3FMProject

Bringing Dublin Port To 2040

Environmental Impact Assessment Report

Appendix 13.4

Volume 3 Part 7

Comhlacht Chalafort Átha Cliath
Dublin Port Company

rps
A Tetra Tech Company

Third & Final Masterplan Project

APPENDIX 13-4

CUMULATIVE IMPACT OF SEDIMENT DEPOSITION AND DISPERSION WITH ACTIVITIES PERMITTED UNDER (S0004-03 AND S0024-02)

DUBLIN PORT COMPANY

DUBLIN HARBOUR CAPITAL DREDGING PROJECT DUMPING AT SEA PERMIT (S0033-01)

Response to Section 5(2) Notice

Capital Dredging Programme
Dumping at Sea Permit
S0033-01

Response to Section 5(2)
Notice

D01
4 January 2024

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Dr A G Barr	Alan Barr	4 January 2024

Prepared by:

RPS

Kristopher Calder BSc (Hons) MSc C.Sci MCIWEM C.WEM AMICE
Technical Director - Water Environment and Flood Risk Management

Elmwood House

74 Boucher Road, Belfast

Co. Antrim BT12 6RZ

T +44 2890 667 914
E kristopher.calder@rpsgroup.com

Prepared for:

Dublin Port Company

Eamon McElroy
Port Engineer

Dublin Port Centre
Alexandra Road, Dublin 1

T 01 8876000
E emcelroy@dublinport.ie

Declaration

I certify that the information given in this Section 5(2) response is truthful, accurate and complete.

I give consent to the EPA to copy this Section 5(2) response for its own use and to make it available for inspection and copying by the public, both in the form of paper files available for inspection at EPA and local authority offices, and via the EPA's website.

This consent relates to this Section 5(2) response itself and to any further information or submission, whether provided by me as Applicant, any person acting on the Applicant's behalf, or any other person.

Signed by: ***Date:*** *4th January 2024*

(on behalf of the organisation)

Print signature name: Eamon McElroy

Position in organisation: Port Engineer

Contents

1 INTRODUCTION

Dublin Port Company (DPC) submitted a Dumping at Sea Permit Application to the EPA for the Dublin Harbour Capital Dredging Project on 26th August 2021 (DAS Permit Ref S0033- 01). The application was supported by an EIAR, AA Screening Report and NIS.

A public consultation was undertaken between 8th September 2021 to 8th October 2021.

A Section 5(2) Notice was issued to DPC from the EPA on 7th November 2023 requesting additional information so that the Agency may complete a comprehensive assessment of the application.

This technical document provides a response to Issue No.3 of the Section 5(2) notice which requires DPC to:

> "Provide details on the predicted sediment deposition and sediment dispersion from loading and dumping activities, cumulatively from the proposed activities and those permitted under (S0004-03 and S0024-02) and any subsequent impacts on the wider environment. As a minimum a modelling assessment is required to describe the fate of sediments and the impact on the receiving environment, and address how the activities will be managed to ensure that they will comply with, or will not result in the contravention of the following Directives:
>
> - The Habitats Directive 82/43/EEC and Birds Directive 2009/147/EEC,
> - The Water Framework Directive 2000/60/EC,
> - The Marine Strategy Framework Directive 2008/56/EC.

The cumulative assessment includes the following permitted loading and dumping activities:

- Dumping at Sea Permit S0004-03 - Dublin Port 2022-2029 Maintenance Dredging Programme
- Dumping at Sea Permit S0024-02 - MP2 Project Capital Dredging

For robustness, the cumulative assessment also includes for proposed capital dredging required by the 3FM Project, the third and final Strategic Infrastructure Development to be brought forward for planning consent from the Dublin Port Masterplan 2040, reviewed 2018. The planning application for the 3FM Project is anticipated to be issued to An Bord Pleanála (ABP) in Q2/Q3 2024. The Dumping at Sea Permit application is anticipated to be issued to the EPA in Q3/Q4 2024. The assessment of this element of loading and dumping is contingent on the granting of consents from ABP and the EPA.

It should be noted that this response builds and expands upon an accepted response to a previous Section 5(2) Notice received as part of the D@S application for S0024-02 which requested "*details on the predicted sediment deposition from loading and dumping activities, cumulatively from all three projects (S0024-02, S0004-03 and S0033-01) and any subsequent impacts on the wider environment.*"

2 DREDGE VOLUMES, PROGRAMME AND KEY MITIGATION MEASURES

2.1 Dredge Volumes and Programme

The cumulative assessment has been based on the maximum dredge volumes presented in Table 2-1.

Table 2-1 Maximum Dredge Volumes

Project	Dumping at Sea Reference	Status	Maximum Dredge Volume (m^3)
Dublin Harbour Capital Dredging Project	S0033-01	Current Application	500,000 m^3
Dublin Port 2022-2029 Maintenance Dredging Programme	S0004-03	Permitted	2,400,000 m^3 (Annual Max 300,000 m^3)
MP2 Project Capital Dredging	S0024-01	Permitted	668,317 m^3
3FM Project Capital Dredging	N/A	Application expected Q3/Q4 2024	1,117,000 m^3

Notes

- MP2 Project (S0024-02) - Dredging Campaign No.1 was completed 15th Oct to 6th Dec 2022; the dredge volume was 339,683 m^3.
- Dublin Port 2022-2029 Maintenance Dredging Programme - Dredging Campaign No.1 was completed 19th July - 20th August 2023; the dredge volume was 298,152 m^3.
- 3FM Project Capital Dredging – A breakdown of the anticipated maximum dredge volumes are presented in Table 2-2.

Table 2-2 Breakdown of 3FM Project anticipated Maximum Dredge Volumes

Location	Dredged Depth (m, Chart Datum)	Volume (m^3)
Poolbeg Marina (Maritime Village)	-3.0 m CD	197,000 m^3
South Port Berths (Proposed Ro-Ro Terminal – Localised Scour Protection to 220 kV cables)	-12.5 m CD	13,000 m^3
Sludge Jetty (Proposed Turning Circle)	-10.0m CD	444,000 m^3
Poolbeg Oil Jetty (Proposed Lo-Lo Terminal Berthing Pocket)	-13.0 m CD	533,000 m^3
	Total Dredge Volume	**1,187,000 m^3**
	Volume not suitable for disposal at sea (top 1.0m at Poolbeg Marina)	70,000 m^3
	Total Dredge Volume suitable for disposal at sea	**1,117,000 m^3**

Notes

- Sediment Chemistry Sampling and Analysis showed that the surface layer at Poolbeg Marina exhibited a wide range of Class 2 material. This material will be brought ashore for treatment and will not be disposed of at sea.

The proposed Overarching Dredge Programme (2022 – 2038) is presented in Appendix A. This programme was submitted to the EPA on 29th November 2023 in response to the Section 5(2) Notice, Issue No.2. The dredging programme takes on board the following common constraints:

- All capital dredging activity at Dublin Port takes place over the winter period (October – March).
- All Maintenance dredging activity at Dublin Port takes place over the summer period (April – September).

2.2 Key Mitigation Measures

The following two key mitigation measures apply to all loading activity within the Inner Liffey Channel (capital dredging and maintenance dredging):

- No overspill is permitted within the inner Liffey channel.
- The hopper volume is limited to 4,100m^3 per trip.

These mitigation measures are enforced to both minimise the source of sediment entering the receiving waters and to control the formation of sediment plumes.

3 PREDICTED SEDIMENT DEPOSITION FROM LOADING ACTIVITIES

The most sensitive receptor for sediment deposition is the Tolka Estuary which forms part of the South Dublin Bay and Tolka Estuary Special Protection Area (SPA). The qualifying interests of this Natura 2000 site are over-wintering water birds.

3.1 Natural Sediment Deposition

Prior to assessing the predicted sediment deposition from loading activities, it is important to first define natural deposition within the Port Area.

To this end, the natural sediment load from the upstream Liffey catchment is estimated at about 200,000 tonnes per annum (DPC Maintenance Dredge AER 2017, Dumping at Sea Permit S0004-01). If dispersed over the Port Area between Tom Clarke Bridge and Poolbeg Lighthouse and the Tolka Estuary; this is roughly equivalent to a natural sediment load of 30 kg/m^2 in any one year (30,000 g/m^2).

This is equivalent to an average siltation depth of 2cm per year (based on a silt material).

3.2 Sediment Deposition from Loading Activity

Considering dredging activities, computational modelling studies have been undertaken to predict sediment deposition within the Tolka Estuary as a result of loading activity associated with each of the following capital and maintenance dredging programmes:

- Dublin Harbour Capital Dredging Project (subject of current application).
- Dumping at Sea Permit S0004-03 - Dublin Port 2022-2029 Maintenance Dredging Programme.
- Dumping at Sea Permit S0024-02 - MP2 Project Capital Dredging.
- 3FM Project Capital Dredging (application expected Q3/Q4 2024).

The maximum dredge volumes. programme and key mitigation measures as outlined in Section 2 were used as input to the computational modelling studies.

The output of the computational studies is summarised in Table 3-1.

Table 3-1 Predicted Sediment Deposition within the Tolka Estuary for various capital and maintenance dredging activities

Dredging Campaign	Predicted Sediment Deposition	Maximum deposition depth	Reference Document
Dublin Harbour Capital Dredging Project (S0033-01)	<0.30g/m^2	<0.2µm	Dublin Harbour Capital Dredging Project EIAR, Dumping at Sea Permit Application (August 2021)
MP2 Project (S0024-02)	<0.50g/m^2	*c.*0.33µm	RPS Report on Additional Sediment Plume Modelling, Response to Section 5(2) Notice (November 2021)
Dublin Port 2022 - 2029 Maintenance Dredging Programme (S0004-03)	<0.30g/m^2	<0.2µm	RPS Report on Coastal Processes Risk Assessment, Dumping at Sea Permit Application (December 2020)
3FM Project Capital Dredging (application expected Q3/Q4 2024)	<128g/m^2	85 µm	See detailed results below
Comparison with Natural Sedimentation	**30,000g/m^2**	***c.*2cm**	**Dublin Port Maintenance Dredging AER (March 2017)**

Whilst outputs from the numerical modelling studies used to inform the summary assessment presented in Table 3-1 can be found in the respective reference document, it is acknowledged that the 3FM Project EIAR is not yet publicly available for review. Therefore, in the interest of transparency, the predicted deposition of the silt fractions lost to the water column during proposed capital dredging are presented in Figure 3-1 to Figure 3-4 respectively.

It should be noted that with all planned dredging activities, dredging proceeds until the specified design depth is reached and any material deposited within the dredge area will be removed by the dredger until the specification is met. As such, the values presented in Figure 3-1 to Figure 3-4 and summarised in Table 3-1 are considered conservative.

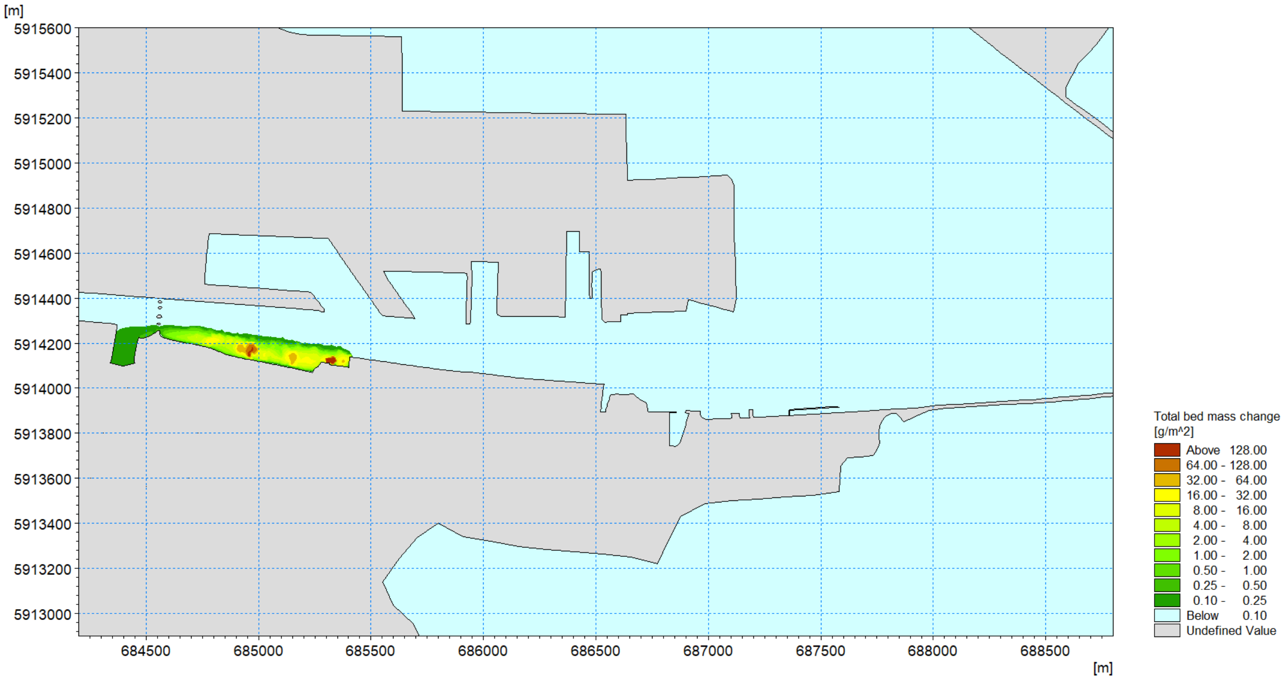


Figure 3-1 3FM Project - Deposition of sediment following dredging activities at Poolbeg Marina for a proposed Maritime Village

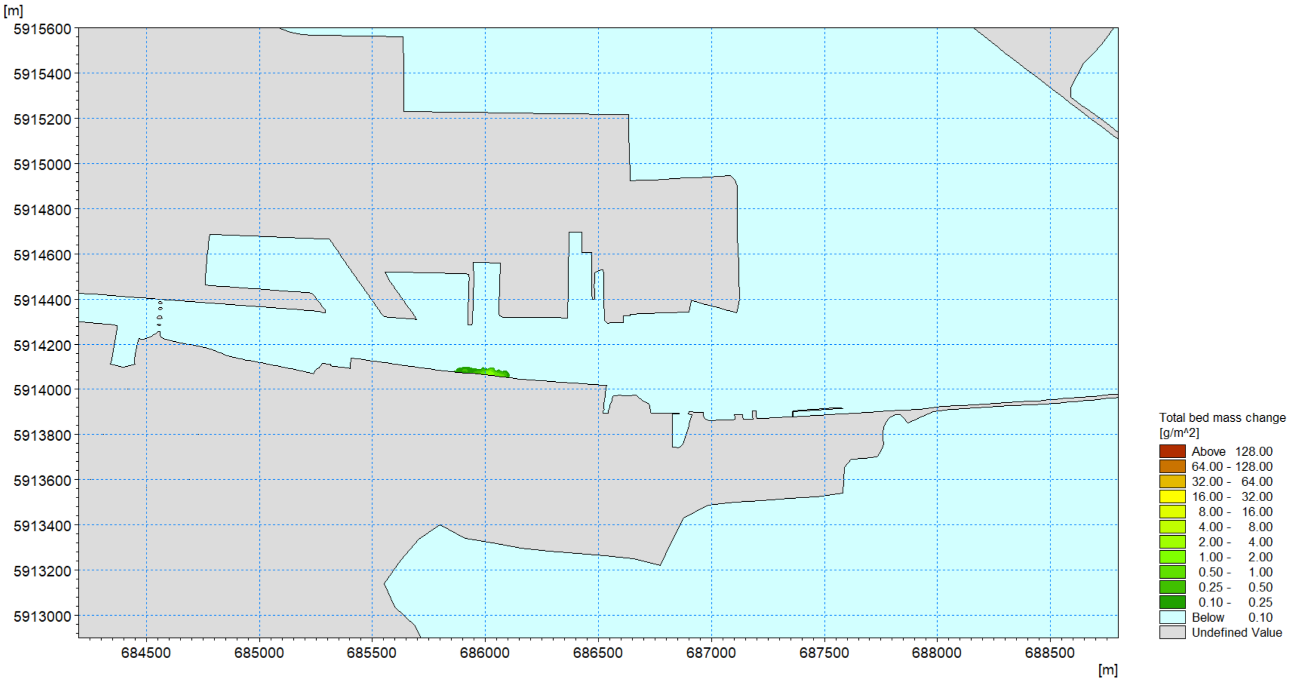


Figure 3-2 3FM Project - Deposition of sediment following dredging activity at South Port Berths for a proposed Ro-Ro Terminal (Localised Scour Protection to 220 kV cables)

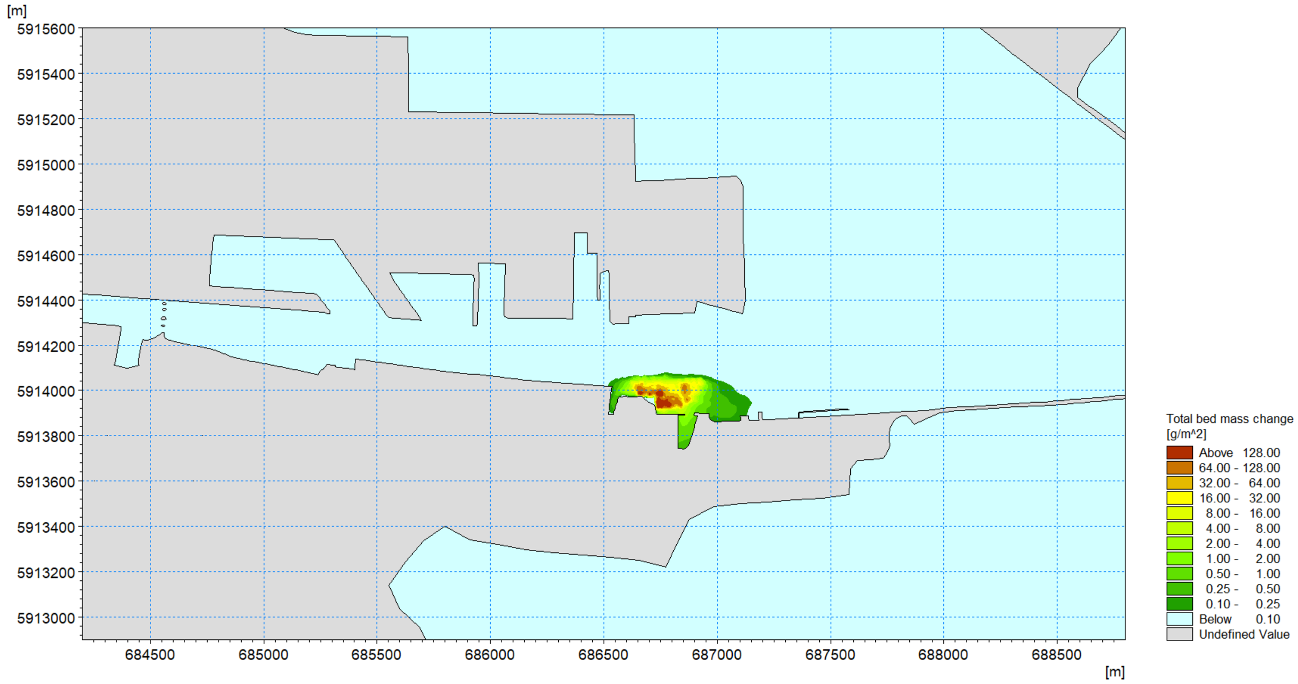


Figure 3-3 3FM Project - Deposition of sediment following capital dredging activity at the Sludge Jetty to create a proposed Turning Circle

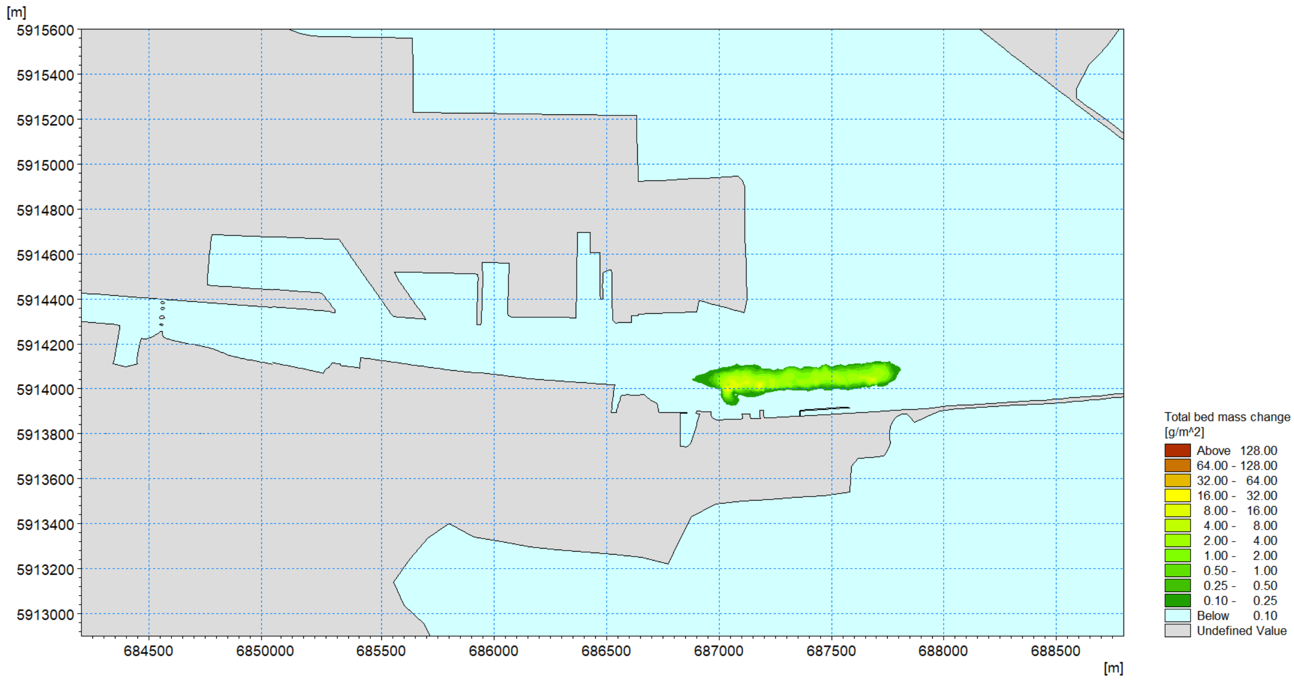


Figure 3-4 3FM Project - Deposition of sediment following capital dredging activity at Poolbeg Oil Jetty to create a proposed Lo-Lo Container Terminal Berthing Pocket

The results of the computational modelling studies demonstrate that only an imperceptible amount of silt will be deposited within the Tolka Estuary during loading activities within the inner Liffey.

In general, dredging activities associated with each project is expected to result in a maximum deposition depth of less than between 0.2µm and 0.33µm. The exception to this is the proposed dredging activity at Poolbeg Marina and the Turning Circle under the proposed 3FM Project whereby owing to local tide conditions, bathymetry and configuration of the channel, loading activities could result in a maximum deposition depth of c. 85µm.

When considered in context of natural sedimentation within the Port Area (i.e., 30,000 $g/m^2/yr$ which is equivalent to a deposition rate of *c.*2cm/yr), it is clear that the impact of sediment deposition from all loading activities is several magnitudes lower than natural sedimentation rates. The impact of predicted sediment deposition from all capital and maintenance dredging loading activities can therefore be considered to be *de minimis*.

In conclusion, the computational modelling studies of the capital and maintenance dredging loading activities within the inner Liffey, in adherence with the key mitigation measures set out in Section 2, will ensure that cumulatively they will comply with, or will not result in the contravention of the following Directives:

- The Habitats Directive 82/43/EEC and Birds Directive 2009/147/EEC,
- The Water Framework Directive 2000/60/EC,
- The Marine Strategy Framework Directive 2008/56/EC.

4 PREDICTED SEDIMENT DEPOSITION FROM DUMPING ACTIVITIES

Numerical modelling work undertaken previously in support of the Alexandra Basin Redevelopment (ABR) Project (RPS, 2014) found that sediment material to be dredged throughout the Port Area could generally be characterised by three discrete fractions with mean diameters of 200µm, 20µm and 3µm with each fraction constituting 1/3 of the total volume of the dredge material. This specification was based on Particle Size Distributions (PSDs) of sediment samples collected from the Harbour area (RPS, 2014) (Dublin Port Company, 2020).

Based on this earlier work, the sand fraction of the dredge material was found to behave differently to silt material in that the sand fraction remained on the dump site whereas the silt material was dispersed by tidal currents.

Recognising the different dispersion and deposition characteristics of these different fractions, the sediment deposition as a result of disposing the silt and sand dredge material at the dump site is considered separately in Sections 4.1 and 4.2 respectively.

4.1 Silt deposition arising from each dredging project

4.1.1 Modelling Approach

For this study, RPS adopted a similar comprehensive modelling approach to that used to validate the Alexandra Basin Redevelopment (ABR) capital dredging programme (RPS, 2020) under Dumping at Sea Permit S0024-01. The analysis of the ABR Project using detailed recorded information from loading and dumping logs provided by the dredging contractor to create bespoke, site specific sediment source terms that were then applied to a calibrated and validated hydrodynamic model. The Sediment Plume Validation Study Report is presented in Appendix C (RPS, 2020).

This approach involved defining exact spill rates and quantities for 210 individual trips between 09/03/2020 – 28/03/2020 and simulating all 210 trips in a single model. In total, the dispersion and fate of 218,686T Total Dry Solids was represented in one single simulation, with the average quantity of material being disposed of per trip equating to 1,041T TDS (*n* =210, *SD* =126 TDS).

The output from the ABR Project simulation of recorded trips was then scaled to reflect the dredging and disposal requirements associated with S0024-02, S0004-03, S0033-01 and the 3FM project as summarised in Figure 4-1. These scaled results were then combined to provide details on the cumulative impacts from all four projects over the full period of the planned projects as set out in the overarching dredging programme presented in Appendix A.

As this approach utilised actual spill rates and quantities and varied locations of the dump releases within the boundary of the dump site, the model simulations were considered to be reflective of the proposed future dumping at sea activities. The location of the dredge hopper during the disposal of sediment during 3 of the 210 dumping activities is illustrated in Figure 4-2.

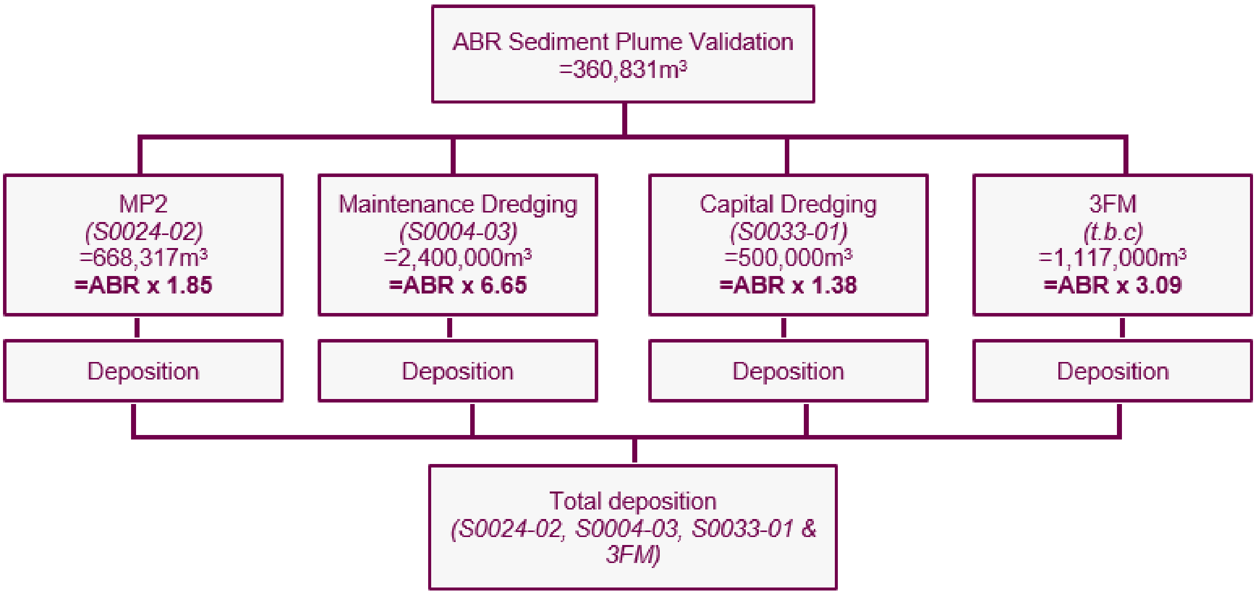


Figure 4-1 Summary of the modelling approach used to assess the cumulative impact of all four projects.

The coupled MIKE 21 sediment transport model was used to simulate the fate of the silt released from the Trailing Suction Hopper Dredger (TSHD) / bottom opening barge over the dump site by moving a sediment source along the track that the barge would take as it traversed the dump site area during the disposal operation. The model then simulated the dispersion, deposition of silt material in response to the tidal currents throughout the model area.

The location of the licenced offshore dump site at the approaches to Dublin Bay, west of the Burford Bank is presented in Figure 4-3.

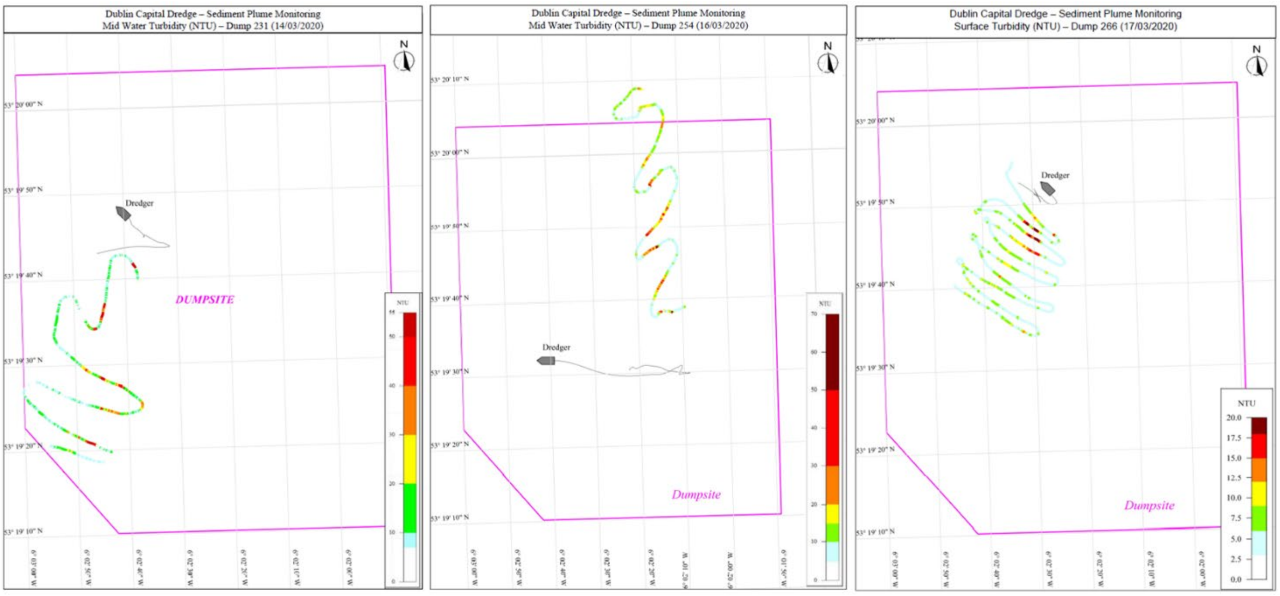


Figure 4-2 TSHD track during the disposal of sediment across three individual dumping activities (trips) with the corresponding measured suspended sediment concentration

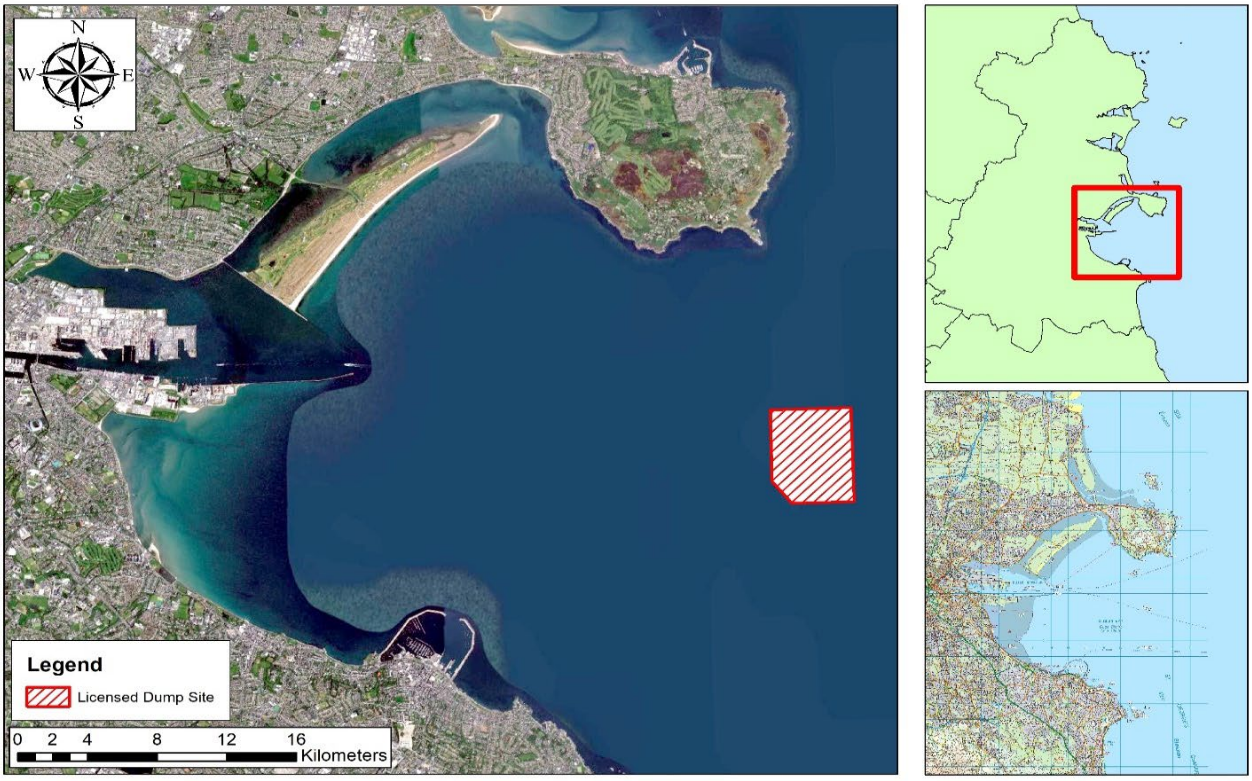


Figure 4-3 Location of the licenced offshore dump site at the approaches to Dublin Bay, west of the Burford Bank

4.1.2 Modelling Overview

RPS used the MIKE 21 hydrodynamic numerical modelling software package developed by DHI, to undertake the sediment plume simulations presented in Section 4.1.1 of this report.

The MIKE system is a state of the art, industry standard, modelling system, based on a flexible mesh approach. This software was developed for applications within oceanographic, coastal and estuarine environments.

A brief synopsis of the MIKE system and modules used for this assessment is outlined below:

- **MIKE 21 FM system** - Using this flexible mesh modelling system, it was possible to simulate the mutual interaction between currents, waves and sediment transport by dynamically coupling the relevant modules in two dimensions.
  - **The Hydrodynamic (HD) module** - This module is capable of simulating water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions. The HD Module is the basic computational component of the MIKE 21 Model system providing the hydrodynamic basis for the Sediment Transport and Spectral Wave modules. The Hydrodynamic module solves the two-dimensional incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and of hydrostatic pressure. Thus the module consists

of continuity, momentum, temperature, salinity and density equations. In the horizontal domain both Cartesian and spherical coordinates can be used.

- **The Sediment Transport module** - The Sediment Transport Module simulates the erosion, transport, settling and deposition of cohesive sediment in marine and estuarine environments and includes key physical processes such as forcing by waves, flocculation and sliding. The module can be used to assess the impact of marine developments on erosion and sedimentation patterns by including common structures such as jetties, piles or dikes. Point sources can also be introduced to represent localised increases in current flows as a result of outfalls or ship movements etc.

4.1.3 Computational Models and Data Sources

RPS' model of Dublin Bay was created using flexible mesh technology to provide detailed information on the coastal processes around the licenced dump site and Dublin Port as well as the wider Dublin Bay area. The model uses mesh sizes varying from 250,000m^2 (equivalent to 500m x 500m squares) at the outer boundary of the model down to a very fine 225 m^2 (equivalent to 15m x 15m squares) in Dublin Port and around the licenced dump site. The extent, mesh structure and bathymetry of this model is presented in Figure 4-4.

The bathymetry of this model was developed using data gathered from hydrographic surveys of Dublin Port, the Tolka estuary and the dump site since 2017 to present. This resource was supplemented by data from the Irish National Seabed Survey, INFOMAR and other local surveys collated by RPS for the Irish Coastal Protection Strategy Study (RPS, 2003).

Tidal boundaries for the Dublin Bay model shown in Figure 5 were taken from the Irish Coastal Protection Strategy Study (ICPSS) tidal surge mode. This model was developed using flexible mesh technology with the mesh size varying from *c.* 24km along the offshore Atlantic boundary to *c.* 200m around the Irish coastline. This validated model is run three times daily on behalf of the Office of Public Works (OPW) to provide detailed tidal information around the coast of Ireland. The extent and bathymetry of this model is illustrated in Figure 4-5.

Boundary conditions used to represent the mean annual river flows for the Liffey, Dodder and Tolka were set at 15.6, 2.3 and 1.4m^3/s respectively.

It should be noted that the same computational models used to support the environmental assessment of the ABR Project (RPS, 2014) were used for this technical assessment. A previous calibration and validation exercise that utilised recorded data from throughout Dublin Bay concluded that the Dublin Bay model performed very well and provided a very good representation of the coastal processes in Dublin Port and Dublin Bay (see Appendix B).

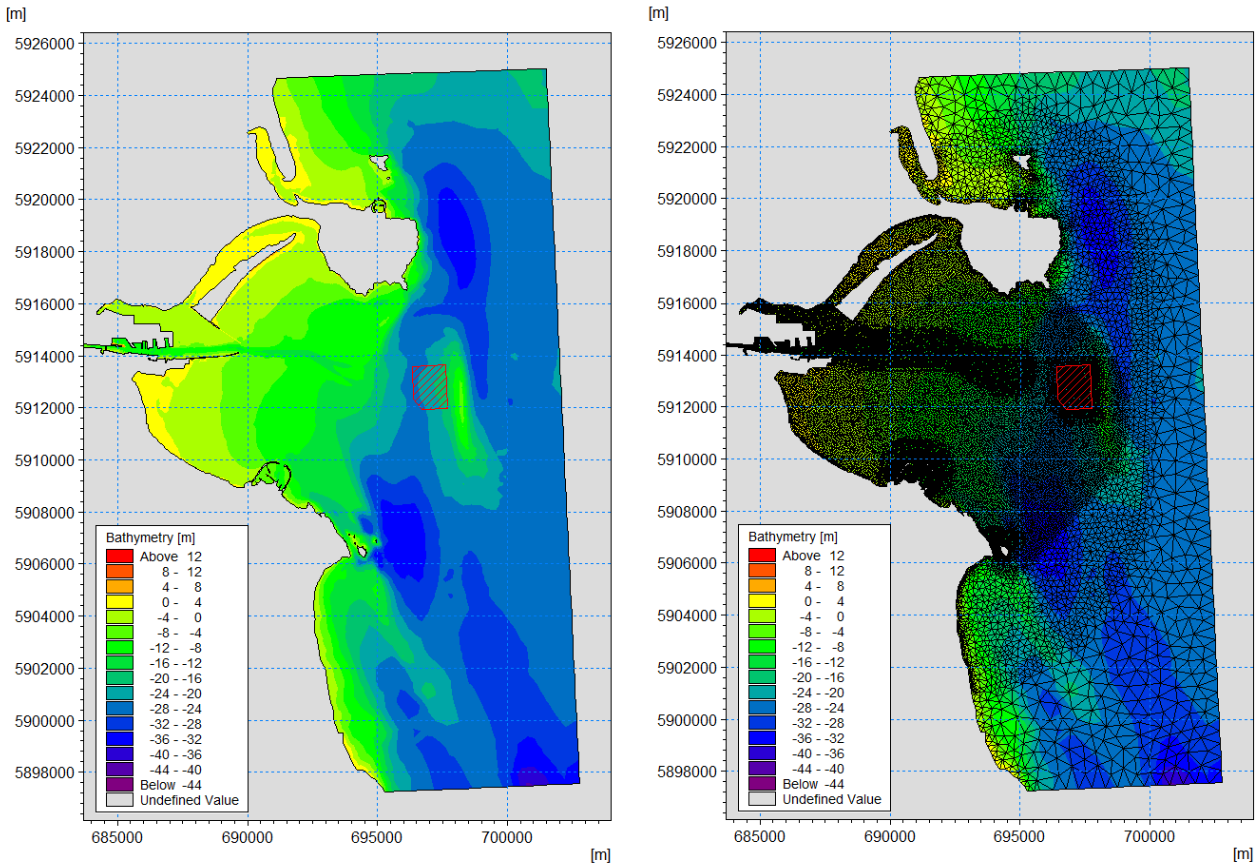


Figure 4-4 Extent and bathymetry (left) and mesh structure (right) of the Dublin Bay model. Location of the licenced dump site shown by red hatch area.

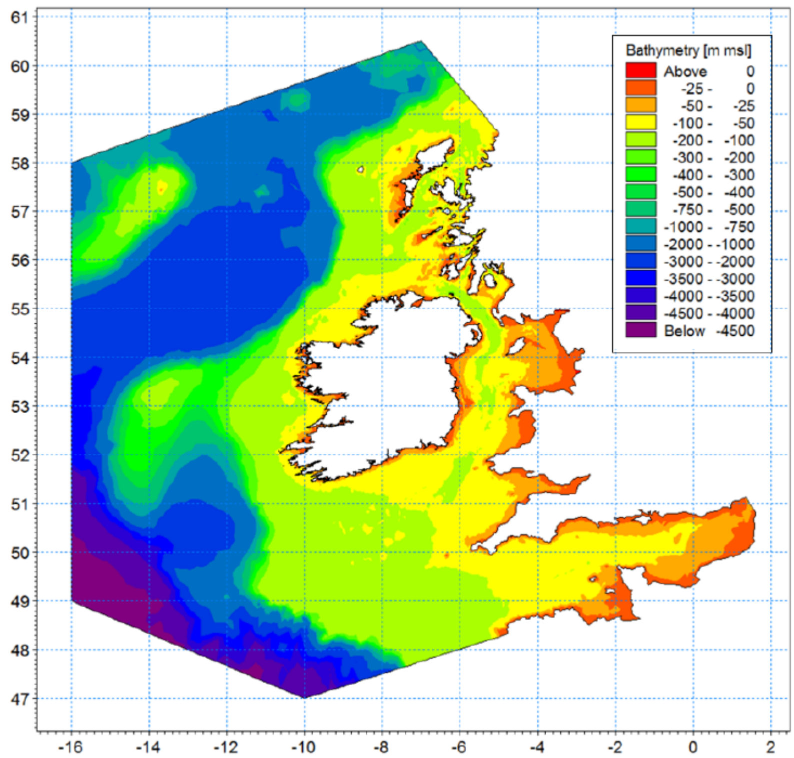


Figure 4-5 Extent and bathymetry of Irish Sea Tidal and Storm Surge model

4.1.4 Silt deposition arising from each dredging project

The coarser fraction of the silt, i.e., the sand fraction that had a mean grain size of 200µm was found to behave differently relative to the two finer fractions that had mean grain diameters of 20µm and 3µm in that it remained almost exclusively within the immediate vicinity of the licenced dump site. Conversely, the two finer silt fractions were carried away by the tidal currents towards the expanse of the Irish Sea.

The predicted total deposition of the silt fractions of the total dredge material disposed under S0024-02, S0004-03, S0033-01 and the 3FM project is presented in Figure 4-6 to Figure 4.9 respectively. As demonstrated by these Figures, the maximum total deposition of silt material within Dublin Bay does generally not exceed 0.40g/m^2.

It should be noted that this is marginal lower than the 0.50g/m^2 as reported in the Additional Sediment Plume Modelling Response to Section 5(2) Notice (RPS, 2021). This can be attributed to how the sediment source term was specified. In previous work including for the ABR Project EIS (RPS, 2014), the source term was defined as a constant spill rate of 108kg/s that was only activated when the dredger was over the dump site. For this assessment, a bespoke source term was defined for each of the 210 individual trips based on dumping logs provided by the dredging contractor. Each source term had a unique spill rate reflective of the corresponding dumping profile. In most instances, spill rates were much higher but persisted for shorter durations.

Given the higher spill rates and suspended concentrations, sediments tended to floc together and settle much faster. As a consequence, more silt material remained within the vicinity of the dump site and less silt material dispersed and settled throughout Dublin Bay.

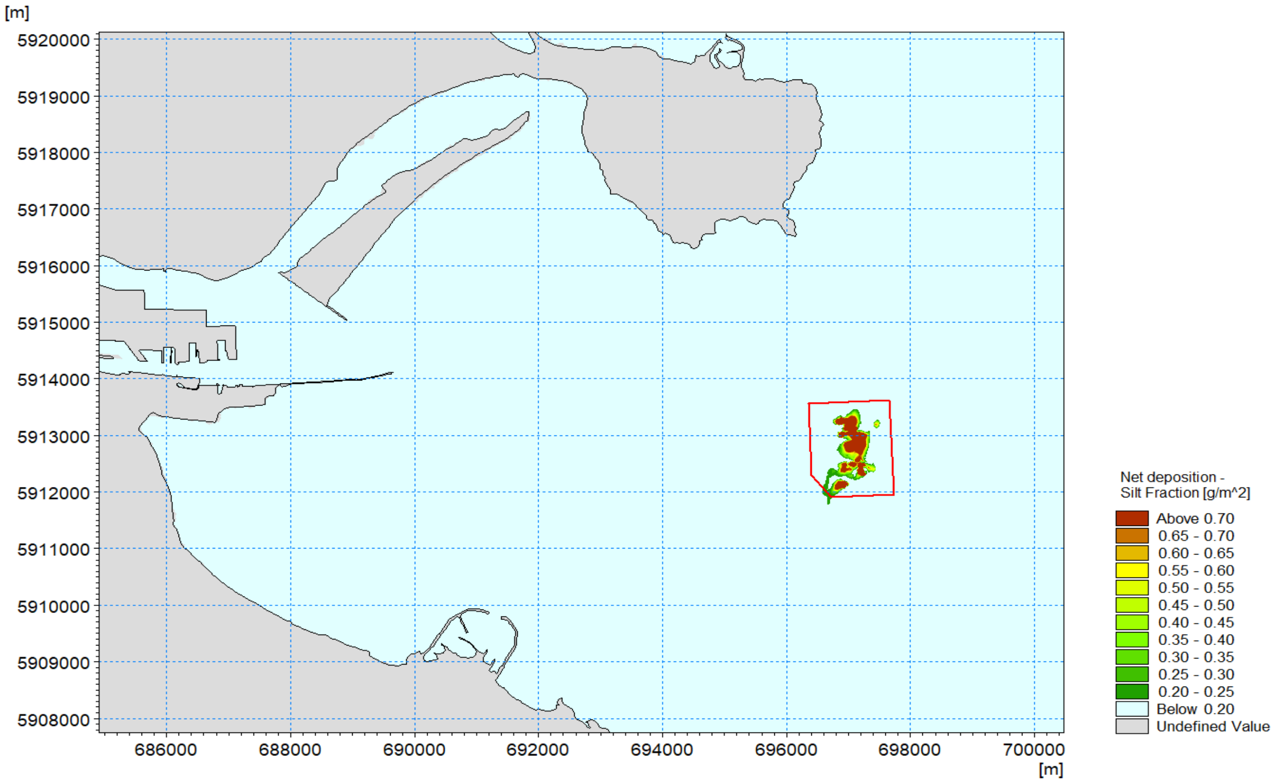


Figure 4-6 Total deposition of silt material following the dumping at sea activities associated with the MP2 Project (S0024-02)

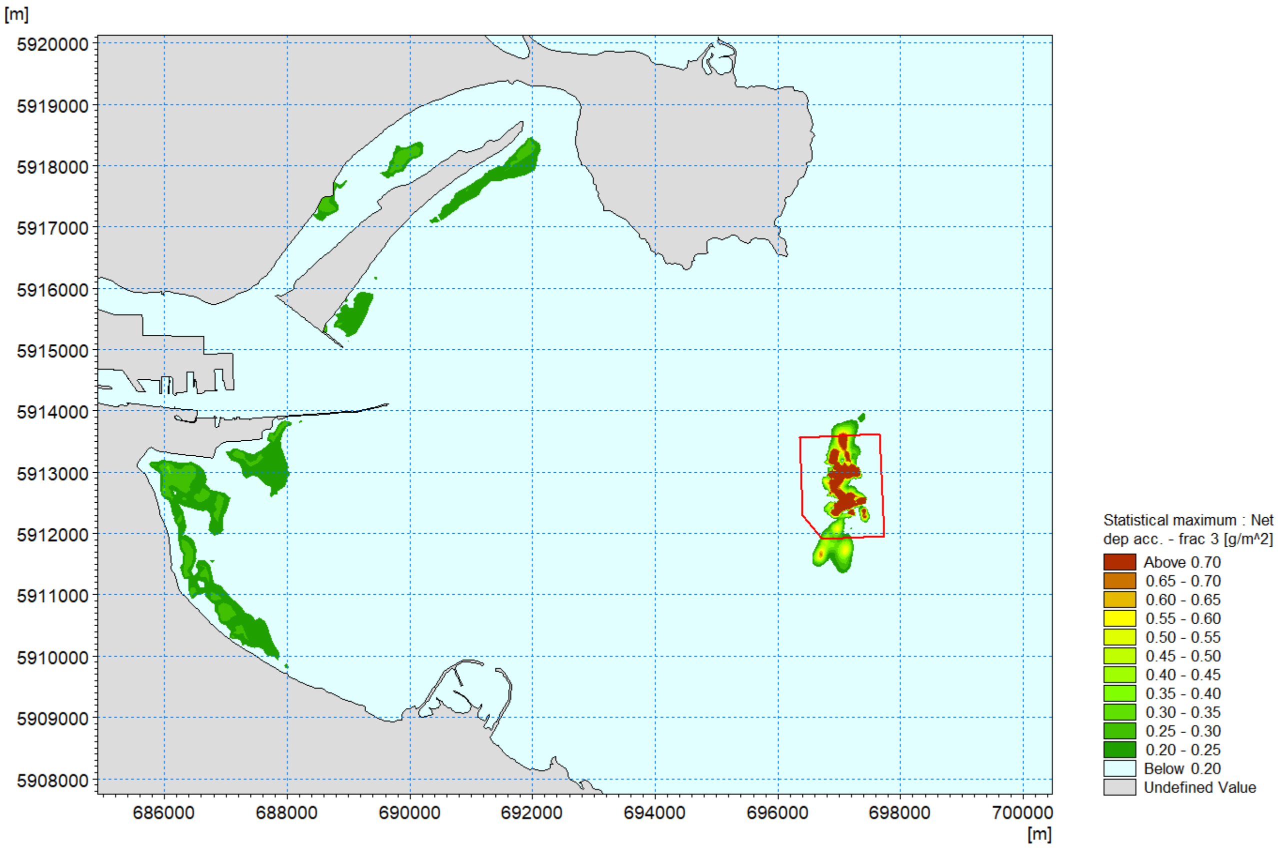


Figure 4-7 Total deposition of silt material following the dumping at sea activities associated with the Dublin Port 2022 - 2029, Maintenance Dredging Programme (S0004-03)

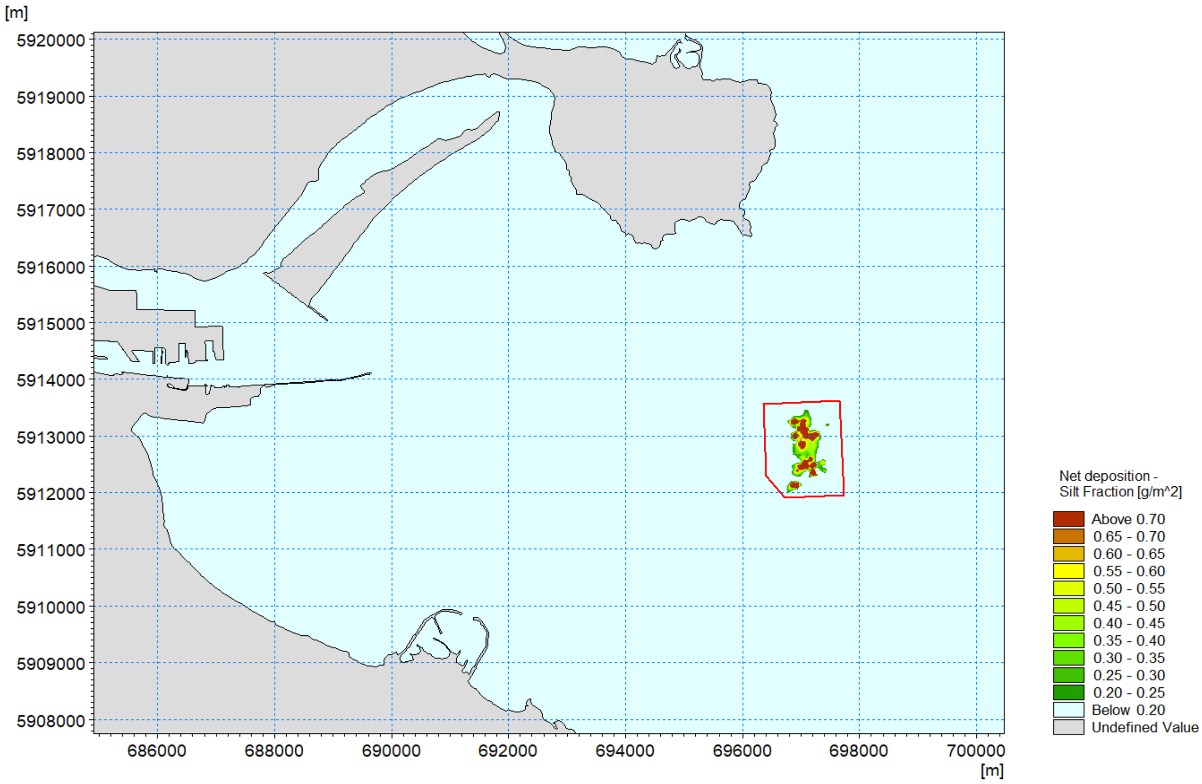


Figure 4-8 Total deposition of silt material following the dumping at sea activities associated with the Dublin Harbour Capital Dredging Project (S0033-01)

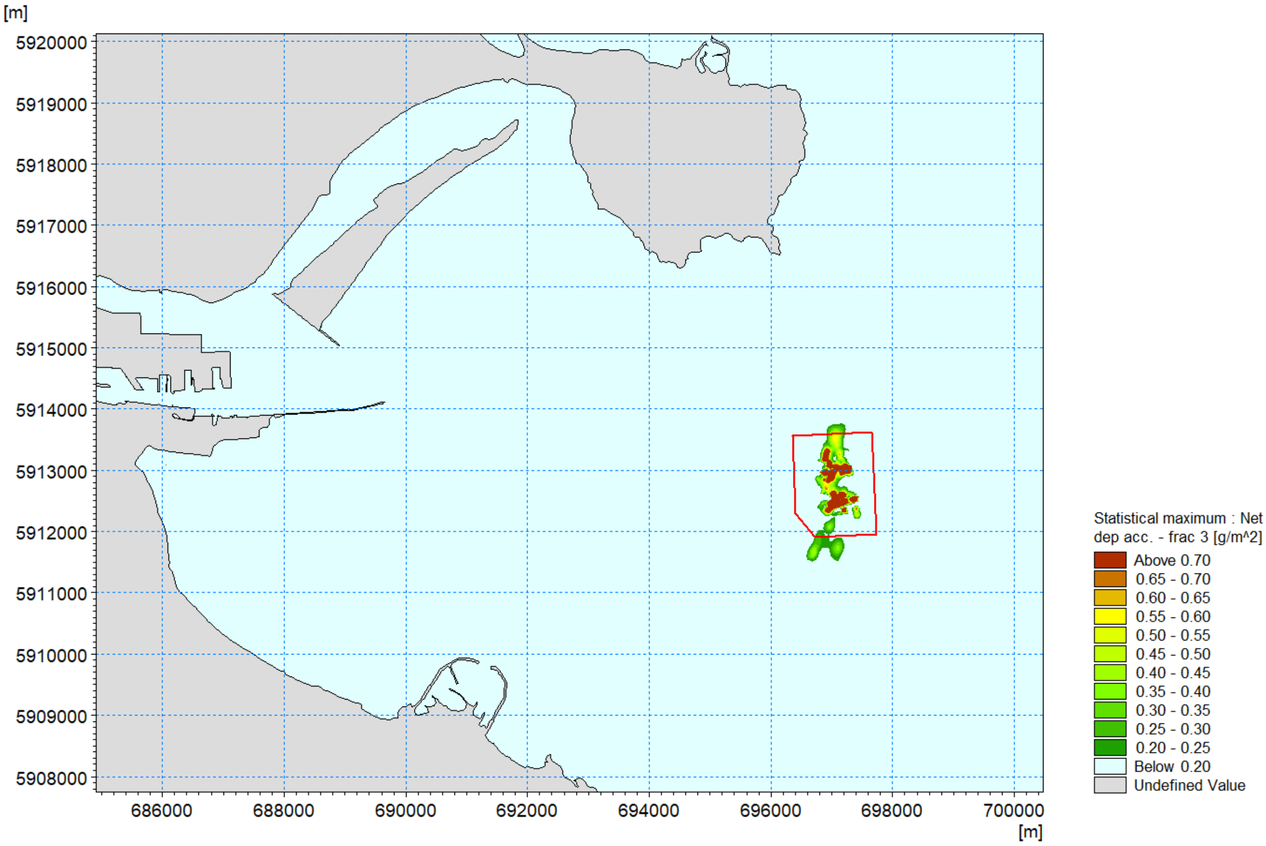


Figure 4-9 Total deposition of silt material following the dumping at sea activities associated with the 3FM Project

4.1.5 Cumulative silt deposition from all four dredging projects (S0024-02, S0004-03, S0033-01 and the 3FM Project)

The cumulative sediment deposition within Dublin Bay as a result of all four dumping at sea activities described in the Section 2 is presented in Figure 4-10. As demonstrated by this Figure, the cumulative total deposition of silt material beyond the immediate vicinity of the disposal site is generally less than 0.60g/m^2. This magnitude of deposition translates to a maximum change in bed level thickness of *c.* 0.45µm as illustrated in Figure 4-11. This is less than the width of a human hair and is not measurable in the field.

For context, the estimated natural sediment load from the upstream Liffey catchment is estimated at circa 200,000 tonnes per annum (DPC Maintenance Dredge AER 2017, Dumping at Sea Permit S0004-01). If dispersed over the Port area between East Link and Poolbeg Lighthouse and the Tolka Estuary; this is roughly equivalent to a natural sediment load of 30 kg/m^2 in any year (30,000 g/m^2). This is equivalent to an average depth of 2cm (based on a silt material).

It is clear that the impact of sediment deposition from dumping activities is several magnitudes lower compared to natural sedimentation and can therefore be considered to be *de minimis*.

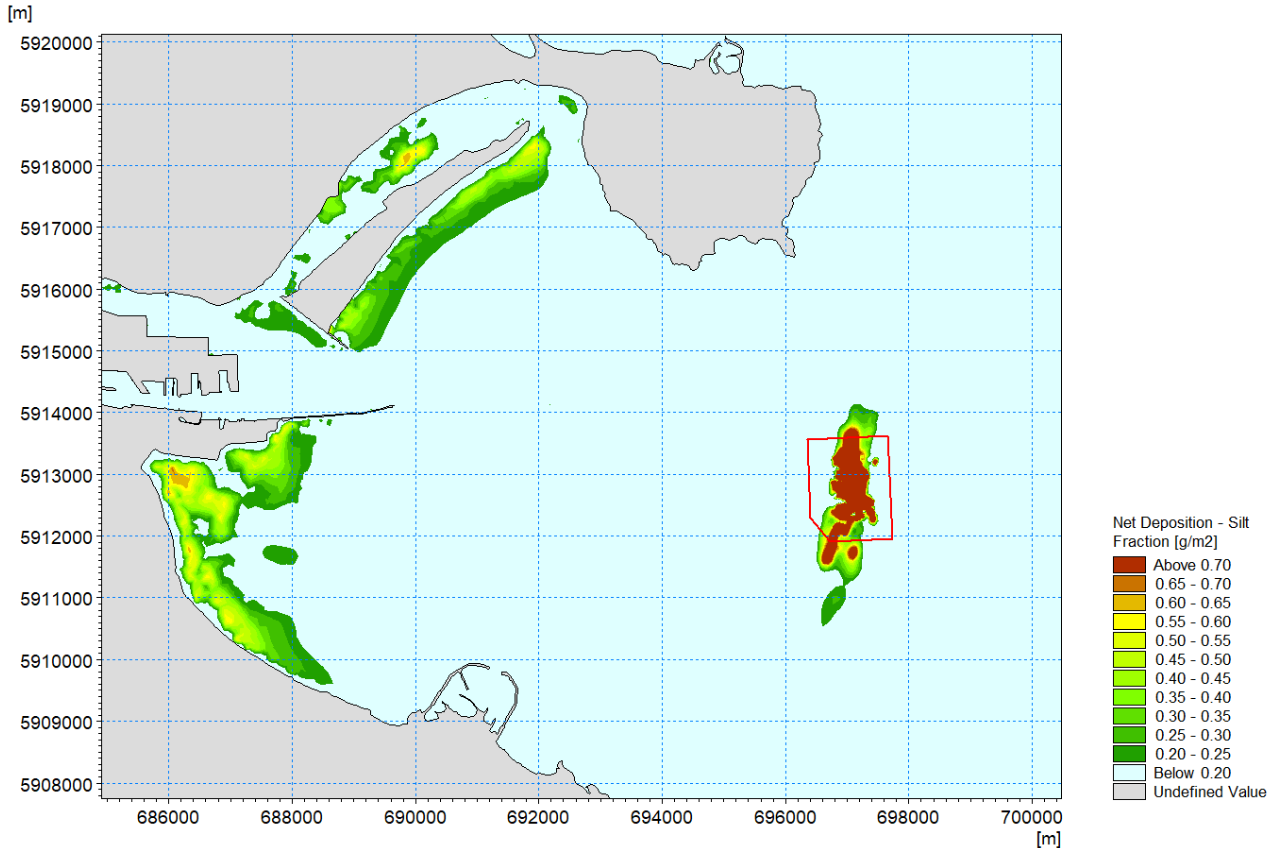


Figure 4-10 Cumulative total deposition of silt material following the dumping at sea activities associated with S0024-02, S0004-03, S0033-01 and the 3FM Project

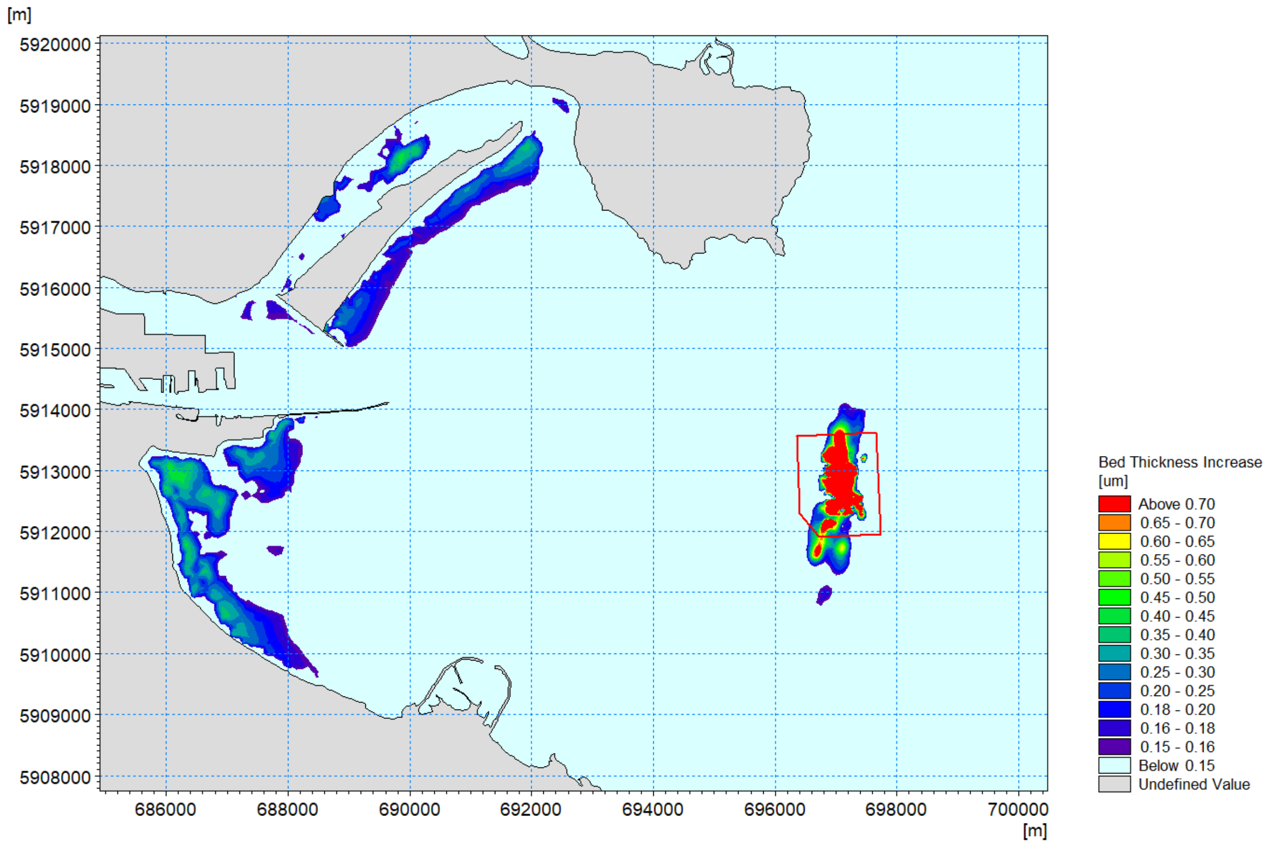


Figure 4-11 Cumulative bed thickness increase as a result of silt deposition from S0024-02, S0004-03, S0033-01 and the 3FM Project

4.2 Sand deposition arising from dredging activities

4.2.1 Sand deposition at the dump site

As noted previously and based on earlier work (RPS, 2014), the sand fraction of the dredge material was found to behave differently to silt material in that the sand fraction of dredge material immediately fell and settled on the dump site owing to the high fall velocities associated with this material. This is demonstrated in Figure 4-12 which illustrates the deposition of *c.* 1million cubic metres of sand material across the dump site following the continuous disposal of sand over the course of 6 months.

These findings are in line with other studies which concluded that sand fractions with higher fall velocities and higher critical shear stress parameters (relative to silt material) tend to remain in the locale of the disposal site with minimal re-suspension occurring (CEFAS, 2021).

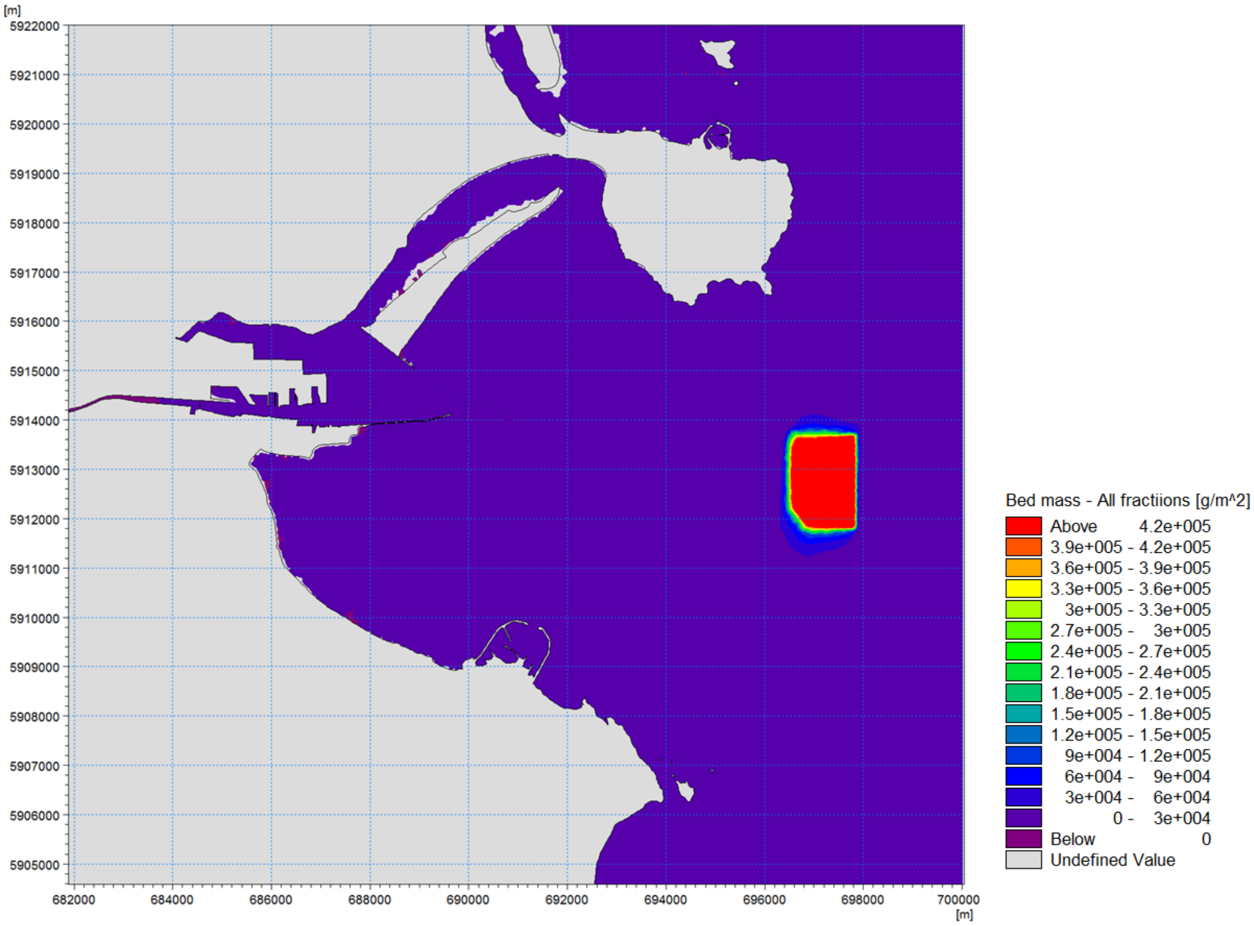


Figure 4-12 Total sand deposition after six months of continuous disposal of sand spoil material

4.2.2 Assessing the movement of coarse material

To assess the potential movement of the coarse material on the dump site, RPS utilised a two-stage approach which firstly involved reviewing site-specific high-resolution bathymetric surveys of the dump site to measure changes in seabed elevations and thus derive rates of change. Given that much of the dump site is characterised by well-defined sand waves, the output from this assessment was used as a proxy to determine the long-term potential for sediment erosion and movement.

Secondly, to further support this assessment, RPS undertook a bespoke numerical modelling exercise to quantify the erosion and movement of coarse material based on met-ocean conditions.

The output of these assessments was used to estimate the long-term fate of coarse sediment material which is deposited on the dump site as a result of dredging operations within Dublin Port.

4.2.3 Review of site specific bathymetric surveys

As part of DPC's extensive environmental monitoring programme, Hydromaster Ltd. is contracted to undertake high-resolution bathymetric surveys of the dump site before and after dredging campaigns. By way of example, the dump site was surveyed prior to the first capital dredging campaign under S0024-02 on 13th October 2022 and again on 7th December 2022 upon completion of the campaign (total volume disposed of during this period equated to 339,683m^3). The output from both of these surveys is illustrated in Figure 4-14. The elevation between these surveys is presented in Figure 4-18 with positive values representing deposition and negative values representing erosion (or sediment movement).

As will be seen from Figure 4-14, the elevation of the dump site ranges between *c.* -24m along the western boundary and *c.* -11m along the eastern boundary. Other notable features from this survey include two areas near the centre of the dump site whereby depths are *c.*5m shallower than the immediately surrounding area.

In addition to these shallower areas, distinct sand waves can also be observed in the shallower areas, particularly along the northeast and southern boundaries of the site.

Using a series of Geographical Information System (GIS) tools that were specifically developed for terrain analyses and the assessment of ridge forms, it was possible to examine both these surveys in greater detail to extenuate key morphological features. The output from this process is presented in Figure 4-15 and clearly illustrates the presence of prominent sand waves common to both surveys and also the deposition of dredge material in the post dredge campaign survey.

By using GIS to digitise key sand wave features common to both surveys and to extract key elevation contours (see Figure 3-16), RPS calculated the spatial difference between the morphological features of both surveys. This involved assessing the spatial change of more than 40,000 unique vertices. These differences were then divided by the duration between the two surveys to estimate rates of movement.

The output of this assessment found that the transport of the coarse material was greatest in shallower water, but that even in these areas the average rate of movement equated to *c.* 0.10m/day. In deeper waters whereby the seabed is not exposed to the same wave radiation or tidal stresses, the average rate of movement equated to just *c.* 0.05m/day. The dominant direction of sediment transport was generally from south to north, however, there was variation across the dump site.

It is worth noting that these surveys were undertaken in October and December 2022, during which period the Marine Institute's M2 wave buoy recorded relatively heavy sea conditions as illustrated in Figure 4-13.

> Given that the dump site is approximately 1.6km in length, it is estimated that coarse fraction of spoil material disposed of at the centre of the dump site would take between c. 10 – 40 years to move beyond the boundary of the dump site.
>
> Whilst the actual rate of movement would be subject to prevailing storm and tidal conditions, this assessment confirms that coarse material remains within the boundary of the dump site for a prolonged period of time.

Table 4-1 Average rate of sediment transport based on a difference assessment of high resolution surveys of the dump site on 13.10.2022 and 07.12.2022

Contour [m]	Average Rate of movement [metres / day]
-24	0.055
-23	0.068
-22	0.053
-21	0.048
-20	0.076
-19	0.084
-18	0.160
-17	0.169
-16	0.123
-15	0.130
-14	0.174
Average	**0.104**

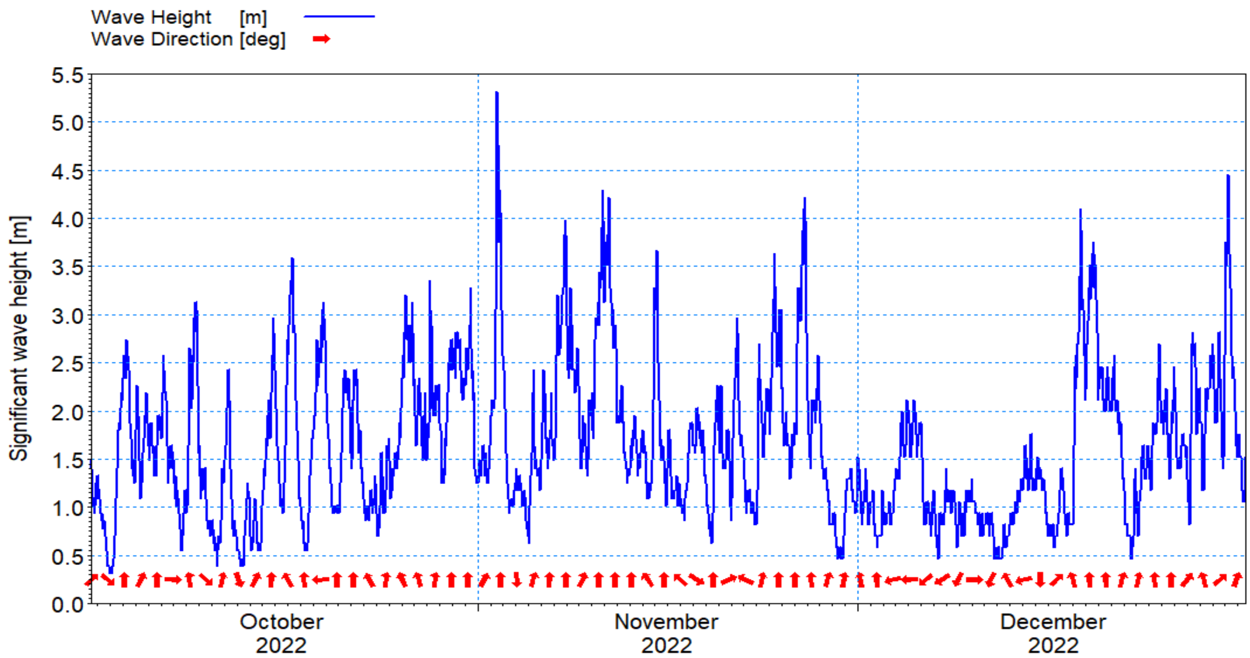


Figure 4-13 Wave climate as recorded by the Marine Institute's M2 wave buoy between October and December 2022.

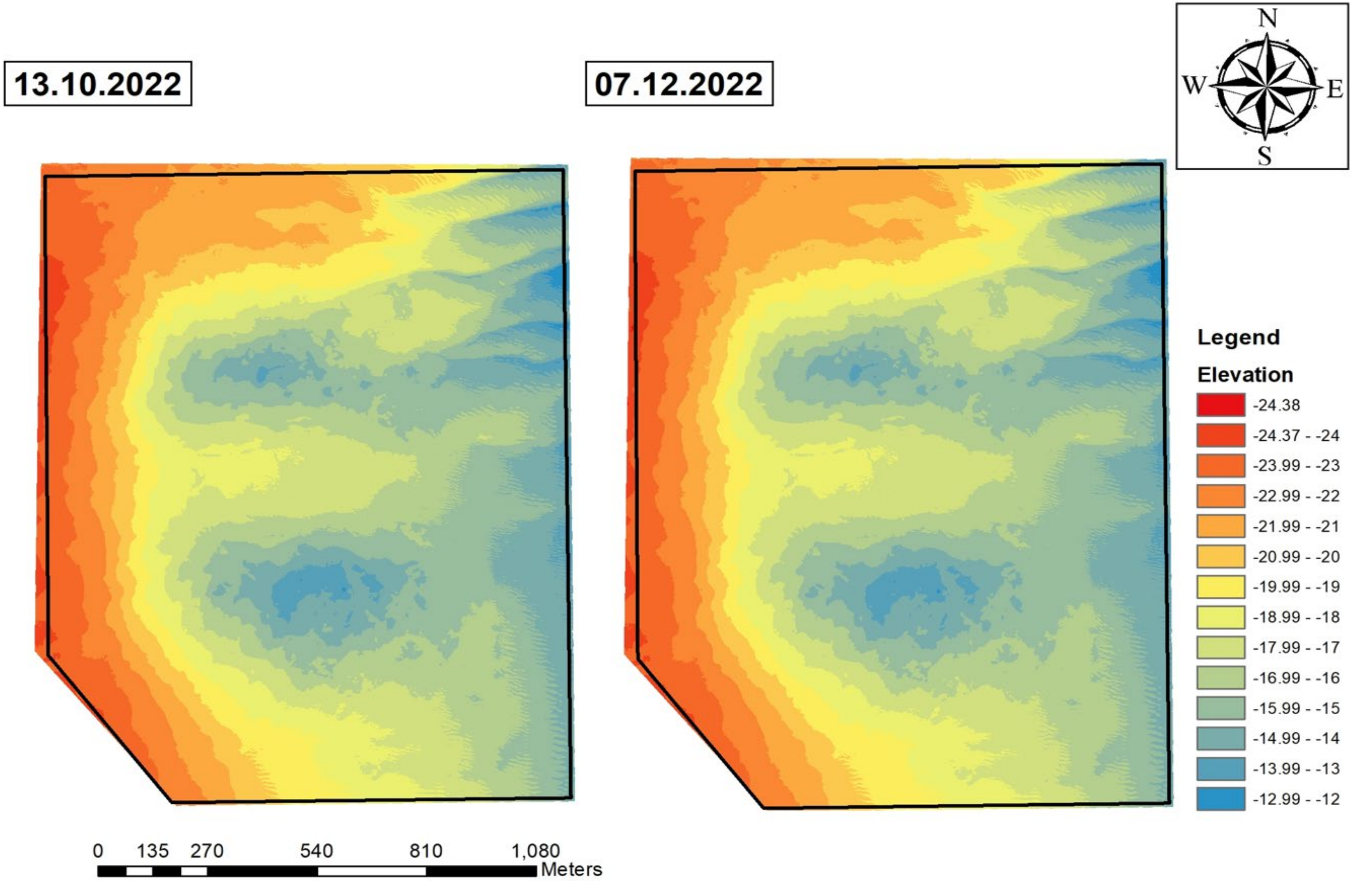


Figure 4-14 Pre and post dredging campaign bathymetric surveys at the licenced offshore dump site at the approaches to Dublin Bay

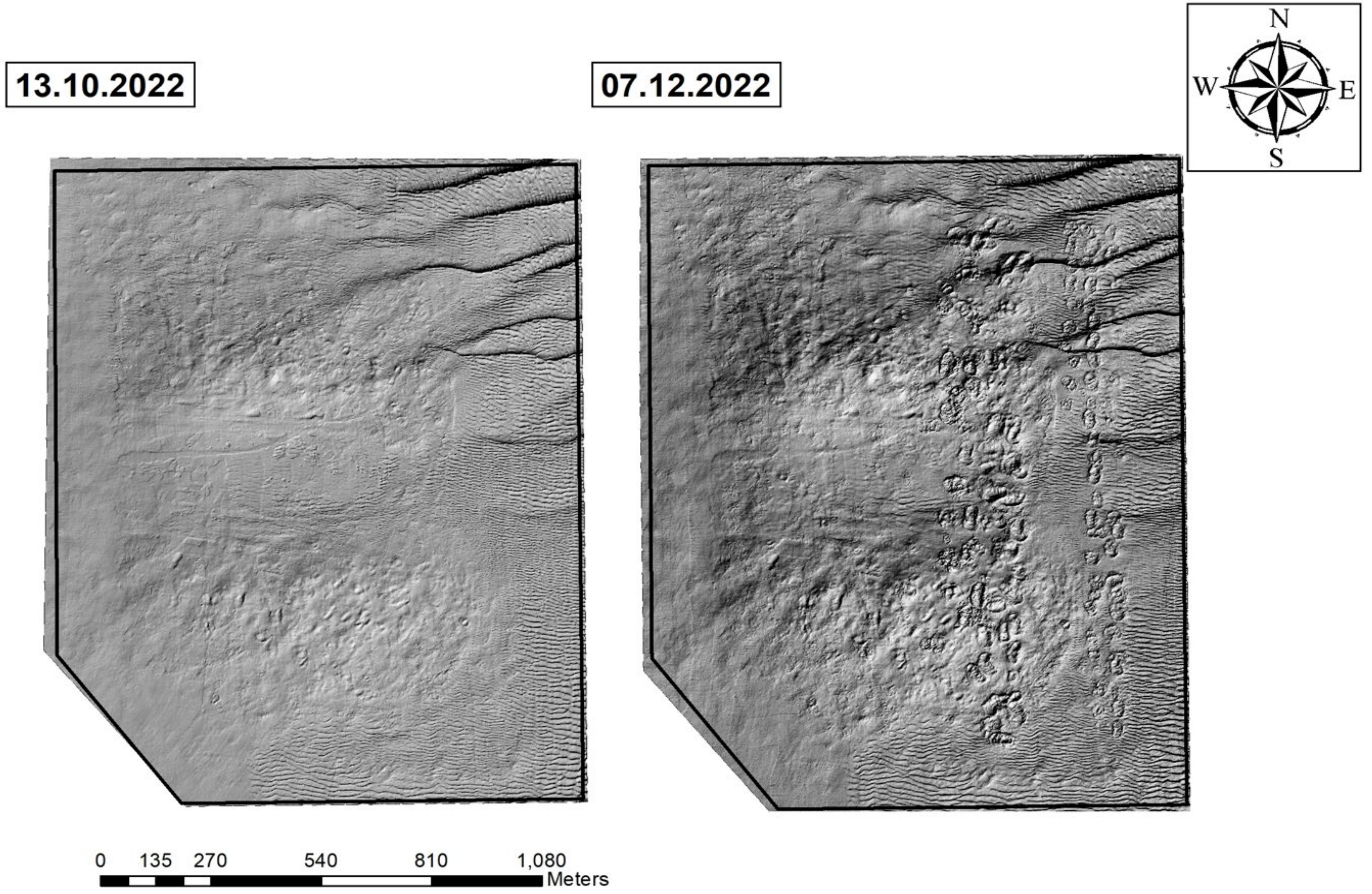


Figure 4-15 Sand wave and other morphological features identified from a terrain analyses of both survey datasets

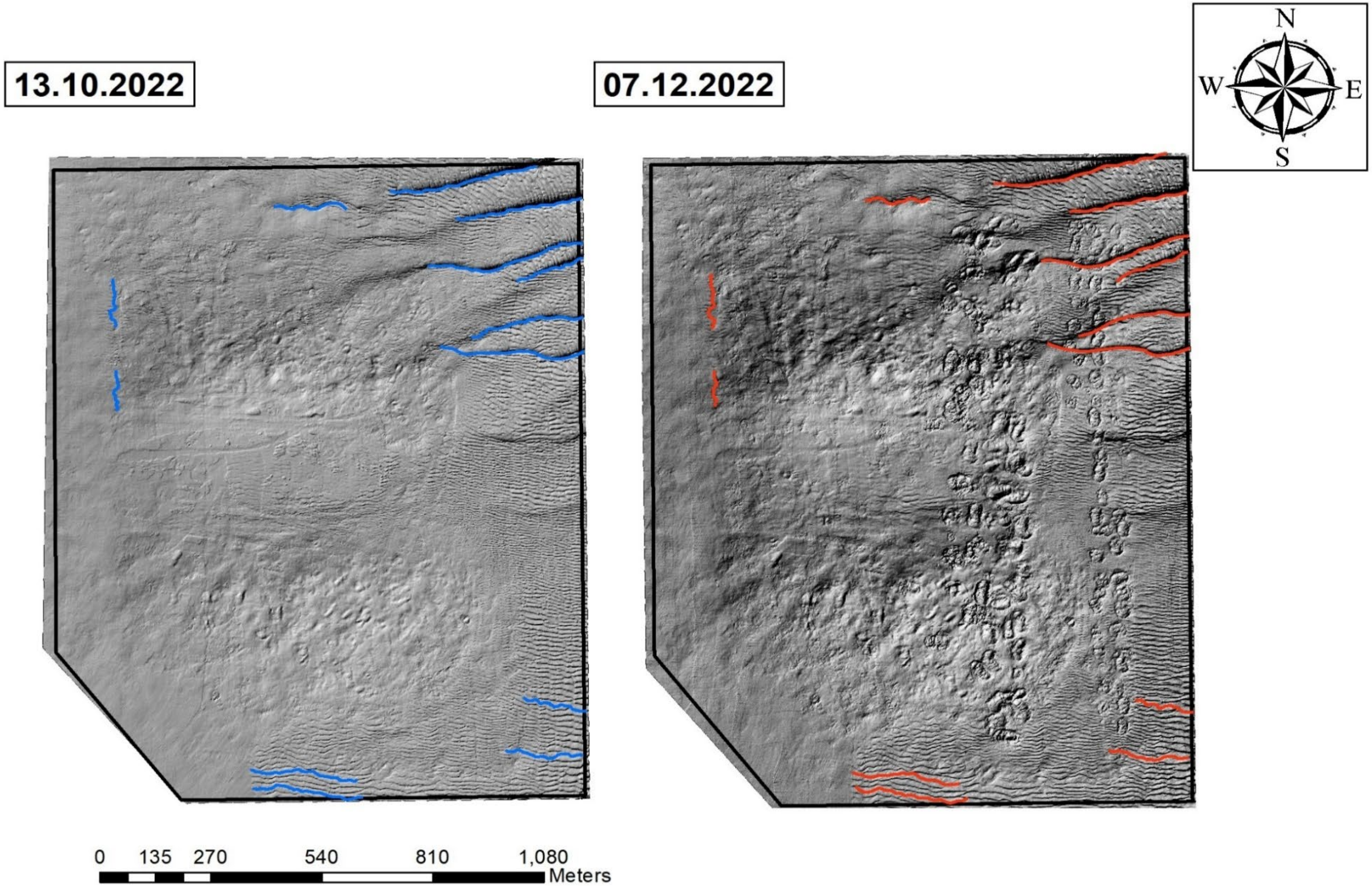


Figure 4-16 Sand wave features common to both surveys identified by blue and red vectors that were used to assess movement of bed material

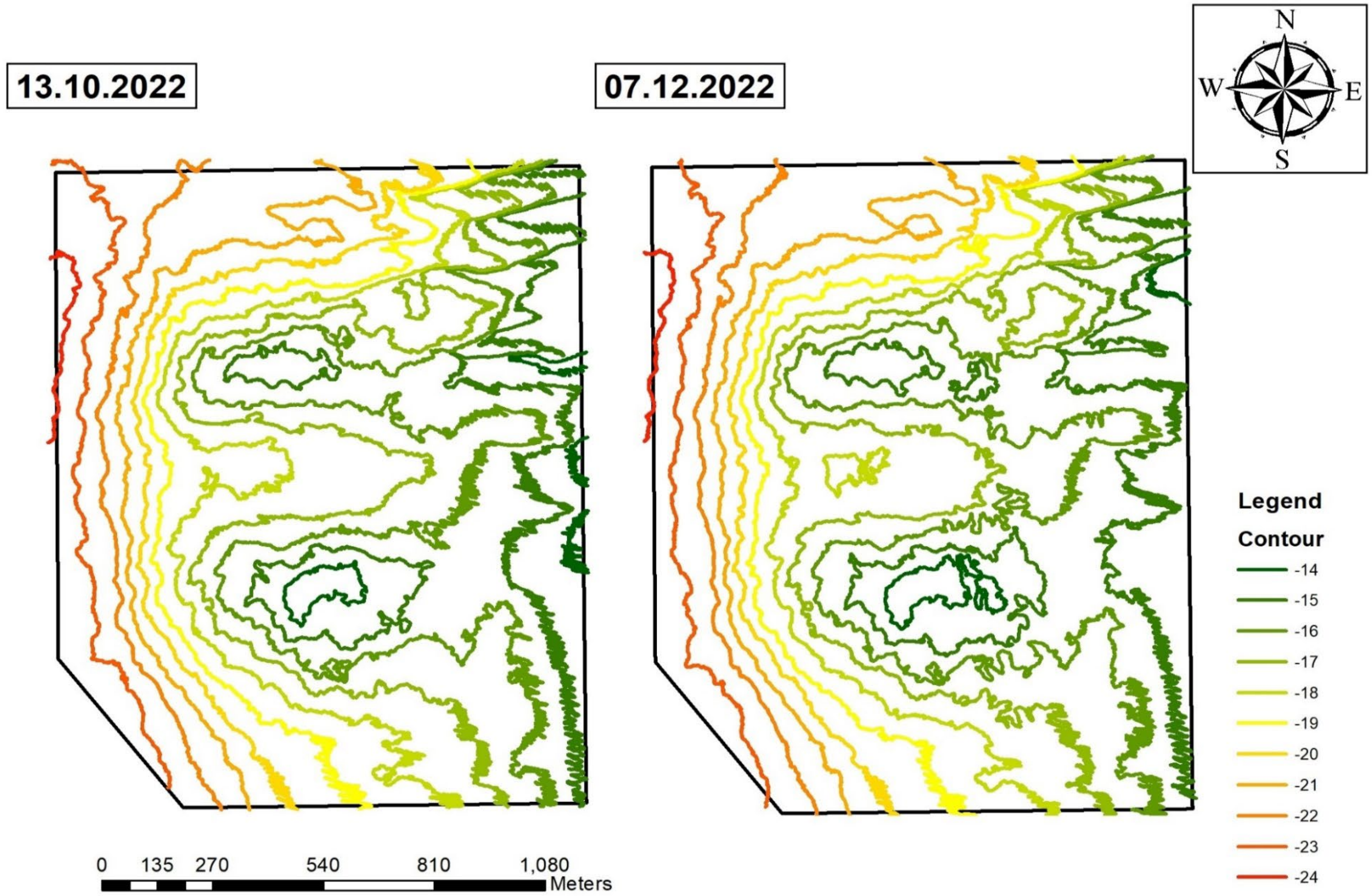


Figure 4-17 Elevation contours of both surveys used to assess the movement of bed material at the dump site

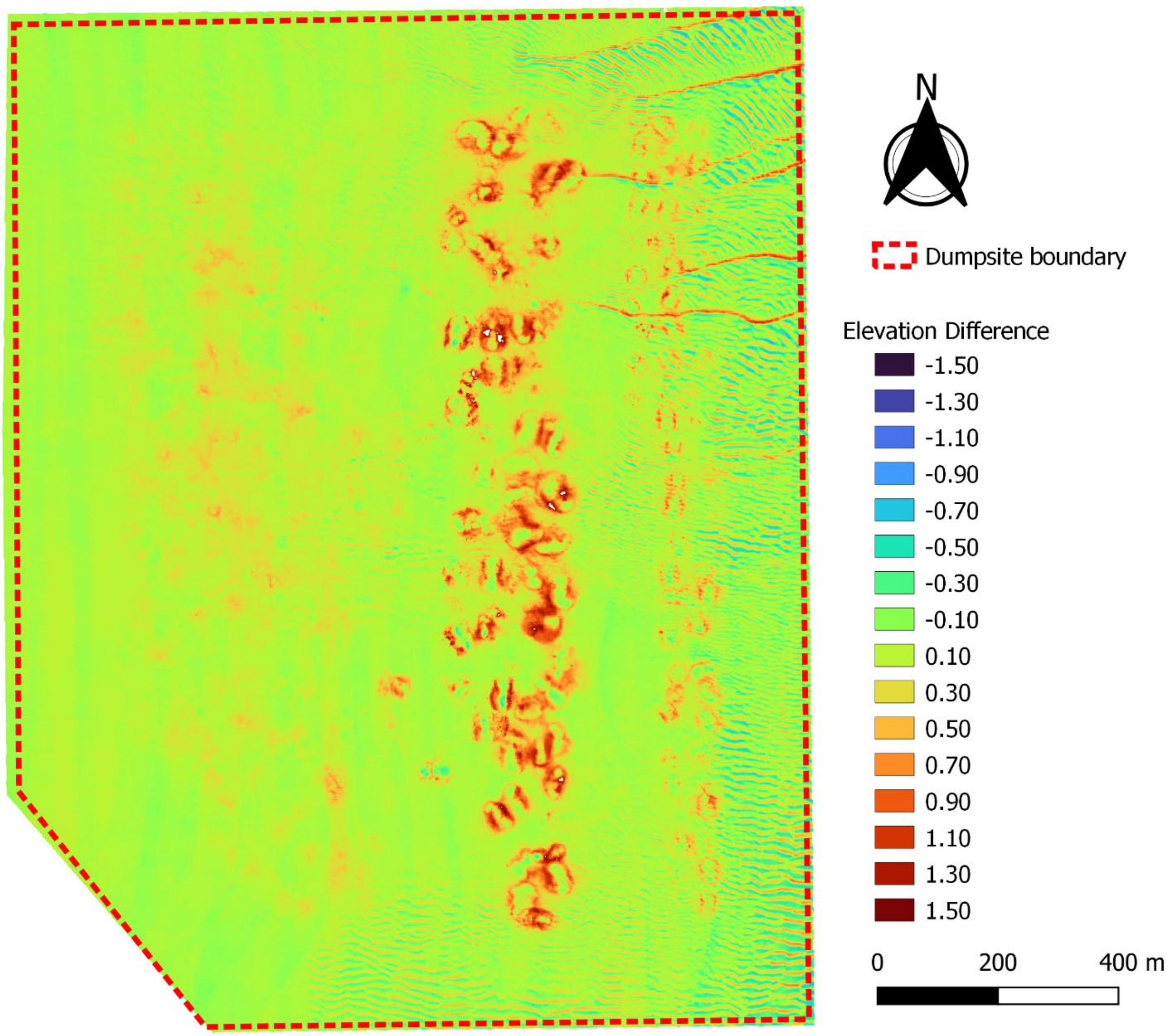


Figure 4-18 Elevation difference between pre and post dredge campaign surveys (*post minus pre*).

4.2.4 Numerical modelling of coarse material

In addition to reviewing high resolution site-specific surveys recorded before and after the capital dredging campaign in Q4 of 2022, RPS also utilised state-of-the-art modelling software to assess the potential erosion and movement of coarse material on the dump site.

Given that the assessment described in the previous Section established that the rate of sediment transport was extremely low (i.e., less than 0.15m/day), it was recognised that long-term morphological modelling could not be undertaken using a conventional two-dimensional modelling approach. This was due to two reasons:

1. The finest cell resolution of the two-dimensional numerical models equates to *c.* 100m^2 which is equivalent to a 10x10m cell. The rate of sediment movement is therefore orders of magnitude smaller than what conventional two-dimensional models are designed to resolve. Thus, standard error margins associated with the models are likely to be significantly greater than any actual morphological change.
2. Using a coupled two-dimensional model to resolve hydrodynamics, spectral waves and sediment transport is very computationally intensive, with a simulation designed to represent 1-month taking several weeks to complete. Thus, undertaking simulations to represent long-term changes of 6 – 12 months would take several months in real time to complete.

To overcome this constraint, RPS utilised the Littoral Process (LITPACK) module which was developed by DHI to calculate sediment transport based on a Quasi Three-Dimensional Sediment Transport model (STPQ3D). This module calculates instantaneous and time-averaged hydrodynamics and sediment transport in two horizontal directions for a single point and can perform long-term assessment very quickly to a high degree of accuracy.

Importantly, this module accounts for many key processes that are critical to governing sediment transport including:

- Wave motion and wave radiation stresses.
- Turbulence and eddy viscosities.
- Bed load transport and suspended load transport.
- Near-bed orbital velocities.
- Shear stresses and ripples

4.2.4.1 Modelling approach & output

To inform the LITPACK model, RPS derived the wave conditions experienced on the dump site between 2022 and 2023 based on data recorded by the Marine Institute's M2 wave buoy. Tidal conditions for the model were derived from the Dublin Port tide gauge for the same period, whilst tidal current conditions were extracted from an existing calibrated hydrodynamic model of the dump site.

Having established boundary conditions, coarse material which was representative of the sand to be dredged from Dublin Port was introduced at various depths which corresponded to the 10 contours described in Table 4-1. The material was defined with a Dn50 size of 0.20mm and was represented using three discrete fractions to account for potential spreading across the sediment grading curve.

The model was run for a total of 1 year which included the October and December period during which the bathymetric surveys described in Section 4.2.3 were undertaken. The output of this simulation produced rates of sediment transport for the sand material at each of the ten unique depth contours. Based on these results, it was found that a sand particle with a Dn50 size of 0.20mm could move, on average, at a rate of between 0.05 and 0.17m/day depending on available water depth. A comparison of these model results and the output from the bathymetric survey assessment is presented in Figure 4-19.

It will be noted from Figure 4-19 that both the observed and modelled rates of sediment transport correlate extremely well. Furthermore, it will be seen that sediment transport under tidal conditions alone does not exceed 0.005m/day regardless of the depth. This further demonstrates that the coarser sand material on the dump site will likely only be mobilised by wave action.

When material does become mobilised through wave action, the direction of transport will correspond to the direction of the prevailing tidal currents, which at the dump site tends to be towards the north during flood tides and towards the south during ebb tides. Over the long-term, the net movement of coarse material will be influenced primarily by the direction of residual tidal movements, which as illustrated in Figure 4-20, is towards the north.

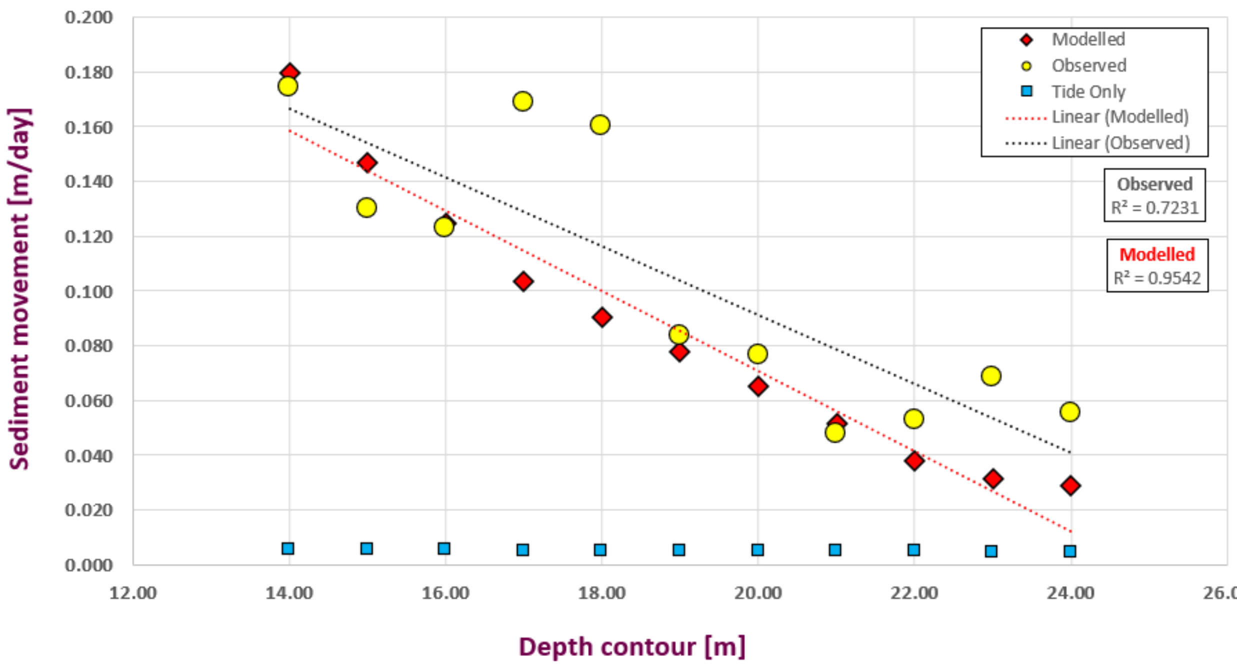


Figure 4-19 Comparison of sediment movement rates at the dump site as derived from numerical modelling and an assessment of bathymetric survey data. Modelled sediment Dn50 = 0.20m

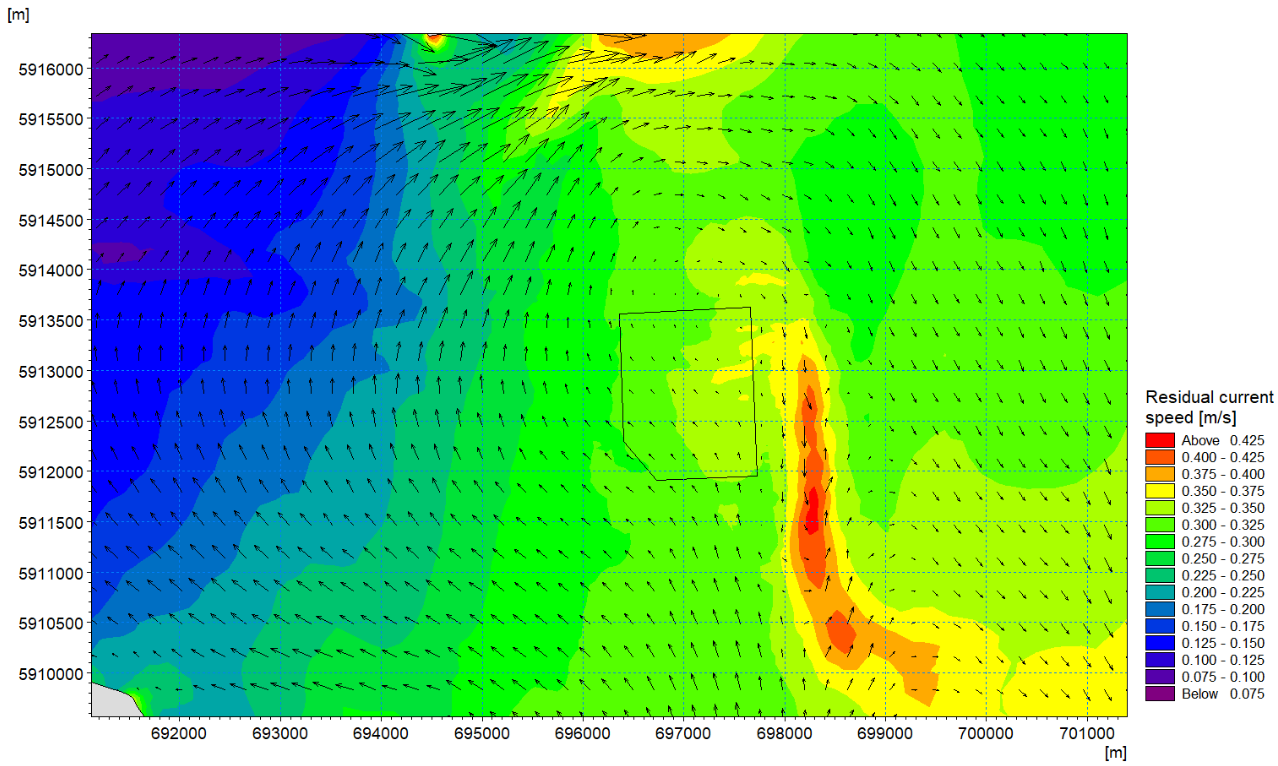


Figure 4-20 Residual current speeds at the dump site

4.3 Context provided by Marine Institute Studies

Since 2012, the Marine Institute, has carried out monitoring to determine macroinvertebrate ecological quality status (EQS) in coastal and transitional waters around the Irish Coast in order to fulfil requirements of the Water Framework Directive (WFD). As part of this programme, sampling must be carried out within each waterbody, including Dublin Bay, at least twice within the 6-year cycle (once every three years).

Based on the sampling and monitoring of 15 individual locations illustrated in Figure 4-21, the seabed material was found to comprise of muddy and fine sand or very fine sands at all stations. Coarse material was found to contribute an insignificant part of the sediment. Furthermore, the benthic communities surveyed in Dublin Bay were characteristic of the shallow muddy fine sand sediments sampled. Taxa common throughout the stations included, amongst others, the polychaetes *Glycera tridactyla, Nephtys hombergii, Spiophanes bombyx* and *Chaetozone christiei.*

> Work undertaken by the Marine Institute which included extensive sampling and monitoring throughout Dublin Bay concluded that the effects of dredging (loading) and spoil disposal appear to be contained within the areas in question and do not appear to be impacting the wider seabed invertebrate communities in Dublin Bay.

The results of the Marine Institute's long-term (*since 2012*) environmental benthic surveys therefore support the findings presented in this report which conclude that the movement of coarse material into Dublin Bay as a result of disposing of dredge material at the dump site is *extremely* limited and highly unlikely to result in a large-scale deposition event in Dublin Bay.

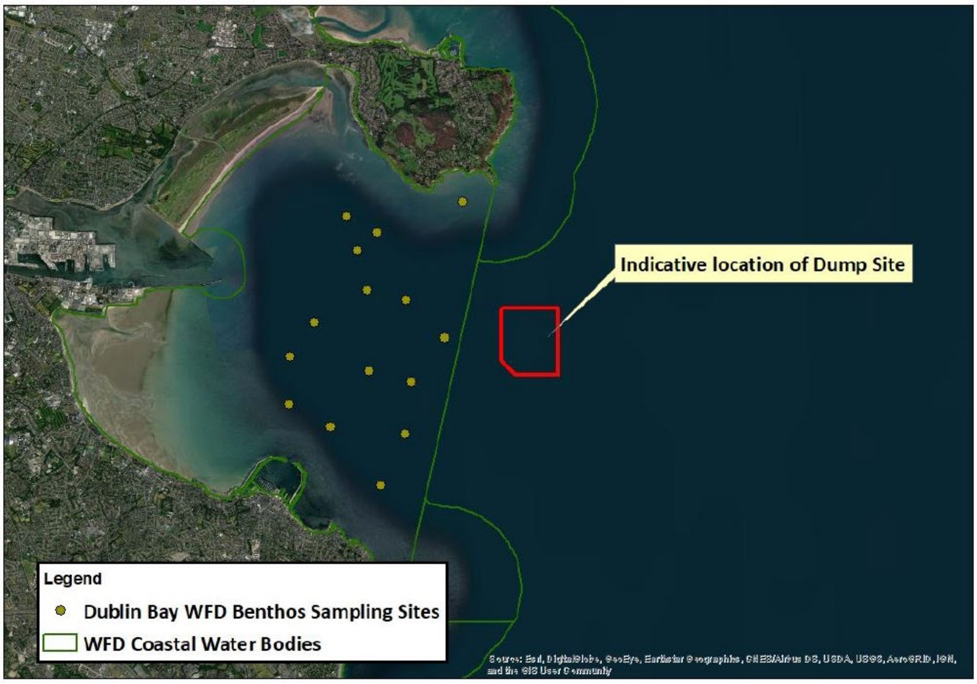


Figure 4-21 Dublin Bay Water Framework Directive benthos macro-invertebrate sampling points (n=15) in relation to the dump site

4.4 Conclusion

When considered in context of natural sedimentation within the Port Area (i.e., 30,000 g/m^2/yr which is equivalent to a deposition rate of *c.*2cm/yr), it is clear that the impact of sediment deposition from all dumping activities is several magnitudes lower than natural sedimentation rates. The impact of predicted sediment deposition from all capital and maintenance dredging dumping activities can therefore be considered to be *de minimis*.

In conclusion, the computational modelling studies of the capital and maintenance dredging dumping activities within the licensed dump site located at the approaches to Dublin Bay, west of the Burford Bank, in adherence with the key mitigation measures set out in Section 2, will ensure that cumulatively they will comply with, or will not result in the contravention of the following Directives:

- The Habitats Directive 82/43/EEC and Birds Directive 2009/147/EEC,
- The Water Framework Directive 2000/60/EC,
- The Marine Strategy Framework Directive 2008/56/EC.

5 BIBLIOGRAPHY

CEFAS Modelling the Fate of Dredged Material Following Disposal at the Nab Tower Disposal Site [Report]. - 2021.

Dublin Port Company DPC MP2 Project, Environmental Impact Assessment Report [Report]. - 2020.

Hydromaster Dublin Bay Sediment Plume Monitoring Report [Report]. - 2020.

Hydromaster Dublin Bay Sediment Plume Monitoring Report [Book]. - 2020.

RPS ABR Sediment Plume Validation Study [Report]. - 2021.

RPS Additional Sediment Plume Modelling, Response to Section 5(2) Notice [Report]. - 2021.

RPS Alexandra Basin Redevelopment Project - Construction Environmental Management Plan [Report]. - 2018.

RPS Alexandra Basin Redevelopment Project - Construction Environmental Management Plan [Book]. - 2018.

RPS Alexandra Basin Redevelopment Project - Environmental Impact Statement [Report]. - 2014.

RPS Alexandra Basin Redevelopment Project - Environmental Impact Statement [Book]. - 2014. - Vol. 1.

RPS Irish Coastal Protection Strategy Study [Report]. - 2003.

RPS Irish Coastal Protection Strategy Study [Book]. - 2003.

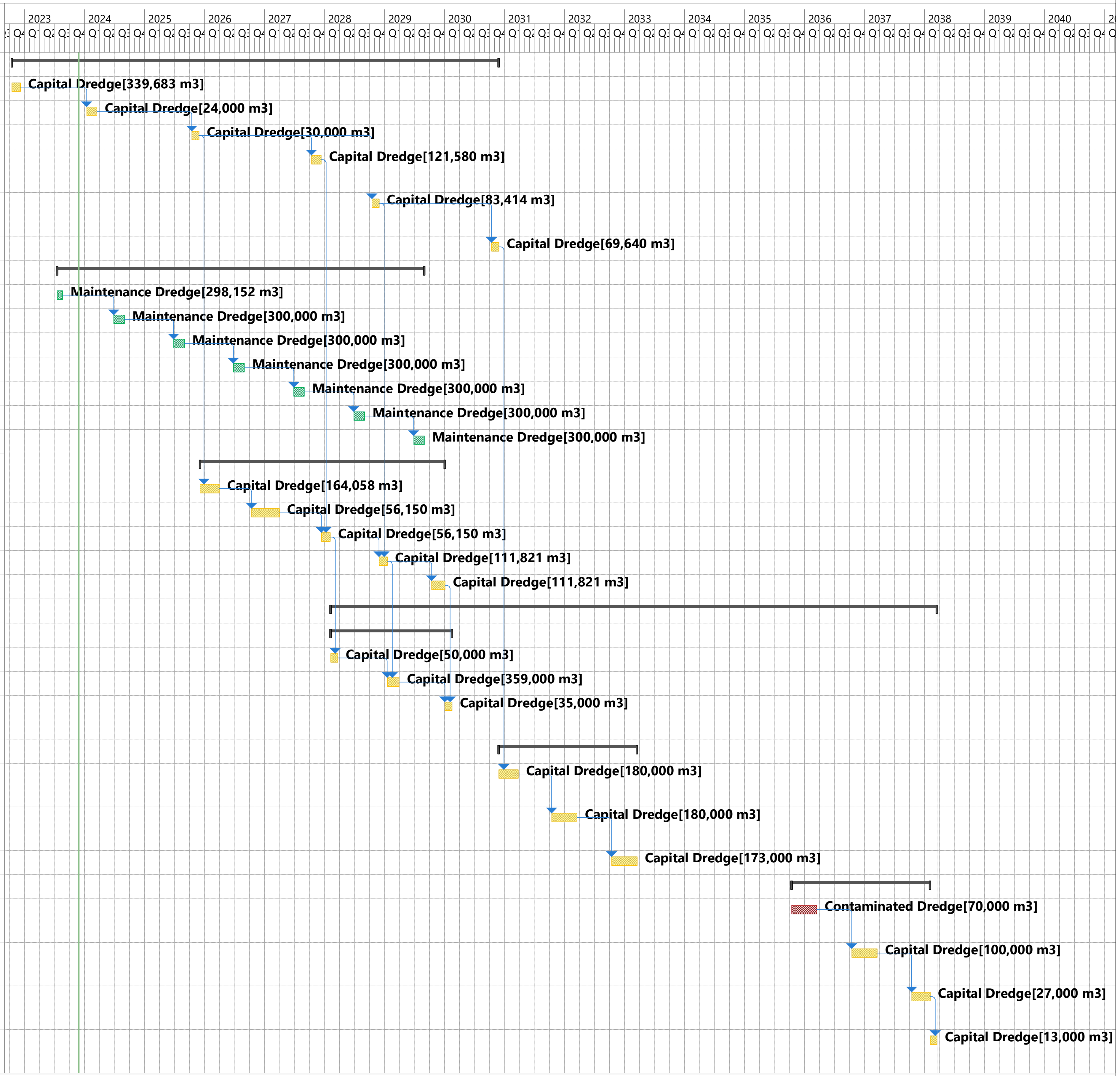
Appendix A

A.1 Dublin Port Overarching Dredging Programme

Dublin Port Company
Forecast Dredge Volumes

COMHLACHT CHALAFORT ÁTHA CLIATH
DUBLIN PORT COMPANY

ID	Task Name	Duration	Start Month	End Moth
1	**MP2 Project Capital Dredging (D@S Permit S0024-02)**	**395.8 wks**	**Oct-2022**	**Nov-2030**
2	Dredging Campaign No.1 Berth 53 Phase 1	36 days	Oct-2022	Dec-2022
3	Dredging Campaign No.2 Berth 53 Phase 2	44 days	Jan-2024	Mar-2024
4	Dredging Campaign No.3 Berth 53 Scour Protection	6 wks	Oct-2025	Nov-2025
5	Dredging Campaign No.4 Berth 52 Channel Widening	8 wks	Oct-2027	Dec-2027
6	Dredging Campaign No.5 Quay Rd and Oil Jetty pocket	6 wks	Oct-2028	Nov-2028
7	Dredging Campaign No.6 Berth 50A Pockets	6 wks	Oct-2030	Nov-2030
8	**Maintenance Dredging (D@S Permit S0004-03)**	**298.6 wks**	**Jul-2023**	**Aug-2029**
9	Maintenance Dredging Campaign No. 1	22 days	Jul-2023	Aug-2023
10	Maintenance Dredging Campaign No. 2	9 wks	Jun-2024	Aug-2024
11	Maintenance Dredging Campaign No. 3	9 wks	Jun-2025	Aug-2025
12	Maintenance Dredging Campaign No. 4	9 wks	Jun-2026	Aug-2026
13	Maintenance Dredging Campaign No. 5	9 wks	Jun-2027	Aug-2027
14	Maintenance Dredging Campaign No. 6	9 wks	Jun-2028	Aug-2028
15	Maintenance Dredging Campaign No. 7	9 wks	Jun-2029	Aug-2029
16	**Dublin Harbour Capital Dredging Project**	**198 wks**	**Dec-2025**	**Jan-2030**
17	Navigation Channel	14 wks	Dec-2025	Mar-2026
18	Berth Pocket Widening Campaign No.1	21 wks	Oct-2026	Mar-2027
19	Berth Pocket Widening Campaign No.2	6 wks	Dec-2027	Feb-2028
20	Basins Campaign No.1	6 wks	Nov-2028	Jan-2029
21	Basins Campaign No.2	10 wks	Oct-2029	Jan-2030
22	**3FM Project - Application Lodgment Spring 2024**	**518.4 wks**	**Feb-2028**	**Mar-2038**
23	**Turning Circle**	**100 wks**	**Feb-2028**	**Feb-2030**
24	Turning Circle Campaign No.1 - New Sea Wall	6 wks	Feb-2028	Mar-2028
25	Turning Circle Campaign No.2 - Main Dredge	10 wks	Jan-2029	Mar-2029
26	Turning Circle Campaign No.3 - Post Sludge Jetty Demolition	6 wks	Jan-2030	Feb-2030
27	**Lo-Lo Terminal (Area N) Berthing Pocket**	**118.6 wks**	**Nov-2030**	**Mar-2033**
28	Lo-Lo Terminal (Area N) Berthing Pocket Campaign No.1	15 wks	Nov-2030	Mar-2031
29	Lo-Lo Terminal (Area N) Berthing Pocket Campaign No.2	22 wks	Oct-2031	Mar-2032
30	Lo-Lo Terminal (Area N) Berthing Pocket Campaign Nc	22 wks	Oct-2032	Mar-2033
31	**Maritime Village / Marina**	**120.6 wks**	**Oct-2035**	**Feb-2038**
32	Maritime Village / Marina (top 1.0m at Maritime Village / Marina)	22 wks	Oct-2035	Mar-2036
33	Maritime Village / Marina - Main Dredge Campaign No.1	22 wks	Oct-2036	Mar-2037
34	Maritime Village / Marina - Main Dredge Campaign No.2	16 wks	Oct-2037	Feb-2038
35	**Ro-Ro Terminal (Area K) – Localised Scour Protection to 220 kV cables**	**6 wks**	**Feb-2038**	**Mar-2038**



Project: DPC Capital & Maintenance Dredge
Date: 28/11/2023

Task	Maintenance Dredge	Milestone	Deadline
Capital Dredge	Contaminated Dredge	Summary	Progress

Appendix B

B.1 Model Validation

Introduction

For more than a decade, RPS have been providing Dublin Port Company with an extensive suite of engineering design, environmental assessment, planning and consent services needed to support Strategic Infrastructure Development (SID) projects, including the Alexandra Basin Redevelopment (ABR), Masterplan 2 (MP2) and most recently the third and final Masterplan project (3FM).

Through this work and using industry standard software, RPS have developed, calibrated and validated a range of hydraulic models to assess coastal processes within the Dublin Port area and wider vicinity. This Appendix presents the key findings from the validation exercise which is relevant to this study.

Model Validation Process

The Time Series Comparator tool provided within MIKE was used to undertake statistical analysis of modelled and measured datasets for both tidal and wave parameters.

The MIKE tool provides several performance measures and statistics including the Index of Agreement which is also known as d_2 or "*model skill*". Model performance may be assessed using two main types of metrics: those related to absolute values such as the mean absolute error (MAE) or the root-mean-square error (RMSE) and those which are normalised such as the model skill (d_2) or the Coefficient of determination (R^2).

The MIKE analysis provides three normalised parameters directly:

- Coefficient of determination R^2 being the square of the Pearson's product-moment correlation coefficient. It ranges from 0 to 1 with larger values indicating a better fit.
- Coefficient of efficiency or Nash-Sutcliffe coefficient E (Nash and Sutcliffe, 1970)[1]. It ranges from minus infinity to 1 with larger values indicating a better fit.
- Index of agreement d_2 (Willmott et al., 1985)[2]. It ranges from 0 to 1 with large values indicating a better fit.

Having developed a value relating to goodness-of-fit between measured and modelled data it is necessary to determine if the model is fit for the purpose of assessment. Classification is a useful tool in this respect. The simplest form of classification, shown in Table A.2, may be applied to those metrics whose values range from zero to unity.

Table A.2: Coefficient of Determination Interpretation

Coefficient of Determination (R^2)	Interpretation
0	The model does not predict the outcome
Between 0 and 1	The model partially predicts the outcome
1	The model perfectly predicts the outcome

[1] Nash, J.E., Sutcliffe, J., (1970), River flow forecasting through conceptual models, Part I A discussions of principles, J. Hydrol., 10, 282-290.

[2] Willmott, C.J., Ackleson, S.G., Davis, R.E., Feddema, J.J, Klink, K.M., Legates, D.R., O'Donnell, J., Rowe, C.M., (1985), Statistics for the evaluation and comparison of models, J. Geophys. Res., 90, 8995-9005.

On the other end of the scale more complex classifications have been developed, such as that proposed by Ladson for application of the coefficient of efficiency in stream flow modelling (Ladson, 2008)[3]. This is a dual system in which a reduced level of fit is accepted as satisfactory for the validation phase compared with that from the calibration phase parameters, Table A.3.

Table A.3: Coefficient of Efficiency Interpretation

Classification	Coefficient of Efficiency Calibration	Coefficient of Efficiency Validation	
Excellent	E ≥ 0.93	E ≥ 0.93	
Good	0.8 ≤ E < 0.93	0.8 ≤ E < 0.93	
Satisfactory	0.7 ≤ E < 0.8	0.6 ≤ E < 0.8	
Passable	0.6 ≤ E < 0.7	0.3 ≤ E < 0.6	
Poor	E < 0.6	E < 0.3	

For the purposes of this study the classification proposed by Sutherland is applied to the model output (Sutherland *et al* 2004)[4]. This classification is applied to metrics based around the normalising the Mean Absolute Error (MAE), where an allowance is made for the potential inaccuracy of the monitoring equipment, to derive an Average Relative Mean Absolute Error (ARMAE), as shown in Table 4.1. Model results from the study were analysed without accounting for potential device errors in the first instance (i.e. RMAE); therefore, the classification was applied on a conservative basis with a value of <0.7 providing a satisfactory level of model accuracy.

For each of the model parameters the MIKE timeseries comparator was used to derive statistics and performance measures.

Table 4.1: Average Relative Mean Absolute Error (ARMAE) Interpretation

Classification	Range of ARMAE	
Excellent	< 0.2	
Good	0.2 – 0.4	
Reasonable	0.4 – 0.7	
Poor	0.7 – 1.0	
Bad	> 1.0	

[3] Ladson, A. R. (2008) Hydrology: an Australian Introduction. Oxford University Press.

[4] J. Sutherland, D.J.R. Walstra, T.J. Chesher, L.C. van Rijn, H.N. Southgate. (2004), Evaluation of coastal area modelling systems at an estuary mouth. Coastal Engineering 51, 119– 142.

Tidal Regime Validation

The validation process of the baseline Dublin Port 3D hydrodynamic model was undertaken using data recorded by two Acoustic Doppler Current Profilers (ADCPs) that were moored in the Port and Dublin Bay as part of a previous monitoring programme. The location of these devices is illustrated in Figure A.1.

The validation process focused on establishing agreement between the model output and recorded observations and thus assessing overall model performance based on several key parameters including tidal range, current speed and direction.

Data from the tide gauge at Dublin Port was also used to verify simulated surface elevations.

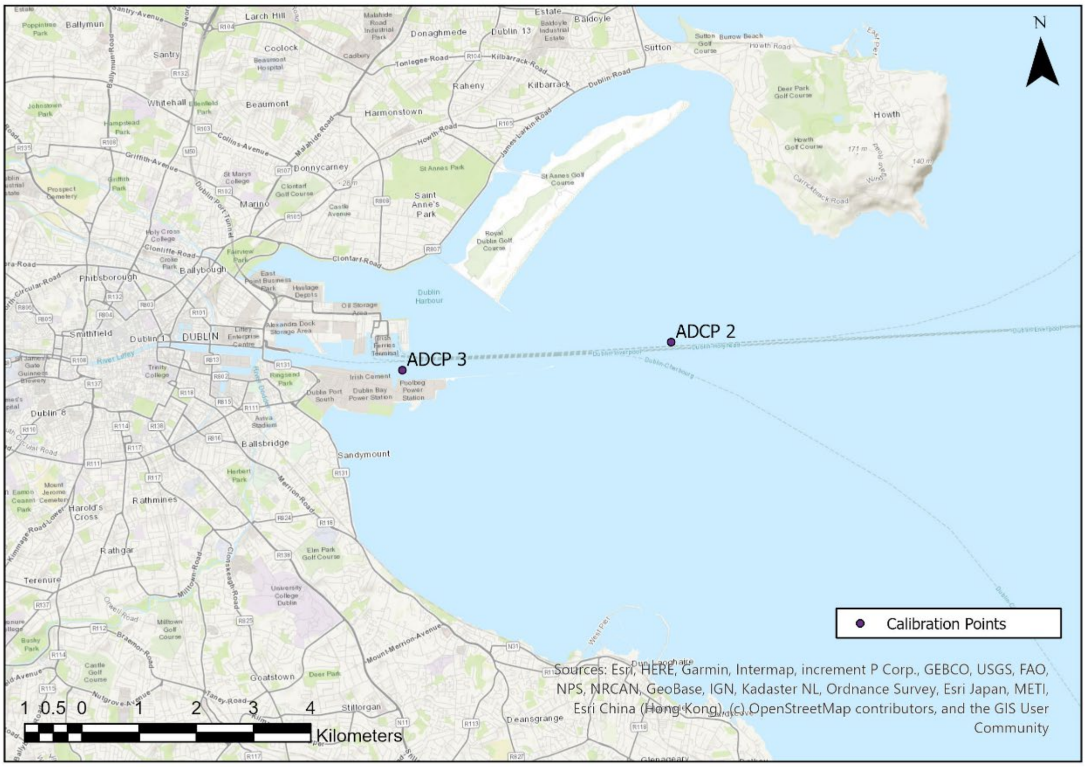


Figure A.1: Location of the ADCP devices in Dublin Bay that were used to validate the baseline 3D hydrodynamic model

The statistics and performance measures ascertained from the MIKE comparator software were supplemented to provide the Averaged Absolute Value (AAV) for the simulation to determine the Relative Mean Absolute Error (RMAE). Table A.1 presents a summary of the statistics and performance measures for the calibration period at each of the two ADCPs and Dublin Port tide gauge.

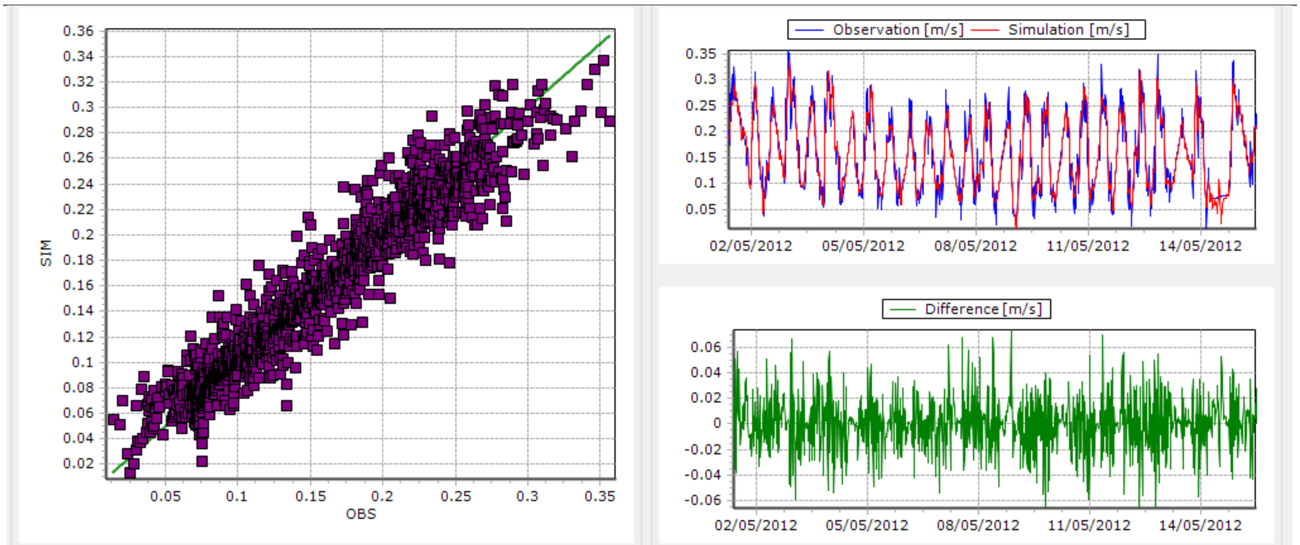
Based on this validation exercise, it was found that:

- Applying the Sutherland ARMAE classification, without any allowance for measuring device inaccuracies, shows that the goodness of fit for all parameters would be classed as either **'good' (green) or 'excellent' (blue)** at both locations.
- When the Ladson classification is applied on the coefficient of efficiency, all parameters are also rated **'satisfactory'** to **'excellent'**.

The hydrodynamic model described and used to inform the assessment presented in this document was therefore considered accurate and fit for purpose.

Table A.1: Model calibration performance metrics

Metric	Statistic			Performance Measure			
Parameter	Average Absolute Value Observed AAV	Mean Absolute Error MAE	Root Mean Square Error RMSE	Coeff of Determination R^2	Coeff of Efficiency E	Index of Agreement d_2	Relative Mean Absolute Error ARMAE
Dublin Port Tide Gauge							
Surface Elevation	0.1158	0.0461	0.0554	0.9973	0.9972	0.993	0.39
Inner ADCP – Current Velocity							
Surface layer	0.1835	0.0285	0.0387	0.8859	0.8652	0.9682	0.16
Middle layer	0.1313	0.0217	0.0324	0.8814	0.8619	0.6972	0.17
Bottom layer	0.0859	0.0178	0.0234	0.7839	0.7067	0.9344	0.21
Outer ADCP – Current Velocity							
Surface layer	0.1866	0.0210	0.0310	0.9494	0.9484	0.9870	0.11
Middle layer	0.1598	0.0148	0.0200	0.9195	0.9119	0.9786	0.09
Bottom layer	0.1392	0.0130	0.0175	0.8990	0.8857	0.9725	0.09
Inner ADCP – Current Direction [rad]							
Surface layer	0.6319	14.5418	19.8945	0.9171	0.9152	0.9784	0.04
Middle layer	0.2902	15.4551	20.8287	0.8872	0.8829	0.9702	0.18
Bottom layer	0.7607	13.9571	20.3591	0.9197	0.9101	0.9783	0.03
Outer ADCP – Current Direction [rad]							
Surface layer	4.4792	15.3744	27.7267	0.9461	0.9364	0.9848	0.29
Middle layer	4.0308	14.2014	23.2595	0.9481	0.9393	0.9855	0.28
Bottom layer	1.5296	15.7842	23.8407	0.9292	0.9222	0.9811	0.09



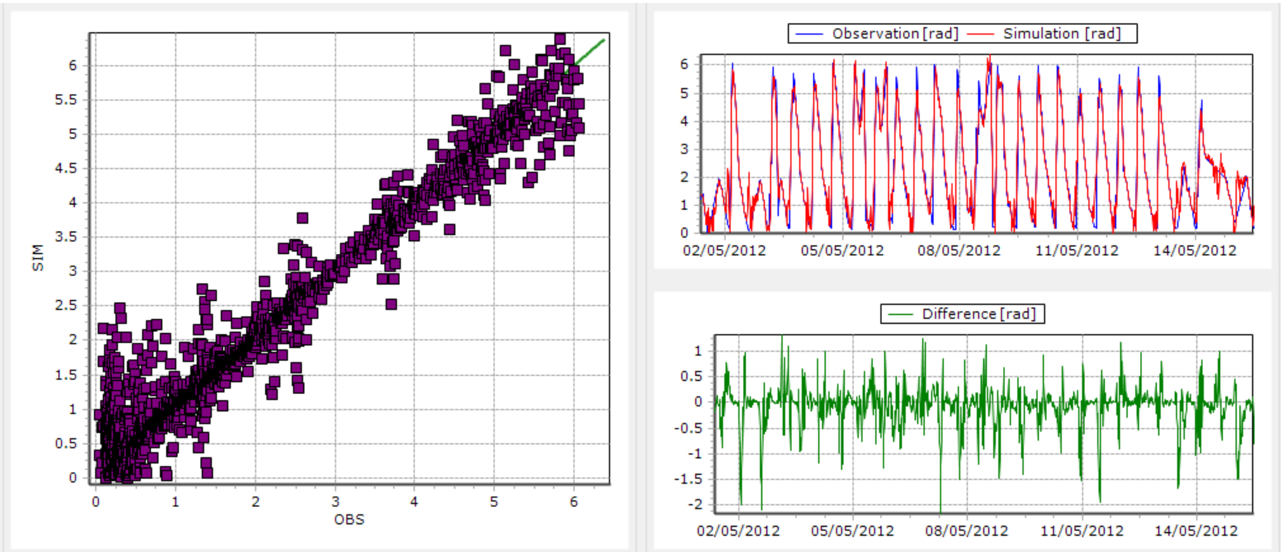
Performance Measures

Indice	Value	Unit
Mean Error	0.0002	[m/s]
Mean Absolute Error	0.0148	[m/s]
Root Mean Square Error	0.0200	[m/s]
Std. dev of Residuals	0.0200	[m/s]
Coefficient of Determination	0.9195	[-]
Coefficient of Efficiency	0.9119	[-]
Index of Agreement	0.9786	[-]

Statistics

	Observation	Simulation	Difference
Item Name	Middle Velocity	Lyr3: Current speed	Difference
Item Unit	[m/s]	[m/s]	[m/s]
Minimum	0.0144	0.0134	-0.0662
Maximum	0.3566	0.3363	0.0739
Average	0.1598	0.1596	0.0002
Std. deviation	0.0704	0.0673	0.0200

Figure A.2: Statistical comparison of middle current velocity from the Outer ADCP and the model



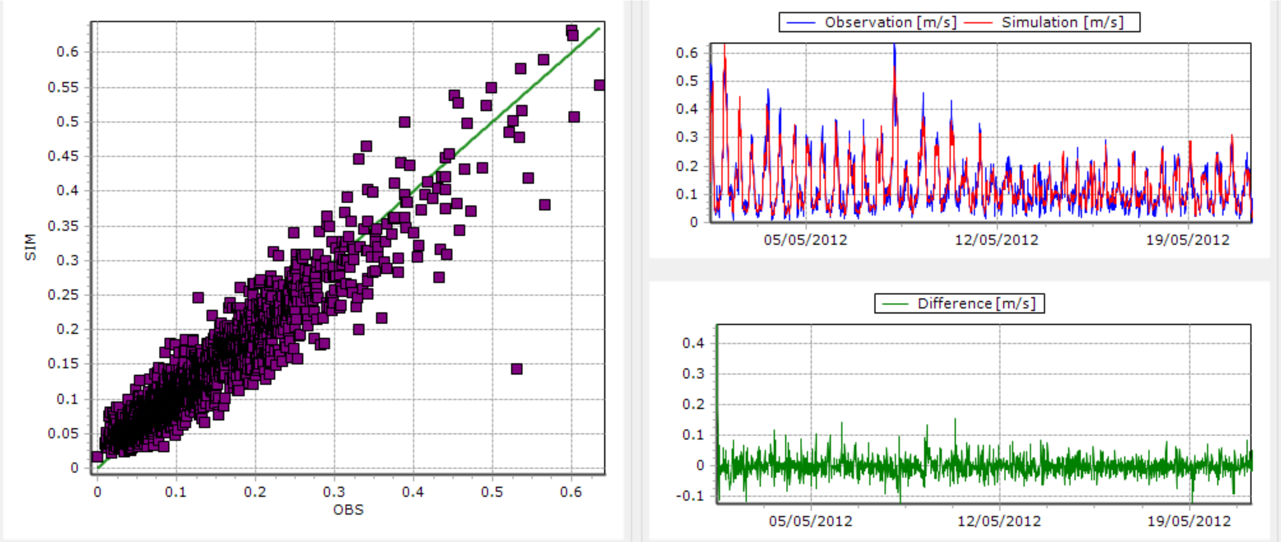
Performance Measures

Indice	Value	Unit
Mean Error	-0.0704	[rad]
Mean Absolute Error	0.2479	[rad]
Root Mean Square Error	0.4060	[rad]
Std. dev of Residuals	0.3998	[rad]
Coefficient of Determination	0.9481	[-]
Coefficient of Efficiency	0.9393	[-]
Index of Agreement	0.9855	[-]

Statistics

	Observation	Simulation	Difference
Item Name	Middle Direction	Lyr3: Current directi...	Difference
Item Unit	[rad]	[rad]	[rad]
Minimum	0.0432	-0.0038	-2.1710
Maximum	6.0706	6.3815	1.3248
Average	2.2816	2.3520	-0.0704
Std. deviation	1.7421	1.6472	0.3998

Figure A.3: Statistical comparison of middle current direction from the Outer ADCP and the model



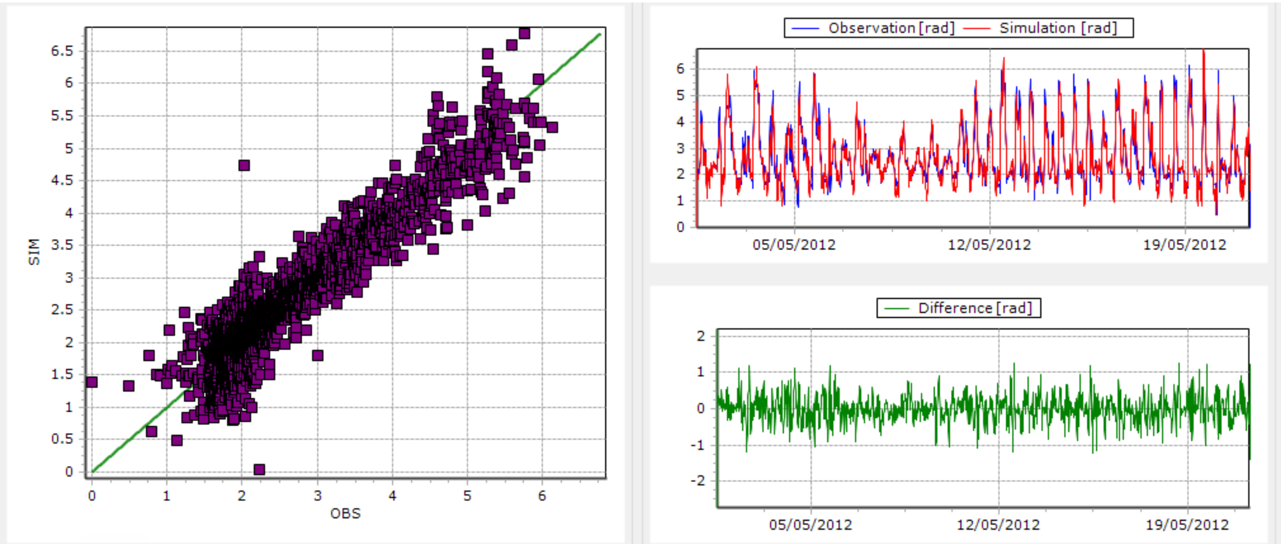
Performance Measures

	Indice	Value	Unit
▶	Mean Error	0.0001	[m/s]
	Mean Absolute Error	0.0217	[m/s]
	Root Mean Square Error	0.0324	[m/s]
	Std. dev of Residuals	0.0324	[m/s]
	Coefficient of Determination	0.8814	[-]
	Coefficient of Efficiency	0.8619	[-]
	Index of Agreement	0.9672	[-]

Statistics

		Observation	Simulation	Difference
▶	Item Name	Middle Velocity	Lyr3: Current speed	Difference
	Item Unit	[m/s]	[m/s]	[m/s]
	Minimum	0.0000	0.0000	-0.1238
	Maximum	0.6358	0.6313	0.4643
	Average	0.1313	0.1312	0.0001
	Std. deviation	0.0941	0.0873	0.0324

Figure A.4: Statistical comparison of middle current velocity from the Inner ADCP and the model



Performance Measures

	Indice	Value	Unit
▶	Mean Error	-0.0051	[rad]
	Mean Absolute Error	0.2694	[rad]
	Root Mean Square Error	0.3635	[rad]
	Std. dev of Residuals	0.3635	[rad]
	Coefficient of Determination	0.8872	[-]
	Coefficient of Efficiency	0.8829	[-]
	Index of Agreement	0.9702	[-]

Statistics

		Observation	Simulation	Difference
▶	Item Name	Middle Direction	Lyr3: Current directi...	Difference
	Item Unit	[rad]	[rad]	[rad]
	Minimum	0.0000	0.0393	-2.7215
	Maximum	6.1317	6.7727	2.1953
	Average	2.7122	2.7173	-0.0051
	Std. deviation	1.0699	1.0624	0.3635

Figure A.5: Statistical comparison of middle current direction from the Inner ADCP and the model

Wave Validation

The spectral wave model was verified using data collected by an Acoustic Wave and Current Profile (AWAC) device which was deployed in the centre of the licensed spoil site in Dublin Bay as part of a previous monitoring programme. The location of this device is illustrated in Figure A.6.

For the purposes of the validation exercise, wave simulations were run and compared for the following two periods when notable wave activity was recorded by the AWAC device:

- **Event 1:** 01/01/2018 to 09/03/2018
- **Event 2:** 29/01/2021 to 01/03/2021

The output for the significant wave height and wave periods at the site over the calibration period is presented in Figure A.7. An example of the MIKE timeseries comparator output for the wave components at the site is shown in Figure A.8.

Based on this validation exercise, it was found that:

- Applying the Sutherland classification, without any allowance for measuring device inaccuracies, shows that the goodness of fit for all parameters would be classed as either **'good' (green) or 'excellent' (blue)** during both events.
- When the Ladson classification is applied on the coefficient of efficiency, all parameters are also rated **'excellent' for both events**.

The spectral wave model described and used to inform the assessment presented in this document was therefore considered accurate and fit for purpose.

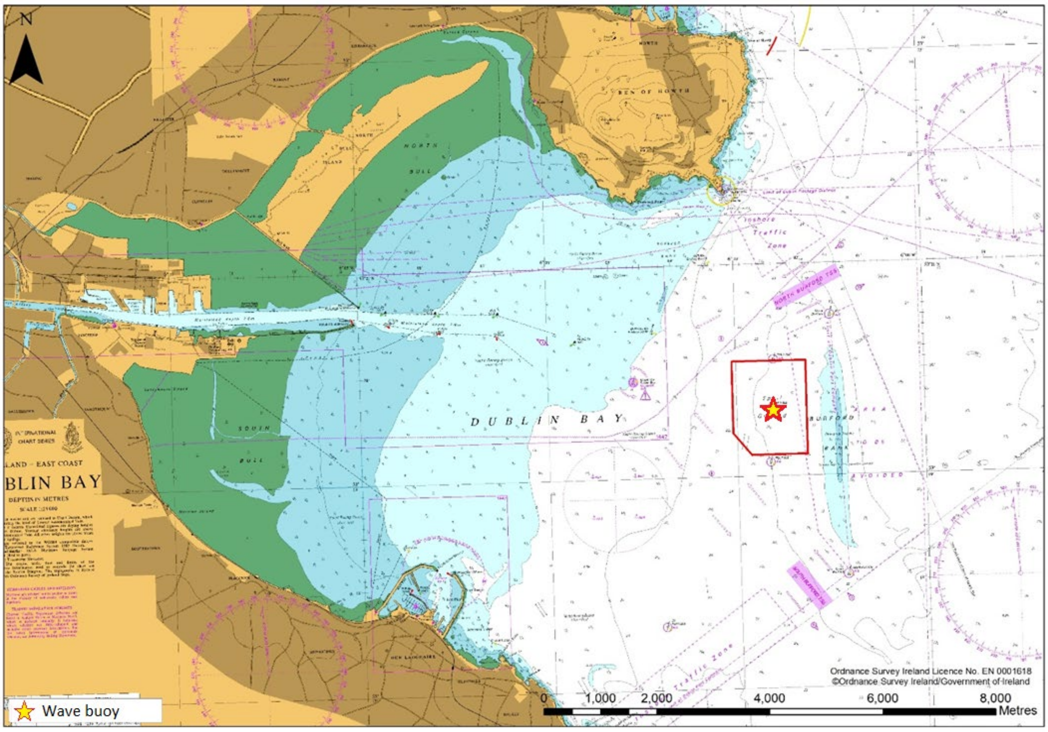
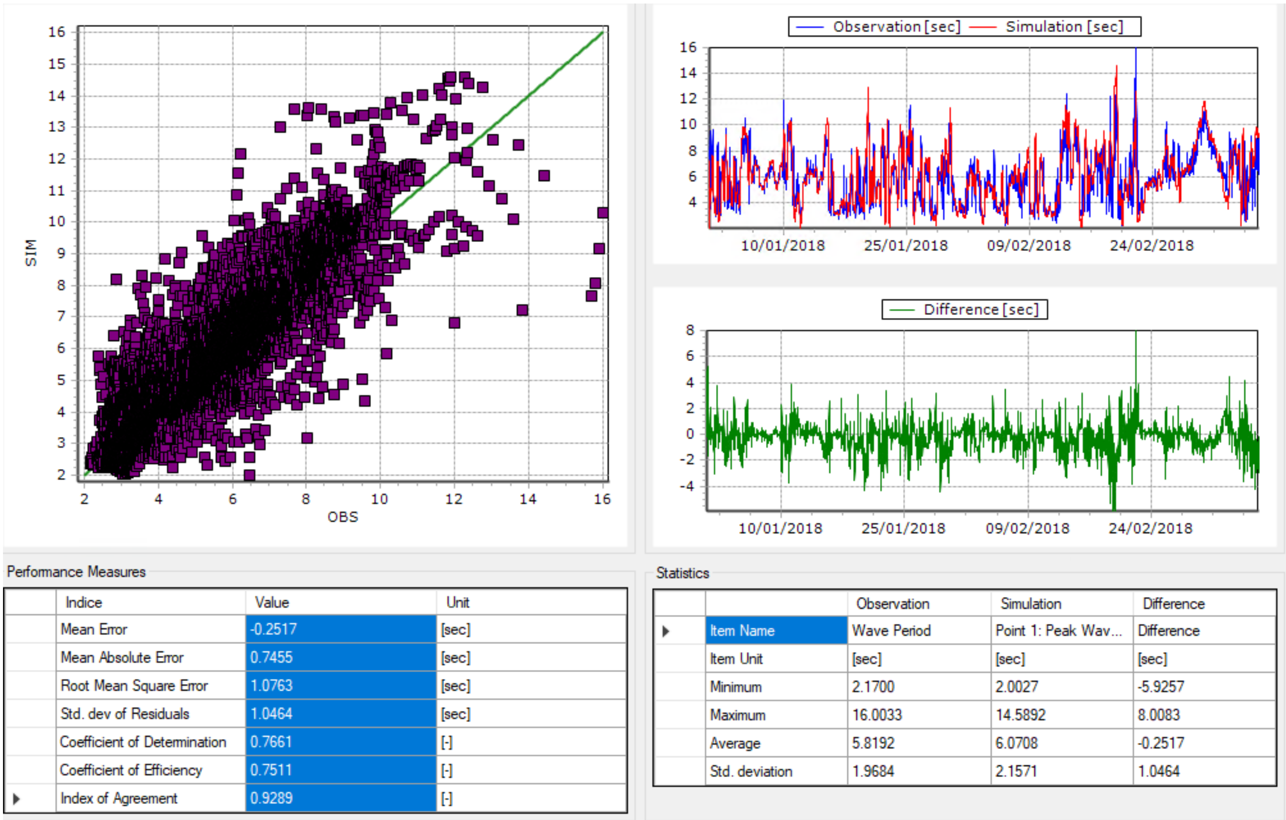


Figure A.6: Location of the licensed dredged spoil disposal site

Table 4.2: Validation statistics for significant wave height and period

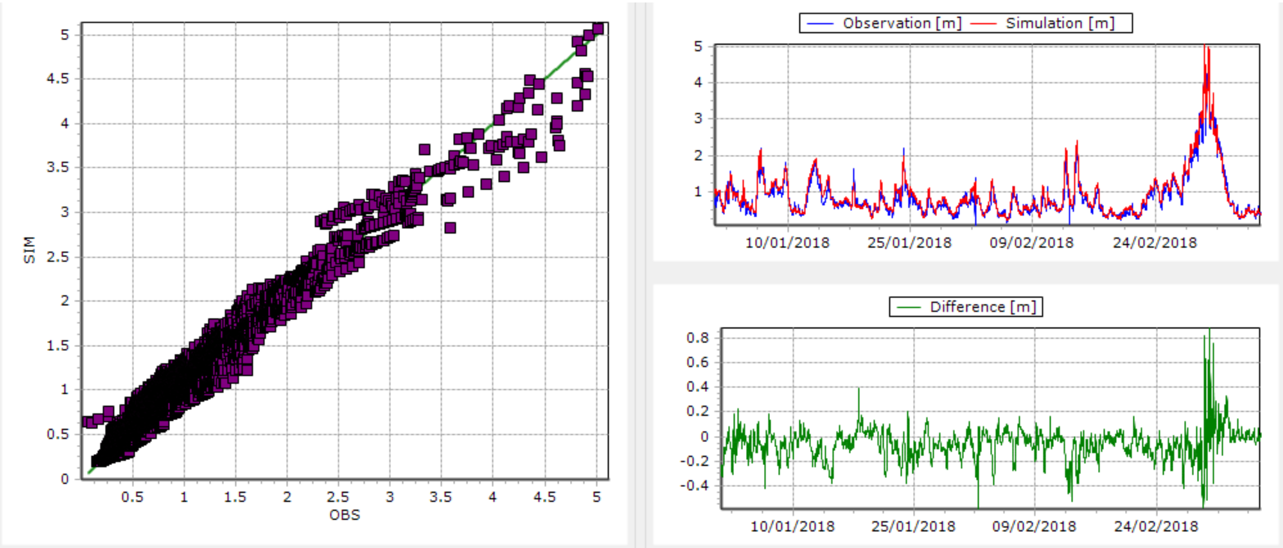
Metric		Statistic			Performance Measure		
Parameter	**Average Absolute Value Observed AAV**	**Mean Absolute Error MAE**	**Root Mean Square Error RMSE**	**Coeff of Determination R^2**	**Coeff of Efficiency E**	**Index of Agreement d_2**	**Relative Mean Absolute Error* ARMAE**
Early Event							
Wave period	5.8192	0.7455	1.0763	0.7661	0.7511	0.9289	0.13
Sig. Wave Height	0.8516	0.0972	0.1341	0.9624	0.9531	0.9882	0.12
Later Event							
Wave period	7.4180	0.7157	1.0735	0.8299	0.7500	0.9443	0.10
Sig. Wave Height	1.0912	0.1041	0.1390	0.9591	0.9539	0.9874	0.10



Indice	Value	Unit
Mean Error	-0.2517	[sec]
Mean Absolute Error	0.7455	[sec]
Root Mean Square Error	1.0763	[sec]
Std. dev of Residuals	1.0464	[sec]
Coefficient of Determination	0.7661	[-]
Coefficient of Efficiency	0.7511	[-]
Index of Agreement	0.9289	[-]

	Observation	Simulation	Difference
Item Name	Wave Period	Point 1: Peak Wav...	Difference
Item Unit	[sec]	[sec]	[sec]
Minimum	2.1700	2.0027	-5.9257
Maximum	16.0033	14.5892	8.0083
Average	5.8192	6.0708	-0.2517
Std. deviation	1.9684	2.1571	1.0464

Figure A.7: Statistical comparison of wave period between the modelled and observed for the 2018 storm event



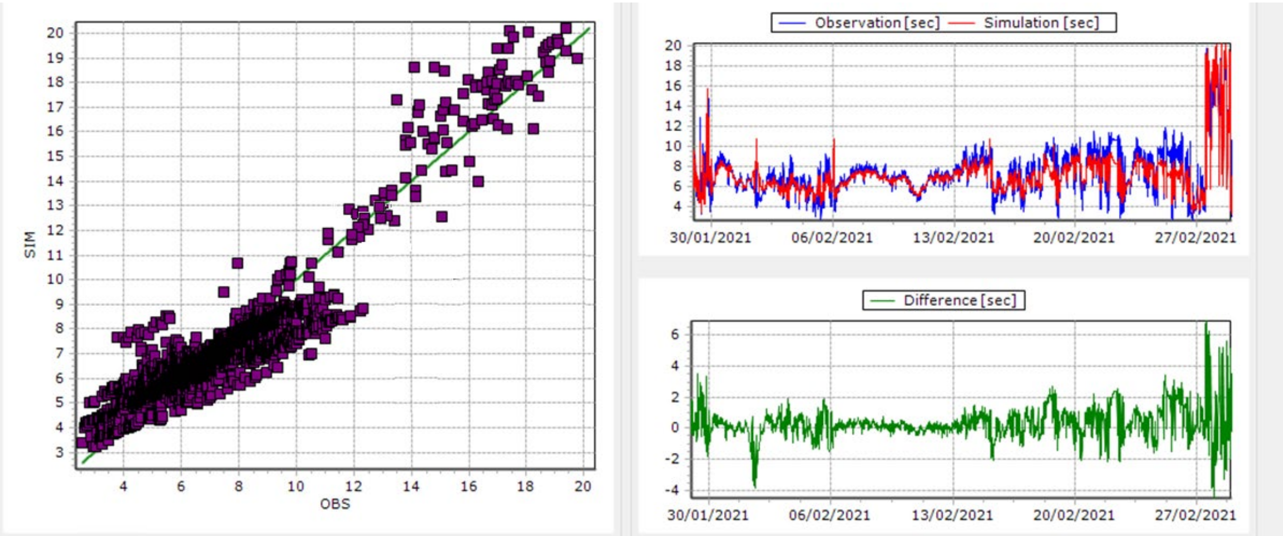
Performance Measures

Indice	Value	Unit
Mean Error	-0.0584	[m]
Mean Absolute Error	0.0972	[m]
Root Mean Square Error	0.1341	[m]
Std. dev of Residuals	0.1207	[m]
Coefficient of Determination	0.9624	[-]
Coefficient of Efficiency	0.9531	[-]
Index of Agreement	0.9882	[-]

Statistics

	Observation	Simulation	Difference
Item Name	Hs	Point 1: Sign. Wav...	Difference
Item Unit	[m]	[m]	[m]
Minimum	0.0678	0.1932	-0.5841
Maximum	5.0157	5.0671	0.8800
Average	0.8516	0.9101	-0.0584
Std. deviation	0.6202	0.6190	0.1207

Figure A.8: Statistical comparison of significant wave height between the modelled and observed for the 2018 storm event



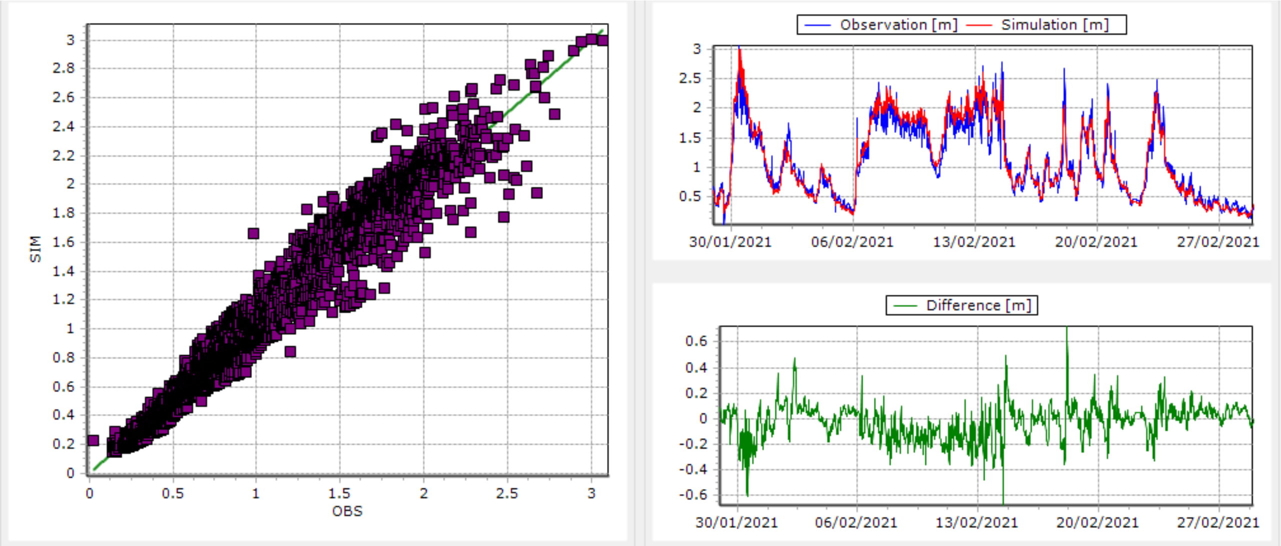
Performance Measures

Indice	Value	Unit
Mean Error	0.3091	[sec]
Mean Absolute Error	0.7157	[sec]
Root Mean Square Error	1.0735	[sec]
Std. dev of Residuals	1.0281	[sec]
Coefficient of Determination	0.8299	[-]
Coefficient of Efficiency	0.7500	[-]
Index of Agreement	0.9443	[-]

Statistics

	Observation	Simulation	Difference
Item Name	Wave Period	Point 1: Peak Wav...	Difference
Item Unit	[sec]	[sec]	[sec]
Minimum	2.5700	3.2109	-4.4773
Maximum	19.7625	20.2003	6.8736
Average	7.4180	7.1090	0.3091
Std. deviation	2.4782	2.1472	1.0281

Figure A.9: Statistical comparison of wave period between the modelled and observed for the 2021 storm event



Performance Measures

Indice	Value	Unit
Mean Error	-0.0314	[m]
Mean Absolute Error	0.1041	[m]
Root Mean Square Error	0.1390	[m]
Std. dev of Residuals	0.1354	[m]
Coefficient of Determination	0.9591	[-]
Coefficient of Efficiency	0.9539	[-]
Index of Agreement	0.9874	[-]

Statistics

	Observation	Simulation	Difference
Item Name	Hs	Point 1: Sign. Wav...	Difference
Item Unit	[m]	[m]	[m]
Minimum	0.0258	0.1457	-0.6827
Maximum	3.0675	3.0095	0.7245
Average	1.0912	1.1226	-0.0314
Std. deviation	0.5991	0.6472	0.1354

Figure A.10: Statistical comparison of significant wave height between the modelled and observed for the 2021 storm event

Appendix C

C.1 Sediment Plume Validation Modelling

ALEXANDRA BASIN REDEVELOPMENT (ABR) PROJECT

CAPITAL DREDGING PROGRAMME

Sediment Plume Validation Modelling

IBE1686 Sediment Plume
Validation Modelling
Final
9 September 2020

rpsgroup.com

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
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Approval for issue

Dr A G Barr	Alan Barr	9 September 2020

Prepared by:

RPS

Kristopher Calder BSc (Hons) MSc C.Sci MCIWEM C.WEM AMICE
Associate - Water Environment and Flood Risk Management

Elmwood House
74 Boucher Road, Belfast
Co. Antrim BT12 6RZ

T +44 2890 667 914
E kristopher.calder@rpsgroup.com

Prepared for:

Dublin Port Company

Eamon McElroy
Port Engineer

Dublin Port Centre
Alexandra Road, Dublin 1

T 01 8876000
E emcelroy@dublinport.ie

Contents

Appendices

1 INTRODUCTION

1.1 Background

Dublin Port Company (DPC) was granted a Dumping at Sea Permit (S0024-01) by the Environmental Protection Agency (EPA) on 13th September 2016 for the loading and dumping at sea of dredged material arising from capital dredging as part of the Alexandra Basin Redevelopment (ABR) Project. The permit sets out in detail the conditions under which DPC will carry out loading and dumping at sea operations and the required monitoring programmes.

Condition 4.11 of the Dumping at Sea Permit sets out the sediment plume monitoring at the dump site required to enable the horizontal and vertical extent of the sediment plume generated by the permitted dumping activity at different stages of the tide to be measured.

> *"The permit holder shall carry out sediment plume monitoring in the vicinity of the dumping activity during the first dumping campaign and thereafter as may be required by the Agency."* Condition 4.11.1
>
> *Furthermore, "The results of the sediment plume monitoring, together with the results of the hydrographic monitoring, shall be used to validate the sediment transport model presented in Appendix C: Coastal Process Modelling to the Natura Impact Statement submitted as part of the application."* Condition 4.11.3

In response to this statutory requirement, DPC commissioned Techworks Marine Ltd to undertake a comprehensive sediment plume monitoring programme and RPS to undertake a modelling validation study during the first winter dredging campaign (October 2017 to March 2018). The results of this study are presented in the Dumping at Sea Permit S0024-01 Annual Environmental Report 2017.

1.1.1 Review of Sediment Plume Monitoring undertaken during the First Winter Capital Dredging Campaign (October 2017 – March 2018) in Dublin Bay

The first winter dredging capital dredging campaign commenced on 22nd October 2017 and Techworks Marine Ltd undertook their first sediment plume monitoring survey on 27th October 2017 whilst loading and dumping activity was taking place.

The survey was undertaken in full compliance with methodology agreed with the EPA. Turbidity was measured close to the water surface using a meter attached to a small craft (RIB). The location of the turbidity transects were designed to record the full extent of the dredge plume, beyond the footprint of the dump site.

The recorded turbidity levels at 1m below the surface did not differ within the dumping area and in adjacent areas outside the dumping site or at a background site. The results therefore showed that the released dredge spoil did not create a significant dredge plume within the surface waters. This suggests that the dredged material fell rapidly towards the seabed.

All loading and dumping activity during the first winter capital dredging season was confined to one section of the navigation channel and fairway within Dublin Bay (AER 2017, Appendix 2.2). The dredged material is predominately fine sand throughout the dredge area so the behaviour of any sediment plume arising from the dumping operations was expected to be similar for all loading and dumping trips.

Based on the results of the first sediment plume monitoring survey, it was clear that that the monitoring programme needed to be adapted in order to gain a better understanding of the dispersion and fate of marine sediments during dumping operations.

Techworks Marine Ltd therefore designed an adapted dredge plume monitoring programme that measured in-situ turbidity depth profiles at nine locations in the vicinity of the dump site and at a control site. A survey based on this technique took place on 4th December 2017 during loading and dumping operations.

Again, the recorded turbidity levels were low and no significant differentiation could be made between turbidity levels recorded at the dump site and at the background, control site. Techworks Marine Ltd concluded that sediment appears to settle rapidly and proximally to the release point within the dumping site.

At this point, RPS undertook model simulations of the dredge trips that coincided with the dredge plume monitoring surveys. The results are reported in the Annual Environmental Report (AER) 2017 (pages 75 – 84). The model simulations showed that the sediment was predicted to settle rapidly and proximally to the release point within the dumping site in agreement with the survey results.

Techworks Marine Ltd determined that there was no further scientific value in undertaking further plume monitoring surveys during the first winter capital dredging season. This was because that the dredging operations were confined to one section of the navigation channel and fairway within Dublin Bay and the dredged material was predominately a fine sand throughout the dredge area. As such, the behaviour of any sediment plume arising from the dumping operations was expected to be similar for all loading and dumping trips.

1.1.1.1 Conclusions

The following conclusions can be drawn from the review of Sediment Plume Monitoring undertaken during the First Winter Capital Dredging Campaign (October 2017 – March 2018):

- A sediment plume monitoring programme was established in full compliance to the monitoring protocols agreed with the EPA.
- The results of the first sediment plume monitoring survey showed that the released dredge spoil did not create a significant dredge plume within the surface waters. This suggests that the dredged material fell rapidly towards the seabed.
- Based on the results of the first sediment plume monitoring survey, it was clear that that the monitoring programme needed to be adapted in order to gain a better understanding of the dispersion and fate of marine sediments during dumping operations.
- An adapted dredge plume monitoring programme was developed which measured in-situ turbidity depth profiles at nine locations in the vicinity of the dump site and at a control site. Again, the recorded turbidity levels were low and no significant differentiation could be made between turbidity levels recorded at the dump site and at the background, control site. The sediments appear to settle rapidly and proximally to the release point within the dumping site.
- Model simulations of the dredge trips that coincided with the dredge plume monitoring surveys showed that the sediment was predicted to settle rapidly and proximally to the release point within the dumping site in agreement with the survey results.
- There was no further scientific value in undertaking further plume monitoring surveys during the first winter capital dredging season, given the dredging operations were confined to one section of the navigation channel and fairway within Dublin Bay. In addition, the dredged material was predominately a fine sand throughout the dredge area so the behaviour of any sediment plume arising from the dumping operations was expected to be similar for all loading and dumping trips.

1.1.2 Change in Scope – Proposed Sediment Plume Monitoring within the inner Liffey channel

Schedule B.2.4 of the Dumping at Sea Permit requires the Permit Holder to undertake sediment plume monitoring during the first dumping campaign and thereafter as may be required by the Agency.

The AER 2017 sets out the results of the sediment plume monitoring undertaken during the first dumping campaign. The results, as summarised above, demonstrate that for loading and dumping activity within Dublin Bay, sediments settle rapidly and proximally to the release point within the dumping site. This is consistent with the findings of computational modelling (Section 10.6 of the AER 2017).

Based on the results of the sediment plume monitoring undertaken during the first dumping campaign, DPC believes that further sediment plume monitoring for loading and dumping of sediments sourced from the navigation channel and fairway within Dublin Bay would be of no additional scientific value.

DPC however proposed that further sediment plume monitoring and model validation would be undertaken when dredging commenced within the inner Liffey channel. The material to be dredged in this area contains a highly silt content and model simulations showed that the silts where expected to be dispersive in nature during dumping operations.

In accordance with Condition 4.4 of Dumping at Sea Permit S0024-01, DPC proposed this amendment to the scope of the sediment plume monitoring requirements to the EPA, which was subsequently accepted.

1.1.3 Sediment Plume Monitoring undertaken during the Third Winter Capital Dredging Campaign (October 2019 – March 2020) within the inner Liffey channel

Capital dredging within the inner Liffey channel (Dublin Harbour) took place in February - March 2020 during third winter dredging capital dredging campaign (October 2019 – March 2020).

DPC appointed Hydromaster Ltd to undertake a comprehensive sediment plume monitoring survey during the dumping operations (March 2020). Hydromaster's monitoring report is presented separately (Hydromaster, 2020).

DPC appointed RPS to undertake a modelling validation study using the results of the sediment plume monitoring survey undertaken by Hydromaster.

This technical report describes the numerical modelling programme undertaken using results of the sediment plume monitoring, together with the results of hydrographic monitoring, to validate the sediment transport model presented in Appendix C: Coastal Process Modelling to the Natura Impact Statement submitted as part of the application.

The location of the licenced offshore dump site at the approaches to Dublin Bay, west of the Burford Bank is where permitted dumping activities took place is presented in Figure 1.1.

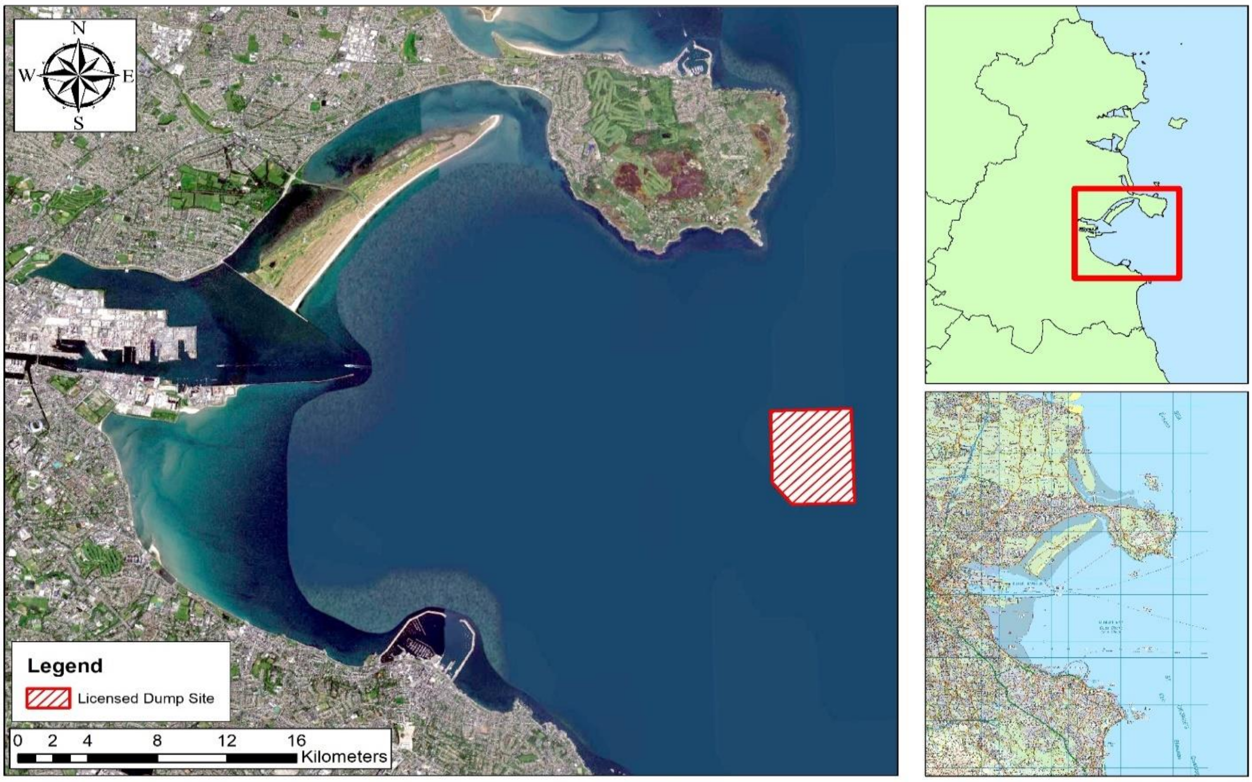


Figure 1.1: Location of the licenced offshore dump site at the approaches to Dublin Bay, west of the Burford Bank

2 OVERVIEW OF THE DUMPING AT SEA CAMPAIGN

2.1 Dredging programme

Based on detailed loading and dumping logs provided by the dredging contractor, the capital dredging campaign in March 2020 comprised 210 individual trips between 09/03/2020 – 28/03/2020 and involved the loading and dumping of 218,686 Total Dry Solids. The quantity of material disposed of per trip averaged 1,041T TDS (*n* =210, *SD* =126 TDS). No overspill of dredged material was permitted within the inner Liffey channel.

Owing to the turbulent nature of the dredging process it was not possible to d characterise and quantity the composition of dredge material during each trip. However, it was reported that the dredge material was generally dominated by silt and sand material with a smaller fraction of gravel.

2.2 Equipment

The dredging and disposal activities under Dumping at Sea Permit S0024-01 were undertaken by Irish Dredging a subsidiary of Royal Boskalis Westminster N.V. The vessel used was the purpose built 4,500m^3 trailing suction hopper dredger “Shoalway” which is illustrated in Figure 2.1 below. This 90m vessel was specifically designed for dredging operations within harbour environments.

Figure 2.1: The trailing suction hopper dredger “*Shoalway”* used for the March 2020 capital dredging campaign within the inner Liffey channel

3 OVERVIEW OF SEDIMENT PLUME MONITORING PROGRAMME

DPC commissioned Hydromaster Ltd to undertake a detailed sediment plume monitoring programme to gather robust data, representative of a range of tidal conditions, which could be used to validate computational plume simulations of the dumping activity. A total of 20 trips were monitored by Hydromaster as summarised in Table 3.1.

Table 3.1: Summary of the 20 dumping trips monitored by Hydromaster between 14th March and 27th March 2020

Date	Dump Trip	Start of Dump Activity	Dump Duration (min)	Turbidity Survey data available?	Corresponding detailed dredge log data available?
14/03/2020	231	17:44:42	11	✓	✓
16/03/2020	254	11:07:52	17	Mid layer data only	✓
17/03/2020	266	09:18:20	13	✓	✓
	267	10:57:09	16	✓	✓
	268	12:40:12	17	✓	✓
18/03/2020	280	08:42:53	15	✓	✓
	281	10:22:01	13	Surface layer data only	✓
	282	12:16:22	14	Surface layer data only	✓
	283	13:41:42	19	✓	✓
19/03/2020	284	08:42:05	17	✓	✗
	286	11:51:01	18	✓	✗
	287	14:12:02	14	✓	✗
	288	16:29:44	19	✓	✗
25/03/2020	356	10:36:15	11	✓	✗
	357	12:08:52	14	✓	✗
	360	17:46:03	17	✓	✗
27/03/2020	373	15:08:51	24	✓	✓
	374	17:02:36	26	✓	✓
	375	19:03:41	14	✓	✓

Note: Only the total dredge quantity per trip was available for 19th and 25th March 2020.

It should be noted that the turbidity measurements show how cloudy/clear the seawater is and is measured in Nephelometric Turbidity Units (NTU). An assessment of sediment samples taken from the inner Liffey channel and Dublin Bay identified a clear relationship between the Total Suspended Solids (TSS) within the seawater and Turbidity (NTU) (RPS, 2018). As shown in Figure 3.1, this assessment found that seawater dominated by silts and sands had a NTU to TSS conversion factor of *c.* 2.5 and 1.5 respectively.

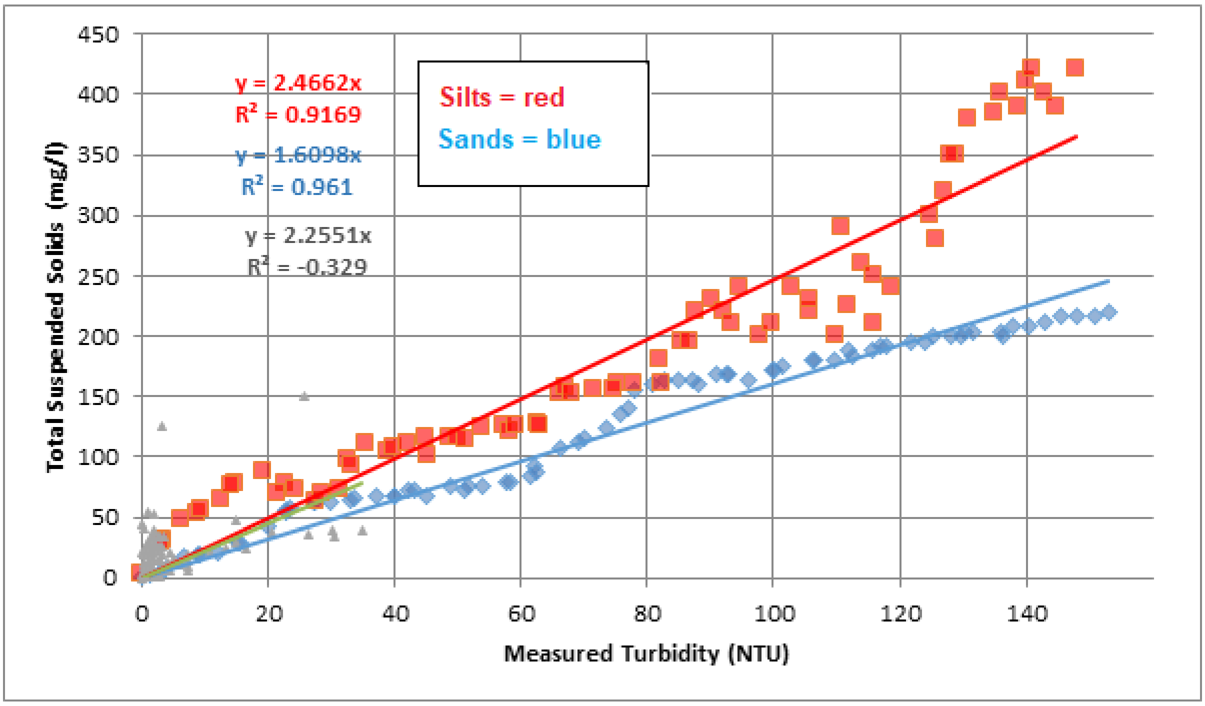


Figure 3.1: Relationship between TSS and NTUs for sand and silt dominated seawater within the Inner Liffey Channel and Dublin Bay (RPS, 2018)

3.1 Measuring Turbidity

Hydromaster utilised a vessel equipped with two turbidity monitors to track sediment plumes arising from the dumping of dredged spoil from the inner Liffey channel.

The survey vessel tracked back and forth across the plume until the turbidity monitors indicated background levels. This enabled the vessel to record spatial and temporally varying data across the plume envelope and produce turbidity tracks similar to the one presented in Figure 3.2 overleaf. The colour scale represents a “heatmap” with highest turbidity values (plume) shown by red and lowest turbidity values shown by blue.

Turbidity data was recorded at the surface and mid-point of the water column for most of the events summarised in Table 3.1 except for event 254 during which an instrumentation failure meant data could only be recorded at the mid-point. No mid layer data was recorded for events 281 and 285 due to a similar issue. Using this approach it was possible to produce plots to show the range of turbidity values between the surface and mid-points of the water column as shown in Figure 3.3.

It is important to note that each data point within this plot represents a turbidity measurement at a different location and at a different moment of time. The data is however very useful in showing the movement and rate of dispersion of the sediment plume.

This data was supported by turbidity measurements recorded at four fixed monitoring buoy locations as shown in Figure 3.4 where turbidity was recorded close to the surface, at mid-depth and close to the seabed.

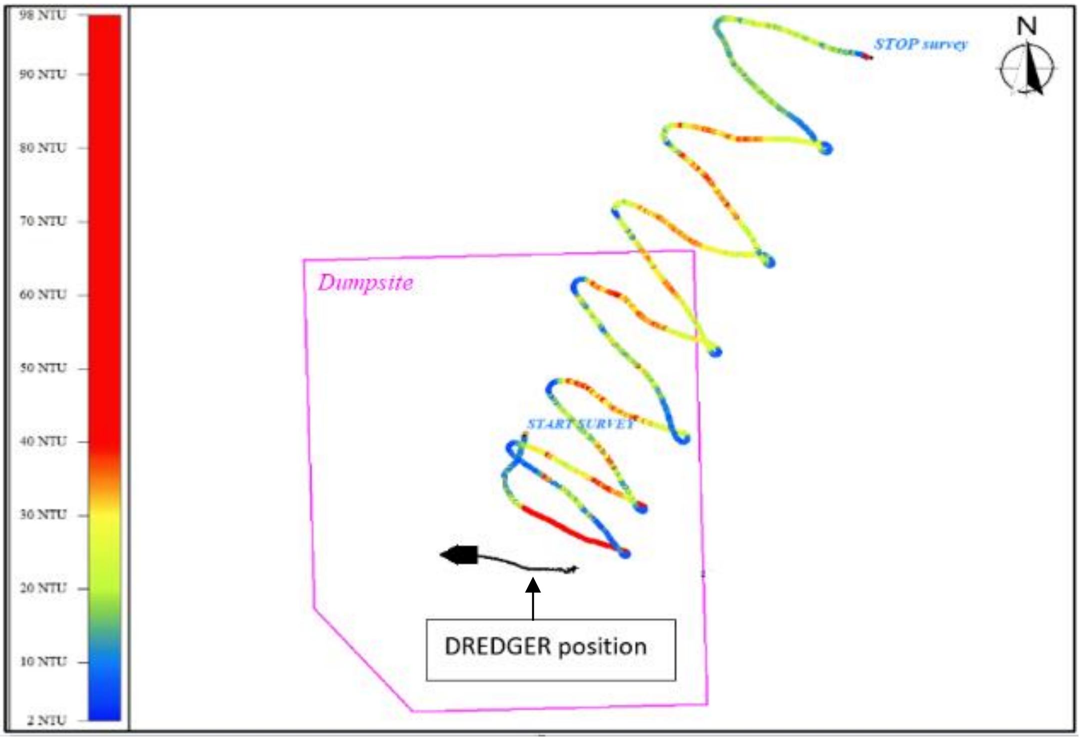


Figure 3.2: Example of a plume survey track with turbidity displayed as NTUs

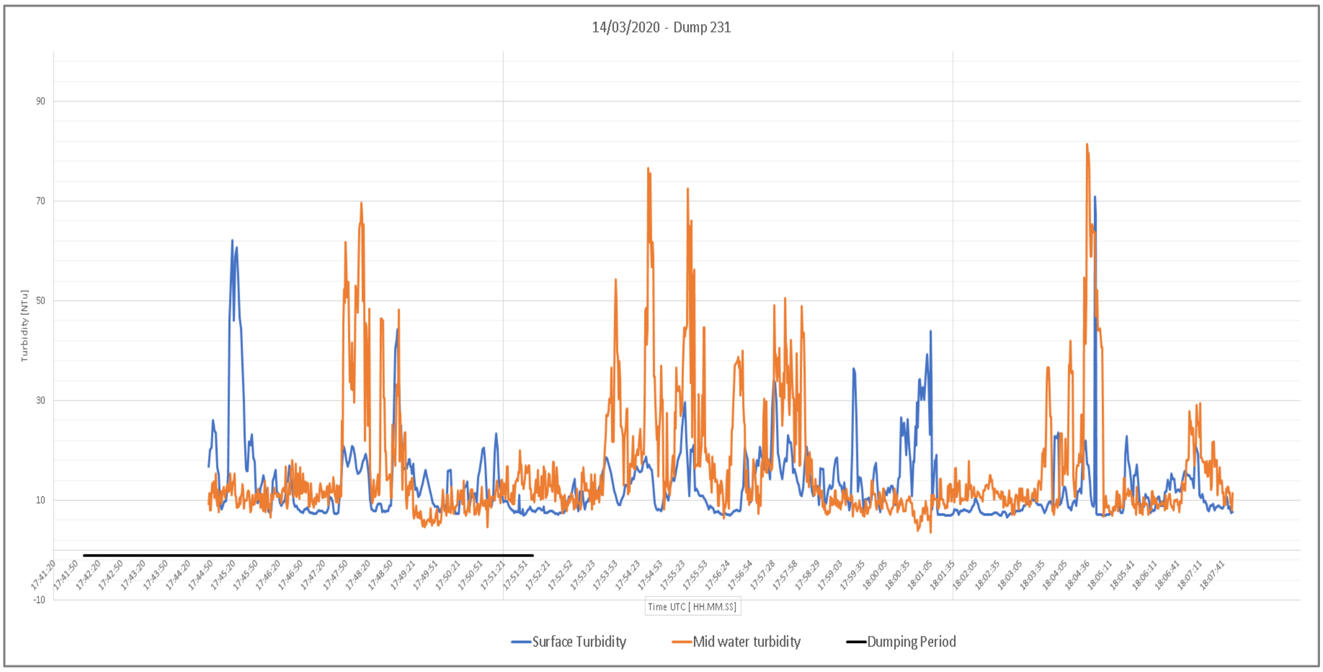


Figure 3.3: Example turbidity readings at the surface and mid-point of the water column during Dump Trip 231

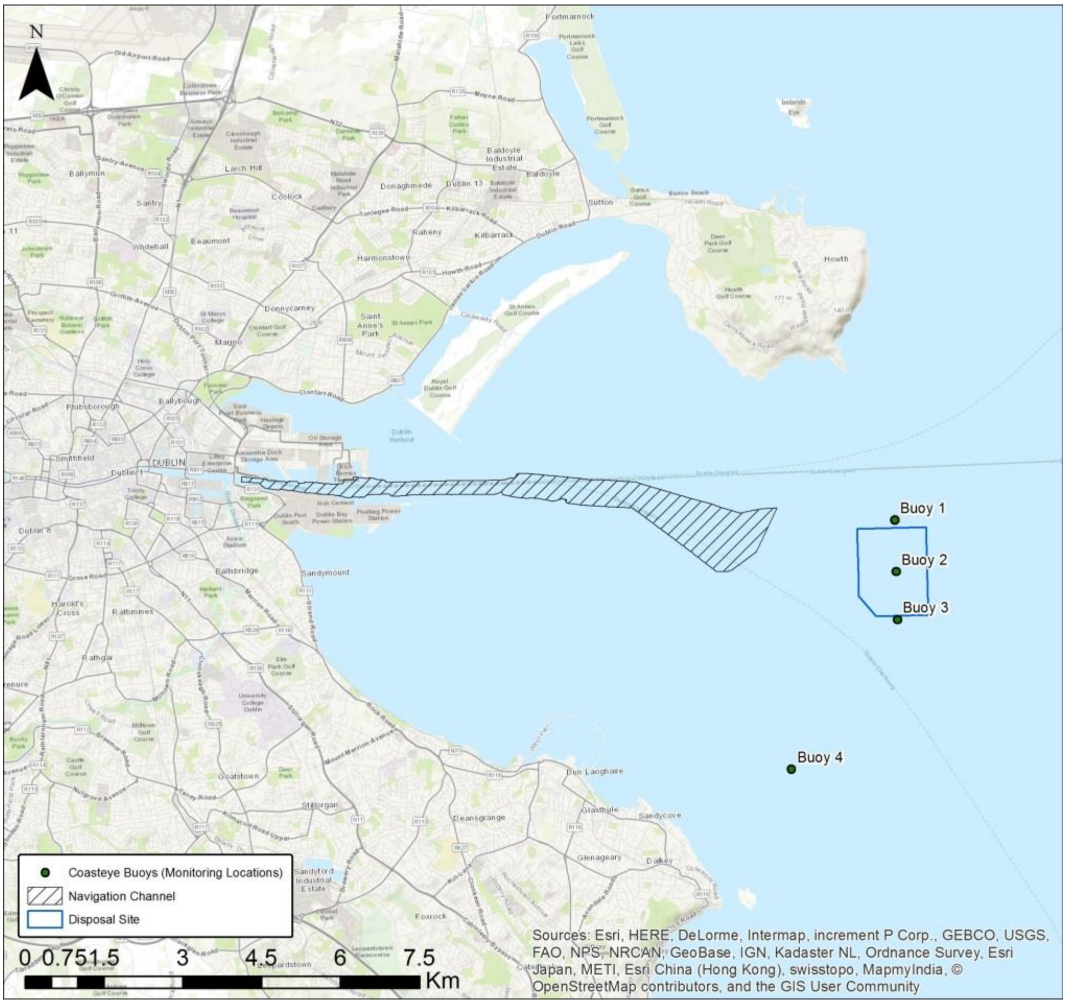


Figure 3-4: Locations of the Monitoring Buoys at the Dump Site

4 COMPUTATIONAL MODELS

4.1 Modelling Overview

RPS used the MIKE 21 hydrodynamic numerical modelling software package developed by DHI, to undertake the sediment plume simulations presented in Appendix C: Coastal Process Modelling to the Natura Impact Statement submitted as part of the application. The same models were used in the model validation process.

The MIKE system is a state of the art, industry standard, modelling system, based on a flexible mesh approach. This software was developed for applications within oceanographic, coastal and estuarine environments.

A brief synopsis of the MIKE system and modules used for this assessment is outlined below:

- **MIKE 21 FM system** - Using this flexible mesh modelling system, it was possible to simulate the mutual interaction between currents, waves and sediment transport by dynamically coupling the relevant modules in two dimensions.
    - **The Hydrodynamic (HD) module** - This module is capable of simulating water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions. The HD Module is the basic computational component of the MIKE 21 Model system providing the hydrodynamic basis for the Sediment Transport and Spectral Wave modules. The Hydrodynamic module solves the two-dimensional incompressible Reynolds averaged Navier-Stokes equations subject to the assumptions of Boussinesq and of hydrostatic pressure. Thus the module consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain both Cartesian and spherical coordinates can be used.
    - **The Sediment Transport module** - The Sediment Transport Module simulates the erosion, transport, settling and deposition of cohesive sediment in marine and estuarine environments and includes key physical processes such as forcing by waves, flocculation and sliding. The module can be used to assess the impact of marine developments on erosion and sedimentation patterns by including common structures such as jetties, piles or dikes. Point sources can also be introduced to represent localised increases in current flows as a result of outfalls or ship movements etc.

4.2 Computational Models and Data Sources

RPS' model of Dublin Bay was created using flexible mesh technology to provide detailed information on the coastal processes around the licenced dump site and Dublin Port as well as the wider Dublin Bay area. The model uses mesh sizes varying from 250,000m^2 (equivalent to 500m x 500m squares) at the outer boundary of the model down to a very fine 225 m^2 (equivalent to 15m x 15m squares) in Dublin Port and around the licenced dump site. The extent, mesh structure and bathymetry of this model is presented in Figure 4.1.

The bathymetry of this model was developed using data gathered from hydrographic surveys of Dublin Port, the Tolka estuary and the dump site since 2017 to present. This resource was supplemented by data from the Irish National Seabed Survey, INFOMAR and other local surveys collated by RPS for the Irish Coastal Protection Strategy Study (RPS, 2003).

Tidal boundaries for the Dublin Bay model shown in Figure 4.1 were taken from the Irish Coastal Protection Strategy Study (ICPSS) tidal surge mode. This mode was developed using flexible mesh technology with the mesh size varying from *c.* 24km along the offshore Atlantic boundary to *c.* 200m around the Irish coastline. This validated model is run three times daily on behalf of the Office of Public Works (OPW) to provide detailed tidal information around the coast of Ireland. The extent and bathymetry of this model is illustrated in Figure 4.2

Boundary conditions used to represent the mean annual river flows for the Liffey, Dodder and Tolka were set at 15.6, 2.3 and 1.4m^3/s respectively.

It should that the same computational models used to support the environmental assessment of the Alexandra Basin Redevelopment project (RPS, 2014) were used for this technical assessment. A previous calibration and validation exercise that utilised recorded data from throughout Dublin Bay concluded that the Dublin Bay model performed very well and provided a very good representation of the coastal processes in the Dublin Port and Dublin Bay.

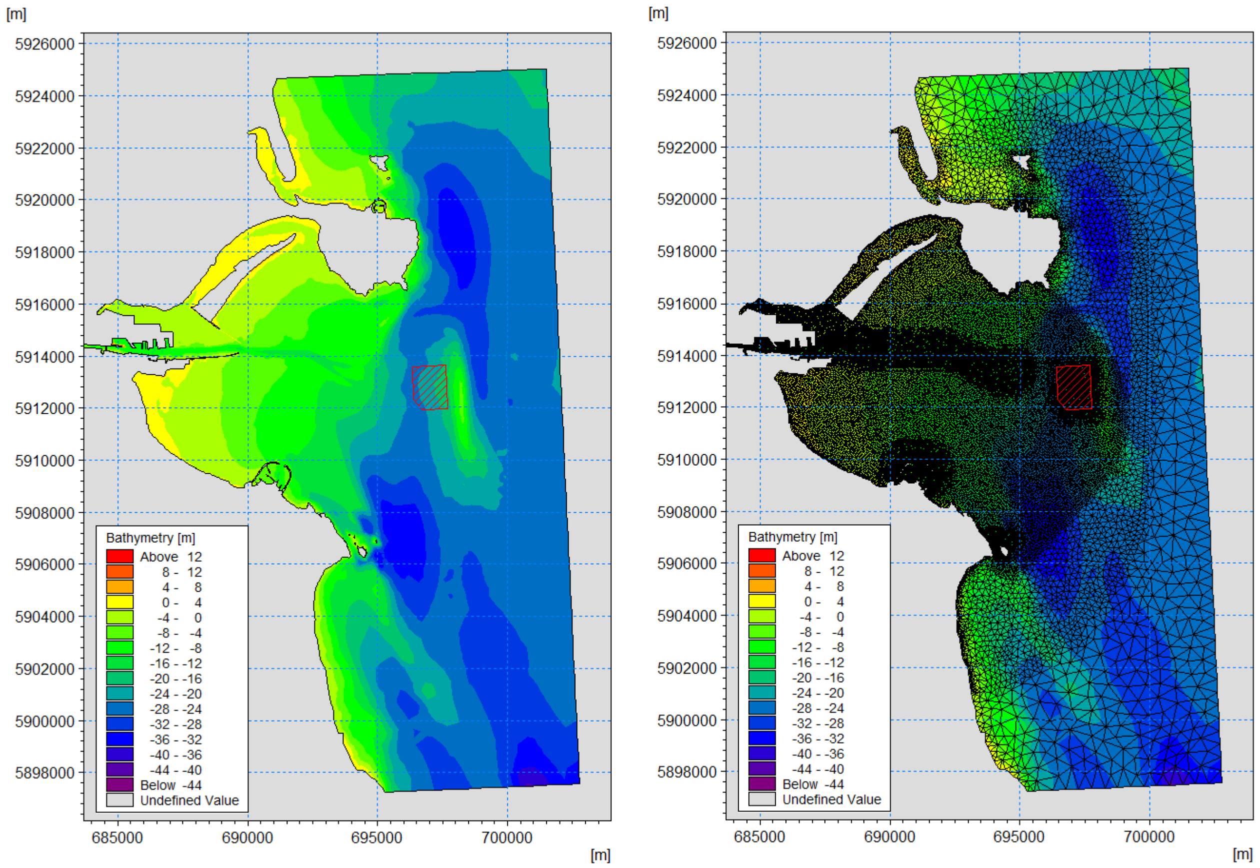


Figure 4.1: Extent and bathymetry (left) and mesh structure (right) of the Dublin Bay model. Location of the licenced dump site shown by red hatch area.

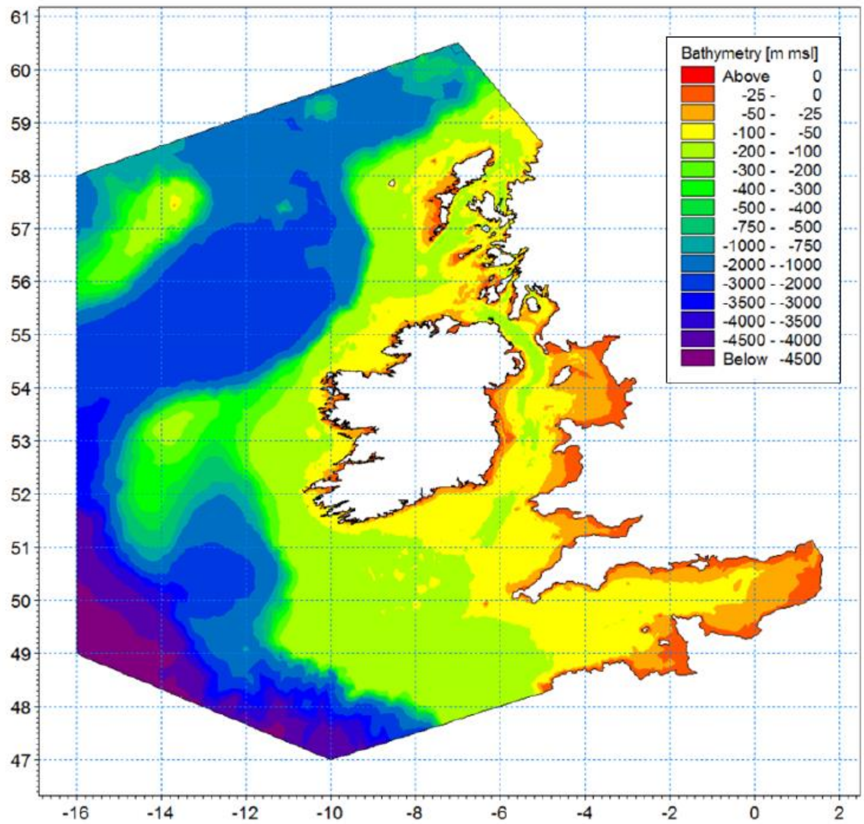


Figure 4.2: Extent and bathymetry of Irish Seas Tidal and Storm Surge model

4.3 Characterisation of Dumping Material

Simulations were undertaken to determine the concentration and distribution of sediment lost to the water column during the dumping events at the licenced offshore dump site. As described in the following Section, the sediment material was first characterised by a number of different mixtures with different sand and silt fractions. Upon identification of the most suitable mixture type and composition, these parameters were used to simulation all 210 dredging trip undertaken in March 2020. It should be noted that all dumping events were assessed using a single simulation so that sediment plumes from previous dumping events were fully accounted for.

The coupled MIKE 21 sediment transport model was used to simulate the fate of the silt released from the barges over the dump site by moving a sediment source along the track that the barge would take as it transversed the dump site area during the disposal operation. The model then simulated the dispersion, settlement and re-erosion of each fraction of the dredged material in response to the tidal currents throughout the model area.

The spill rate and the dump co-ordinates for each dumping event was specified using information from detailed dredge logs provided by the dredging contractor. Given the duration of the dredging and disposal campaign, simulations were run for using a range of spring and neap tidal conditions. These models also included for the effect of wind driven currents.

An example of the dredge track used to specify the location of the sediment source in the models is presented in Figure 4.3 below.

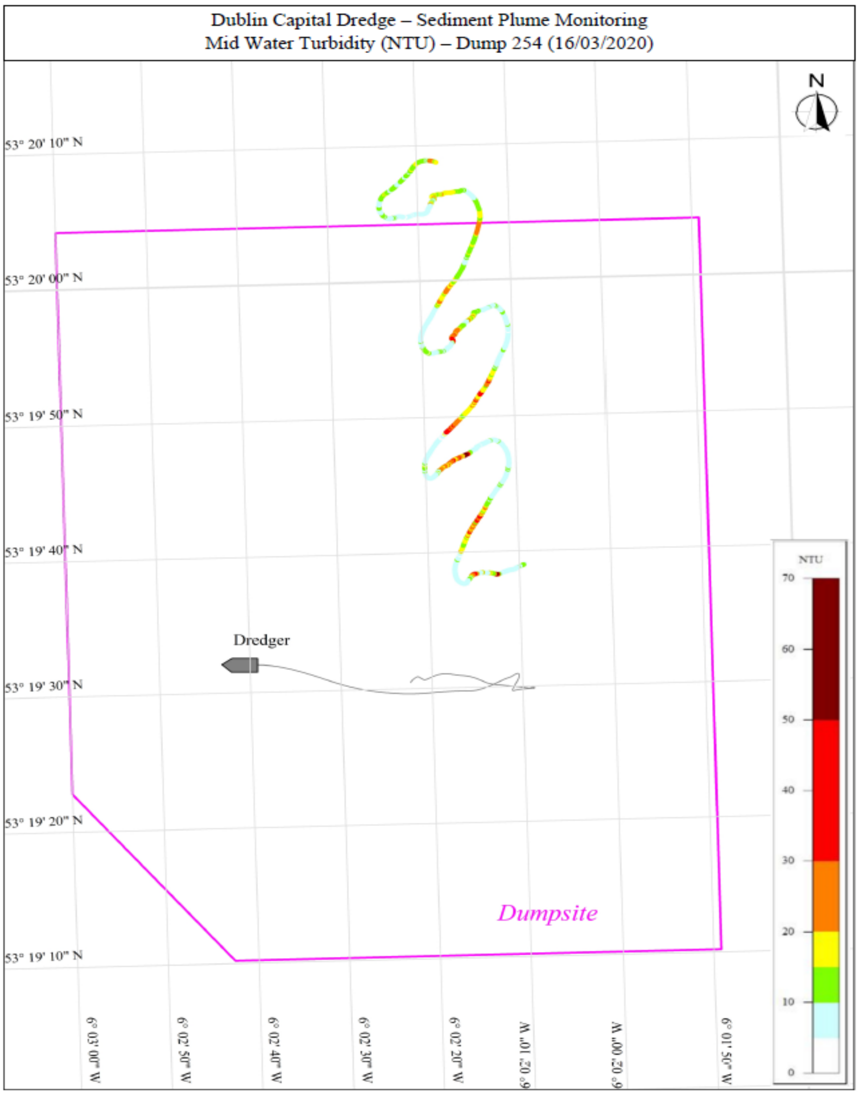


Figure 4.3: Example of the dredge track used to specify the coordinates of the sediment source in the numerical model runs

5 REVIEW OF PARAMETERS USED FOR THE ABR ENVIRONMENTAL ASSESSMENT

The numerical modelling work undertaken in support of the Alexandra Basin Redevelopment (ABR) Project (RPS, 2014) specified sediment material as being characterised by three discrete fractions with mean diameters of 200µm, 20µm and 3µm with each fraction constituting 1/3 of the total volume dredge material (Mixture 1 in Figure 5.1 below). This specification was based on Particle Size Distributions (PSDs) of sediment samples collected from the Harbour area (RPS, 2014).

In order to validate this parameter RPS ran a series of sediment plume models for dump event 231 using a range of different sediment material characteristics. Dump event 231 was chosen for this analyses as it was the first event that Hydromaster collected detailed survey data for. The four different mixture types used for this assessment are summarised in Figure 5.1 and were comprised of various fine sand to fine silt fractions.

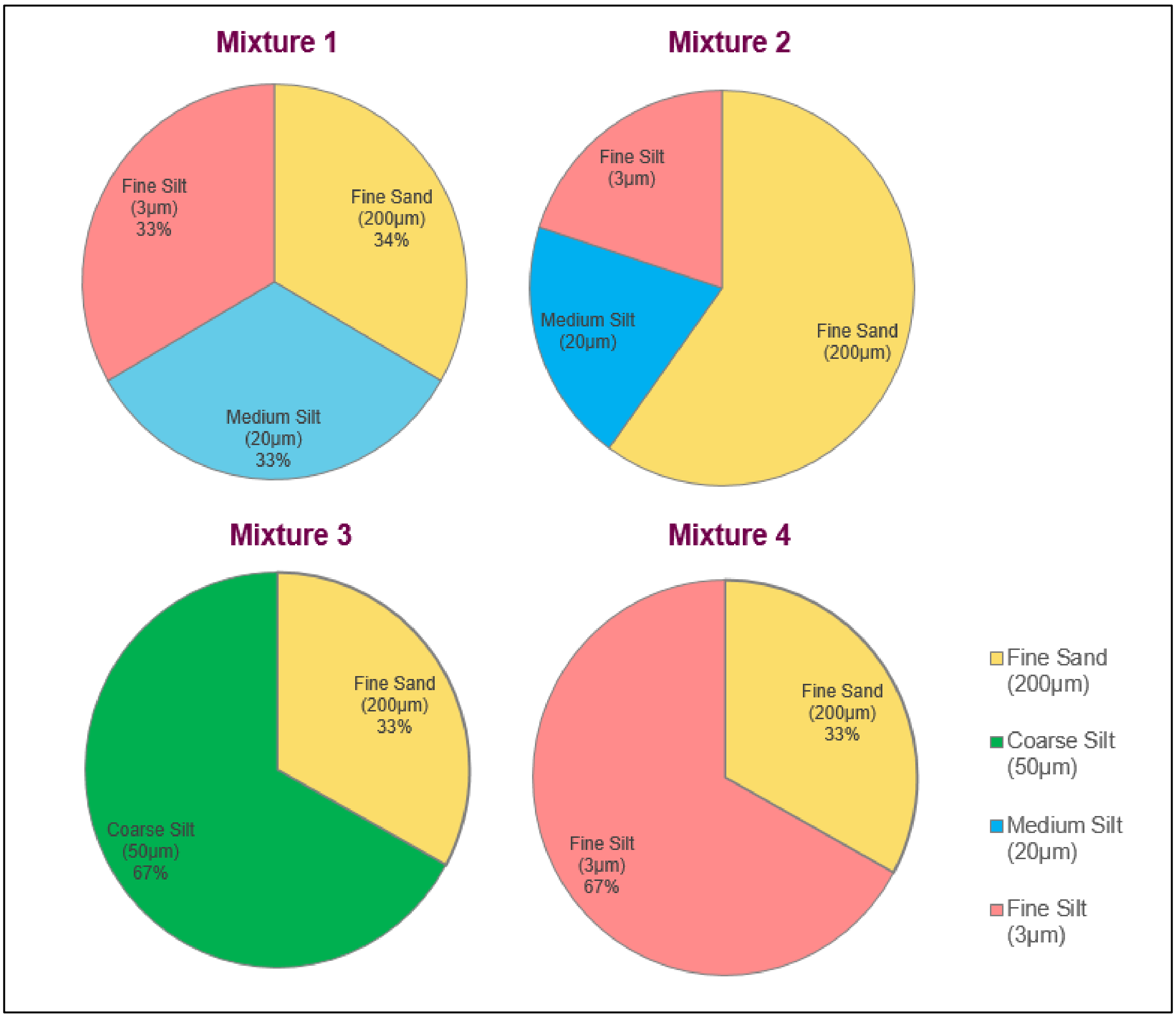


Figure 5.1: Composition of sediment mixtures used to represent the dredge material dumped at the dump site

The output from these simulations are presented in Figure 5.2 to Figure 5.5 for Mixtures 1 – 4 respectively. As demonstrated by these plots, the sediment plumes generated by these mixtures correspond well to recorded data. However, as summarised in Table 5.1 Mixture 1 was found to agree best with recorded turbidity levels with simulated turbidity levels falling within the recorded surface and mid-point measurements 79% of the time.

Based on this information it can be concluded that the sediment was specified correctly in Appendix C: Coastal Process Modelling to the Natura Impact Statement submitted as part of the application. All subsequent model simulations in this study were therefore undertaken using sediment parameters reflective of mixture 1.

Table 5.1: Summary of sediment mixtures and % agreement with actual turbidity levels recorded during dump event 231

Sediment	Composition [%]			
	Mixture 1	Mixture 2	Mixture 3	Mixture 4
Fine Sand (200µm)	33	60	33	33
Coarse Silt (50µm)	n/a	n/a	67	n/a
Medium Silt (20µm)	33	20	n/a	n/a
Fine Silt (3µm)	33	20	n/a	67
Agreement with recorded Turbidity levels during event 231 [%]	79.22	61.66	63.15	68.47

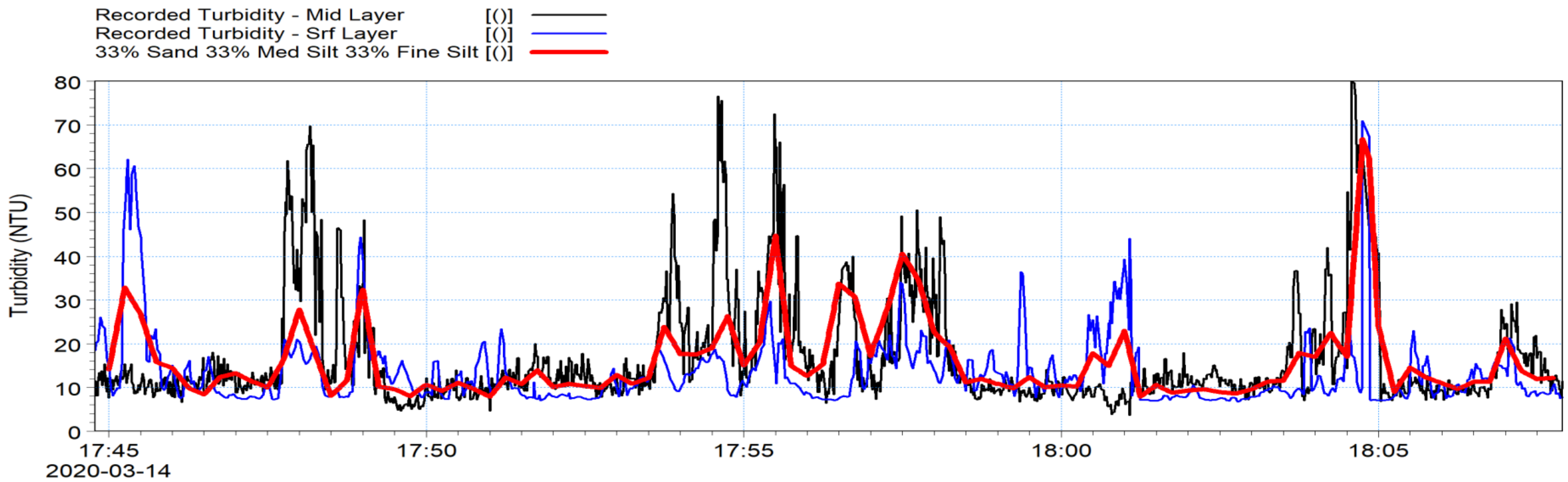


Figure 5.2: Comparison of recorded and simulated turbidity levels during dump event 231 – Mixture 1 (33% fine sand; 33% medium silt; 33% fine silt)

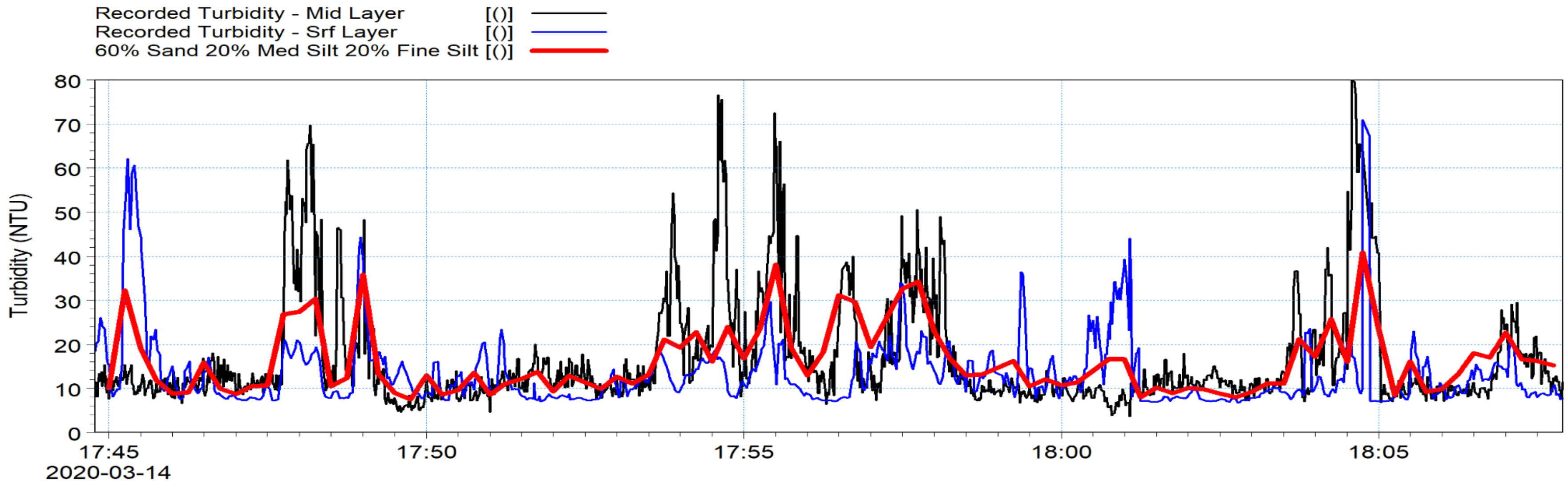


Figure 5.3: Comparison of recorded and simulated turbidity levels during dump event 231 – Mixture 2 (60% fine sand; 20% medium silt; 20% fine silt)

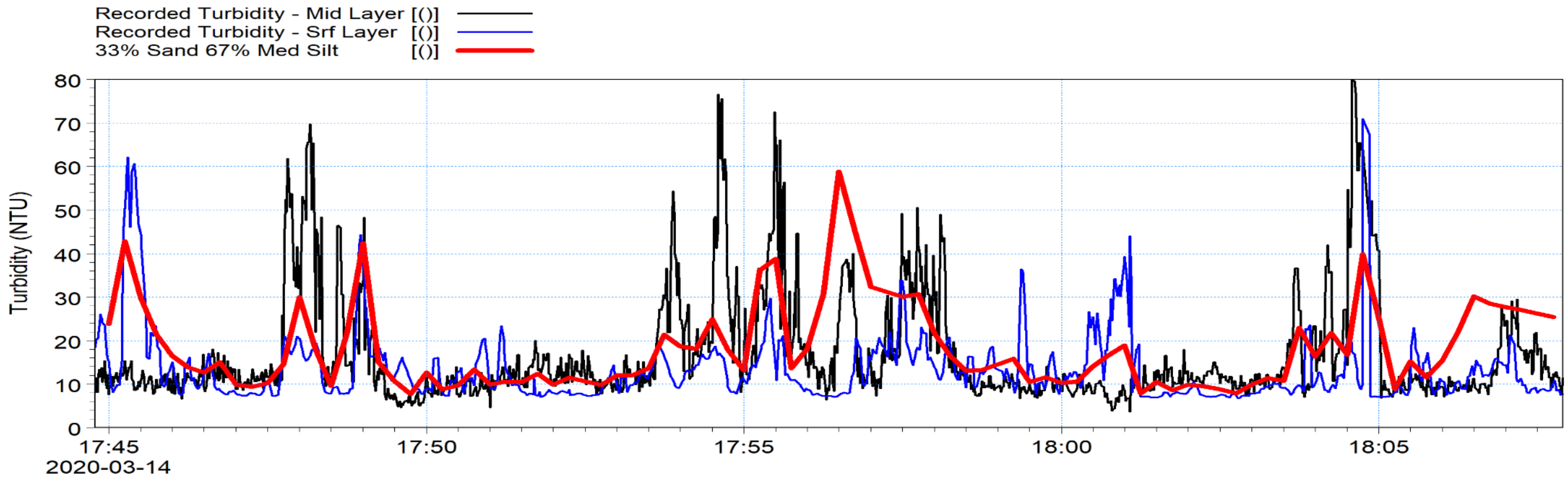


Figure 5.4: Comparison of recorded and simulated turbidity levels during dump event 231 – Mixture 3 (33% fine sand; 67% medium silt)

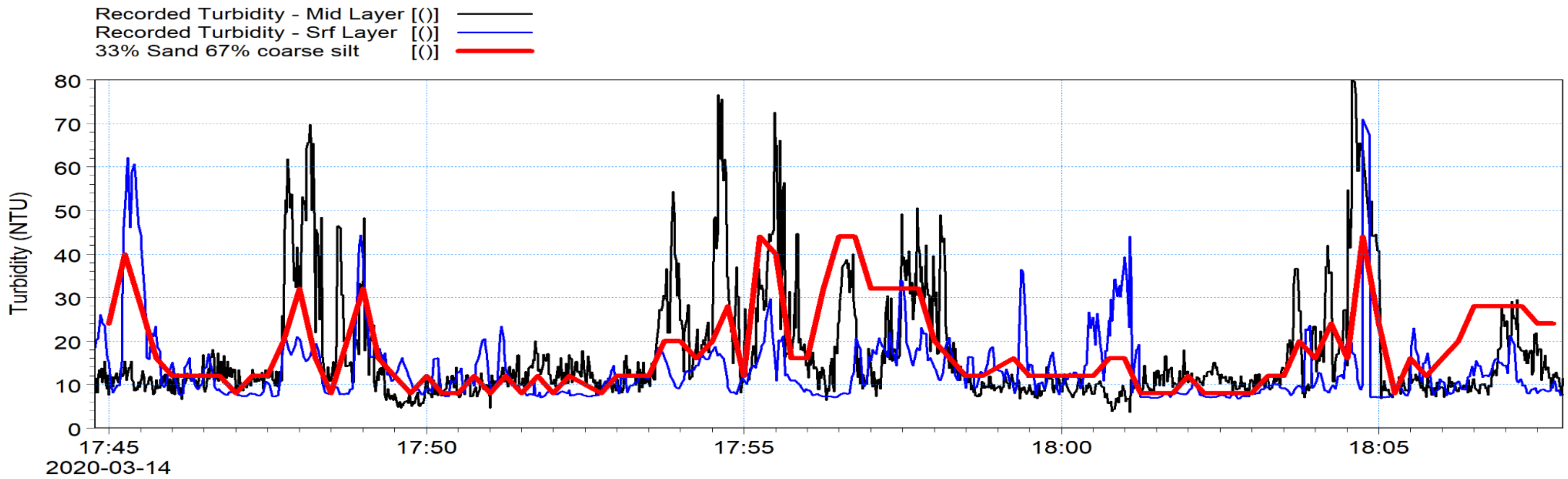


Figure 5.5: Comparison of recorded and simulated turbidity levels during dump event 231 – Mixture 4 (33% fine sand; 67% coarse silt)

6 OUTPUT FROM SEDIMENT PLUME MODELLING

Having determined suitable specifications for the sediment material (see Section 5), RPS produced a series of figures that compares simulated and recorded turbidity levels at the Dump Site.

- To determine the spatial accuracy of the model used, each figure illustrates the extent and concentration of the sediment plume for one time-step relative to the recorded survey tracks.
- The temporal accuracy of the model is demonstrated by time series plots that compare 2D depth averaged simulated turbidity concentration levels with recorded data. These plots remove the spatial element of the data so that a direct comparison of concentrations can be easily made.

As it was not practical to produce a sediment plume plot for every time-step and dump event, RPS instead provided time-series plots for each dump event for which there was suitable data (see Table 3.1 in Section 3).

In total, this equated to 12 individual events across a range of typical spring and neap tidal conditions. Environmental conditions were also varying with dumping events regularly occurring during windy spells with notable wave action from different directions. The results which are presented in Appendix A demonstrate that the computational models accurately simulate the temporal and spatial dispersion of sediment plumes during the dumping activities to a very high degree of accuracy.

6.1 Sediment Plume Envelopes

RPS has produced sediment plume plots for a number of representative dump events presented in Table 6.1 below.

The ***spatial accuracy*** of the numerical model is demonstrated by comparing the spatial extent of the simulated sediment plumes illustrated in the 2D plots and survey tracks in Figure 6.1 to Figure 6.8**.** It will be seen that the general plume envelope size and direction of transport is very similar to the corresponding survey track.

A comprehensive demonstration of the ***temporal accuracy*** of the numerical models is provided by means of time-series plots that compare simulated and recorded data in Figure 6.1 to Figure 6.8**.** These plots show that the 2D depth averaged simulated turbidity concentration usually falls within the envelope of values recorded at the surface and mid water column points.

Importantly, the model accurately represents the dredge plumes from the time of initial release to the point whereby the sediment plume reduces to below background levels, i.e. becomes fully dispersed.

Table 6.1: Index of sediment plume plots across a range of typical tidal conditions

Tidal Phase	Dump #	Figure No.	Time after initial release
Mid-ebb	**231**	Figure 6.1	**19min**
Low water	**254**	Figure 6.2	**21min**
Mid-ebb	**266**	Figure 6.3	**6min**
Low Water	**267**	Figure 6.4	**15min**
Mid-flood	**268**	Figure 6.5	**30min**
Mid-ebb	**280**	Figure 6.6	**28min**
Mid ebb	**281**	Figure 6.7	**31min**
Mid-flood	**283**	Figure 6.8	**1hr 2min**

The numerical model utilised by RPS accurately simulates the dispersion of sediment across a range of tidal events and environmental conditions to a very high degree of accuracy. It can therefore be concluded that the model is well calibrated and fit for purpose.

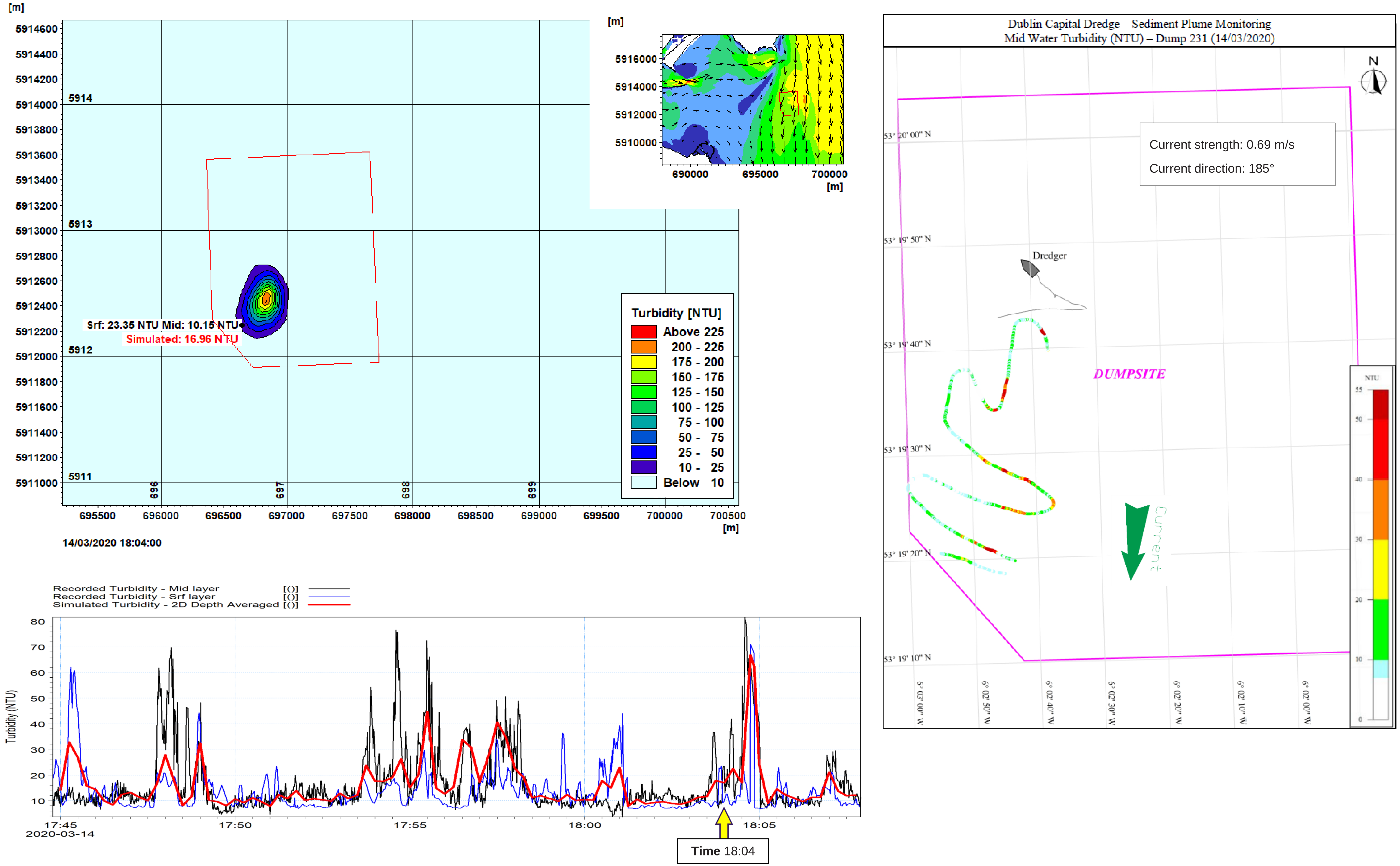


Figure 6.1: Event 231. 2D Sediment plume envelope *c.* 19min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)

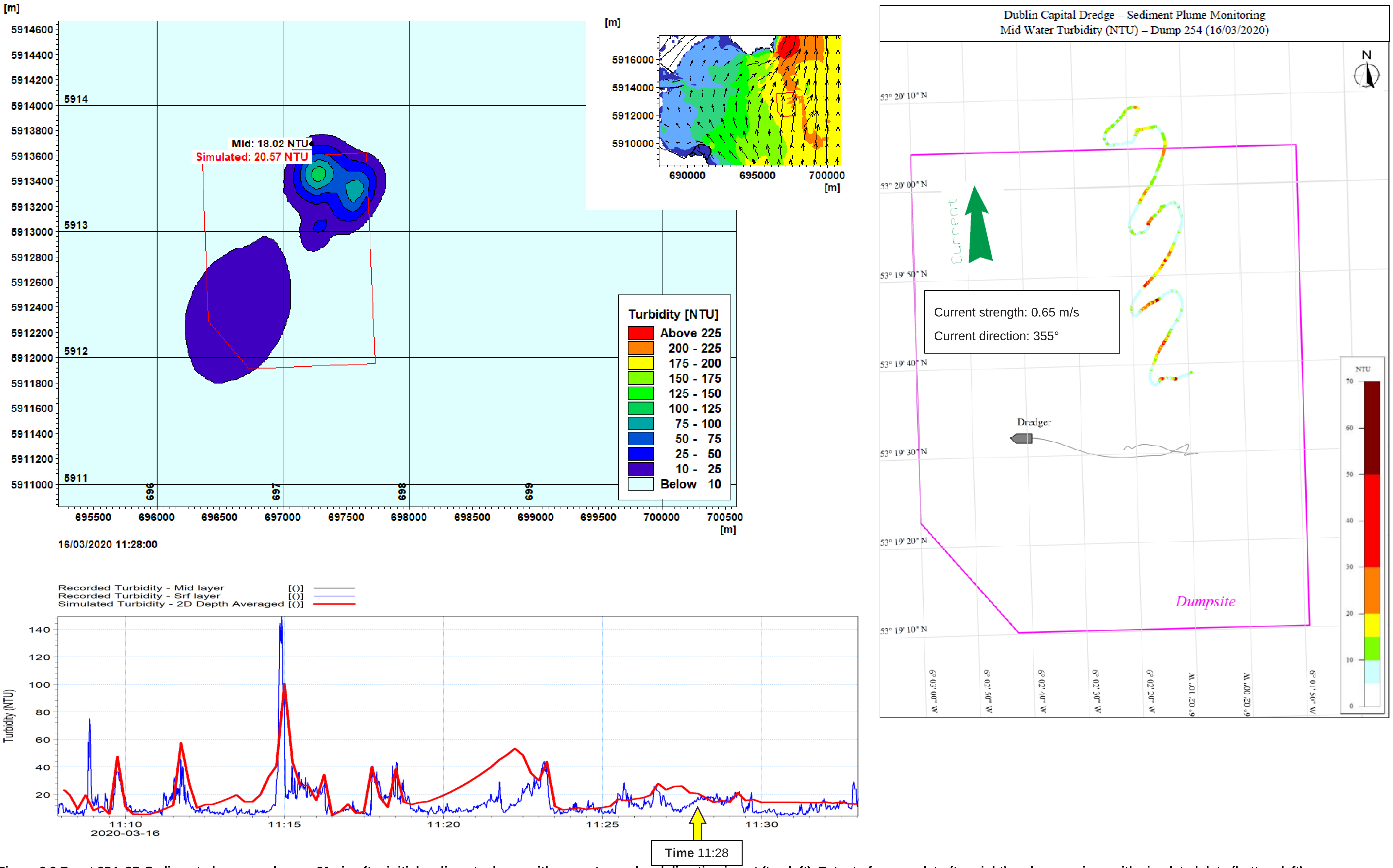
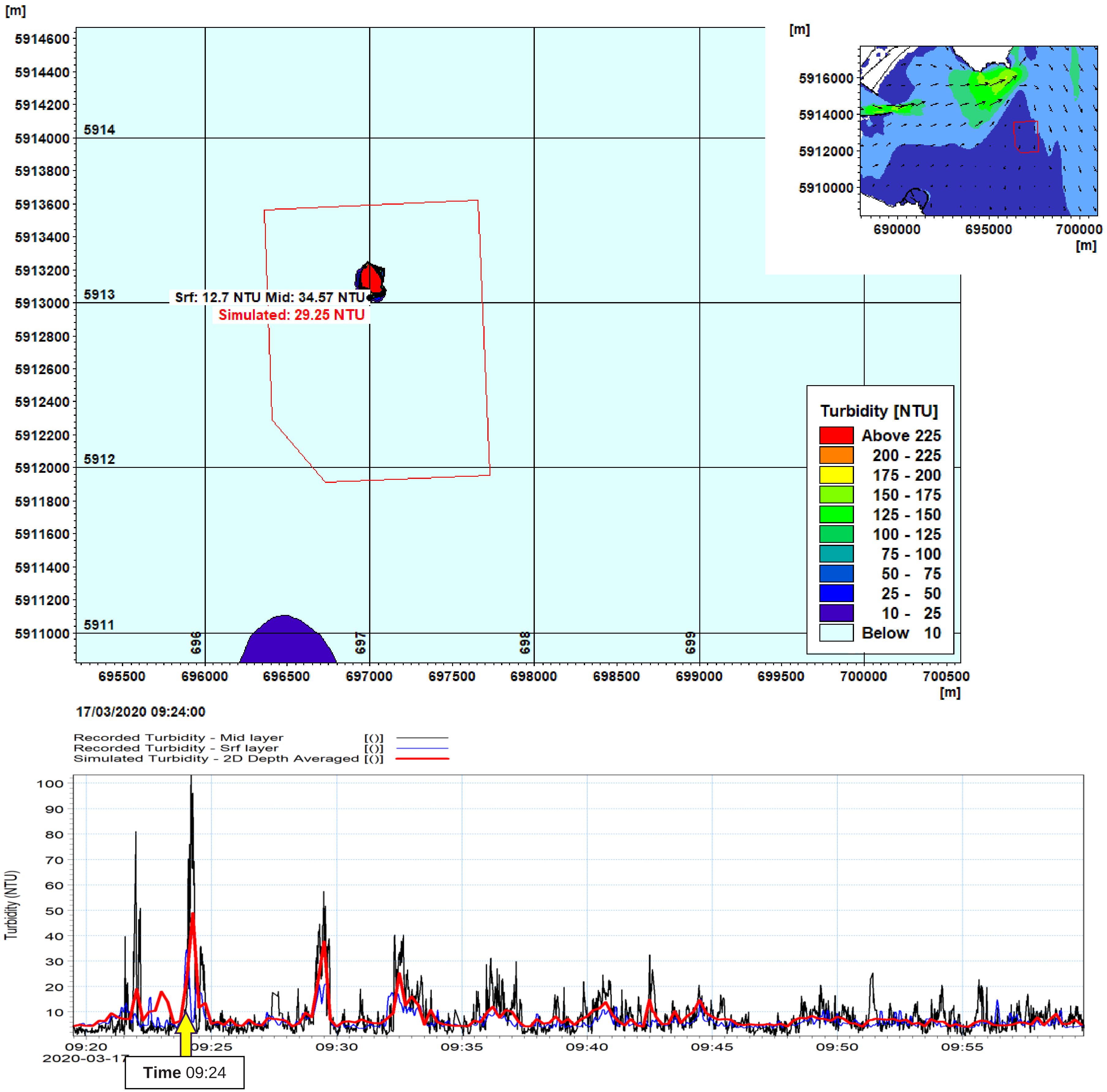


Figure 6.2 Event 254. 2D Sediment plume envelope *c.* 21min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)



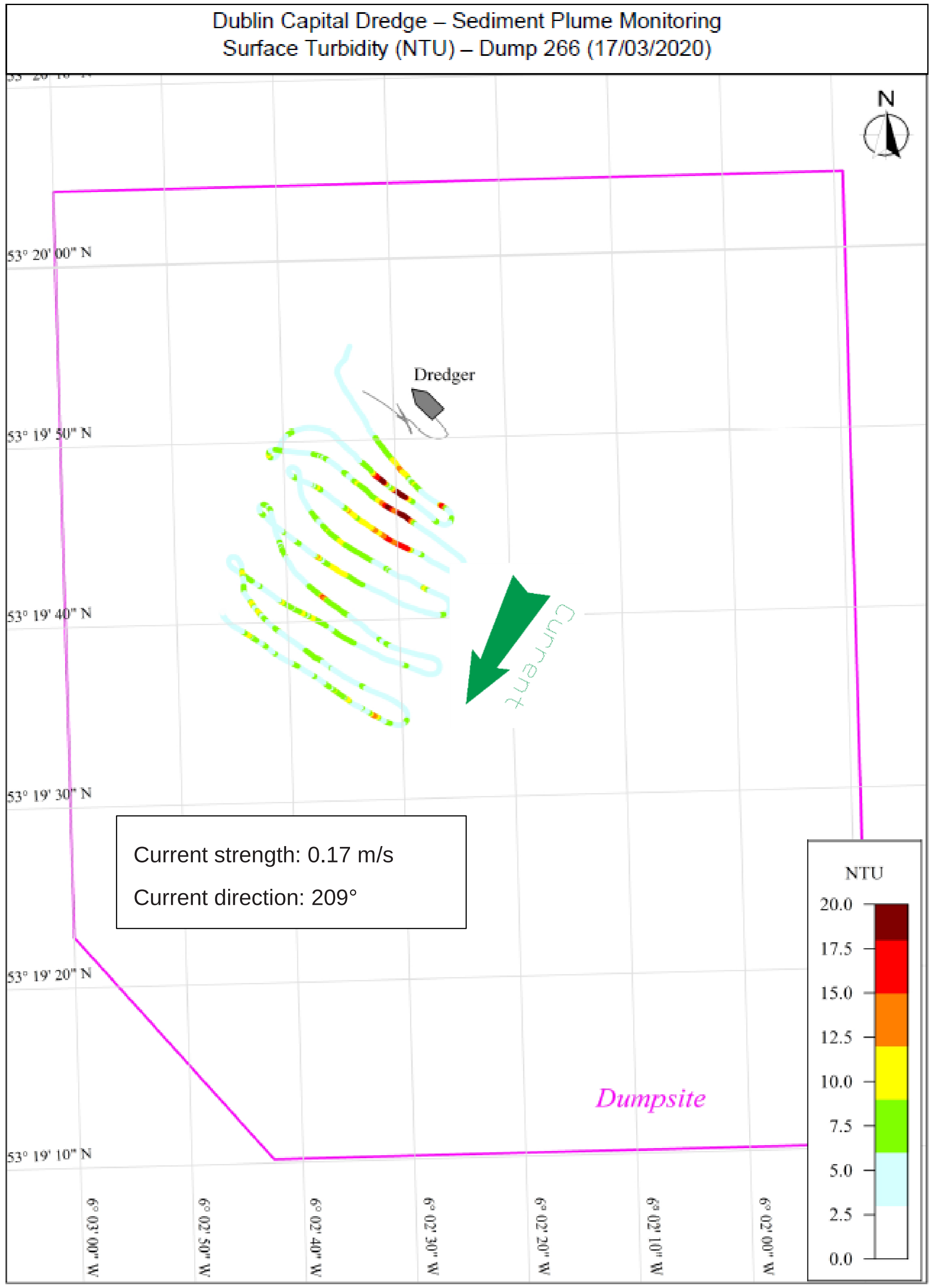
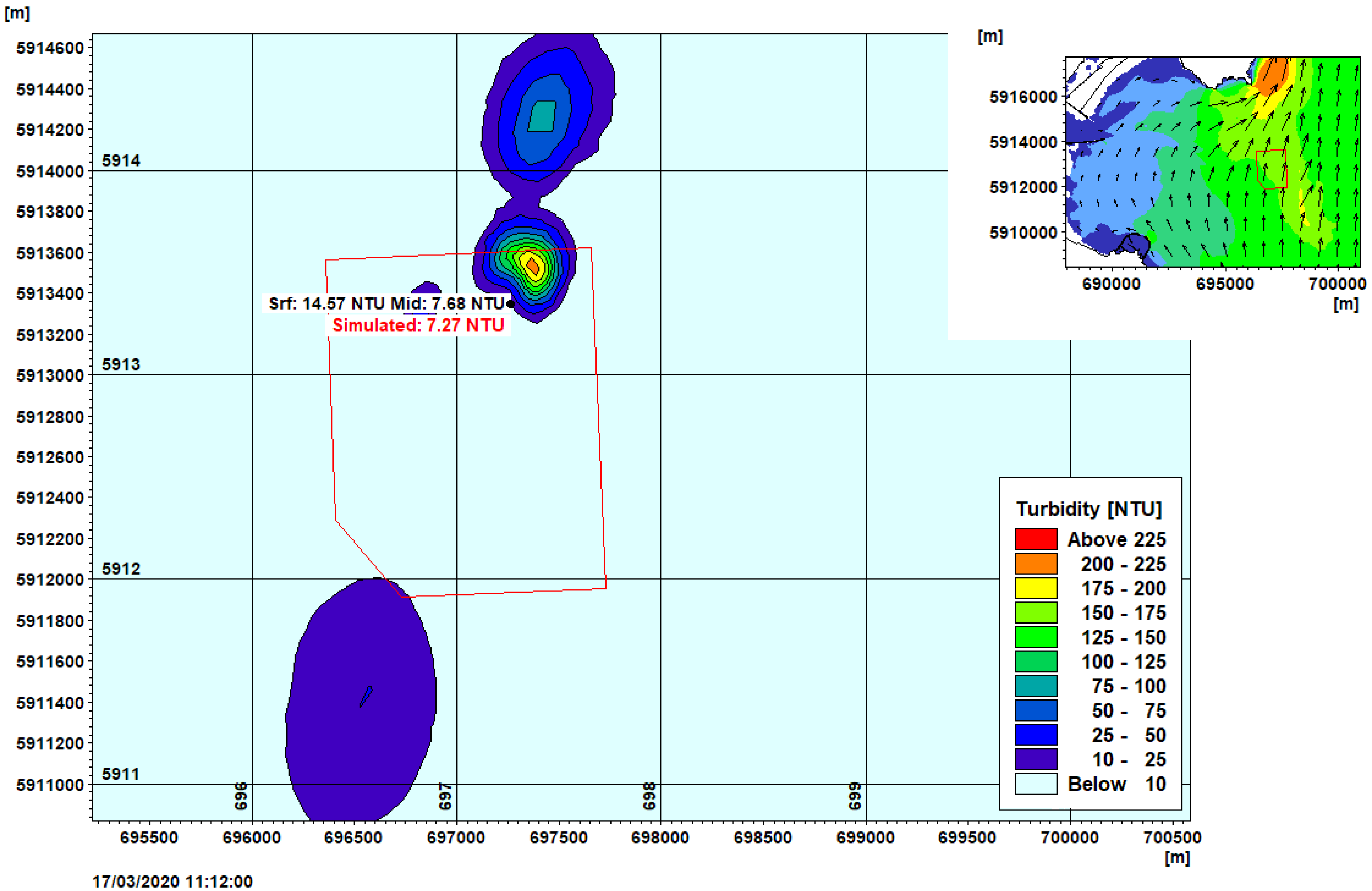
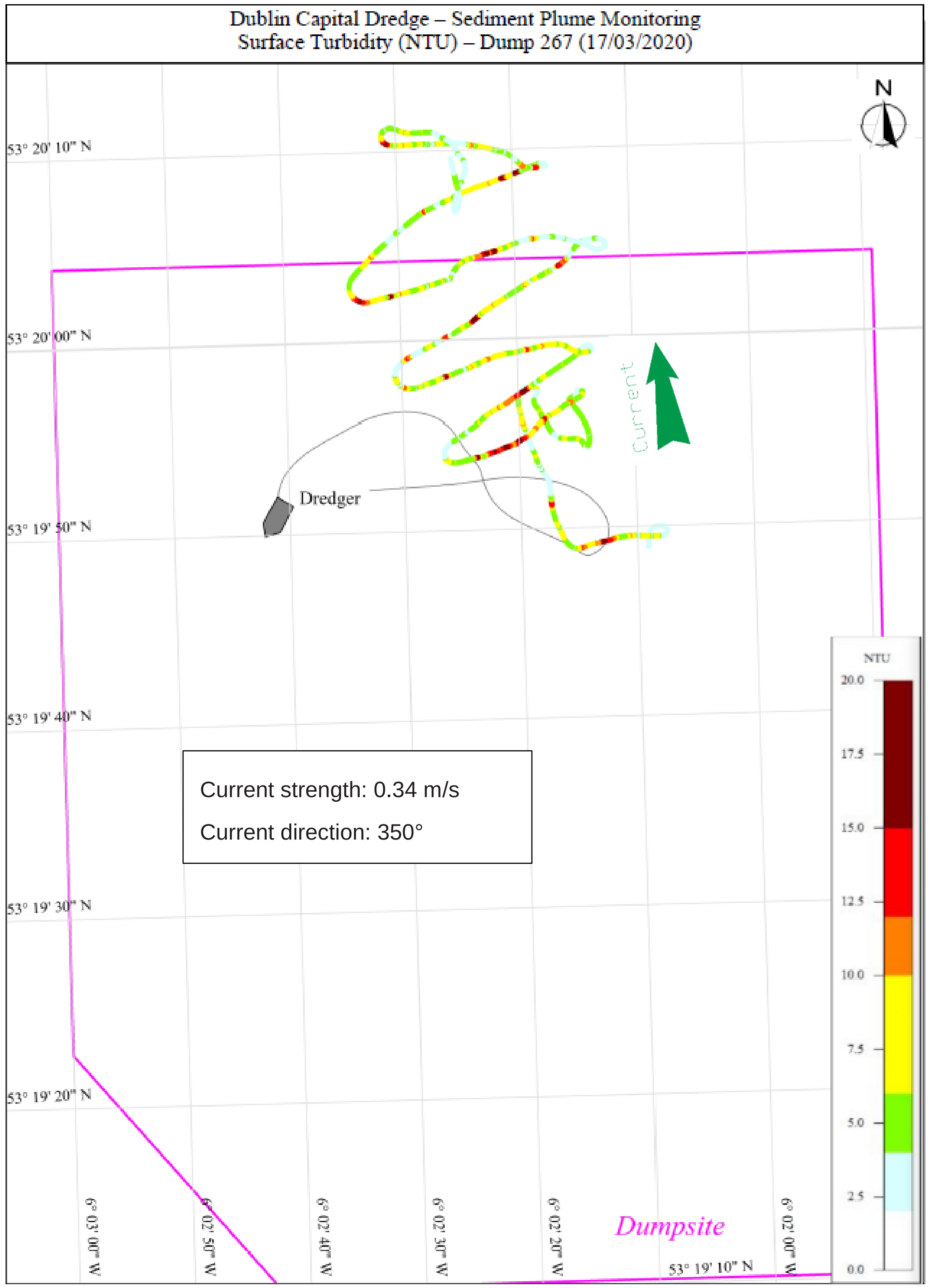


Figure 6.3 Event 266. 2D Sediment plume envelope *c.* 6min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)





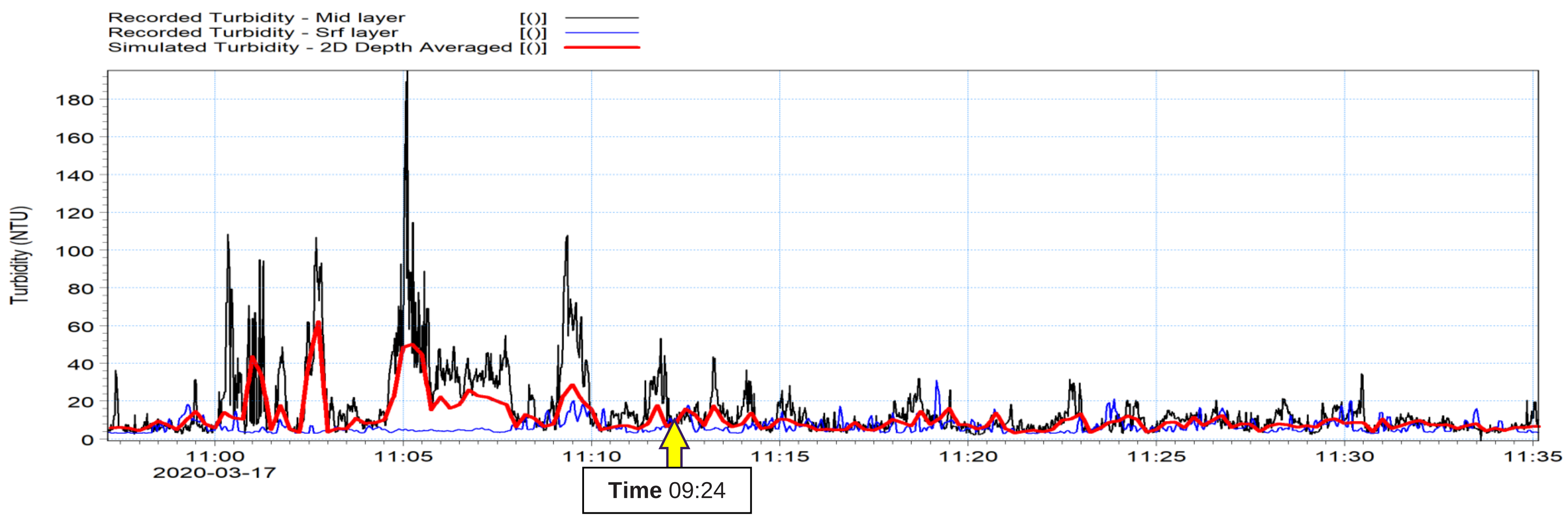


Figure 6.4 Event 267. 2D Sediment plume envelope *c.* 15min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)

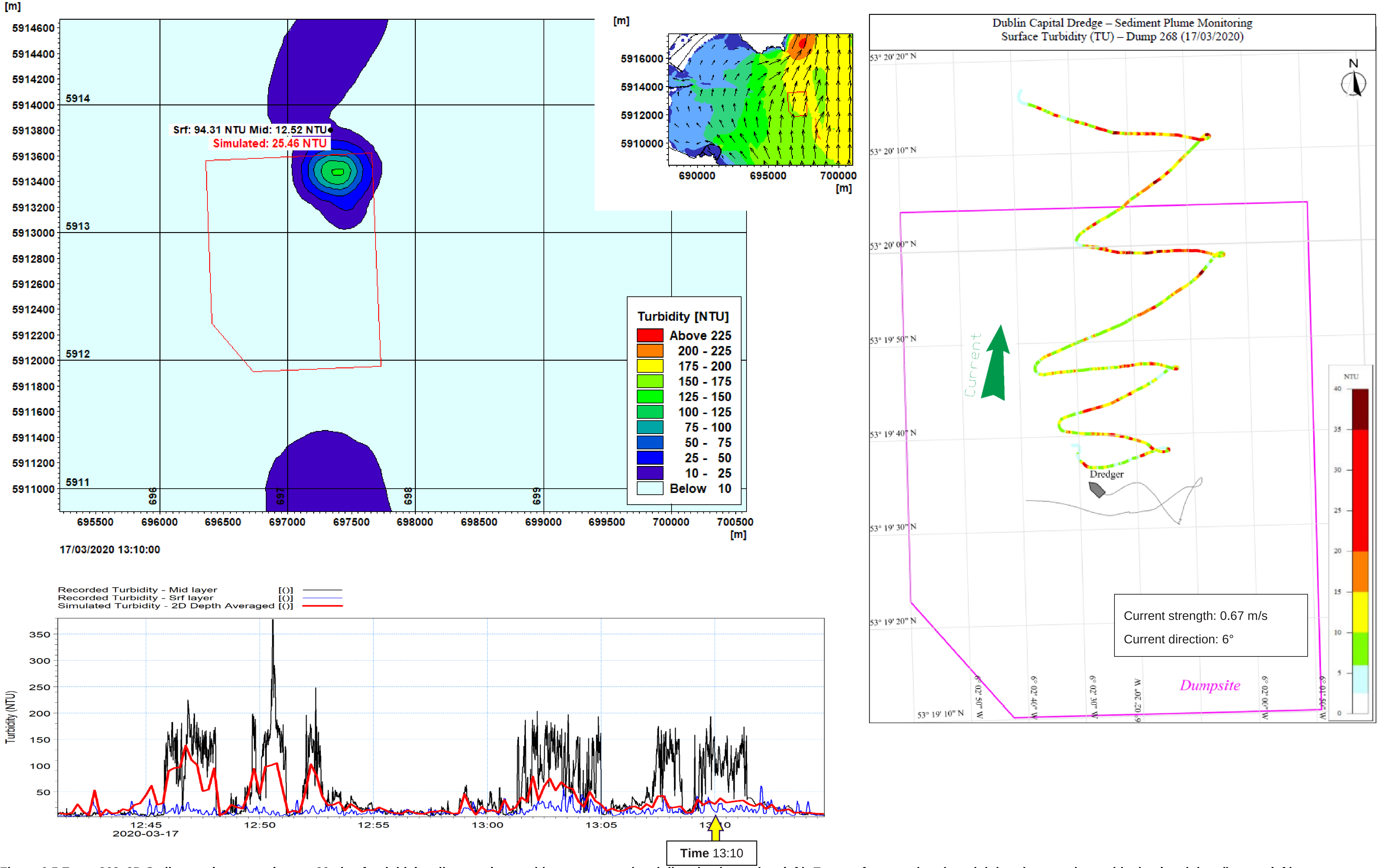


Figure 6.5 Event 268. 2D Sediment plume envelope *c.* 30min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)

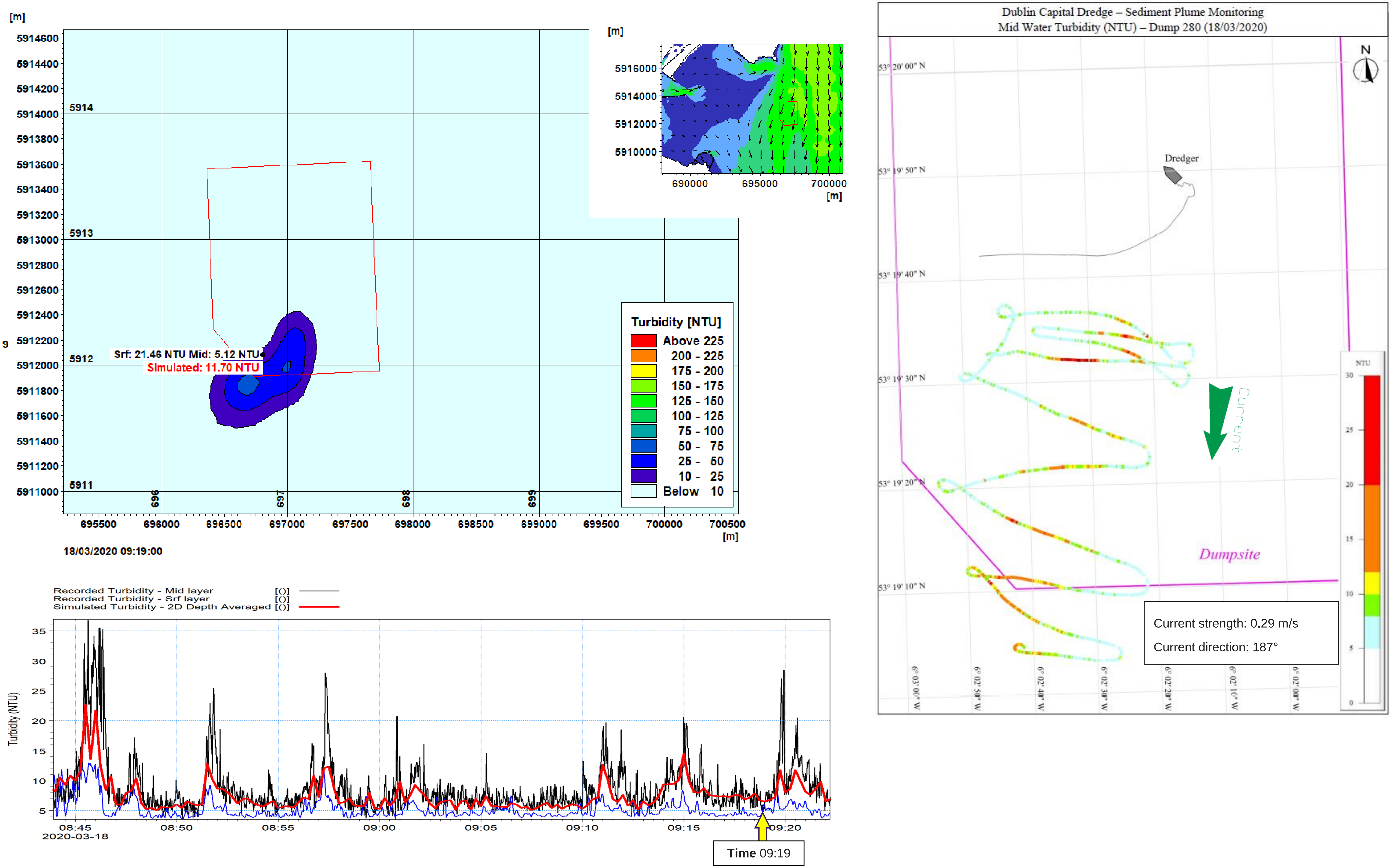
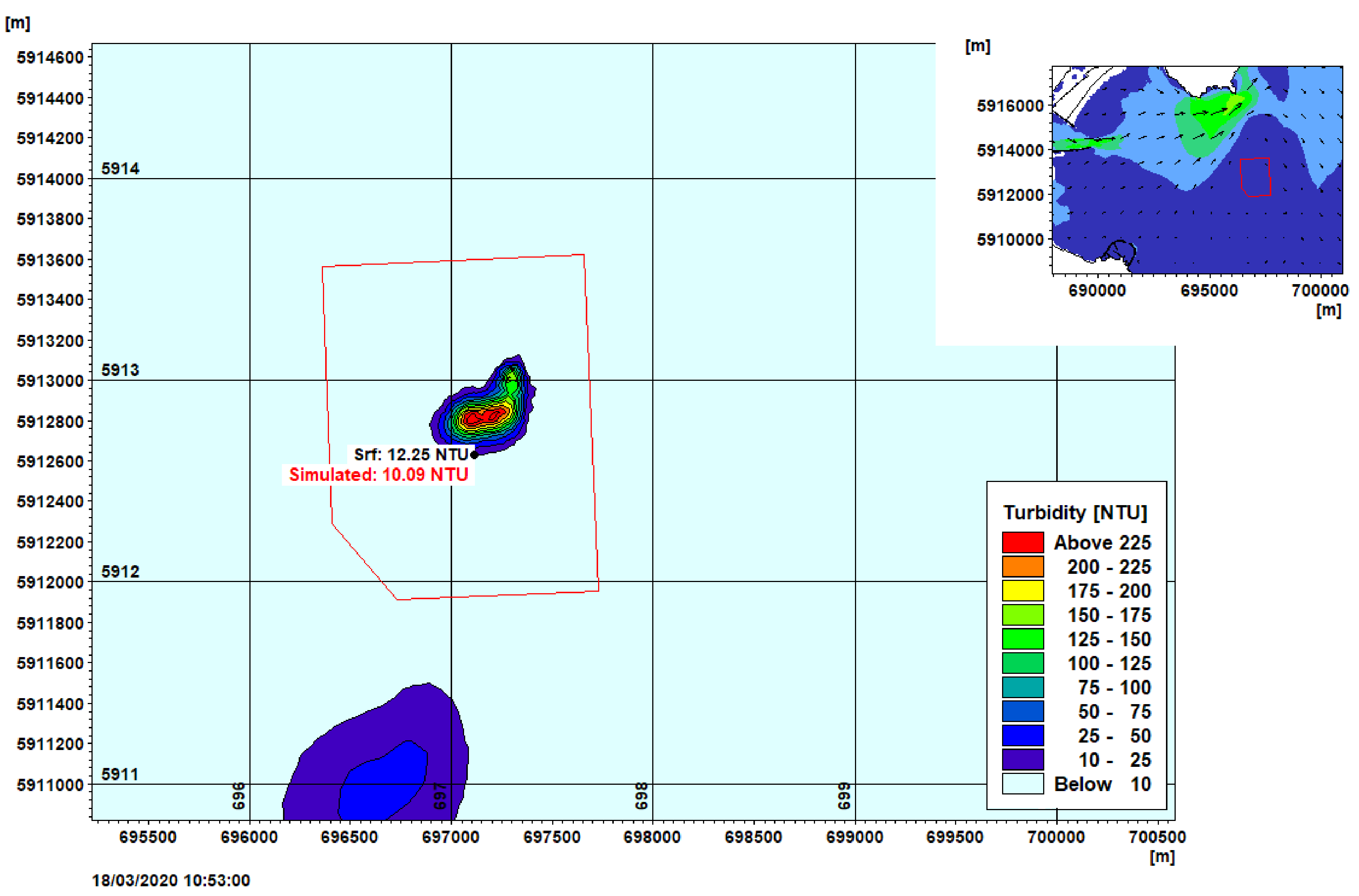
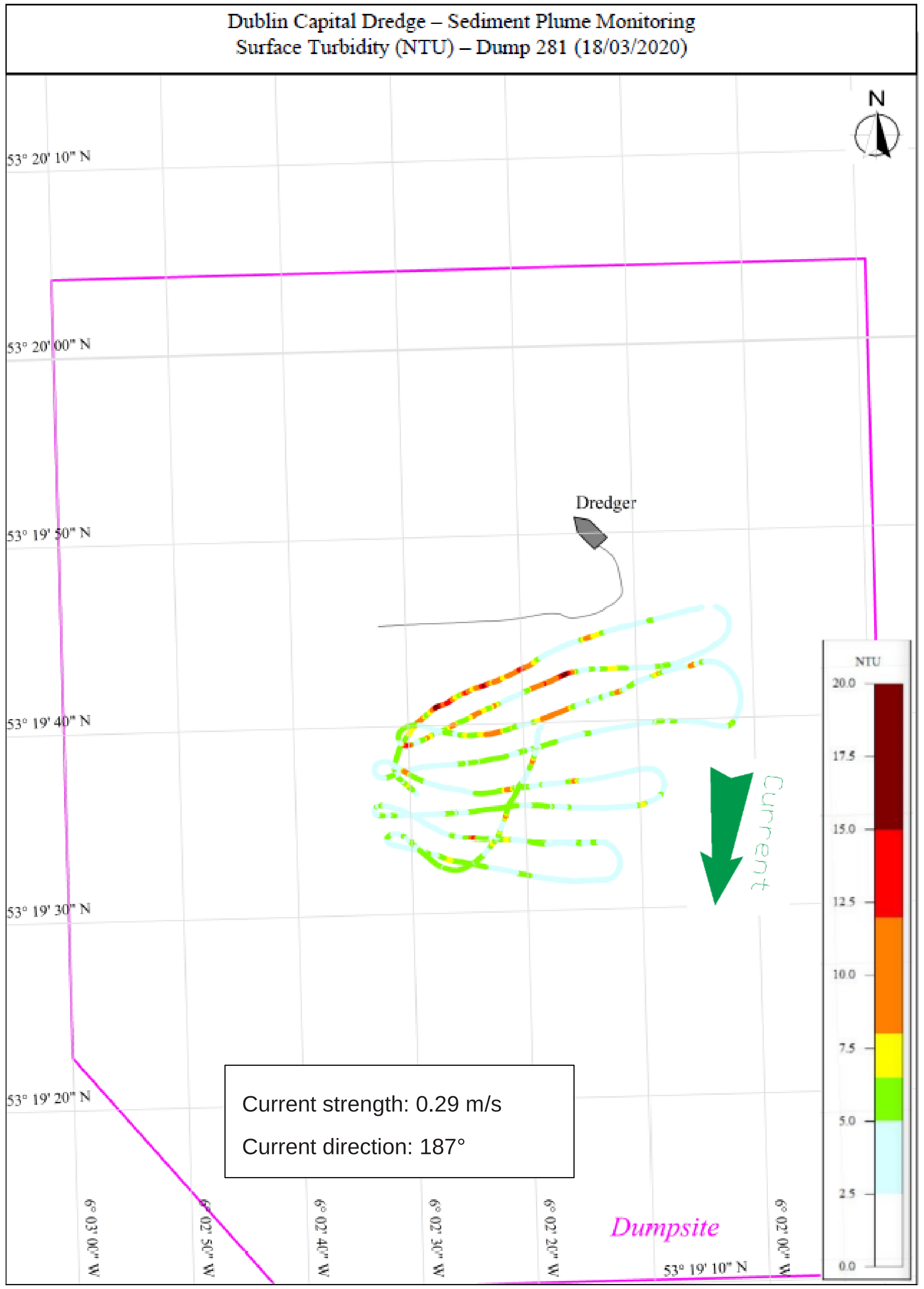


Figure 6.6 Event 280. 2D Sediment plume envelope *c.* 28min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)





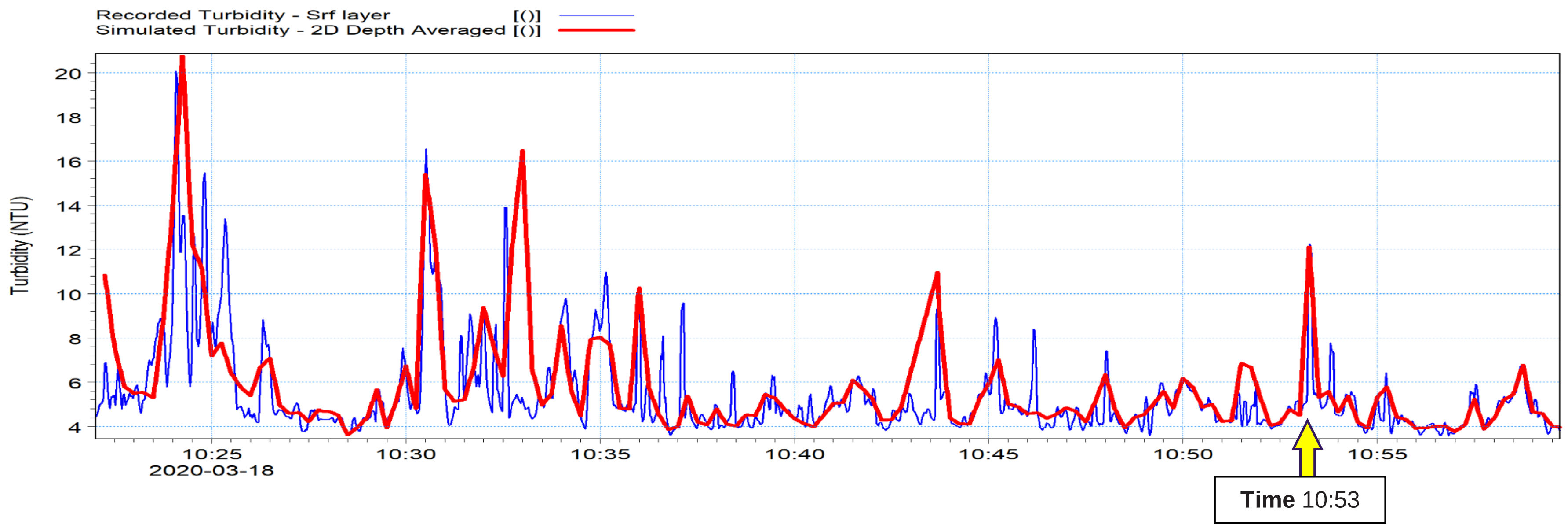


Figure 6.7 Event 281. 2D Sediment plume envelope *c.* 31min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)

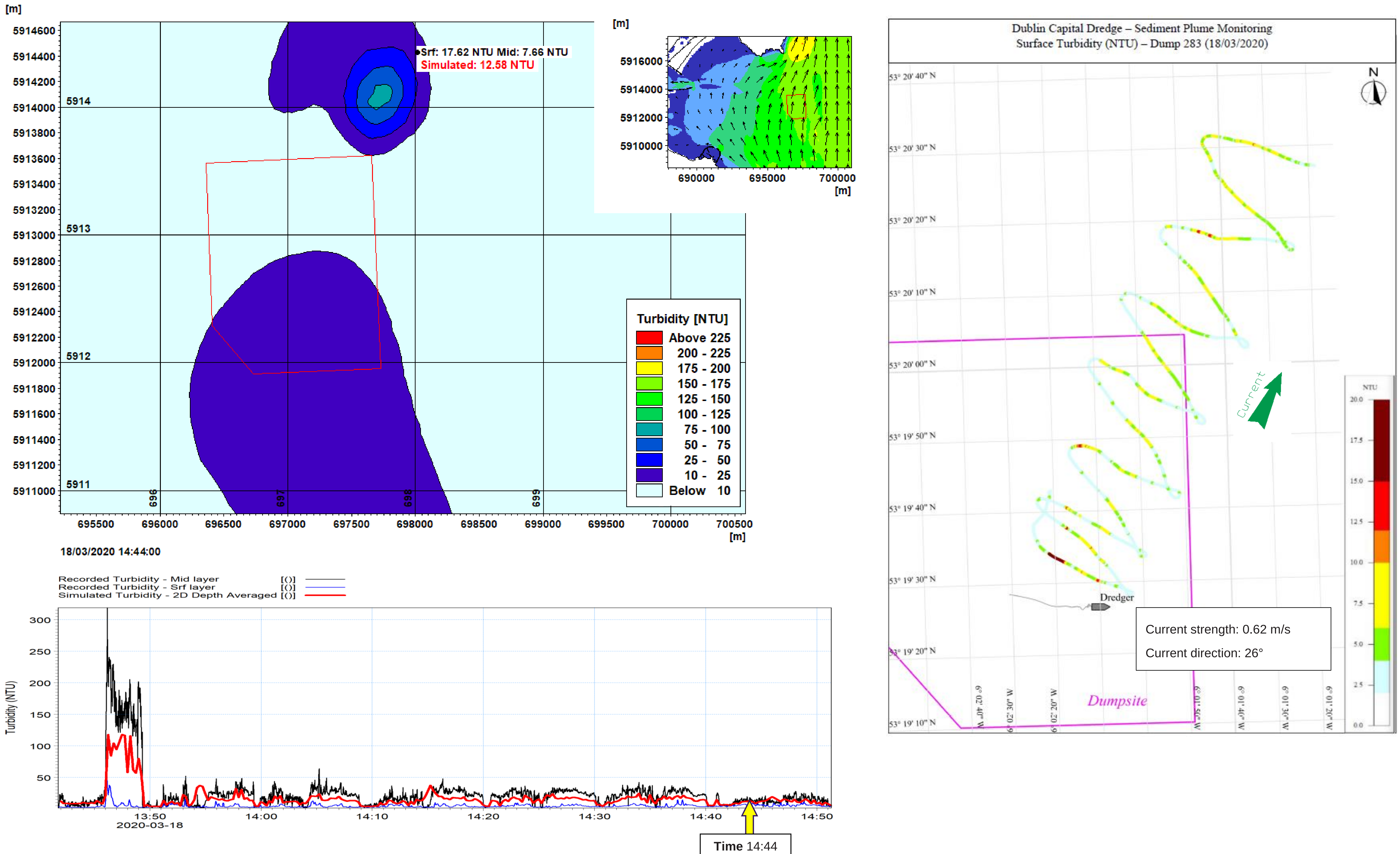


Figure 6.8 283: Event 283. 2D Sediment plume envelope *c.* 1hr 2min after initial sediment release with current speed and direction insert (top left). Extent of survey data (top right) and comparison with simulated data (bottom left)

7 CONCLUSIONS

Dublin Port Company (DPC) was granted a Dumping at Sea Permit (S0024-01) by the Environmental Protection Agency (EPA) on 13th September 2016 for the loading and dumping at sea of dredged material arising from capital dredging as part of the Alexandra Basin Redevelopment (ABR) Project. The permit sets out in detail the conditions under which DPC will carry out loading and dumping at sea.

In order to satisfy Condition 4.11 of this permit RPS undertook an extensive modelling programme to validate the numerical modelling parameters used in Appendix C: Coastal Process Modelling to the Natura Impact Statement submitted as part of the application.

- This was achieved using project specific monitoring data collected by Hydromaster (Hydromaster, 2020).
- Produce sediment plume plots for dumping events of the March 2020 campaign during which dredging took place within the inner Liffey channel over a range of spring and neap tidal conditions.

In summary, this assessment found that:

- The sediment was specified correctly in Appendix C: Coastal Process Modelling to the Natura Impact Statement submitted as part of the application and that the numerical modelling parameters used for this technical assessment were valid and fit for purpose.
- Simulated turbidity levels were generally found to be well within the surface and mid-point envelope of recorded turbidity levels for all dump events.
- Turbidity levels beyond the immediate vicinity of the dump site did not generally exceed the background turbidity levels recorded when there was no dumping. This is confirmed by the Hydromaster survey tracks presented in Appendix A.
- Sediment plumes did not disperse into the inner Dublin Bay area.
- The tidal conditions at the dump site are fully dispersive for material dominated by silt.

Based on the findings of this technical assessment it can be concluded that the dispersion, fate of sediment plumes arising from the dredging and disposal operations associated with the ABR Project will not significantly impact water quality in Dublin Bay or beyond.

8 REFERENCES

Hydromaster. (2020). Dublin Bay Sediment Plume Monitoring Report.

RPS. (2003). Irish Coastal Protection Strategy Study.

RPS. (2014). Alexandra Basin Redevelopment Project - Environmental Impact Statement (Vol. 1).

RPS. (2014). Appendix C: Coastal Process Modelling to the Natura Impact Statement submitted as part of the Dumping at Sea Permit application.

RPS. (2018). Alexandra Basin Redevelopment Project - Construction Environmental Management Plan.

Appendix A Hydromaster Survey Monitoring Tracks and Comparison with Model Simulations

A.1 Vessel track and Turbidity data (surface and mid-water)

The following Figures have been taken from (Hydromaster, 2020) and display the track of the survey vessel with turbidity data overlaid, the current direction and speed is also displayed:

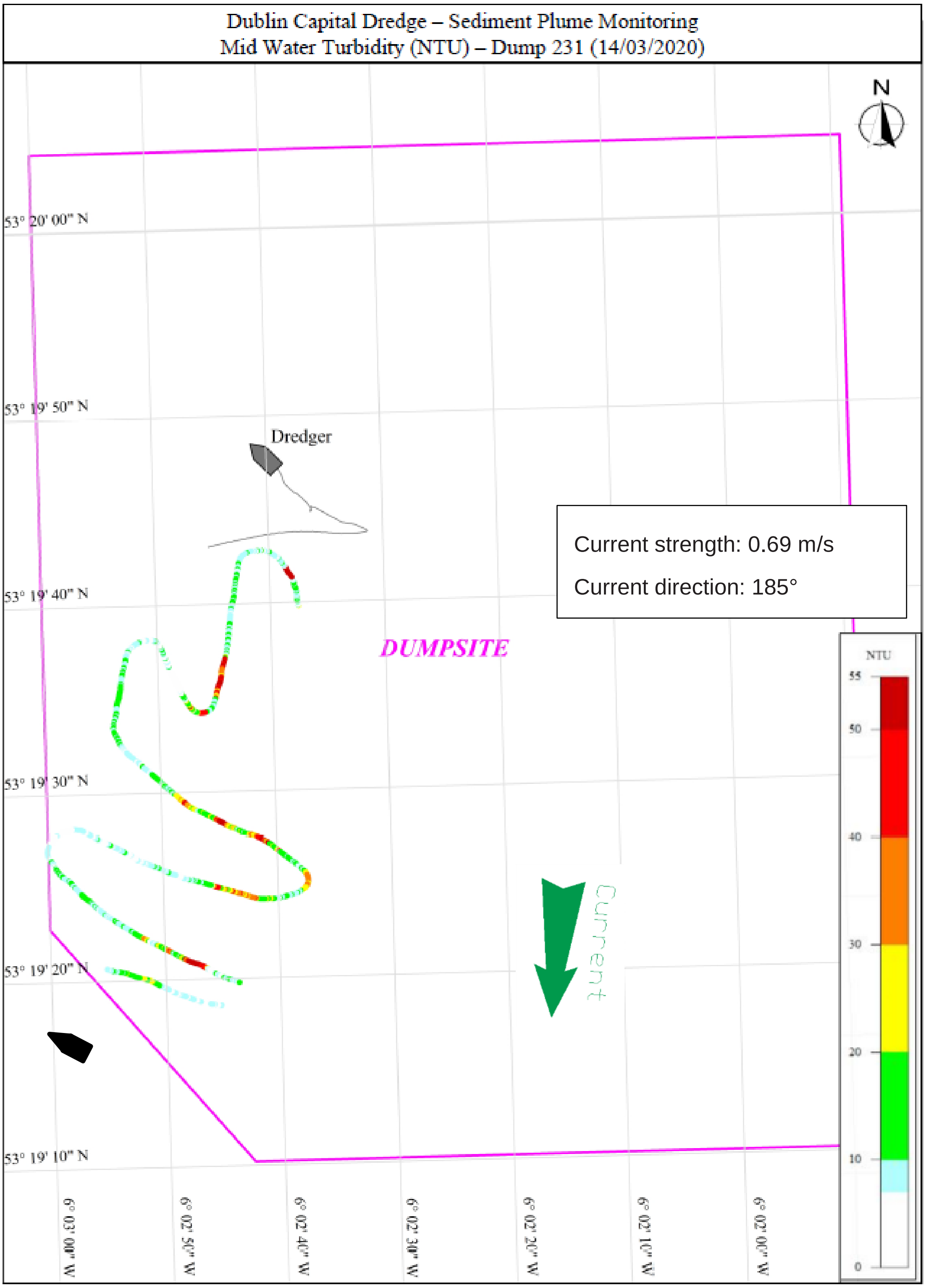


Figure 8.1: Dump 231 Survey track with mid water turbidity [NTU]

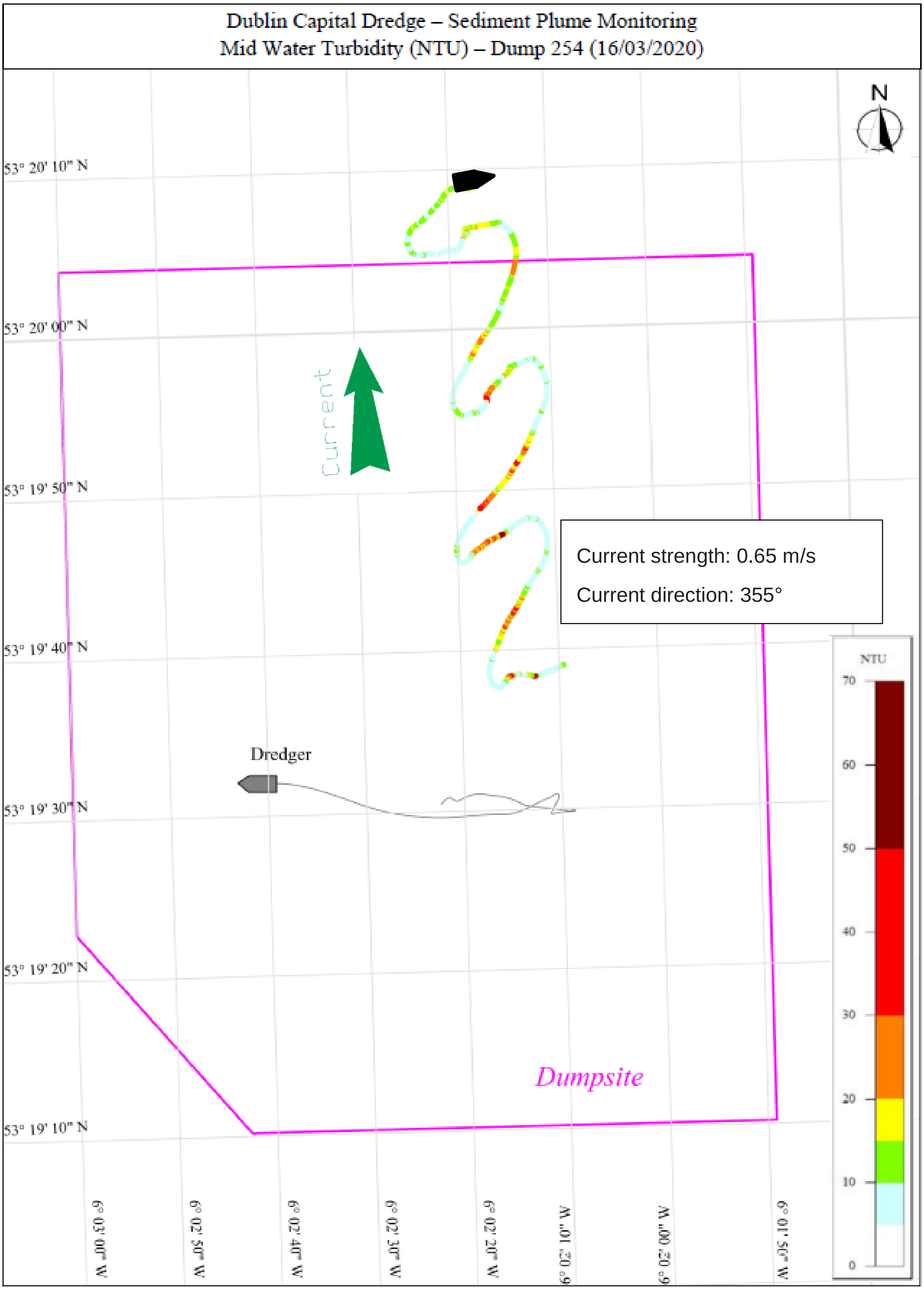


Figure 8.2: Dump 254 Survey track with mid water turbidity [NTU]

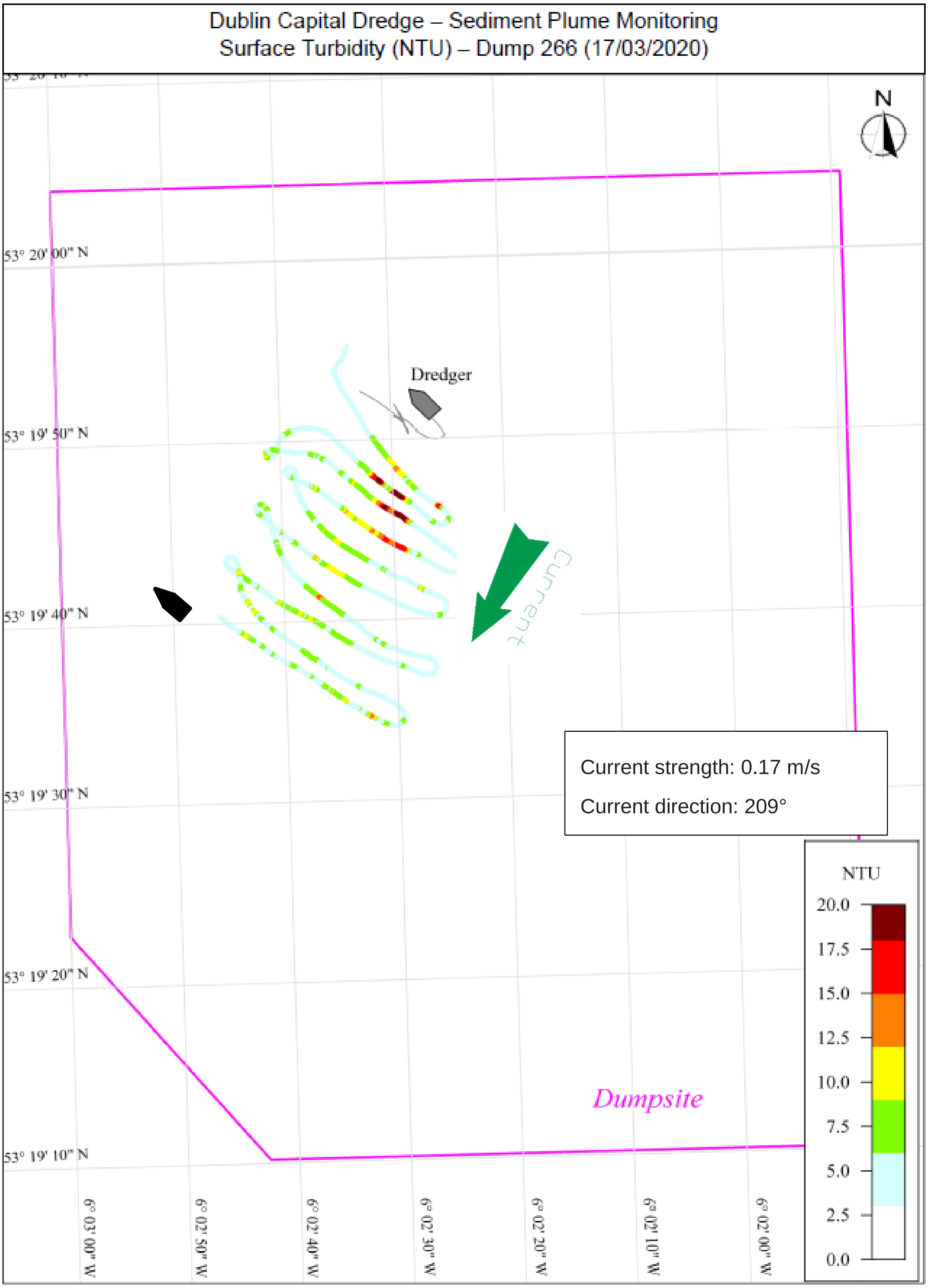


Figure 8.3: Dump 266 Survey track with surface turbidity [NTU]

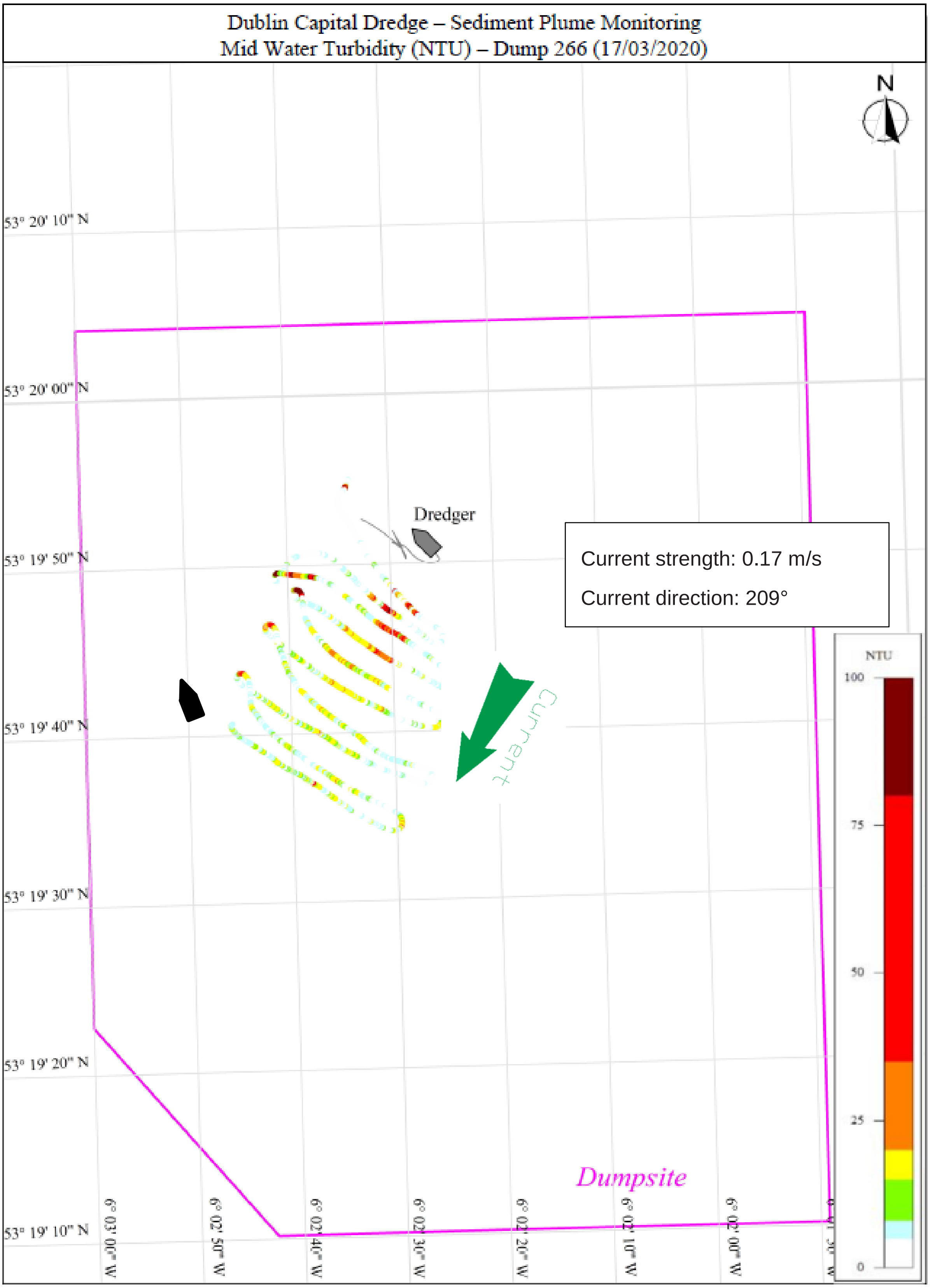


Figure 8.4: Dump 266 Survey track with mid water turbidity [NTU]

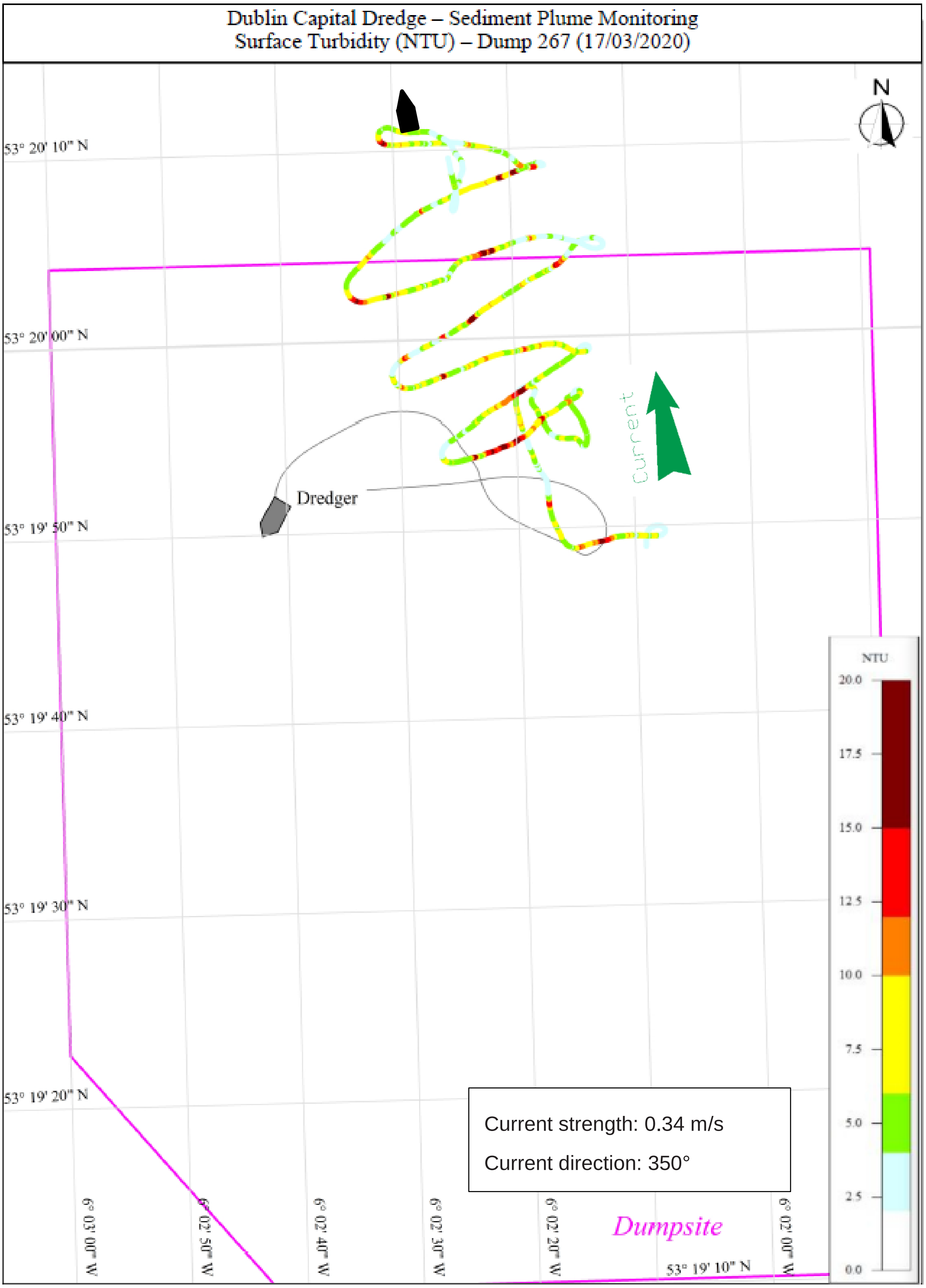


Figure 8.5: Dump 267 Survey track with surface turbidity [NTU]

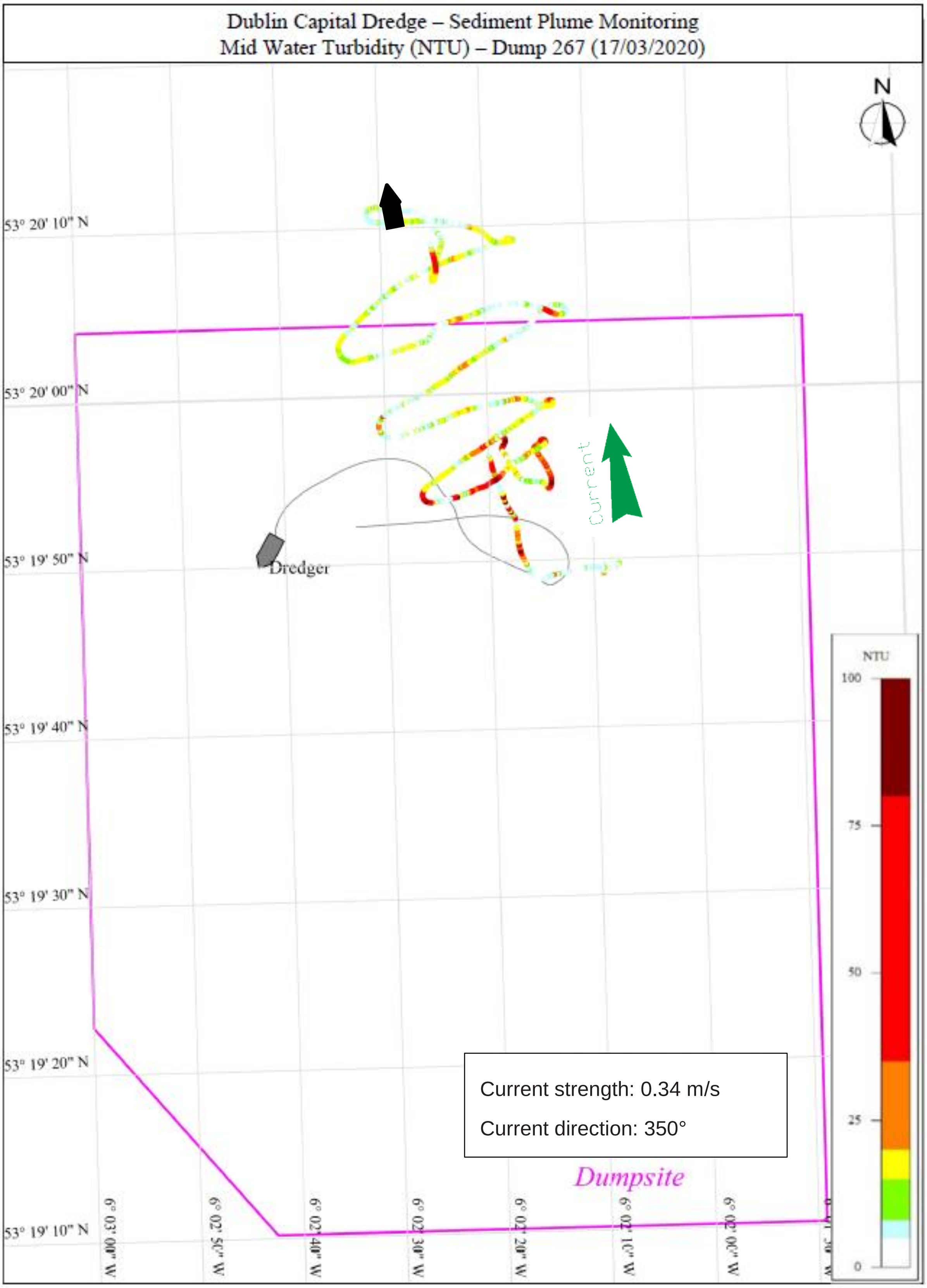


Figure 8.6: Dump 267 Survey track with mid water turbidity [NTU]

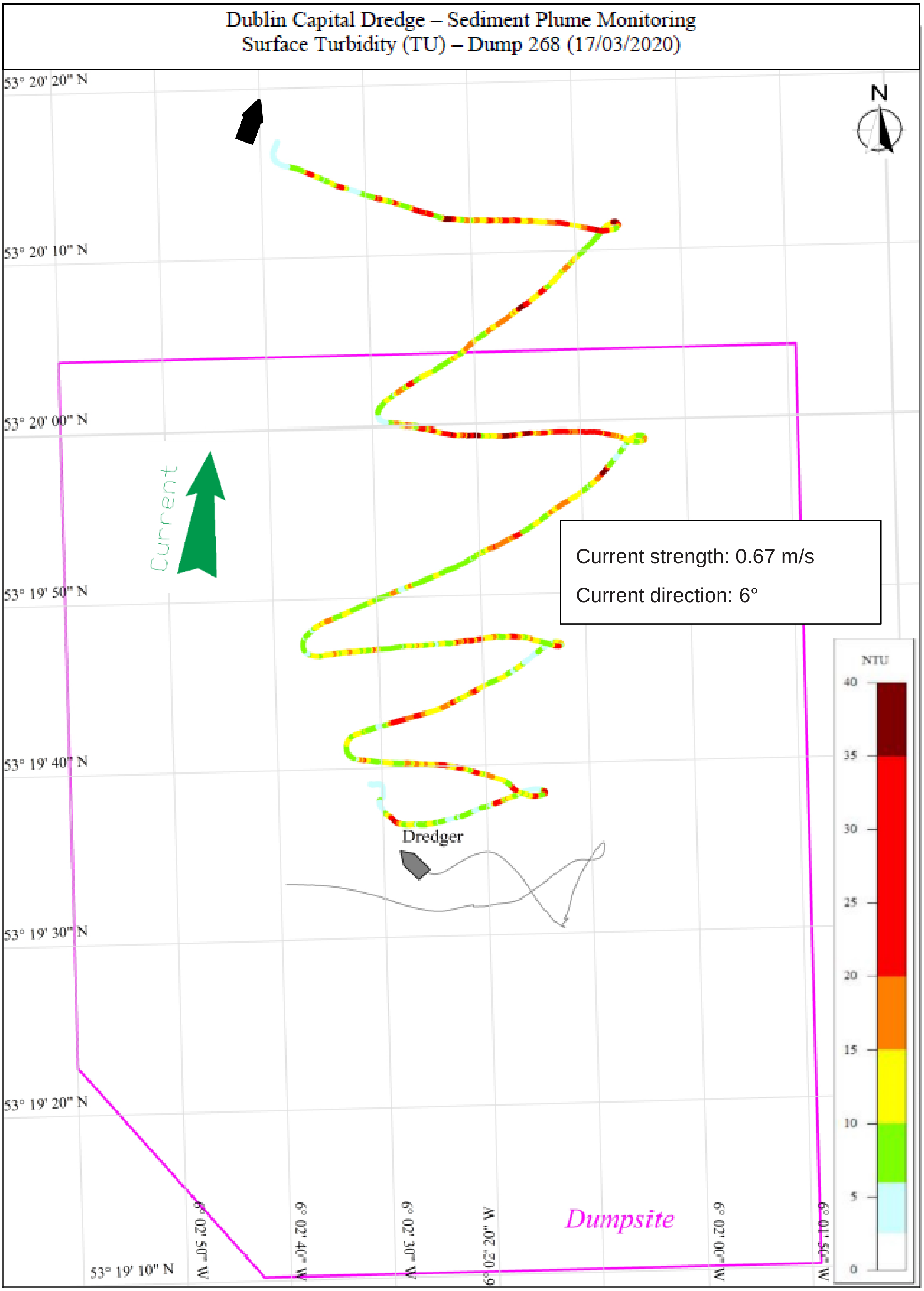


Figure 8.7: Dump 268 Survey track with surface turbidity [NTU]

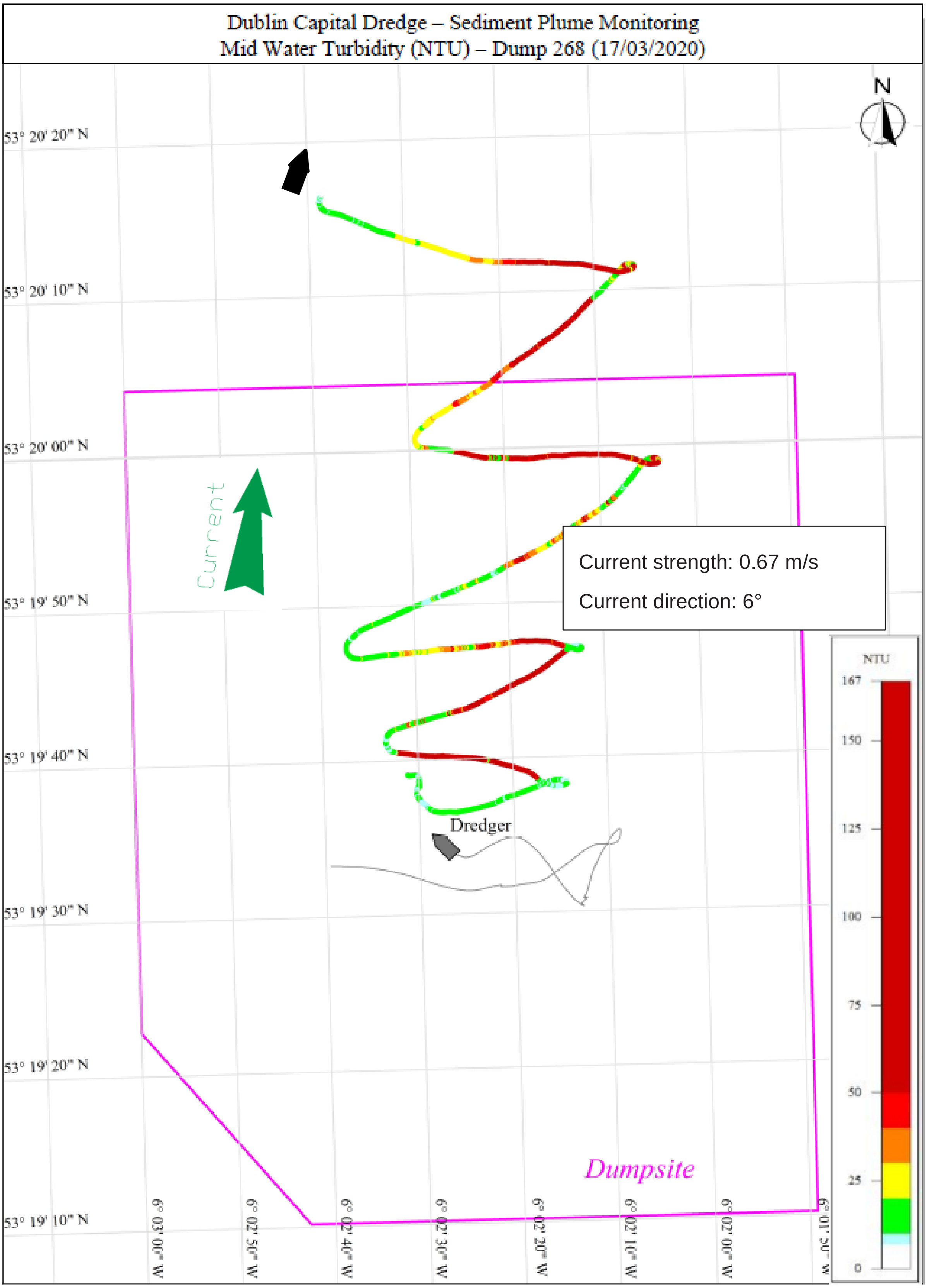


Figure 8.8: Dump 268 Survey track with mid water turbidity [NTU]

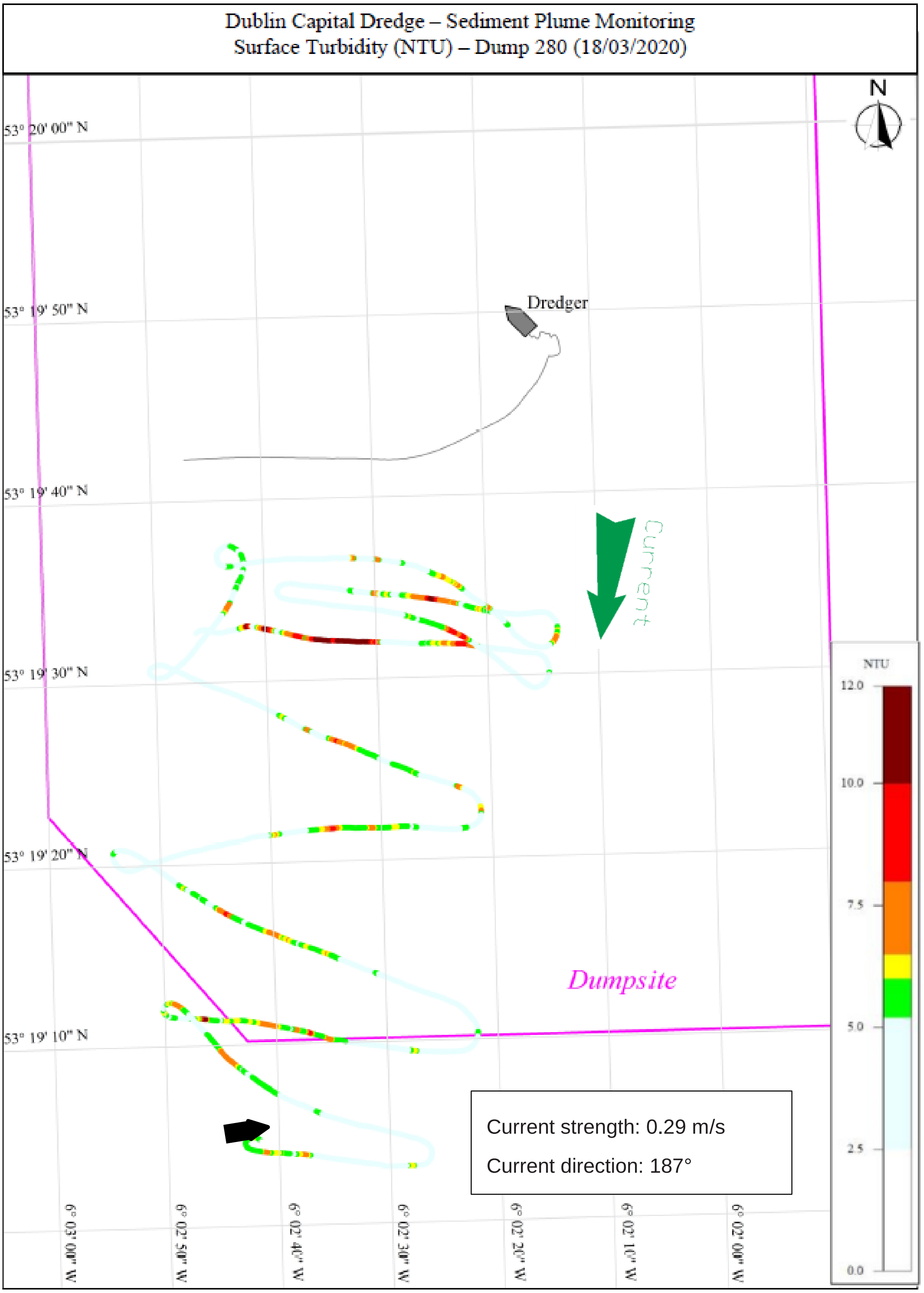


Figure 8.9: Dump 280 Survey track with surface turbidity [NTU]

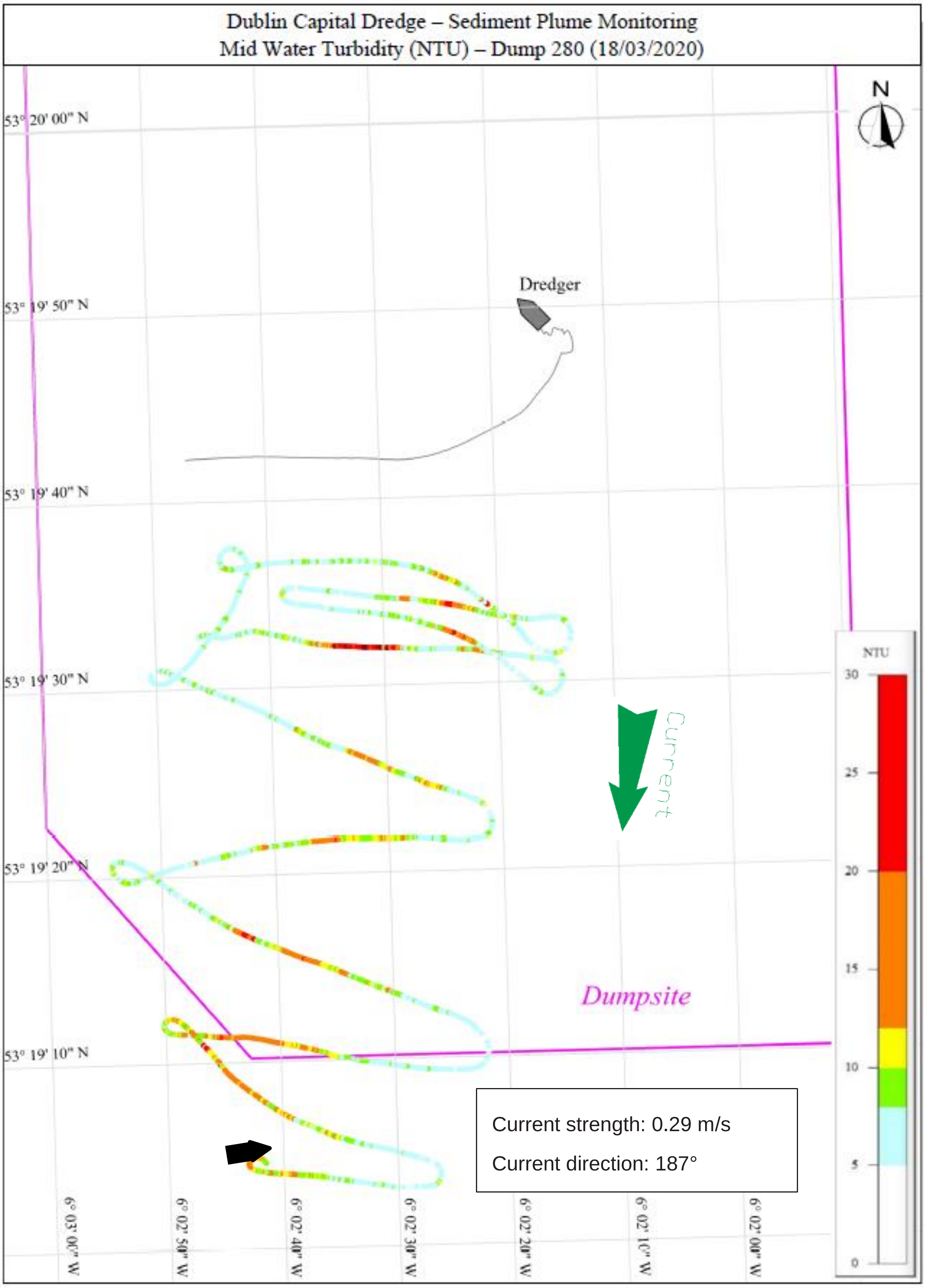
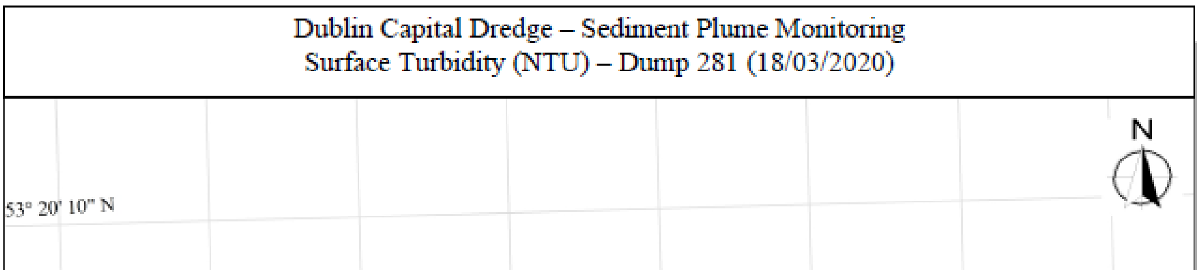


Figure 8.10: Dump 280 Survey track with mid water turbidity [NTU]



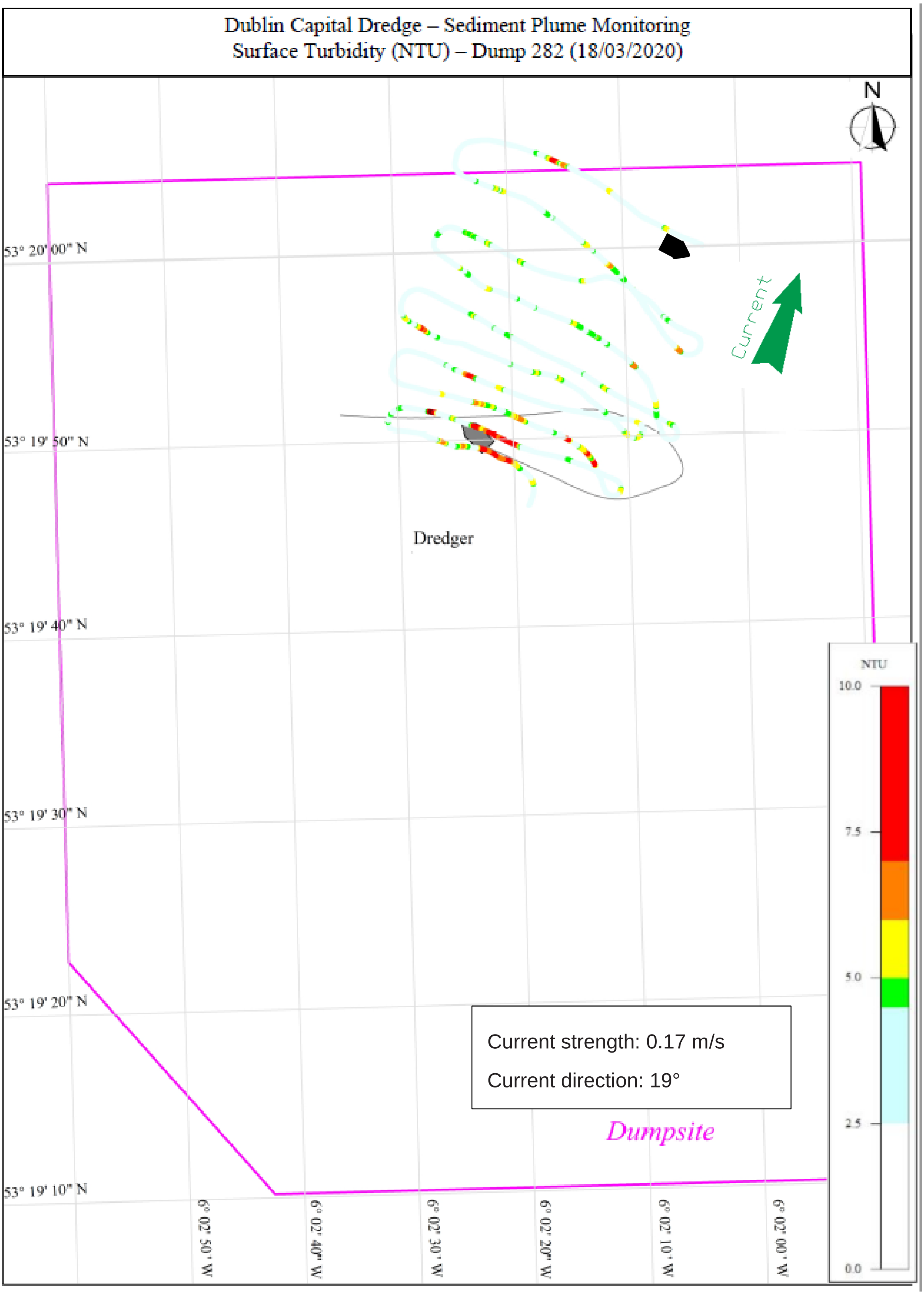


Figure 8.12: Dump 282 Survey track with surface turbidity [NTU]

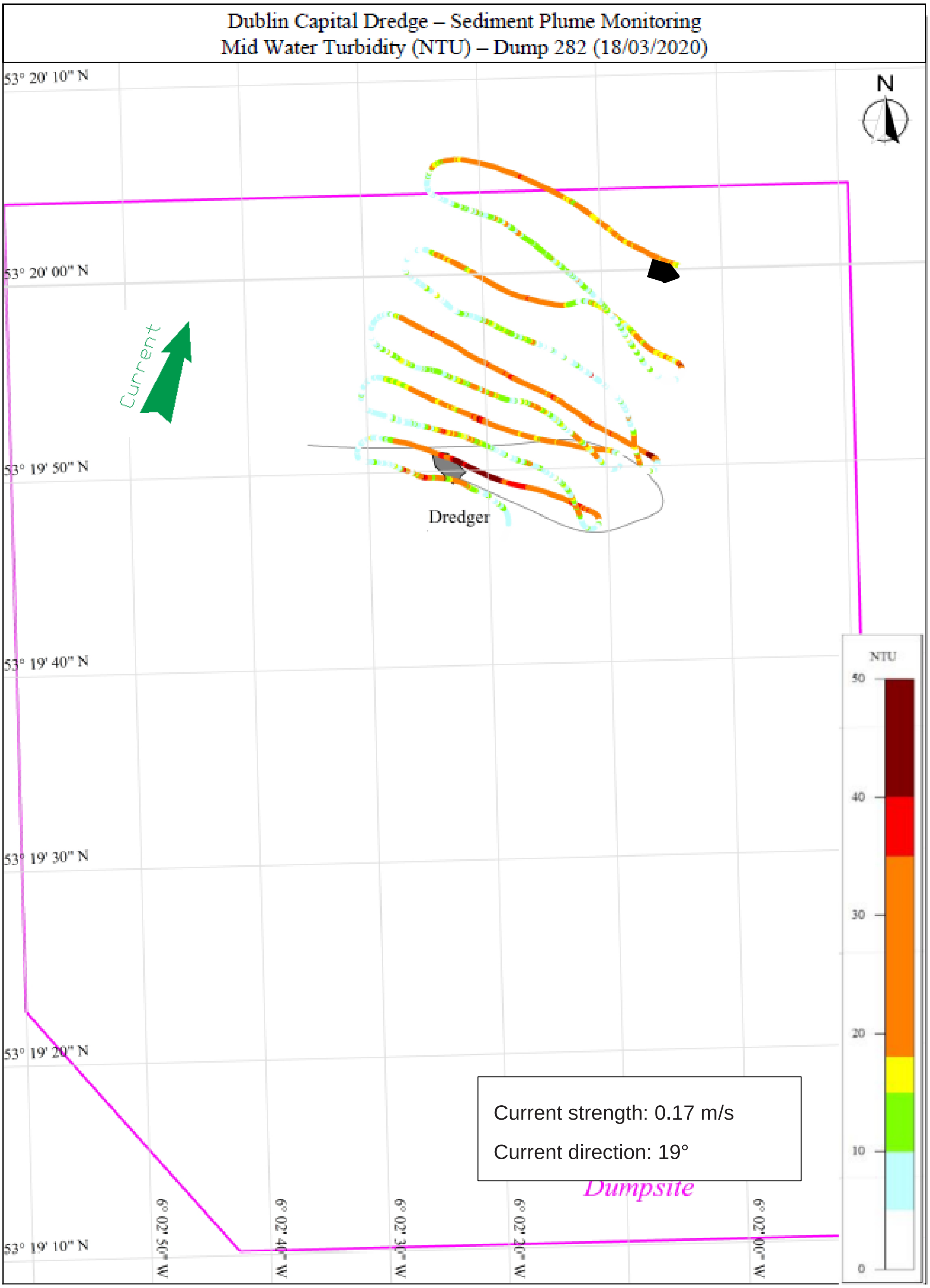


Figure 8.13: Dump 282 Survey track with mid water turbidity [NTU]

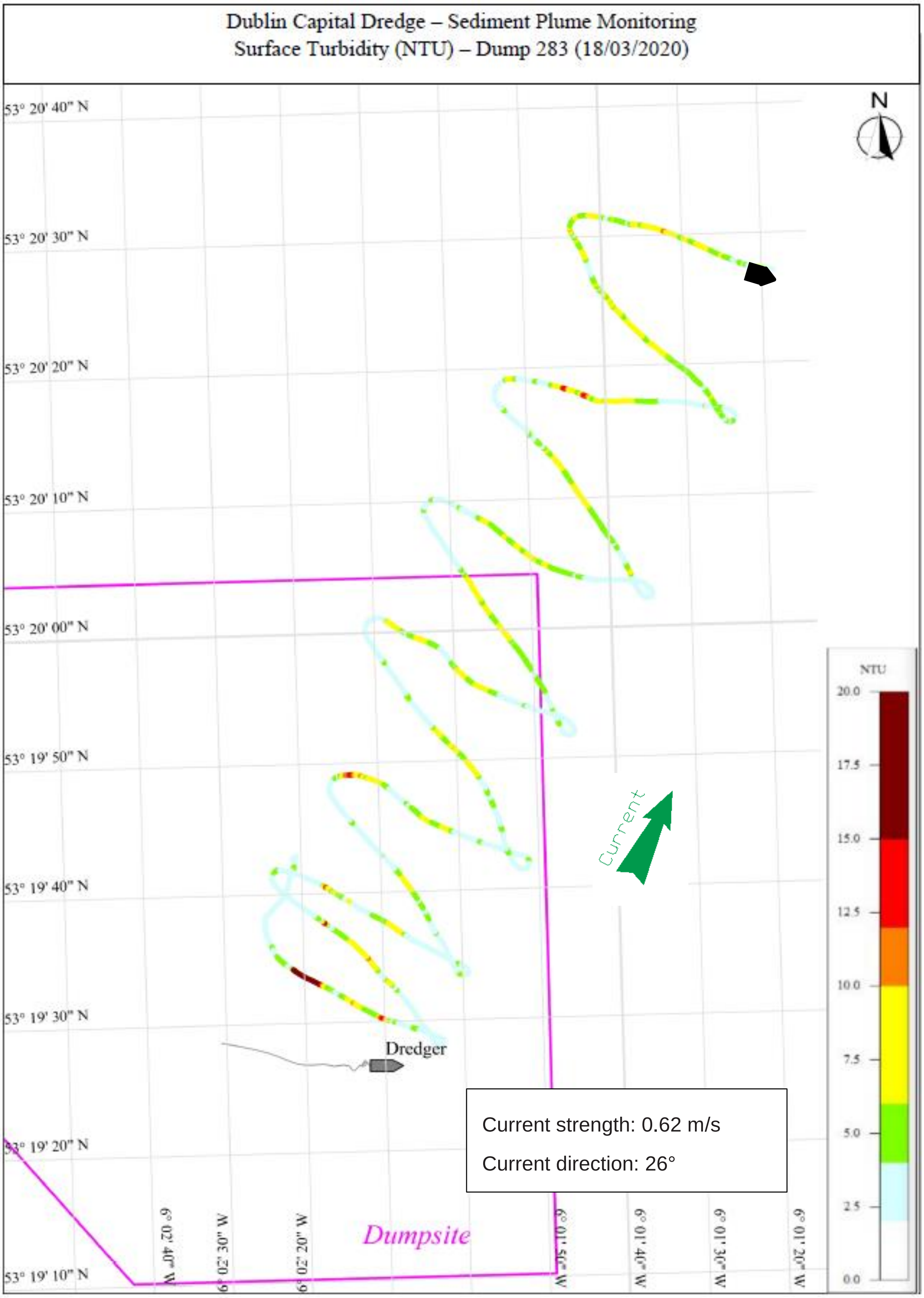


Figure 8.14: Dump 283 Survey track with surface turbidity [NTU]

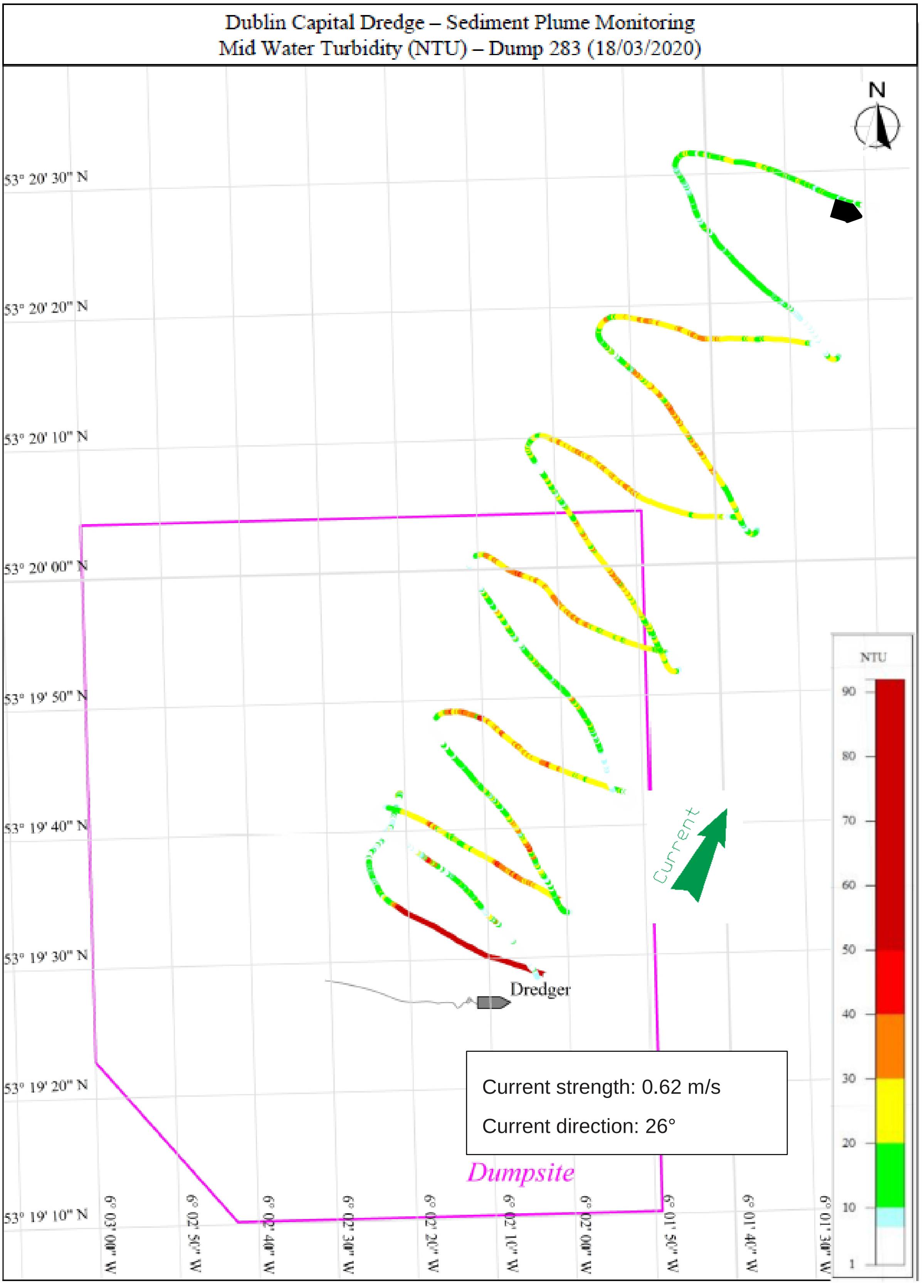


Figure 8.15: Dump 283 Survey track with mid water turbidity [NTU]

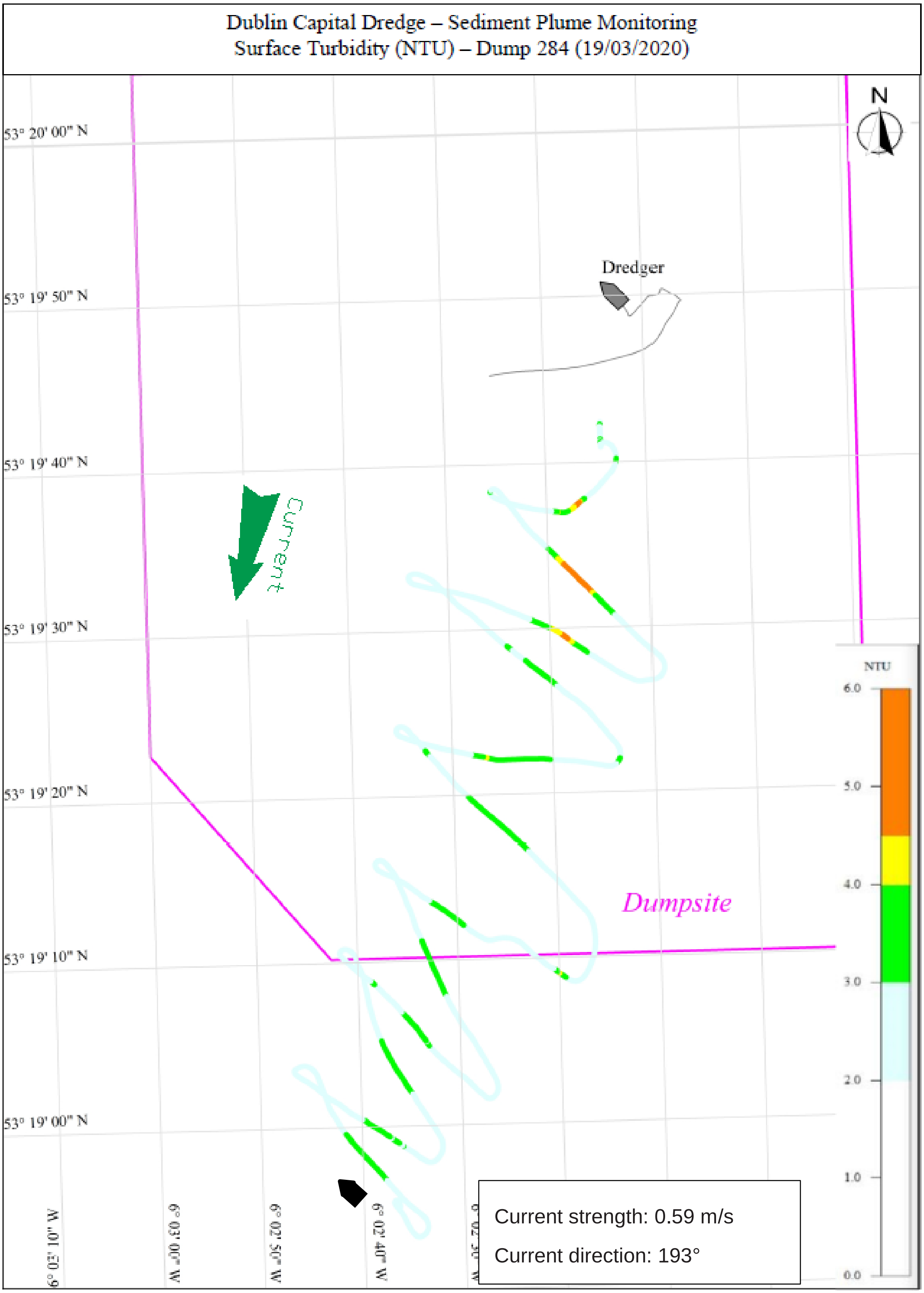


Figure 8.16: Dump 284 Survey track with surface turbidity [NTU]

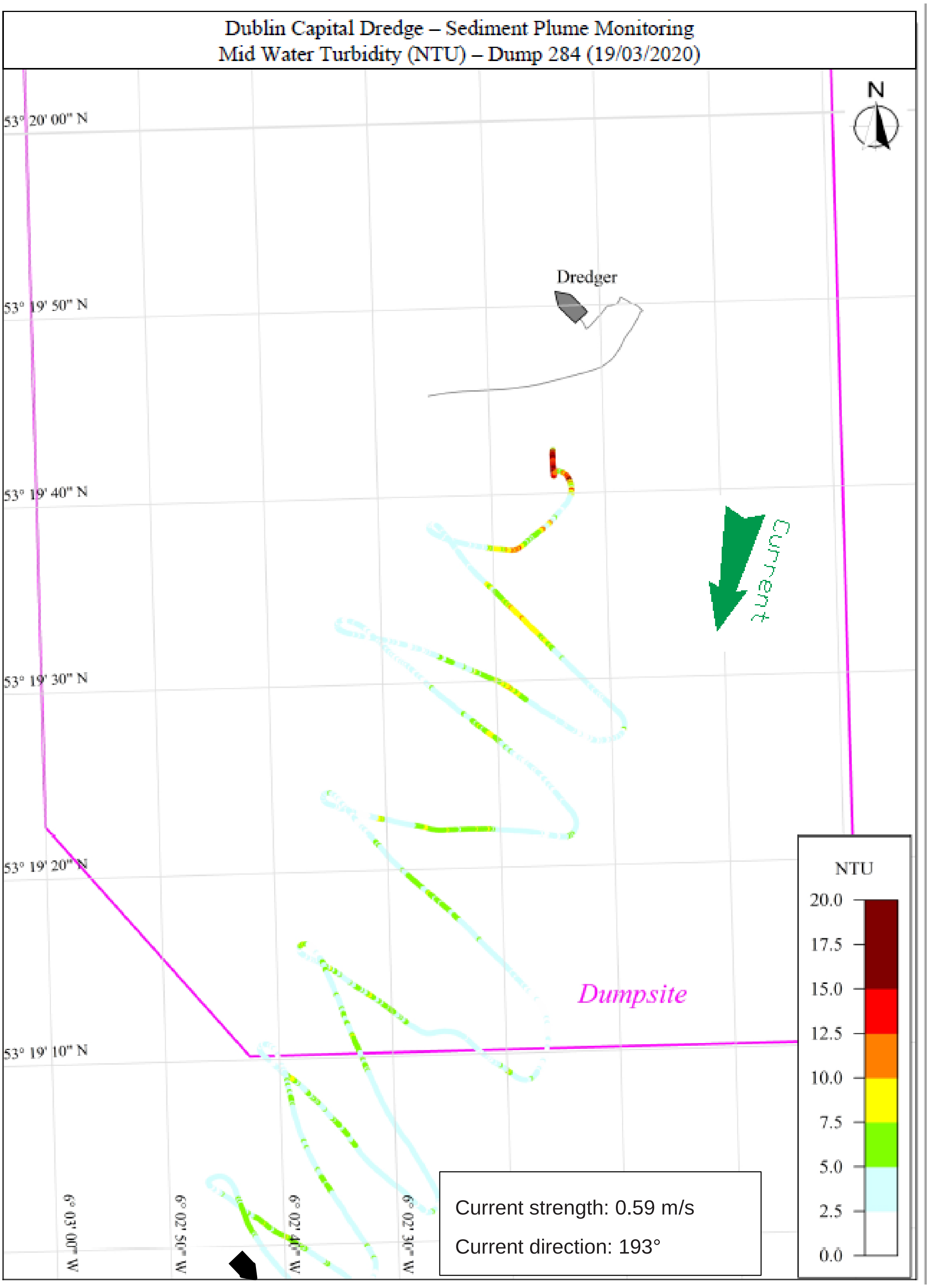


Figure 8.17: Dump 284 Survey track with mid water turbidity [NTU]

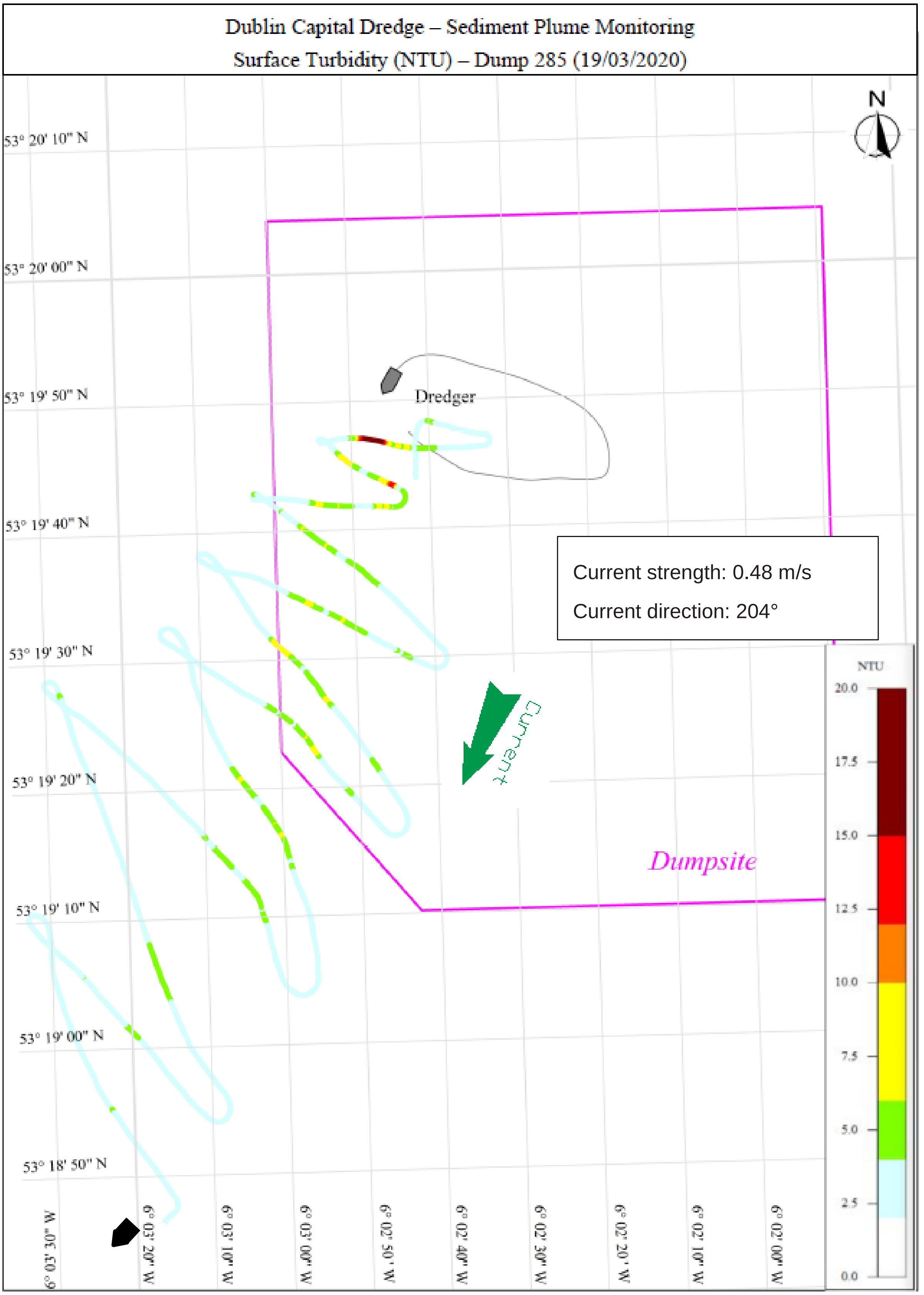


Figure 8.18: Dump 285 Survey track with surface turbidity [NTU]

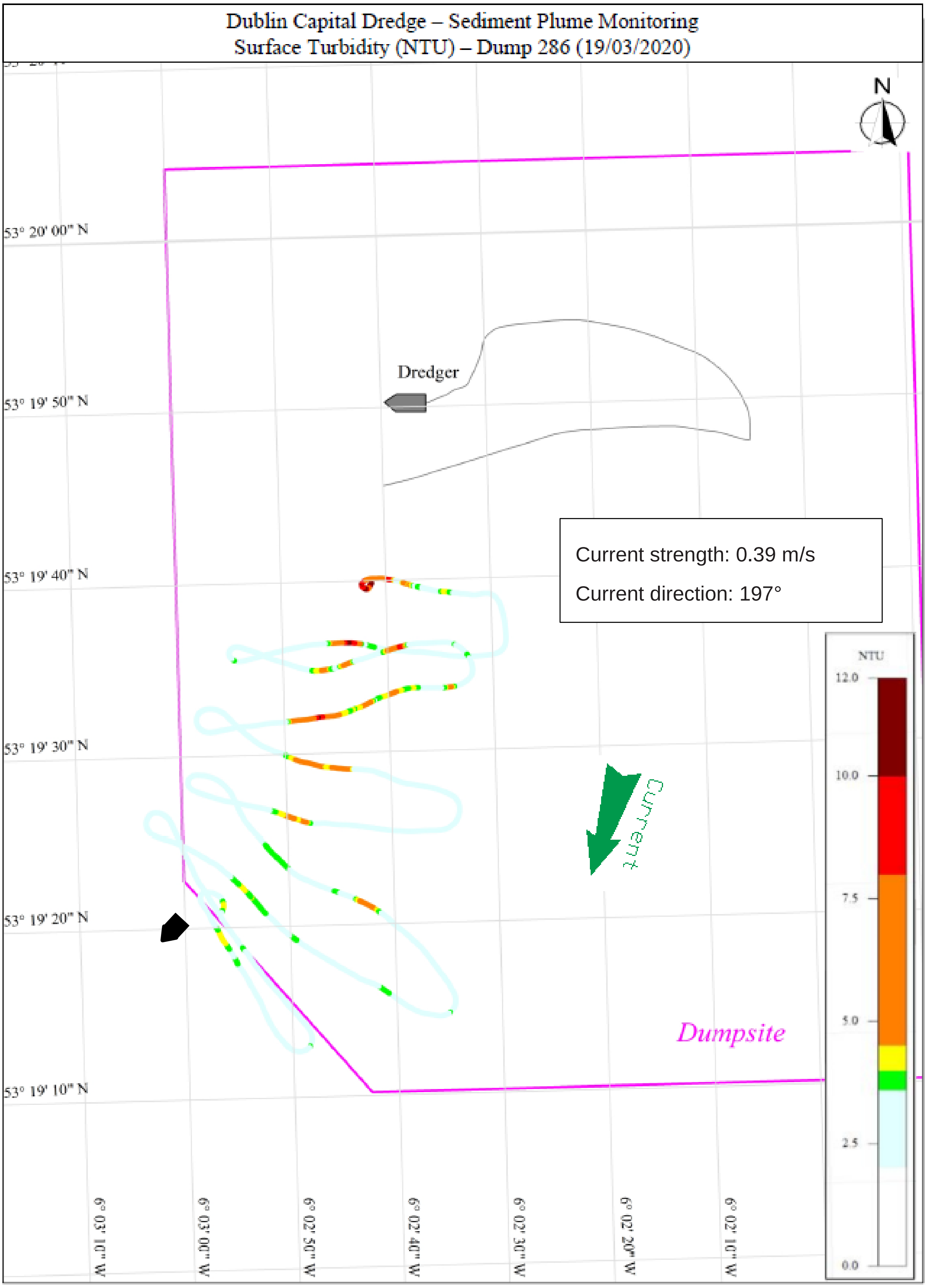


Figure 8.19: Dump 286 Survey track with surface turbidity [NTU]

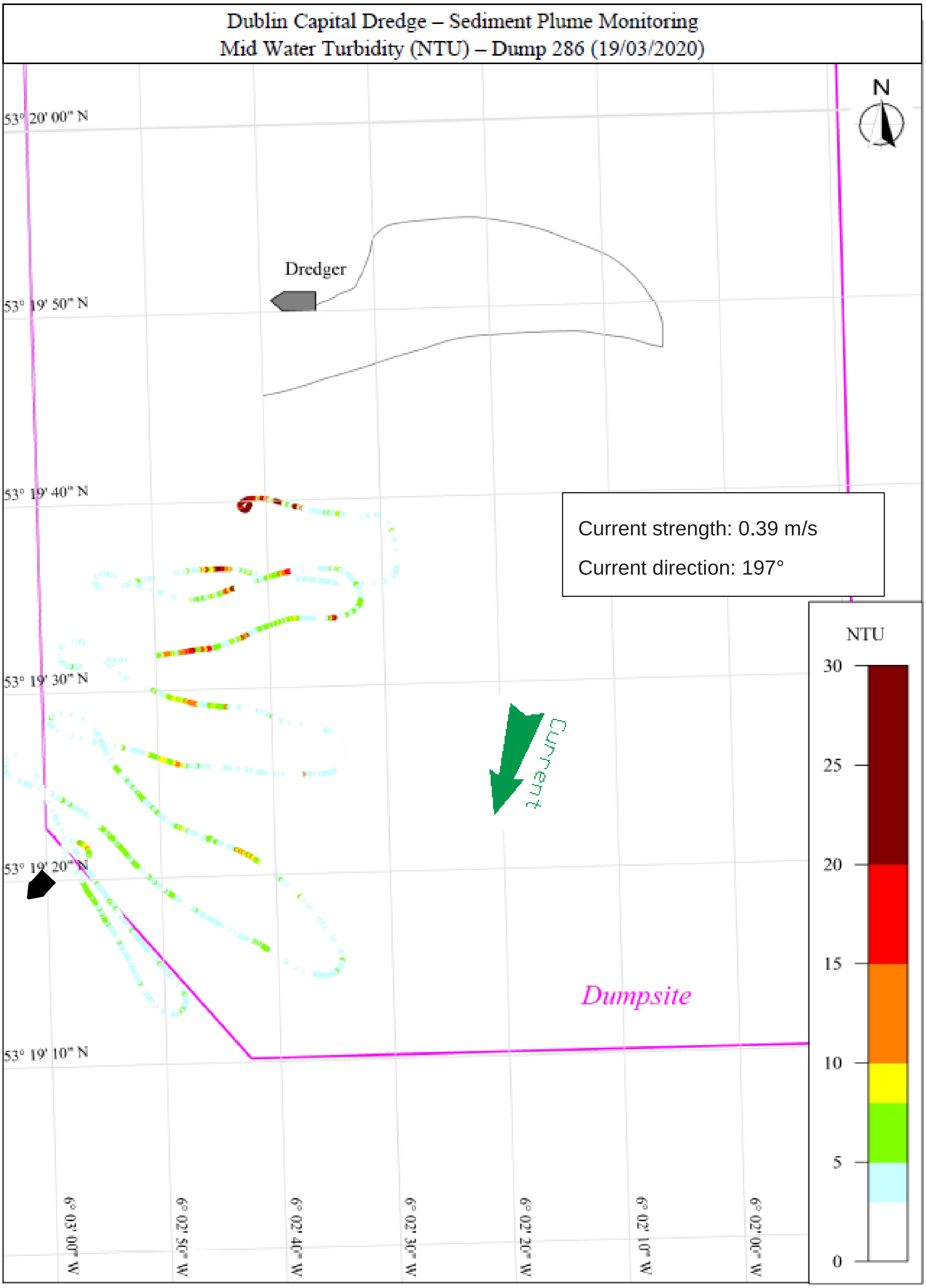


Figure 8.20: Dump 286 Survey track with mid water turbidity [NTU]

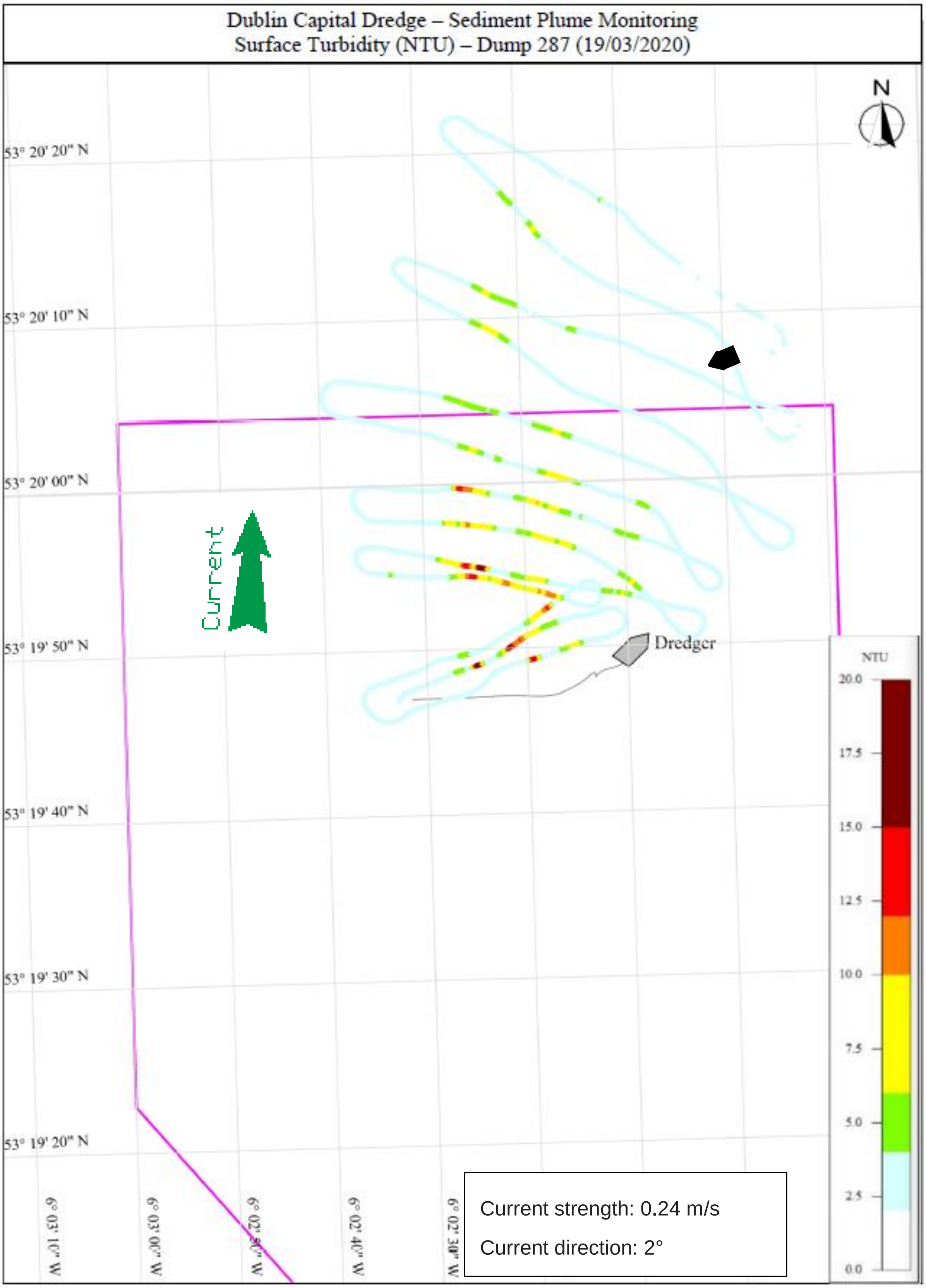


Figure 8.21: Dump 287 Survey track with surface turbidity [NTU]

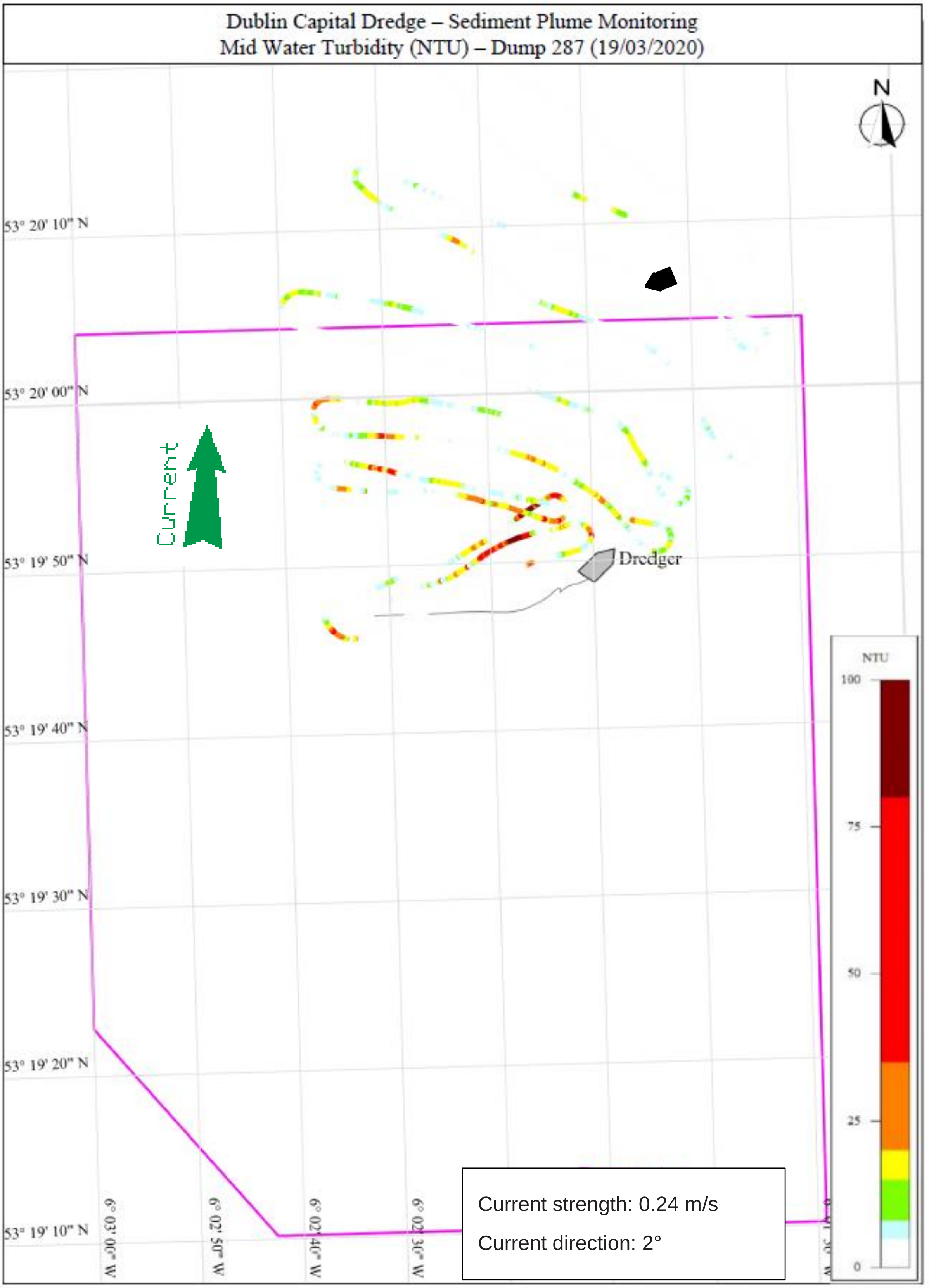


Figure 8.22: Dump 287 Survey track with mid water turbidity [NTU]

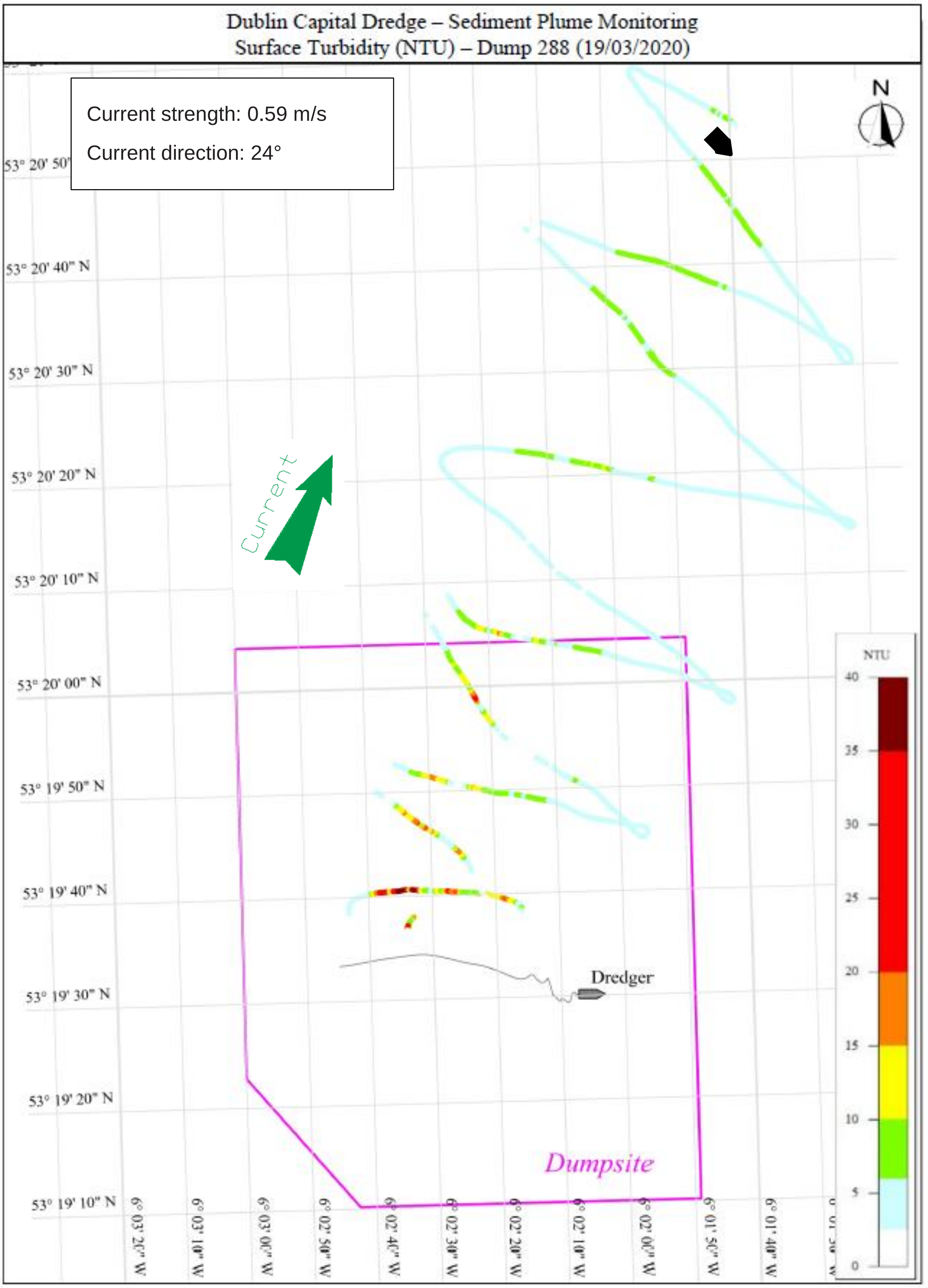


Figure 8.23: Dump 288 Survey track with surface turbidity [NTU]

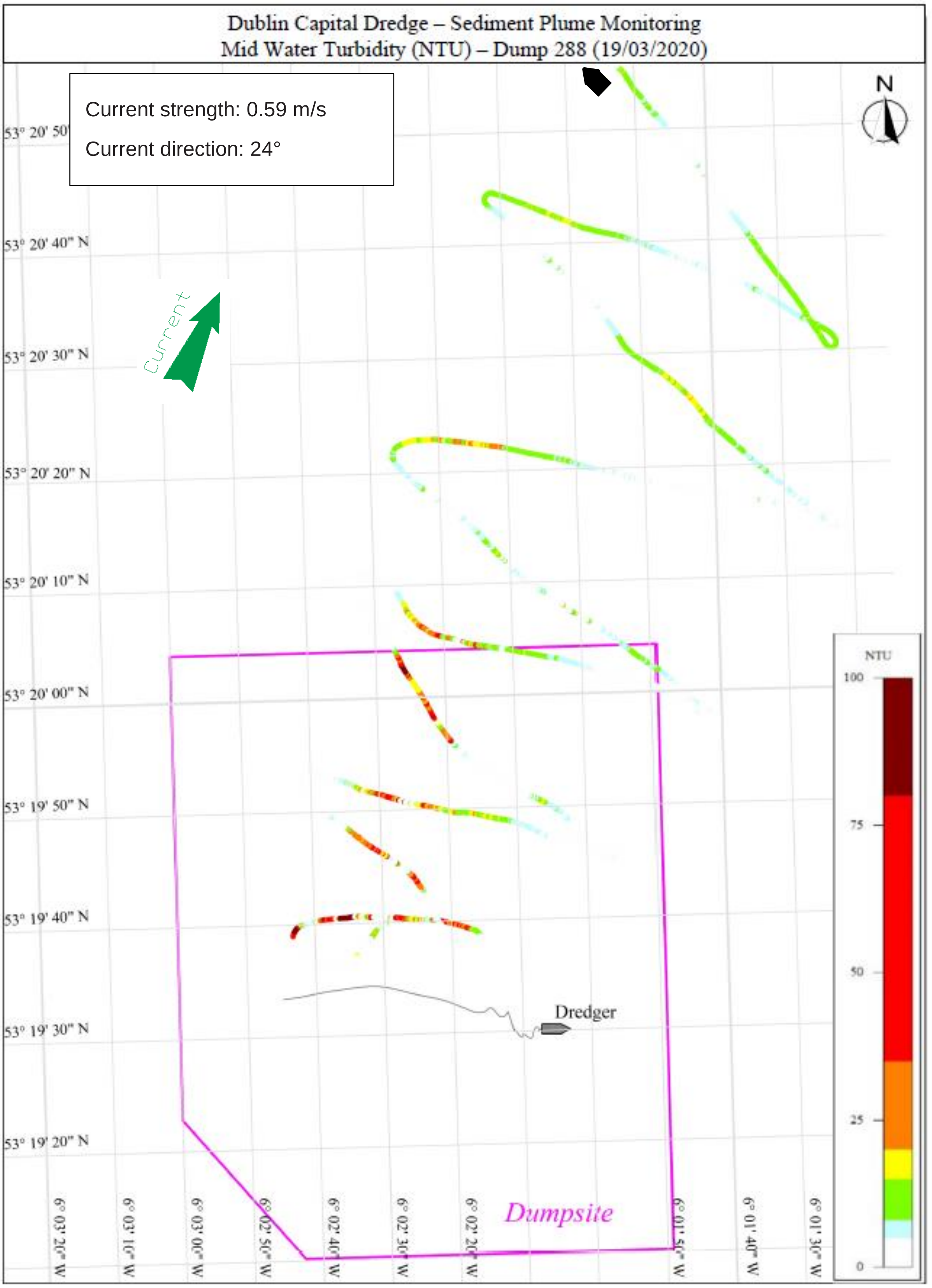


Figure 8.24: Dump 288 Survey track with mid water turbidity [NTU]

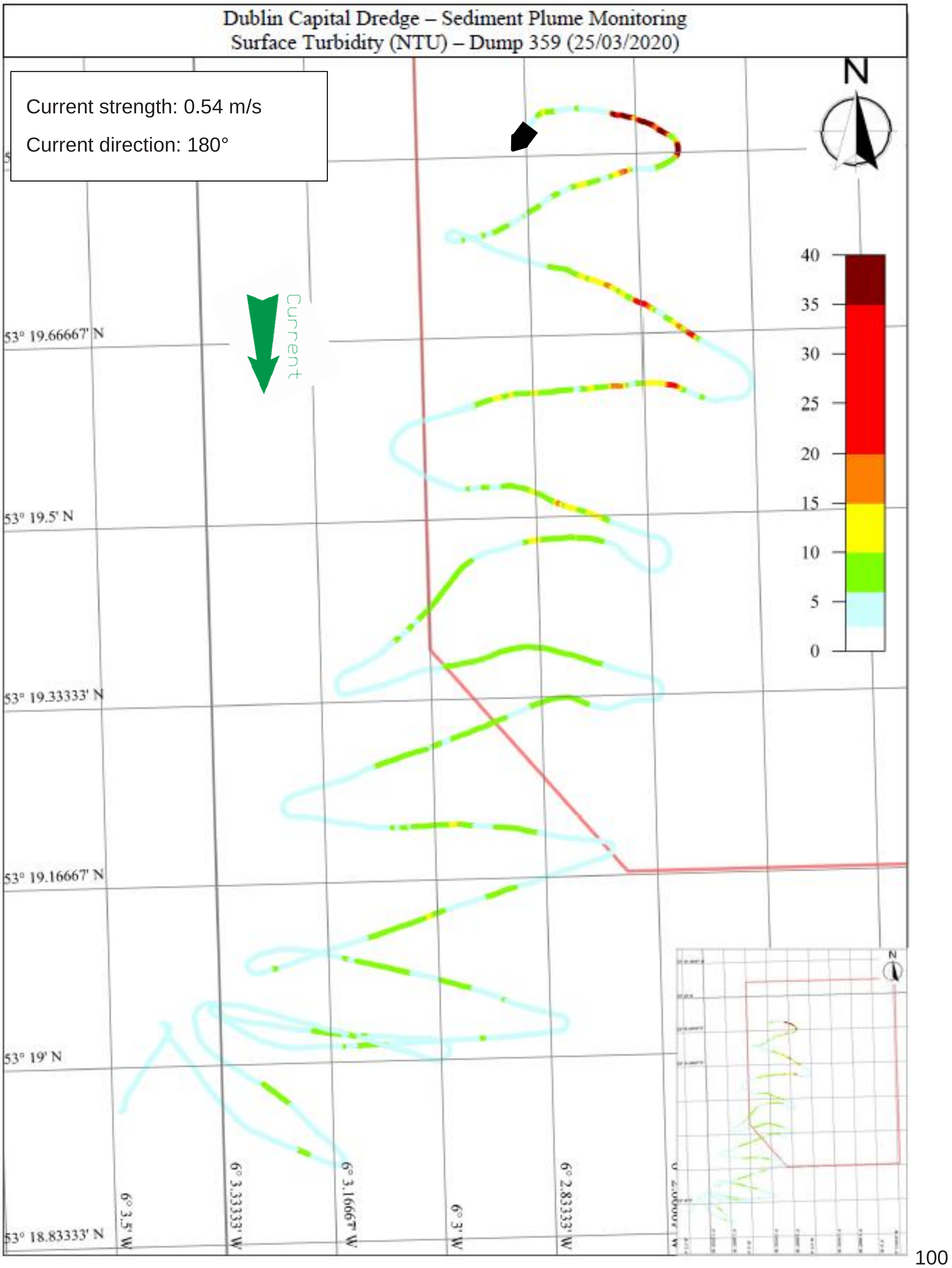


Figure 8.25: Dump 359 Survey track with surface turbidity [NTU]

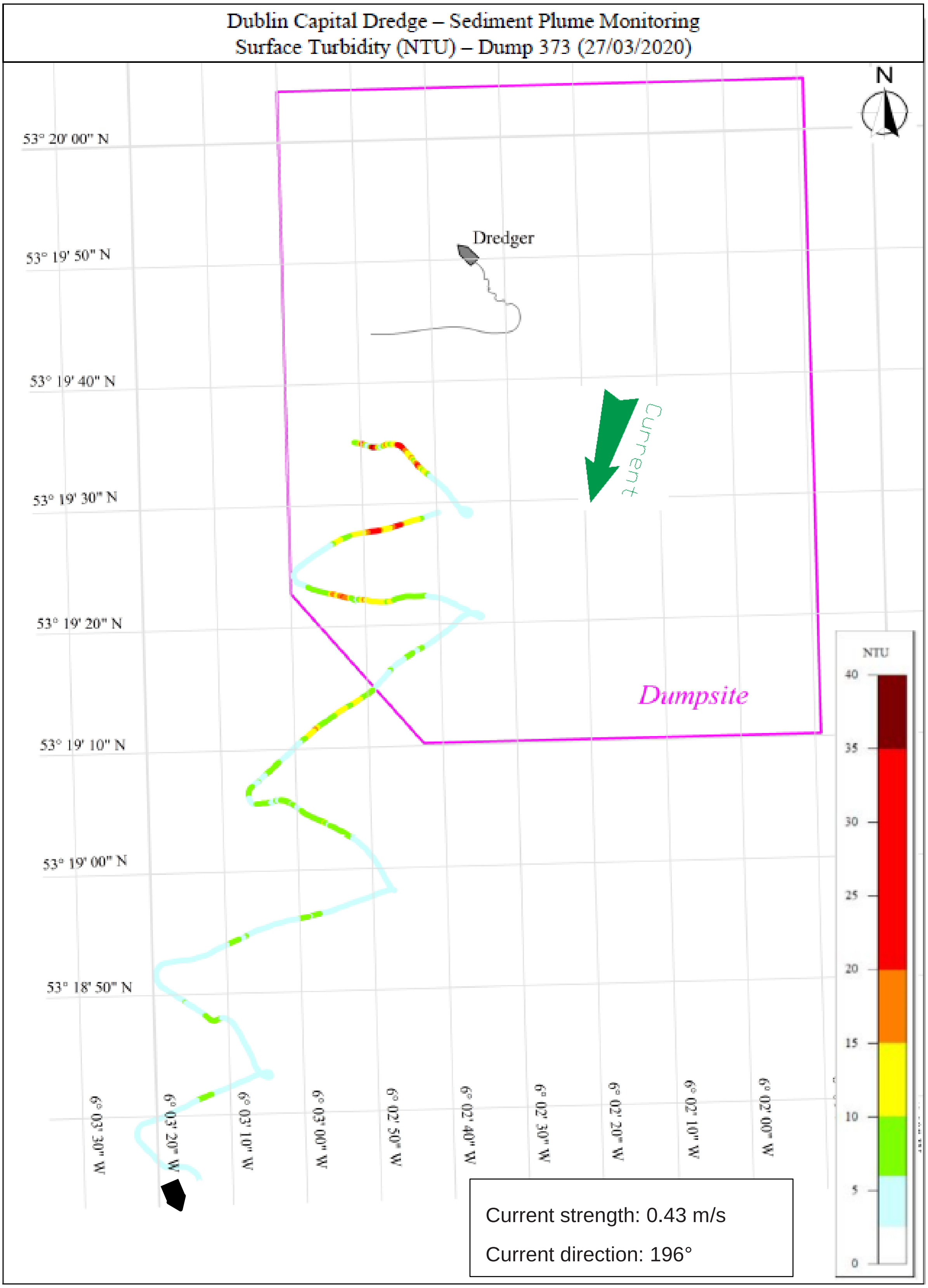


Figure 8.26: Dump 373 Survey track with surface turbidity [NTU]

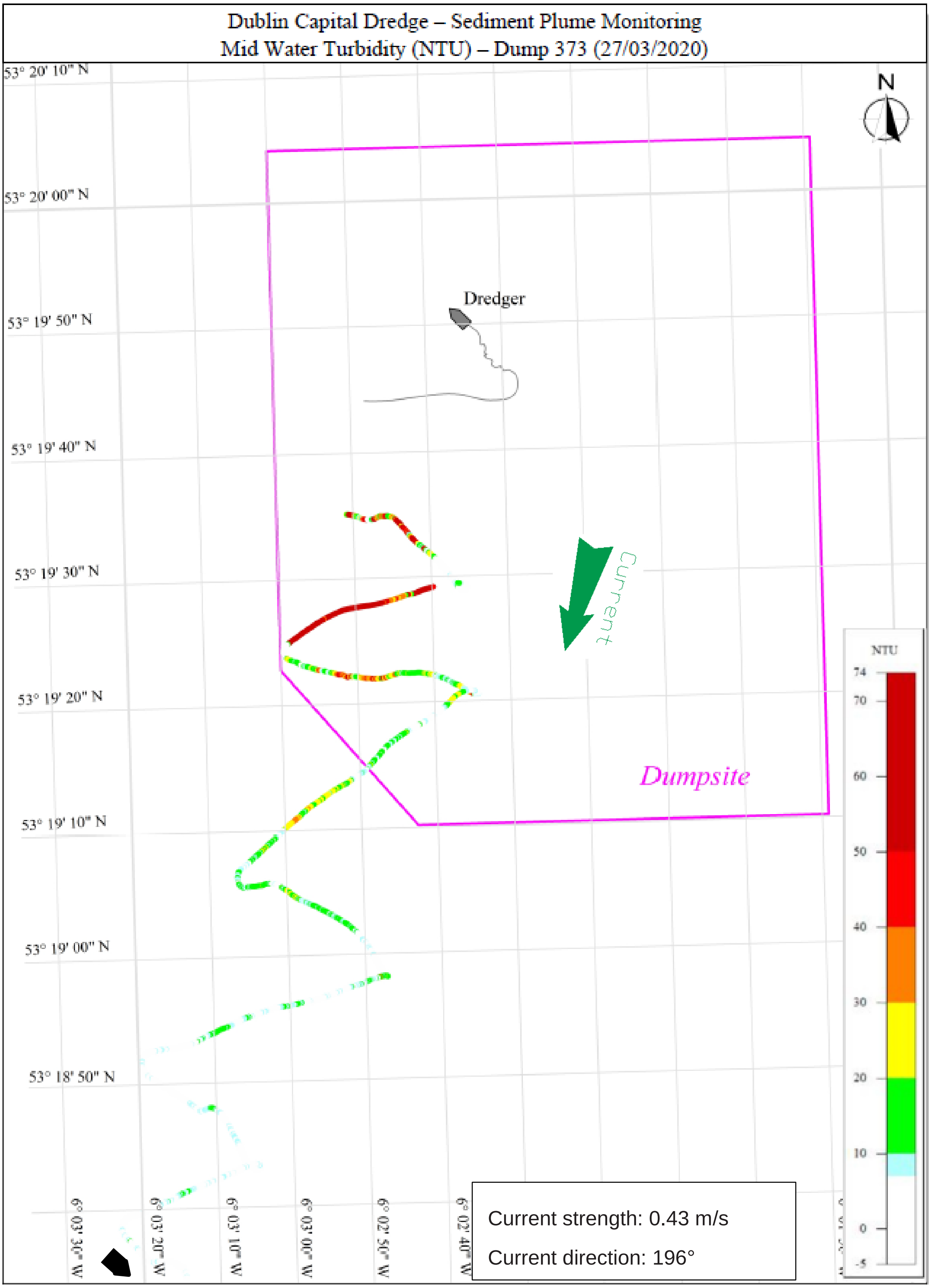


Figure 8.27: Dump 373 Survey track with mid water turbidity [NTU]

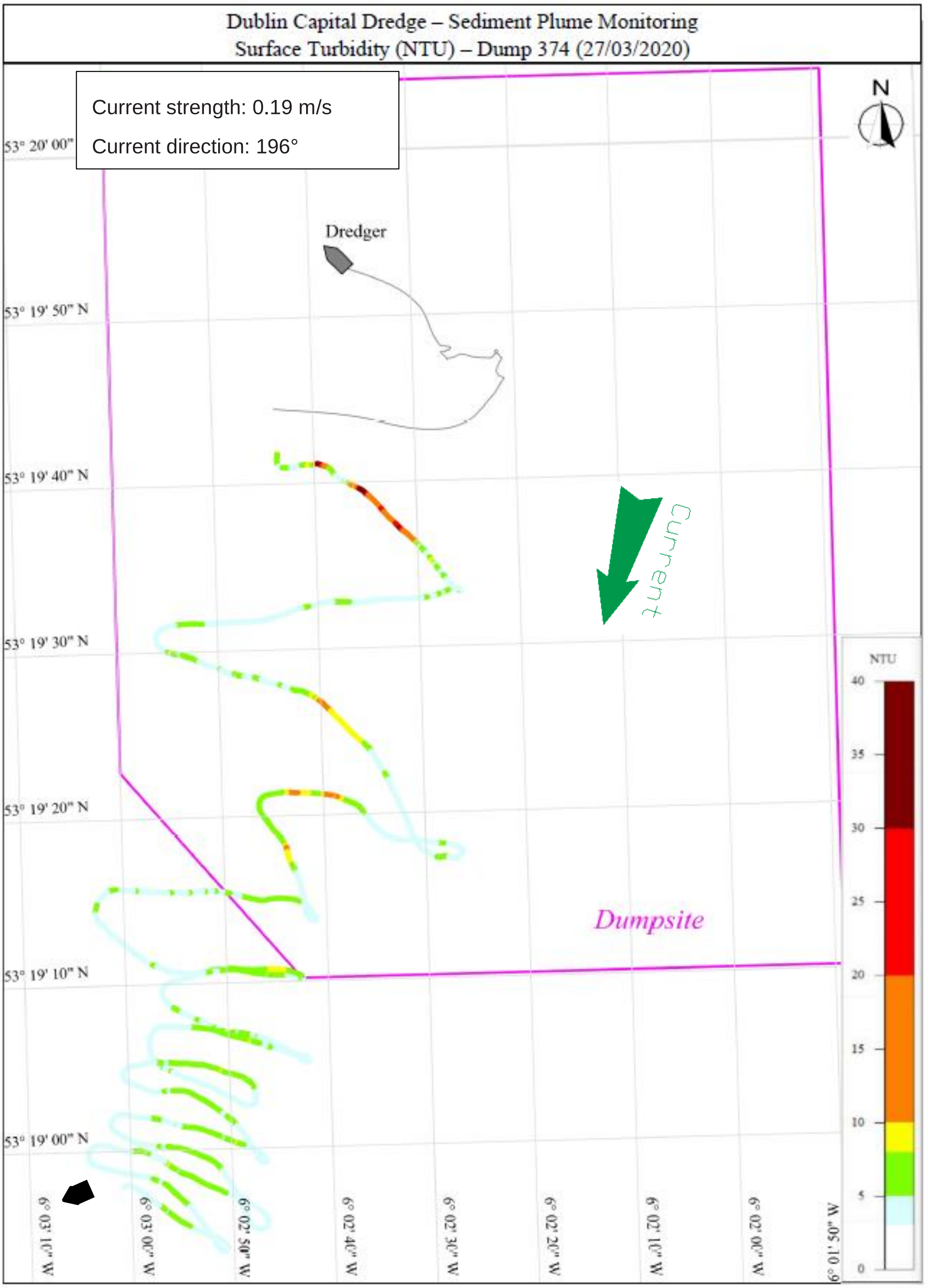


Figure 8.28: Dump 374 Survey track with surface turbidity [NTU]

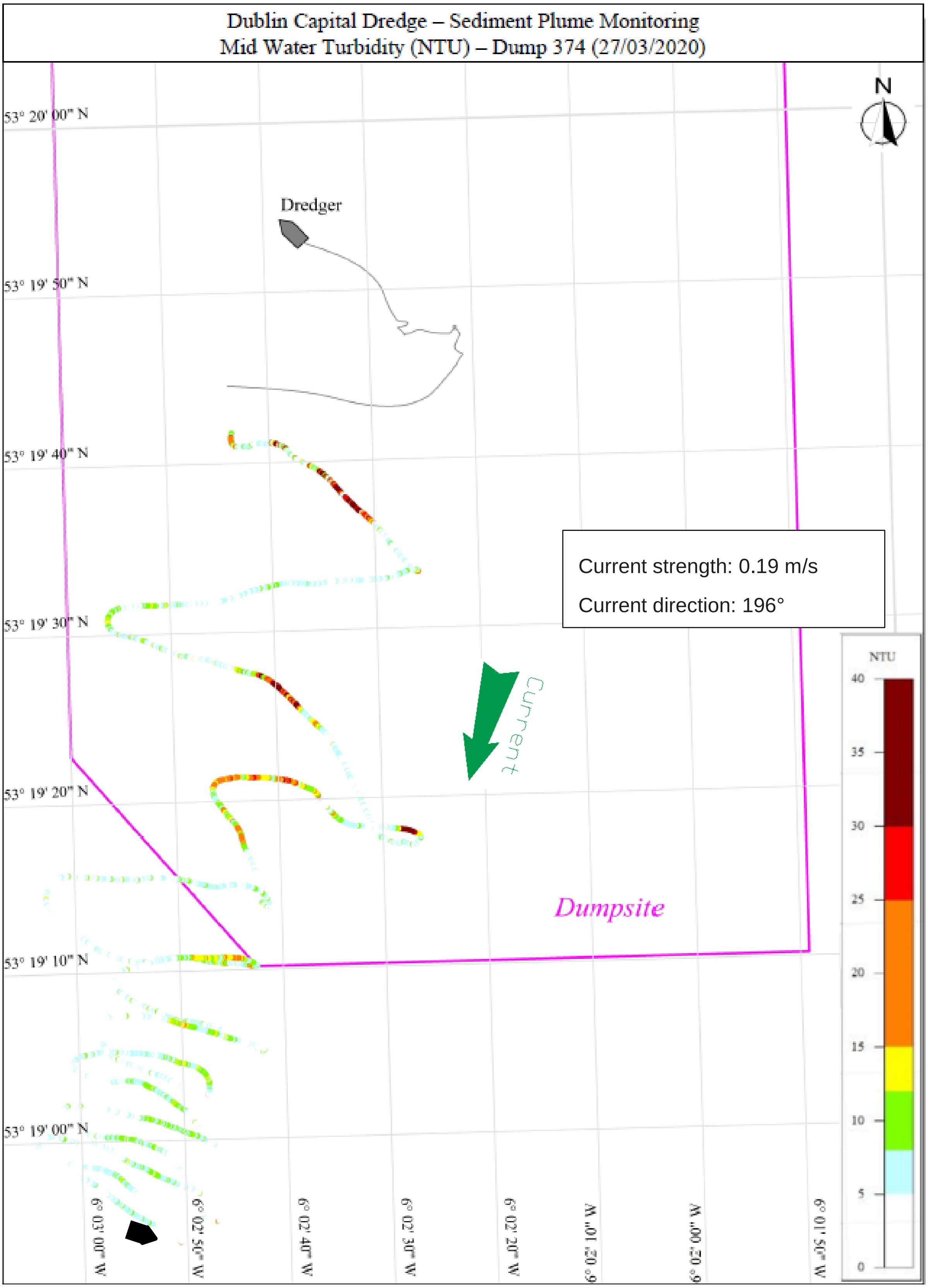


Figure 8.29: Dump 374 Survey track with mid water turbidity [NTU]

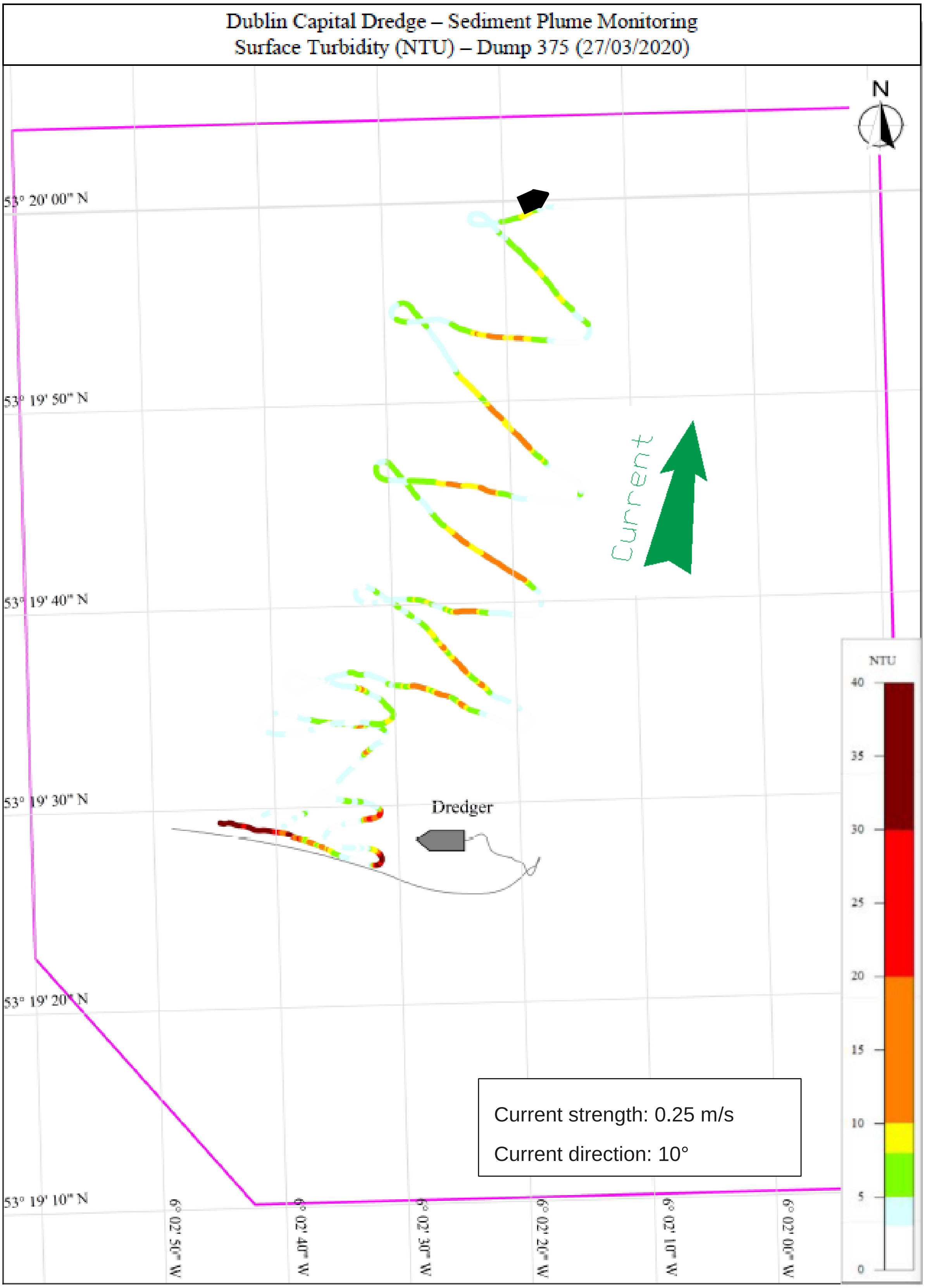


Figure 8.30: Dump 375 Survey track with surface turbidity [NTU]

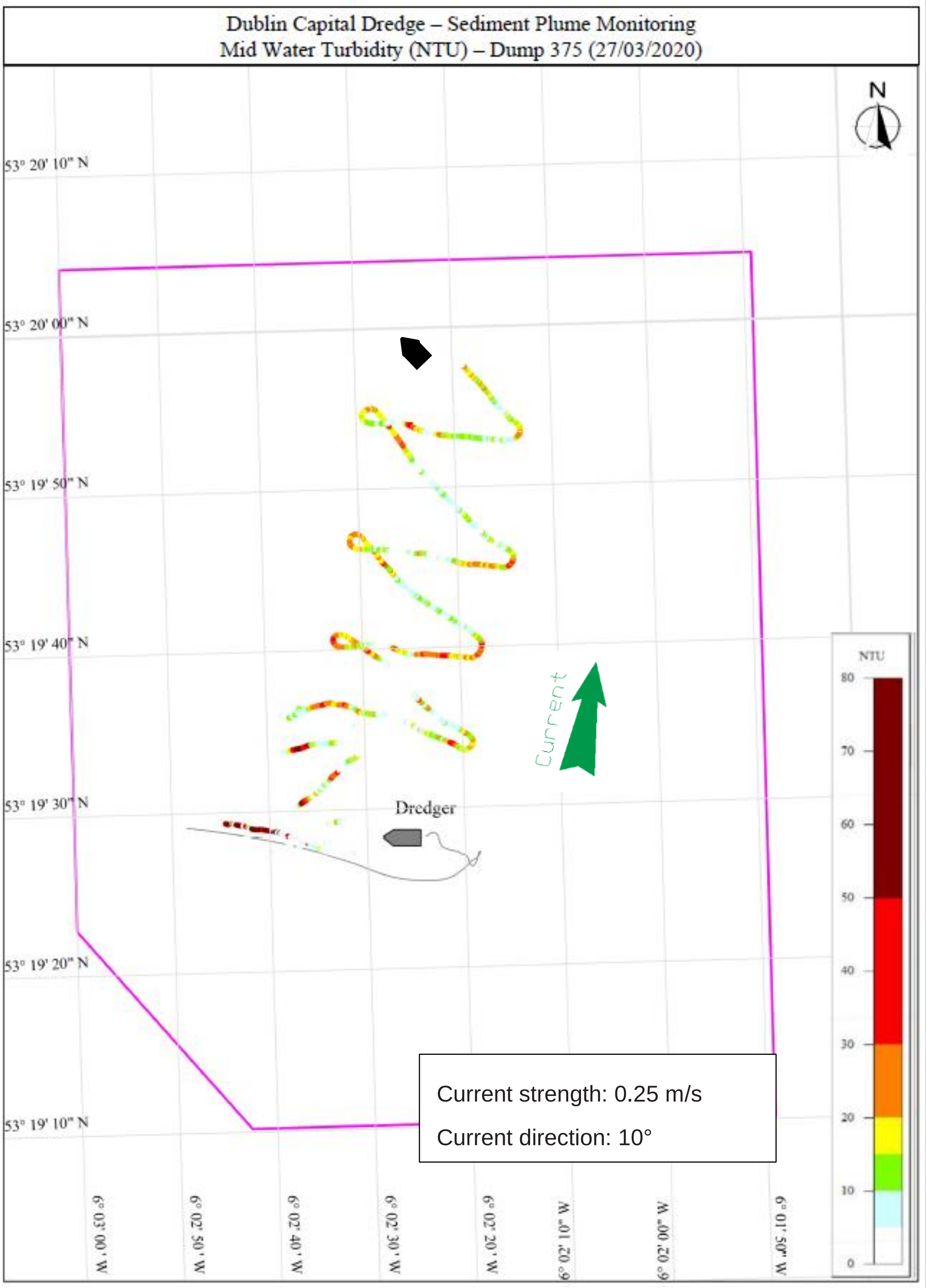


Figure 8.31: Dump 375 Survey track with mid water turbidity [NTU]

A.2 Comparison of Simulated and Recorded Data

In order to supplement the results presented in Section 6.1 and further validate the numerical modelling programme, RPS have produced 1D validation plots for all relevant dump events.

These plots illustrate the depth averaged simulated turbidity levels and actual turbidity levels recorded at the surface and mid-point of the water column as recorded by Hydromaster. It should be noted that each data in these plots have a unique spatial coordinate (i.e. as the survey vessel traversed the dump site) but this element has been omitted so data could be easily presented in one dimensional time series plots.

Table 8.1: Index of sediment plume validation plots for dump events 231 – 375

Date	Dump #	Figure No.
14/03/2020	**231**	Figure 8.32
16/03/2020	**254**	Figure 8.33
17/03/2020	**266**	Figure 8.34
	267	Figure 8.35
	268	Figure 8.36
18/03/2020	**280**	Figure 8.37
	281	Figure 8.38
	282	Figure 8.39
	283	Figure 8.40
27/03/2020	**373**	Figure 8.41
	374	Figure 8.42
	375	Figure 8.43

As demonstrated in Figure 8.32 to Figure 8.43, the computational models accurately simulate the temporal and spatial dispersion of sediment plumes during the dumping activities to a very high degree of accuracy.

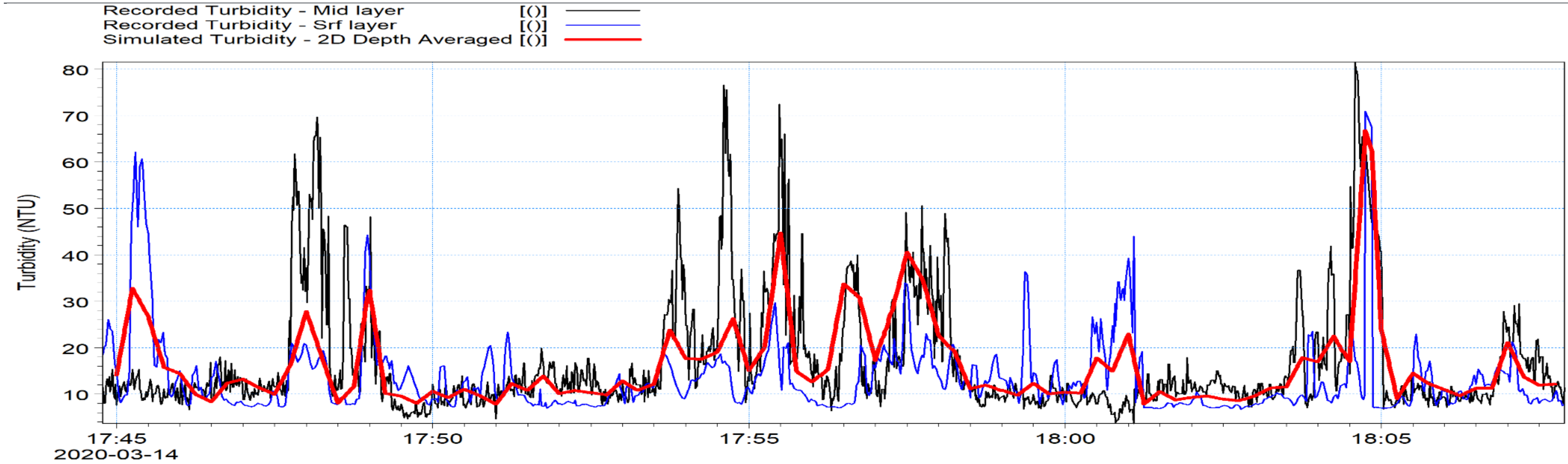


Figure 8.32: Comparison of recorded and simulated turbidity measurements across the dump site during Event 231

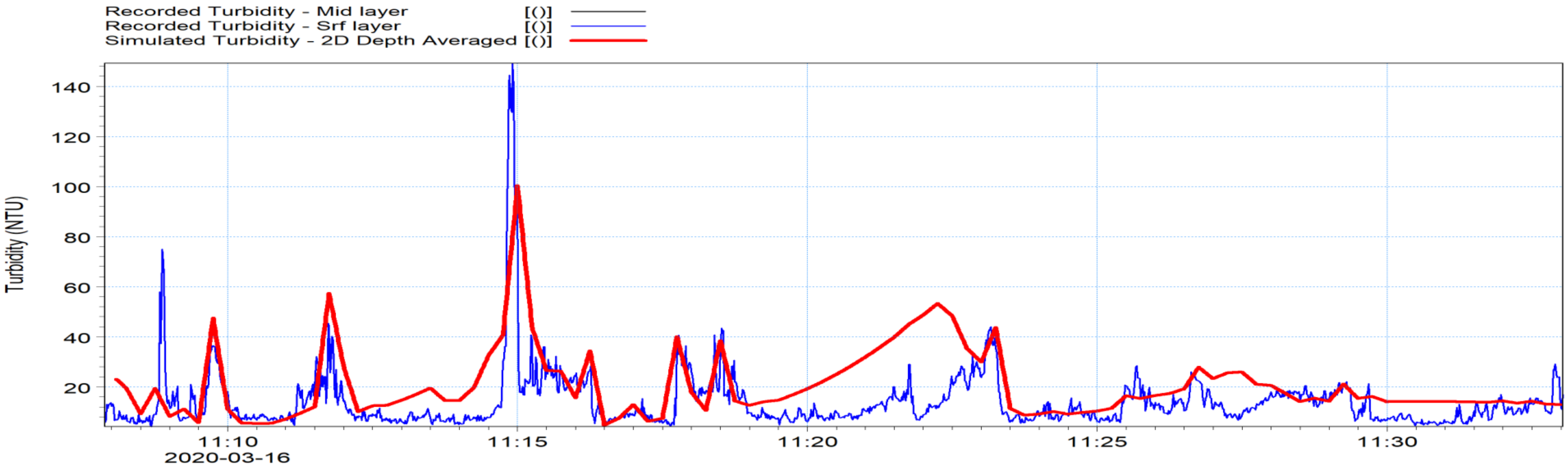


Figure 8.33: Comparison of recorded and simulated turbidity measurements across the dump site during Event 254

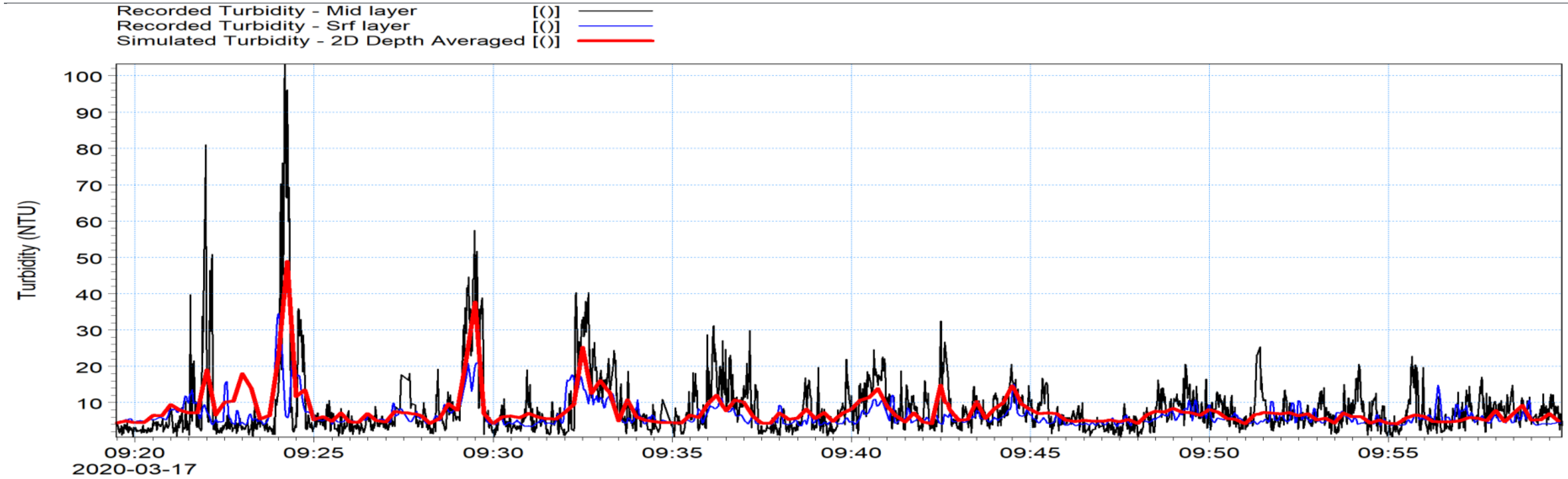


Figure 8.34: Comparison of recorded and simulated turbidity measurements across the dump site during Event 266

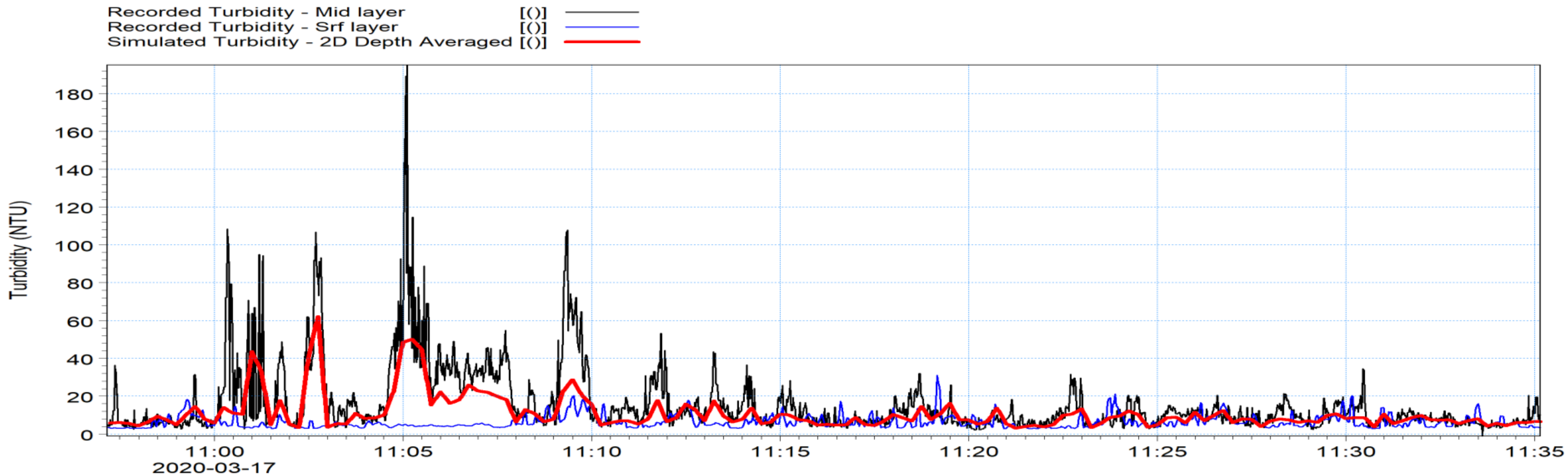


Figure 8.35: Comparison of recorded and simulated turbidity measurements across the dump site during Event 267

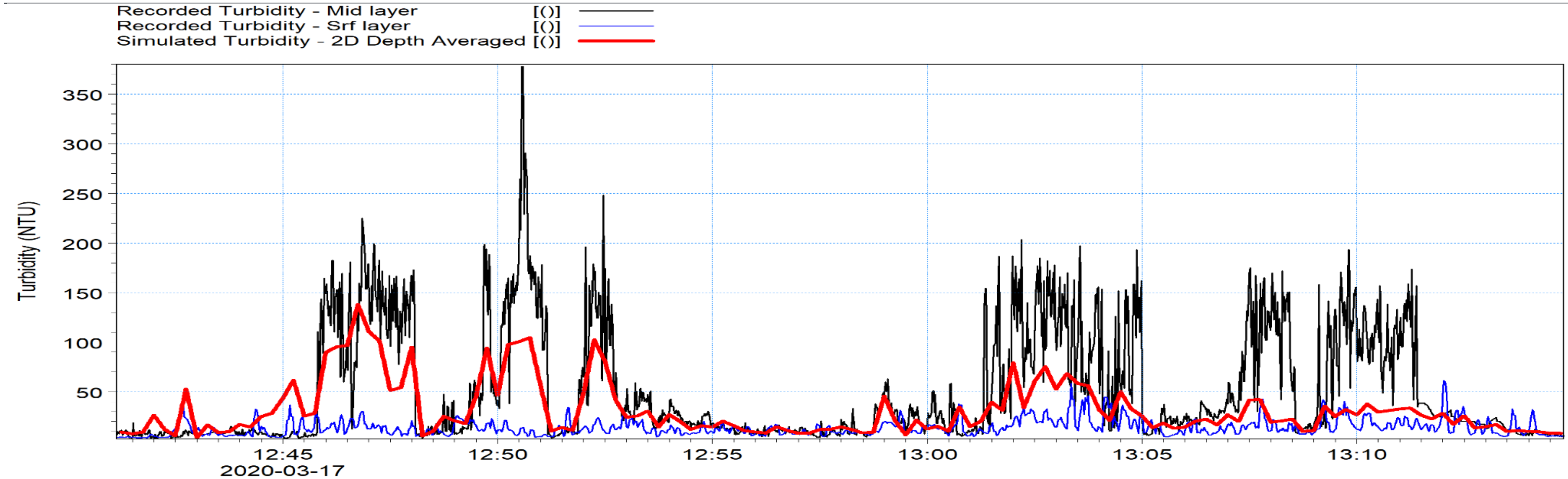


Figure 8.36: Comparison of recorded and simulated turbidity measurements across the dump site during Event 268

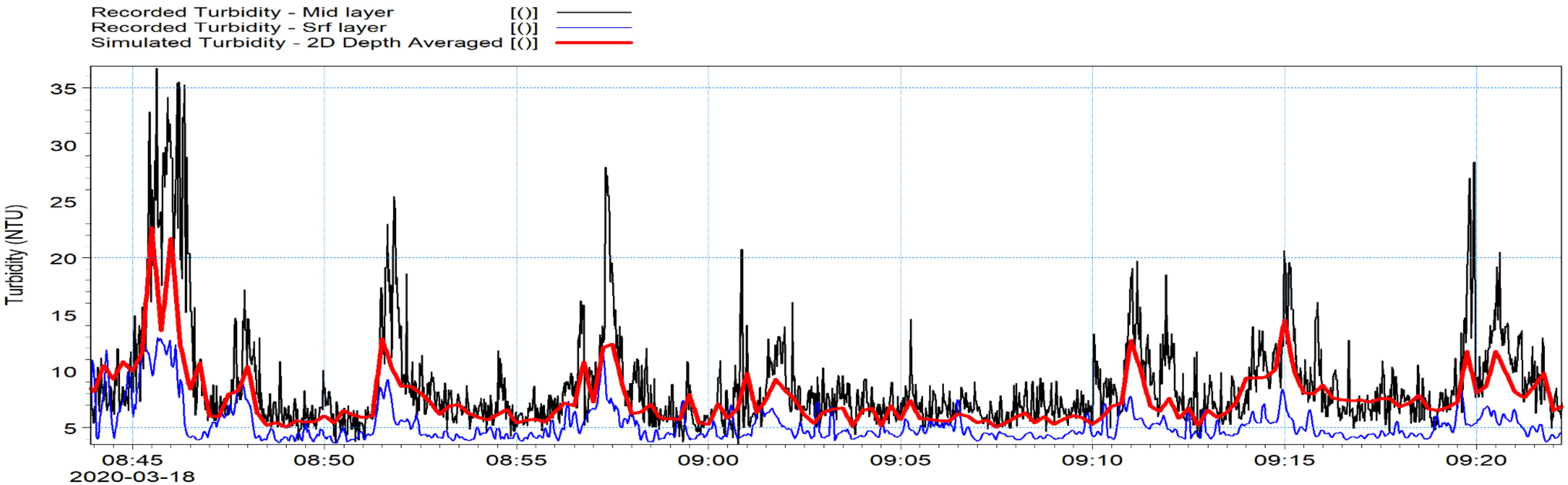


Figure 8.37: Comparison of recorded and simulated turbidity measurements across the dump site during Event 280

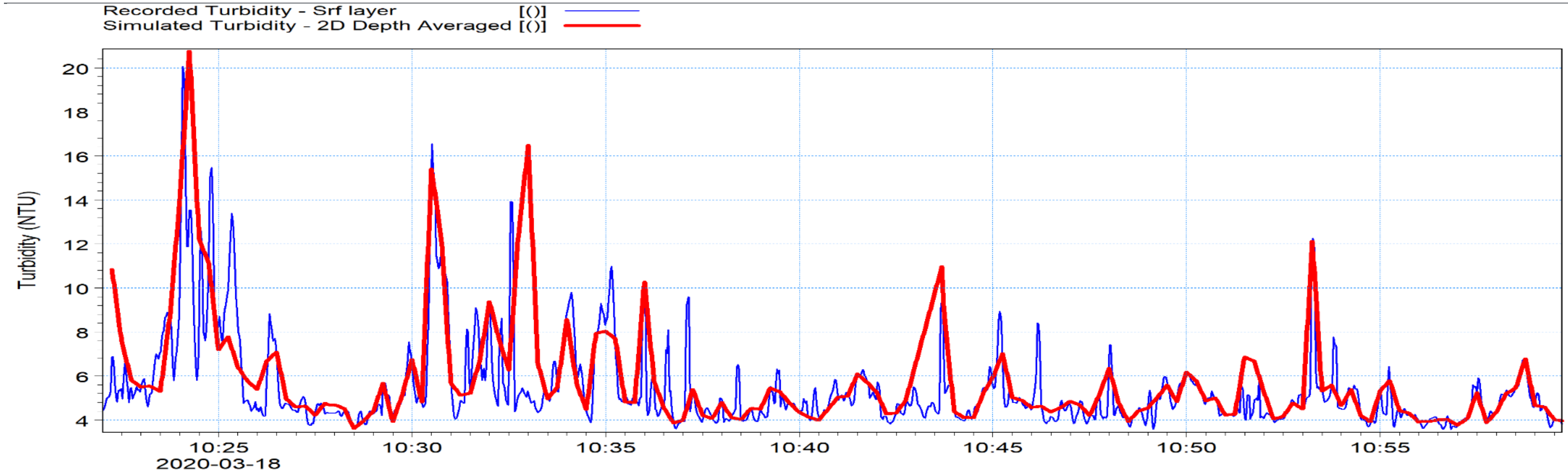


Figure 8.38: Comparison of recorded and simulated turbidity measurements across the dump site during Event 281

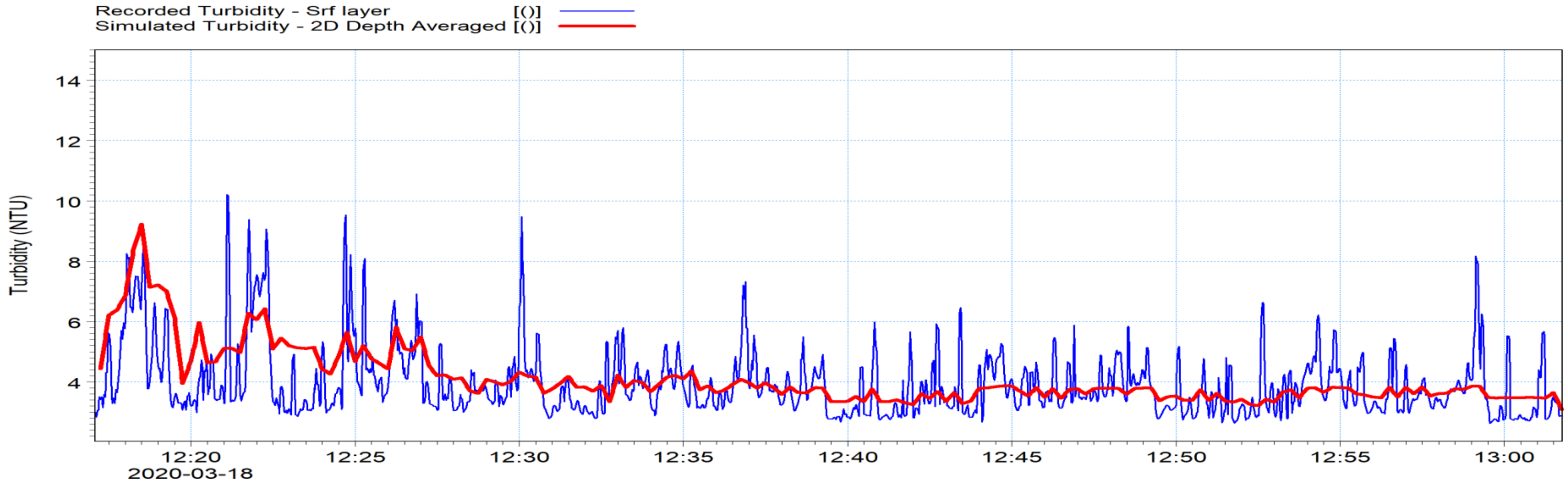


Figure 8.39: Comparison of recorded and simulated turbidity measurements across the dump site during Event 282

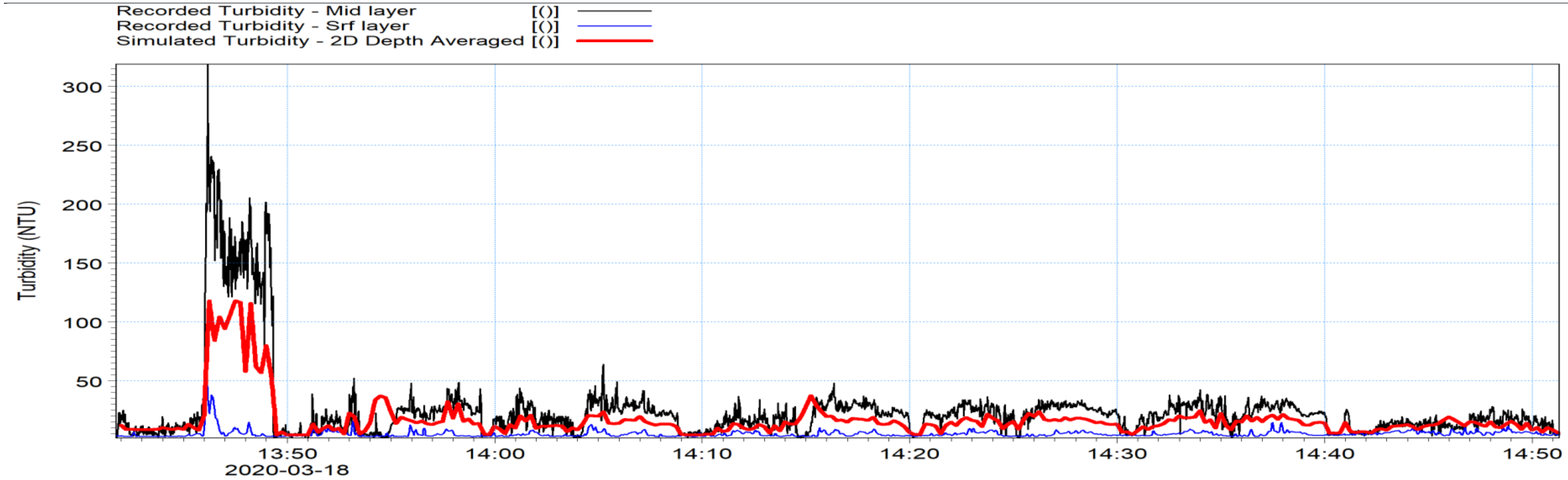


Figure 8.40: Comparison of recorded and simulated turbidity measurements across the dump site during Event 283

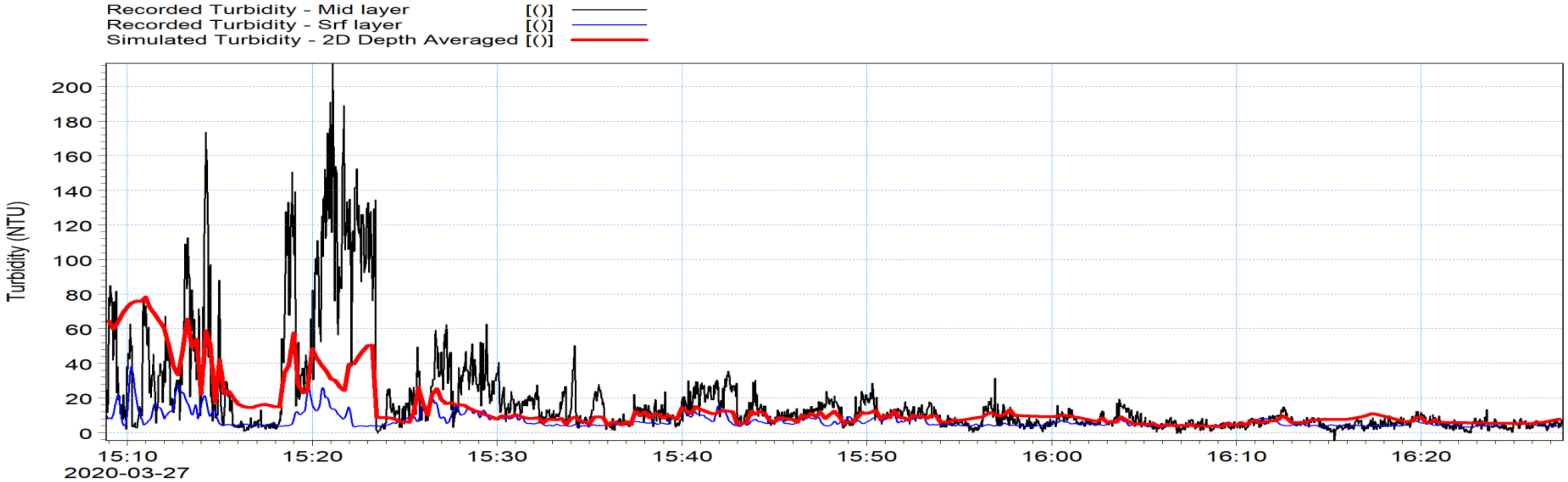


Figure 8.41: Comparison of recorded and simulated turbidity measurements across the dump site during Event 373

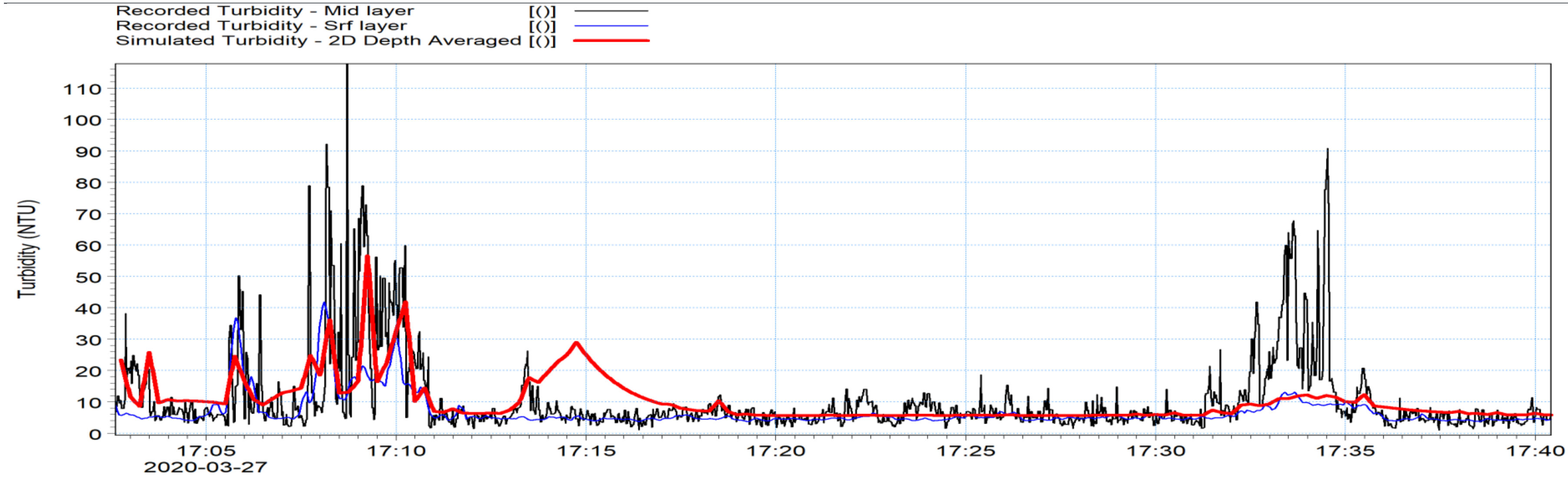


Figure 8.42: Comparison of recorded and simulated turbidity measurements across the dump site during Event 374

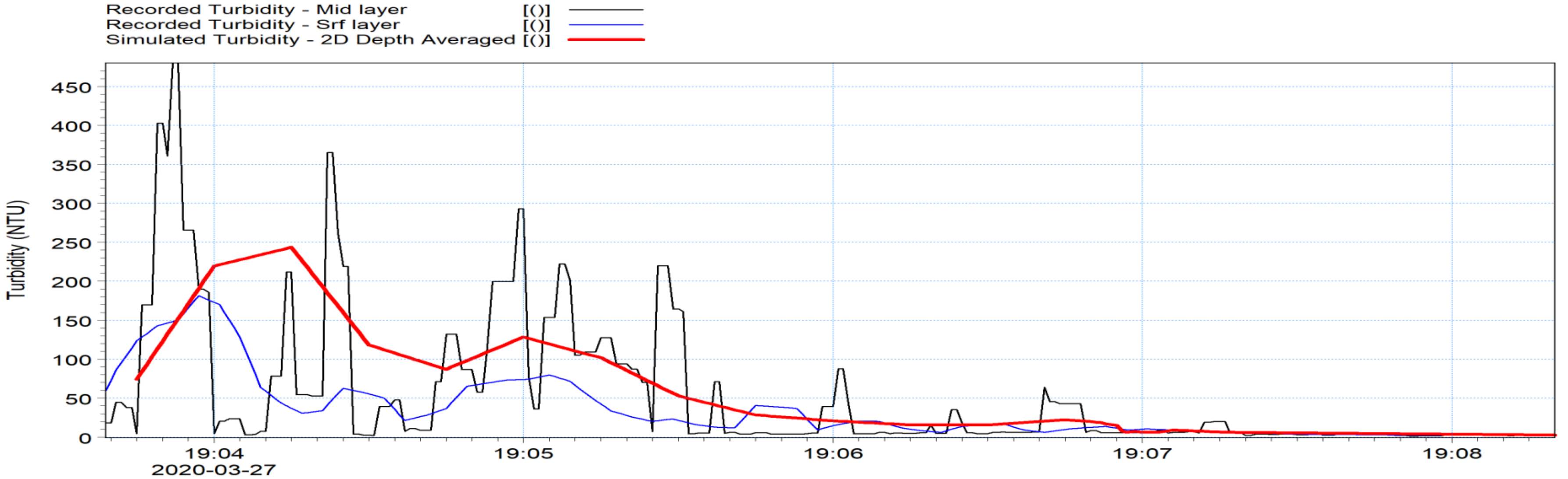


Figure 8.43: Comparison of recorded and simulated turbidity measurements across the dump site during Event 375