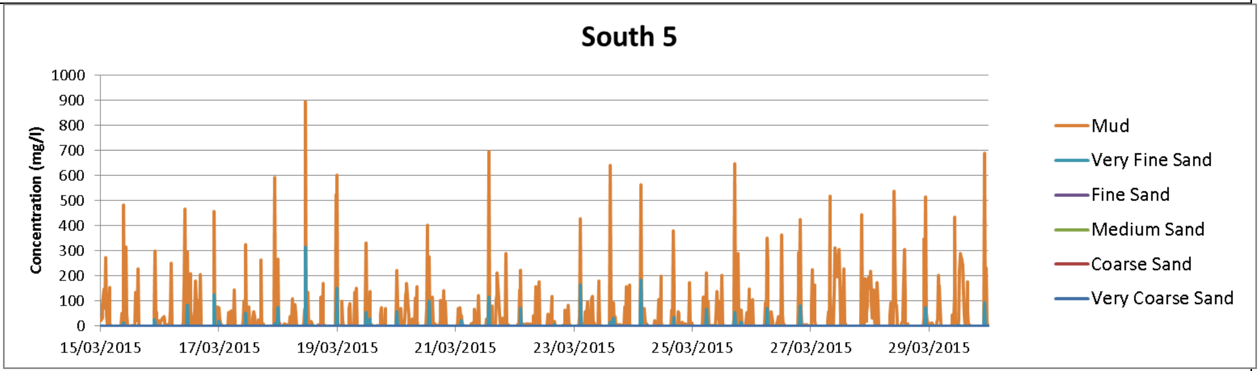
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


South 5
Concentration (mg/l)
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900
800
700
600
500
400
300
200
100
0
15/03/2015
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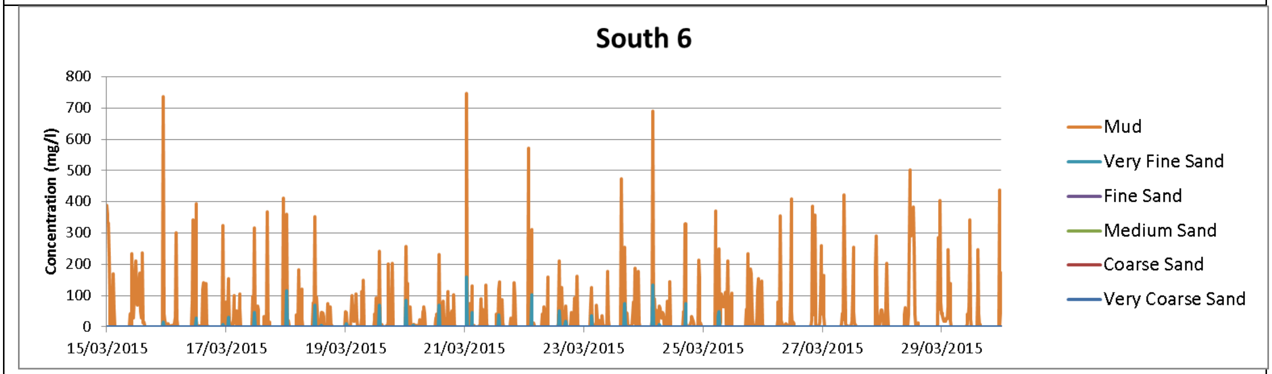
Medium Sand
Coarse Sand
Very Coarse Sand


South 6
Concentration (mg/l)
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700
600
500
400
300
200
100
0
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Mud
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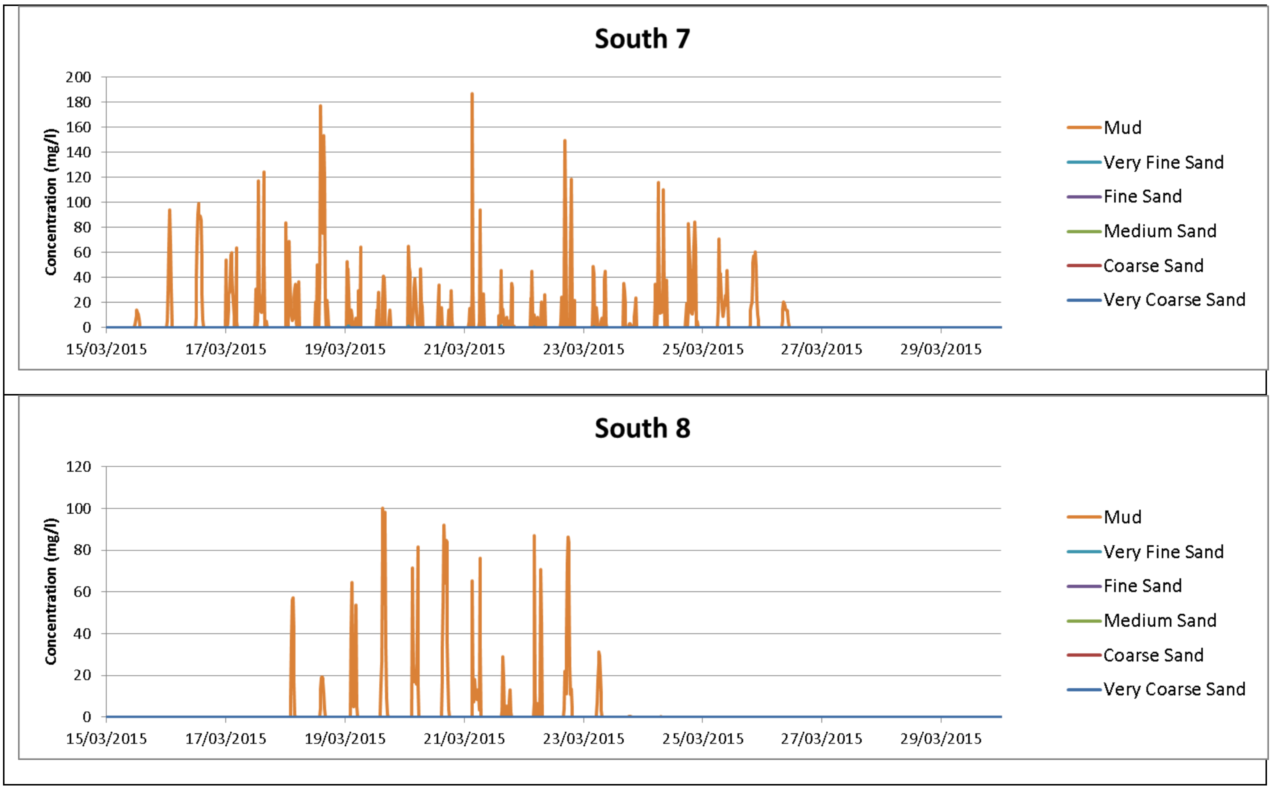


Figure A-3: Baseline average suspended sediment concentration

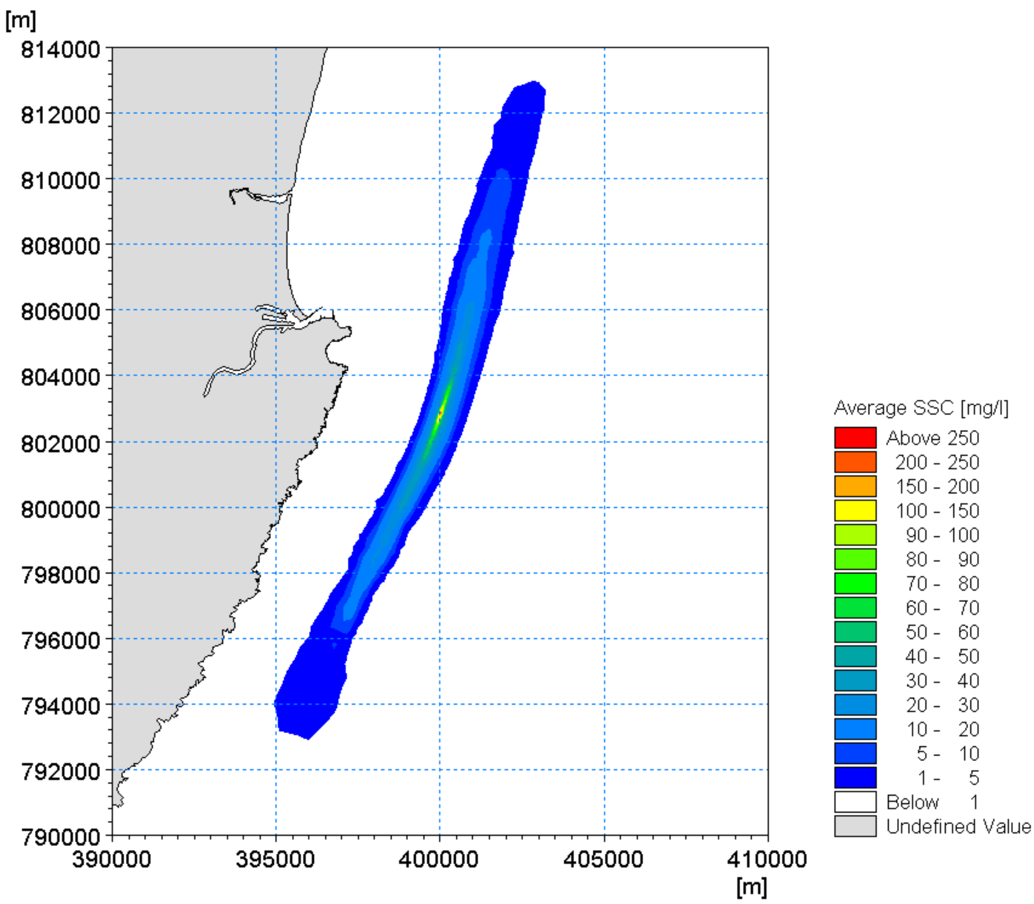


Figure A-4: Baseline maximum suspended sediment concentration

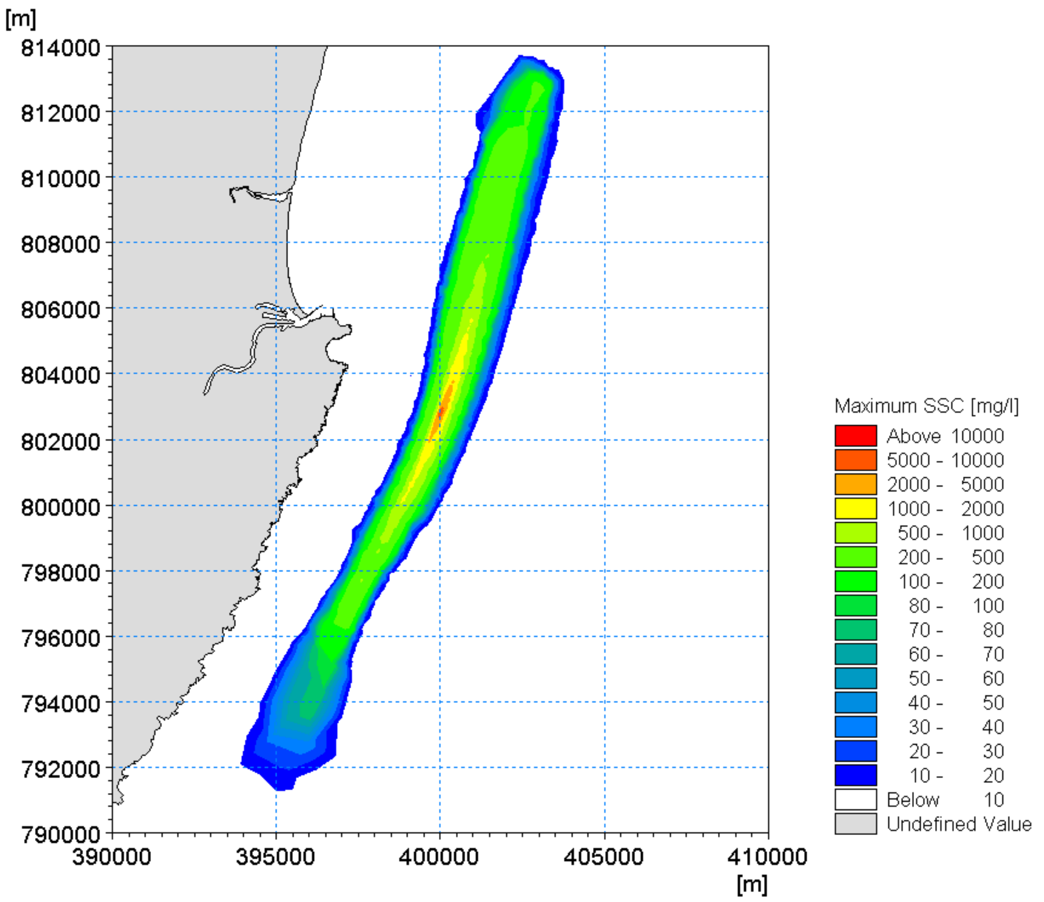


Table A-2: Baseline average suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.6	35.6	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine sand (mg/l)	0.0	0.0	0.0	0.0	0.2	1.2	3.7	5.8	46.5	6.1	2.5	0.8	0.1	0.0	0.0	0.0	0.0
Very fine sand (mg/l)	0.0	0.0	0.4	0.9	5.3	7.4	14.0	14.7	96.3	15.1	10.0	6.4	2.1	1.6	1.0	0.0	0.0
Mud (mg/l)	1.5	8.9	13.2	18.8	33.0	42.2	66.6	69.7	326.6	75.3	59.7	45.8	30.4	32.5	28.5	6.4	2.4
Total suspended solids (mg/l)	1.5	9.0	13.7	19.7	38.4	50.7	84.4	91.8	526.5	98.6	72.2	53.0	32.5	34.0	29.5	6.4	2.4

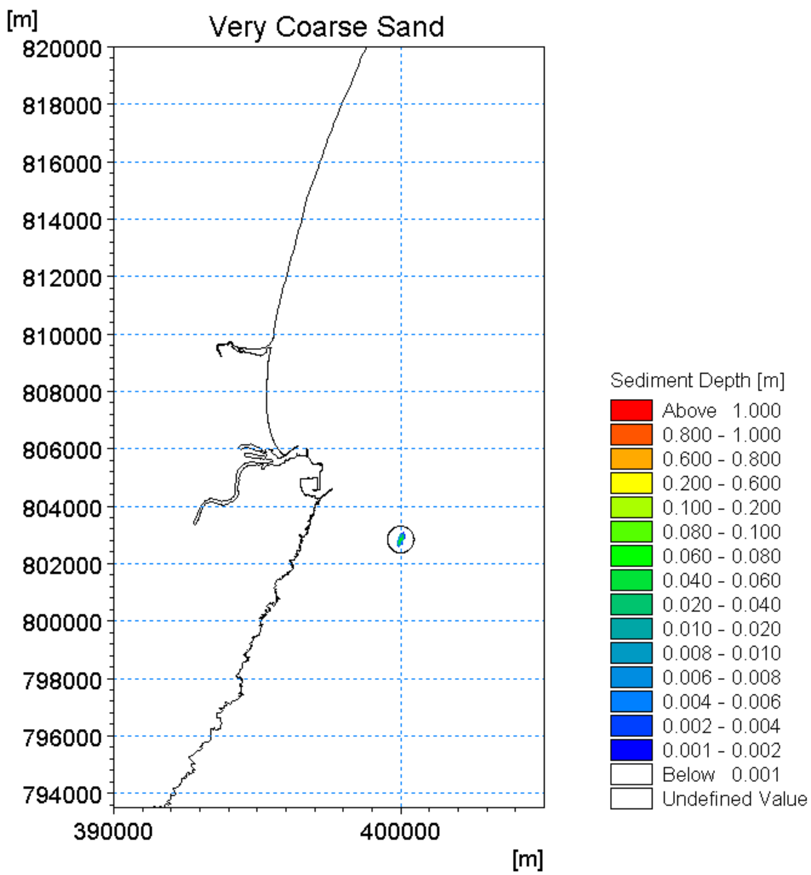
Table A-3: Baseline maximum suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	56	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	748	2	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	67	149	1482	177	1	0	0	0	0	0	0
Fine sand (mg/l)	0	0	0	0	70	148	238	362	1864	409	176	119	26	0	0	0	0
Very fine sand (mg/l)	0	14	97	178	314	361	485	691	3719	723	526	534	227	315	159	1	0
Mud (mg/l)	164	466	451	573	981	1306	1501	2326	11657	2456	1931	1342	879	896	747	187	100
Total suspended solids (mg/l)	164	466	532	751	1295	1631	2153	3379	19524	3556	2457	1846	1052	1211	905	187	100

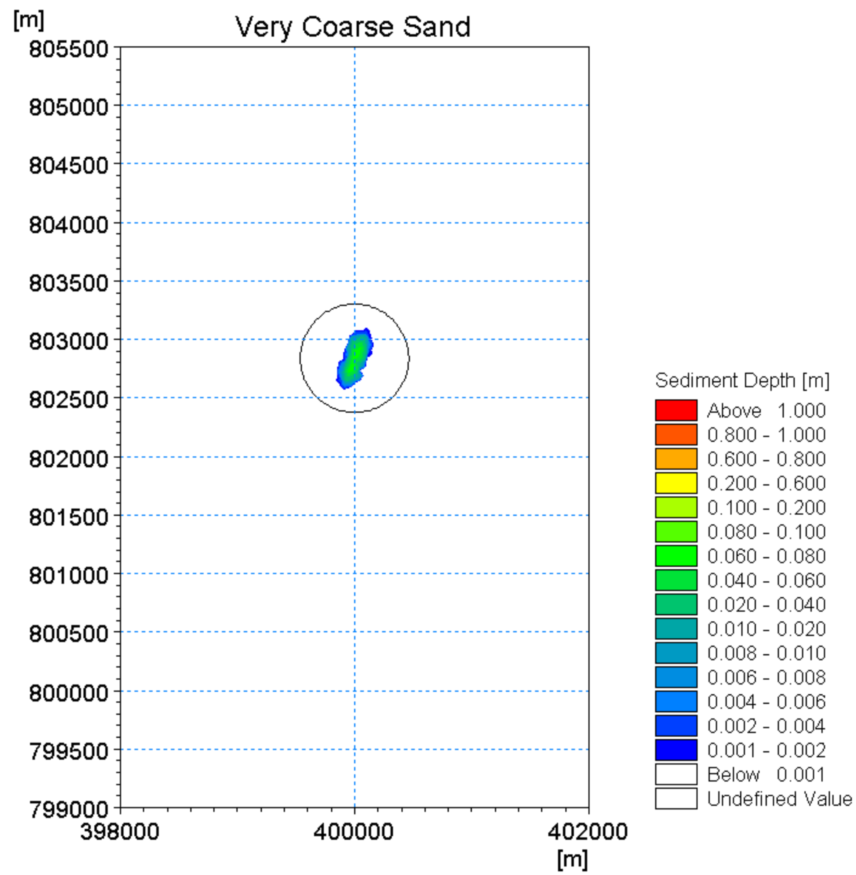
Appendix B Operational Phase Results

Figure B-1: Operational area and depth of redeposited sediment

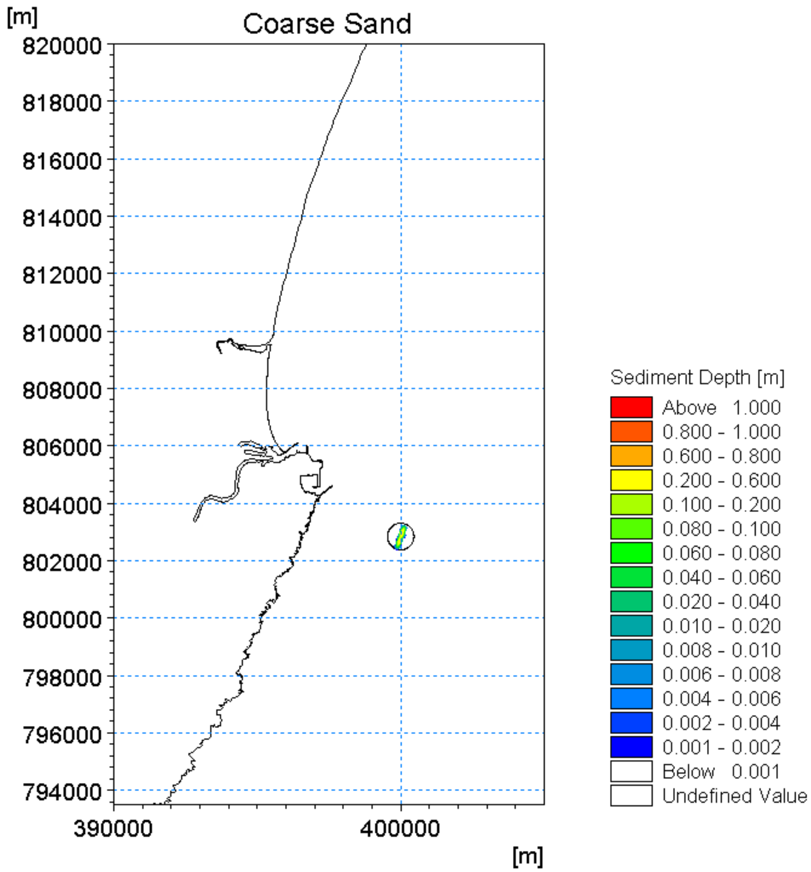
Over a Large Extent



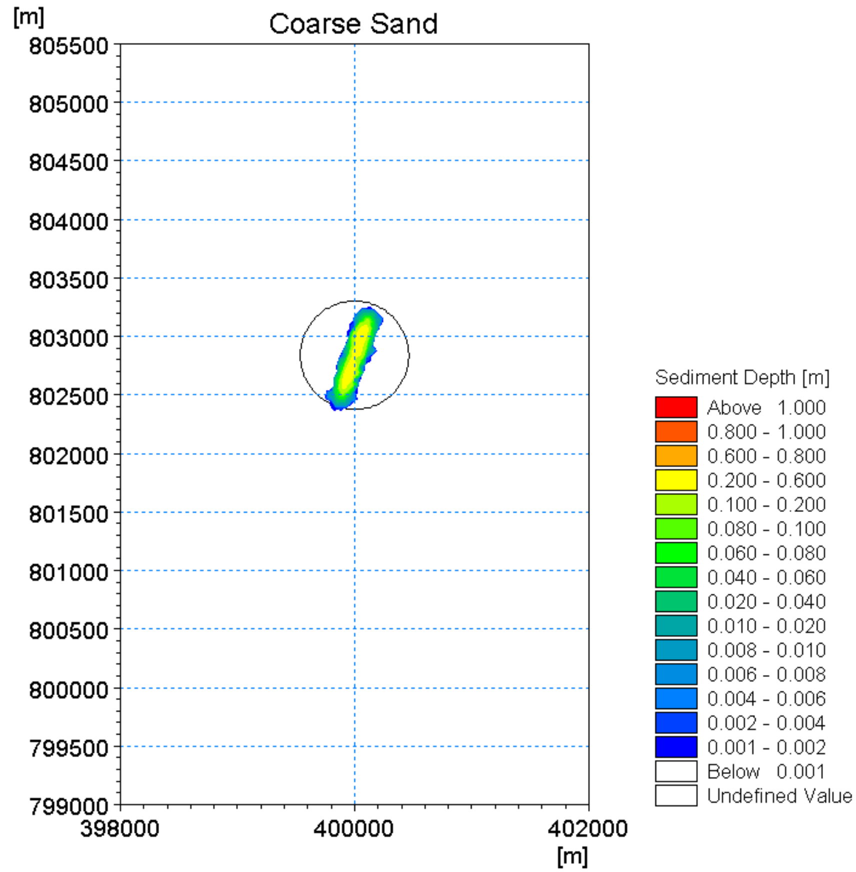
Local to the Disposal Site



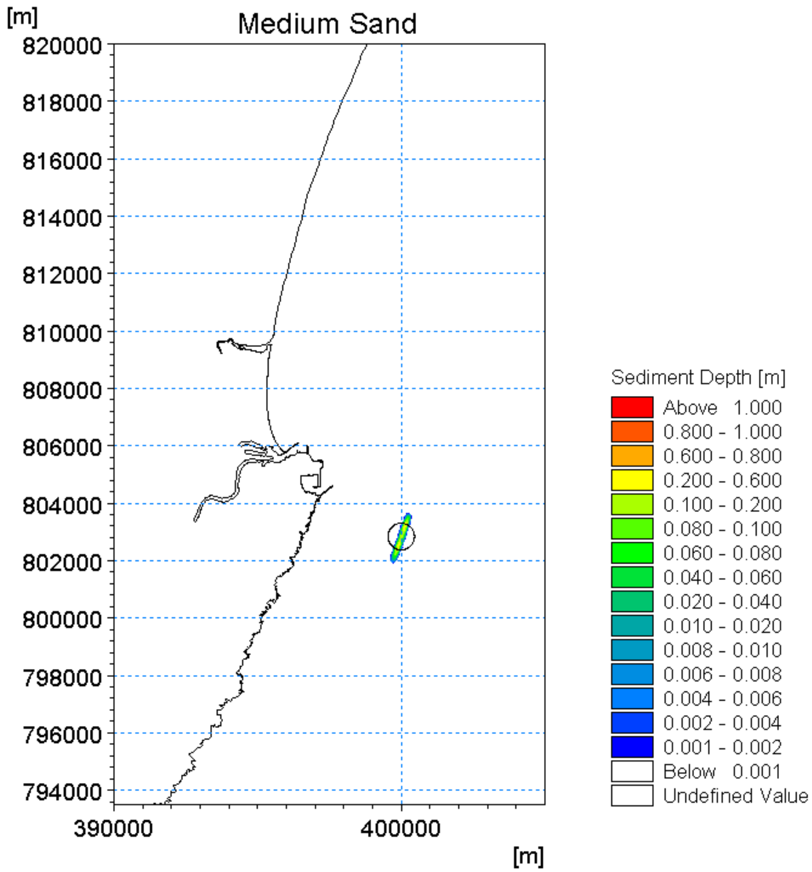
Over a Large Extent



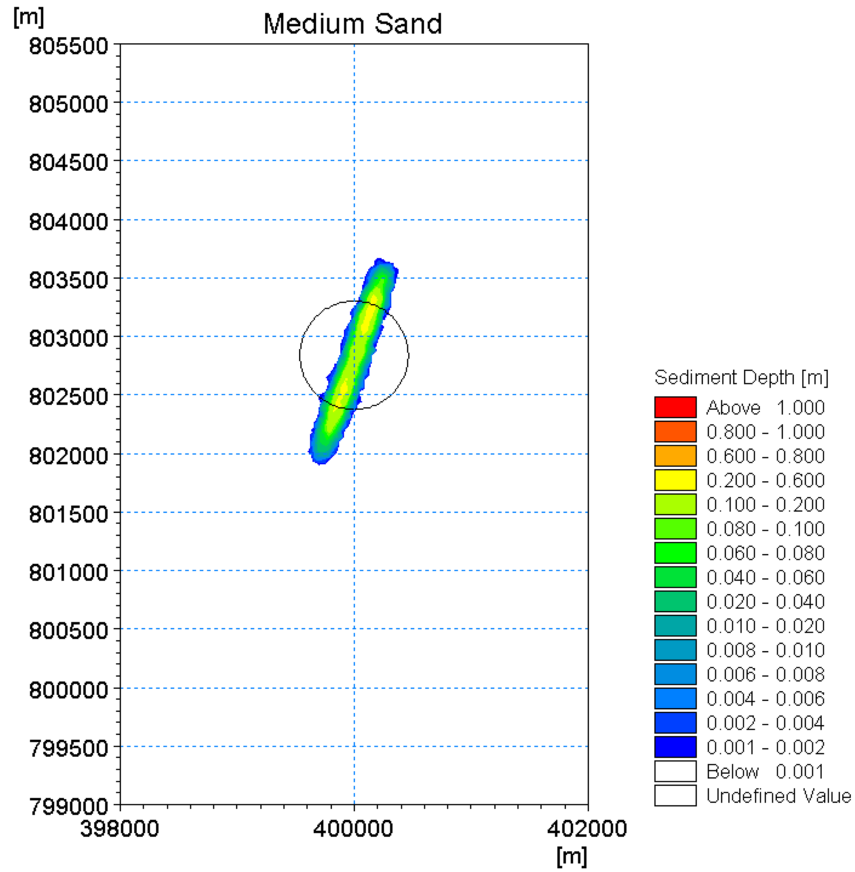
Local to the Disposal Site



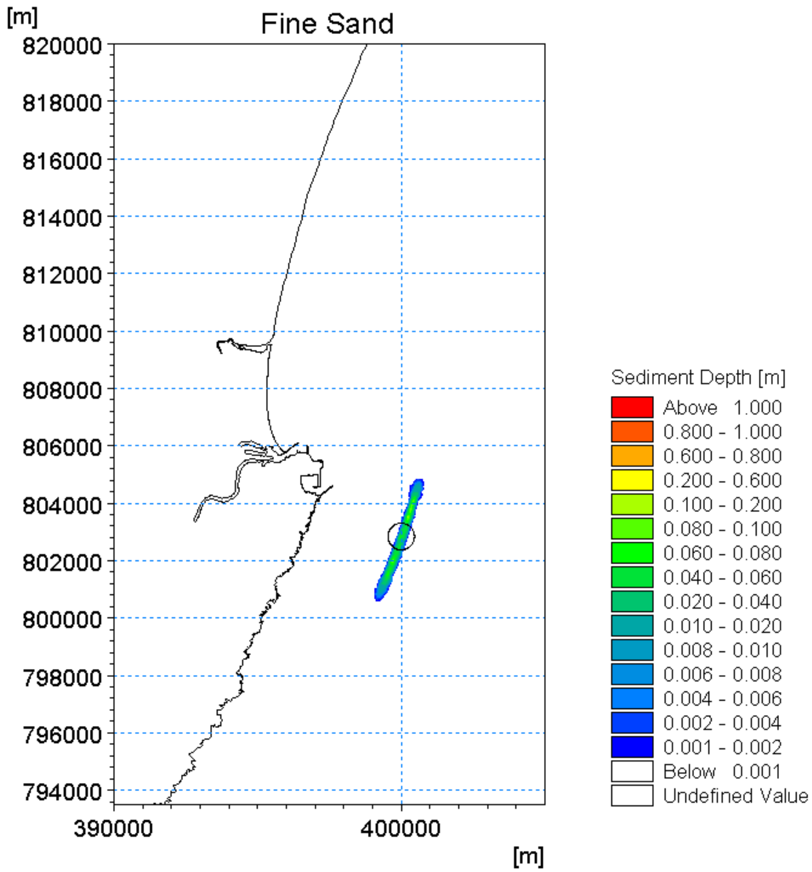
Over a Large Extent



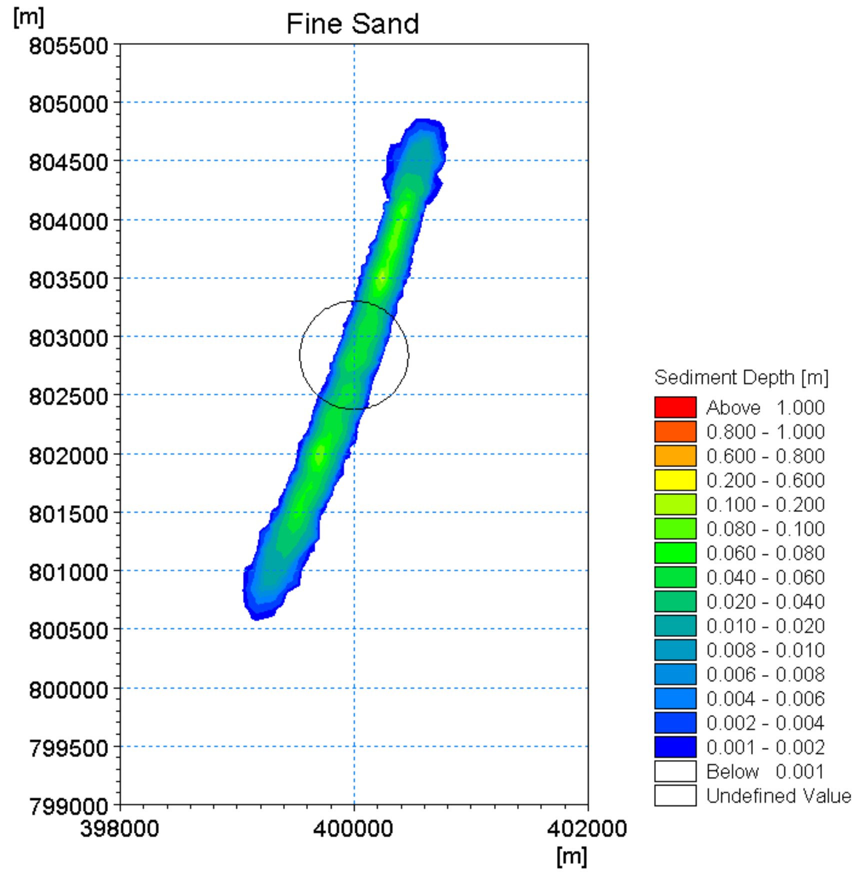
Local to the Disposal Site



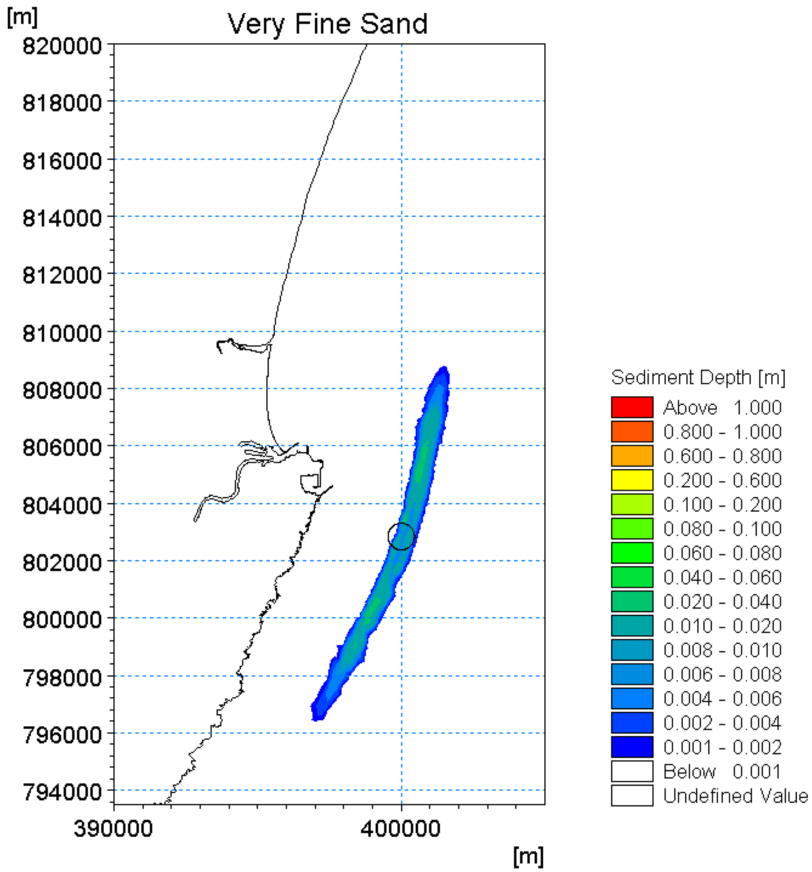
Over a Large Extent



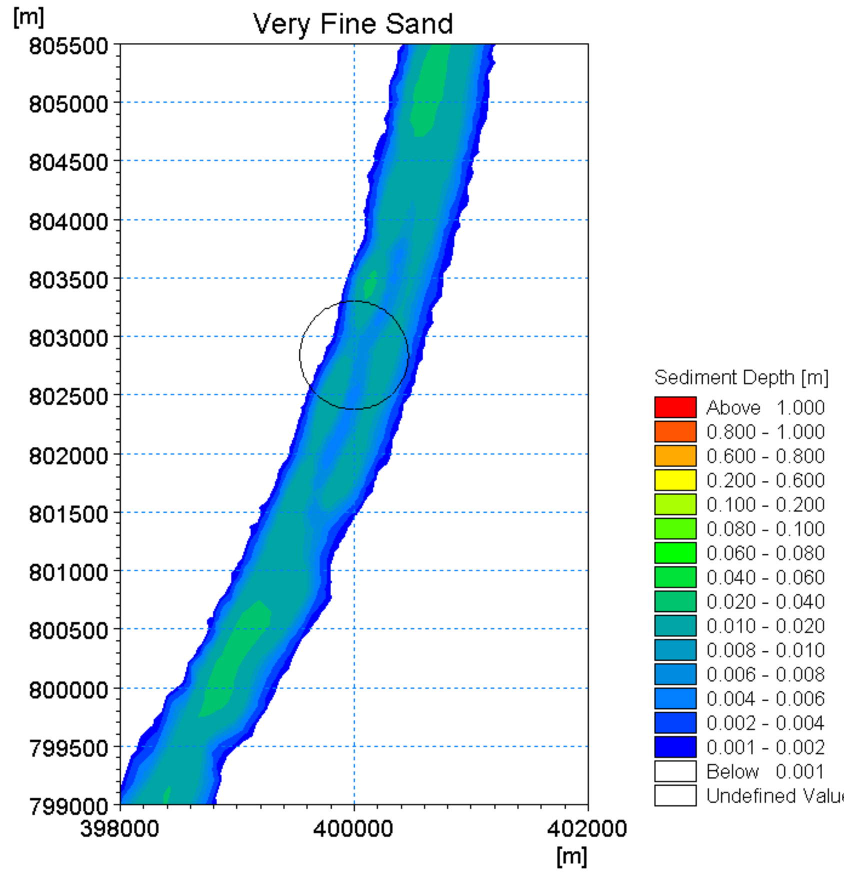
Local to the Disposal Site



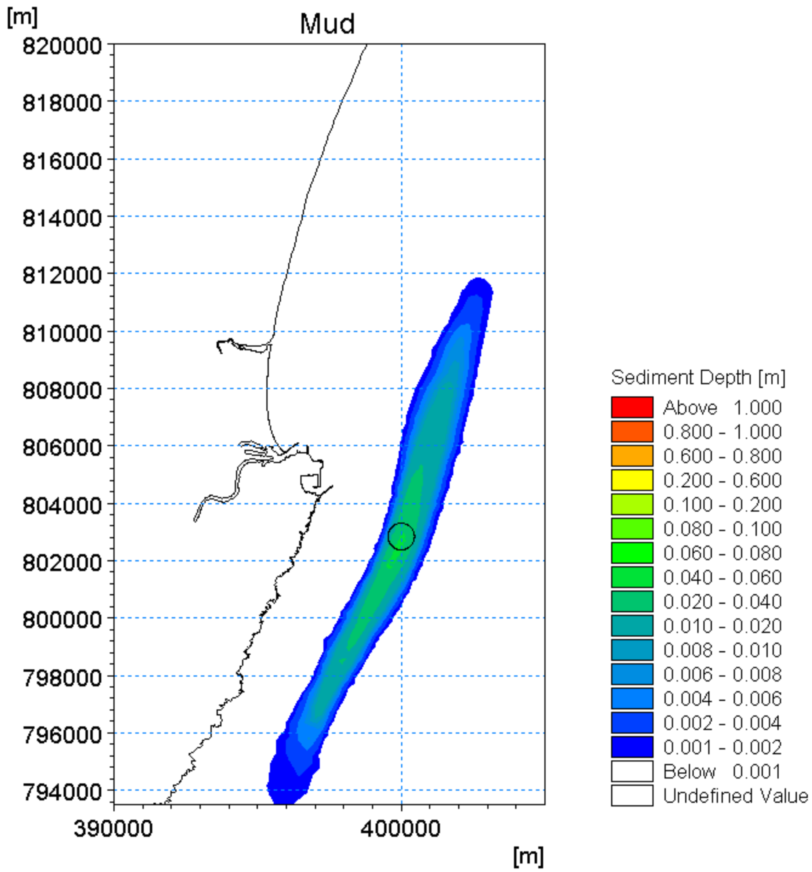
Over a Large Extent



Local to the Disposal Site



Over a Large Extent



Local to the Disposal Site

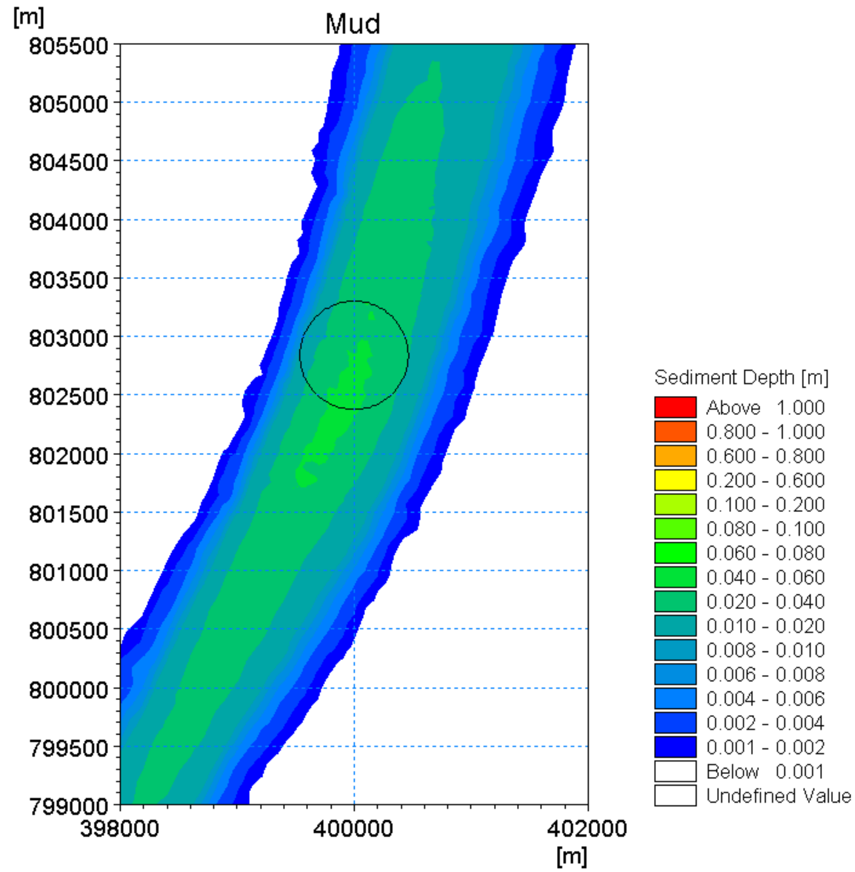
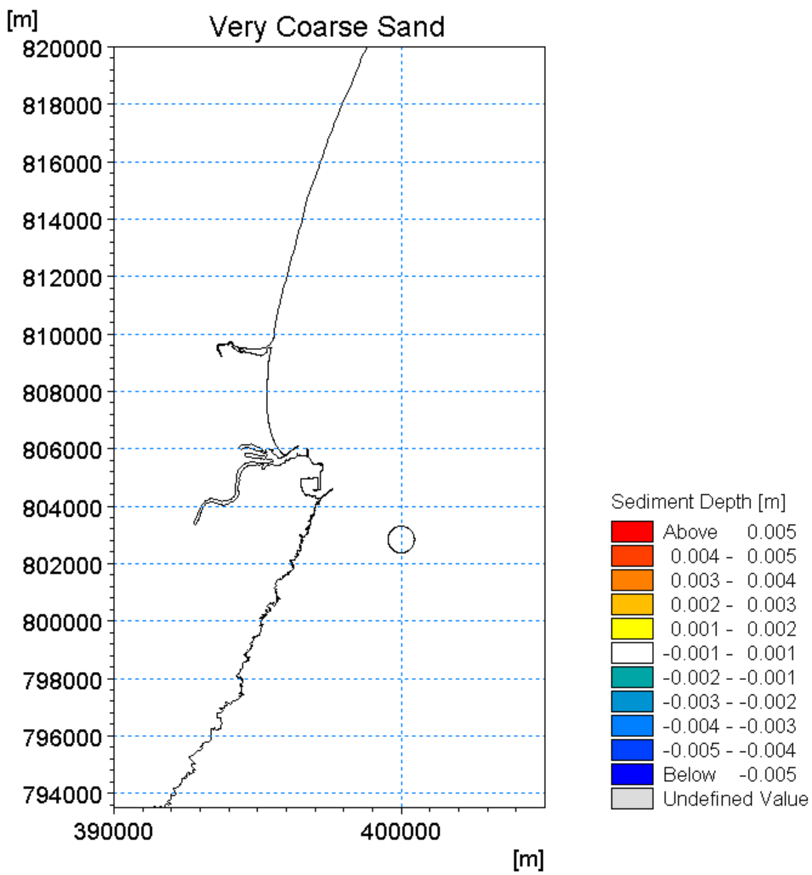
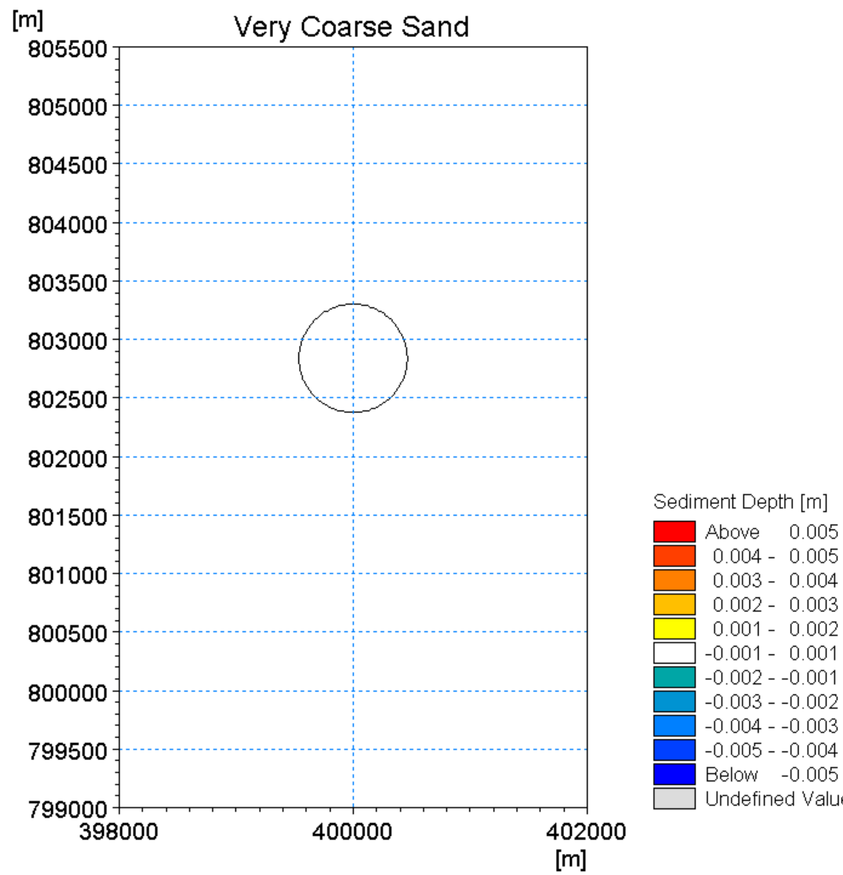


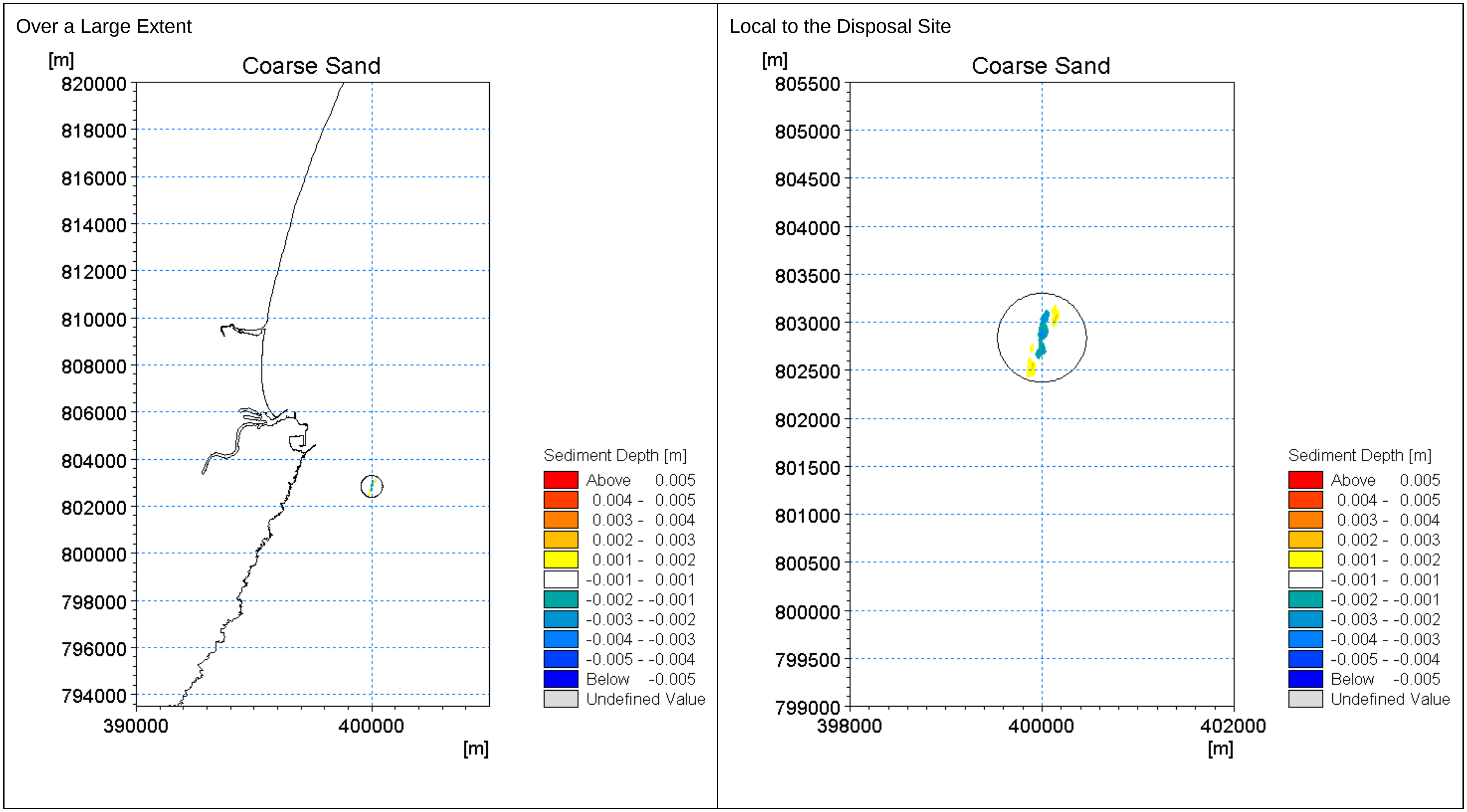
Figure B-2: Operational change in area and depth of redeposited sediment

Over a Large Extent

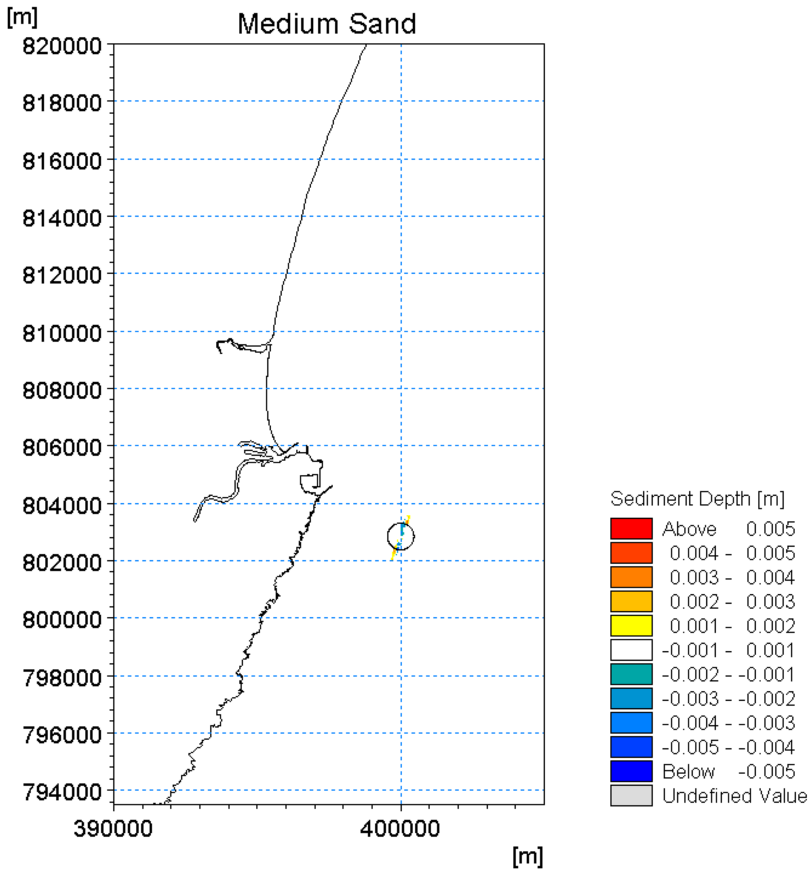


Local to the Disposal Site

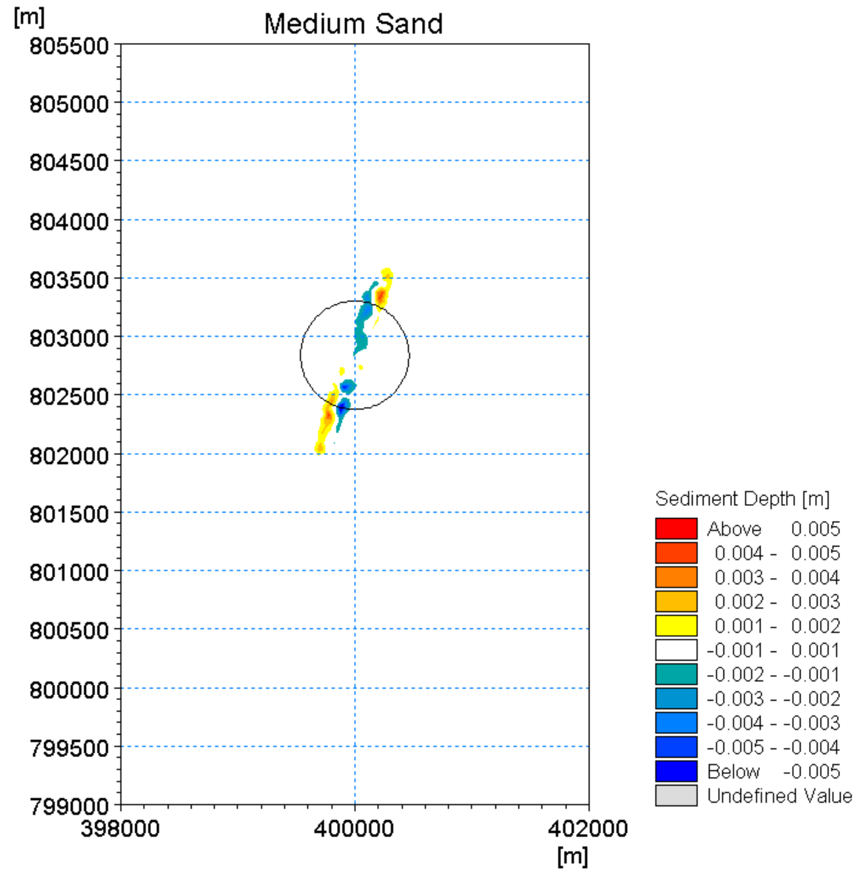



Over a Large Extent
Coarse Sand
[m]
820000
818000
816000
814000
812000
810000
808000
806000
804000
802000
800000
798000
796000
794000
390000
400000
[m]
Sediment Depth [m]
Above 0.005
0.004 - 0.005
0.003 - 0.004
0.002 - 0.003
0.001 - 0.002
-0.001 - 0.001
-0.002 - -0.001
-0.003 - -0.002
-0.004 - -0.003
-0.005 - -0.004
Below -0.005
Undefined Value
Local to the Disposal Site
Coarse Sand
[m]
805500
805000
804500
804000
803500
803000
802500
802000
801500
801000
800500
800000
799500
799000
398000
400000
402000
[m]
Sediment Depth [m]
Above 0.005
0.004 - 0.005
0.003 - 0.004
0.002 - 0.003
0.001 - 0.002
-0.001 - 0.001
-0.002 - -0.001
-0.003 - -0.002
-0.004 - -0.003
-0.005 - -0.004
Below -0.005
Undefined Value

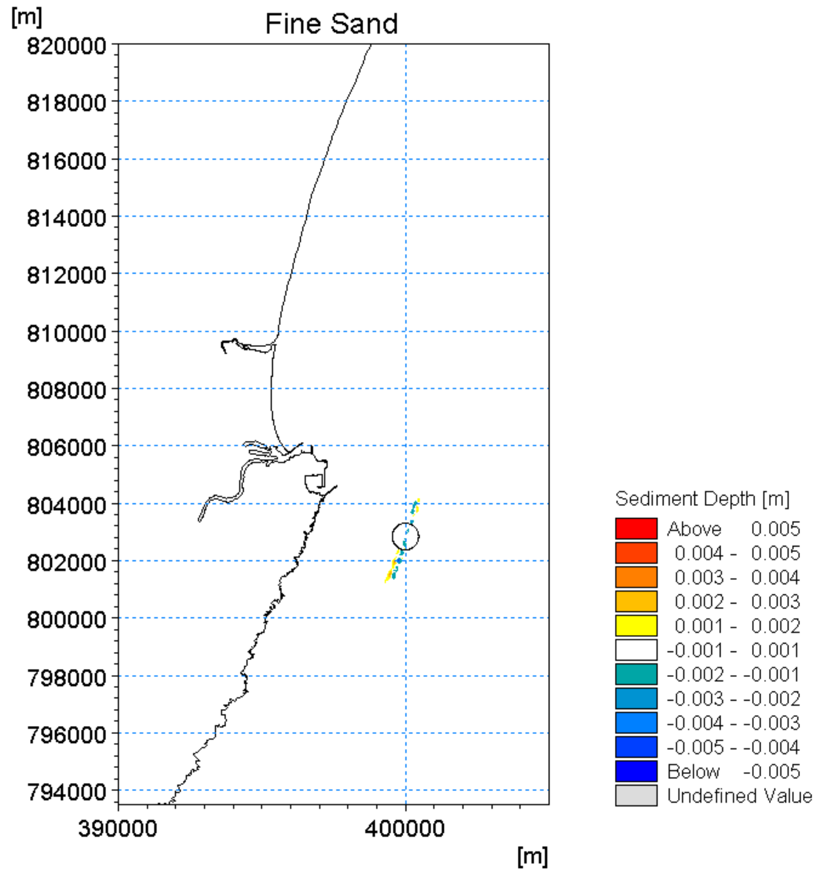
Over a Large Extent



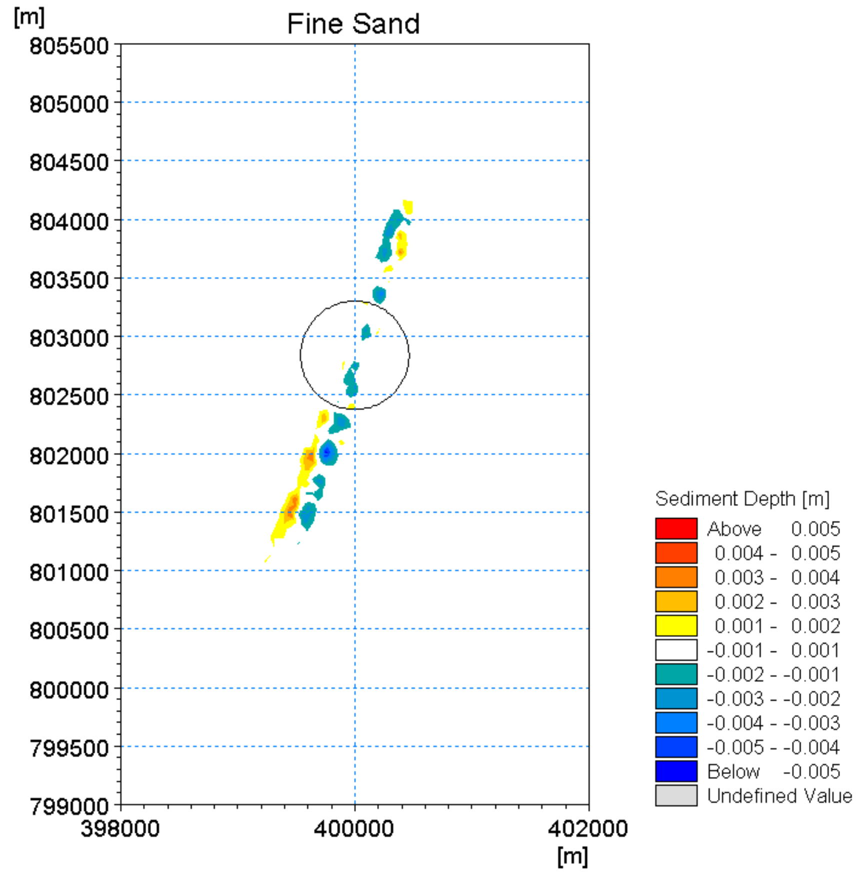
Local to the Disposal Site



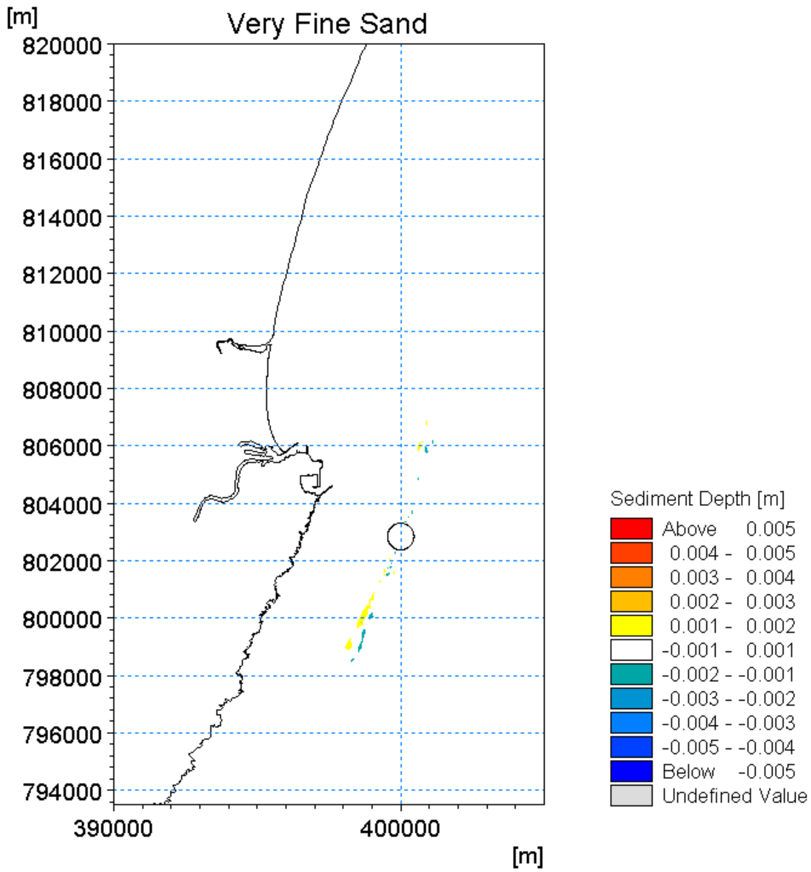
Over a Large Extent



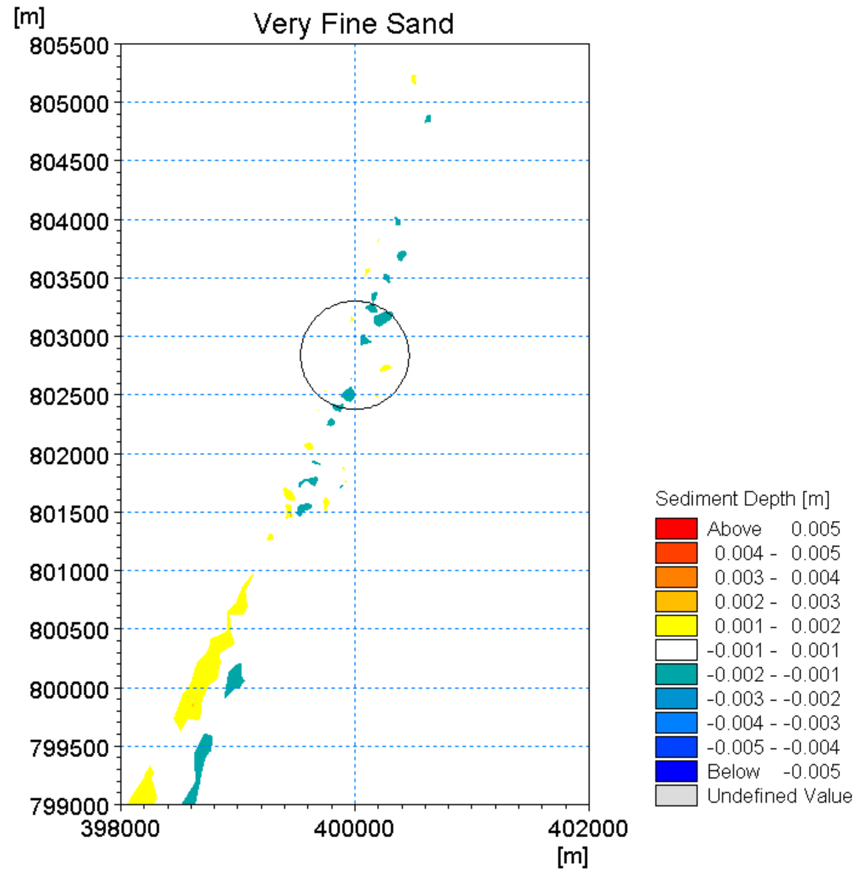
Local to the Disposal Site



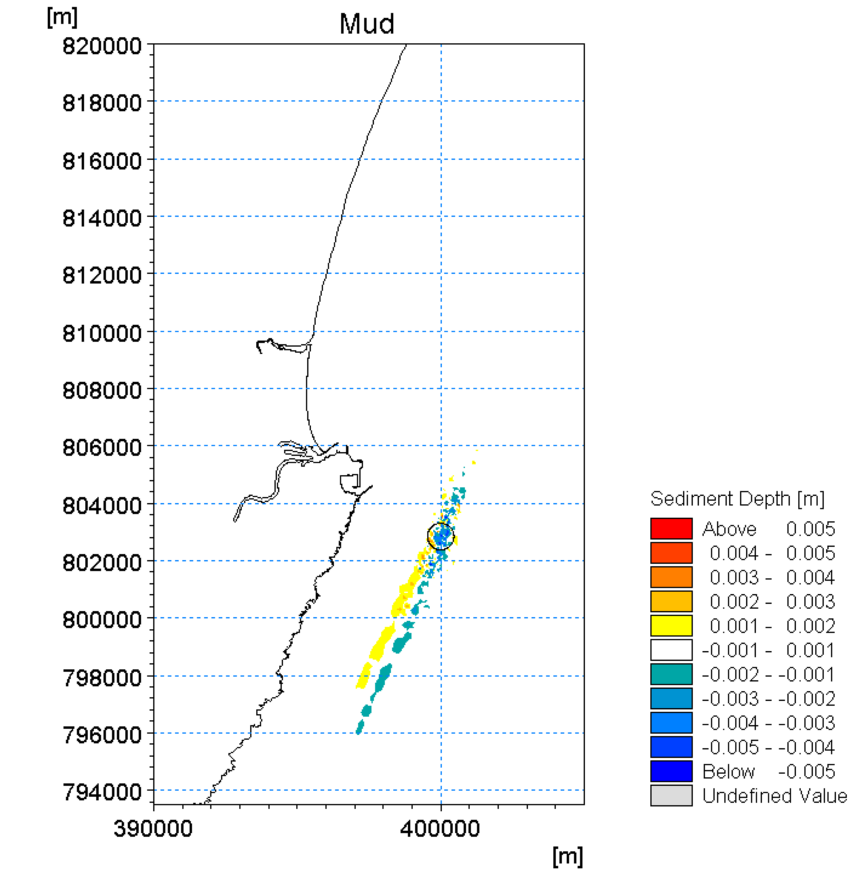
Over a Large Extent



Local to the Disposal Site



Over a Large Extent



Local to the Disposal Site

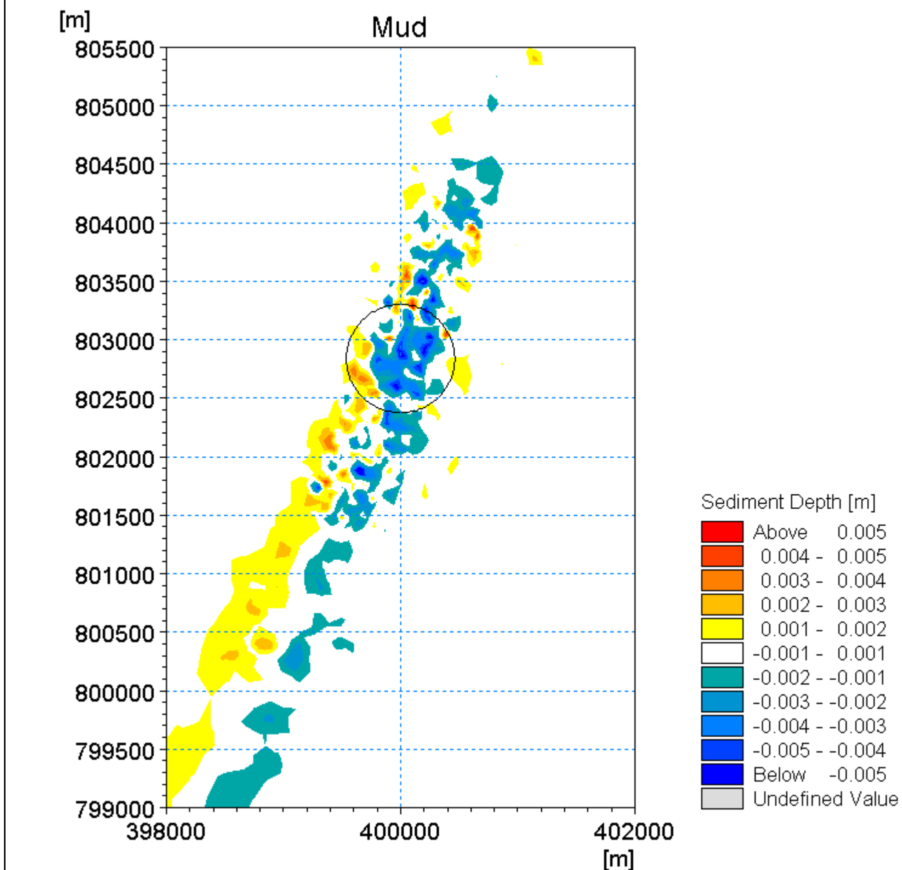


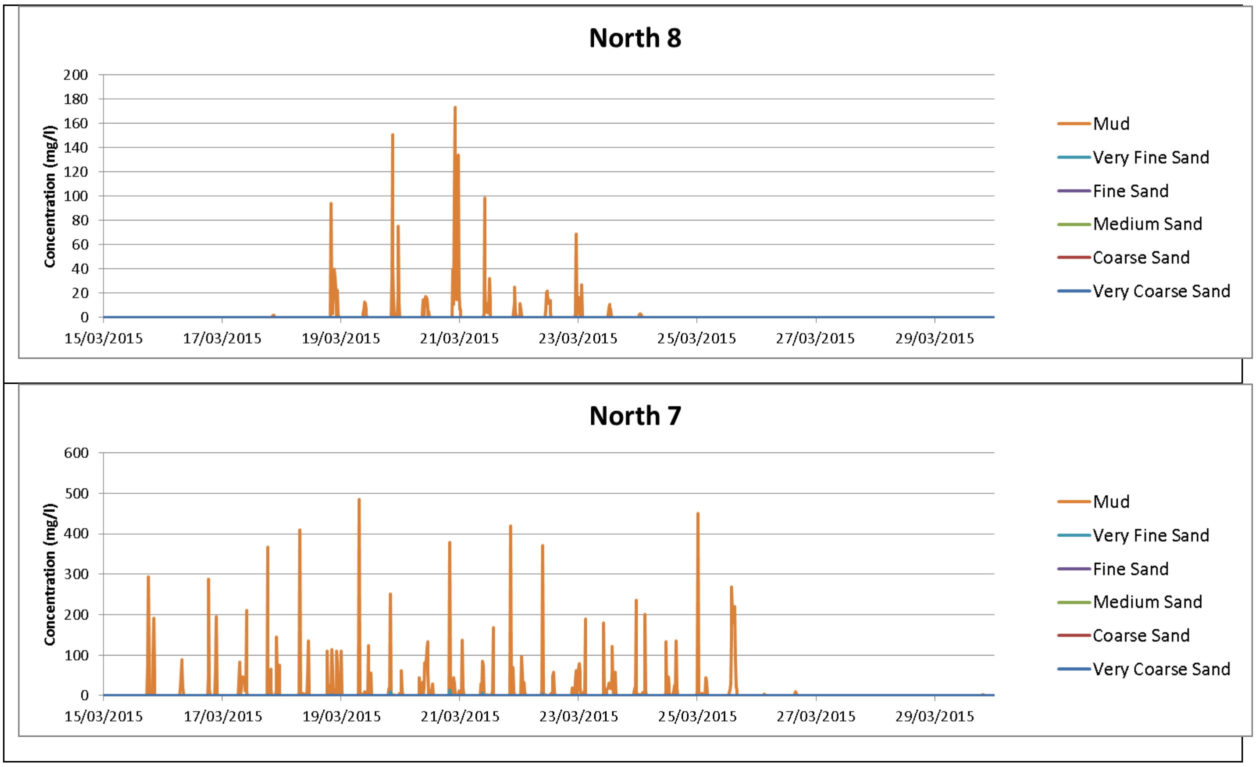
Table B-1: Operational depth of redeposited sediment

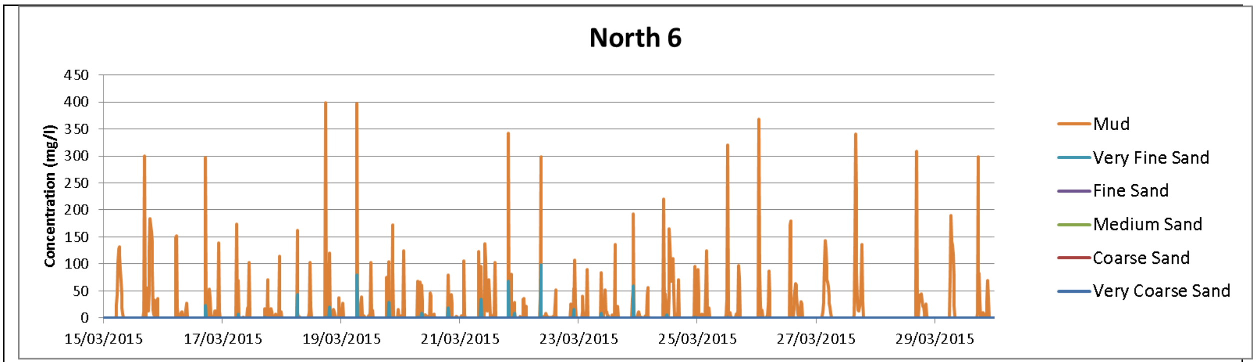
Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mm)	0	0	0	0	0	0	0	0	64	0	0	0	0	0	0	0	0
Coarse sand (mm)	0	0	0	0	0	0	0	0	254	7	0	0	0	0	0	0	0
Medium sand (mm)	0	0	0	0	0	0	88	236	166	221	16	0	0	0	0	0	0
Fine sand (mm)	0	0	0	0	18	82	108	50	60	45	89	67	10	0	0	0	0
Very fine sand (mm)	0	1	12	17	13	11	12	13	9	13	8	14	14	25	16	1	0
Mud (mm)	1	6	14	17	26	30	36	38	41	43	42	38	30	26	21	10	1
Total (mm)	1	7	26	34	57	123	244	337	594	329	155	119	54	51	37	11	1

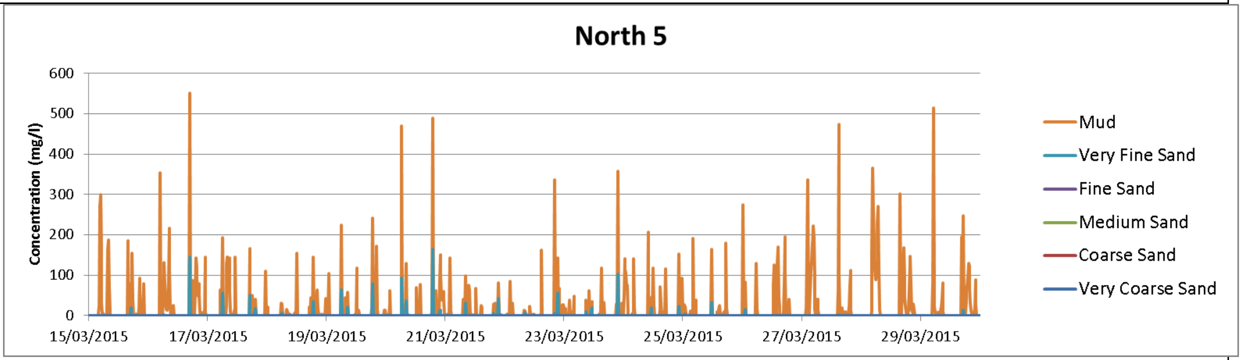
Table B-2: Change in depth of redeposited sediment

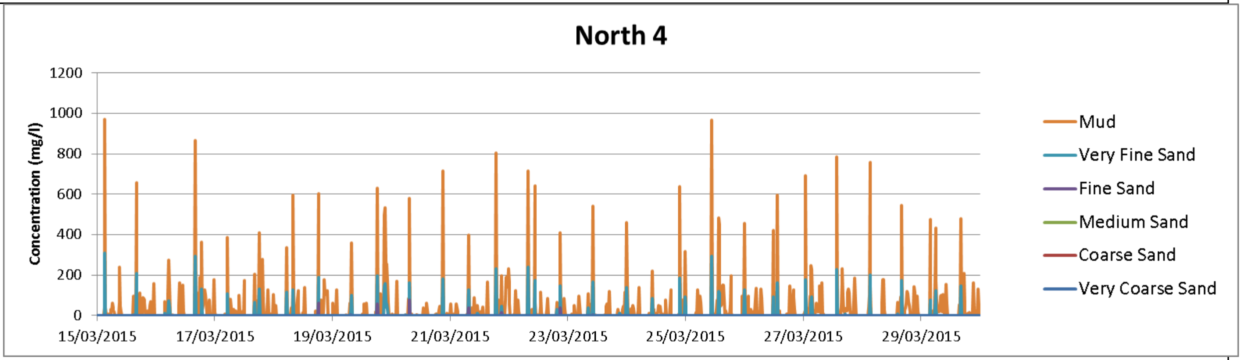
Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coarse sand (mm)	0	0	0	0	0	0	0	0	-2	1	0	0	0	0	0	0	0
Medium sand (mm)	0	0	0	0	0	0	2	0	-1	-1	1	0	0	0	0	0	0
Fine sand (mm)	0	0	0	0	0	-1	0	0	0	-1	-2	0	0	0	0	0	0
Very fine sand (mm)	0	0	0	-1	0	-1	-1	-1	0	-1	0	-1	0	1	1	0	0
Mud (mm)	0	0	0	0	-1	0	-2	-1	-4	1	1	0	-2	0	0	0	0
Total (mm)	0	0	-1	-1	-1	-2	-1	-2	-7	-1	0	-1	-2	1	1	0	0

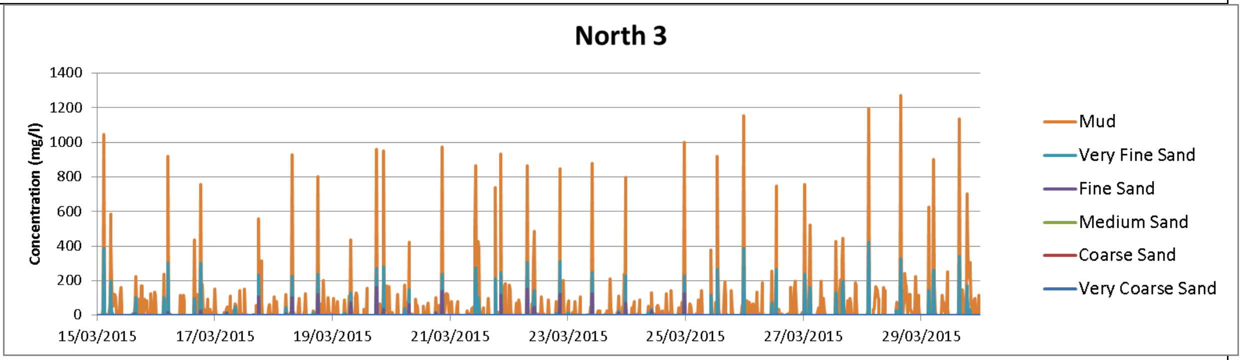
Figure B-3: Operational average suspended sediment concentrations

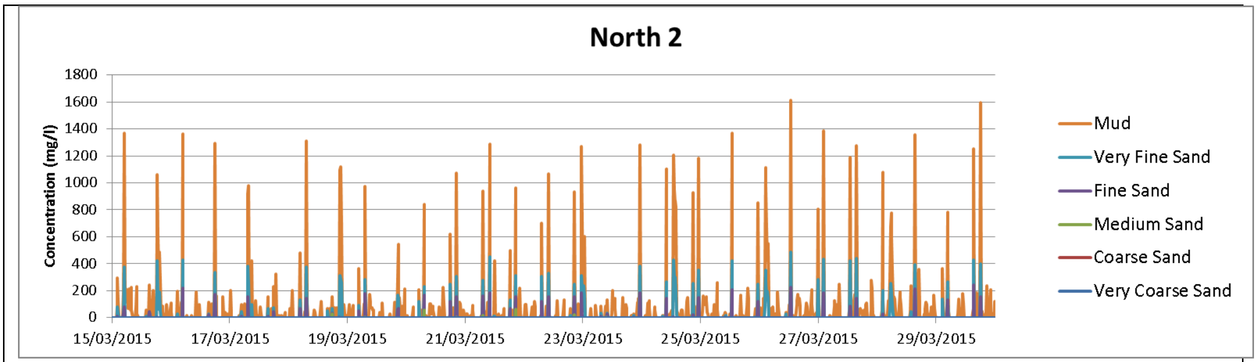


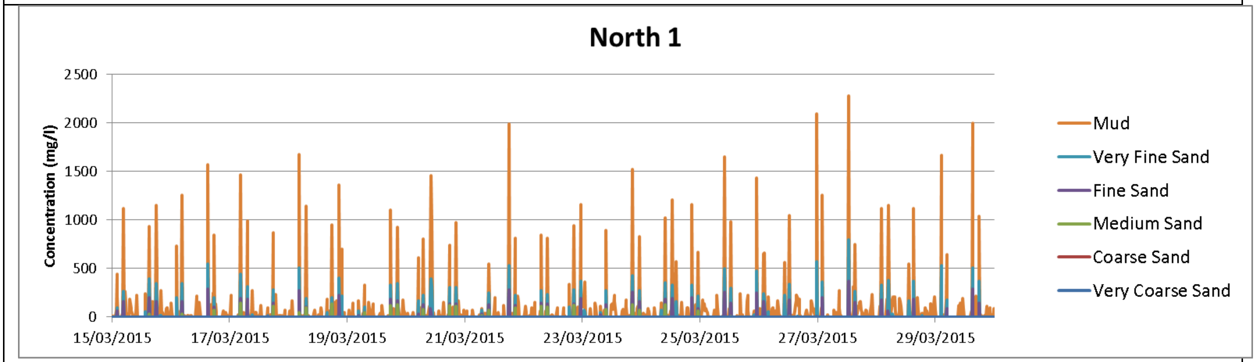

North 6
450
400
350
300
250
200
150
100
50
0
Concentration (mg/l)
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

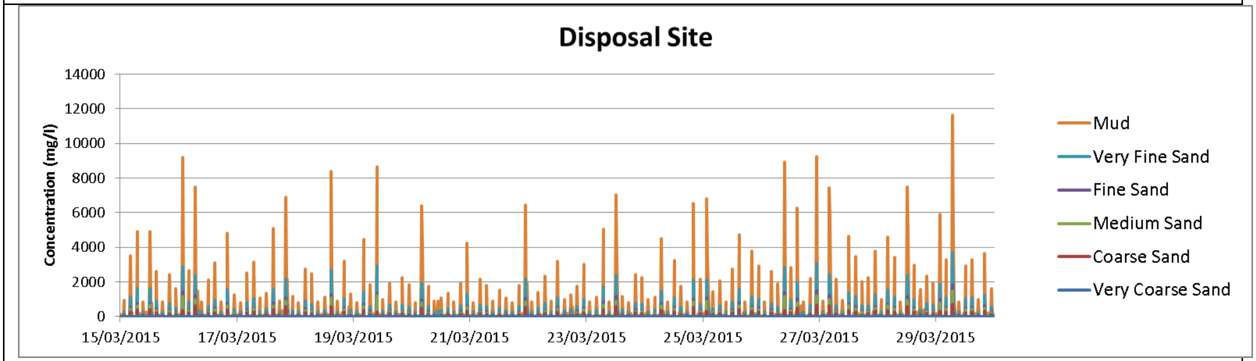

North 5
600
500
400
300
200
100
0
Concentration (mg/l)
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

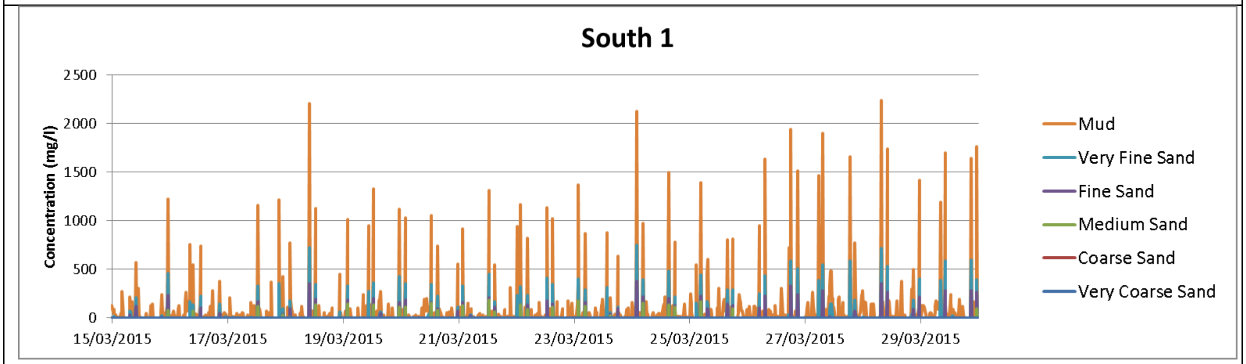

North 4
1200
1000
800
600
400
200
0
Concentration (mg/l)
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

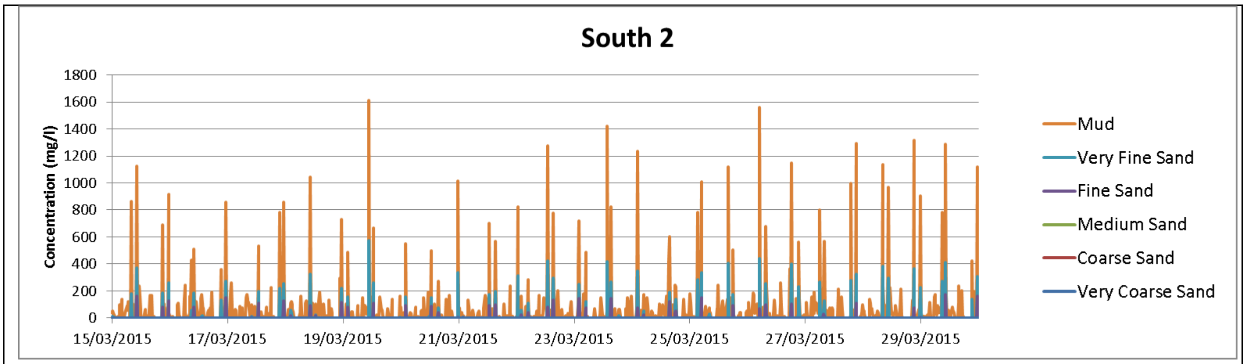

North 3
1400
1200
1000
800
600
400
200
0
Concentration (mg/l)
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

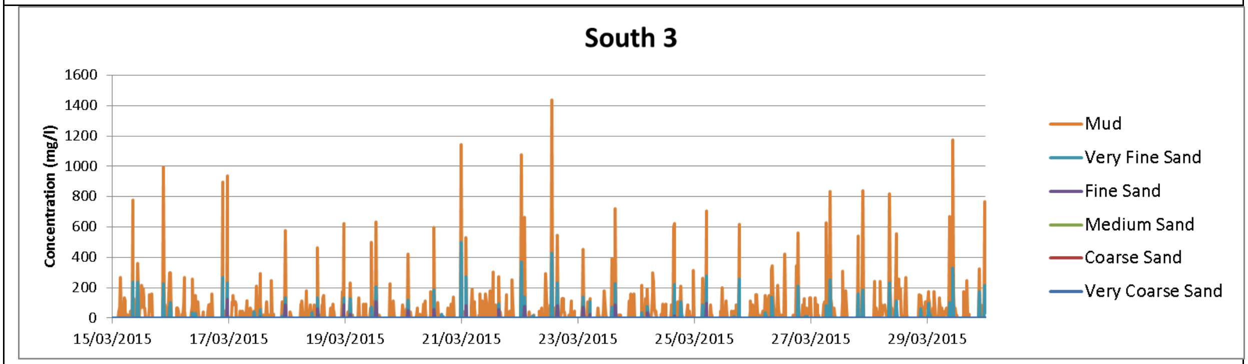

North 2
Concentration (mg/l)
1800
1600
1400
1200
1000
800
600
400
200
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

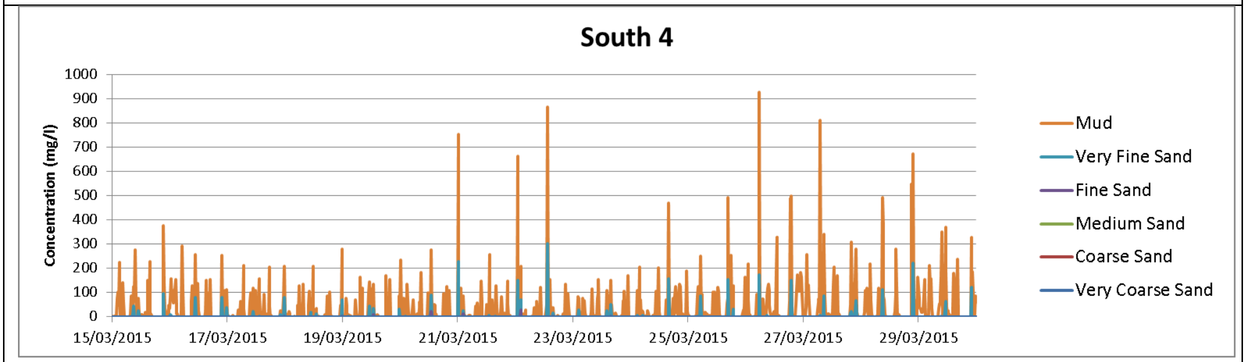

North 1
Concentration (mg/l)
2500
2000
1500
1000
500
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

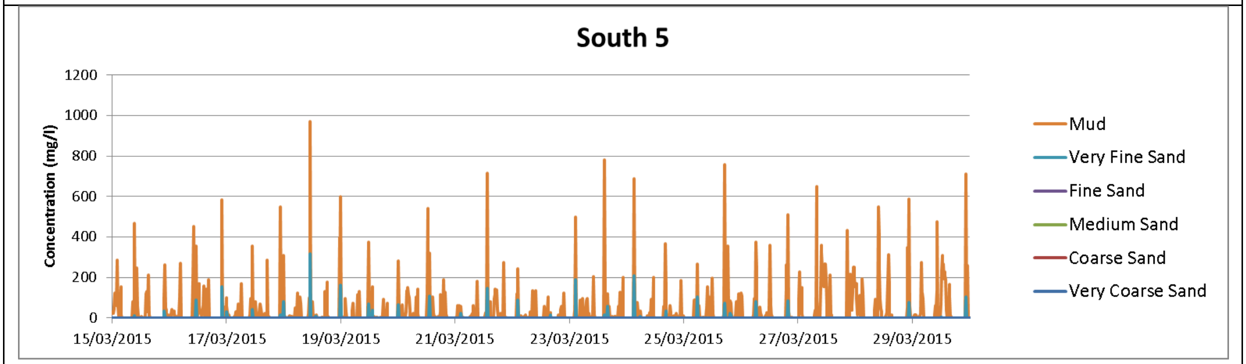

Disposal Site
Concentration (mg/l)
14000
12000
10000
8000
6000
4000
2000
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

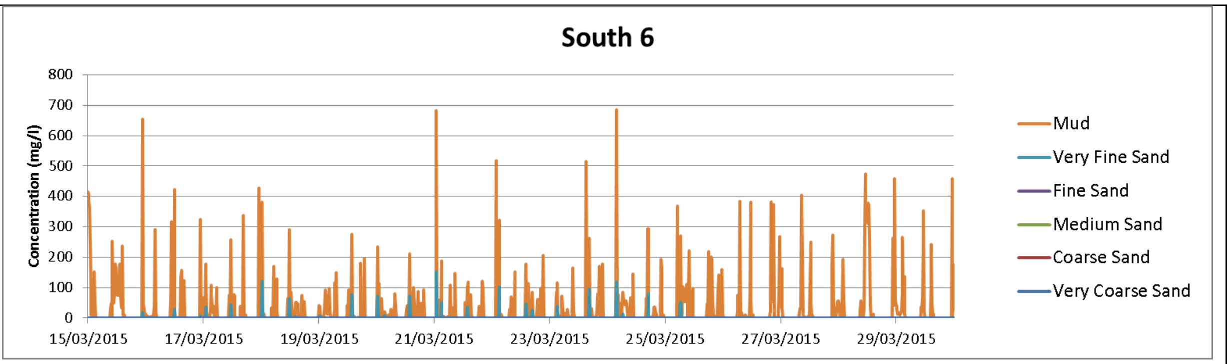

South 1
Concentration (mg/l)
2500
2000
1500
1000
500
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

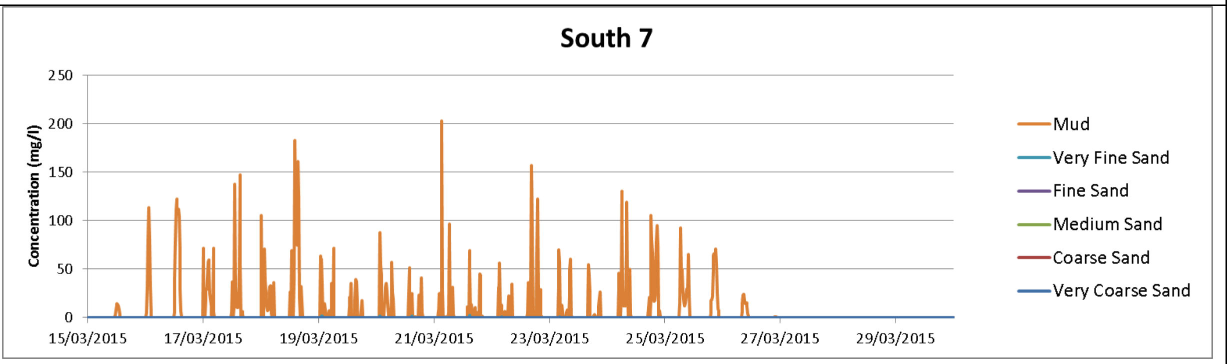

South 2
Concentration (mg/l)
1800
1600
1400
1200
1000
800
600
400
200
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


South 3
Concentration (mg/l)
1600
1400
1200
1000
800
600
400
200
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


South 4
Concentration (mg/l)
1000
900
800
700
600
500
400
300
200
100
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


South 5
Concentration (mg/l)
1200
1000
800
600
400
200
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


South 6
800
700
600
500
400
300
200
100
0
Concentration (mg/l)
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand


South 7
250
200
150
100
50
0
Concentration (mg/l)
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

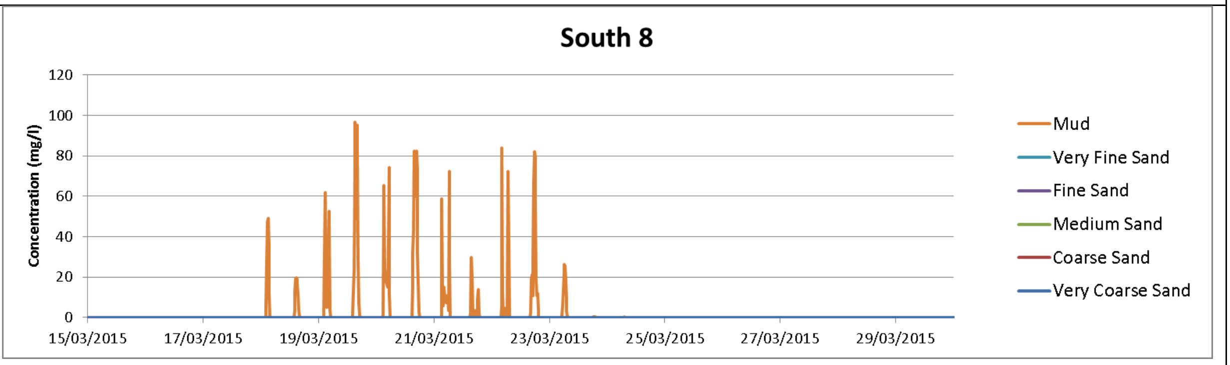

South 8
120
100
80
60
40
20
0
Concentration (mg/l)
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand

Figure B-4: Operational average suspended sediment concentration

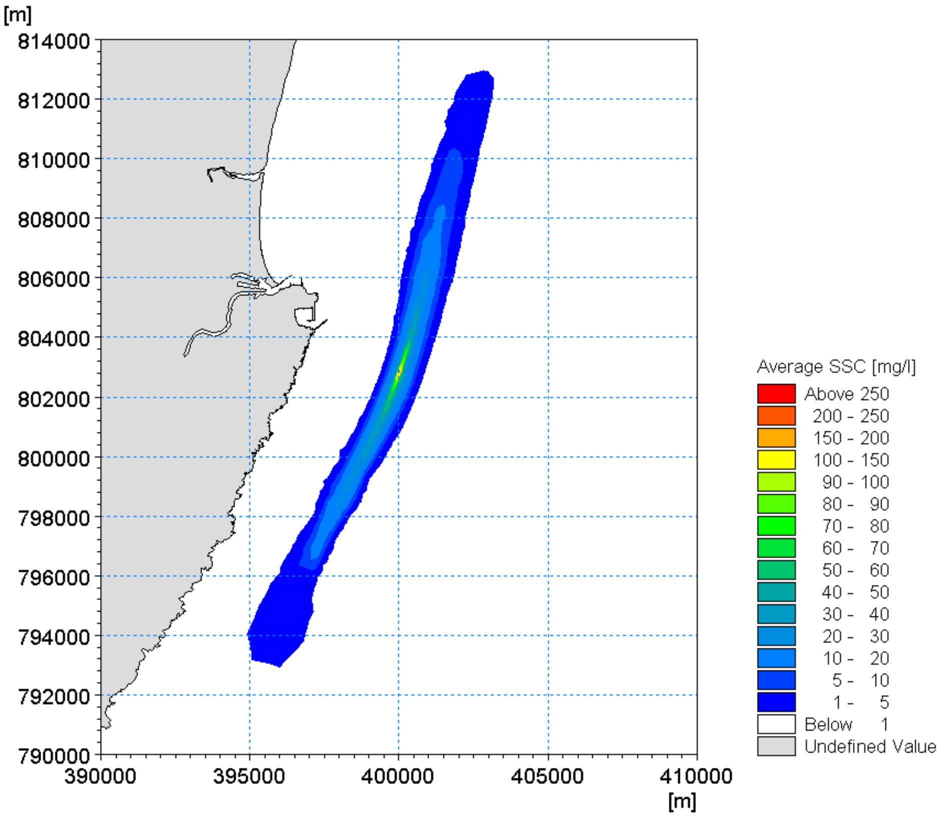


Figure B-5: Operational maximum suspended sediment concentration

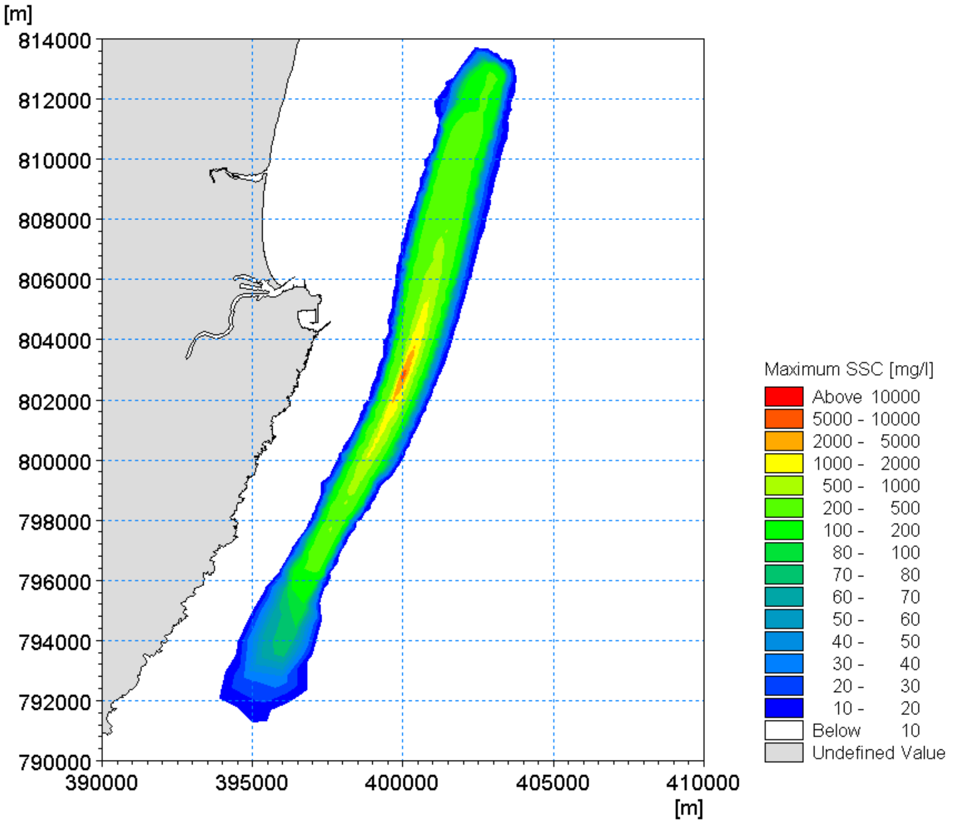


Table B-3: Operational average suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.6	35.5	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine sand (mg/l)	0.0	0.0	0.0	0.0	0.2	1.2	3.7	6.0	45.9	6.1	2.6	0.9	0.1	0.0	0.0	0.0	0.0
Very fine sand (mg/l)	0.0	0.0	0.4	0.9	5.0	7.5	13.7	14.6	96.2	14.9	10.1	6.6	2.3	1.8	1.0	0.0	0.0
Mud (mg/l)	1.5	9.0	12.8	18.2	32.6	43.1	66.3	70.1	323.6	75.8	58.3	44.2	31.7	33.2	28.2	7.3	2.2
Total suspended solids (mg/l)	1.5	9.1	13.2	19.1	37.8	51.7	83.9	92.3	522.7	98.8	71.0	51.7	34.0	35.0	29.3	7.3	2.2

Table B-4: Operational maximum suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	57	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	723	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	63	146	1490	183	1	0	0	0	0	0	0
Fine sand (mg/l)	0	0	0	0	76	164	245	368	1825	379	174	122	28	0	0	0	0
Very fine sand (mg/l)	0	13	98	163	309	422	489	799	3681	747	576	497	303	318	152	2	0
Mud (mg/l)	173	485	399	550	969	1272	1614	2277	11657	2241	1612	1438	928	972	686	203	97
Total suspended solids (mg/l)	173	485	477	694	1278	1867	2329	3443	19429	3311	2188	1867	1170	1289	835	203	97

Table B-5: Operational change in average suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	-0.2	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	0	0	-0.1	0	0	0	0	0	0	0	0
Fine sand(mg/l)	0	0	0	0	0	0	0	0.2	-0.6	0	0.1	0.1	0	0	0	0	0
Very fine sand (mg/l)	0	0	0	0	-0.3	0.1	-0.3	-0.1	-0.1	-0.2	0.1	0.2	0.2	0.2	0	0	0
Mud (mg/l)	0	0.1	-0.4	-0.6	-0.4	0.9	-0.3	0.4	-3	0.5	-1.4	-1.6	1.3	0.7	-0.3	0.9	-0.2
Total suspended solids (mg/l)	0	0.1	-0.5	-0.6	-0.6	1	-0.5	0.5	-3.8	0.2	-1.2	-1.3	1.5	1	-0.2	0.9	-0.2

Maximum Concentration

Table B-6: Operational change in maximum suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	-25	-2	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	-4	-3	8	6	0	0	0	0	0	0	0
Fine sand(mg/l)	0	0	0	0	6	16	7	6	-39	-30	-2	3	2	0	0	0	0
Very fine sand (mg/l)	0	-1	1	-15	-5	61	4	108	-38	24	50	-37	76	3	-7	1	0
Mud (mg/l)	9	19	-52	-23	-12	-34	113	-49	0	-215	-319	96	49	76	-61	16	-3
Total suspended solids (mg/l)	9	19	-55	-57	-17	236	176	64	-95	-245	-269	21	118	78	-70	16	-3

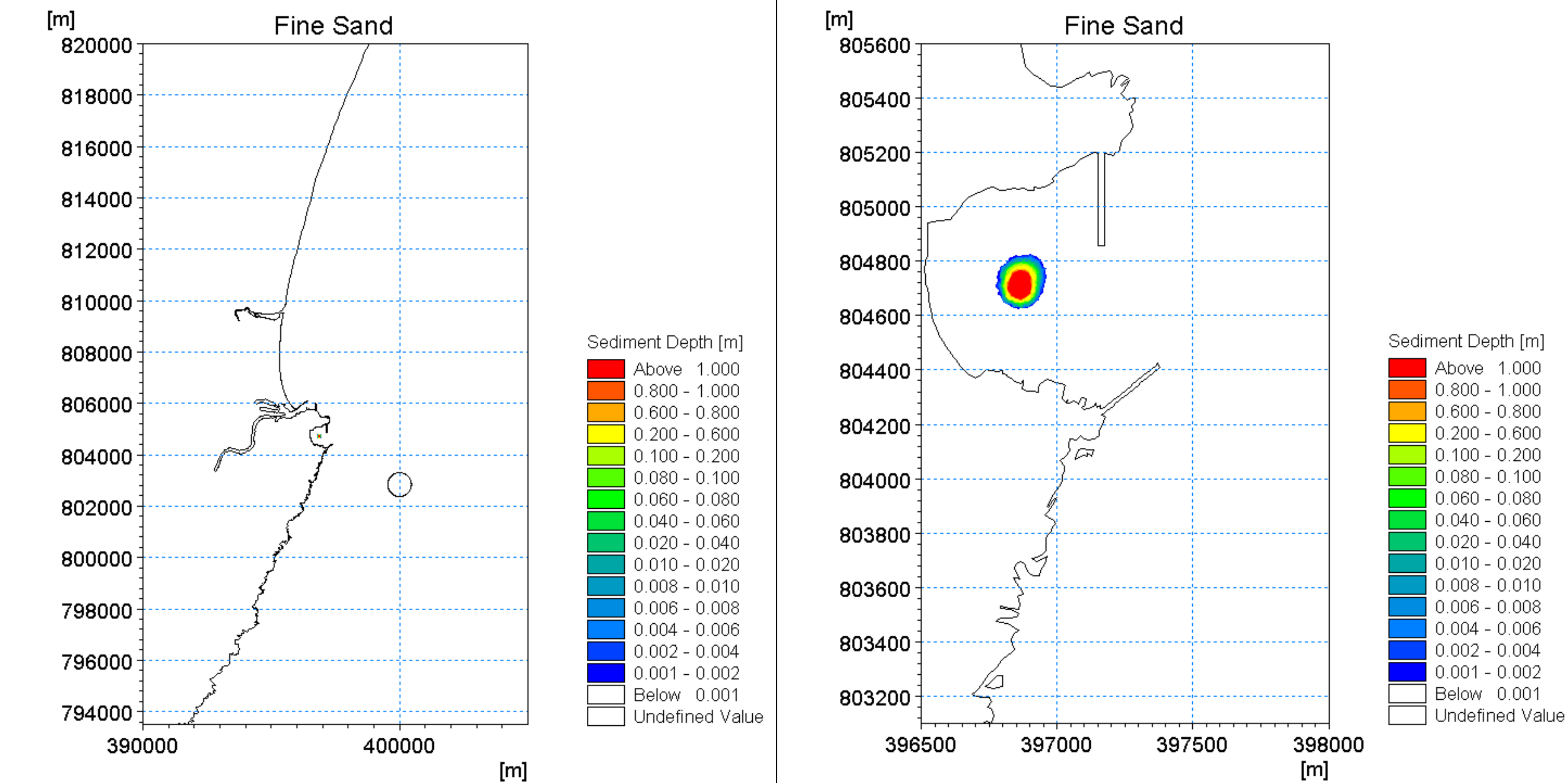
Appendix C Construction Phase Results

C.1 Trailing Suction Hopper Dredger

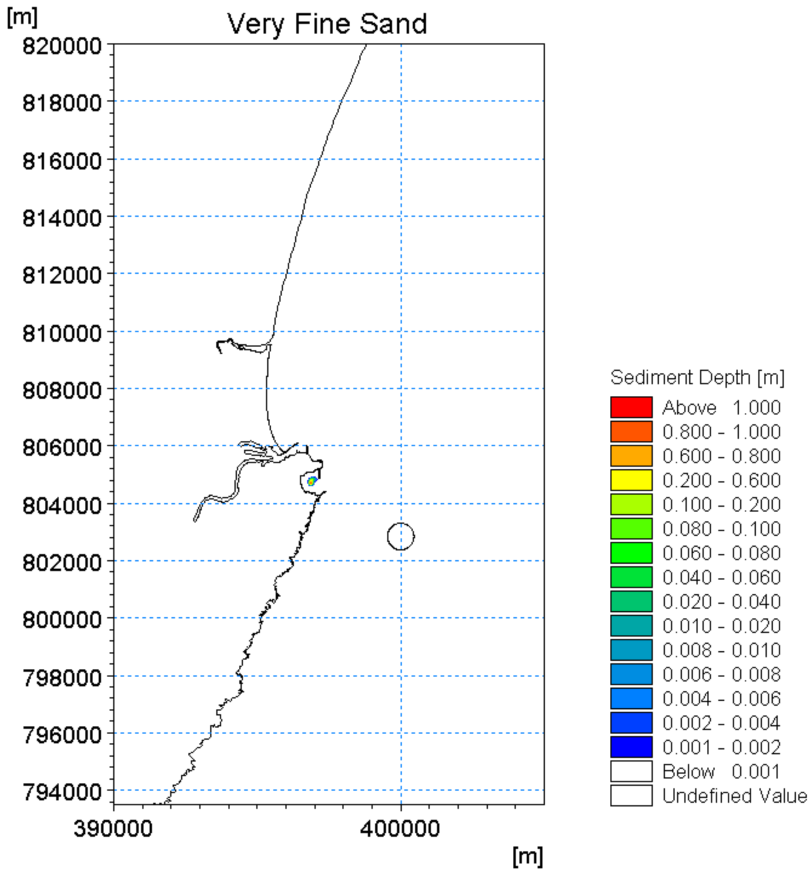
Figure C-1: TSHD overspill area and depth of redeposited sediment

Over a Large Extent

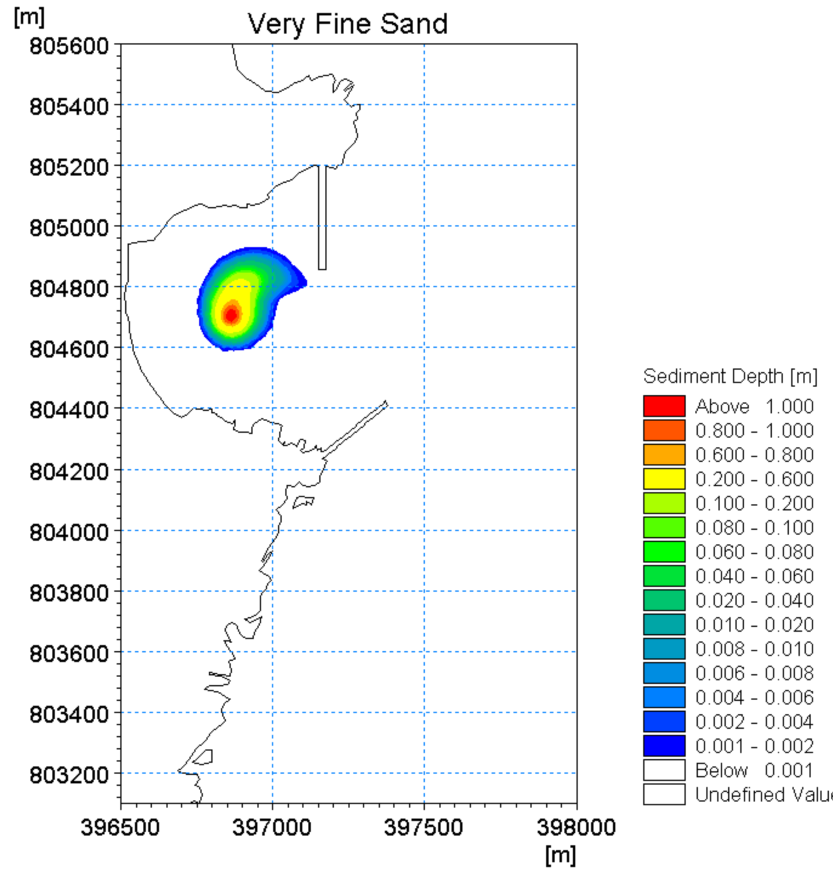
Local to the Development



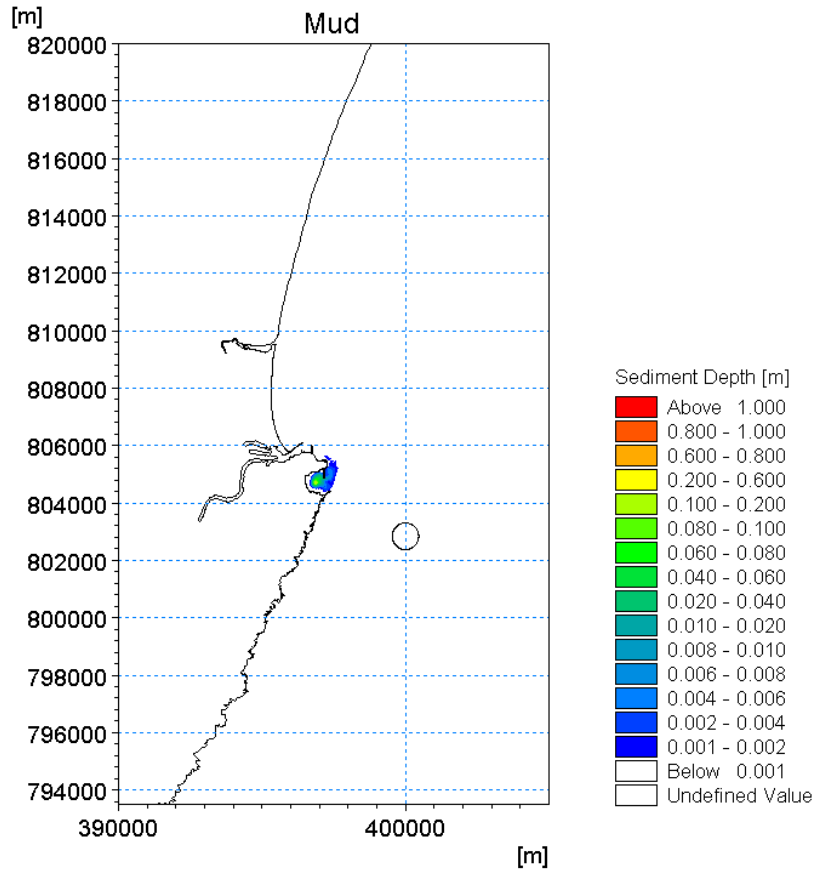
Over a Large Extent



Local to the Development



Over a Large Extent



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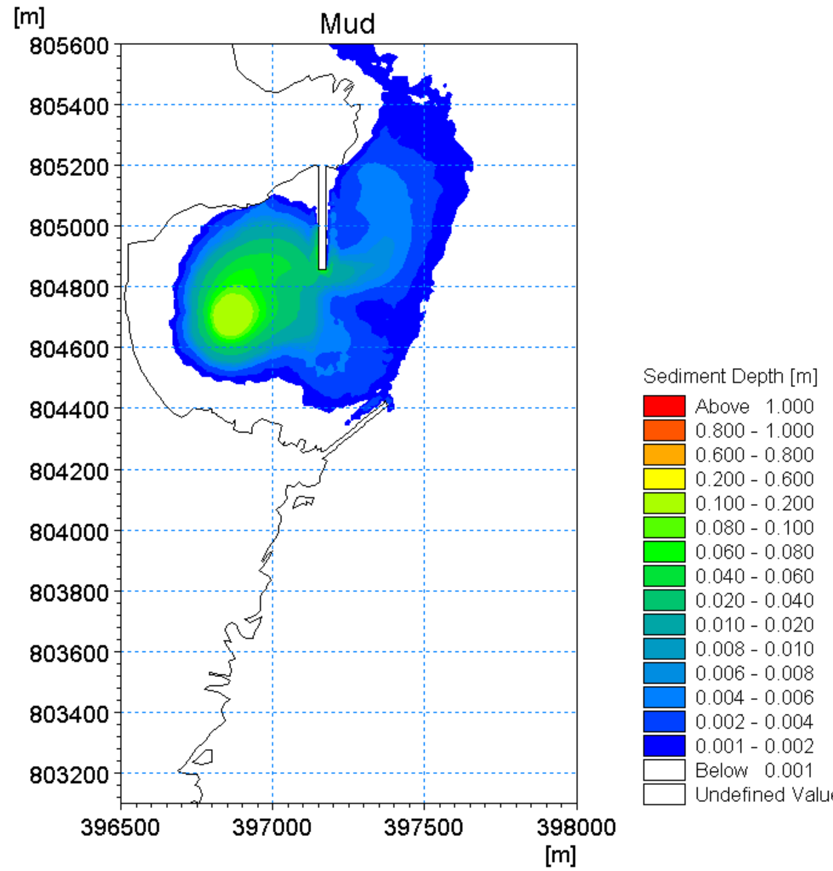


Figure C-2: TSHD overspill redeposited sediment area and depth over whole dredging duration

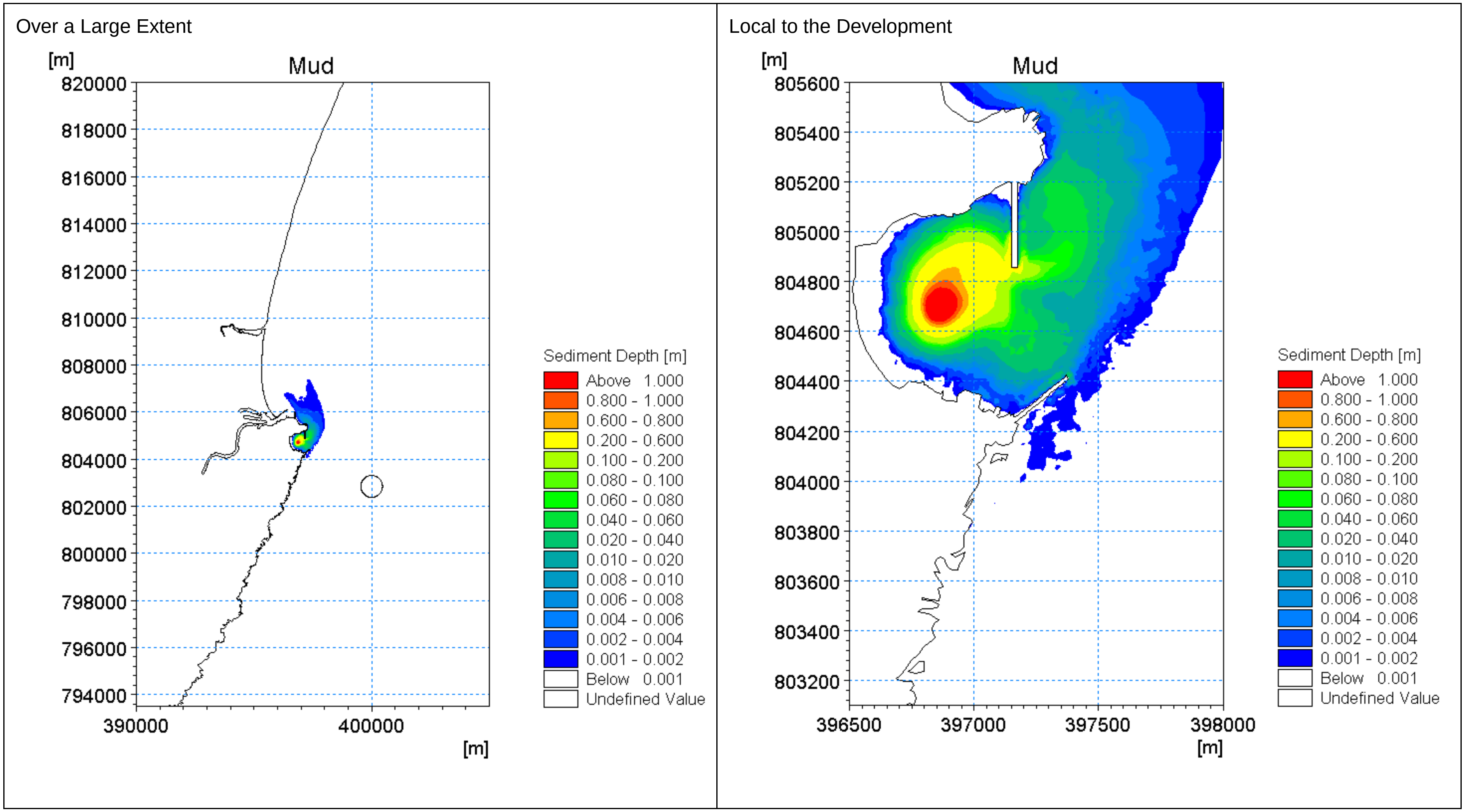
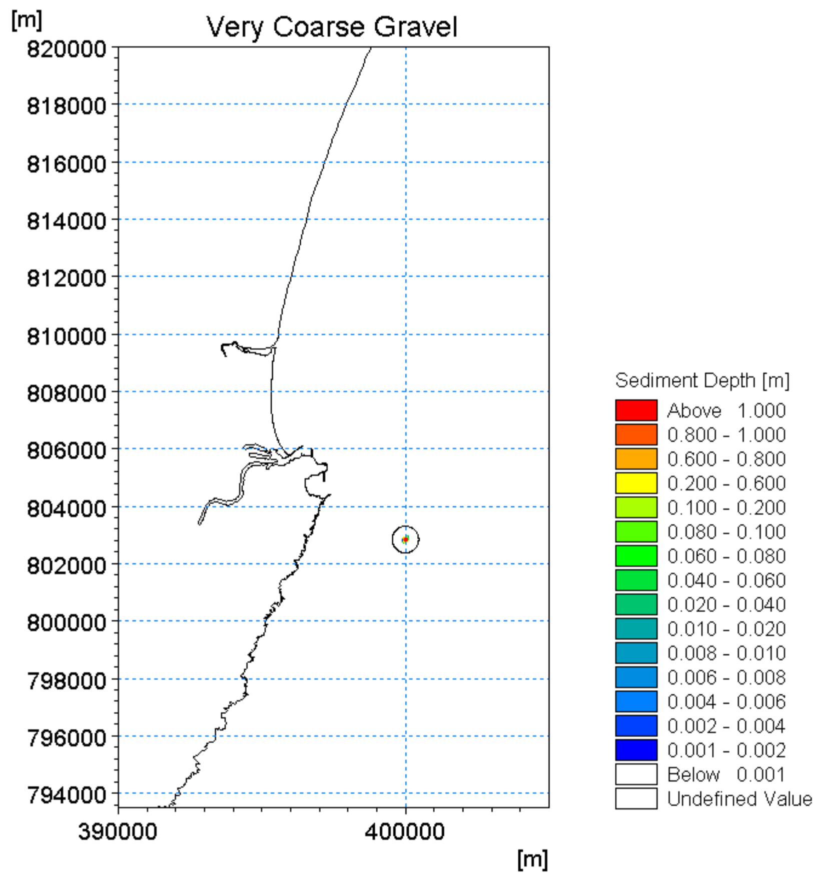
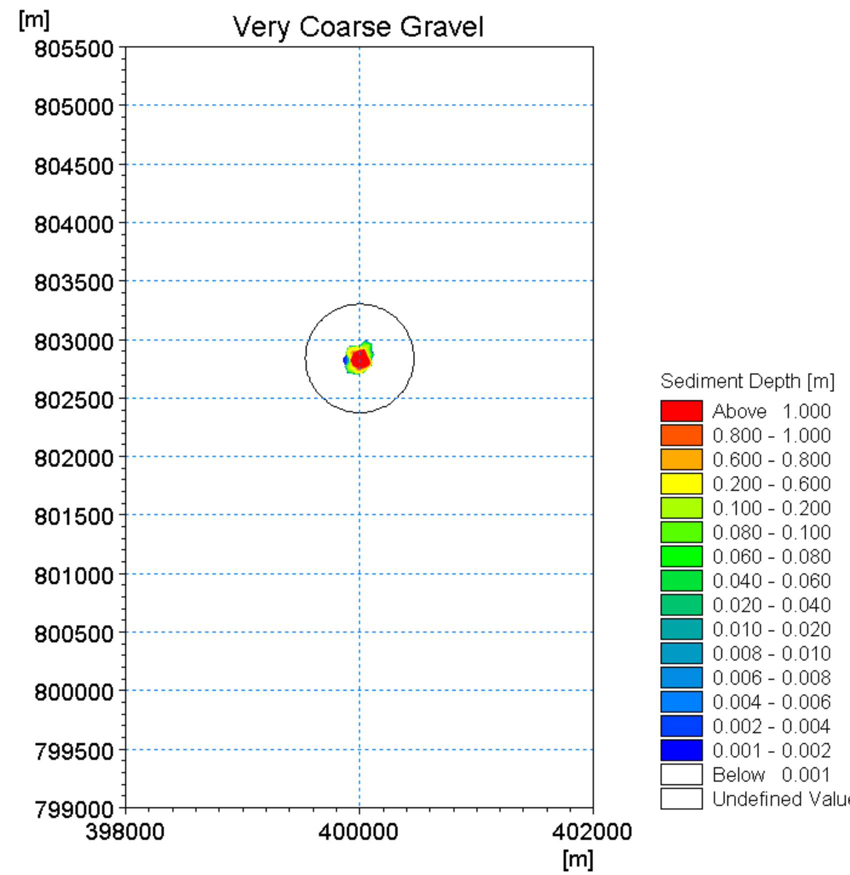


Figure C-3: TSHD disposal site area and depth of redeposited sediment

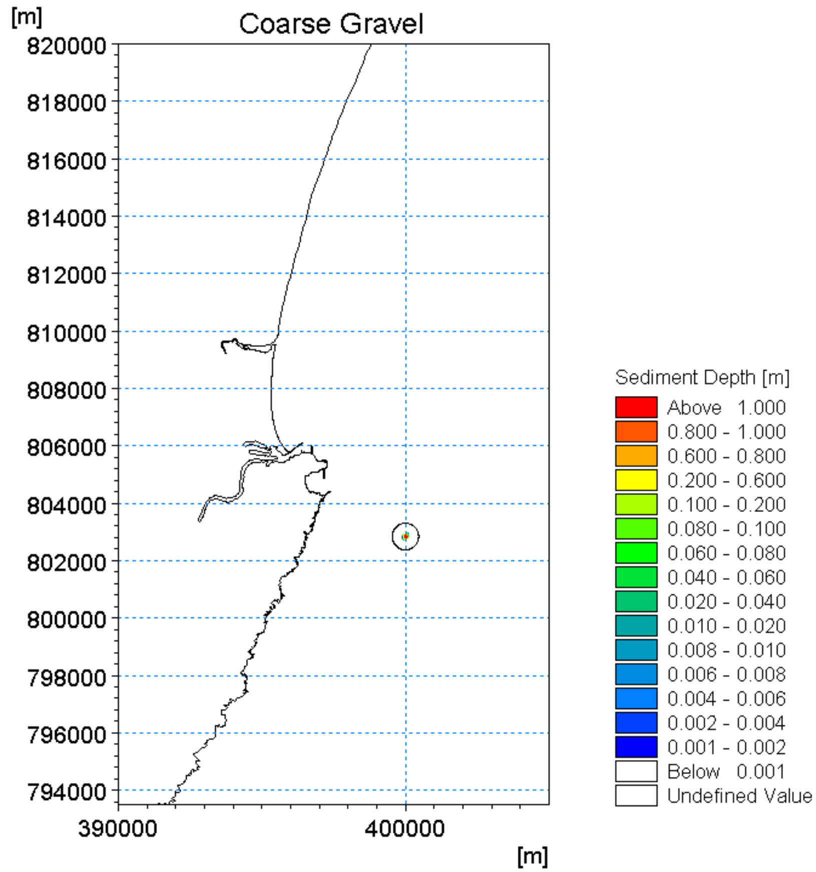
Over a Large Extent



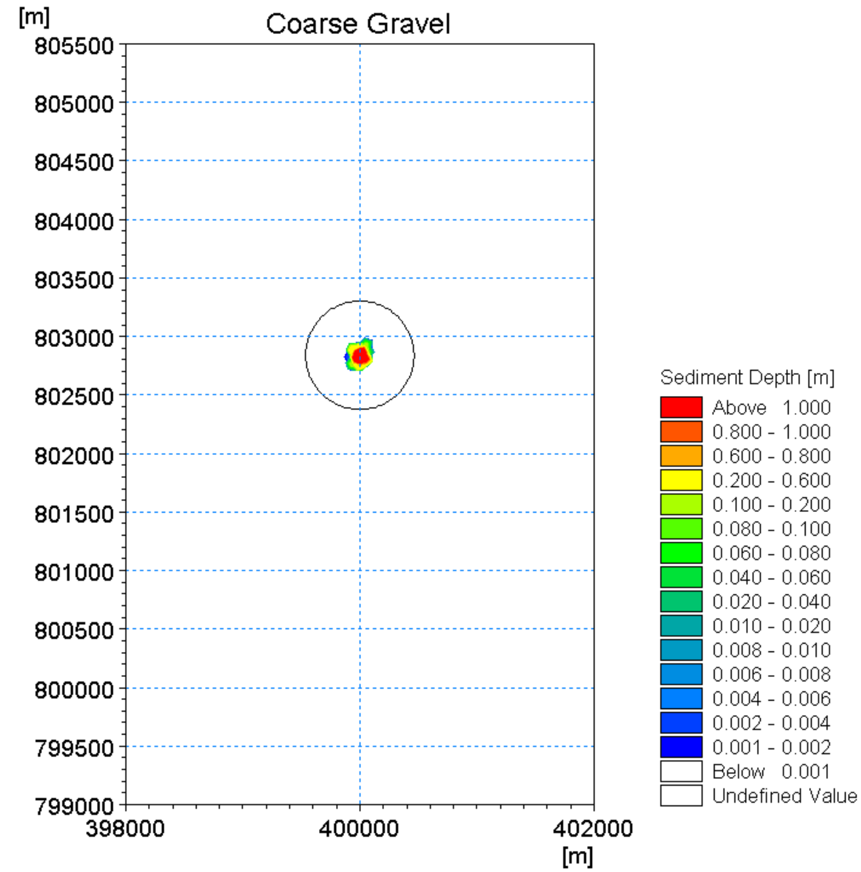
Local to the Development



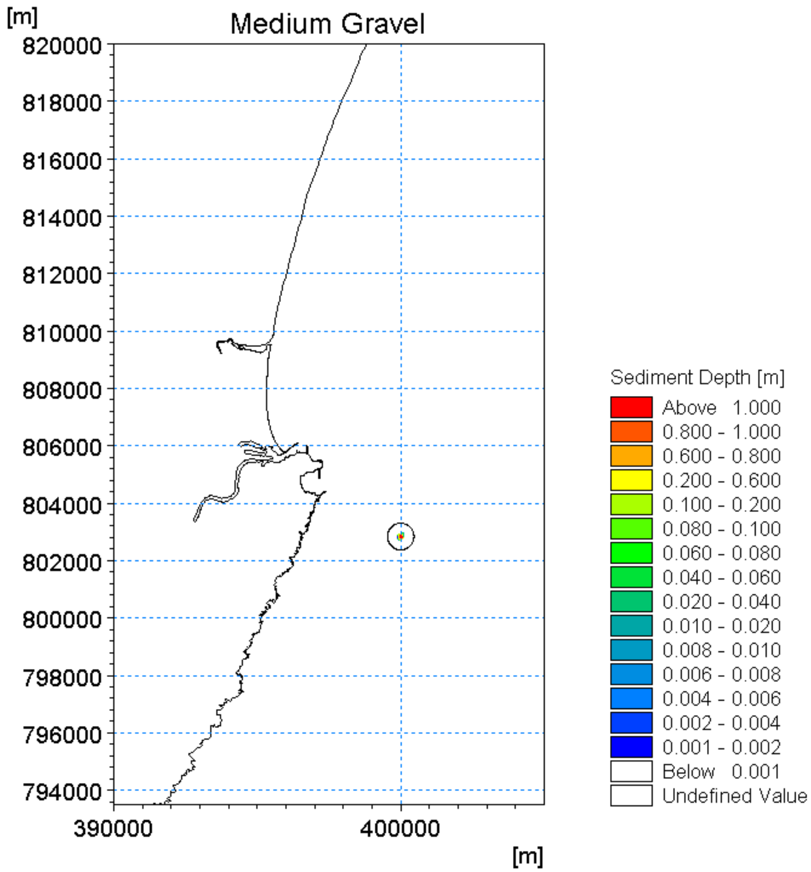
Over a Large Extent



Local to the Disposal Site



Over a Large Extent



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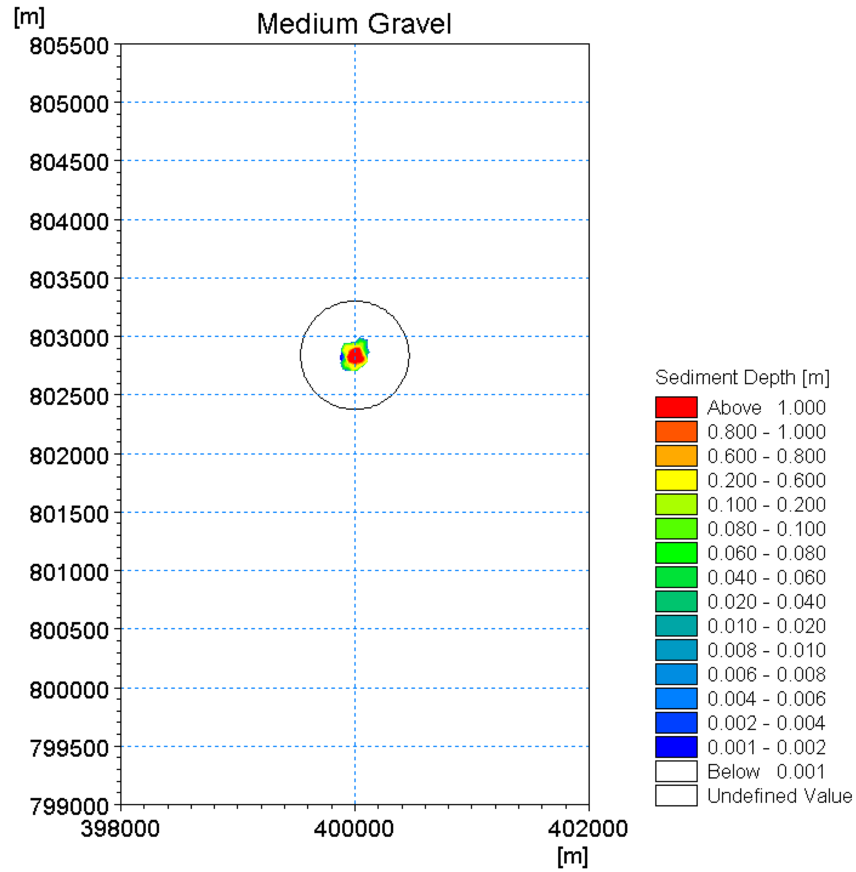
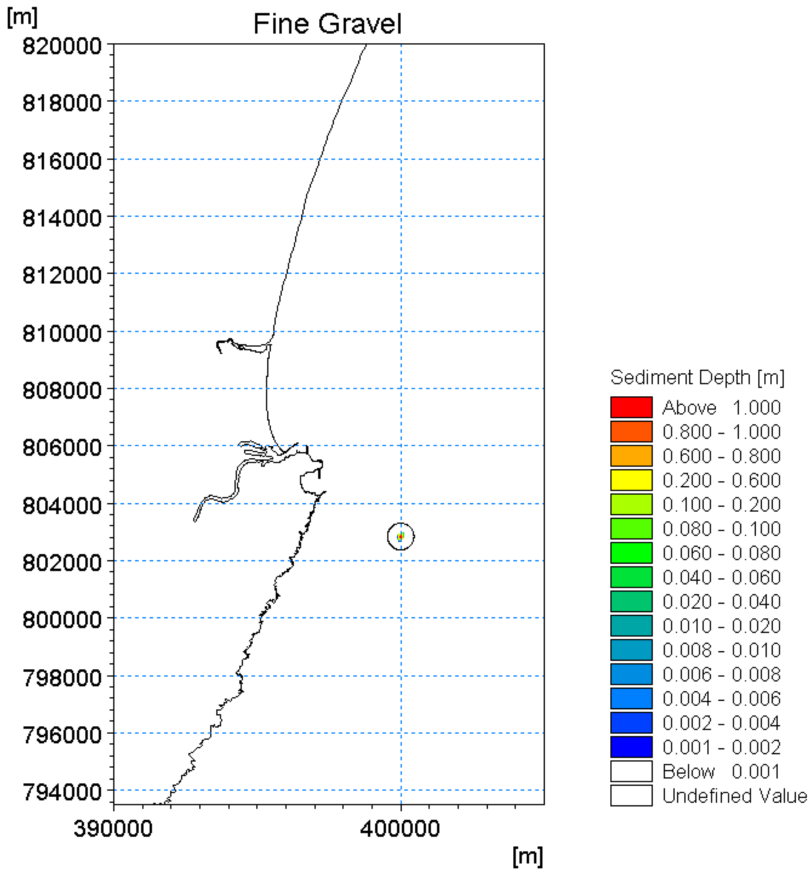
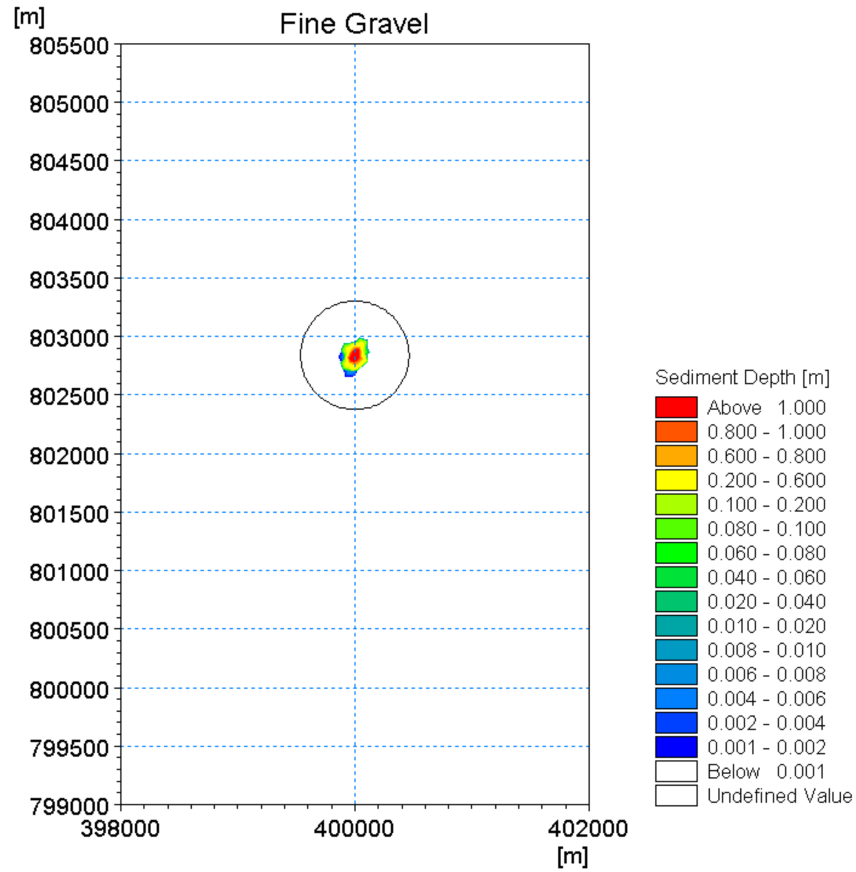


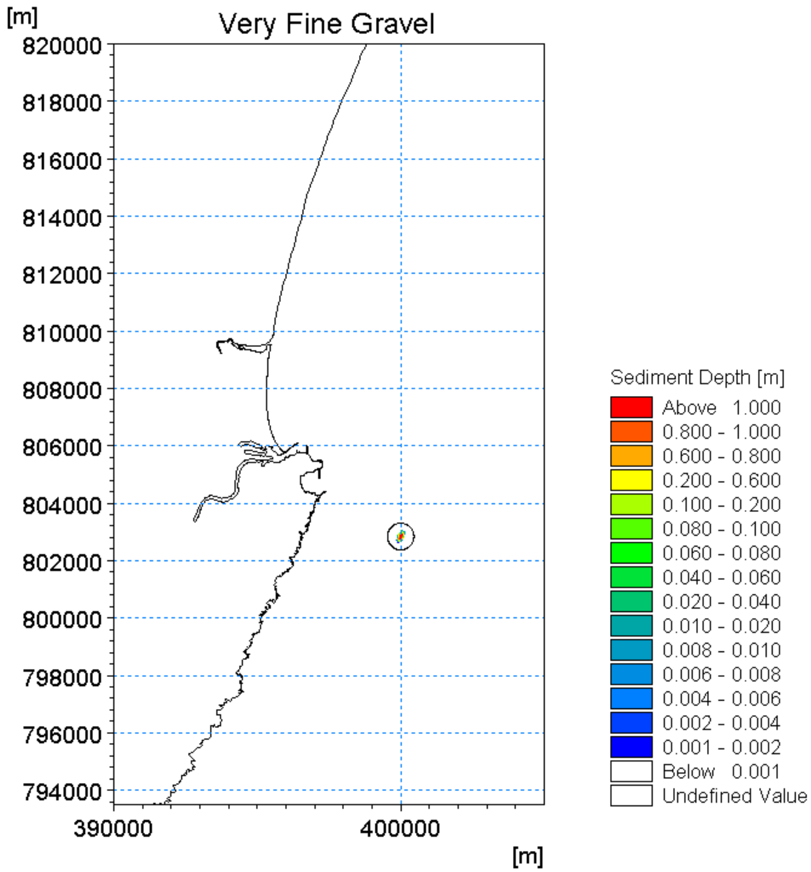
Over a Large Extent



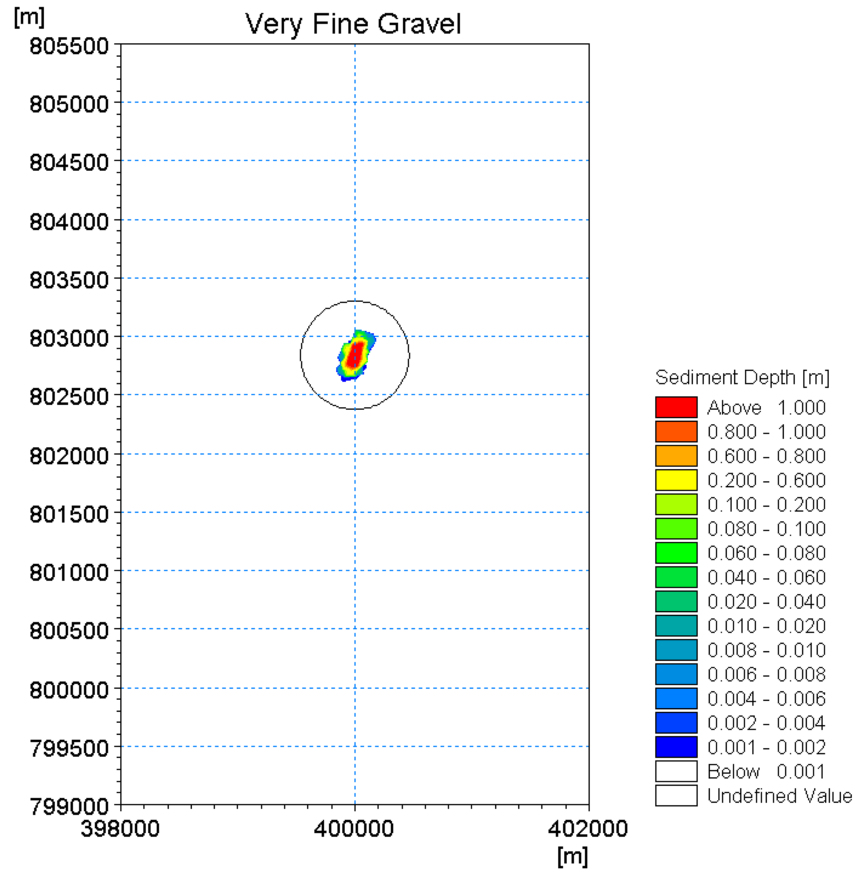
Local to the Disposal Site



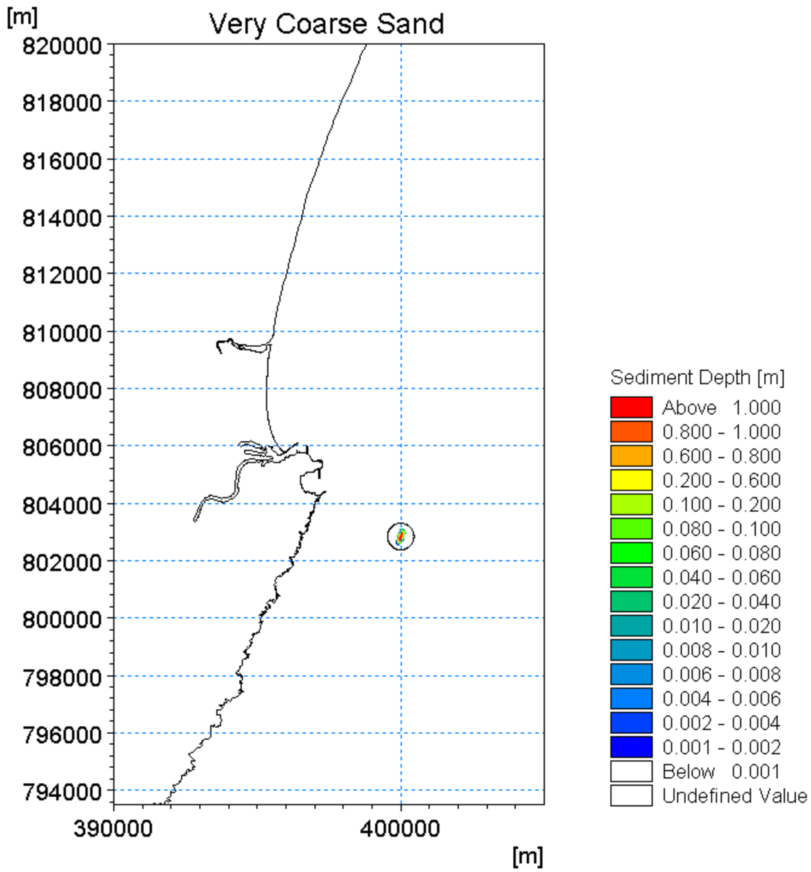
Over a Large Extent



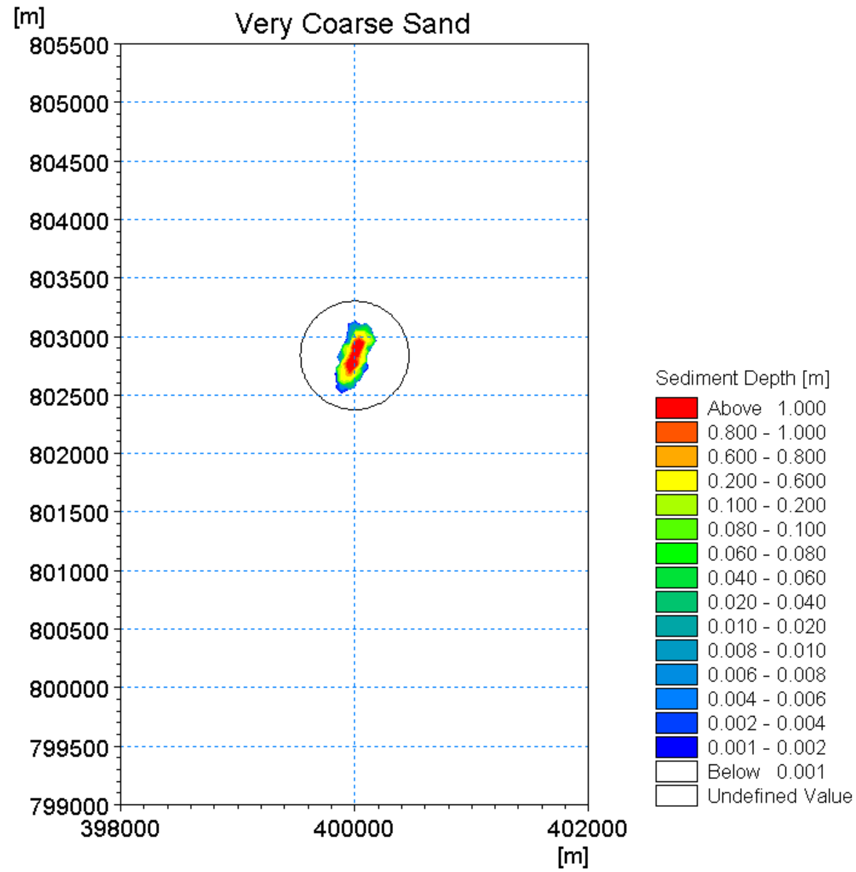
Local to the Disposal Site



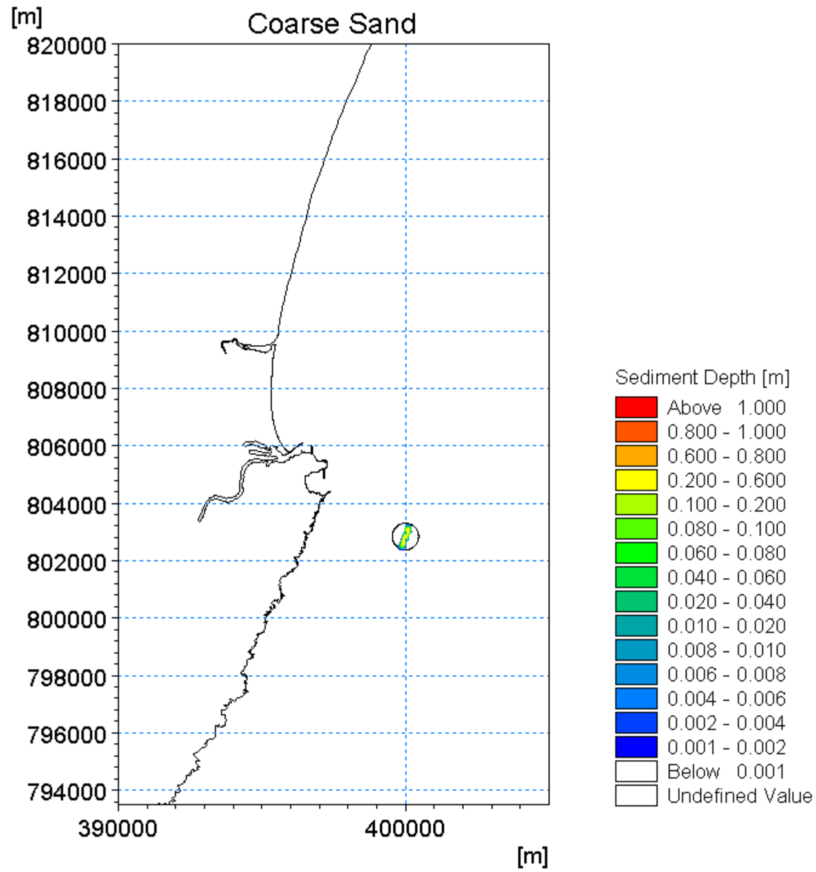
Over a Large Extent



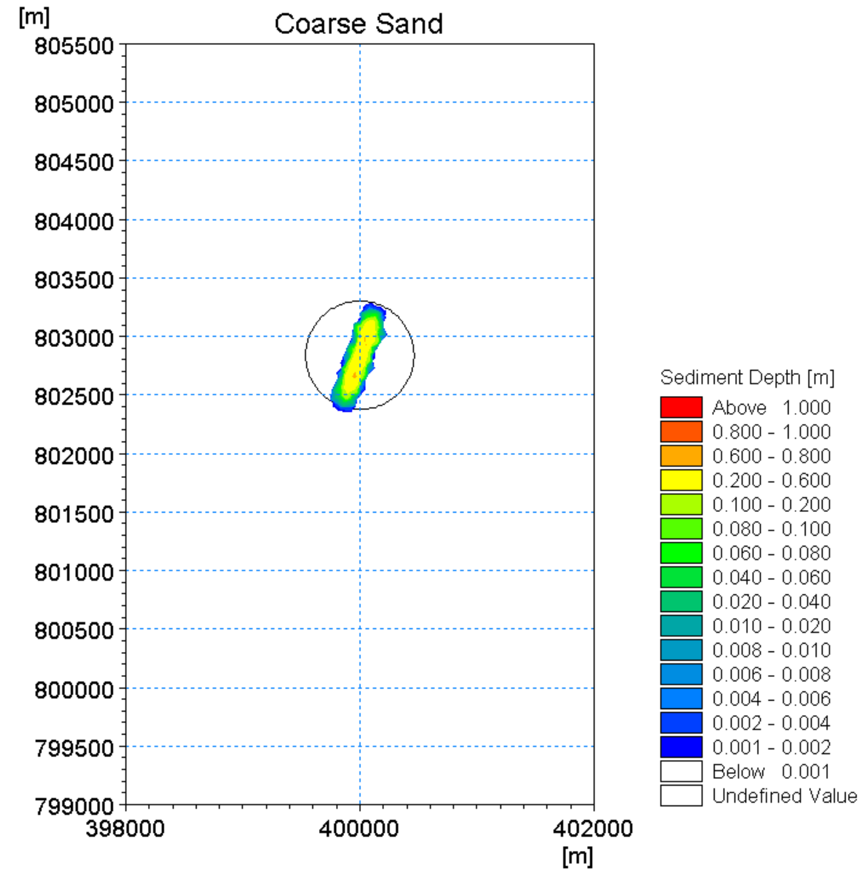
Local to the Disposal Site



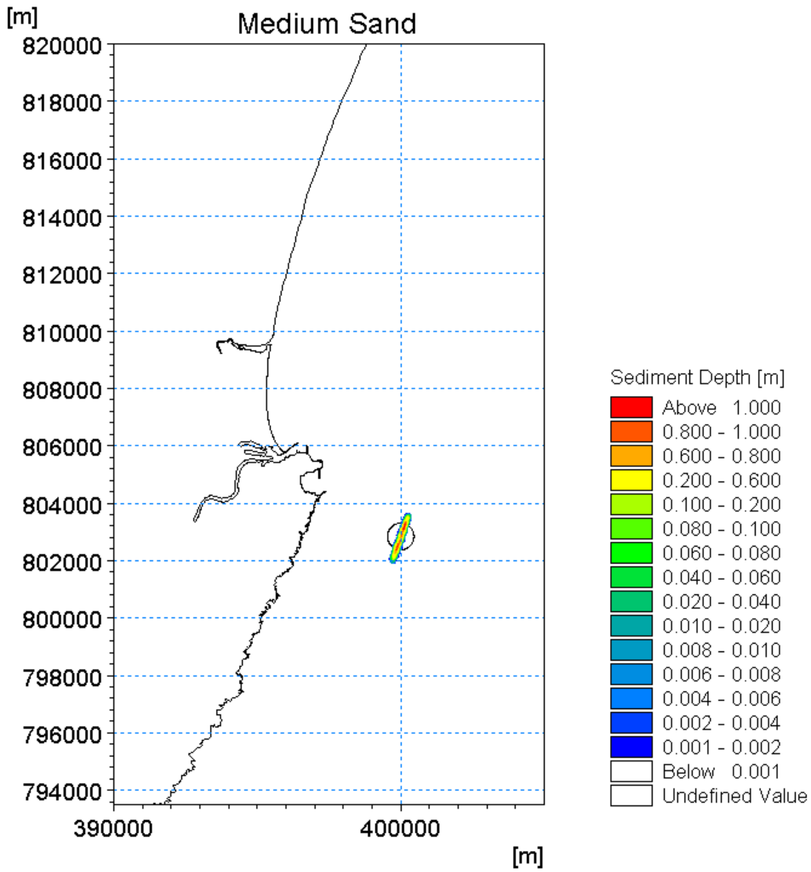
Over a Large Extent



Local to the Disposal Site



Over a Large Extent



Local to the Disposal Site

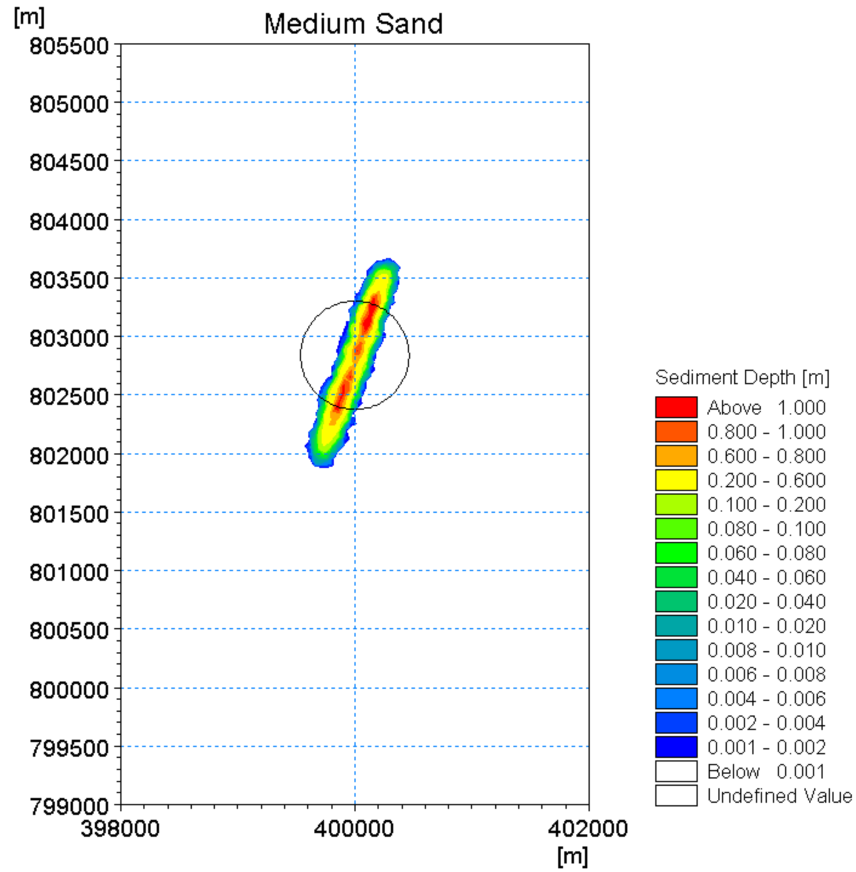


Table C-1: TSHD overspill redeposited sediment depth

Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Fine sand (mm)	0	0	0	0	0	0	0	0	0	0
Very fine sand (mm)	0	0	0	2	5	1	0	0	0	0
Mud (mm)	12	3	1	43	62	56	4	0	0	0
Total (mm)	12	3	1	45	67	57	4	0	0	0

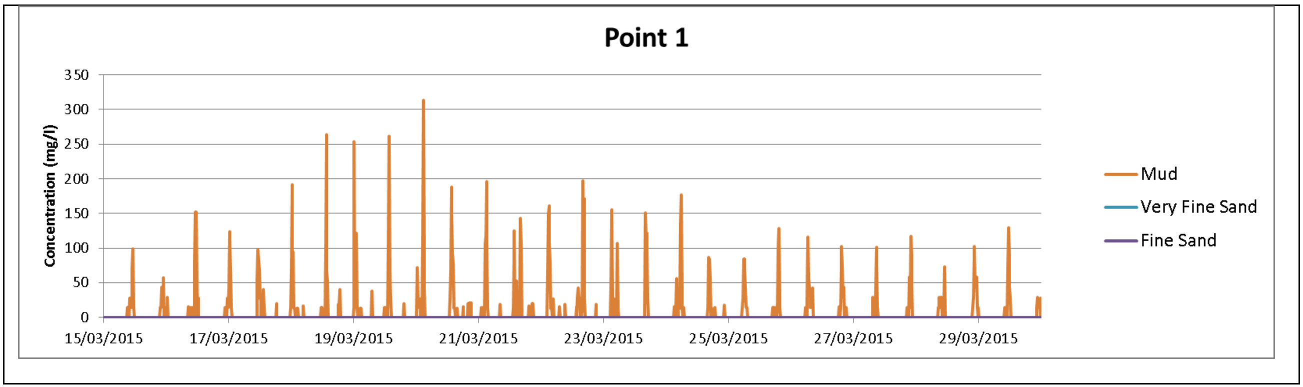
Table C-2: TSHD overspill redeposited sediment depth over whole dredging duration

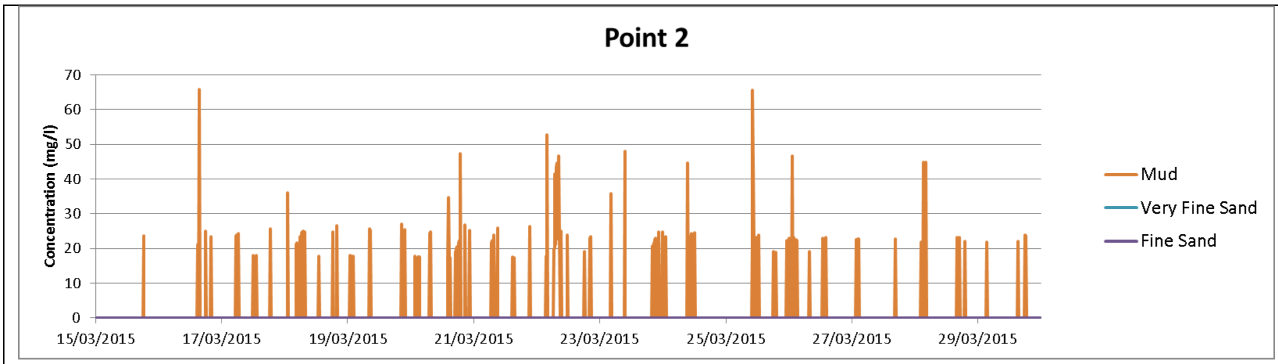
Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Mud (mm)	120	28	5	431	620	561	45	0	3	1

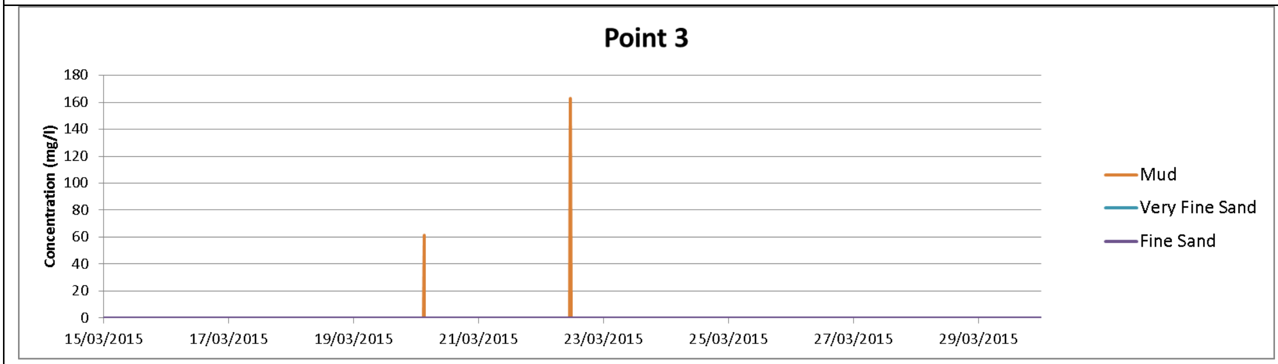
Table C-3: TSHD disposal area of redeposited sediment depth

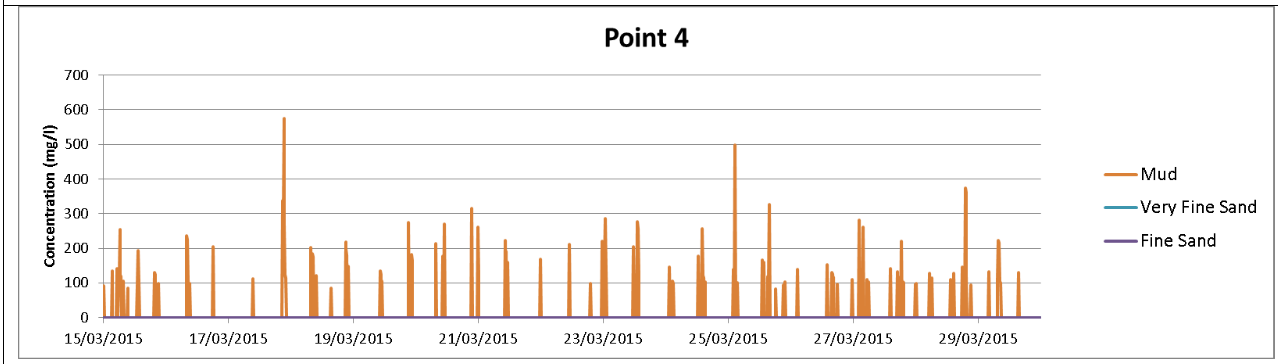
Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mm)	0	0	0	0	0	0	0	0	4161	0	0	0	0	0	0	0	0
Coarse gravel (mm)	0	0	0	0	0	0	0	0	2496	0	0	0	0	0	0	0	0
Medium gravel (mm)	0	0	0	0	0	0	0	0	2344	0	0	0	0	0	0	0	0
Fine gravel (mm)	0	0	0	0	0	0	0	0	1441	0	0	0	0	0	0	0	0
Very fine gravel (mm)	0	0	0	0	0	0	0	0	1992	0	0	0	0	0	0	0	0
Very Coarse sand (mm)	0	0	0	0	0	0	0	0	1370	0	0	0	0	0	0	0	0
Coarse sand (mm)	0	0	0	0	0	0	0	0	454	12	0	0	0	0	0	0	0
Medium sand (mm)	0	0	0	0	0	0	313	1042	797	1040	74	0	0	0	0	0	0
Total (mm)	0	0	0	0	0	0	313	1042	15055	1052	74	0	0	0	0	0	0

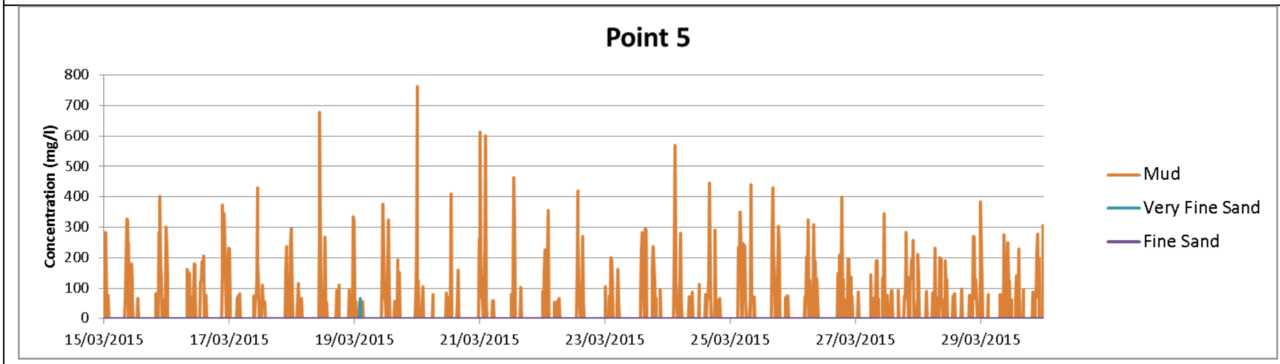
Figure C-4: TSHD overspill suspended sediment concentration time series




Point 2
Concentration (mg/l)
70
60
50
40
30
20
10
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand


Point 3
Concentration (mg/l)
180
160
140
120
100
80
60
40
20
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand


Point 4
Concentration (mg/l)
700
600
500
400
300
200
100
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand


Point 5
Concentration (mg/l)
800
700
600
500
400
300
200
100
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
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25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand

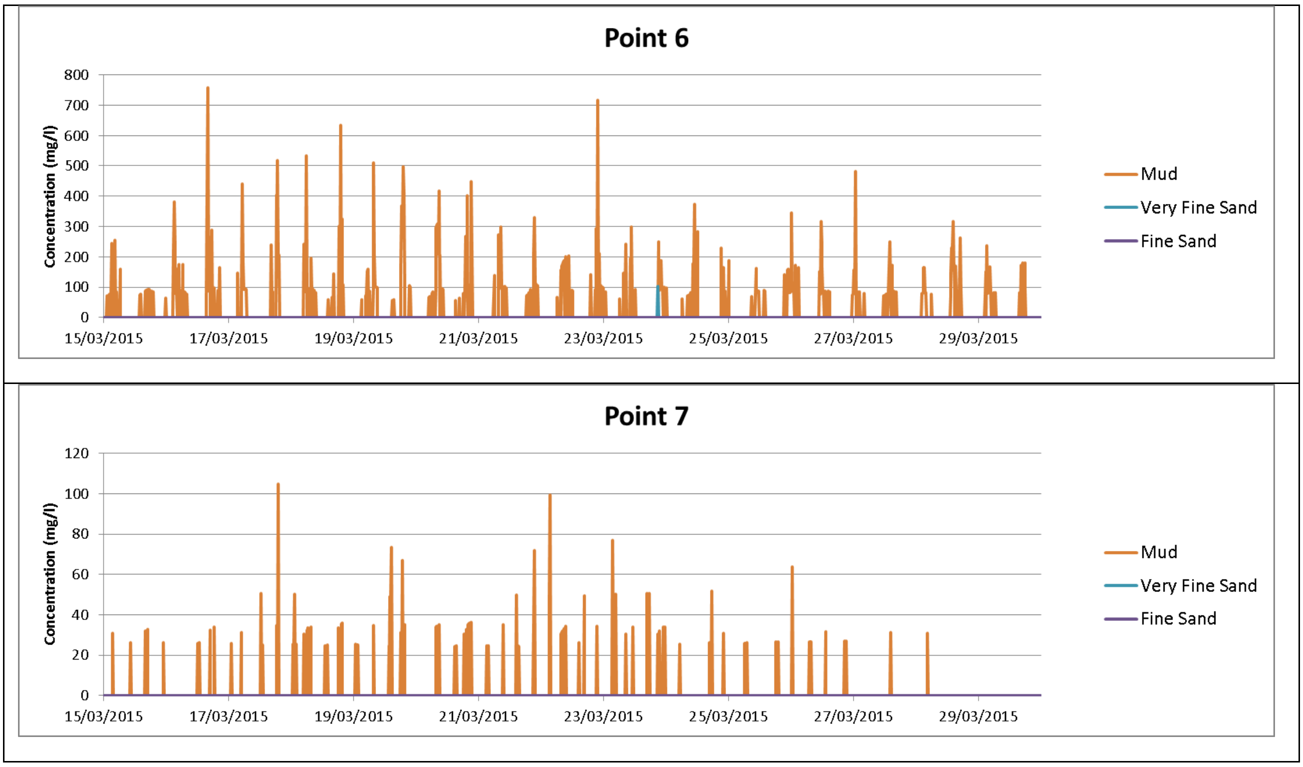


Figure C-5: TSHD overspill average suspended sediment concentration

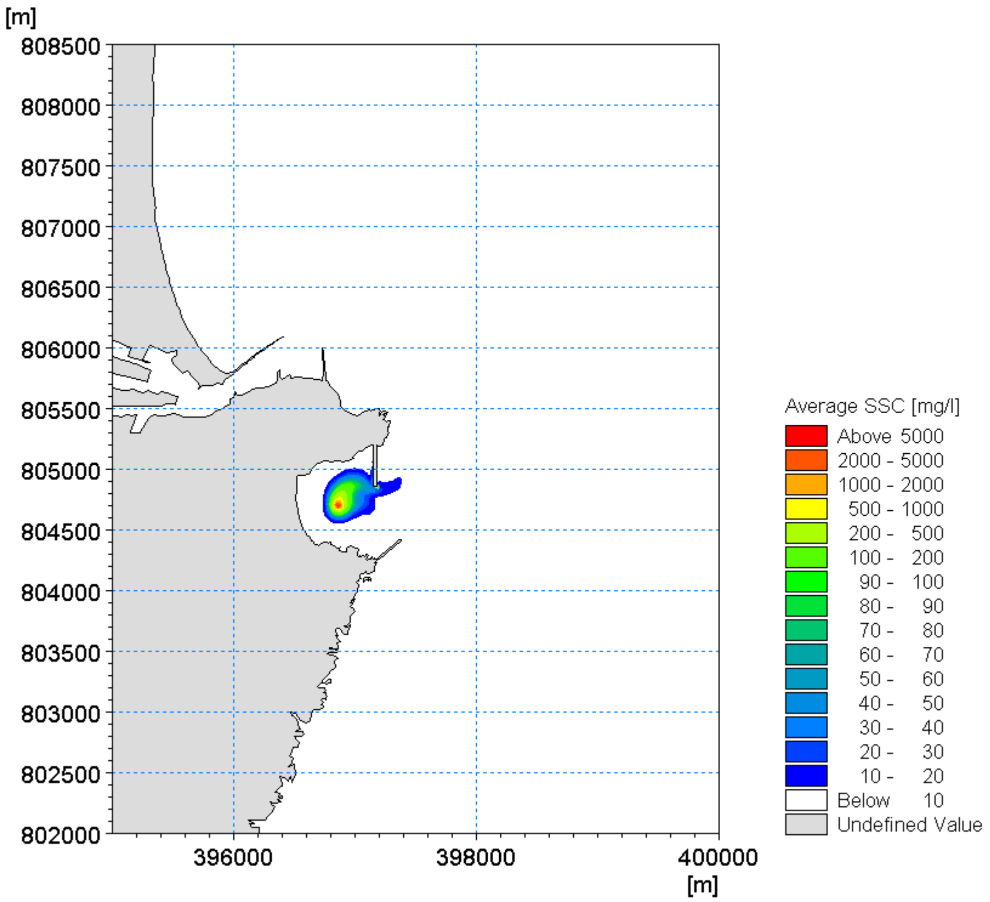


Figure C-6: TSHD overspill maximum suspended sediment concentration

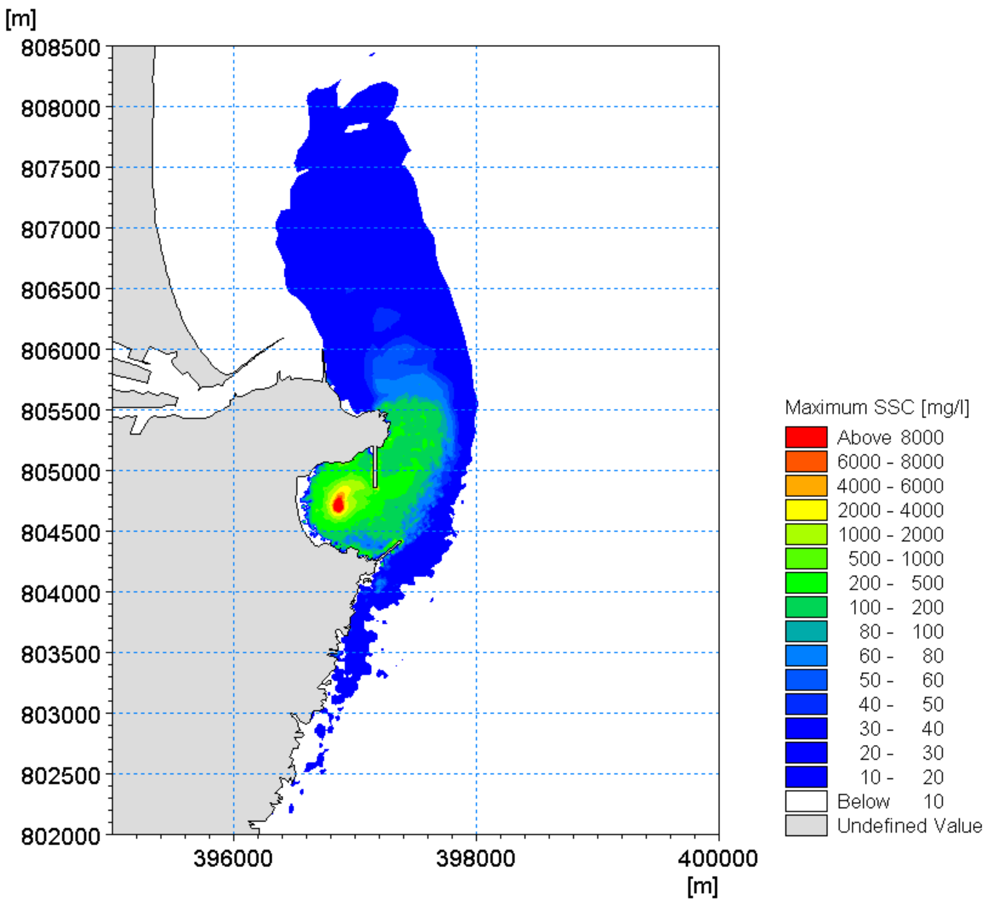


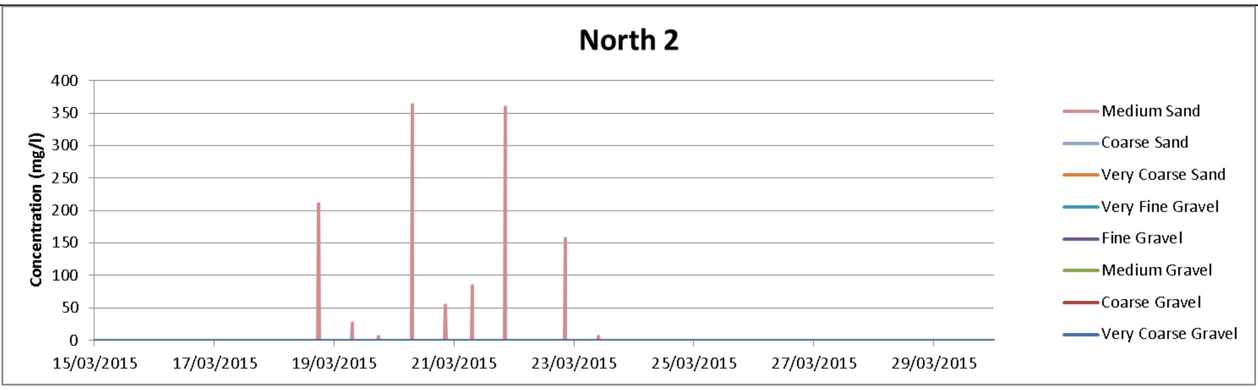
Table C-4: TSHD overspill average suspended sediment concentrations

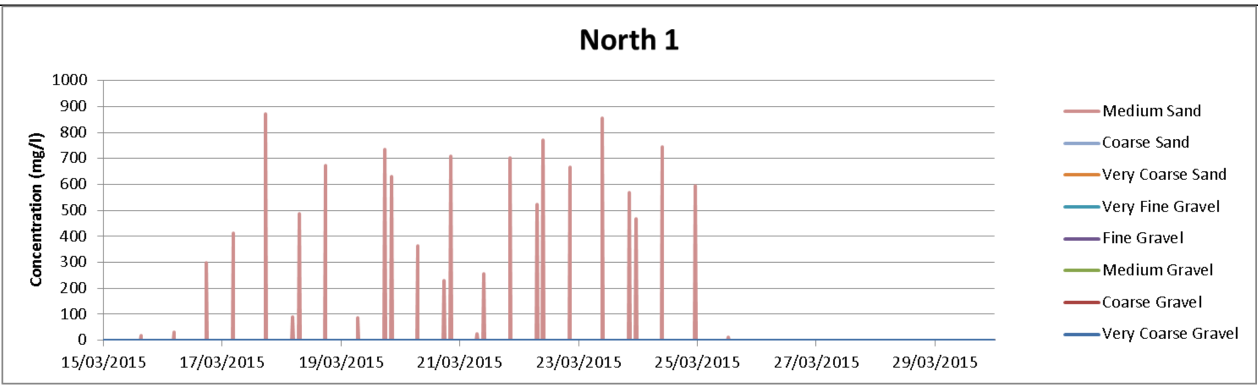
Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Fine sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very fine sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Mud (mg/l)	9.3	2.1	0.2	14.4	36.2	31.5	2.5	0.0	0.0	0.0
Total suspended solids (mg/l)	9.3	2.1	0.2	14.4	36.3	31.6	2.5	0.0	0.0	0.0

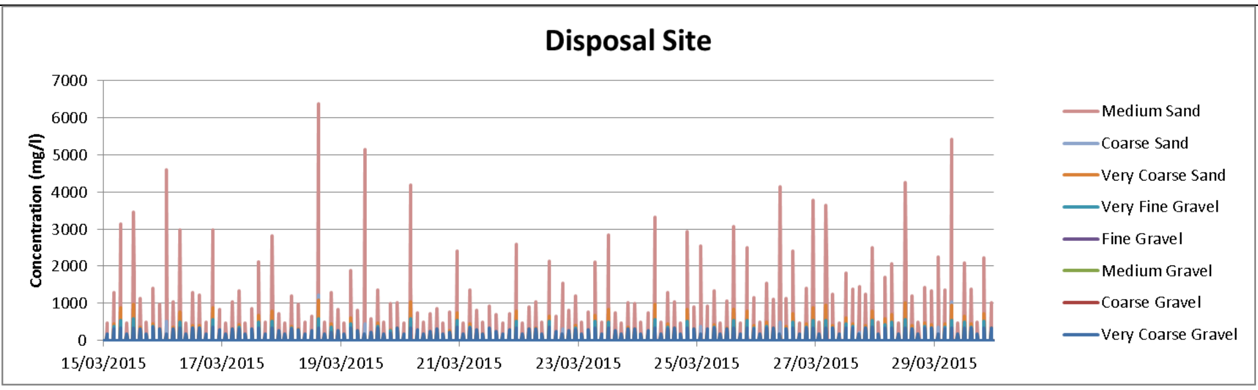
Table C-5: TSHD overspill maximum suspended sediment concentrations

Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Fine sand (mg/l)	0	0	0	0	0	0	0	0	0	0
Very fine sand (mg/l)	0	0	0	0	67	102	0	0	0	0
Mud (mg/l)	314	66	163	576	763	757	105	0	0	0
Total suspended solids (mg/l)	314	66	163	576	763	757	105	0	0	0

Figure C-7: TSHD disposal site average suspended sediment concentration time series







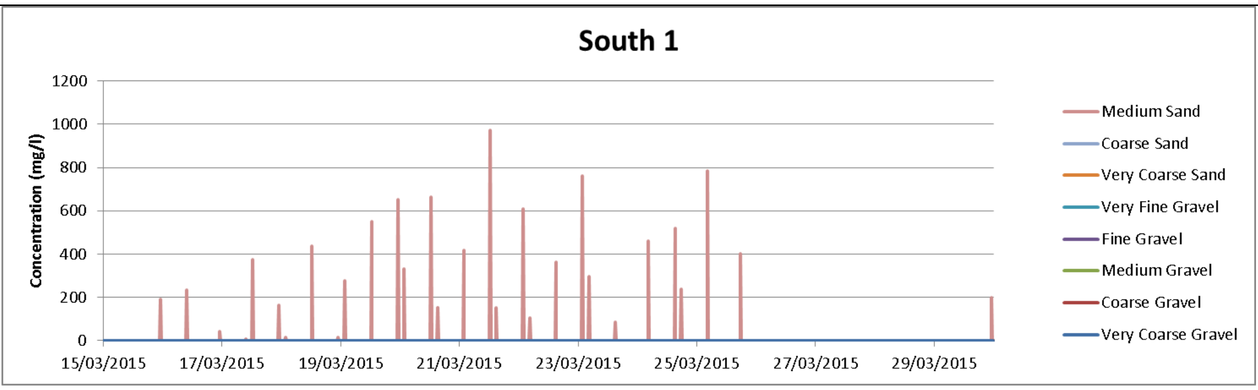


Figure C-8: TSHD disposal site average suspended sediment concentration

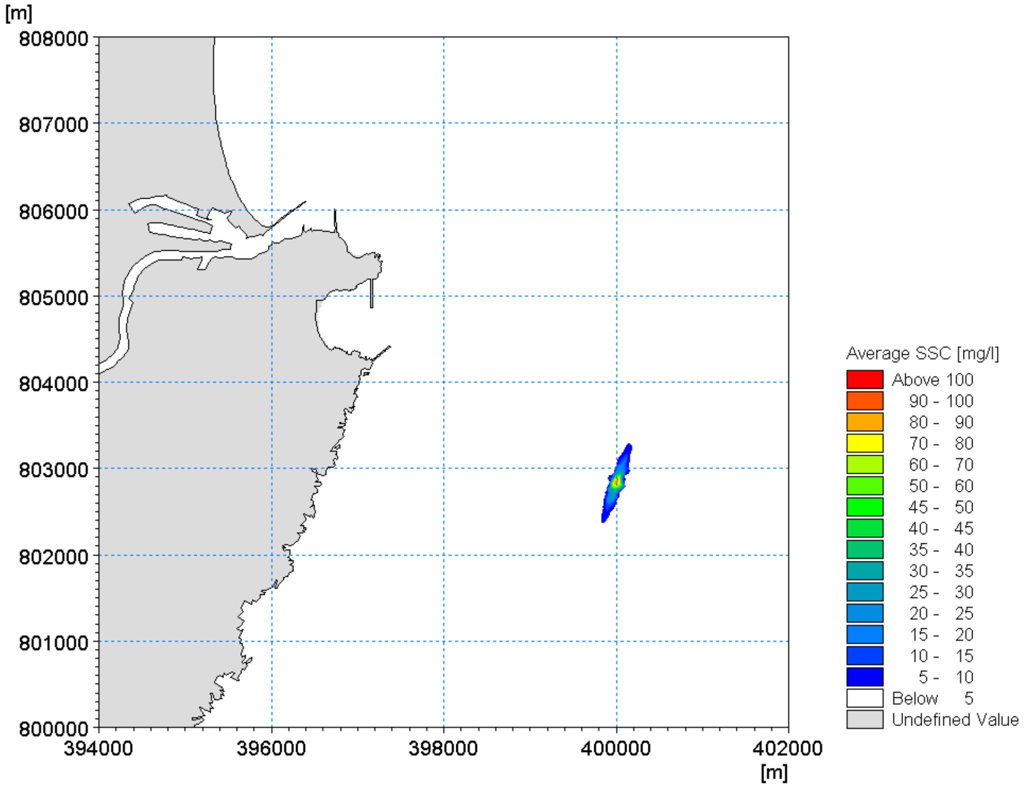


Figure C-9: TSHD disposal site maximum suspended sediment concentration

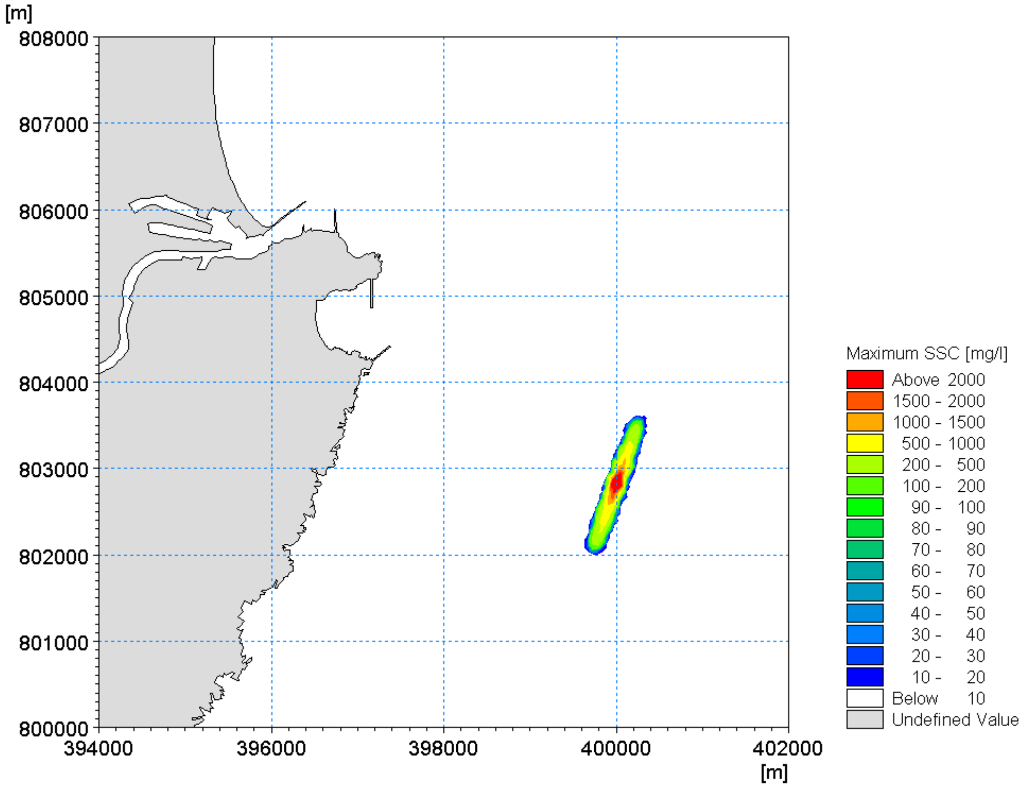


Table C-6: TSHD disposal site average suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	8.2	141.6	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total suspended solids (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.9	8.2	300.4	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table C-7: TSHD disposal site maximum suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0	0	0	0	0	0	0	0	354	0	0	0	0	0	0	0	0
Coarse gravel (mg/l)	0	0	0	0	0	0	0	0	215	0	0	0	0	0	0	0	0
Medium gravel (mg/l)	0	0	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0
Fine gravel (mg/l)	0	0	0	0	0	0	0	0	202	0	0	0	0	0	0	0	0
Very fine gravel (mg/l)	0	0	0	0	0	0	0	0	586	0	0	0	0	0	0	0	0
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	1091	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	1221	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	363	872	6372	974	0	0	0	0	0	0	0
Total suspended solids (mg/l)	0	0	0	0	0	0	363	872	10192	974	0	0	0	0	0	0	0

Table C-8: TSHD and Aberdeen Harbour maintenance disposal site average suspended sediment concentrations

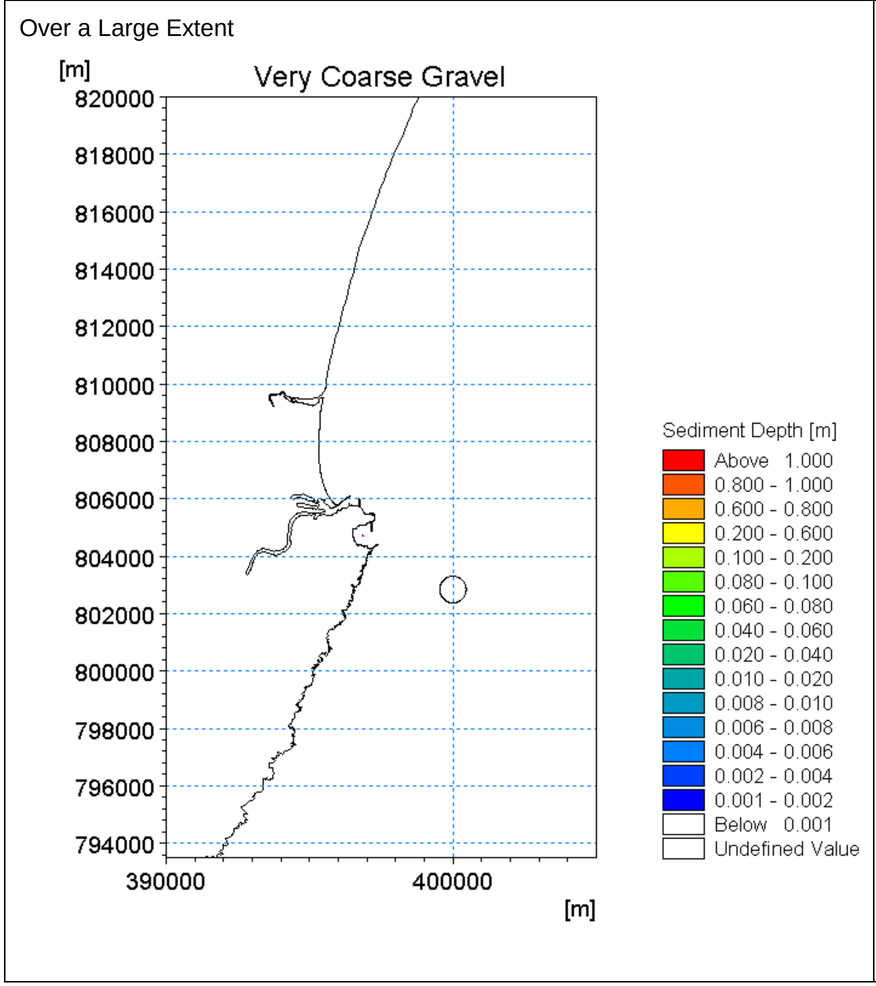
Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0	0	0	0	0	0	0	0	25.1	0	0	0	0	0	0	0	0
Coarse gravel (mg/l)	0	0	0	0	0	0	0	0	15.3	0	0	0	0	0	0	0	0
Medium gravel (mg/l)	0	0	0	0	0	0	0	0	14.3	0	0	0	0	0	0	0	0
Fine gravel (mg/l)	0	0	0	0	0	0	0	0	12.1	0	0	0	0	0	0	0	0
Very fine gravel (mg/l)	0	0	0	0	0	0	0	0	26.4	0	0	0	0	0	0	0	0
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	28.4	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	48.9	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	1	9.8	177.1	9.4	0	0	0	0	0	0	0
Fine sand (mg/l)	0	0	0	0	0.2	1.2	3.7	6	45.9	6.1	2.6	0.9	0.1	0	0	0	0
Very fine sand (mg/l)	0	0	0.4	0.9	5	7.5	13.7	14.6	96.2	14.9	10.1	6.6	2.3	1.8	1	0	0
Mud (mg/l)	1.5	9	12.8	18.2	32.6	43.1	66.3	70.1	323.6	75.8	58.3	44.2	31.7	33.2	28.2	7.3	2.2
Total suspended solids (mg/l)	1.5	9	13.2	19.1	37.8	51.8	84.7	100.5	813.3	106.2	71	51.7	34.1	35	29.2	7.3	2.2

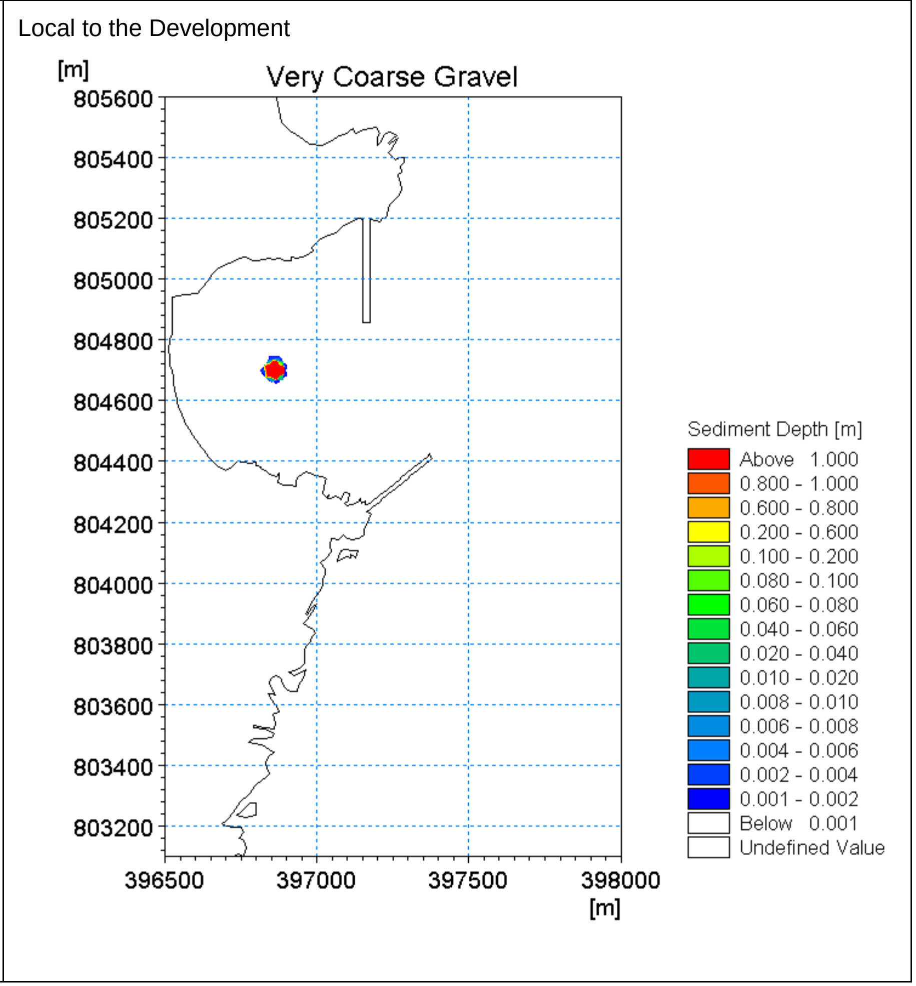
Table C-9: TSHD and Aberdeen Harbour maintenance disposal site maximum suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0	0	0	0	0	0	0	0	354	0	0	0	0	0	0	0	0
Coarse gravel (mg/l)	0	0	0	0	0	0	0	0	215	0	0	0	0	0	0	0	0
Medium gravel (mg/l)	0	0	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0
Fine gravel (mg/l)	0	0	0	0	0	0	0	0	202	0	0	0	0	0	0	0	0
Very fine gravel (mg/l)	0	0	0	0	0	0	0	0	586	0	0	0	0	0	0	0	0
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	643	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	1944	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	426	1018	7862	1157	1	0	0	0	0	0	0
Fine sand (mg/l)	0	0	0	0	76	164	245	368	1825	379	174	122	28	0	0	0	0
Very fine sand (mg/l)	0	13	98	163	309	422	489	799	3681	747	576	497	303	318	152	2	0
Mud (mg/l)	173	485	399	550	969	1272	1614	2277	11657	2241	1612	1438	928	972	686	203	97
Total suspended solids (mg/l)	173	498	497	713	1354	1858	2774	4462	29169	4524	2363	2057	1259	1290	838	205	97

C.2 Backhoe Dredging

Figure C-10: Backhoe overspill area and depth of redeposited sediment





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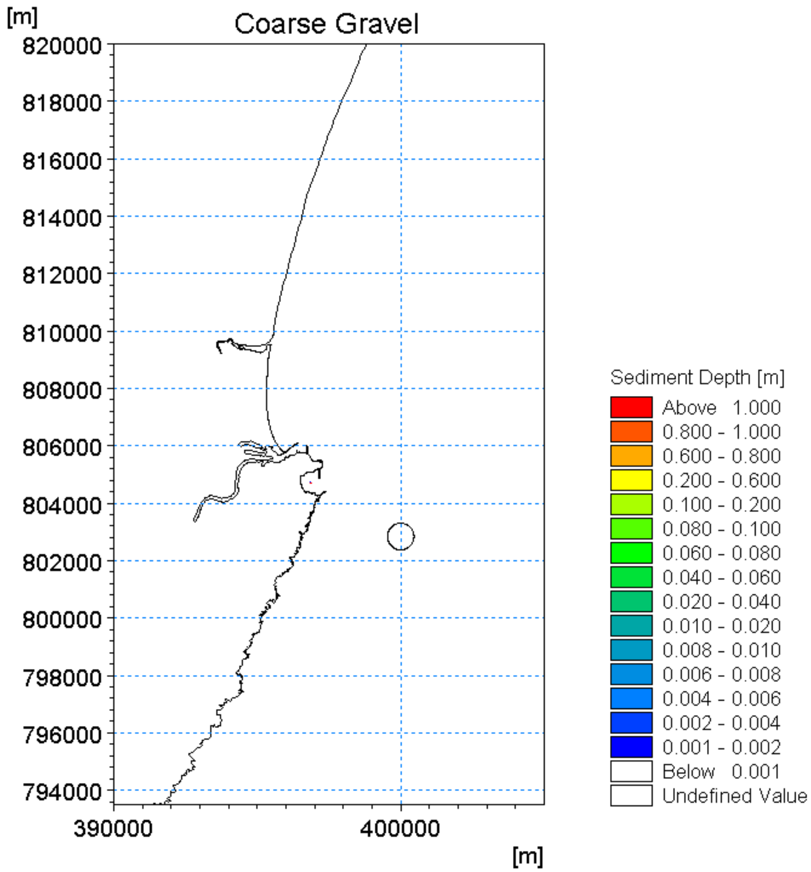

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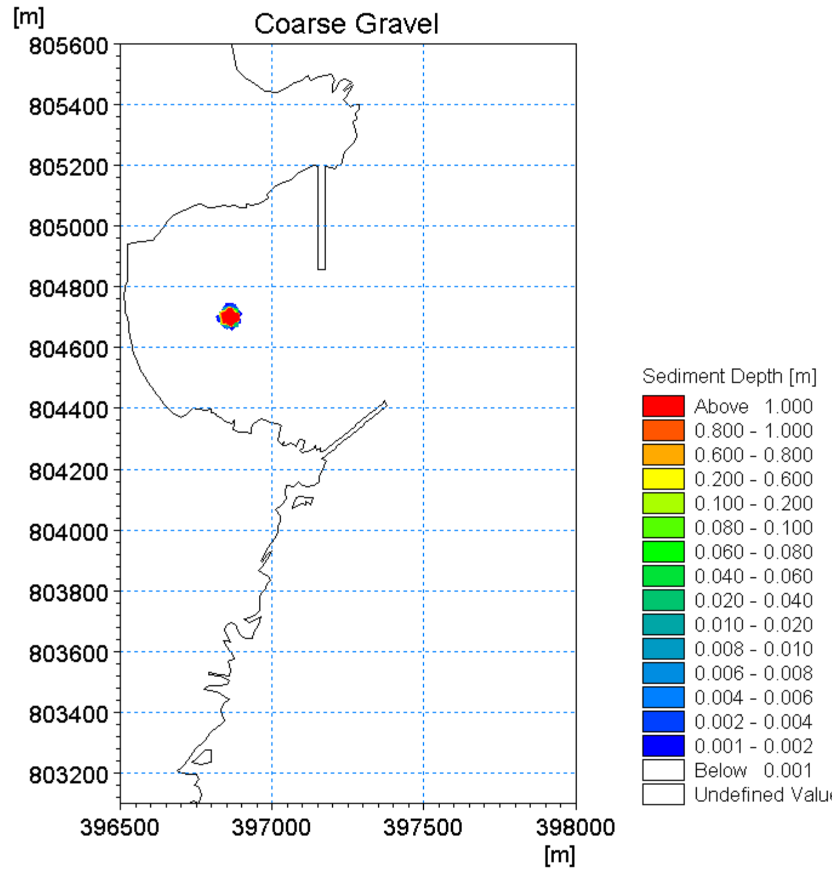

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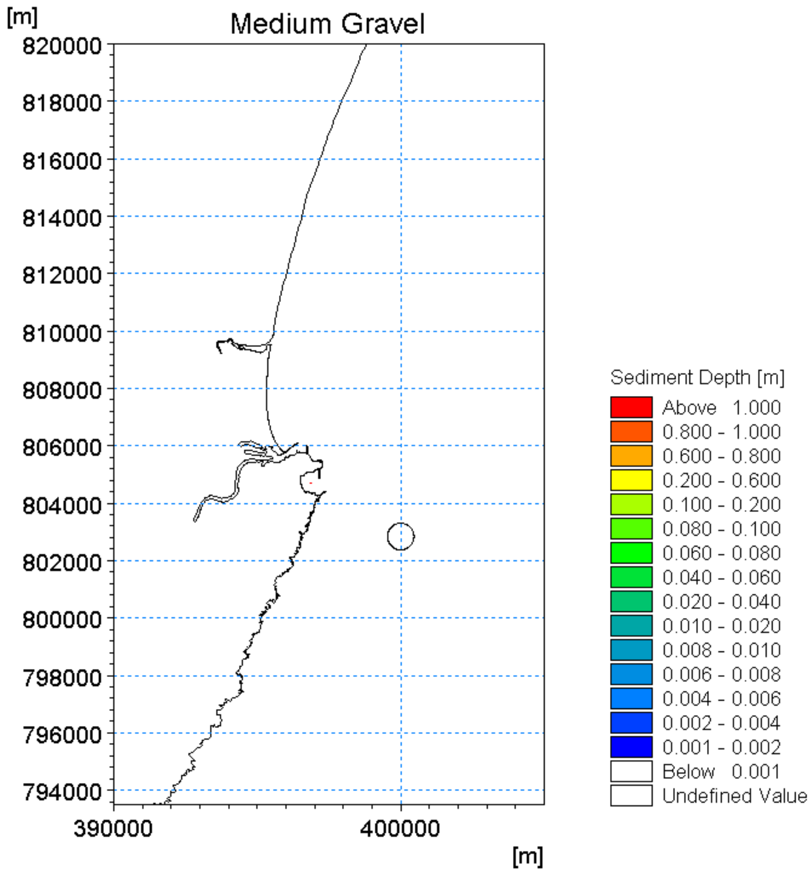

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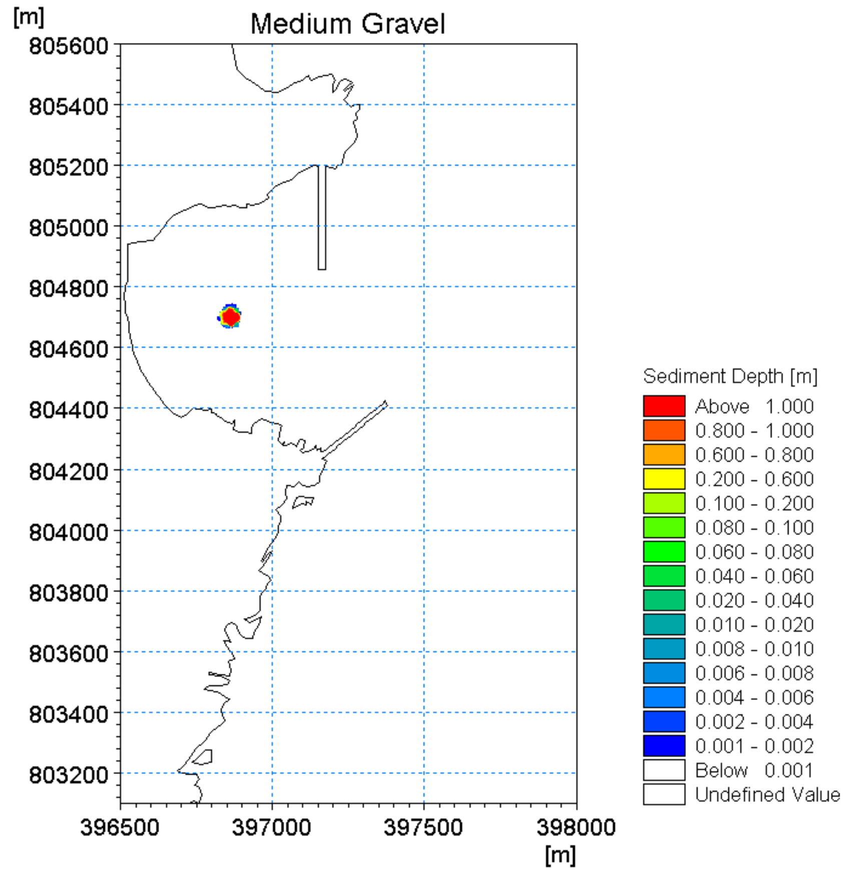

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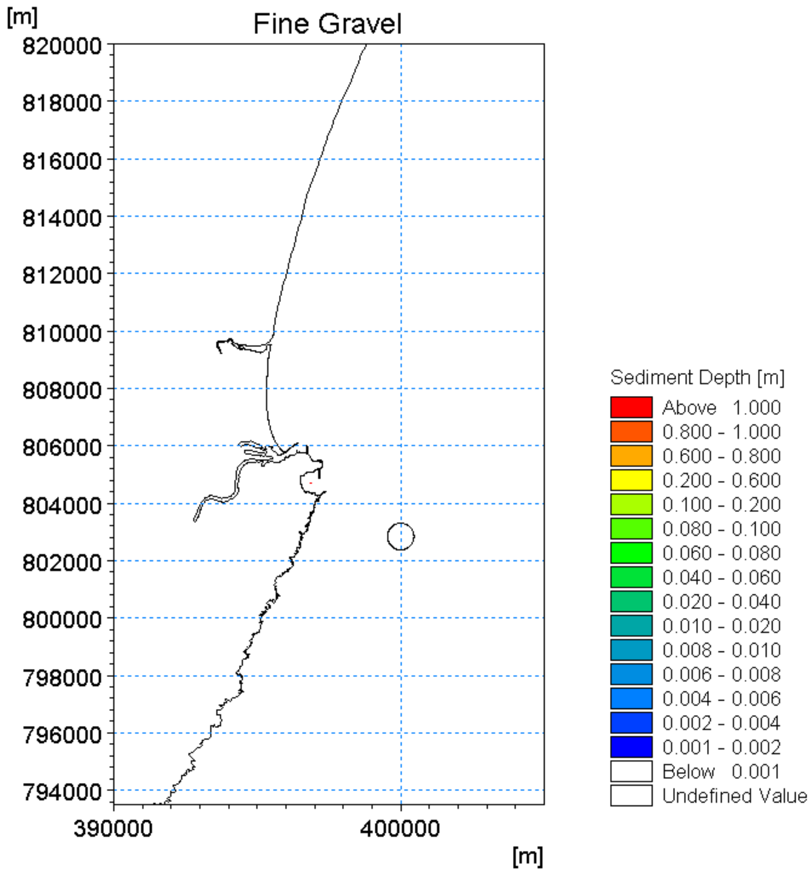	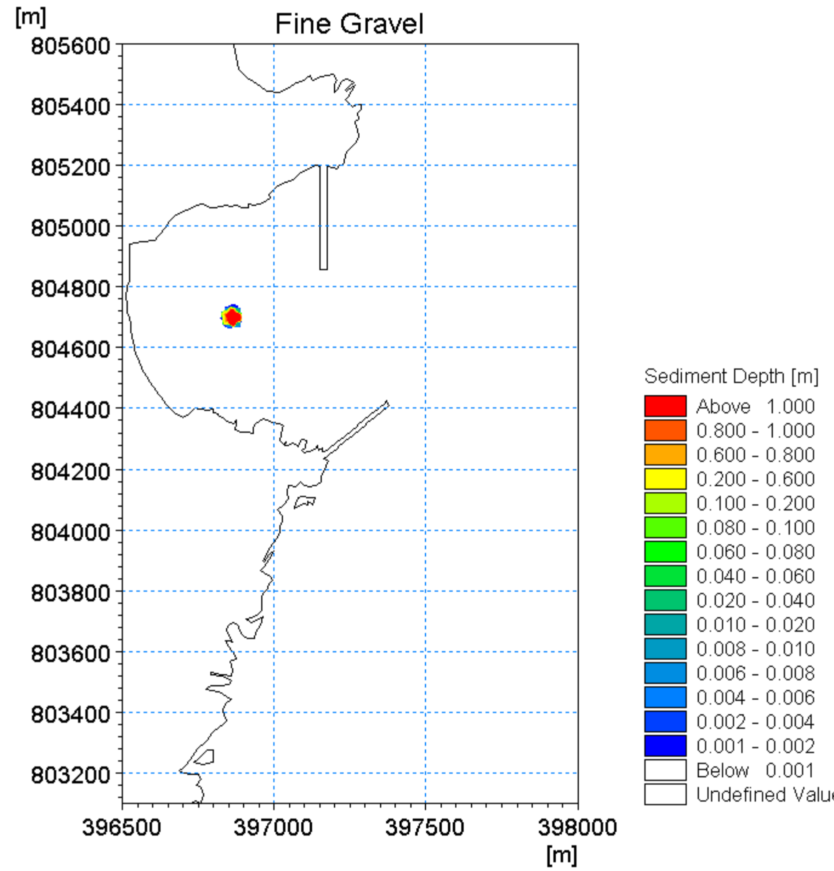

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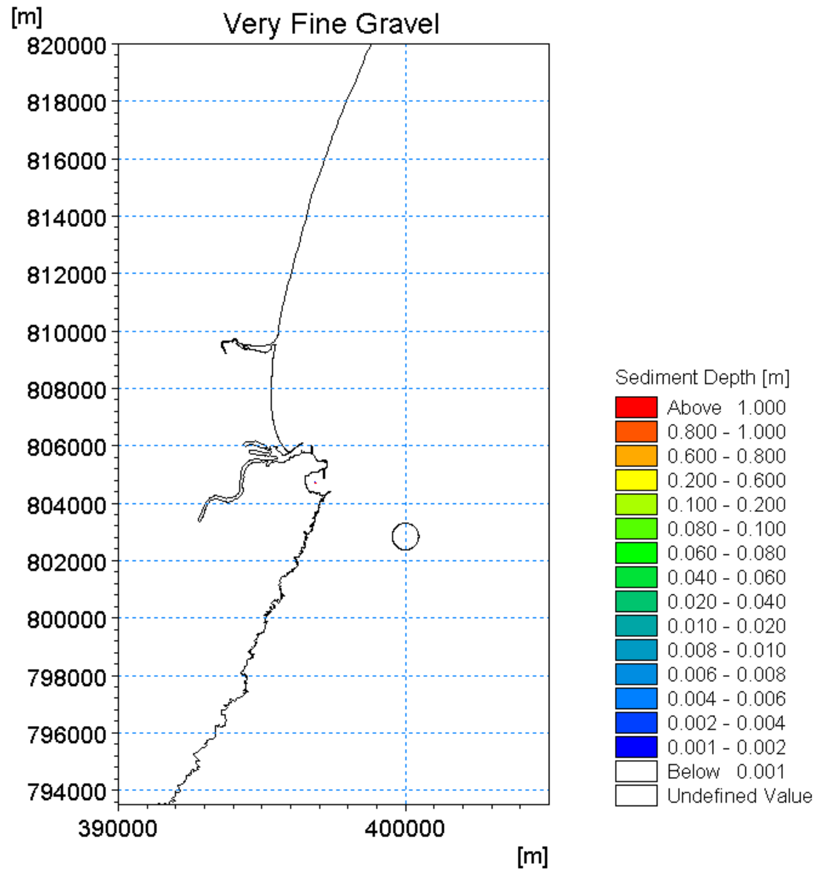

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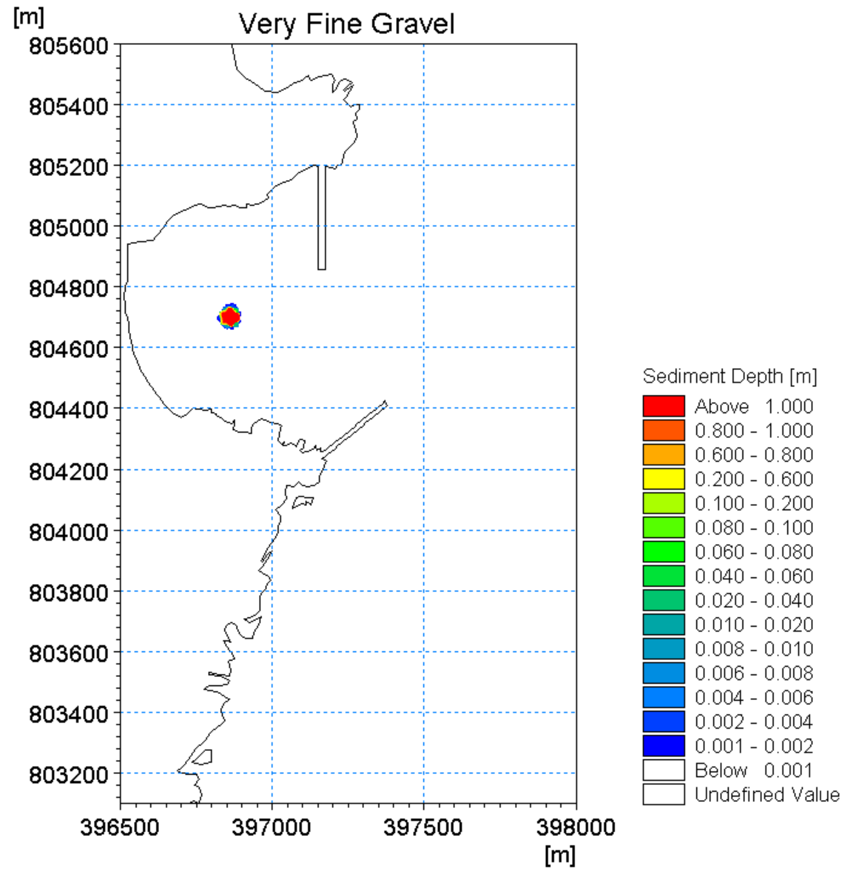

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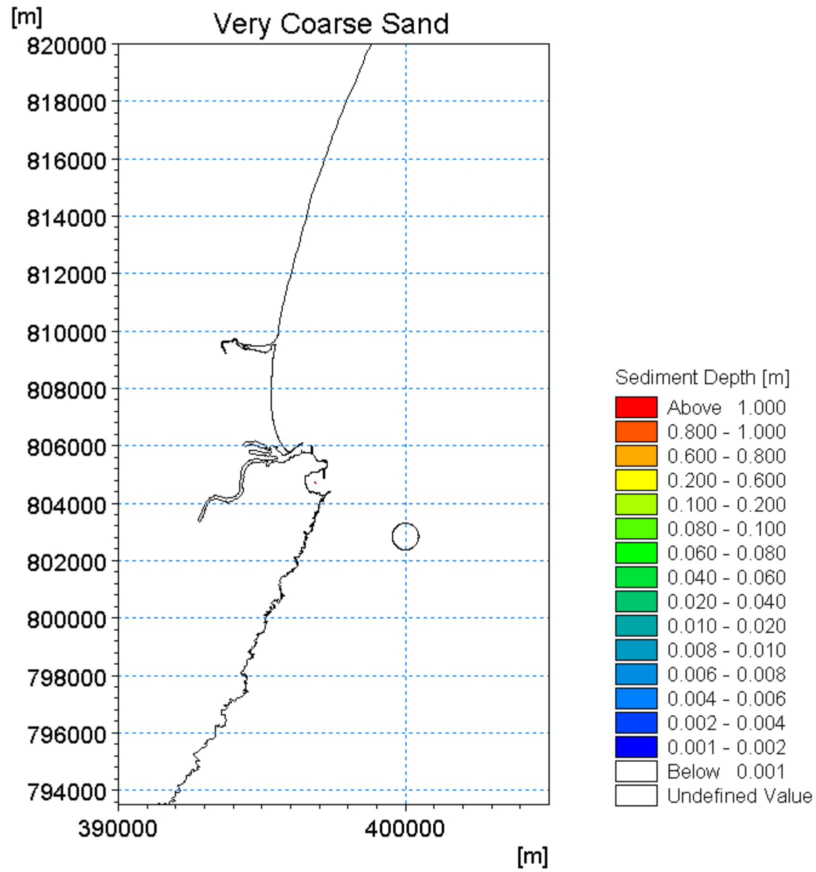

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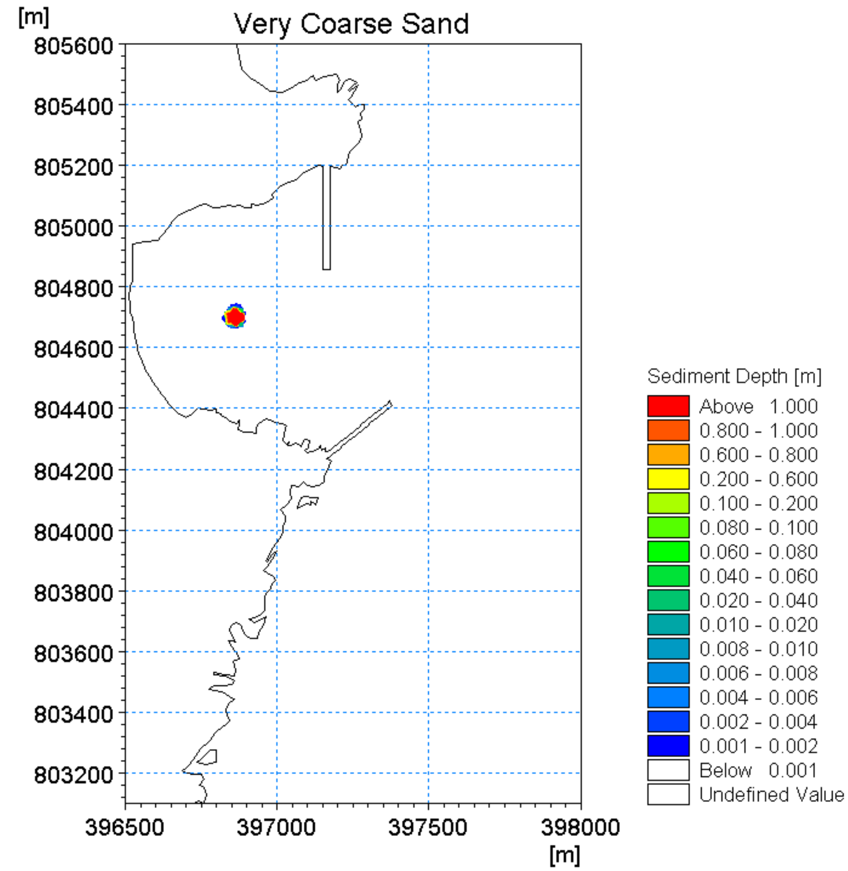

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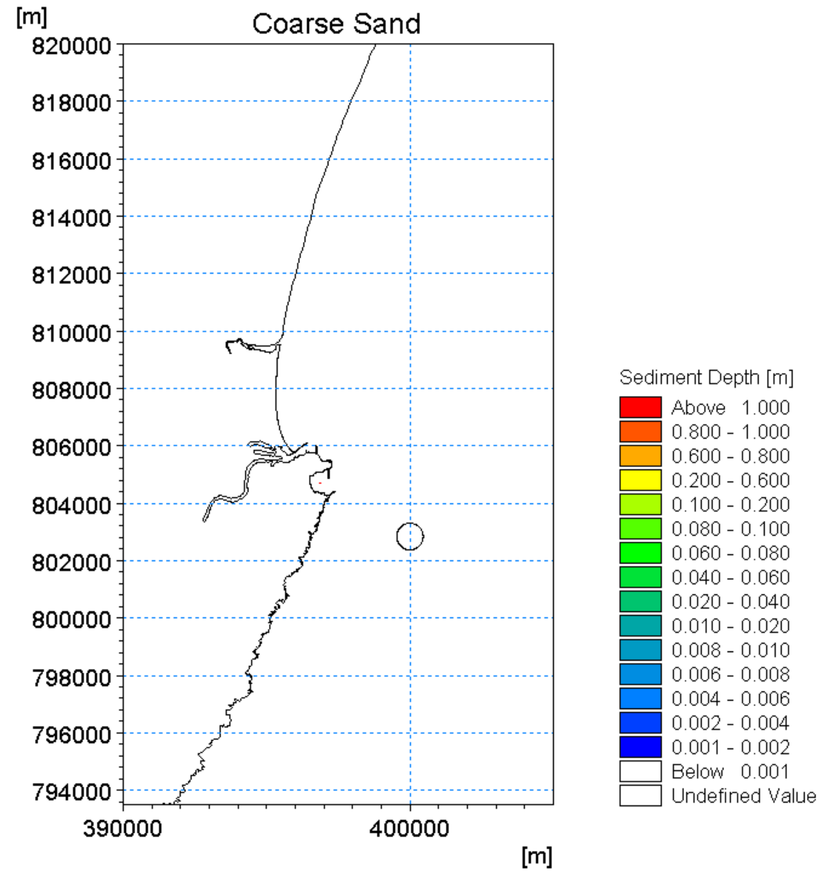

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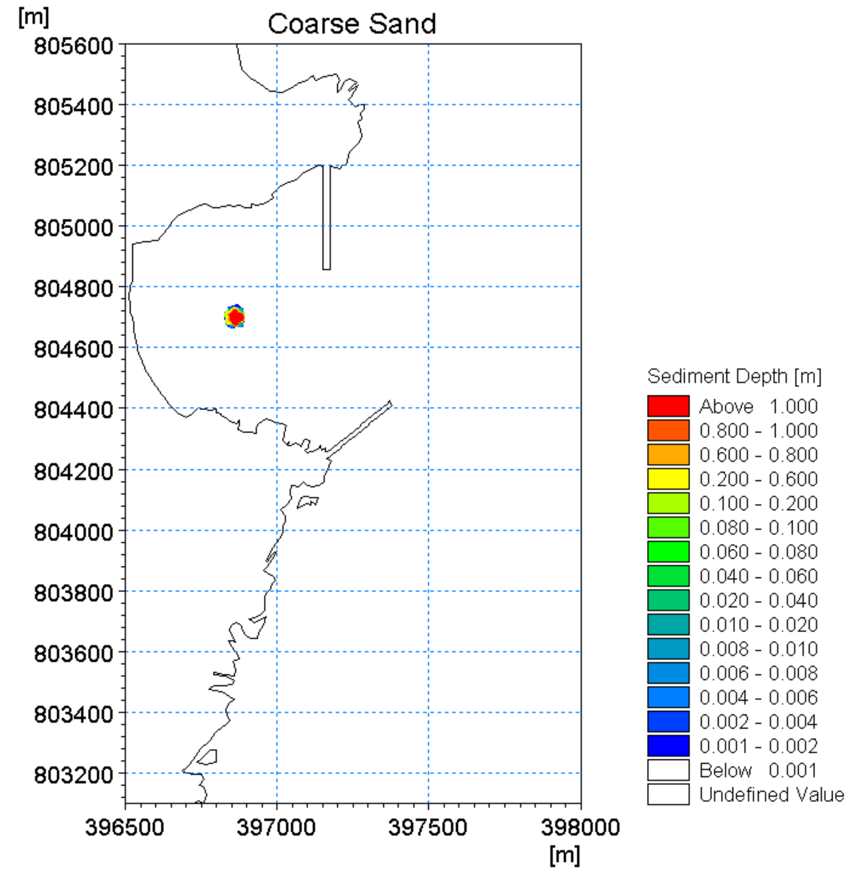

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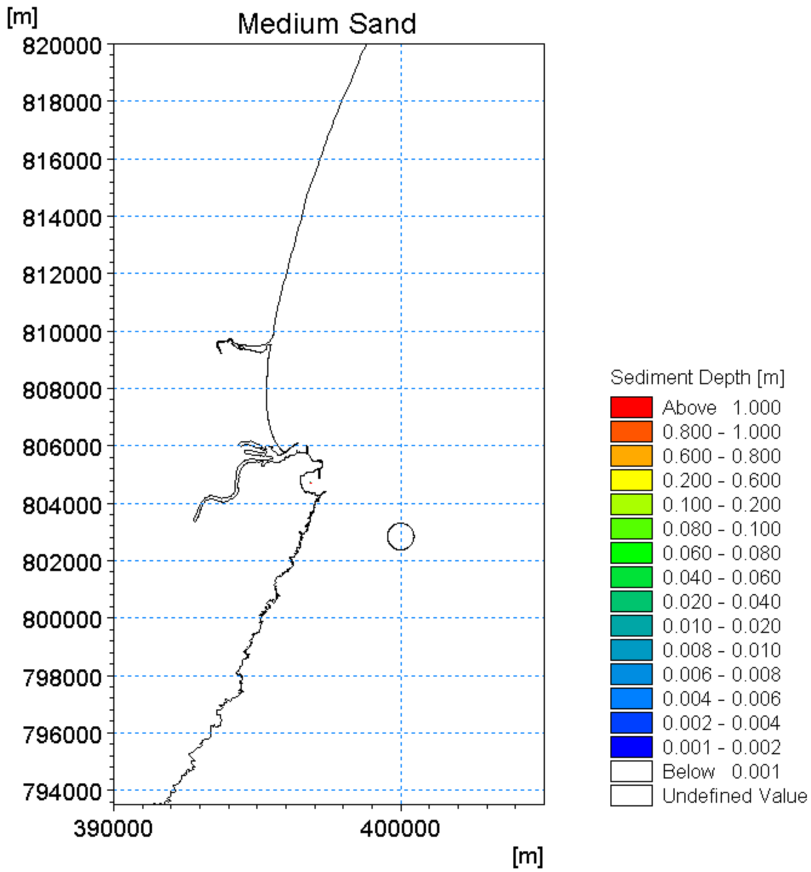

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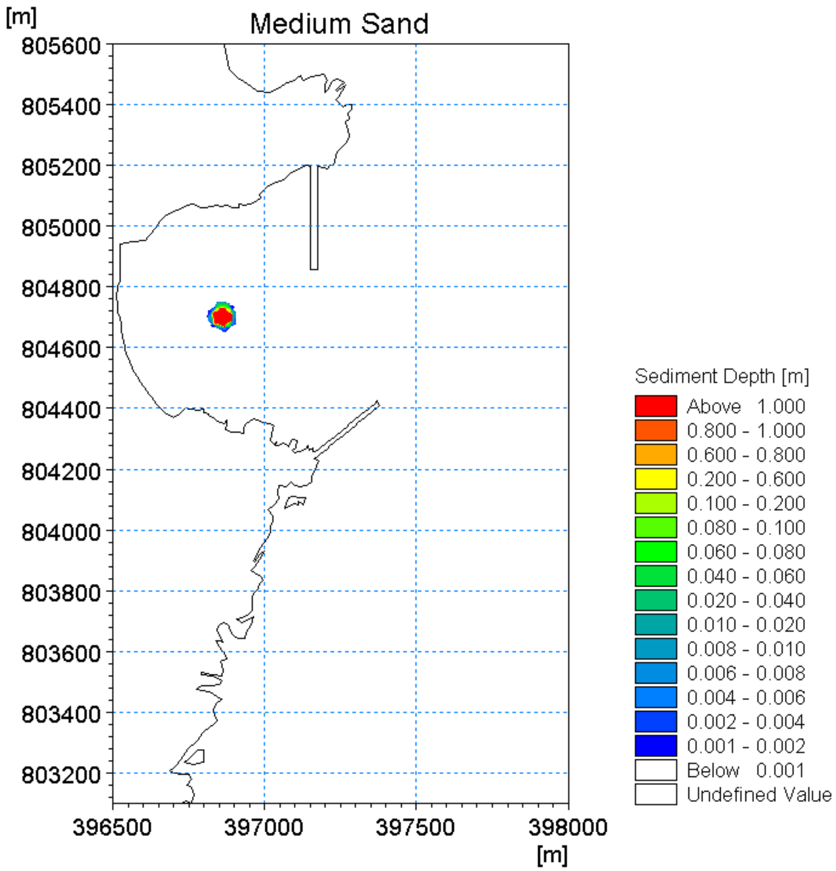

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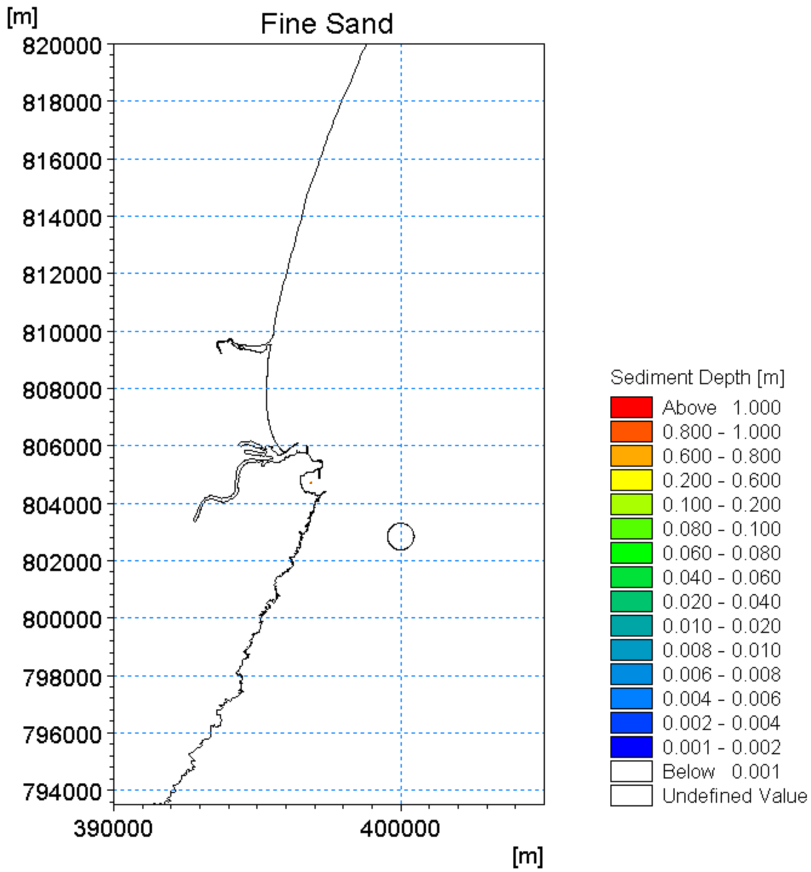

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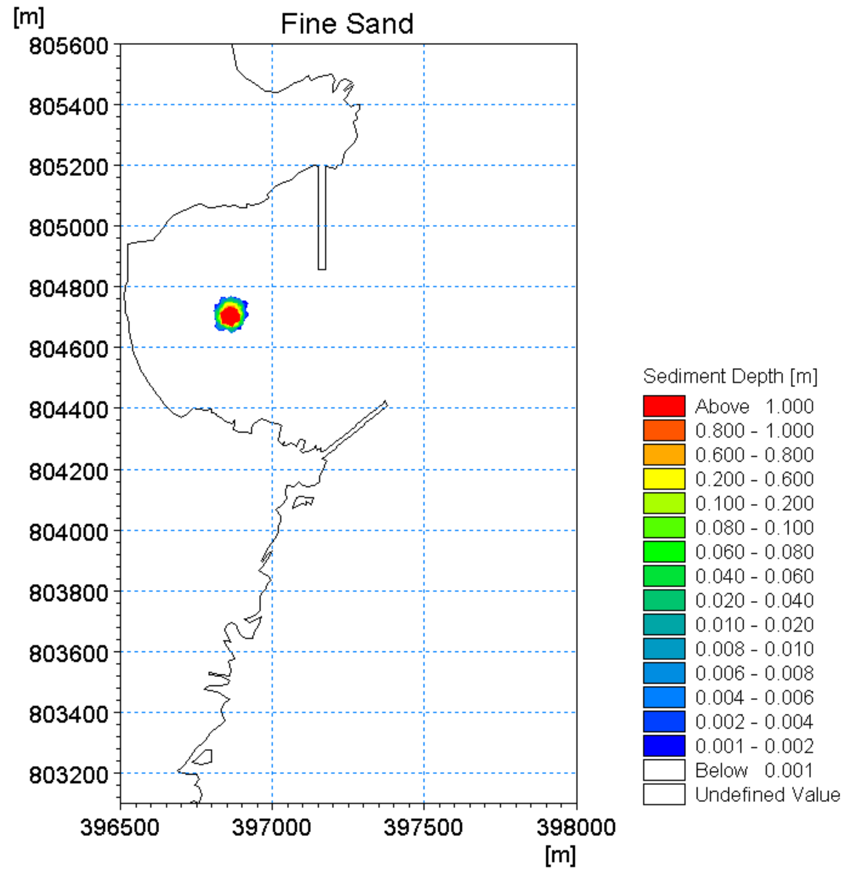

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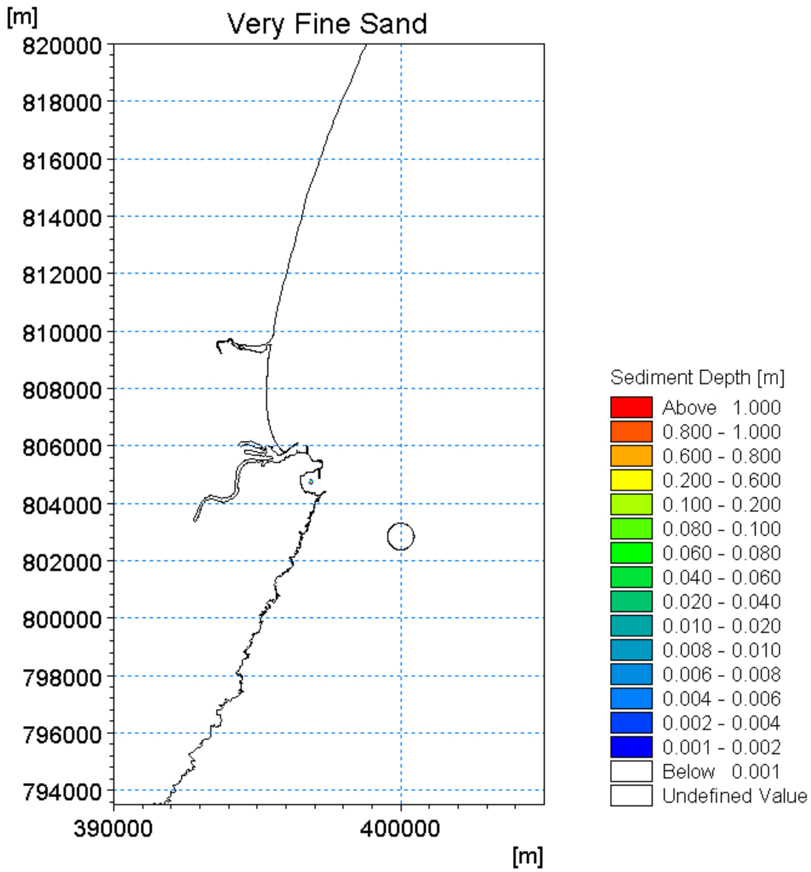

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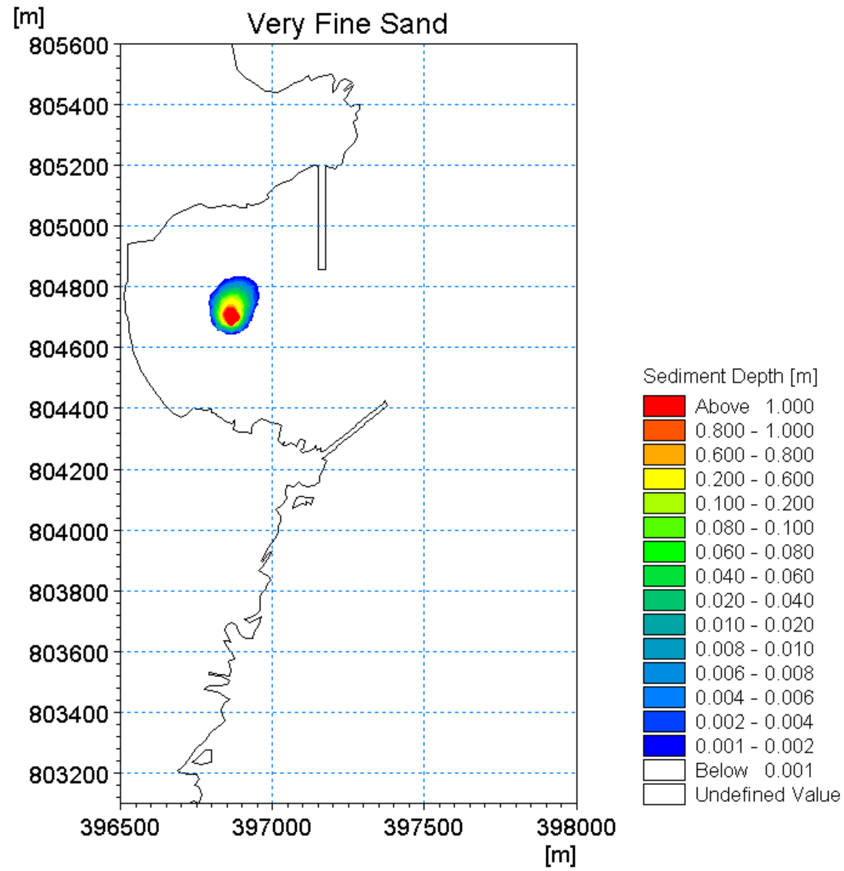

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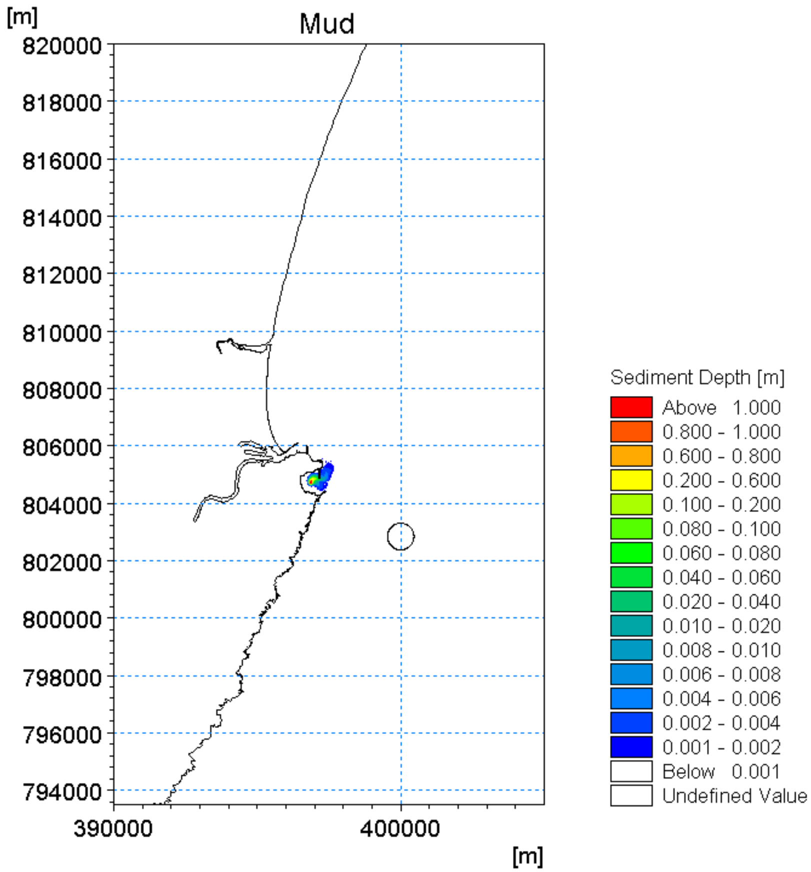

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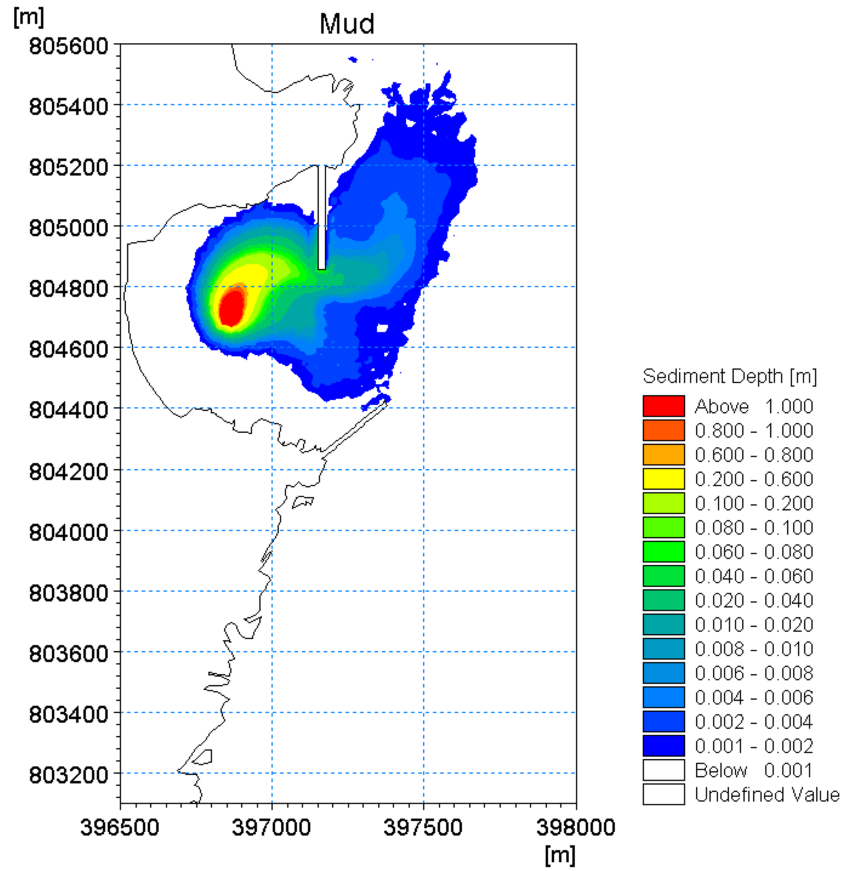


Figure C-11: Backhoe overspill area and depth of redeposited sediment over the whole dredging period

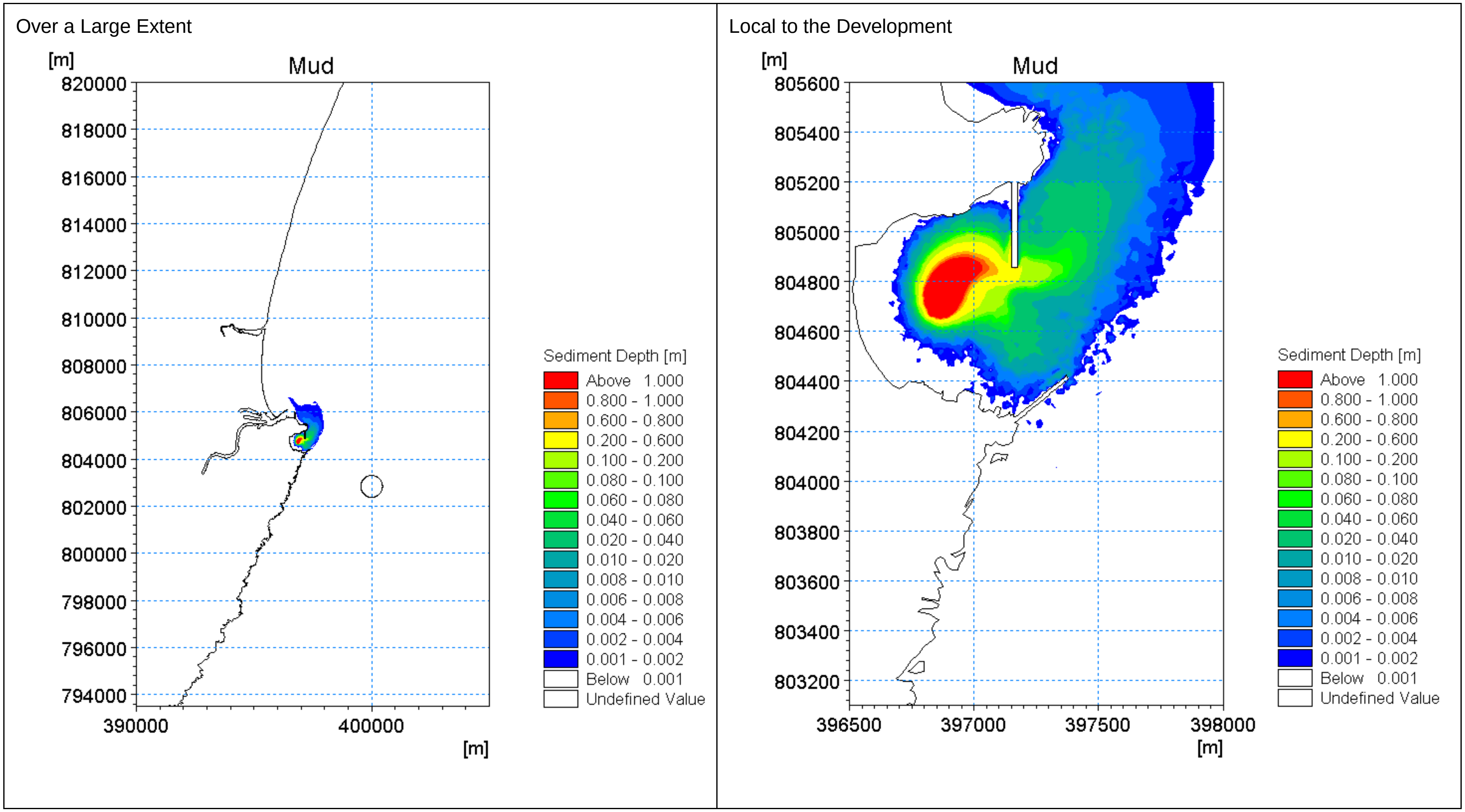
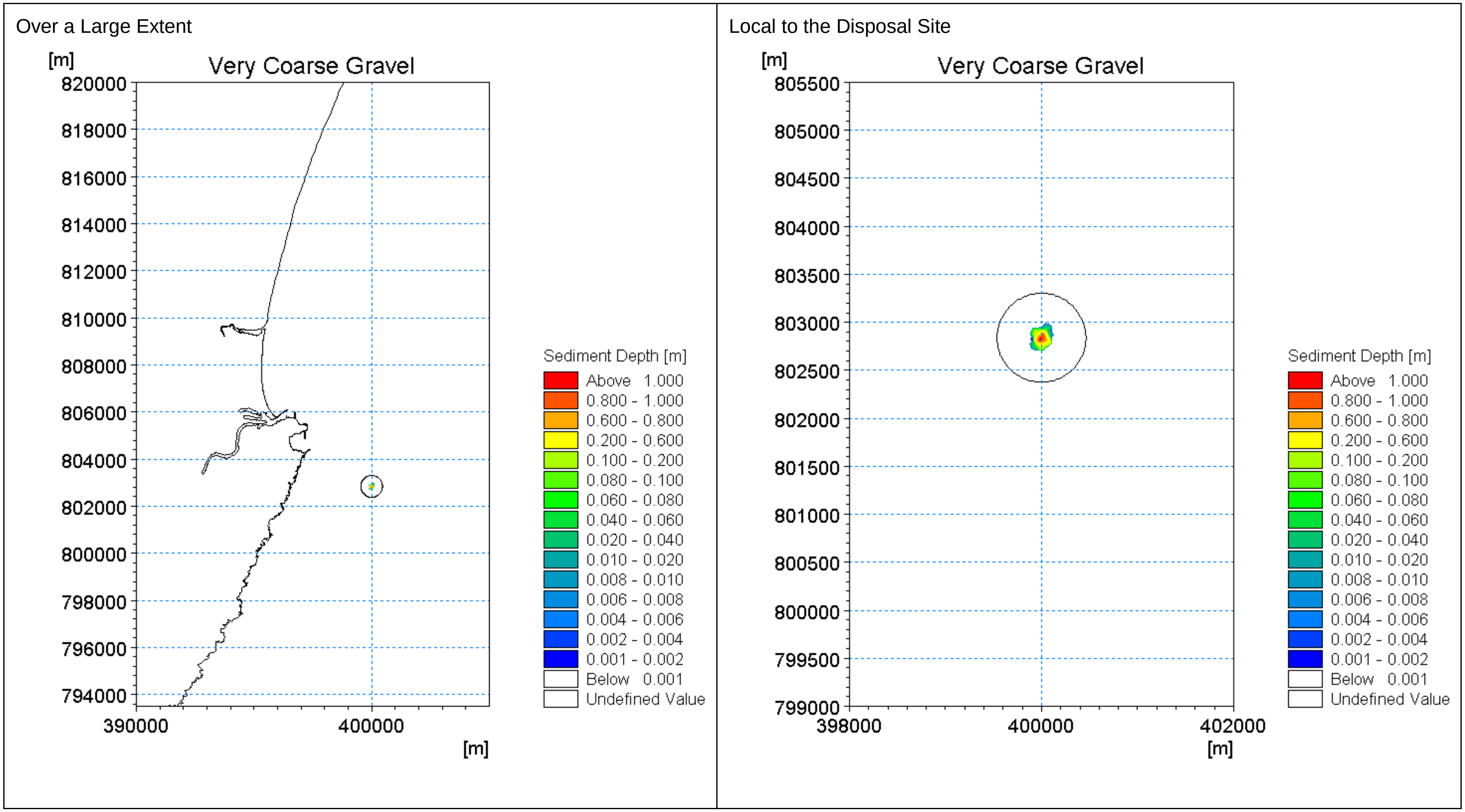
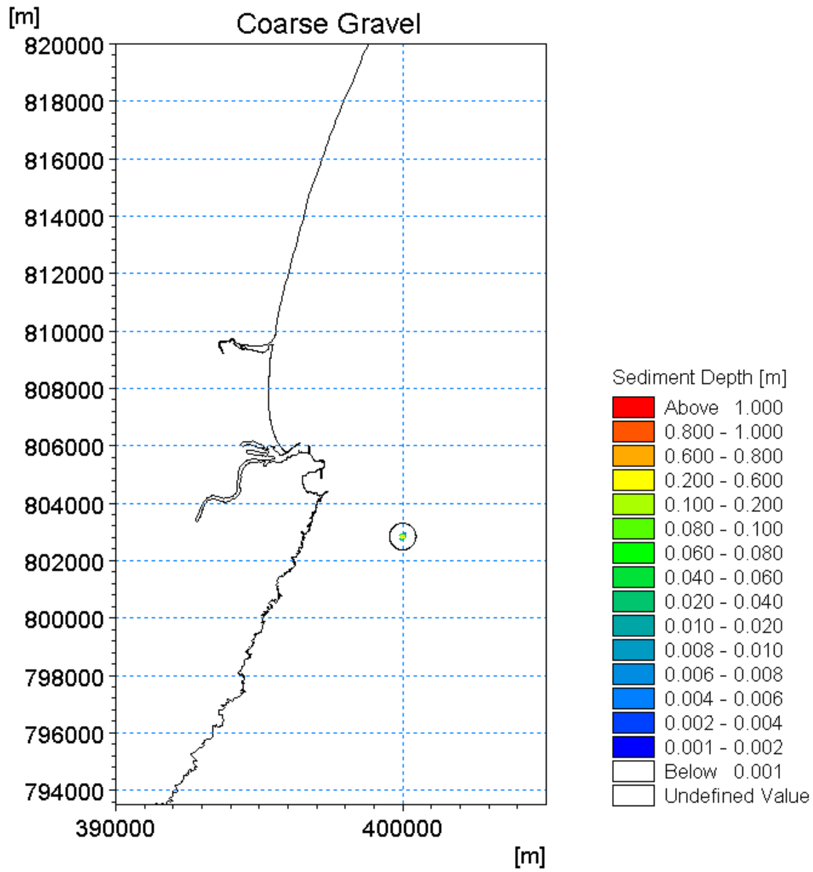


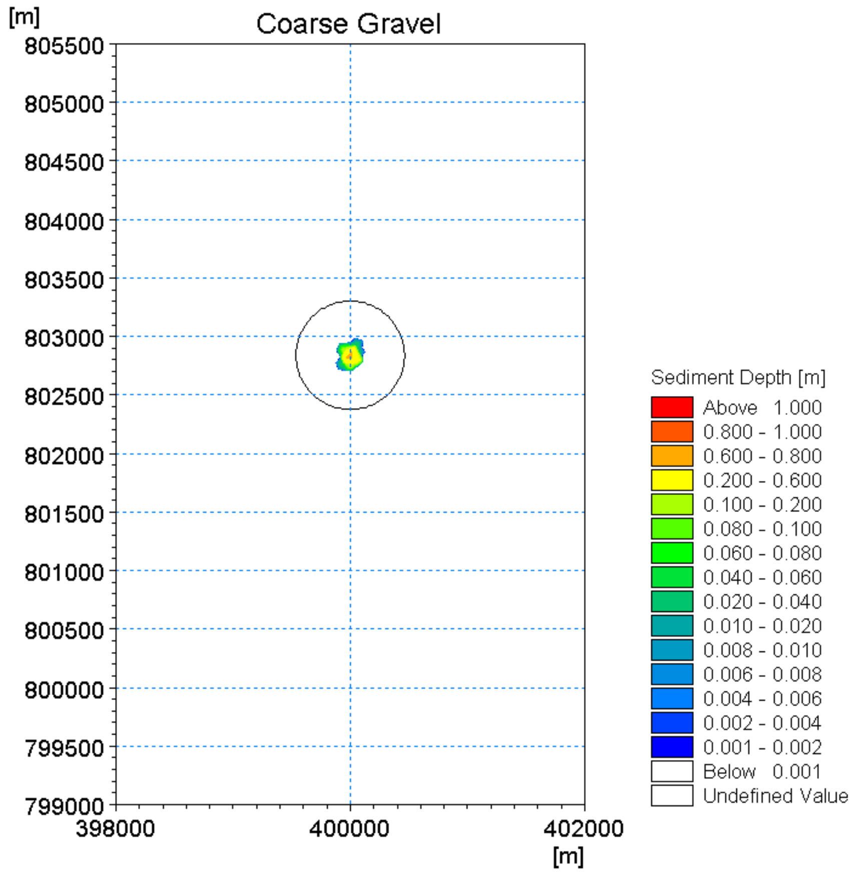
Figure C-12: Backhoe disposal area and depth of redeposited sediment



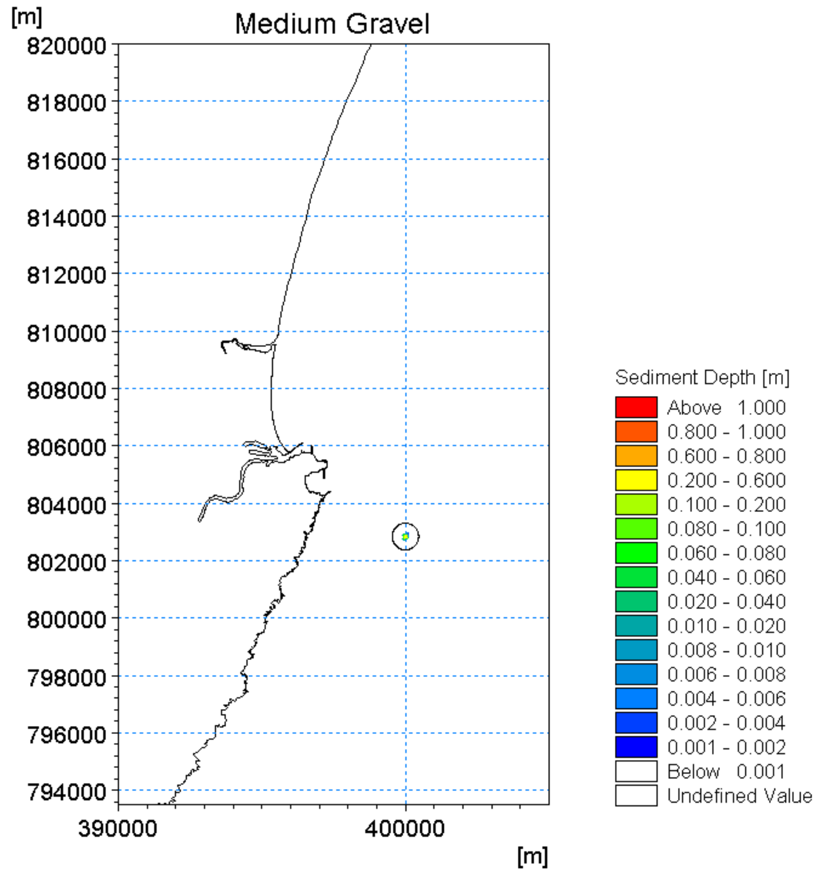
Over a Large Extent



Local to the Disposal Site



Over a Large Extent



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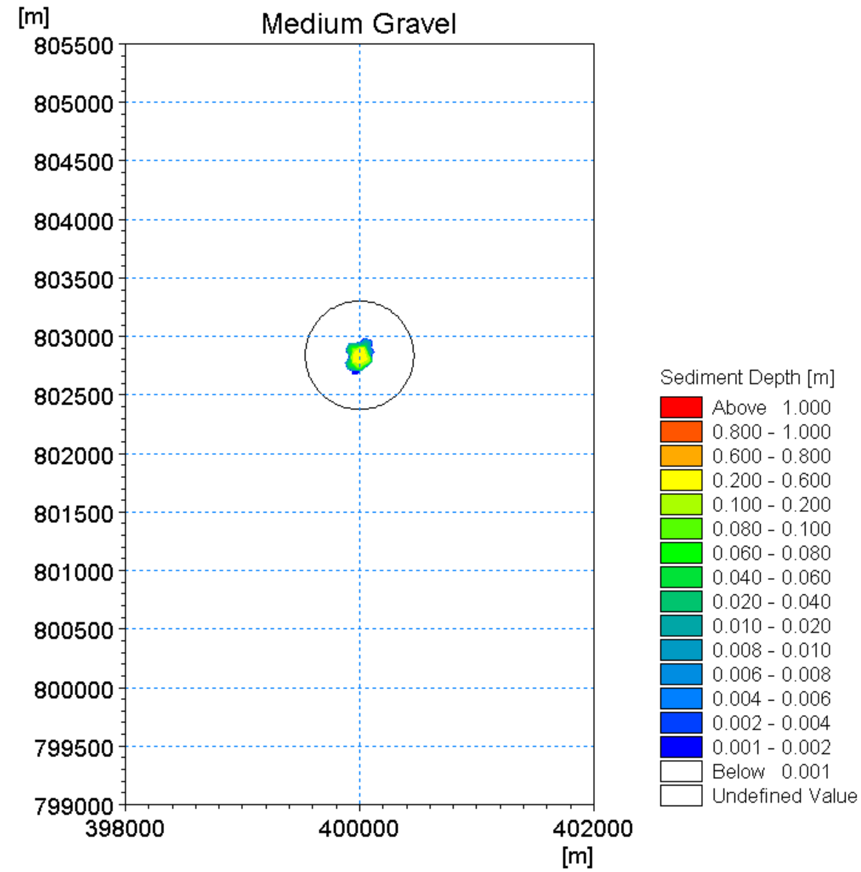

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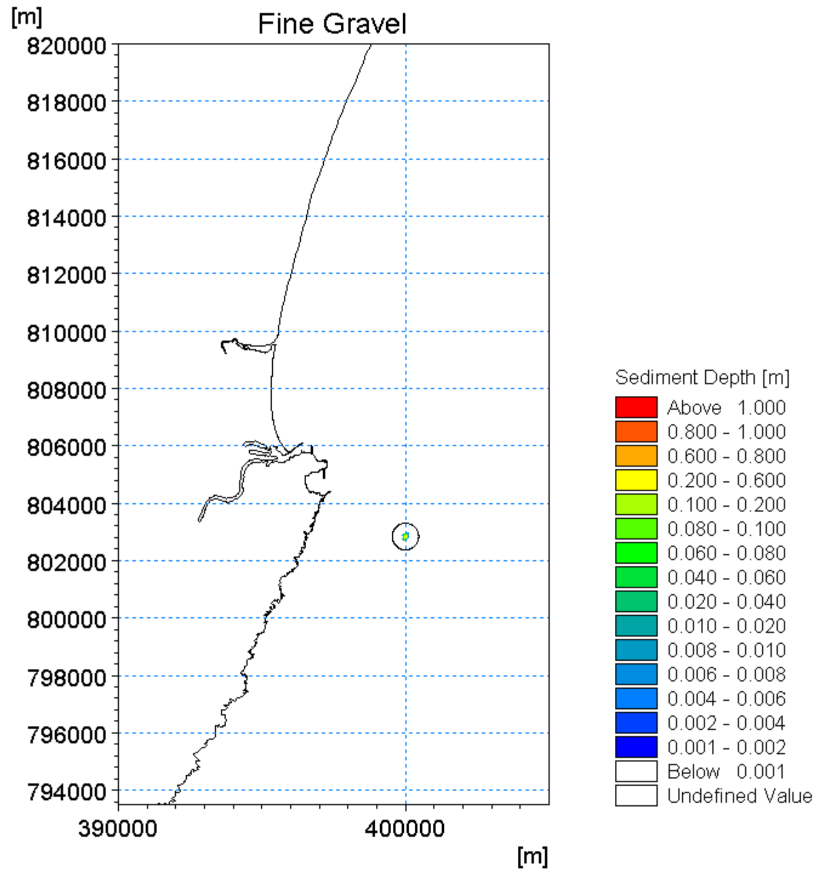

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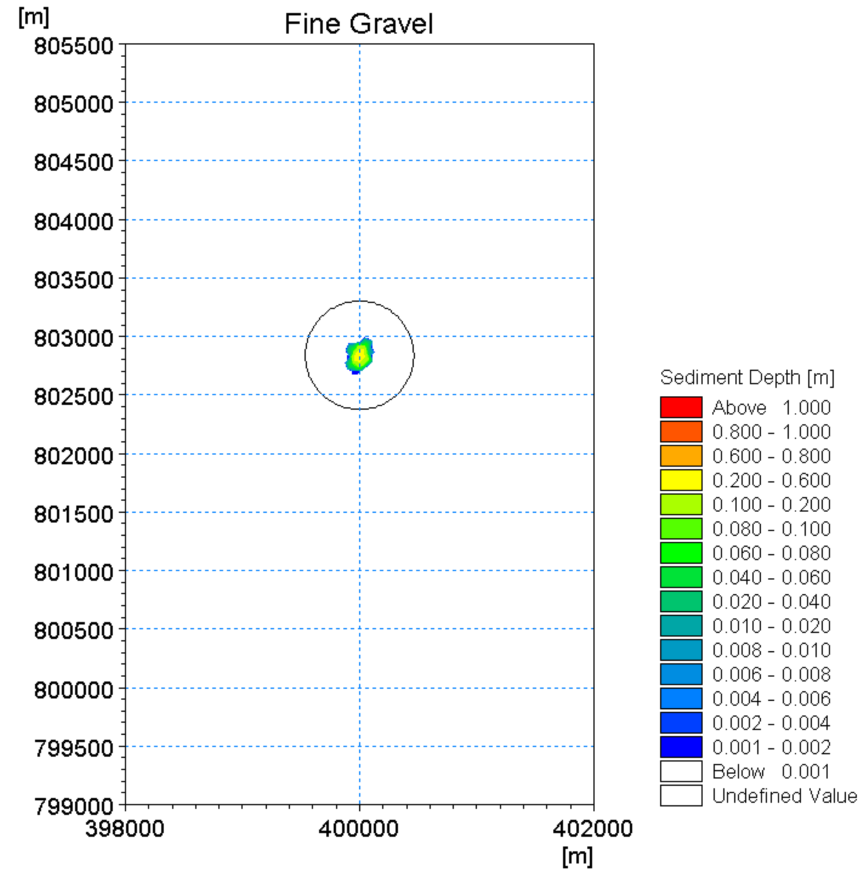

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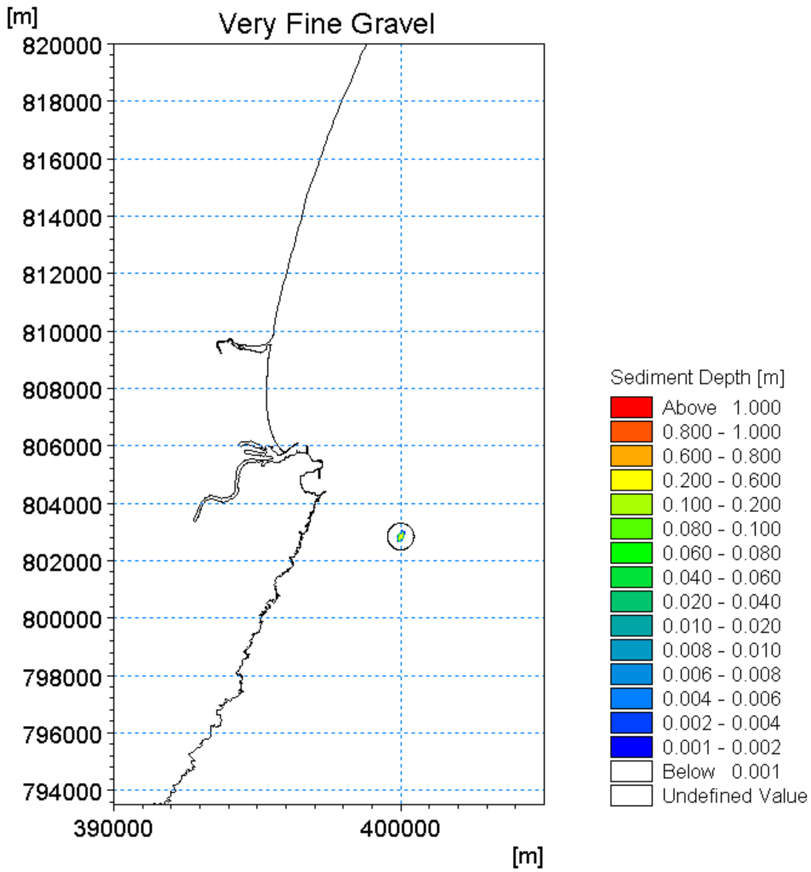

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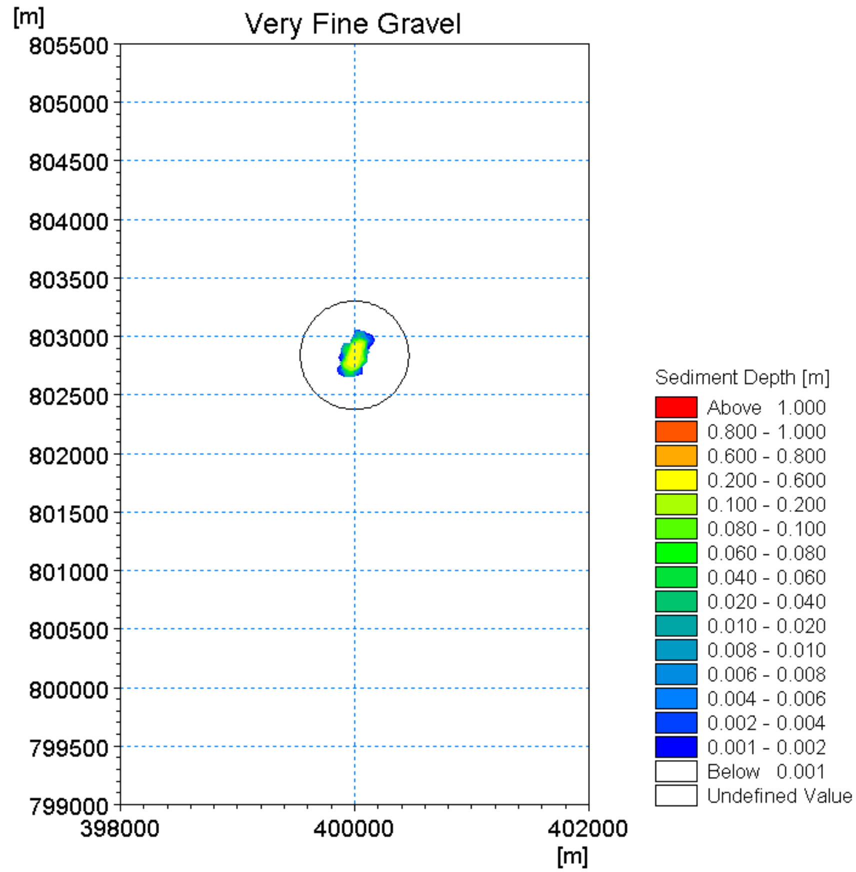

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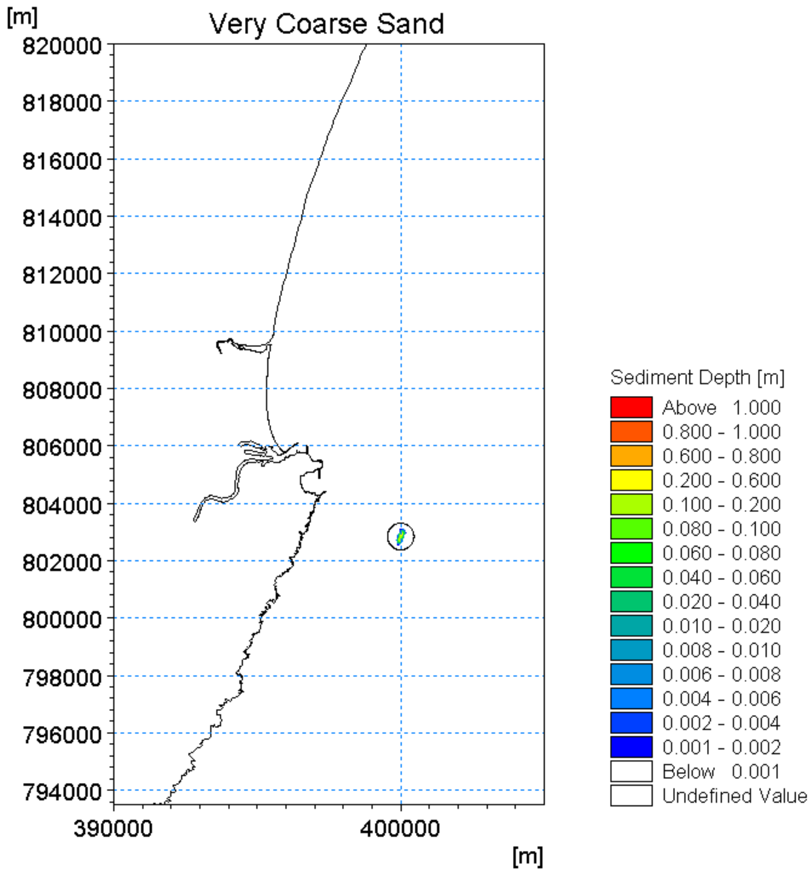

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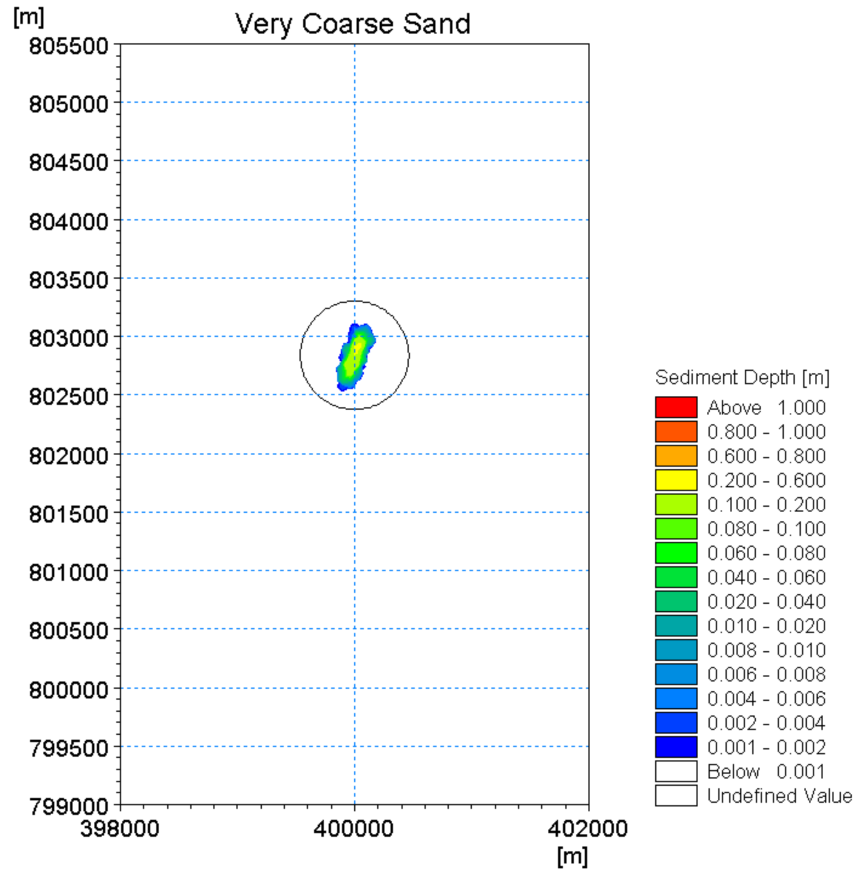

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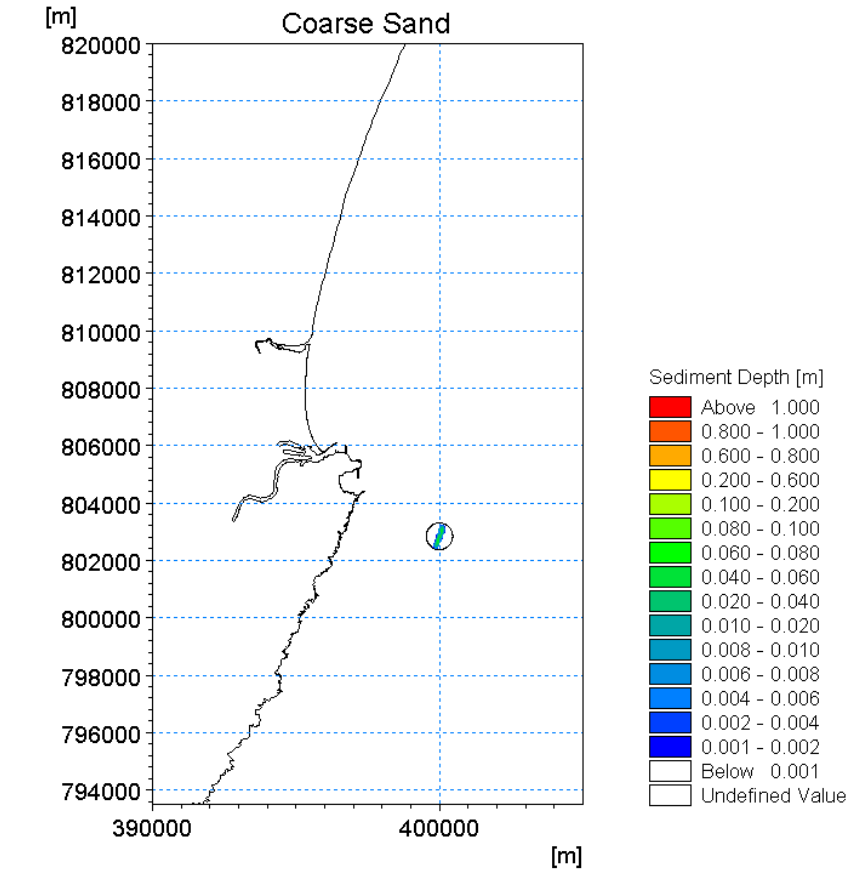

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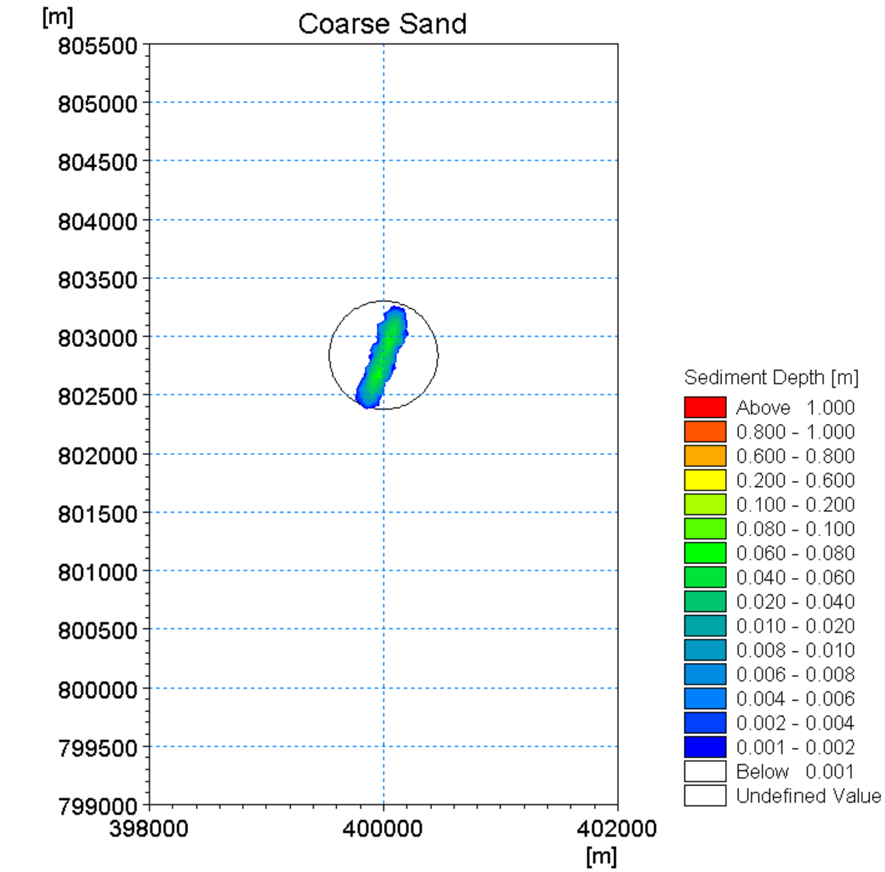

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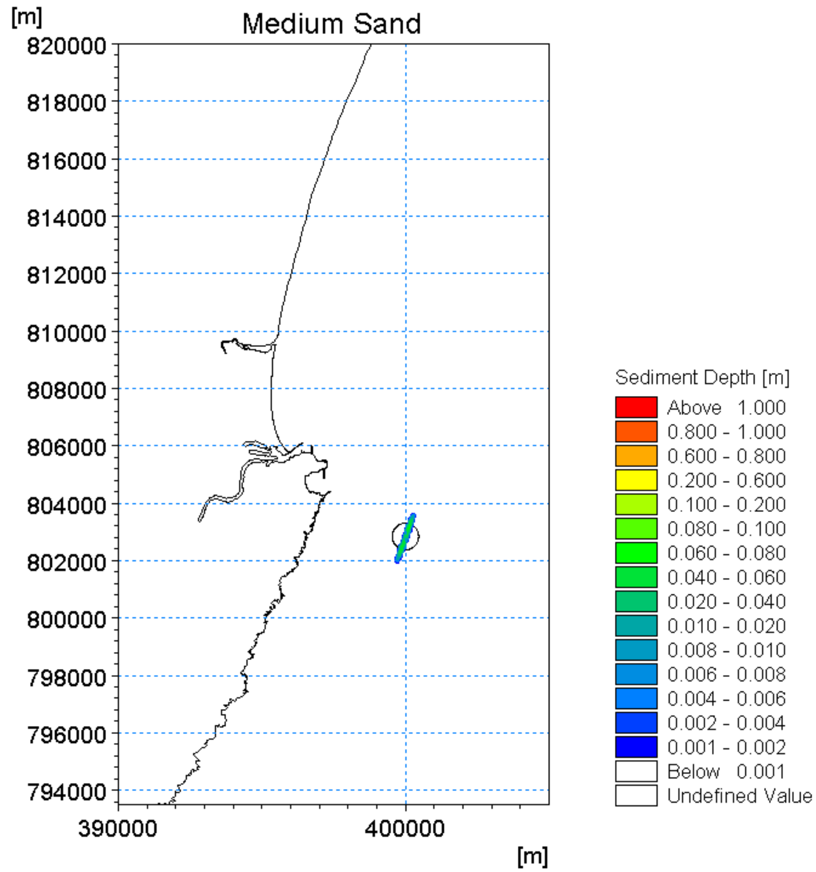

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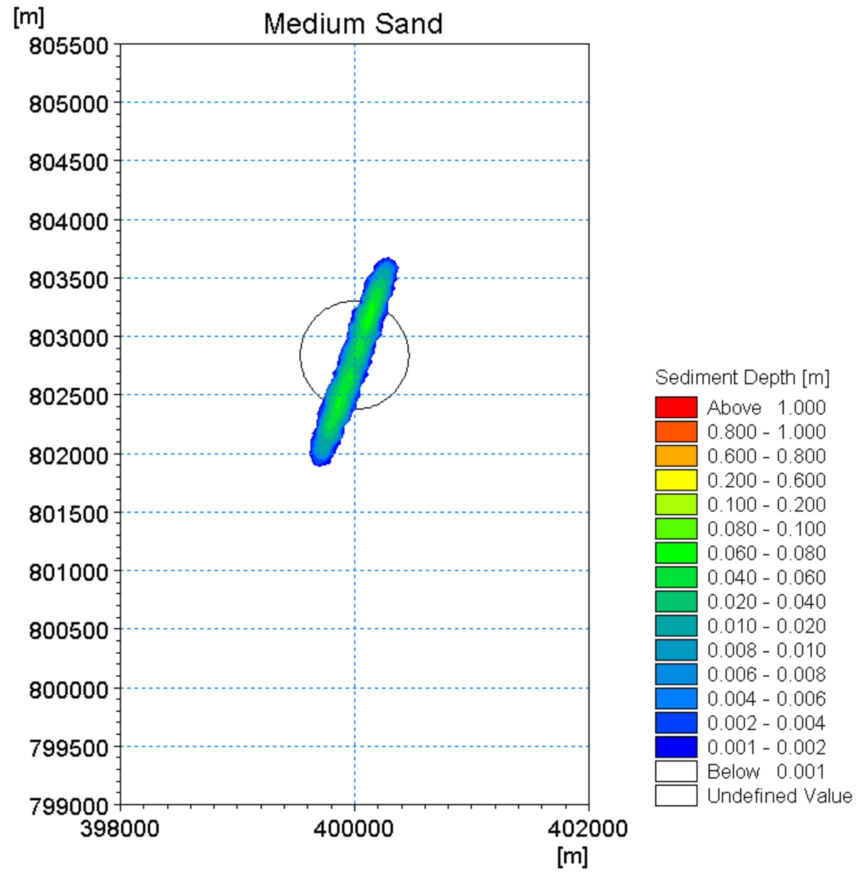

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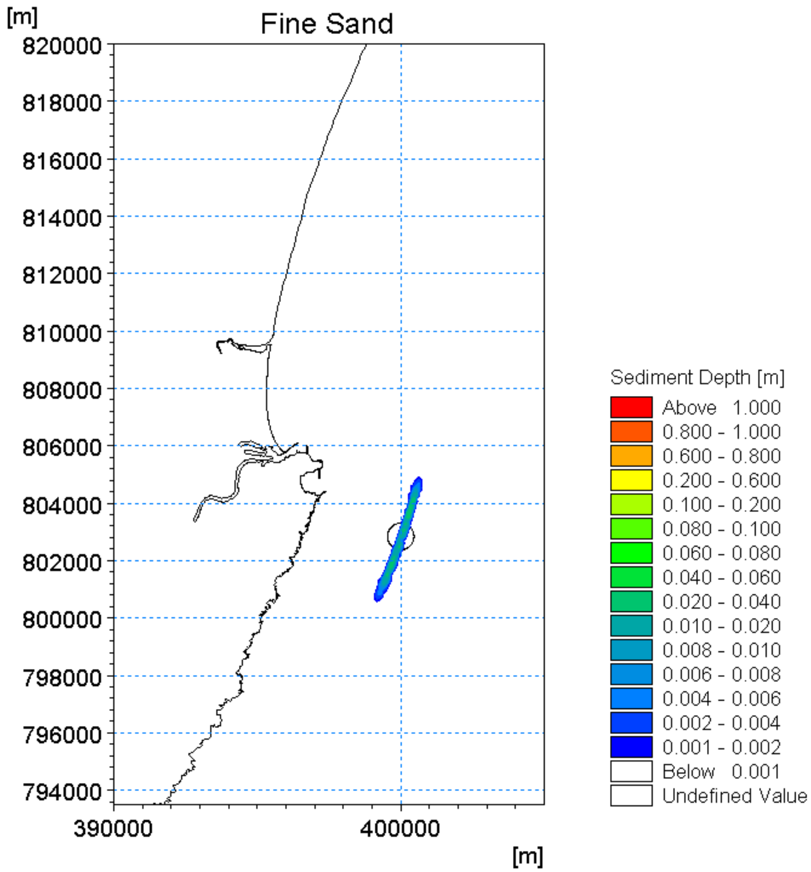

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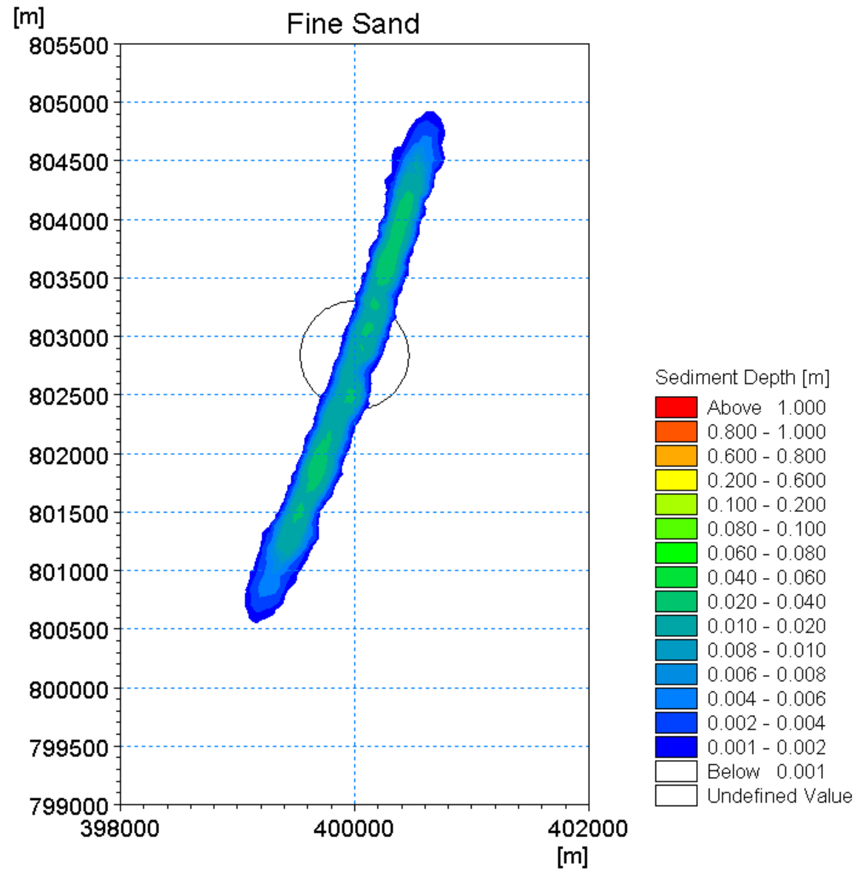

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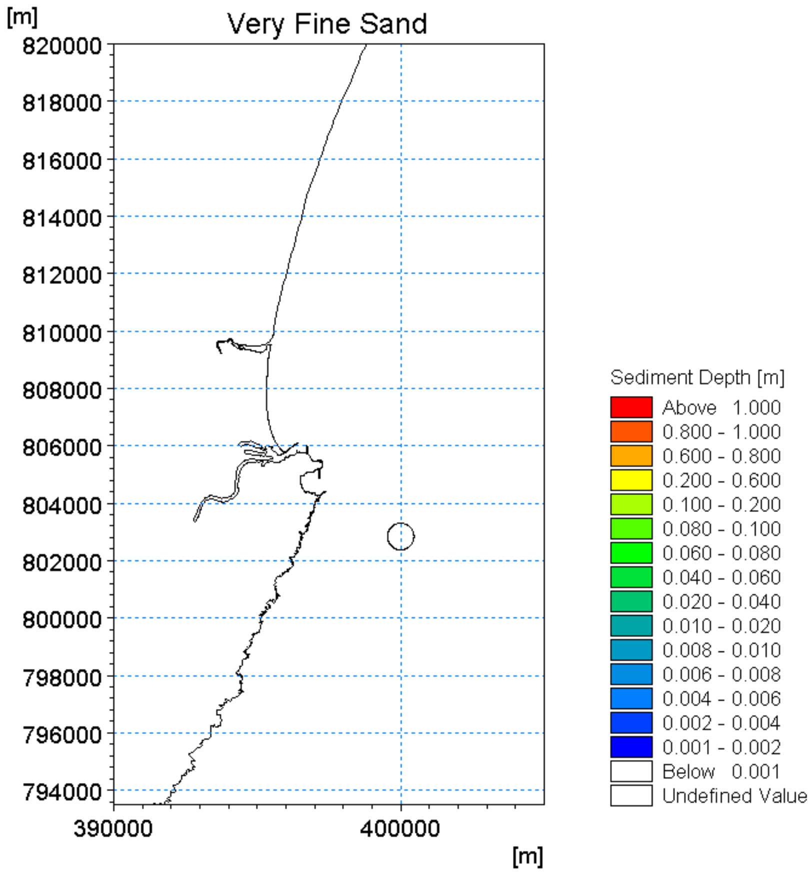
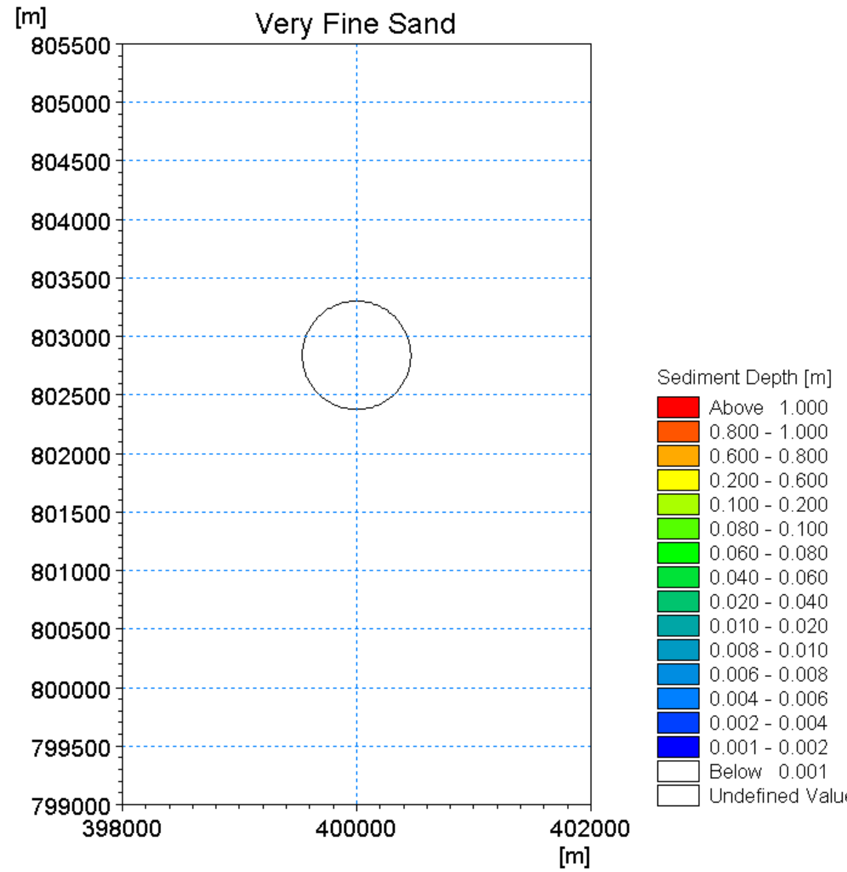


Local to the Disposal Site



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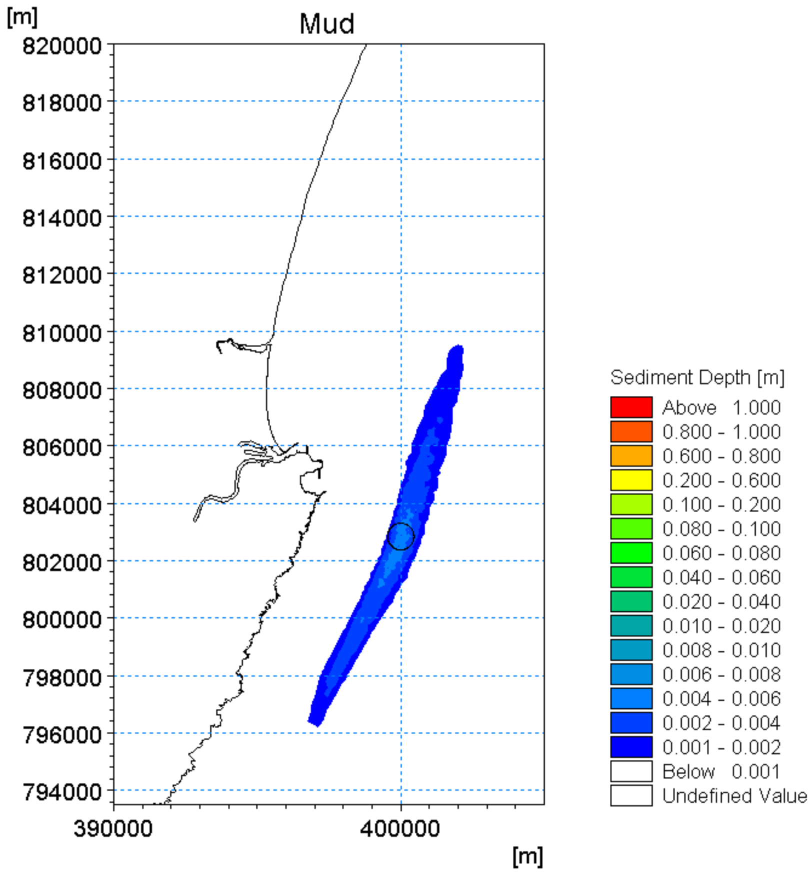

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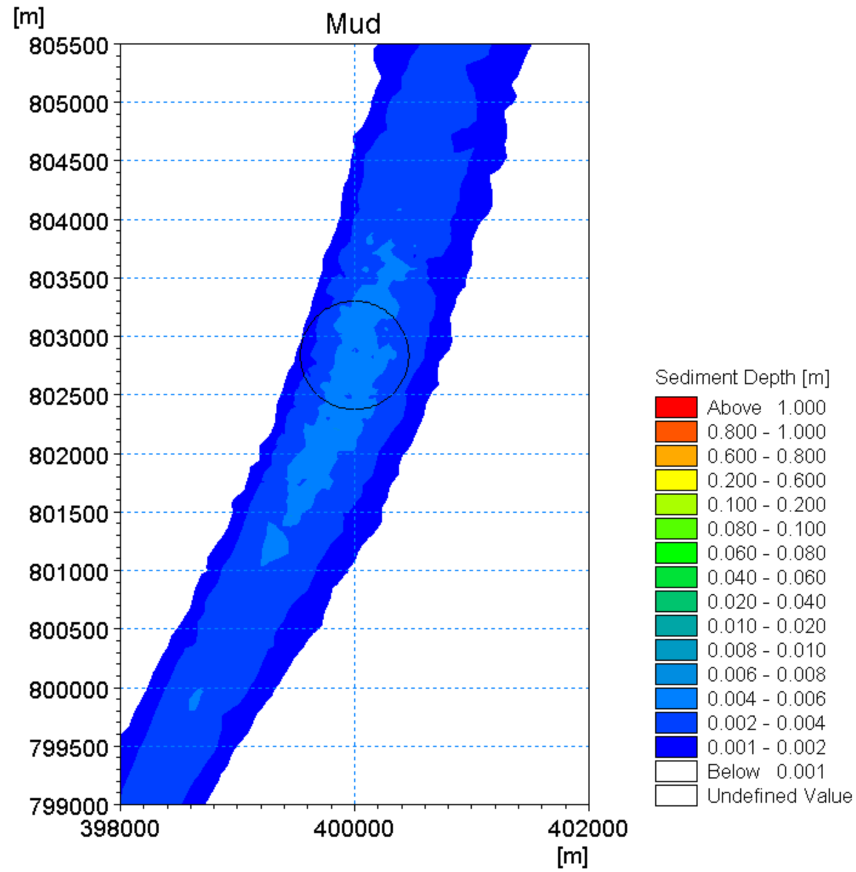


Table C-10: Backhoe overspill depth of redeposited sediment

Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Very coarse gravel (mm)	0	0	0	0	0	0	0	0	0	0
Coarse gravel (mm)	0	0	0	0	0	0	0	0	0	0
Medium gravel (mm)	0	0	0	0	0	0	0	0	0	0
Fine gravel (mm)	0	0	0	0	0	0	0	0	0	0
Very fine gravel (mm)	0	0	0	0	0	0	0	0	0	0
Very Coarse sand (mm)	0	0	0	0	0	0	0	0	0	0
Coarse sand (mm)	0	0	0	0	0	0	0	0	0	0
Medium sand (mm)	0	0	0	0	0	0	0	0	0	0
Fine sand (mm)	0	0	0	0	0	0	0	0	0	0
Very fine sand (mm)	0	0	0	0	0	0	0	0	0	0
Mud (mm)	10	1	0	3	33	10	1	0	0	0
Total (mm)	10	1	0	3	33	10	1	0	0	0

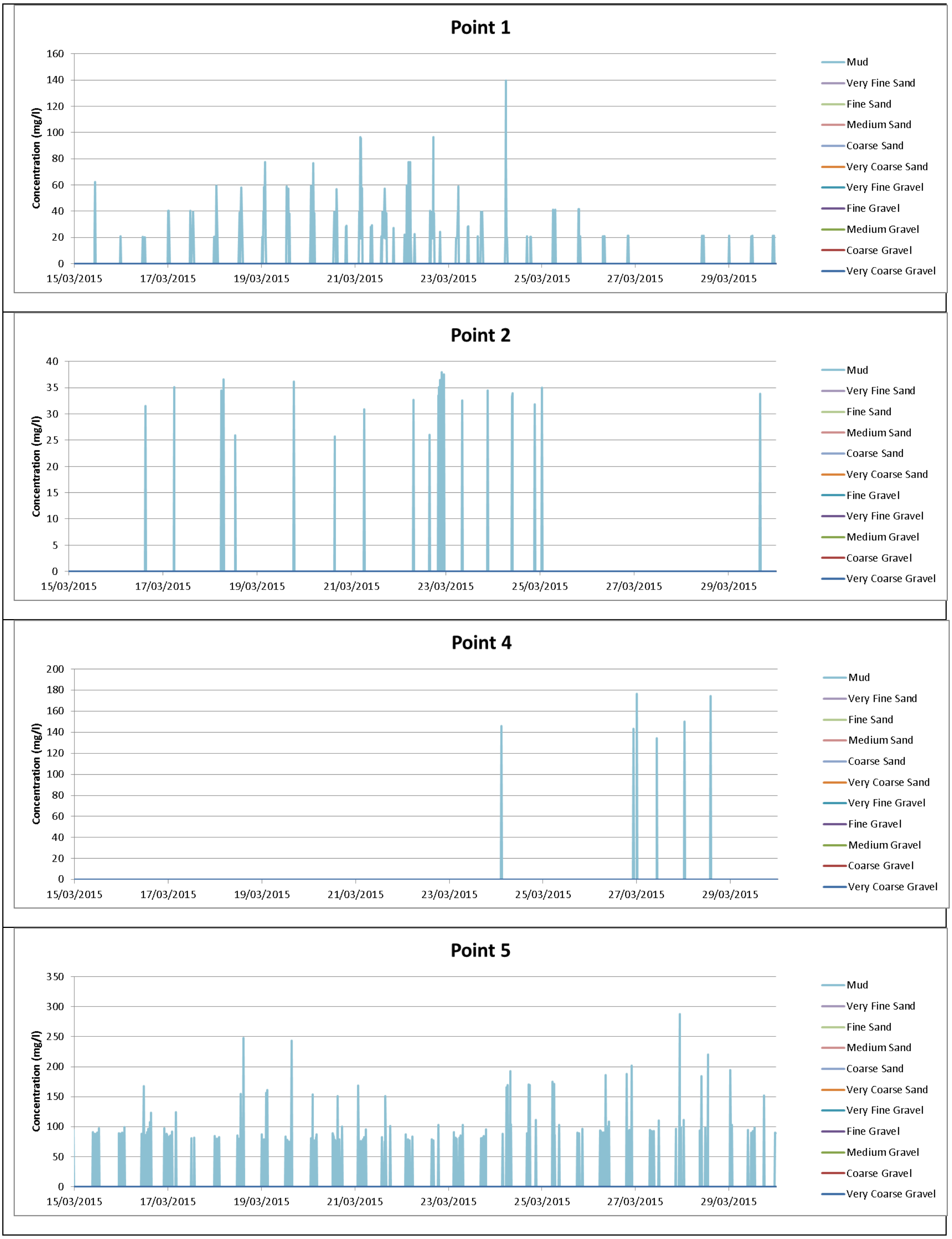
Table C-11: Backhoe overspill depth of redeposited sediment over the whole dredging period

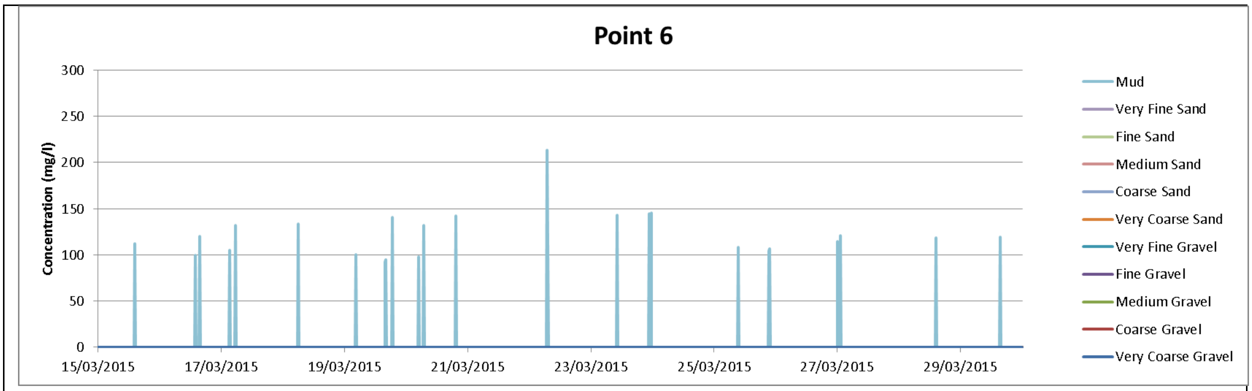
Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Mud (mm)	78	11	0	21	272	78	9	0	0	0

Table C-12: Backhoe disposal redeposited sediment depth

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very Coarse Gravel (mm)	0	0	0	0	0	0	0	0	1032	0	0	0	0	0	0	0	0
Coarse Gravel (mm)	0	0	0	0	0	0	0	0	655	0	0	0	0	0	0	0	0
Medium Gravel (mm)	0	0	0	0	0	0	0	0	432	0	0	0	0	0	0	0	0
Fine Gravel (mm)	0	0	0	0	0	0	0	0	294	0	0	0	0	0	0	0	0
Very Fine Gravel (mm)	0	0	0	0	0	0	0	0	389	0	0	0	0	0	0	0	0
Very Coarse Sand (mm)	0	0	0	0	0	0	0	0	191	0	0	0	0	0	0	0	0
Coarse Sand (mm)	0	0	0	0	0	0	0	0	46	3	0	0	0	0	0	0	0
Medium Sand (mm)	0	0	0	0	0	0	22	59	45	61	10	0	0	0	0	0	0
Fine Sand (mm)	0	0	0	0	9	29	31	22	16	17	27	23	4	0	0	0	0
Very Fine Sand (mm)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Mud (mm)	0	1	2	2	3	3	5	5	5	5	5	5	4	4	3	1	0
Total (mm)	0	1	2	2	12	32	58	86	3105	86	42	28	8	5	3	1	0

Figure C-13: Backhoe overspill suspended sediment concentration time series




Point 6
Concentration (mg/l)
300
250
200
150
100
50
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

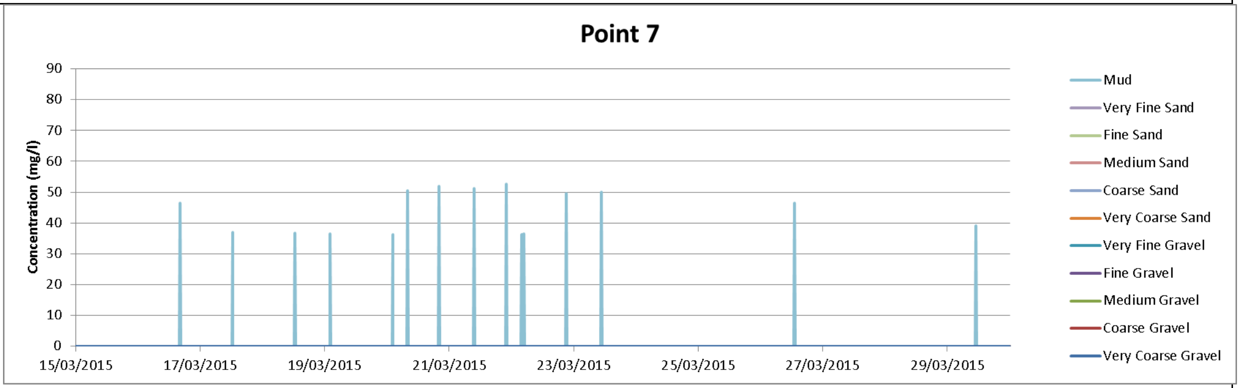

Point 7
Concentration (mg/l)
90
80
70
60
50
40
30
20
10
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

Figure C-14: Backhoe overspill area average suspended sediment concentration

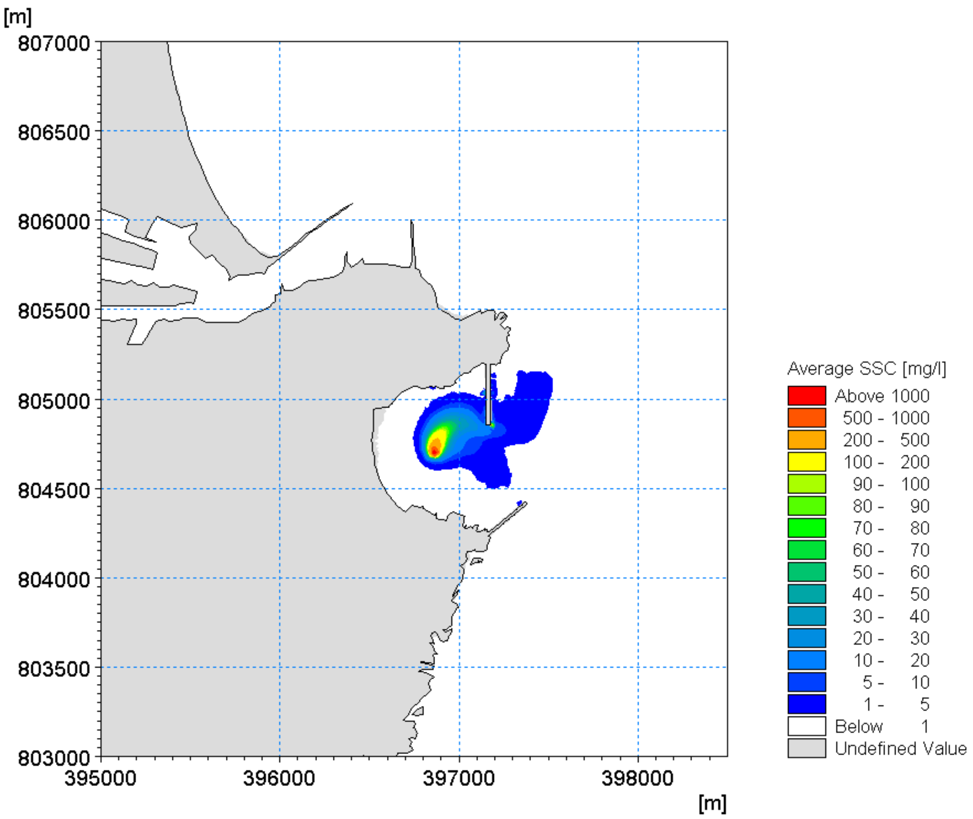


Figure C-15: Backhoe overspill area maximum suspended sediment concentration

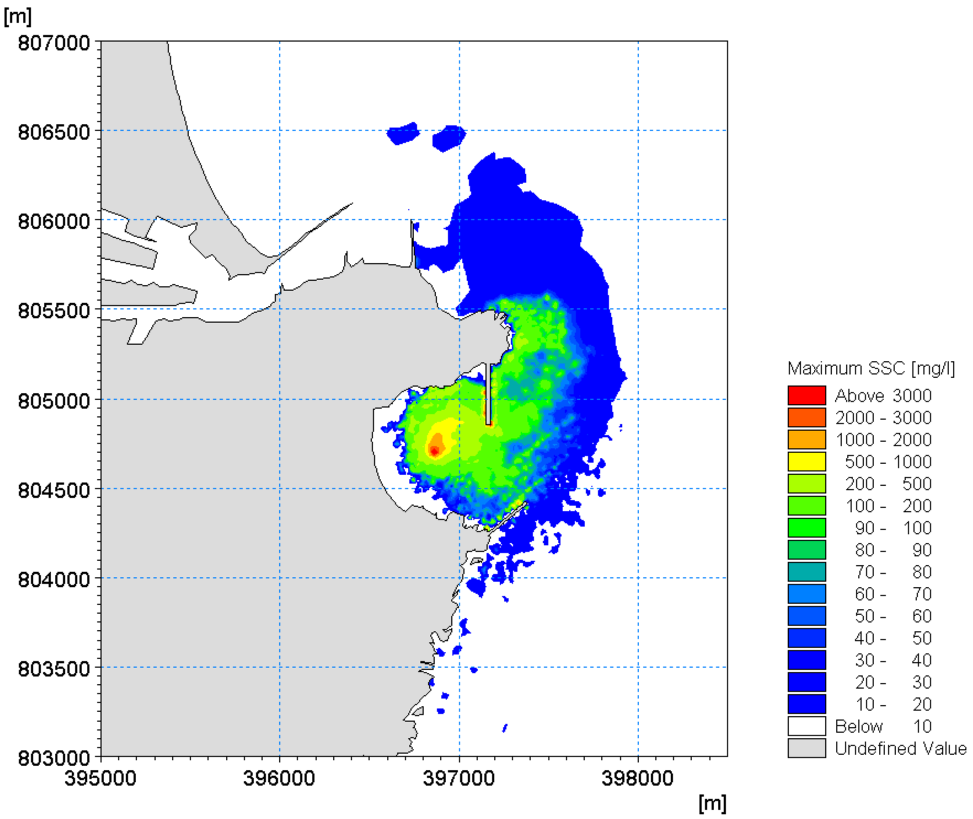


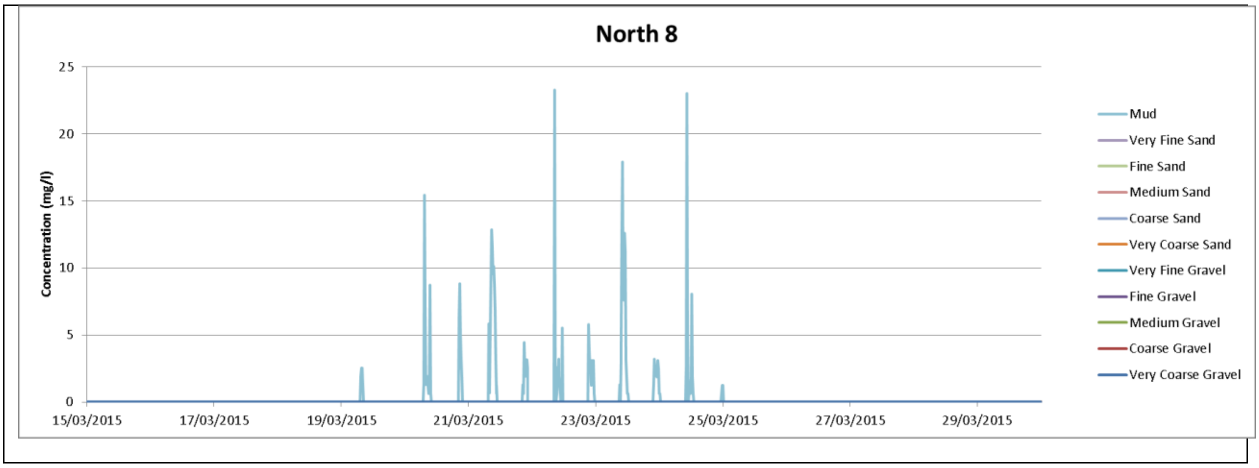
Table C-13: Backhoe overspill average suspended sediment concentrations

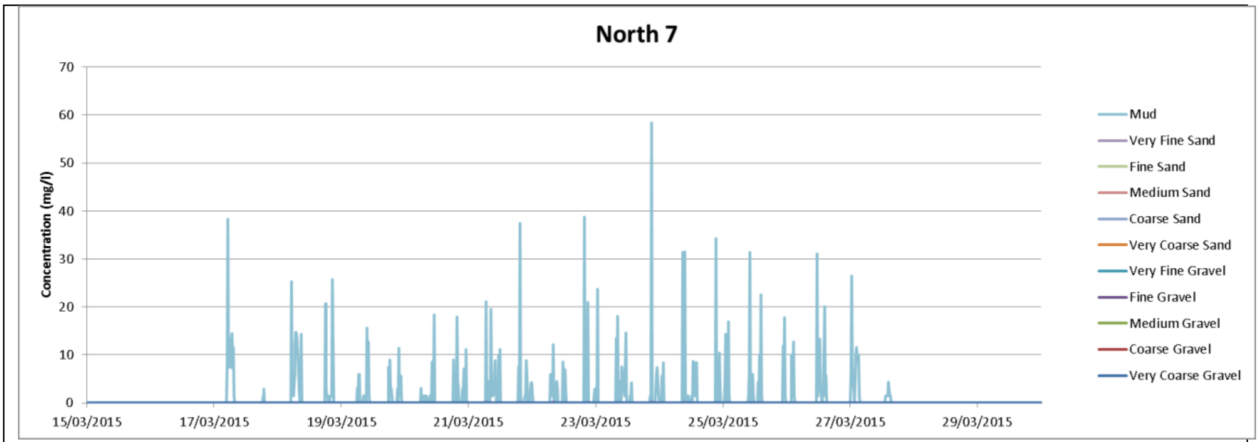
Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Very coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very fine sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mud (mg/l)	2.7	0.5	0.0	0.5	9.1	2.6	0.4	0.0	0.0	0.0
Total suspended solids (mg/l)	2.7	0.5	0.0	0.5	9.1	2.6	0.4	0.0	0.0	0.0

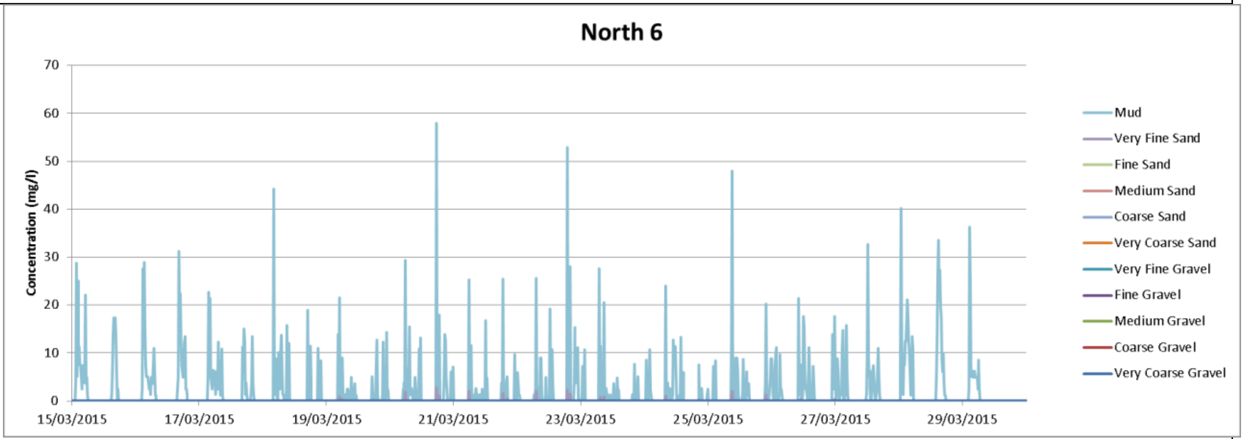
Table C-14: Backhoe overspill maximum suspended sediment concentrations

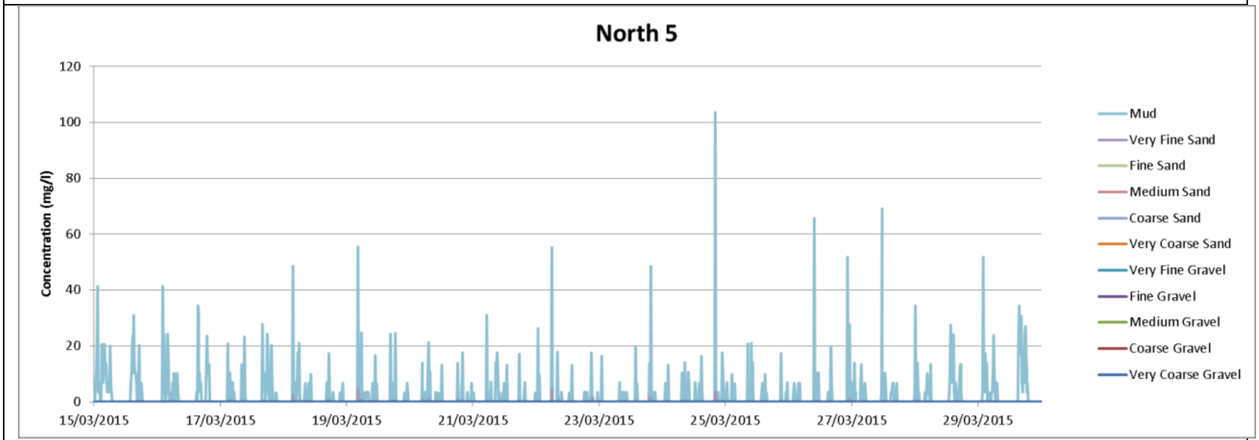
Location	1	2	3	4	5	6	7	BW_1	SSSI_1	SSSI_2
Very coarse gravel (mg/l)	0	0	0	0	0	0	0	0	0	0
Coarse gravel (mg/l)	0	0	0	0	0	0	0	0	0	0
Medium gravel (mg/l)	0	0	0	0	0	0	0	0	0	0
Fine gravel (mg/l)	0	0	0	0	0	0	0	0	0	0
Very fine gravel (mg/l)	0	0	0	0	0	0	0	0	0	0
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	0	0	0	0
Fine sand (mg/l)	0	0	0	0	0	0	0	0	0	0
Very fine sand (mg/l)	0	0	0	0	0	0	0	0	0	0
Mud (mg/l)	140	38	0	176	288	243	77	0	0	0
Total suspended solids (mg/l)	140	38	0	176	288	243	77	0	0	0

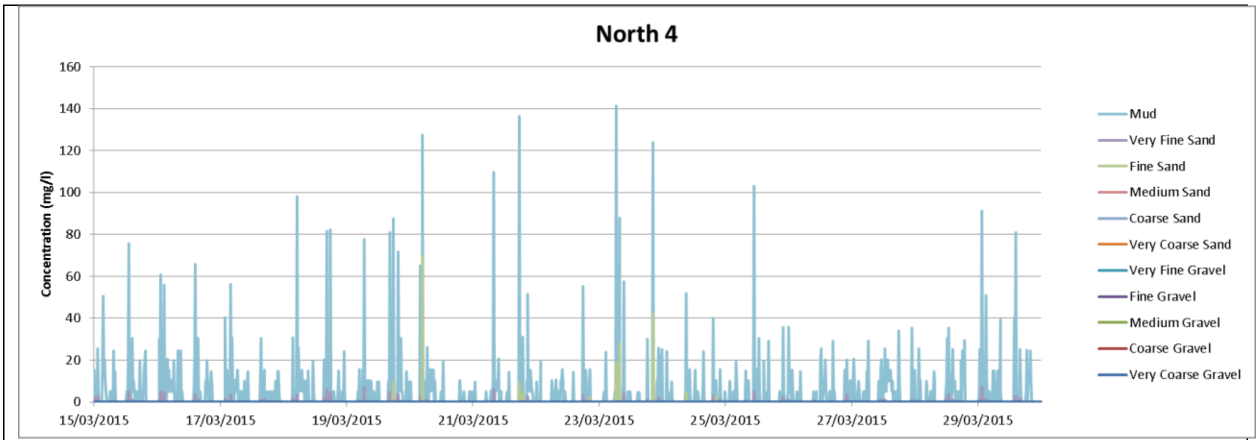
Figure C-16: Backhoe disposal suspended sediment concentration time series

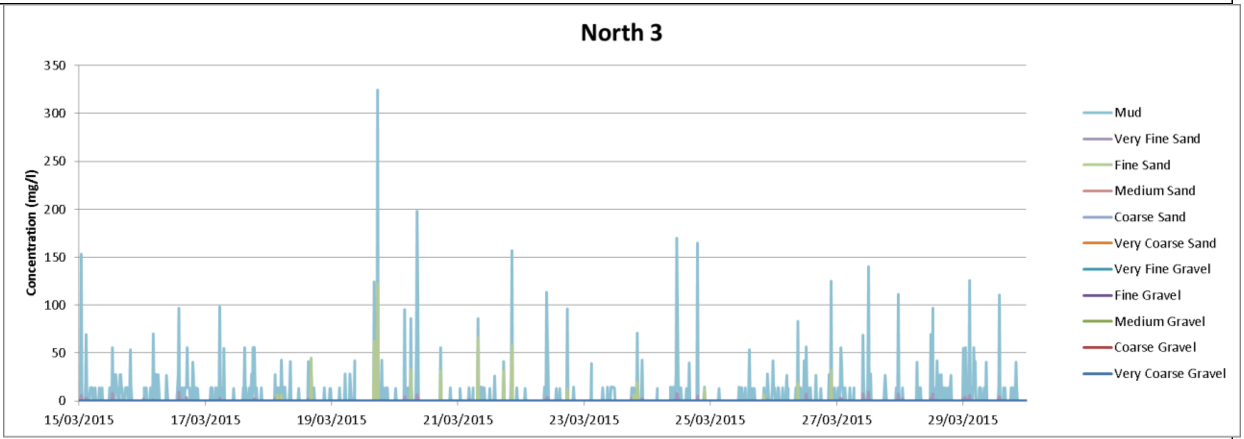


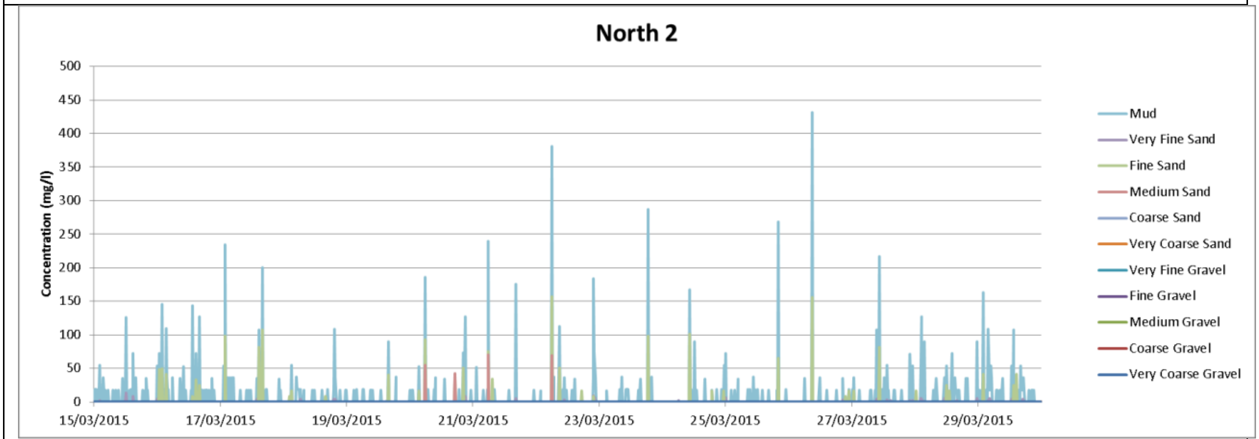

North 7
Concentration (mg/l)
70
60
50
40
30
20
10
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

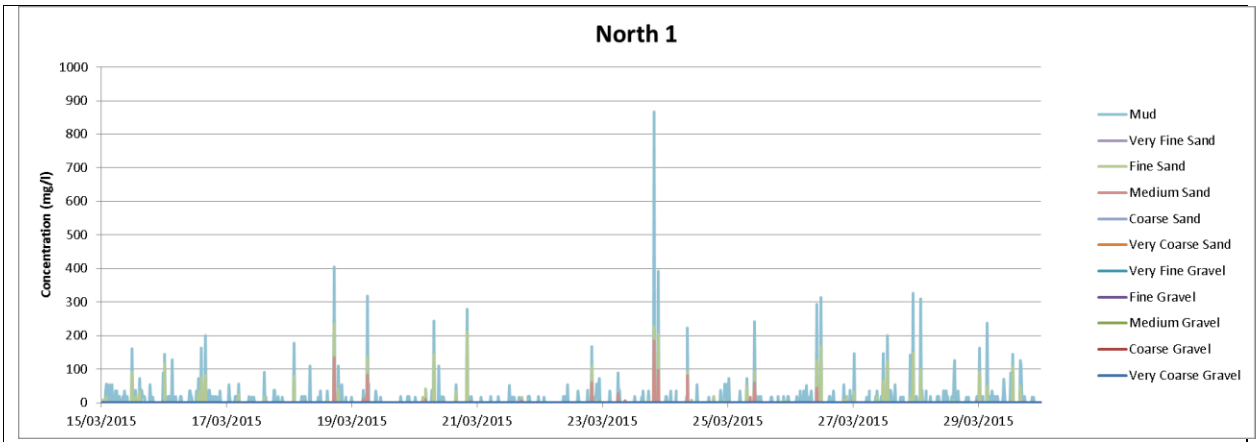

North 6
Concentration (mg/l)
70
60
50
40
30
20
10
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

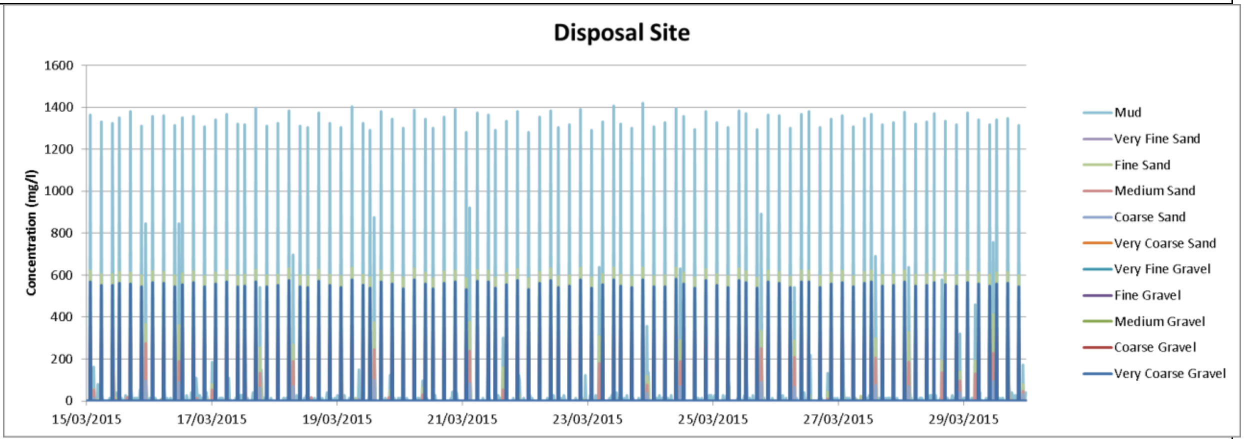

North 5
Concentration (mg/l)
120
100
80
60
40
20
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

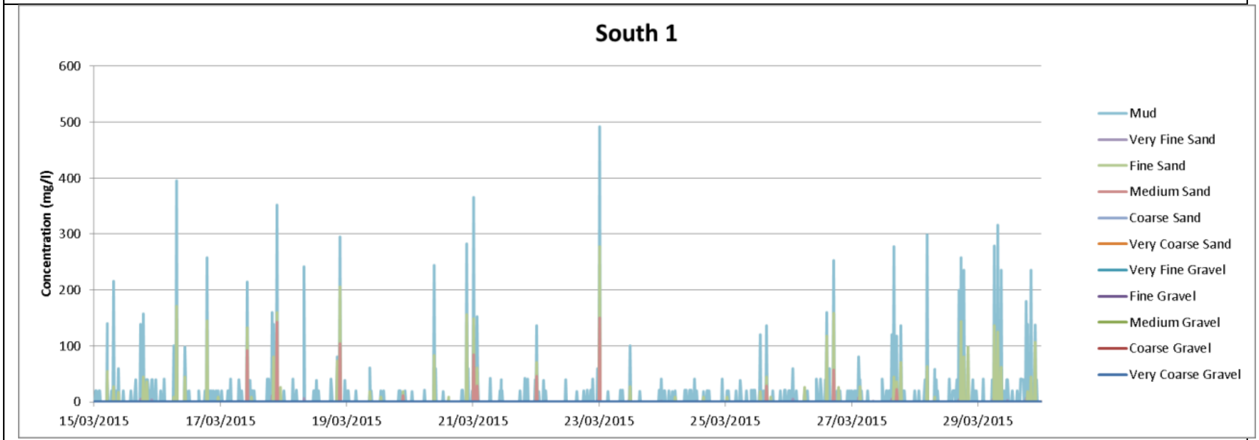

North 4
Concentration (mg/l)
0
20
40
60
80
100
120
140
160
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

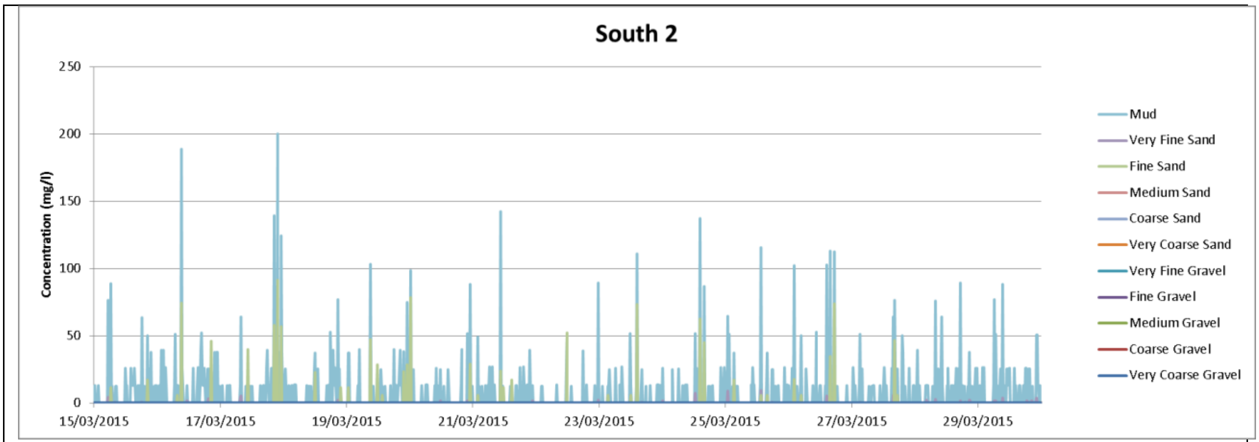

North 3
Concentration (mg/l)
0
50
100
150
200
250
300
350
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

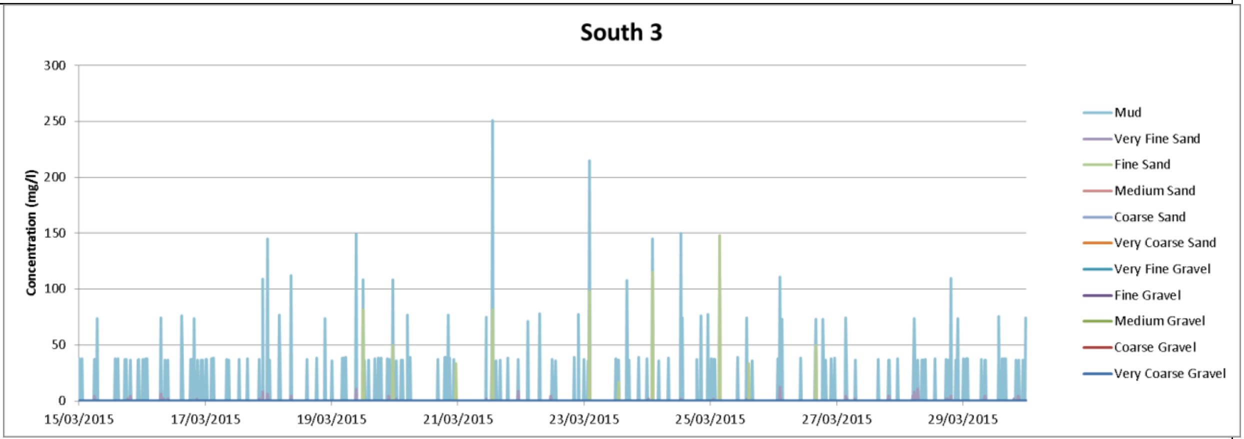

North 2
Concentration (mg/l)
0
50
100
150
200
250
300
350
400
450
500
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

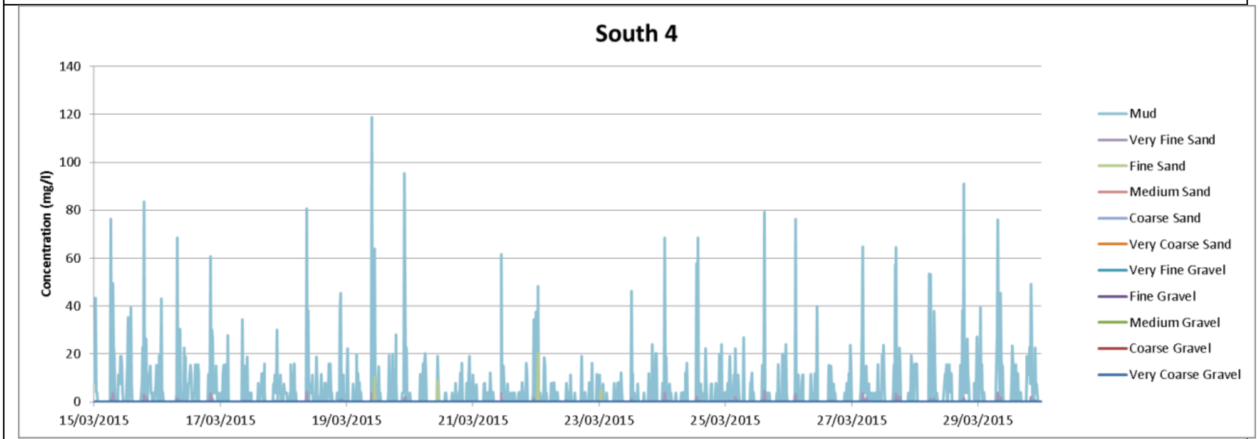

North 1
Concentration (mg/l)
1000
900
800
700
600
500
400
300
200
100
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

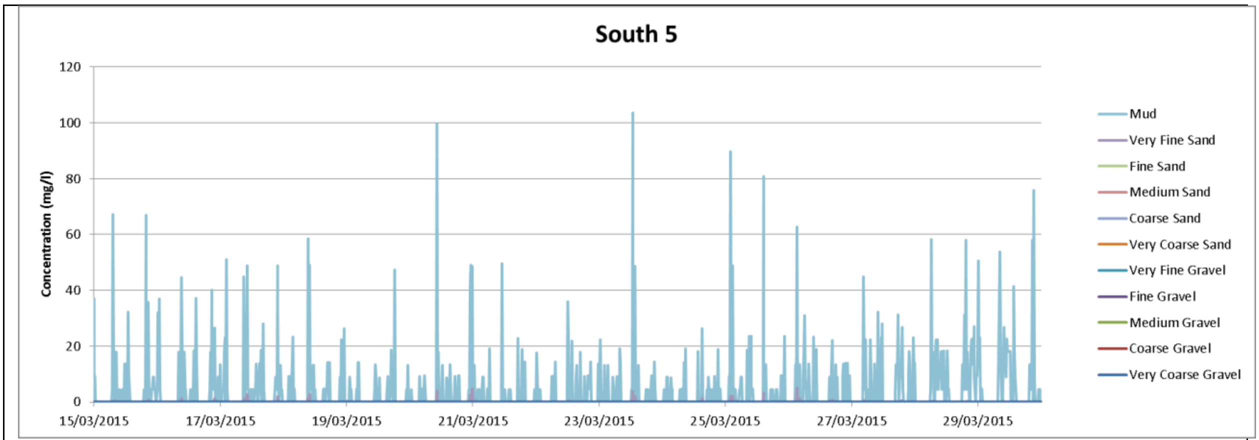

Disposal Site
Concentration (mg/l)
1600
1400
1200
1000
800
600
400
200
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

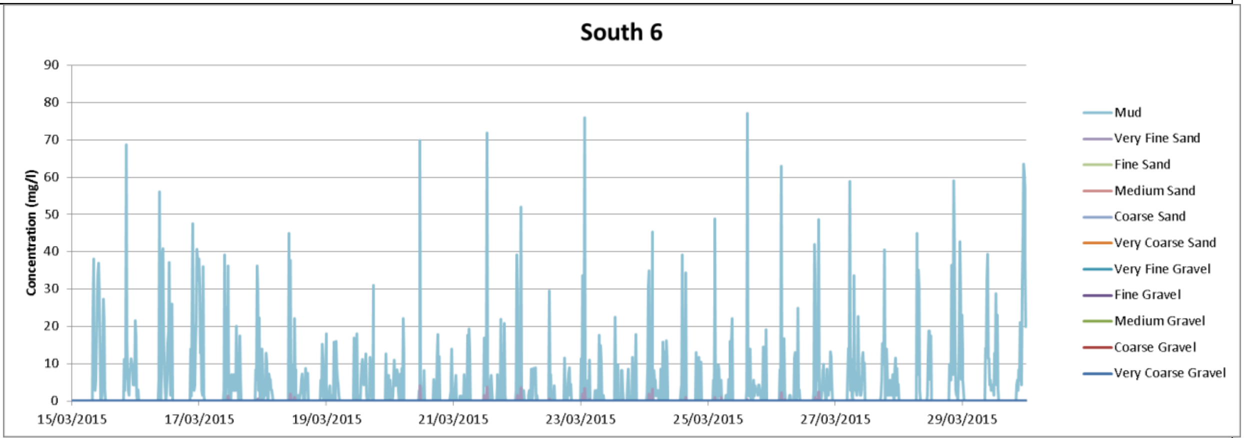

South 1
Concentration (mg/l)
600
500
400
300
200
100
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

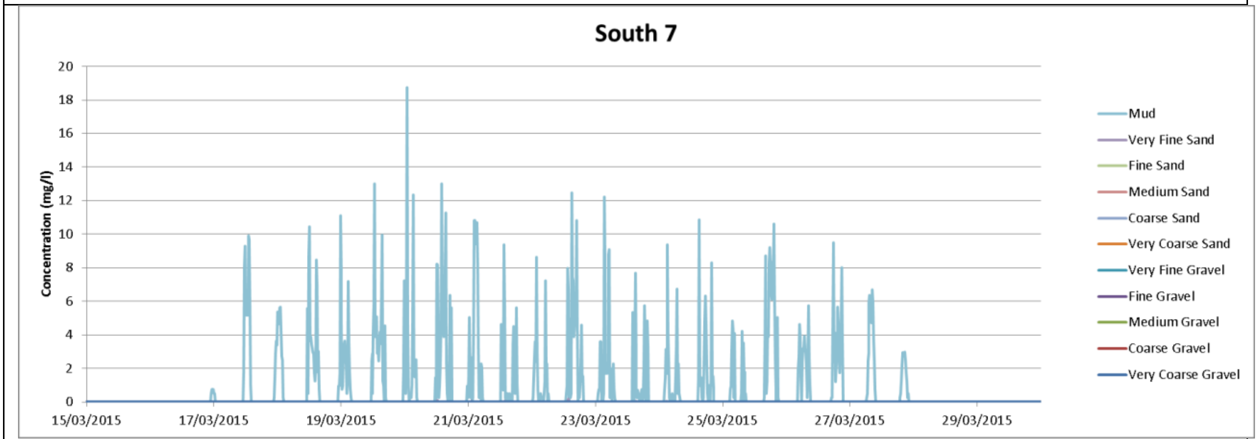

South 2
Concentration (mg/l)
250
200
150
100
50
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel


South 3
Concentration (mg/l)
300
250
200
150
100
50
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel


South 4
Concentration (mg/l)
140
120
100
80
60
40
20
0
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel


South 5
Concentration (mg/l)
0
20
40
60
80
100
120
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel


South 6
Concentration (mg/l)
0
10
20
30
40
50
60
70
80
90
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel


South 7
Concentration (mg/l)
0
2
4
6
8
10
12
14
16
18
20
15/03/2015
17/03/2015
19/03/2015
21/03/2015
23/03/2015
25/03/2015
27/03/2015
29/03/2015
Mud
Very Fine Sand
Fine Sand
Medium Sand
Coarse Sand
Very Coarse Sand
Very Fine Gravel
Fine Gravel
Medium Gravel
Coarse Gravel
Very Coarse Gravel

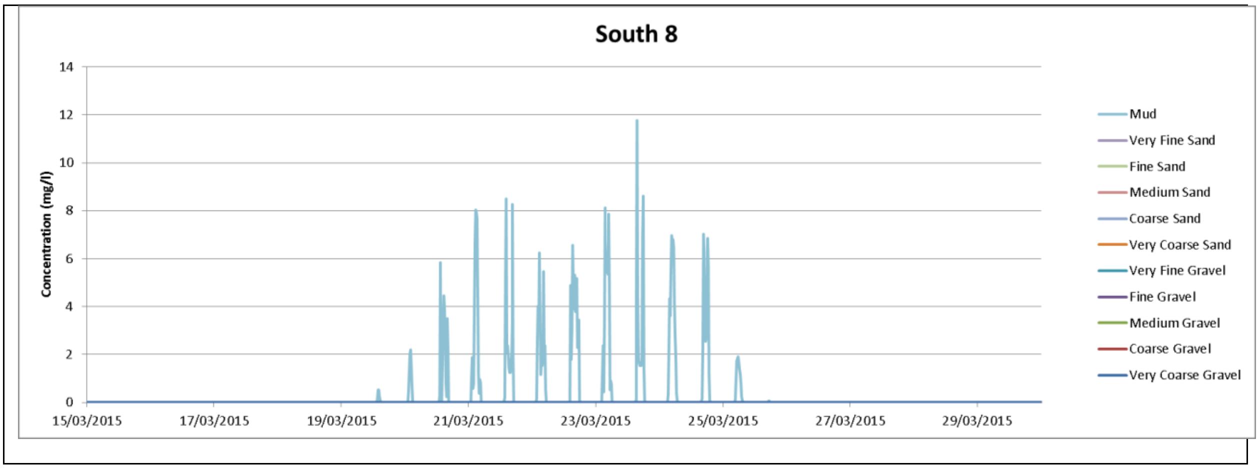


Figure C-17: Backhoe disposal average suspended sediment concentration

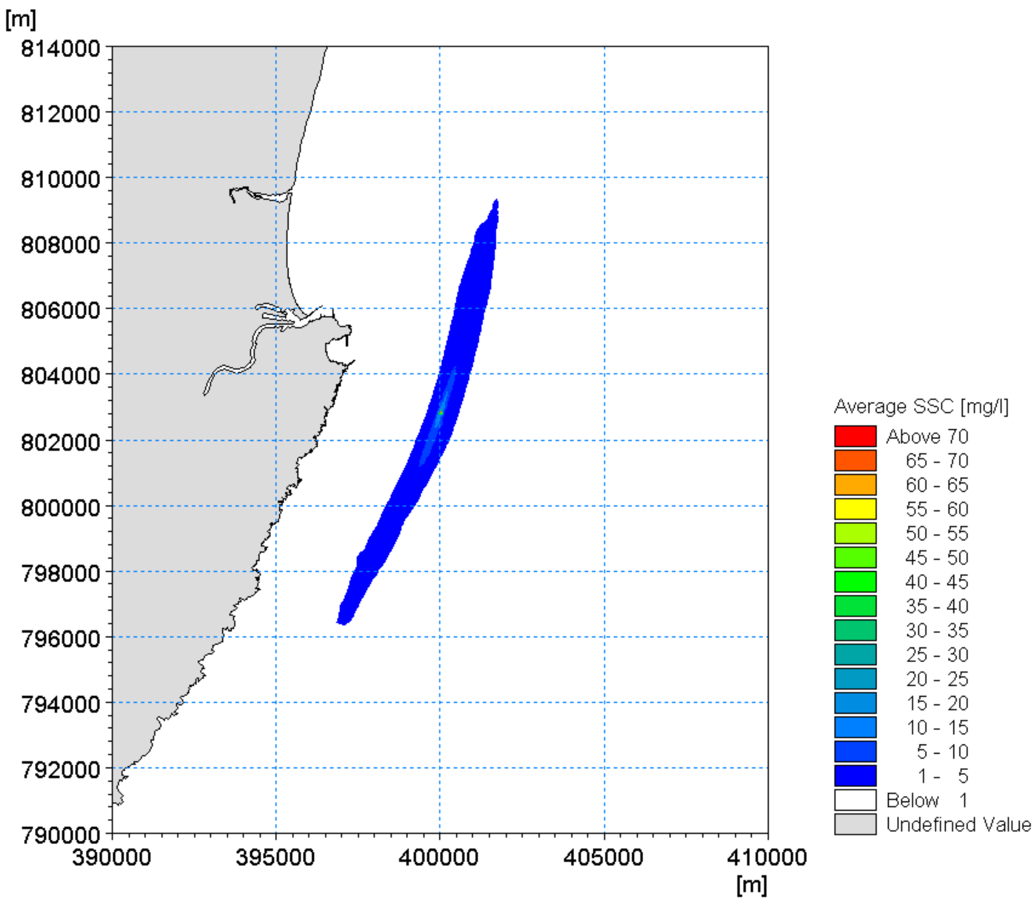


Figure C-18: Backhoe disposal maximum suspended sediment concentration

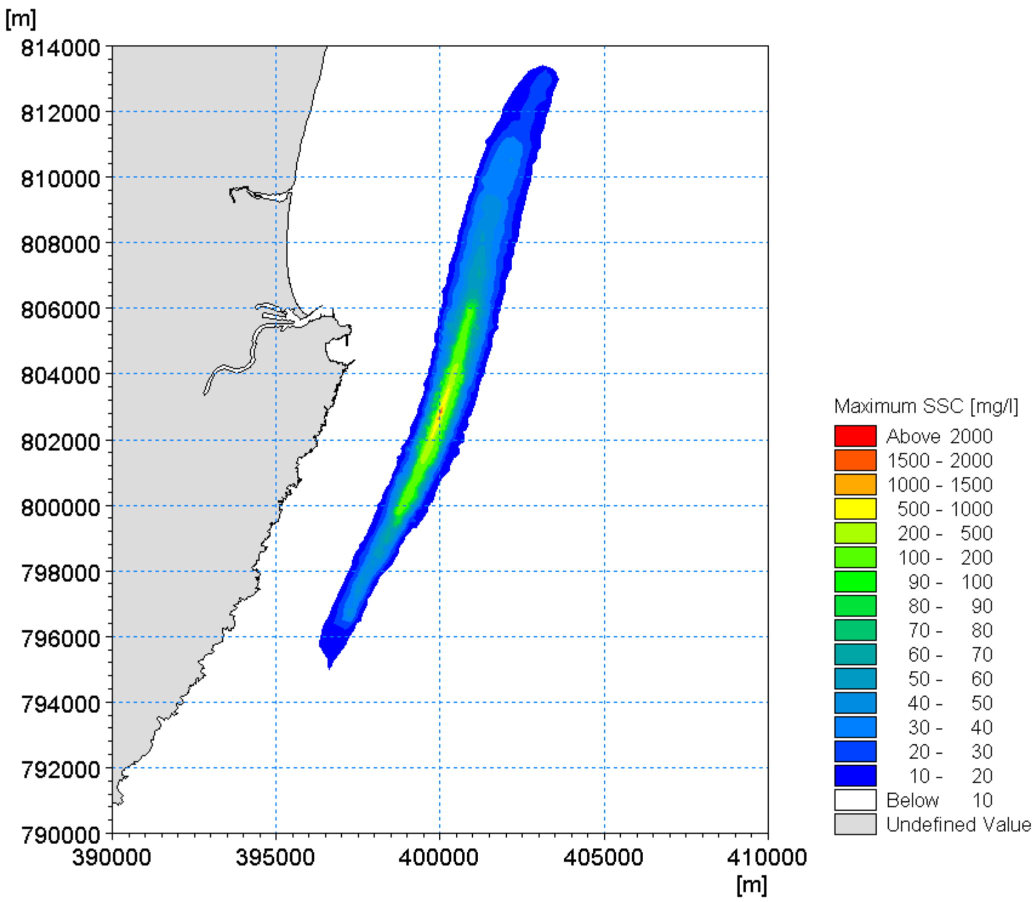


Table C-15: Backhoe disposal average suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	27.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine sand (mg/l)	0.0	0.0	0.0	0.0	0.1	0.4	1.3	2.4	43.6	2.5	0.8	0.5	0.0	0.0	0.0	0.0	0.0
Very fine sand (mg/l)	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.3	5.5	0.4	0.2	0.2	0.1	0.0	0.0	0.0	0.0
Mud (mg/l)	0.3	1.2	2.2	2.5	4.7	5.9	7.9	9.4	100.5	10.3	7.00	5.8	4.6	4.3	4.2	0.9	0.3
Total suspended solids (mg/l)	0.3	1.2	2.2	2.5	4.9	6.5	9.7	12.7	308.4	13.7	8.00	6.5	4.7	4.3	4.2	0.9	0.3

Table C-16: Backhoe disposal maximum suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0	0	0	0	0	0	0	0	580	0	0	0	0	0	0	0	0
Coarse gravel (mg/l)	0	0	0	0	0	0	0	0	368	0	0	0	0	0	0	0	0
Medium gravel (mg/l)	0	0	0	0	0	0	0	0	251	0	0	0	0	0	0	0	0
Fine gravel (mg/l)	0	0	0	0	0	0	0	0	188	0	0	0	0	0	0	0	0
Very fine gravel (mg/l)	0	0	0	0	0	0	0	0	337	0	0	0	0	0	0	0	0
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	298	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	165	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	70	183	408	150	0	0	0	0	0	0	0
Fine sand (mg/l)	0	0	0	0	70	122	157	235	635	278	91	148	20	0	0	0	0
Very fine sand (mg/l)	0	0	3	5	10	17	26	33	79	30	13	25	5	5	4	0	0
Mud (mg/l)	23	58	58	104	141	324	432	867	1420	492	200	251	119	104	77	19	12
Total suspended solids (mg/l)	23	59	61	107	207	460	632	1310	4719	949	304	339	123	107	79	19	12

Table C-17: Backhoe disposal and Aberdeen Harbour maintenance dredging average suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very fine gravel (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Very Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coarse sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Medium sand (mg/l)	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.2	62.8	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fine sand (mg/l)	0.0	0.0	0.0	0.0	0.3	1.6	5.0	8.4	89.5	8.6	3.4	1.4	0.1	0.0	0.0	0.0	0.0
Very fine sand (mg/l)	0.0	0.0	0.4	0.9	5.1	7.7	14.0	15.0	101.7	15.3	10.3	6.8	2.4	1.8	1.0	0.0	0.0
Mud (mg/l)	1.8	10.2	15.0	20.7	37.3	49.0	74.2	79.6	424.1	86.2	65.3	50.0	36.3	37.6	32.4	8.2	2.5
Total suspended solids (mg/l)	1.8	10.3	15.4	21.6	42.8	58.2	93.6	105.1	831.2	112.6	79.0	58.2	38.7	39.4	33.5	8.2	2.5

Table C-18: Backhoe disposal and Aberdeen Harbour maintenance dredging maximum suspended sediment concentrations

Location	N8	N7	N6	N5	N4	N3	N2	N1	DS	S1	S2	S3	S4	S5	S6	S7	S8
Very coarse gravel (mg/l)	0	0	0	0	0	0	0	0	580	0	0	0	0	0	0	0	0
Coarse gravel (mg/l)	0	0	0	0	0	0	0	0	368	0	0	0	0	0	0	0	0
Medium gravel (mg/l)	0	0	0	0	0	0	0	0	251	0	0	0	0	0	0	0	0
Fine gravel (mg/l)	0	0	0	0	0	0	0	0	188	0	0	0	0	0	0	0	0
Very fine gravel (mg/l)	0	0	0	0	0	0	0	0	337	0	0	0	0	0	0	0	0
Very Coarse sand (mg/l)	0	0	0	0	0	0	0	0	355	0	0	0	0	0	0	0	0
Coarse sand (mg/l)	0	0	0	0	0	0	0	0	888	0	0	0	0	0	0	0	0
Medium sand (mg/l)	0	0	0	0	0	0	133	329	1898	333	1	0	0	0	0	0	0
Fine sand (mg/l)	0	0	0	0	146	286	402	603	2460	657	265	270	48	0	0	0	0
Very fine sand (mg/l)	0	13	101	168	319	439	515	832	3760	777	589	522	308	323	156	2	0
Mud (mg/l)	196	543	457	654	1110	1596	2046	3144	13077	2733	1812	1689	1047	1076	763	222	109
Total suspended solids (mg/l)	196	544	538	801	1485	2327	2961	4753	24148	4260	2492	2206	1293	1396	914	222	109