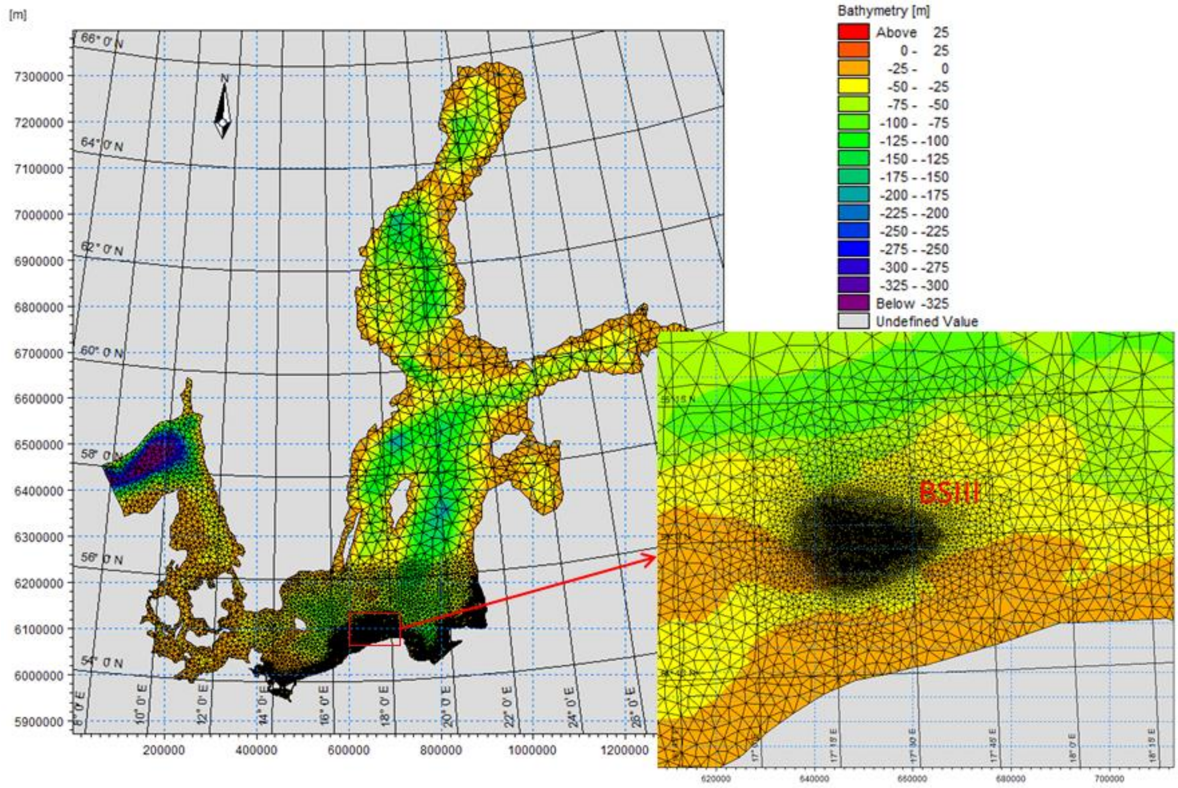
Environmental Impact Assessment of Bałtyk Środkowy III Offshore Wind Farm

Model setup and hydrographic impact assessment for the variant chosen for realisation and the rational alternative variant



Bałtyk Środkowy III Sp. z o.o.

March 2015

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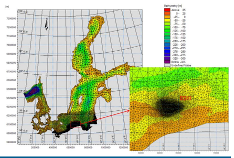

Prepared for Bałtyk Środkowy III Sp. z o.o.

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CONTENTS

LIST OF ABBREVIATIONS

AIS	Automatic Identification System
BANSAI	A MIKE 3 classic hydrodynamic model set-up from 2000 covering the North Sea and the Baltic Sea
BŚ III	Bałtyk Środkowy III
C-MAP	Global Electronic Chart Database provided by Jeppesen Norway
CFSR	Climate Forecast System Reanalysis
(D)	Diameters of Wind Turbines
DNV	Det Norske Veritas
EEZ	Polish Exclusive Economic Zone
Excess concentration	Concentration without background concentration
EIA	Environmental Impact Assessment
FEHY Regional Model	Femarn Hydrodynamic Regional Model
(G)	Gaps between Wind Turbines
GBS	Gravity Based Structure
HBV model	a conceptual distributed hydrological model HBV (Hydrologiska Byroans Vattenbalansavdelning).
HDdkbs	Name of DHI's existing hydrodynamic model of the Baltic Sea
Hm0	Significant Wave Height
Hmax	Maximum Wave Height
Hmean	Mean Wave Height
HVDC	High Voltage Direct Current
ICES area	The International Council for the Exploration of the Sea
IMGW	Institute of Meteorology and Water Management
Mike 21 SW	Spectral Wave Model
Mike 3 Flow Model FM	Mike 3 Flow Model with Flexible Mesh
Mike 3 MT	Mud Transport Model
Mike 3D HD	Hydrodynamic Model
MP	(e.g. Diameter MP)
MSL	Mean Sea level
NCEP/NOAA	National Centers for Environmental Predictions/National Oceanic and Atmospheric Administration
OWF	Offshore Wind Farm
PSU	Practical Salinity Units
PSZW	Pozwolenie na wznoszenie i wykorzystanie sztucznych wysp, konstrukcji i urządzeń w polskich obszarach morskich
RH	Royal Haskoning
MIG	Maritime Institute in Gdańsk
SMHI	Swedish Meteorological and Hydrological Institute
SPM84 formulation	Shore Protection Manual (1984) formulation
SWdkbs	A Short Wave spectral model set up in relation to the Femarn Belt project
Tm02	Wave Period
Tp	Peak Period
TP	(e.g. Weight TP)
TTS	Temporary Loss of Hearing
u	Horizontal Velocity
UNESCO	United Nations Educational, Scientific and Cultural Organization
Vejr2 A/S	Name of a commercial Meteorological Weather company
v	Vertical Velocity
WAMIT	A modelling tool by MIT for wave interaction assessment http://www.wamit.com/index.htm
WRF model	The Weather Research and Forecasting Model

1 Non-technical summary

This report focuses on hydrography and comprises a description of the applied hydrographic models, a description of baseline conditions and an impact assessment in relation to construction of the BŚ III offshore wind farm some 23 km north of the Polish coast.

The approach has been to use intensive measurements done by Maritime Institute Gdansk (MIG) to setup and calibrate a numerical model. Subsequently the model has been used to provide important input to the habitat assessment in relation to bird surveys during the period June 2013 through February 2014. The numerical model was also used to predict future impacts of the wind farms both hydrodynamically, and with regards to spillage. In order to model the potential impact of the turbines with respect to currents and waves it is required to establish a baseline. In the present context the baseline condition is the reference hydrographic year used for making the impact assessment.

The analysis of the impacts in the operational phase has primarily been carried out as a comparative study, where the impacts of the wind turbines are parameterised and included in the numerical models and the impacts are evaluated by comparing the ‘before’ and ‘after’ situation. The impacts in the construction phase such as sediment spill due to dredging operations have been analysed by simulations of the spill based on experience from similar projects. Impacts in the decommissioning phase on the hydrographic conditions are considered insignificant but potential issues will be assessed.

The assessment has been carried out by considering the hydrographic worst case scenario with regard to the design of the wind farm. Scoping indicates that gravity based structures represent the overall worst case for the variants chosen for realization and for the rational alternative variant. No significant differences between monopiles, tripod and Jacket are expected.

The expected effects of the wind farm on the hydrodynamic conditions are minor. Current velocities in the area are in average 0.1-0.2 m/s but can reach up to around 0.5 m/s. The additional flow resistance caused by the wind farm results in small reductions in the current speeds within and downstream the wind farm. Reductions to the current speeds larger than 2% compared with the existing conditions are limited to an area within the BŚ III wind park area only. The mean velocity changes are, however, very small; at the surface they were found to be in the order of 0.001 m/s.

The impact on the wave climate is likewise considered to be minor only. Waves are typically wind generated waves limited by the distance to land areas and duration of the wind field. During the operational phase, the wind farm will cause part of the wave energy to be reflected or diffracted around the foundations and the towers. The wave dampening due to reflection / diffraction will be small. The overall changes to the wave field are small and only insignificant changes near the coast of Poland are expected.

Analysis of sedimentation and spreading of the sediments due to dredging activities connected with earthworks during the construction phase has been carried out. It is found that during the construction phase concentrations of suspended sediment will not exceed 10 mg/l at the sea bed outside the windfarm, which is within the range of the natural variation in the background concentration in this area. The resulting deposition was calculated to be less than 3.5 mm in the project area.

2 Introduction

In this report we present the results from hydrographic modelling of baseline conditions and the impact assessment for the **variant chosen for realization** and for the **rational alternative variant,** respectively (applying a worst case scenario) for the offshore wind farm project BŚ III.

2.1 Background

Bałtyk Srodkowy III Sp. z o.o. plans to develop the offshore wind farm Bałtyk Środkowy III" in the Polish Exclusive Economic Zone of the Baltic Sea. For this purpose an Environmental Impact Assessment (EIA) is required. DHI has been commissioned to assist in the EIA with regards to:

- hydrographics and sediment spillage
- marine mammals
- noise
- birds

The environmental impact assessment has to be based on the **variant chosen for realization** and for the **rational alternative variant,** respectively and in first instance on a “worst case“ scenario for the identification of potential significant impacts. The selection of assessed technical solution thus varies depending on the environmental factor. E.g. from a marine mammal perspective monopile foundations could cause the highest potential impact whereas gravity foundations are thought to be the worst case solution for sediment spreading.

The present report contains the EIA for hydrography (defined as hydrology by the customer and the EIA consultant MIG). The final EIA shall be produced based on a comprehensive baseline study carried out by Maritime Institute in Gdańsk, department of operational oceanography, the numerical modelling that is presented here and under input from the client (the design specifications for the variant chosen for realization and for the rational alternative variant, respectively) and on the basis of a High Level design study from Royal Haskoning (RH). In this project the main focus is on Bałtyk Środkowy III but cumulative effects from other projects implemented or planned in the South-Eastern part of the Baltic Sea are included.

The project “Bałtyk Środkowy III” is situated outside the borders of Polish territorial waters, approximately 23 km from the shore (Figure 2-1).

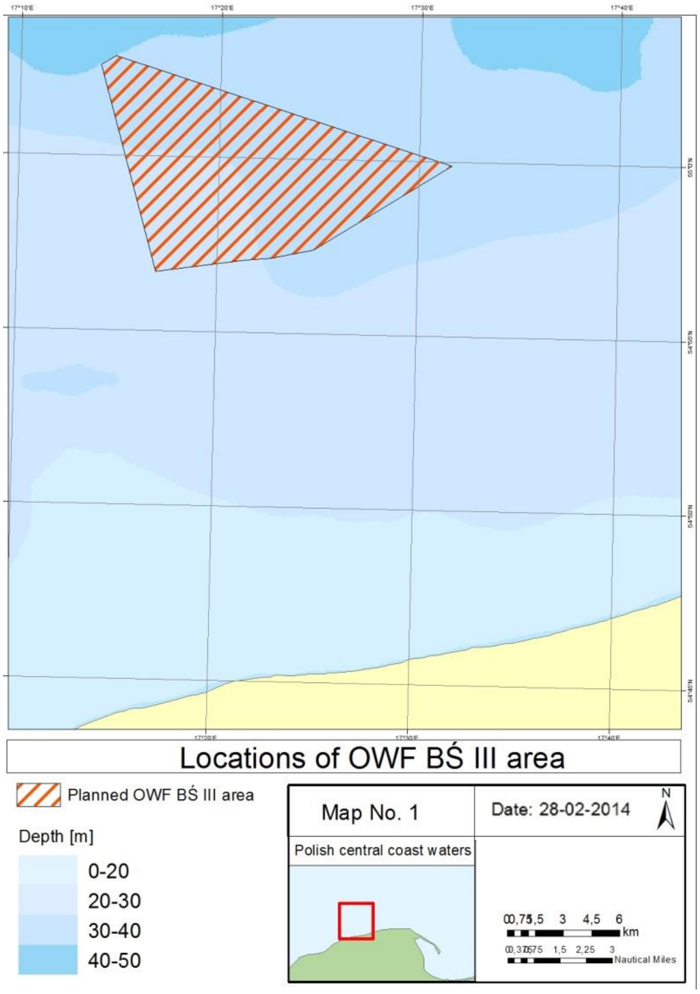


Figure 2-1 Location of the planned OWF "Bałtyk Środkowy III" area

The total area available to construct the wind farm is approximately 89 km^2 for the variant chosen for realization (120 turbines) and for the rational alternative variant (200 turbines). All turbines are interconnected and a land cable provides the wind farm connection with land.

2.2 Content of specific report

The present report focuses on hydrographic and wave conditions as well as spillage of sediment during construction. The purposes of the hydrographic modelling are:

- To establish an area covering baseline conditions with respect to waves, currents, salinity and water temperature
- To assess permanent hydrodynamic impacts of the proposed wind farm location and the temporary and permanent impacts during dredging. In this context permanent effects are the effects after the windfarm has been put into operation and temporary effects are the effects during construction
- To assist in the identification and distribution of suitable habitats for marine mammals and water birds (temporal and spatial distribution of e.g. saline fronts, currents, depths etc.)

In the present context the hydrographic conditions comprise waves, currents, water levels, salinity and sea temperatures. In addition, the hydrographic conditions comprise spreading of sediment spills during dredging operations.

The hydrographic conditions such as the flow conditions (currents, salinities and temperatures) and the wave field will be affected by the foundations which affect the flow and the waves as the foundations and the towers act as an extra resistance to flow and waves.

Water quality is closely linked to the hydrographic conditions and any impacts on hydrographic conditions may affect the water quality parameters such as oxygen levels. Water quality is also influenced by dredging operations during the construction phase. The dredging operations will unavoidably cause sediment spill which again may influence benthic habitats and benthic fauna. Water quality and habitat issues are, however, not covered by the present report.

The report describes the model setup and validation, the baseline study and the environmental impact assessment. In the present context the baseline condition is the reference hydrographic year used for making the impact assessment. The analysis of the impacts in the operational phase is primarily carried out as a comparative study, where the impacts caused by the wind turbines are parameterised and included in the numerical models after which the impacts are evaluated by comparing the 'before' and 'after' situation. The impacts during the construction phase such as sediment spill due to dredging operations are analysed by model simulations of sediment spill using a standard scenario for the dredging operations. The standard scenario in terms of dredged volumes, production rate and spill rate is based on experience from similar operations. Impacts during the decommissioning phase on the hydrographic conditions are considered insignificant but potential issues will be assessed.

2.3 Choice of layout for modelling

Four different layouts may be applied for the present wind farm (Ref /2/):

- Gravity based structure (GBS)
- Jacket
- Monopile
- Tripod structure

All structures have unique impacts on the hydrodynamics; however, the impacts can be rated. The jacket and the tripod structures consist of a system of relatively small steel pipes. These systems can be made equivalent to a massive diameter significantly smaller than the diameter of the pipe system. The jacket consists of four legs with a diameter of 1 m. This gives a total maximum blocking width of 4 m. The tripod consists of a main pile of 5 m and three legs with diameters of 1-3 m. This gives a total maximum blockage of 11 m in the lower part of the water and 5 m in the upper parts. The shaft on a monopile is 7.5 m which is significantly more than the jacket and similar to the tripod. Finally, the GBS also has diameters similar to the monopile but it also has cones at the top and at the bottom, which makes the blockage area larger than for any of the other structures. Therefore, with regard to hydrodynamics the GBS is the worst case no matter whether the variant chosen for realization or the rational alternative variant is selected for implementation.

With regards to sediment spillage the only construction that requires significant dredging is the GBS.

With regards to waves the structure with the largest cross sectional area near the surface will cause the most reflection, diffraction and absorption. Again GBS causes the largest impact.

The worst case method for cable burial will be the case where the cables are buried in sand and mud everywhere thus this is included in the modelling.

2.4 Modelling methodology

The hydrographic modelling around BŚ III has to a large extent been developed from DHI's existing 3D hydrodynamic and wave models of the Baltic Sea and the Danish waters, see Figure 2-2. The modelling utilises the MIKE by DHI Software and comprises different computational modules serving different purposes:

- MIKE 3 HD (**H**ydrodynamic **M**odel): for simulation of currents, water levels, salinity and water temperature
- MIKE 21 SW (**S**pectral **W**ave Model): for simulation of wave conditions
- MIKE 3 MT (**M**ud **T**ransport): for simulation of spreading of dredging spills. The model computes deposition on the sea bed and suspended sediment concentrations in the water column

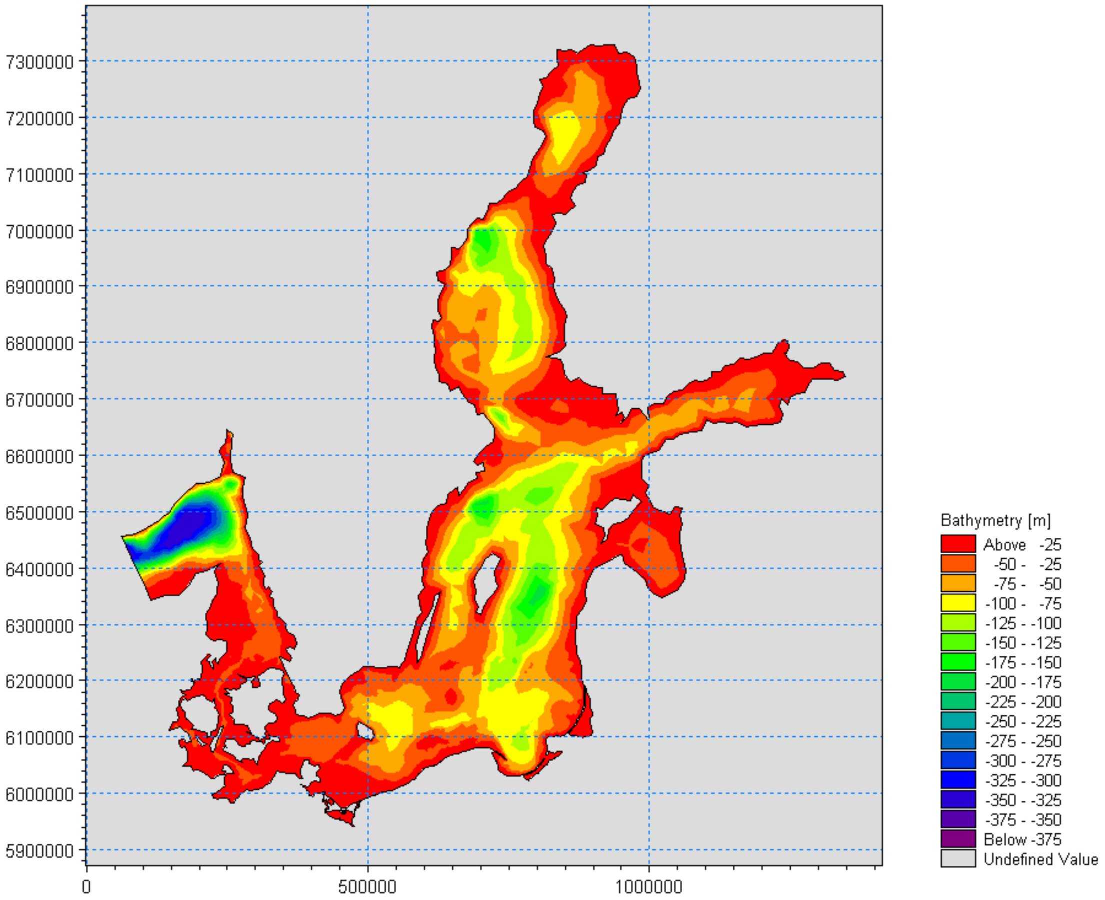


Figure 2-2 DHI's existing 3D model of the Baltic Sea

DHI's existing hydrodynamic model and wave model are set-up and calibrated for use in DHI's forecasting service, Water Forecast by DHI. The models use the same model bathymetry and computational mesh, which has a resolution ranging from 500-1000 m in the Fehmarnbelt area, to 1.0-2.5 km in the western Baltic and the Belt Sea, to 2-6 km in Kattegat and west of Bornholm, to 5-12 km in Skagerrak and finally to 5-20 km in the Baltic Sea east of Bornholm. The two models also use the same meteorological forcing, which is provided from a WRF model covering Northern Europe with a resolution of 0.1 degree. This model is run by StormGeo, Norway, for DHI. The hydrodynamic model (HDdkbs) was setup applying the MIKE by DHI 3-dimensional flow modelling system, MIKE 3 FM. The vertical domain is a combined sigma-z domain with the upper 10 m of the water column represented by 10 sigma-layers and the remaining water column represented by a number of z-layers depending on the local water depth. The adopted vertical resolution allows for the main part of the western Baltic Sea and the Belt Sea including the Fehmarnbelt to be resolved entirely by 1 m layers.

The existing hydrodynamic model was calibrated and validated against water level, current, temperature and salinity observations from 14 stations across the Inner Danish Waters and the Baltic Sea, and a good agreement between model and measurements was achieved. The set-up and calibration were to a large extent based on the work carried out as part of the hydrographic services provided by DHI to Femern A/S in connection with the Fehmarnbelt Fixed Link.

The wave model (SWdkbs) was setup applying the MIKE by DHI Spectral Wave Model, MIKE 21 SW. The frequency domain was divided into 25 bins with a minimum frequency of 0.055 Hz and a frequency factor of 1.128, resulting in resolved wave periods in the interval 1.0-18.2 s, i.e. including the short wave periods occurring in some of the inner Danish Waters. The 360 degree directional domain was divided into 24 bins of 15 deg.

The measurements carried out by MIG were subsequently used for further refinement and validation of the model within the BŚ III area (see Section 3.3).

3 Hydrodynamic model

The MIKE 3 HD (hydrodynamics) is the basic module of the entire MIKE 3 system. It provides the hydrodynamic basis for computations by most other modules. MIKE 3 HD solves the time dependent conservation equations of mass and momentum in three dimensions, the so-called Reynolds-averaged Navier-Stokes equations. The flow field and pressure variation are computed in response to a variety of forcing functions, when provided with the bathymetry, bed resistance, wind field, hydrographic boundary conditions, etc. The conservation equations for heat and salt are included as well. MIKE 3 HD uses the UNESCO equation of state of seawater (1980) as the relation between salinity, temperature and density.

A more detailed description can be found at:
http://mikebydhi.com/Download/DocumentsAndTools/~/media/Microsite_MIKEbyDHI/Publications/PDF/Short%20descriptions/MIKE213_FM_HD_Short_Description.ashx

The main purpose of the hydrodynamic model is to:

- Provide input to habitat modelling
- Provide a platform for sediment spill simulations
- Provide a platform to assess local impact on currents and waves

3.1 Model justification and procedure

The purpose of numerical modelling is to provide a tool that can fill out the gaps in space and time in measured data and provide knowledge on future impacts where no measurements are possible.

All numerical modelling require firm knowledge of the bathymetry in the model area and the hydrodynamics along the boundaries. The bathymetrical data from MIG is incorporated in the model basis as part of the computational mesh. The mesh is a common term for the structure all the calculation points are located in. Once the mesh has been generated and the boundary conditions established the model can be run. The result will be hydrodynamic parameters (currents, salinity, temperature etc) at each mesh point. These results will be compared with the measurements done by MIG. If the comparison is not good enough the model will be adjusted until the model gives a reasonable correlation to the measured data. Typical adjustments can be bed roughnesses, wind friction, solar insolation or size of certain deciding cross sections. Once a reasonable correlation has been established the model can be used to produce hydrodynamic data at all points in the computational mesh. This can be done as time series, 2D surface or 3D. By adding obstacles or changing forcings the model can also be used to predict future conditions. This is something that measurements alone cannot do. The following sections will show how the model was set up and calibrated.

3.2 Model setup

3.2.1 Model area and mesh

The regional hydrodynamic model described above covering the inner Danish and Baltic waters has been applied for the purpose of calculating the local hydrodynamic conditions around the BŚ III wind mill park. A fine resolution has been adopted along the Polish coastline and in particular within the BŚ III wind park area, see Figure 3-1. Whereas the resolution along the coastline is around 2000 m the resolution within the wind park is in the order of 300 m. Although the focus area is around BŚ III the model needs to comprise a much larger geographical area in order to establish solid model boundary conditions. The source for bathymetry data is:

- DHI's existing model of the Baltic Sea (bathymetry data from C-MAP combined with local depth soundings provided by the Danish and German authorities during the Fehmarnbelt investigations)
- Marine Institute - surveyed bathymetry around BŚ III during first half of 2013

The wind mills are not resolved in the mesh. The effect of the individual wind mill will be included as an extra resistance calculated based on the geometrical properties of each wind mill. It is thus enough that the cells are smaller than the distance between the wind mills in order to keep a maximum of one wind mill in each cell.

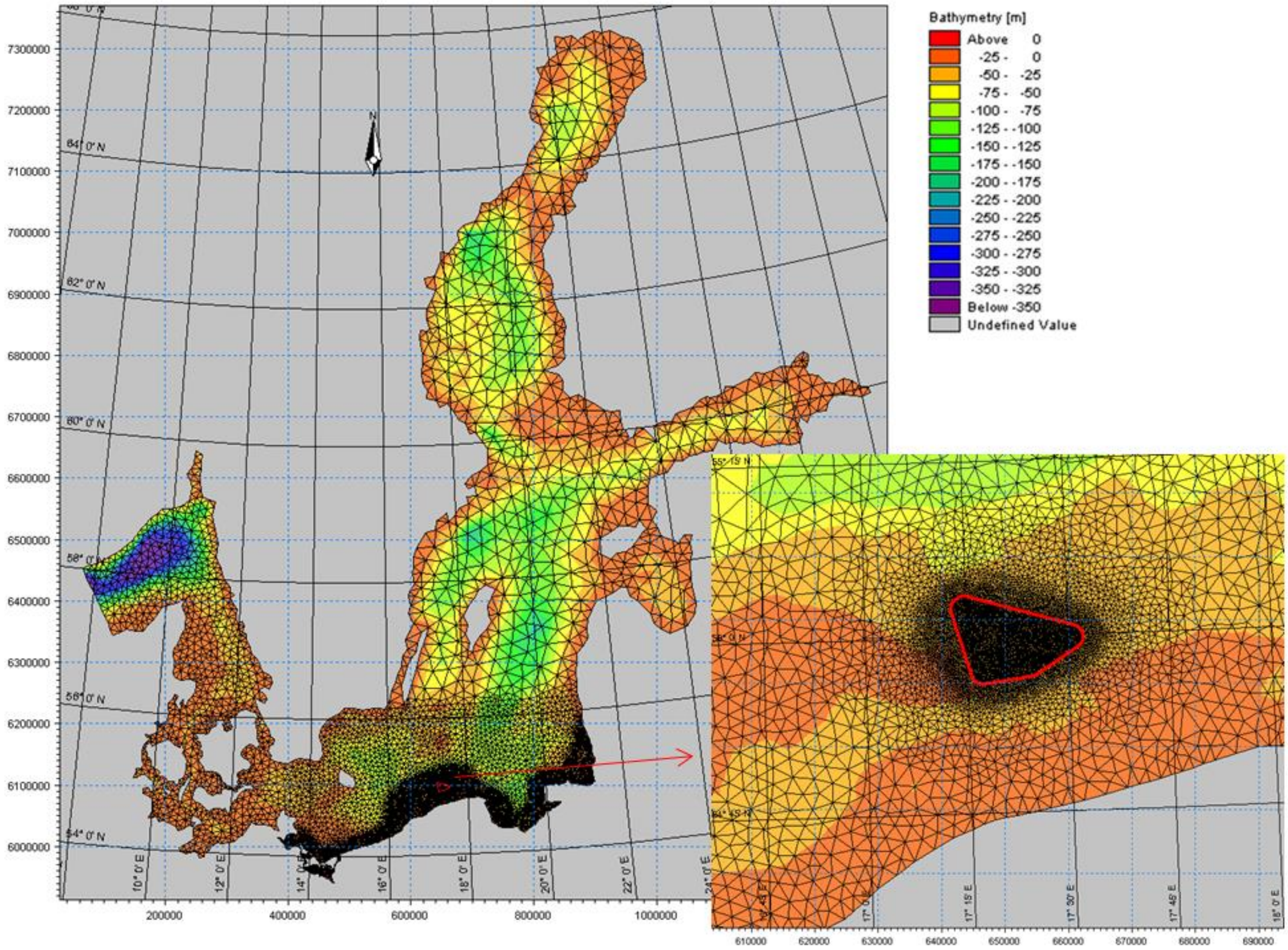


Figure 3-1 Model set-up and resolution around BŚ III

3.2.2 Model period, settings and boundaries

The model has one open northern boundary towards the North Sea boundary. The forcing at the North Sea comprises water level, flux (u and v velocities), salinity and water temperature. The combination of levels and flux at the same boundary is referred to as so-called Flather boundary conditions (see Ref /1/ for more details). Initial fields of sea surface elevation, salinity and temperature have been extracted from DHI's existing model of the Baltic Sea. The meteorological forcing comprises wind, air temperature, insolation and precipitation. The tidal potential is furthermore included as an internal forcing. Finally, the catchment runoff from rivers is represented by a combination of monthly statistical values (from Russian and Swedish rivers) and actual major river outflows (along the Polish and German coastline - see Figure 3-2).

Table 3-1 provides an overview of the data types used to run the model. Likewise the data source is listed. Note that the 2004 data are used to model the reference or baseline year as discussed in Section 5. The model data covering the period June 2012 through February 2014 are used to simulate the hydrographic conditions which are needed for the habitat modelling in relation to birds.

Table 3-1 Boundary types and data source

Boundary types and forcings	**Data source**
Flux (u and v), water level, salinity and temperature at North Sea boundary	2004: Flather boundary of flux (u and v) and water level and salinity and temperature from the Femern model setup (FEHY) 2012-2014: Operational model from ***The Water Forecast*** (Denmark) has provided boundaries as follows: Flather boundary of flux (u and v) and water level from the MIKE3 HD classic hydrostatic model. Model reference HW Salinity and temperature from the MIKE3 HD classic model. Model reference BANSAI
Tidal internal forcing	From astronomical tidal constituents
Meteorological data	2004: Wind and Air Temperature and Total Precipitation from Vejr2 A/S (Denmark). Former weather provider to The Water Forecast Clearness from NCEP/NOAA global weather model CFSR as not available through Vejr2 A/S 2012-2014: Meteorological data from StormGeo (Norway). Data provider to ***The Water Forecast***
River Runoff (monthly statistical values)	SMHI's operational HBV runoff model
River Runoff (actual outflows from Odra and Wisła)	IMGW (Poland)
River Runoff water temperature	From a forecast model (http://model.ocean.univ.gda.pl/php/frame.php?area=ZatokaGdanska) developed and maintained at the Gdansk University, Institute of Oceanography

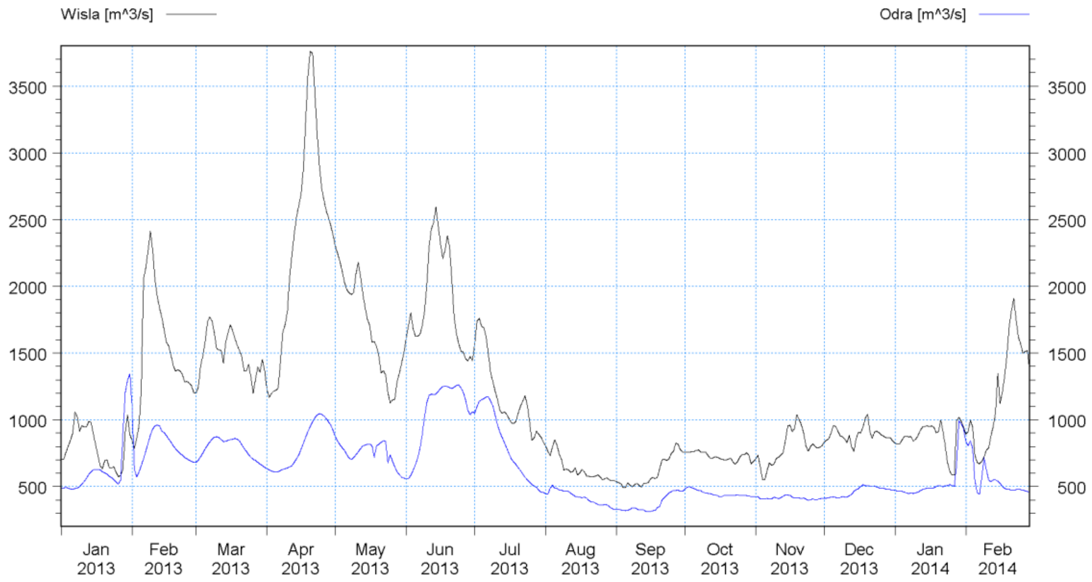


Figure 3-2 Recorded river outflow from the Odra and Wisła rivers in 2013

3.2.3 Validation

The validation comprises comparison between measurements and model results. The relevant data with respect to validations are currents, water levels, salinity and temperature as surveyed and measured by Marine Institute. An overview of data coverage is provided below in Table 3-2 and Table 3-3. Data gaps do occur during the survey periods.

Table 3-2 Data coverage at the measuring station BS31: 54°59'50.268 N, 017°20'32.606 E

Data type	**Parameter/depth**	**Period**
Temperature	At the seabed At a water depth of 4, 8 and 16 m	2012.12.21 - 2014.02.19 2013.01.07 – 2013.10.21
Salinity	At the seabed At a water depth of 4, 8 and 16 m	2013.02.02 - 2014.02.19 2013.01.07 – 2013.10.21
Currents	Average speed and direction at 0-4 [m],4-8 [m],8-12 [m],12-16 [m],16-20 [m],20-24 [m],24-28 [m]	2012.12.21 - 2014.01.10
Waves	Hm0 [m], Tp [s], Hmax [m], Hmean [m],Tm02 [s], Mean direction [deg]	2012.12.21 - 2014.01.10
Meteorology	Air Temperature [deg C],Wind direction [deg],Wind Speed [m/s]	2013.01.07 - 2014.02.19

Table 3-3 Data coverage at the measuring station BS32: 54°57'19.50875 N, 017°17'43.82026 E

Data type	Parameter/depth	Period
Temperature	At seabed	2013.01.07 - 2014.02.19
Currents	Average speed and direction at 0-4 [m],4-8 [m],8-12 [m],12-16 [m],16-20 [m],20-24 [m],24-28 [m]	2013.01.07 - 2014.02.19
Waves	Hm0 [m], Tp [s], Hmax [m], Hmean [m],Tm02 [s], Mean direction [deg]	2013.01.07 - 2014.02.19

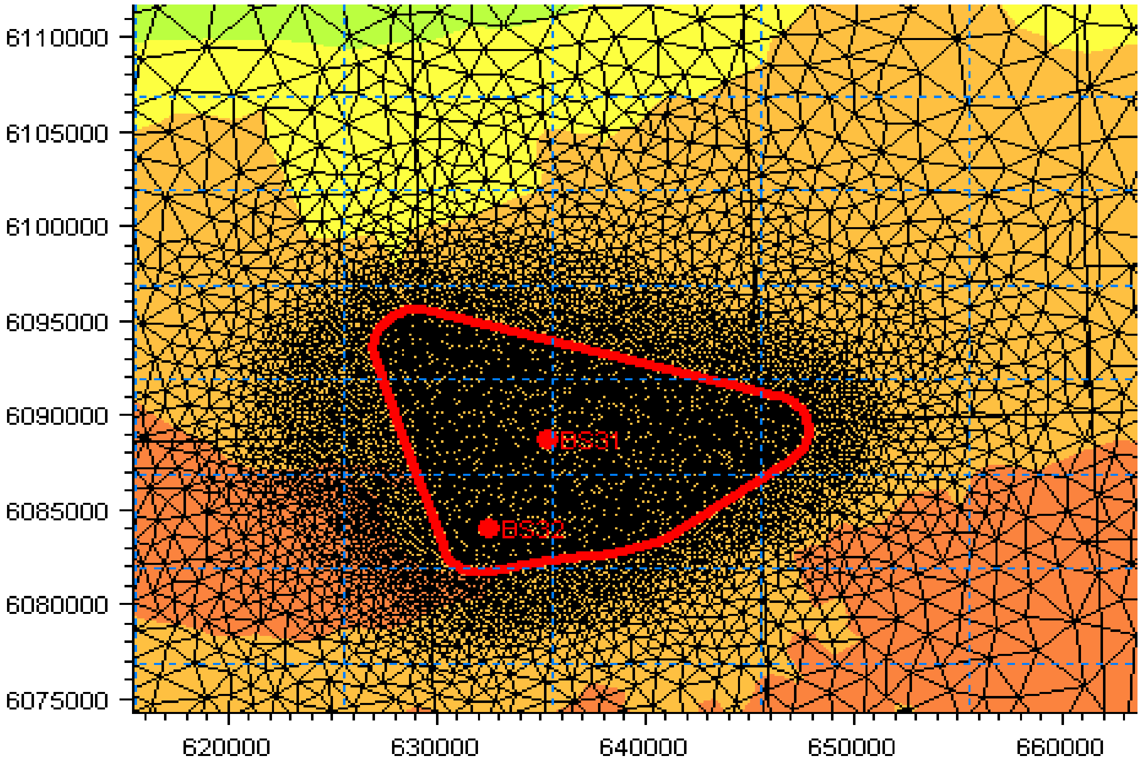


Figure 3-3 Measuring points location

The current is measured at various depths and model results compared with measurements are shown in Figure 3-4 through Figure 3-7 for the two positions BS31 and BS32, respectively.

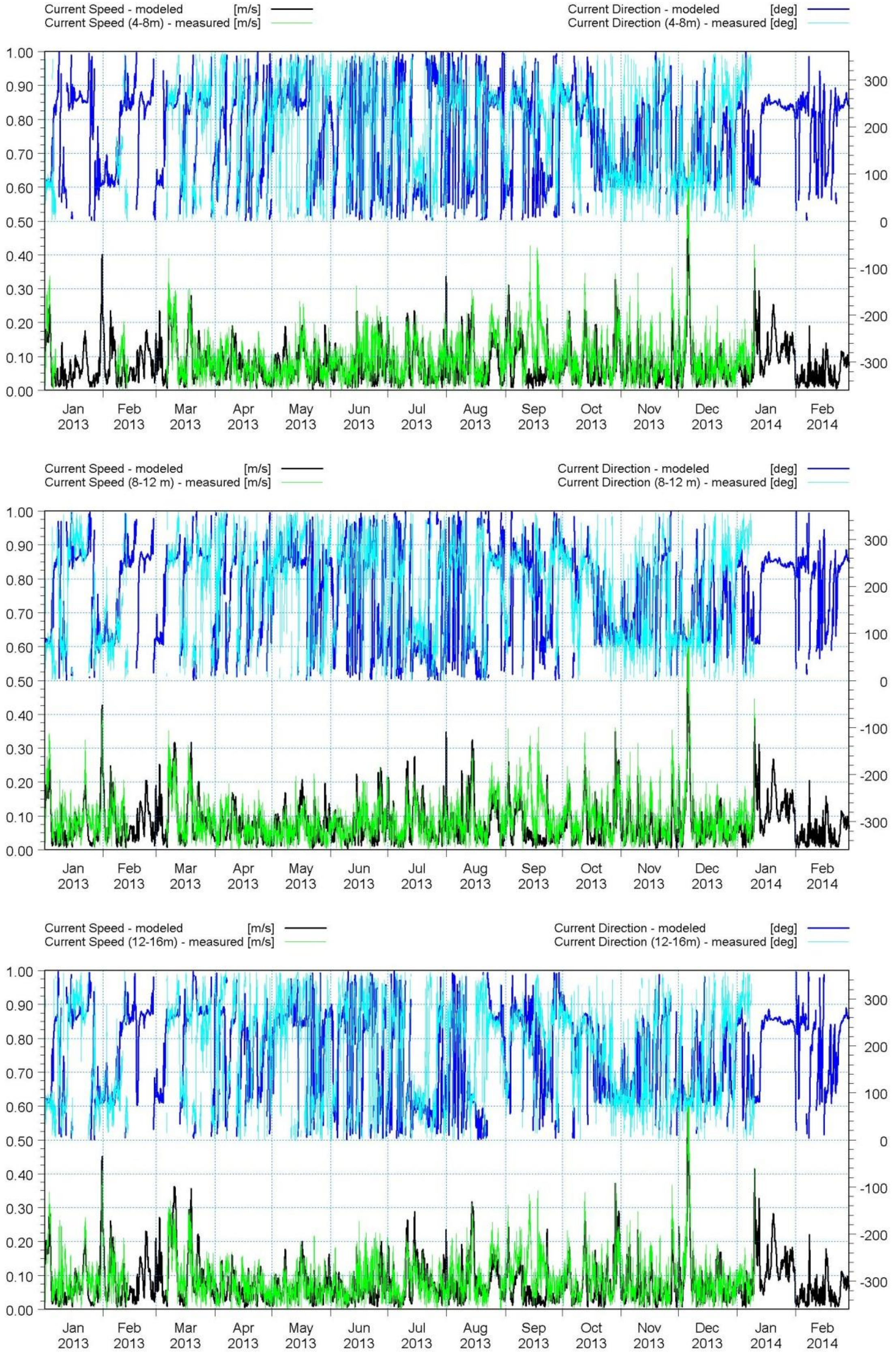


Figure 3-4 Simulated and measured current speed (black and green lines) and direction (dark blue and light blue lines) in the period January 2013 through February 2014 at BS31. Average current speed in the depth intervals 4-8 m, 8-12 m and 12-16 m below the water surface

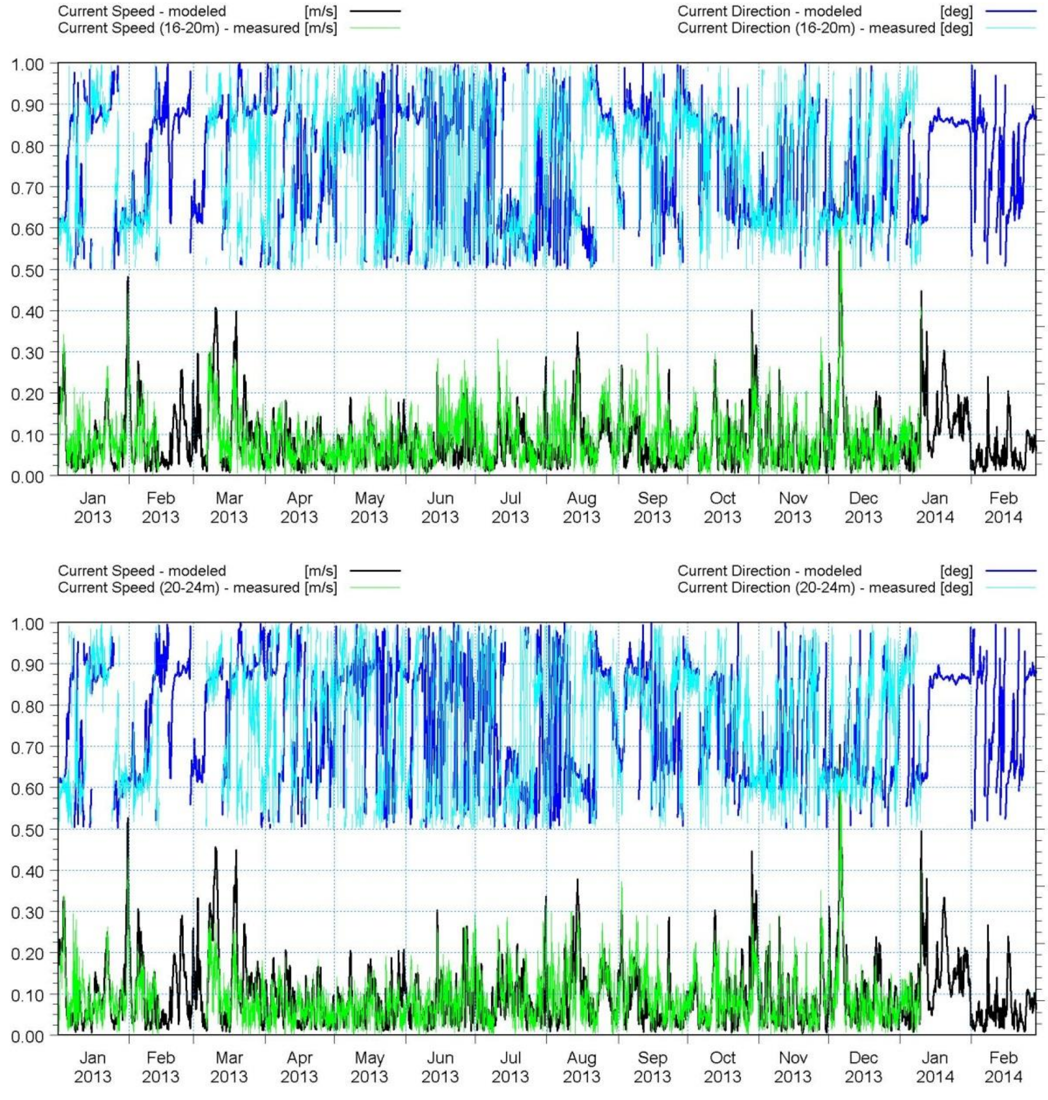


Figure 3-5 Simulated and measured current speed (black and green lines) and direction (dark blue and light blue lines) in the period January 2013 through February 2014 at BS31. Average current speed in the depth intervals 16-20 m and 20-24 m below the water surface

Results at BS31 show very good resemblance. Normally, modelling currents are the most difficult part of hydrodynamic modelling and thus deviations of 20% – 30% on current speeds are often excepted. In this case the deviations are generally smaller than 20 % and the calibration is considered very good both for current speeds and current directions. All major trends are captured.

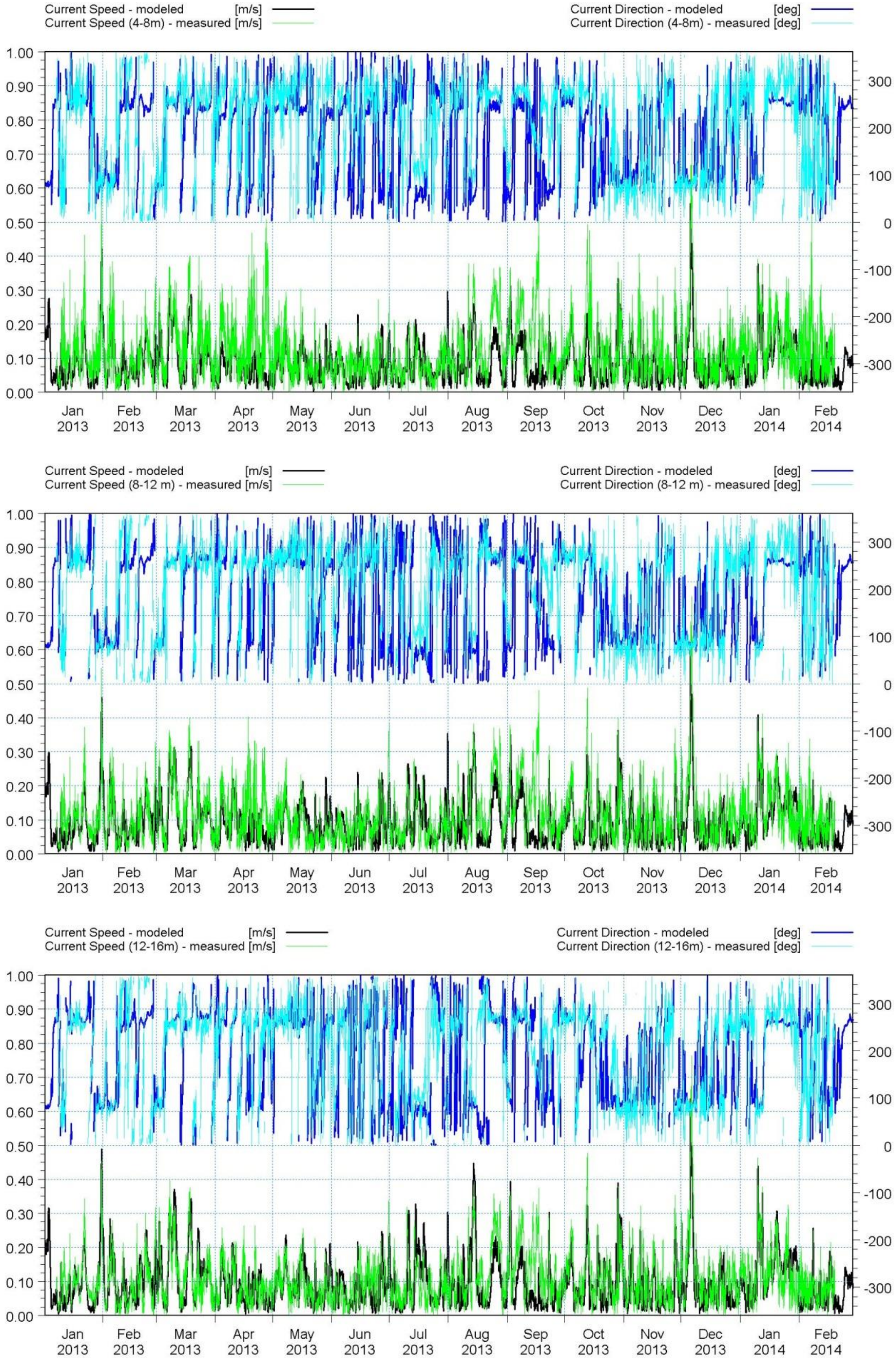


Figure 3-6 Simulated and measured current speed (black and green lines) and direction (dark blue and light blue lines) in the period January 2013 through February 2014 at BS32. Average current speed in the depth intervals 4-8 m, 8-12 m and 12-16 m below the water surface

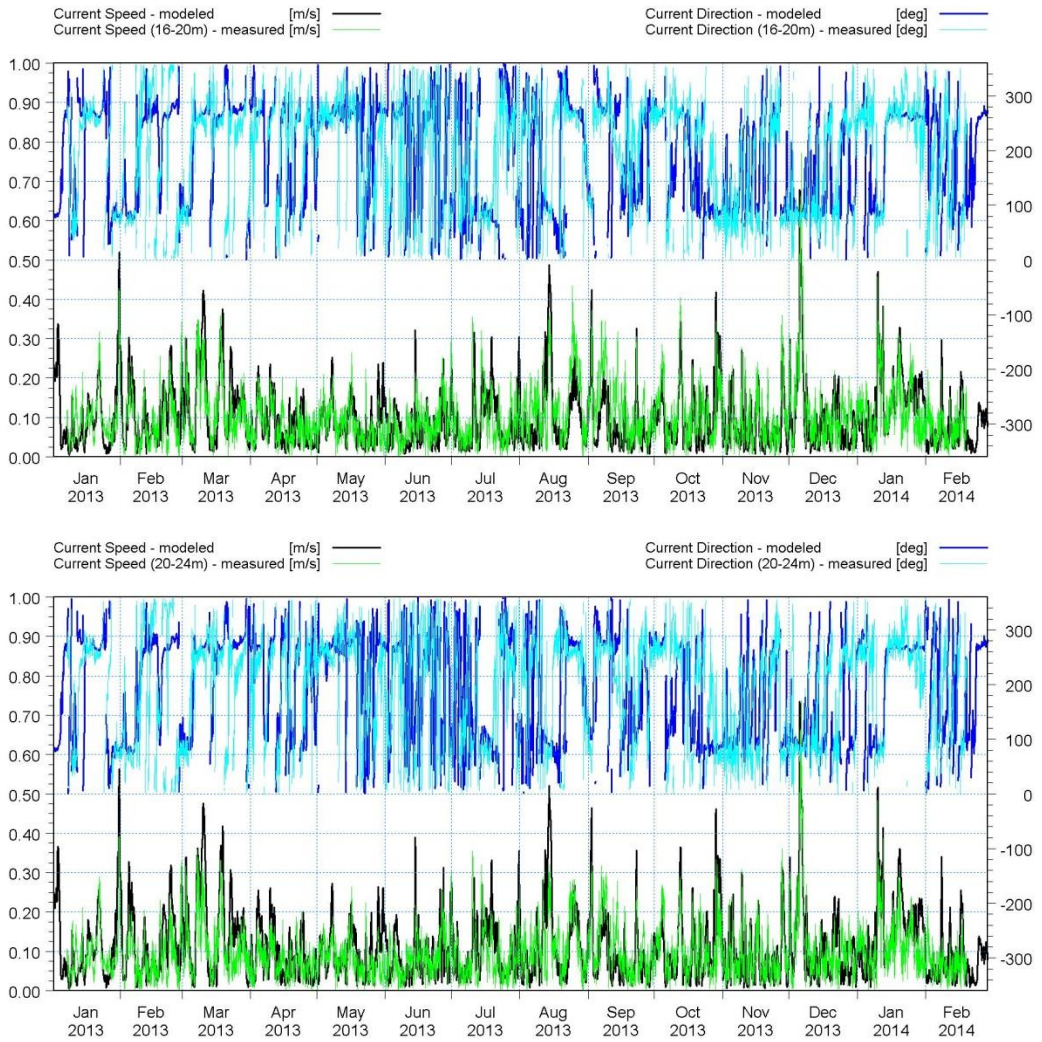


Figure 3-7 Simulated and measured current speed (black and green lines) and direction (dark blue and light blue lines) in the period January 2013 through February 2014 at BS32. Average current speed in the depth intervals 16-20 m and 20-24 m below the water surface

Results at BS32 show very good resemblance. Normally, modelling currents are the most difficult part of hydrodynamic modelling and thus deviations of 20% – 30% on current speeds are often excepted. In this case the deviations are generally smaller than 20 % and the calibration is considered very good both for current speeds and current directions. All major trends are captured, though near the surface current speeds are slightly underpredicted by the model.

Generally, there is a very good agreement between measurements and model simulations. Comparisons have also been made between measured and simulated water elevations at the measuring station within the BŚ III wind park. These are shown in Figure 3-8. The measuring devices do not measure elevation directly but they measure the amount of water above the device. An attempt only has been made to convert the measured depths to water elevation by evaluating the average amount of water over the instruments. Note that the instruments were moved slightly during service visits which impose small discontinuities both in level and in time.

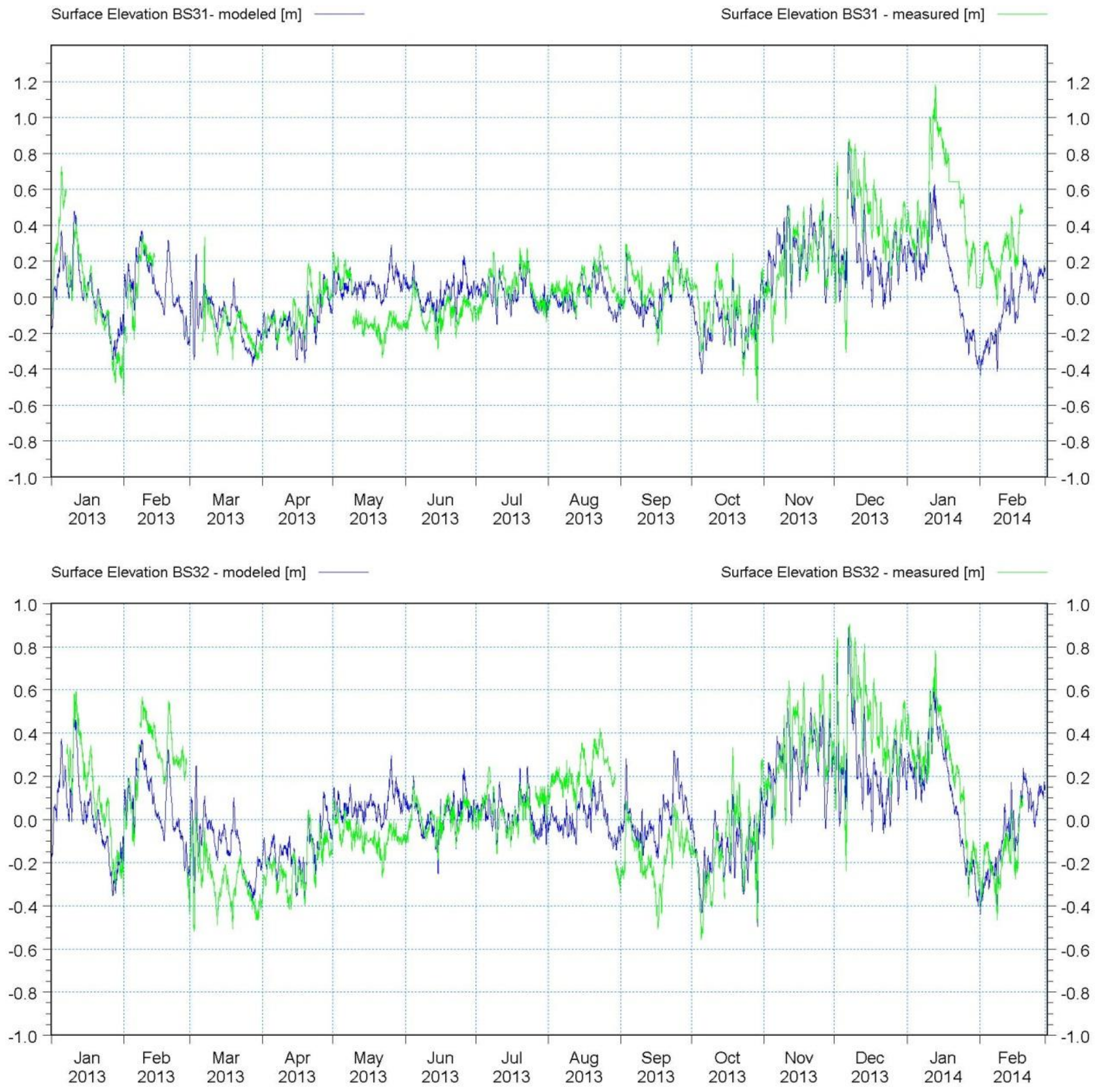


Figure 3-8 Simulated water level and measured depth (converted to water elevation). The offset in some periods is results of change in the position of the monitoring station after service

Discontinuities due to service visits are seen in February, May and August. Other discrepancies are seen in February 2013, August 2013 and in January 2014. Since the two measuring devices are located close to each other one of the devices must be erroneous when the water level difference is 40 cm in January 2014, 25 cm in February 2013 and 20 cm in August 2013. If these periods are omitted the model reproduces the main trends well. Note that the same analysis can be applied to other periods.

Salinity and temperature were also measured and modelled. The results are shown in Figure 3-9 and Figure 3-10.

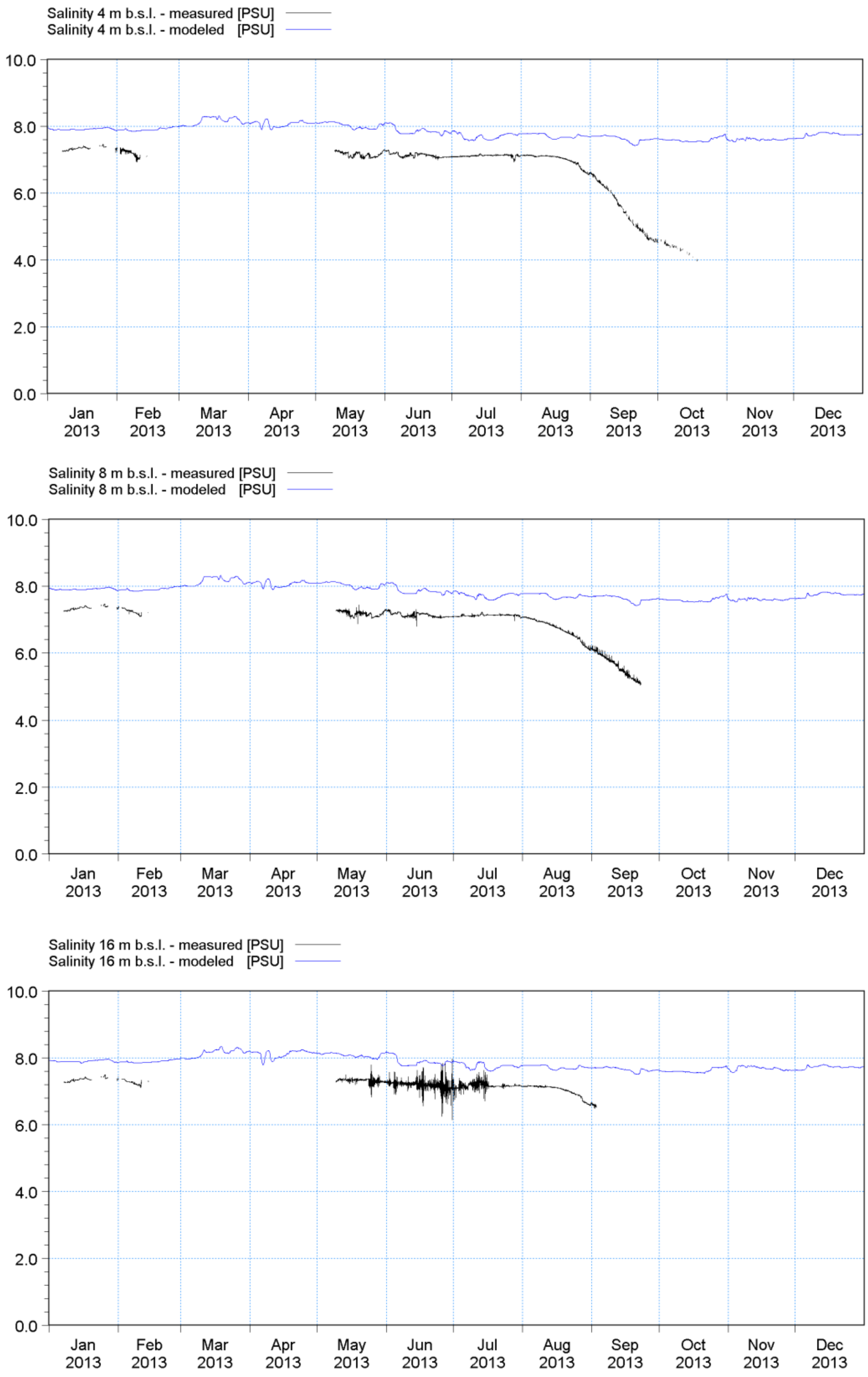


Figure 3-9 Simulated and measured salinity

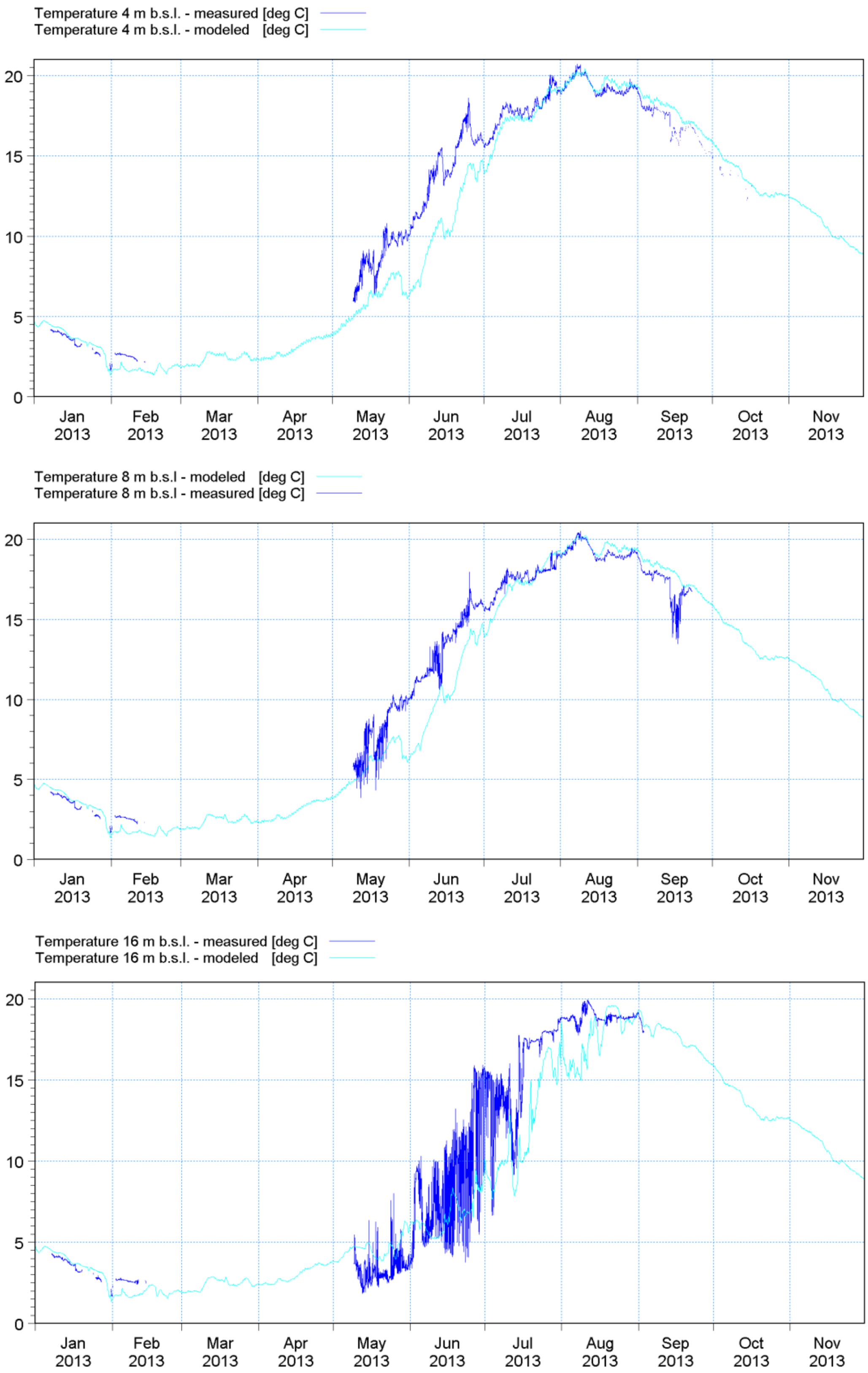


Figure 3-10 Simulated (light blue line) and measured (blue line) water temperature

The salinity and temperature measurements show periodically strange and unstable behaviour. The salinity measurements show a sudden almost linear drop in salinity in August and September 2013. Normal salinities in the area are 7 – 9 PSU. Bottom temperature measurements show unstable behaviour from May till July.

The model reproduces the salinity level inside 0.5 PSU which is generally acceptable. The sudden drop is either due to instrument malfunction or due to a large outflow from the Vistula or one of the other rivers which is not captured by the model. The general trends in temperature are captured well. However, the model slightly underpredicts the temperature in periods.

For the present purpose water temperatures and salinities are not important driving factors and thus the model calibration is sufficient for the purpose.

4 Wave model

The wave climate has been modelled based on DHI's numerical wave model, MIKE 21 SW. MIKE 21 Spectral Wave Model is a third generation spectral wind-wave model. The model simulates the growth, decay and transformation of wind generated waves and swells in offshore and coastal areas by solving the spectral wave action balance equation. At each mesh point, the wave field is represented by a discrete two-dimensional wave action density spectrum. The model includes the following physical phenomena:

- Wave growth by action of wind
- Non-linear wave-wave interaction
- Dissipation by white capping
- Dissipation by depth induced wave breaking
- Dissipation due to bottom friction
- Refraction due to variations in the water depth
- Wave-current interaction

A more detailed description can be found at:
http://www.dhigroup.com/Software/Download/DocumentsAndTools/ShortDescriptions/Marine.aspx

As a part of the environmental impact, the effects of the wind turbines on the incoming waves have been included in the wave prediction.

The purpose of the model is to provide:

- Baseline conditions in relation to waves
- A platform to assess impact on local wave climate (e.g. dampening effects)

4.1 Model setup

The model area and water depths used for the wave simulations are identical to the one used for the current simulations (see Figure 3-1). The wind forcing, which is the only forcing applied in the wave model, is likewise identical to the forcing used in the hydrodynamic model.

4.2 Calibration and validation

The wave model has been executed for the entire period January 1 through December 31, 2013. Subsequently, model calibration and validation have been carried out. The validation comprises comparison between measured (see Table 3-2 and Table 3-3 and simulated significant wave heights, wave periods and wave directions.

The most important calibration factors are provided below.

Wind forcing: the formulation of the wave generation by wind (Directional decoupled parametric formulation) is based on empirical relationships. It is assumed that the directional spreading of the energy from the wind follows a cos2q distribution, the average frequency is independent of the direction. The Spectral Wave module includes 5 wind formulations. The SPM84 formulation has been chosen in this case. SPM84 formulation is based on expressions derived from the Shore Protection Manual (1984) formulation for the wave growth for fetch limited sea states in deep water using a power fit for the growth equations. Combined to the other calibration parameters, the SPM84 wind formulation permits to get the most relevant wave fields.

Bottom friction: the bottom friction is described through a Nikuradse roughness, kN. A quite small value of 1.10-5 m is used in the whole domain.

As depicted in Figure 4-1 and Figure 4-2 there is generally a good agreement between measurements and model simulations at the two locations (p001 and p002) although the model seems to underestimate the wave period with 10-20 %. Such an underestimate is often seen between model simulation and measurements for a number of reasons. In the present context it is not considered critical for the assessment of potential turbine impact on the wave climate. The two locations correspond to the position of the two wave recorders within BŚ III (see Table 3-2 and Table 3-3.

It is thus concluded that the model can provide sound data for the habitat modelling and for further impact assessments in relation to currents and sediment transports.

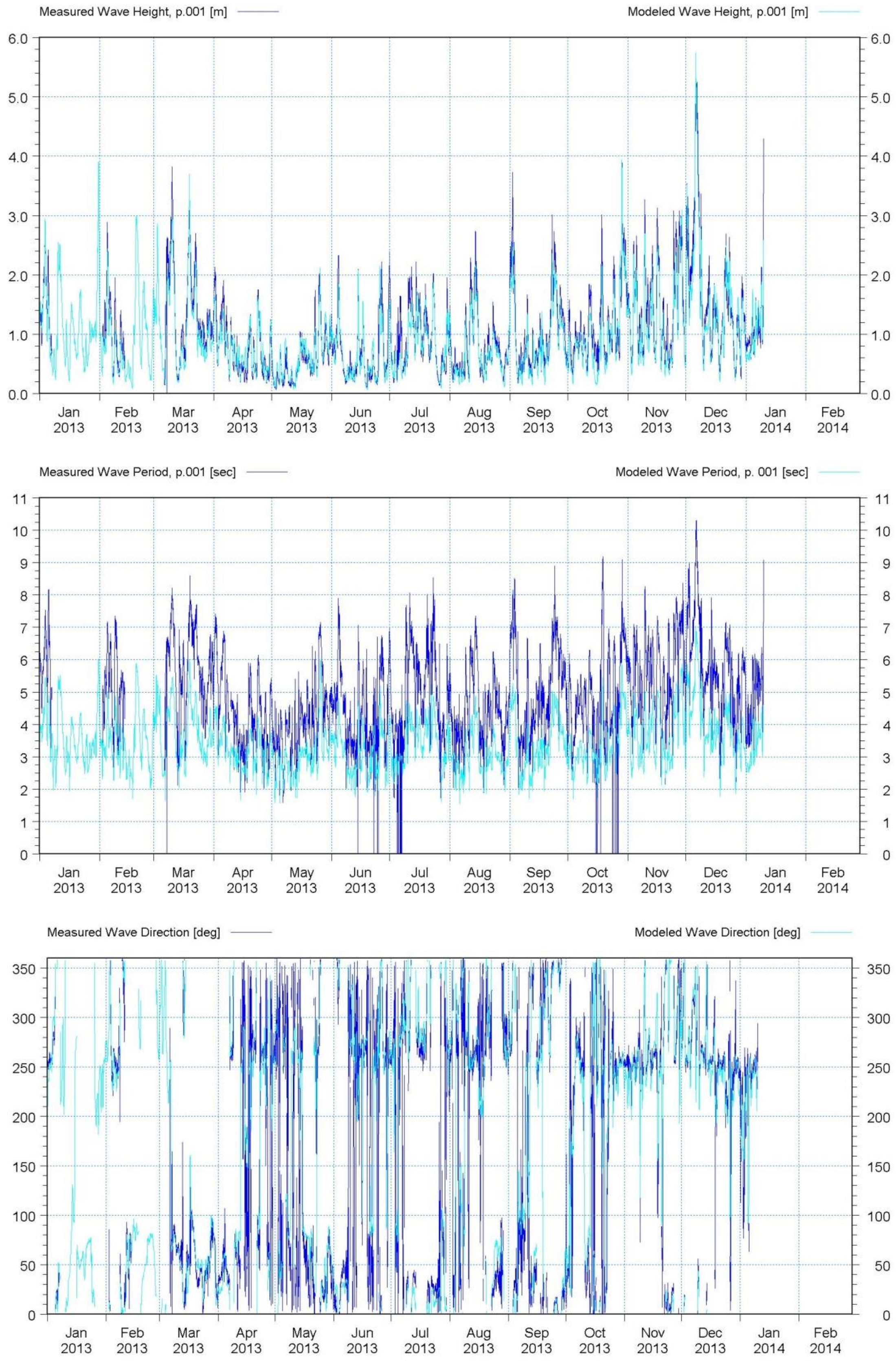


Figure 4-1 Simulated (light blue) and measured (dark blue) wave height, wave period and wave direction at BS31

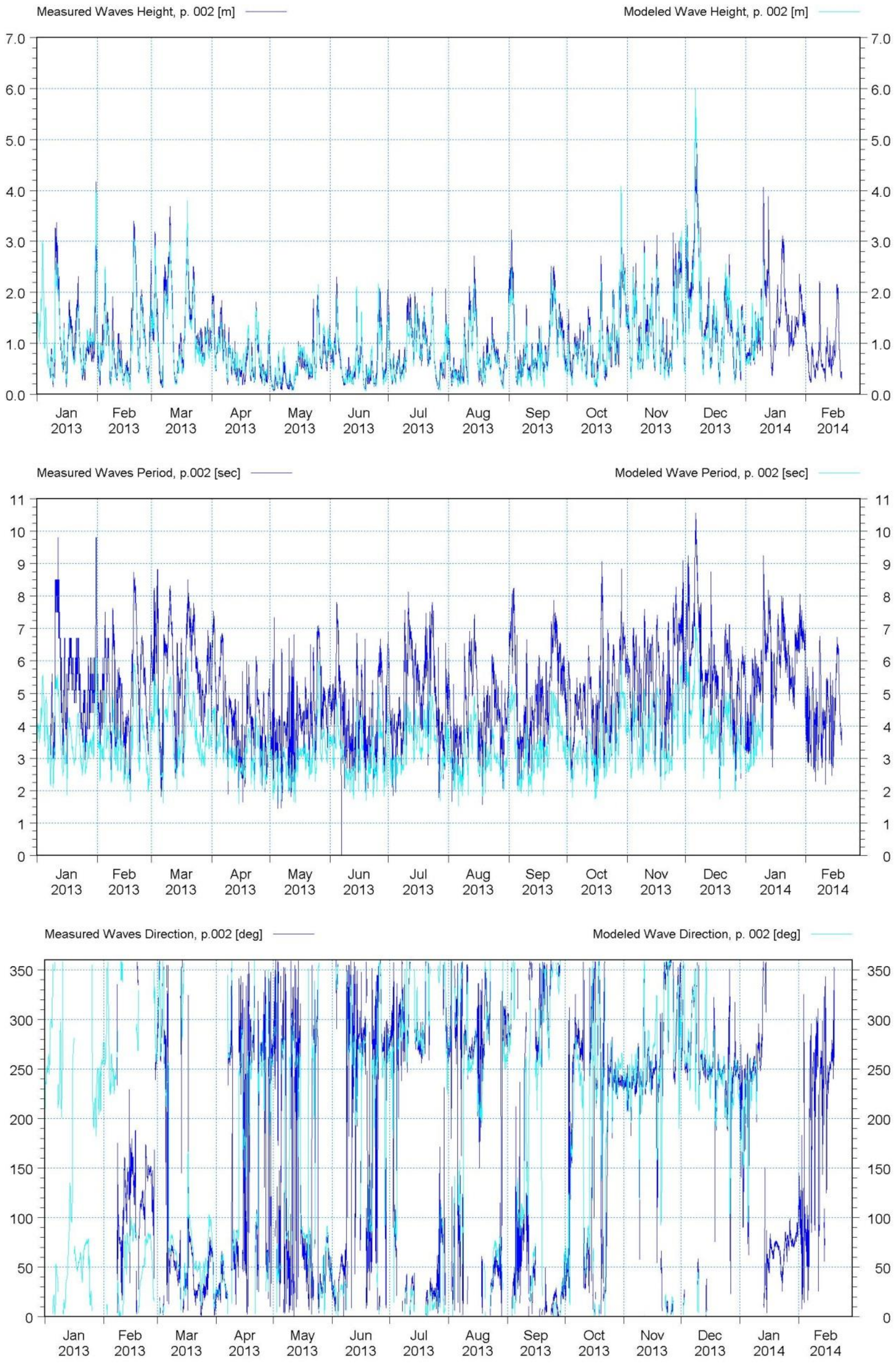


Figure 4-2 Simulated (light blue) and measured (dark blue) wave height, wave period and wave direction at BS32

5 Project description

5.1 Introduction

Polenergia plans to build the offshore wind farm “Bałtyk Środkowy III” in the Polish Exclusive Economic Zone of the Baltic Sea. DHI was involved as a consulting company during the EIA process and assigned to conduct environmental research on marine mammals, background noise and migrating birds, as well as revise and consult research of other components and include the results in the dedicated model.

Project “Bałtyk Środkowy III” is situated outside the borders of Polish territorial waters, approximately 23 km from the shore (Figure 5-1).

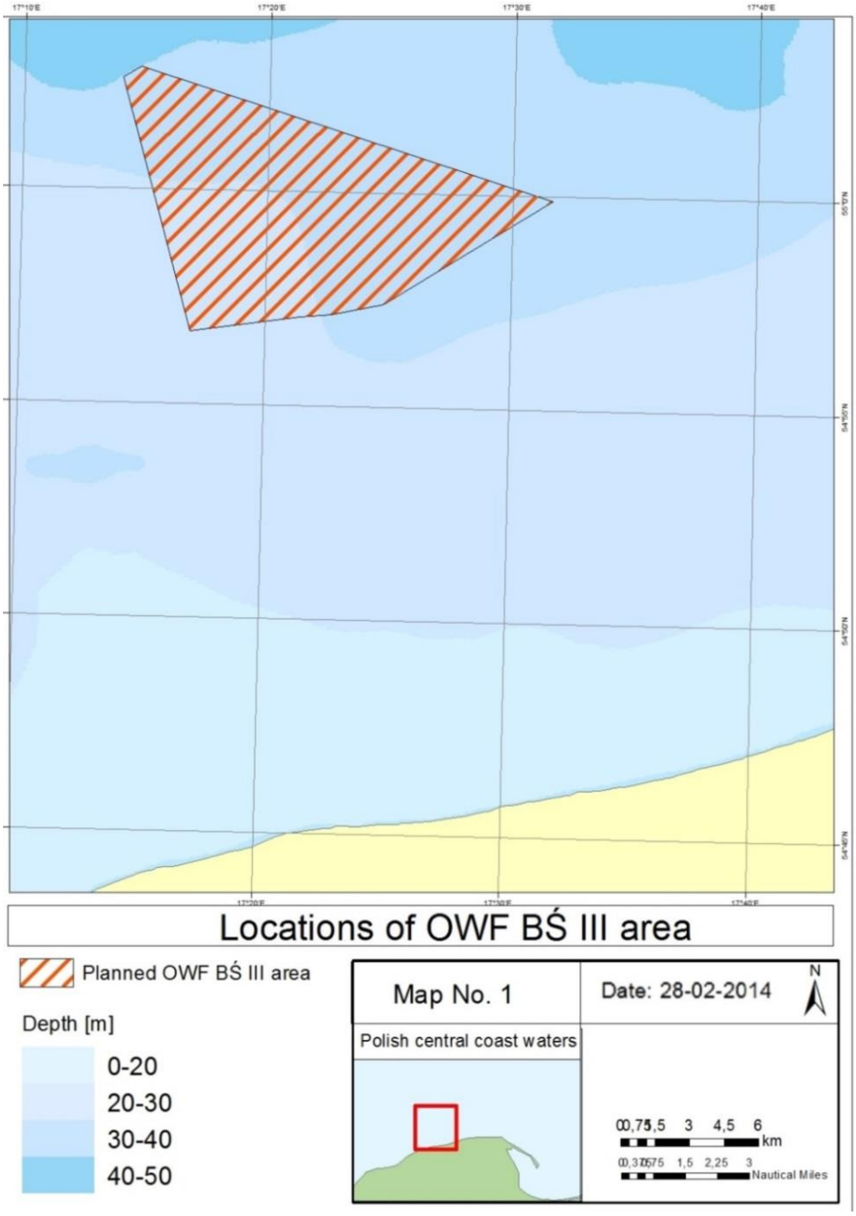


Figure 5-1 Location of the planned OWF “Bałtyk Środkowy III” area

The total area of the farm is approximately 119.52 km^2 according to PSZW (license for construction and use of the artificial islands, installations and devices in the Polish maritime areas, obtained on 30 March 2012).

This area, as defined in PSZW, is reduced by the 500 m buffer from the inner boundary of the project implementation area excluded from location of any structural elements of the farm. The size of the buffer (500 m) is approximately 23 km^2.

Therefore, the maritime area available for implementation of the project is the area defined by PSZW, reduced by the area of the buffer and comprises 89 km^2 (Figure 5-2).

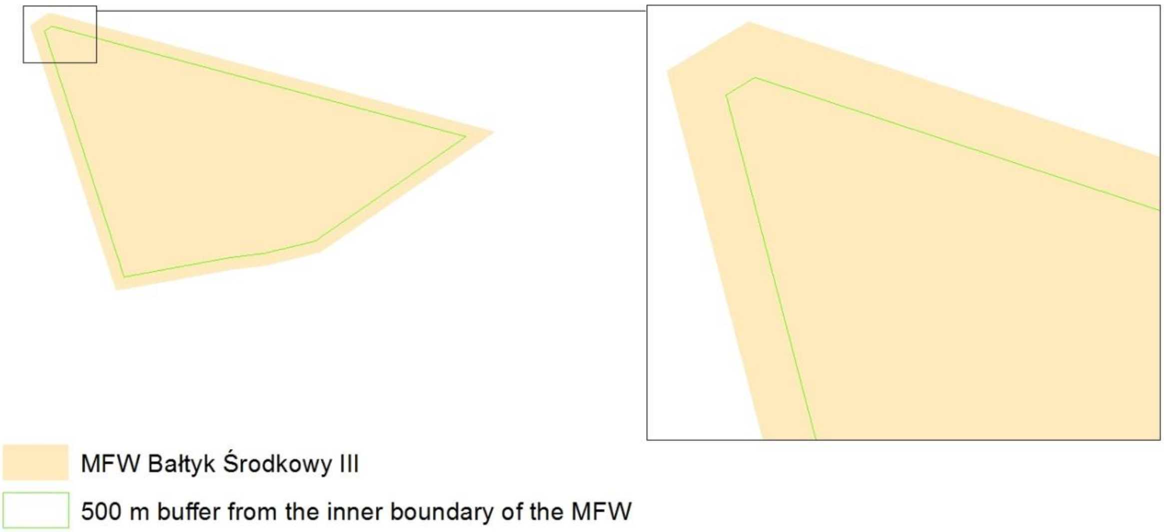


Figure 5-2 Boundaries of OWF BŚ III area and lines of buffers (MWF Bałtyk Środkowy III Sp. z o.o.)

5.2 Analysed variants of the project

5.2.1 Rational alternative variant

The rational alternative variant was prepared by the Investor and combines maximum effectiveness of energy production with respect to formal and technical conditions of the project implementation. In this variant the whole OWF area is used for development taking into account limitations resulting from:

- The license for construction and use of the artificial islands, installations and devices in maritime areas for the OWF project Bałtyk Środkowy III (PSZW)
- “Conditions of connecting the OWF Bałtyk Środkowy III to the transmission network”

Boundary conditions for technical parameters of the wind farm resulting from PSZW and “Conditions of connection…” enable a maximum connection of 1 200 MW and a maximum number of power plants (PSZW) - 200. Maximum technical parameters of the project in this variant were presented in Table 5-1.

Table 5-1 Basic technical parameters of OWF BŚ III (rational alternative variant)

Parameter	Maximum value
Total height of the power plant above the sea surface	212.5 m
Minimum distance from the lowest position of the blade and sea surface	20 m
The diameter of the rotor	192.5 m
Maximum quantity of power plants	200
Maximum zone of a single rotor	29 104 m^2
Maximum total rotor zone	5 820 800 m^2
Maximum quantity of foundations of associated infrastructure	8
Maximum area of sea bottom occupied by 1 foundation (GBS, diameter 40 m)	1 257 m^2
Maximum area of sea bottom occupied by foundations (208)	261 456 km^2
Maximum density of power plants (89 km^2 for development)	2.25 power plant/km^2
Maximum length of cables of the wind farm inner connection infrastructure	200 km

Source: MFW Bałtyk Środkowy III Sp. z o.o. „Morska farma wiatrowa Bałtyk Środkowy III – opis metodyki wariantowania", Investor's data

5.2.2 Variant chosen for implementation

The variant chosen for implementation is at the same time the favourable variant for nature, fulfilling the investment objective, and thereby the energy production effectiveness. This variant results from applying boundary environmental conditions on technologies used in the rational alternative variant. Those limitations enable the development of 120 power plants of a maximum unit power of 10 MW and a maximum rotor diameter of 200 m. The power plant would be located within the area of 89 km^2. The maximum technical parameters of the project in this variant are presented in Table 5-2.

Table 5-2 Basic technical parameters of OWF BŚ III (variant chosen for realization)

Parameter	Maximum value
Total height of the power plant above the sea surface	275 m
Minimum distance from the lower position of the blade and sea surface	20 m
Maximum distance from the lowest position of the blade and the sea surface	75 m
The diameter of the rotor	200 m
Maximum quantity of power plants	120
Maximum zone of a single rotor	31 400 m^2
Maximum total rotors zone	3 768 000 m^2
Maximum quantity of foundations of associated infrastructure	6
Maximum area of sea bottom occupied by 1 foundation (GBS, diameter 40 m)	1 257 m^2
Maximum area of sea bottom occupied by foundations (126)	158 232 km^2
Maximum density of power plants (89 km^2 for development)	1.35 power plant/km^2
Maximum length of cables of the wind farm inner connection infrastructure	200 km

Source: MFW Bałtyk Środkowy III Sp. z o.o. „Morska farma wiatrowa Bałtyk Środkowy III – opis metodyki wariantowania", Investor's data

5.3 Comparison of variants

In the variant chosen for implementation, the number of power plants has been reduced by 40%. Together with this change, the area of sea bottom occupied by foundations decreased by 39%. At the same time the impact on sediment spill, benthos destruction, birds and bat mortality caused by collisions and noise generated during the construction phase decreases which means that the variant chosen for implementation is more favourable for the environment.

Table 5-3 Comparison of technical parameters of both variants

Parameter	Variant chosen for realization	Rational alternative variant
Total height of the power plant above the sea surface	275 m	212.5 m
Minimum distance from the lower position of the blade and sea surface	20 m	20 m
The diameter of the rotor	200 m	192.5 m
Maximum quantity of power plants	120	200
Maximum zone of a single rotor	31 400 m^2	29 104 m^2
Maximum total rotor zone	3 768 000 m^2	5 820 800 m^2
Maximum quantity of foundations of associated infrastructure	6	8
Maximum area of sea bottom occupied by 1 foundation (GBS, diameter 40 m)	1 257 m^2	1 257 m^2
Maximum area of sea bottom occupied by foundations (126/208)	158 232 m^2	261 456 m^2
Maximum density of power plants (89 km^2 for development)	1.35 pc./km^2	2.25 pc./km^2
Maximum length of cables of the wind farm inner connection infrastructure	200 km	200 km

6 Baseline conditions

The purpose of this task is to map the hydrographic baseline conditions with respect to:

- Hydrodynamic conditions (currents, levels, salinity and temperature)
- Wave conditions

In order to establish a sufficient, detailed, temporal and spatial resolution of the baseline conditions the hydrodynamic model as described in Chapter 3 is applied. The modelled baseline conditions will subsequently provide the platform for the modelling of impact assessments.

In this context the first task is to select a representative period representing typical hydrographic conditions.

6.1 Selection of hydrographic period

The water depth at BŚ III varies between 25 m and 38 m. Tidal variations are weak (less than 10 cm). However, as shown by modelling and confirmed by the measurements, the water level may rise to more than 1 m MSL in connection with winter storms. Likewise, significant wave heights reach 4 m as also measured and modelled during January 2013 (see Figure 4-2).

Although stratification is typical in the deeper part of the Baltic Sea the water column at BŚ III seems to be well mixed with only little vertical variation in salinity and water temperature (see Figure 3-9 and Figure 3-10).

Typical current speeds near the free surface are around 0.25 m/s, increasing to 0.5 m/s during more severe weather conditions (Figure 3-4).

In order to identify a typical representative hydrographic period (which will be used in the assessment of hydrographic baseline and impact studies) a statistical analysis has been carried out based on DHI’s existing data bases. In this data base wind data are extracted from the NCEP/NOAA global weather model CFSR and current data are extracted from the Fehmarn model setup (FEHY Regional model).The analysis has been based on 10 years of data.

The statistical analysis (rose plots) of existing model data indicates that 2004 represents a typical year with respect to local currents and wind speeds. As shown below in Figure 6-1 through Figure 6-4, 2004 is very similar to the 10-year statistical results with respect to current, wind speed and directions. The rose plots show the annual distribution or frequency of having a given wind or current speed from a given direction. In other words the calm period (current speed less than 0.025 m/s) occurred in 27.54 % of the time in 2004. Looking at all 10 years the calm period was 27.5 % of the time. Thus, 2004 is very close to the 10-year period with respect to calm conditions. The same argument can be used for higher speeds and directions.

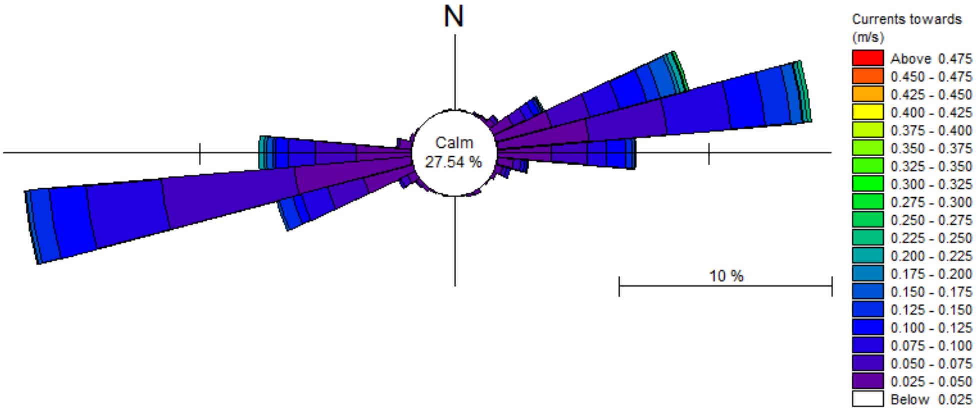


Figure 6-1 Current rose plot for a year 2004

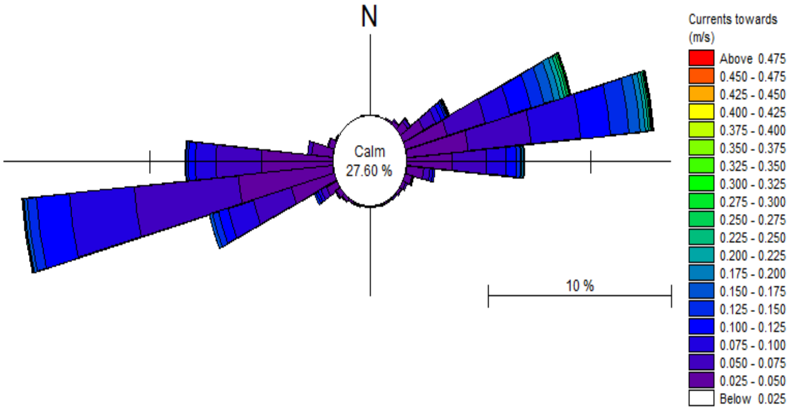


Figure 6-2 Current rose plot for 10-year period 2000-2010

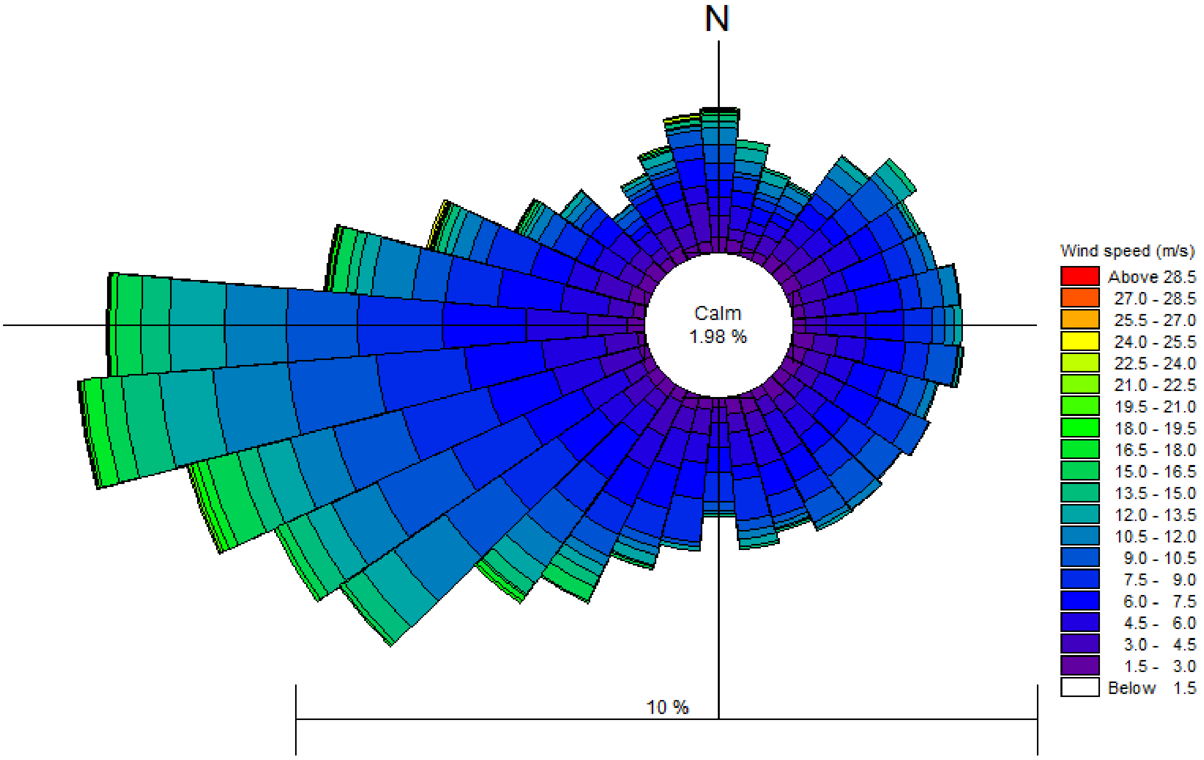


Figure 6-3 Wind rose plot for a year 2004

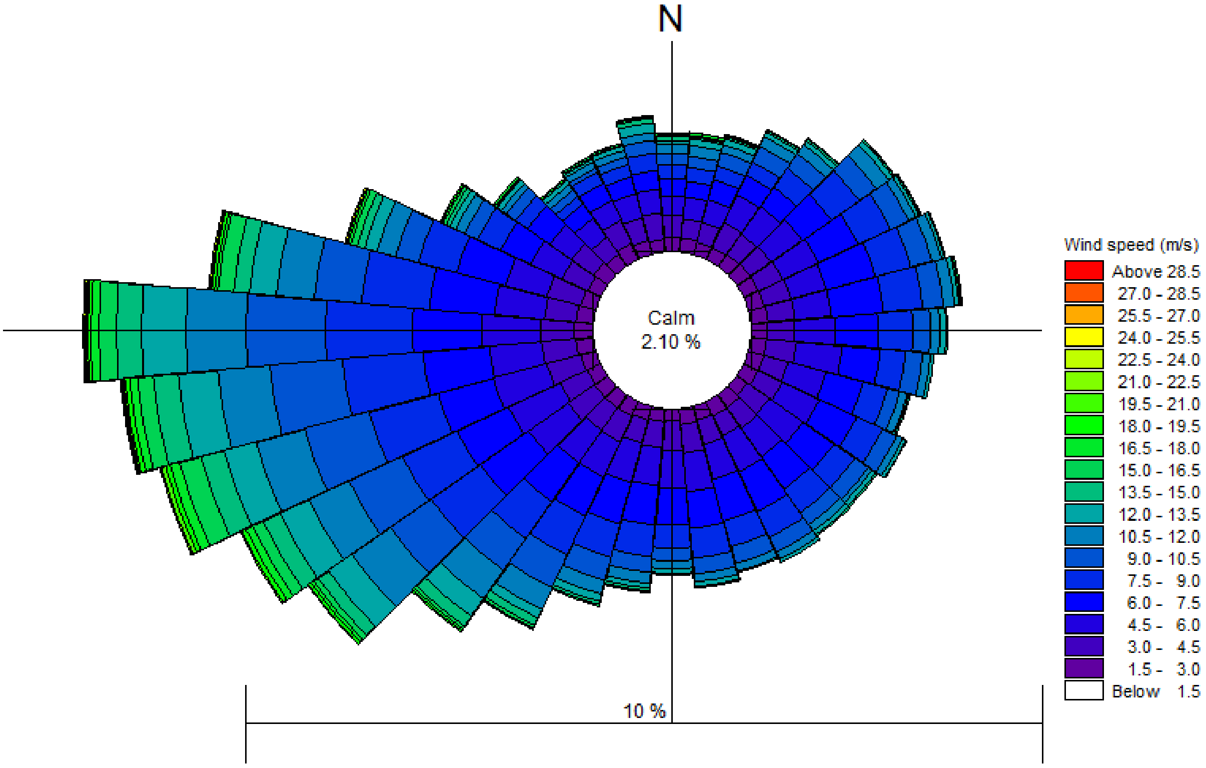


Figure 6-4 Wind rose plot for 10-year period 2000-2010

7 Impact assessment

The impact assessment will be carried out for the GBS option only (See 2.3) and thus all calculations will be done on the GBS. The assessment comprises the variant chosen for realization and the rational alternative variant.

DHI has chosen a typical hydrodynamic year (2004) for the assessments as this year represents typical conditions and thus results from this will be representative for average conditions.

Whereas, currents and waves may be affected during the entire production phase the spill impact from dredging works is primarily limited to the construction phase. However, gravity based structures (GBS) are expected to have the largest impact no matter whether the focus is on currents, waves or sediment spills.

The assessment in relation to currents and waves is conducted for two periods: one summer (July 2004) and one winter (January 2004). These periods represent typical summer and winter conditions. With regard to sediment spill it is anticipated that the wind farm will be constructed during calm weather conditions only and such conditions are most likely found during the summertime.

7.1 Influence on currents

The impact of the wind mill farm on the current field can be divided into *effects felt only very near the foundations* (within a distance from the wind turbine corresponding to 1-2 times the diameter of the foundations) and *regional effects* felt in an area of a scale corresponding to the size of the wind farm area. The following provide the assumptions made and the model results in relation to baseline conditions and in relation to impact from the two alternatives. Only the impact during the production phase is analysed in relation to impacts on currents and only in relation to the GBS option.

7.1.1 Assumptions

The effects very near the foundations (see Figure 7-1) are caused by the changes in the current and pressure field in the immediate vicinity of the wind mill foundation when the flow is forced around the foundation. These changes can cause:

- Eddies or horseshoe vortices on the sides and behind the wind mill foundations
- Increases in the velocity in the immediate vicinity of the foundations due to contraction of streamlines

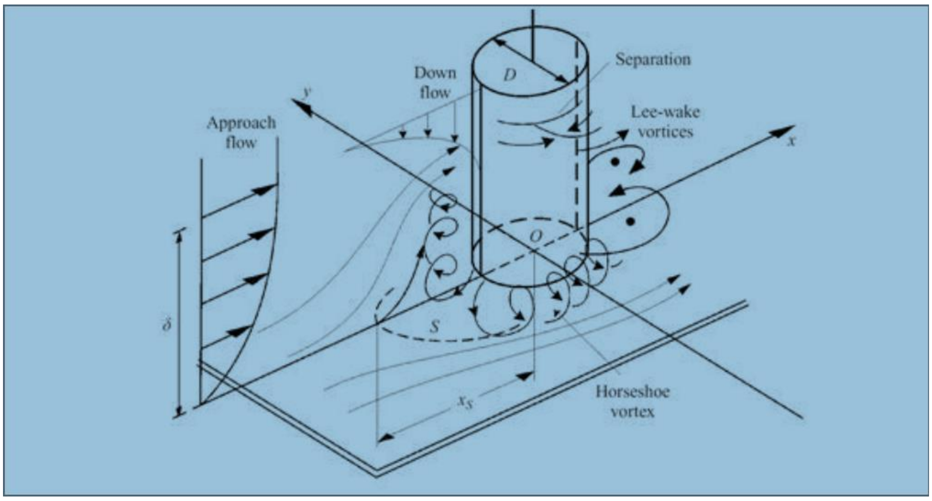


Figure 7-1 Sketch of large turbulent flow structures generated by the presence of a vertical pylon in a channel flow

In addition to changes in the velocity field, also more mixing of the water column may take place reducing the strength of a possible stratification. These modifications occur very near the wind mill foundations and their impacts are insignificant further away than approx. 1-2 foundation diameters away from the individual wind turbines. The distance between the BŚ III wind turbines is in the order of 80 foundation diameters, so these effects do not change the overall current pattern in the wind mill farm and in the surroundings.

The effects very near the foundations are not comprised by the present impact assessment since they have no significant impact on the overall flow pattern.

The regional effects are changes in the current field due to the increased resistance the foundation imposes on the overall current field. These effects impose a change in the current field within the wind mill farm area and in the surrounding area of the wind mill farm.

The regional effects of the wind turbines are assessed using the hydrodynamic models developed to describe the baseline conditions (see 3.1). The model is modified to include the impact of the wind turbines on the flow field and the impacts are assessed by comparing results from the baseline calculations and the calculations with the modified set ups including the wind turbines.

The developed 3D flow model is applied to evaluate the impact on the selected reference period (January and July 2004). The mesh size in the project area is approx. 300 m. By experience it is known that the regional effects in the flow field take place within distances in the order of the size of the wind farm from the wind farm, i.e. in the order of 10 km. Thus, the selected local grid spacing is adequate to describe the expected variations to the general flow field in the area.

In the numerical models the wind turbines are implemented at their individual locations in the form of an increased drag to include the hydrodynamic resistance from the wind turbines.

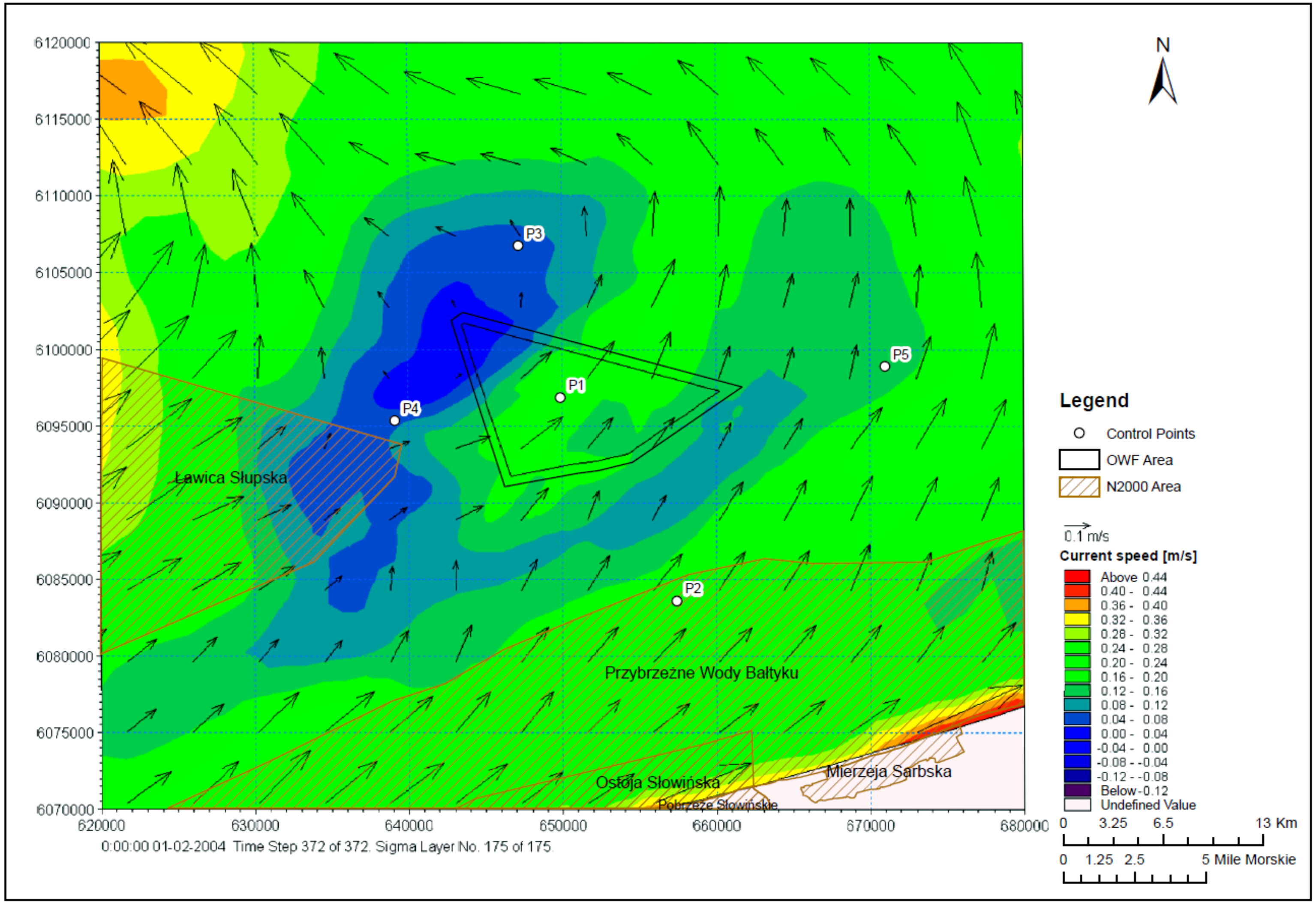
The worst case scenarios selected for numerical modelling are found to be the (120+6 and 200 +8) foundations, respectively on gravity base foundations. The foundations have been evenly distributed within the 89 km^2 available both variants.

The impact is dependent on the size and shape of the wind mill foundations and the distance between the wind turbines compared to the radius of the wind turbines. On one hand, if the wind turbines are placed right next to each other, the wind turbine park will act as one pile where the diameter is equal to the diameter of the group. On the other hand, if the wind turbines are placed very far from each other, the wind turbines will act individually without any group effect. Sumer et. Al. /3/ investigated this effect for the purpose of determining the scour in pile groups. They demonstrated that not only the distance between the piles but also the formation or layout of the piles played a role. They concluded that the less organised the piles were located, the higher was the combined resistance from the piles. However, from their study it was shown that if the distance between the piles was 4 diameters or more then the flow in the middle of the sections between the piles would be practically unchanged (change in flow velocity of less than 5%).

In the BŚ III wind farm, distances from 600 m or more between foundations are planned and the diameter of the shafts vary between 7.5 m (upper part of the water column) and approx. 20 m (lower part of the water column). That gives an approximate ratio G/D of at least 30 – 80 between the diameters (D) and the gaps between the wind turbines (G). Based on this, the main flow should be virtually unaffected. In principle the park acts as an extra roughness or a partial blockage of the overall current field. The blocked water volume is forced around the park which leads to a decrease in the flow inside the park and an increase in flow velocities on the sides of the park. In the following sections modelling results will show the extent of this impact.

7.1.2 Modelling

Two types of presentations have been prepared. One set provides an overview of the currents within the entire domain around the wind farm and another set provides time series at selected locations. The first set of maps includes the location of Natura 2000 areas and shows the baseline condition, the variant chosen for realization and the rational alternative variant during January 2004 (Figure 7-2 through Figure 7-4). Results are only shown for the last time step of the simulation. The corresponding maps for the summer month, July 2004, are shown in (Figure 7-5 through Figure 7-7). Corresponding time series of the simulated surface current speeds at various locations (P1,P2,P3,P4,P5) are shown in Figure 7-8 through Figure 7-13. The baseline maximum simulated velocities at the five locations are around 0.8 m/s with average speeds around 0.27 m/s.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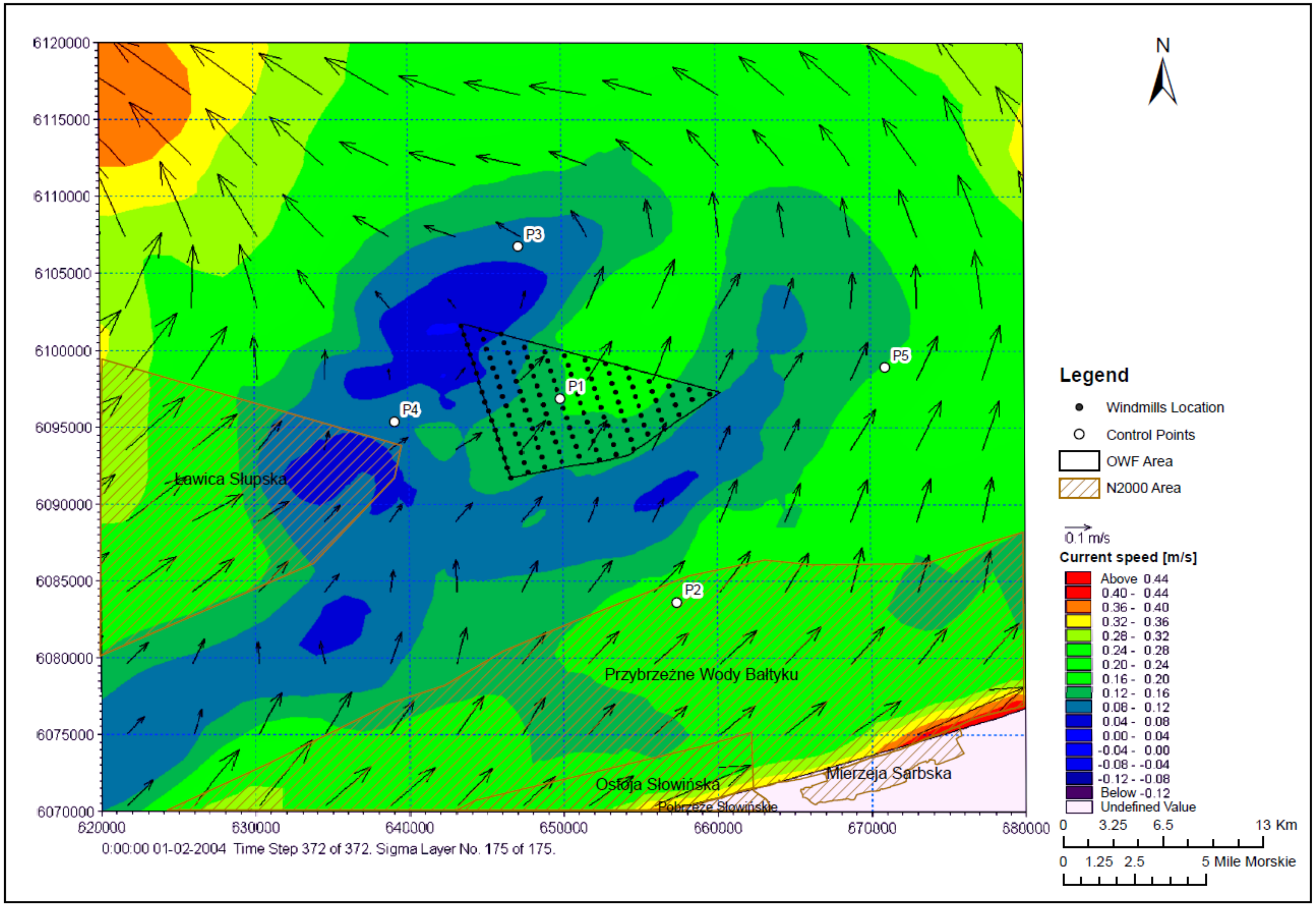


Figure 7-3 Simulated winter current speeds for the variant chosen for realization (last time step only)

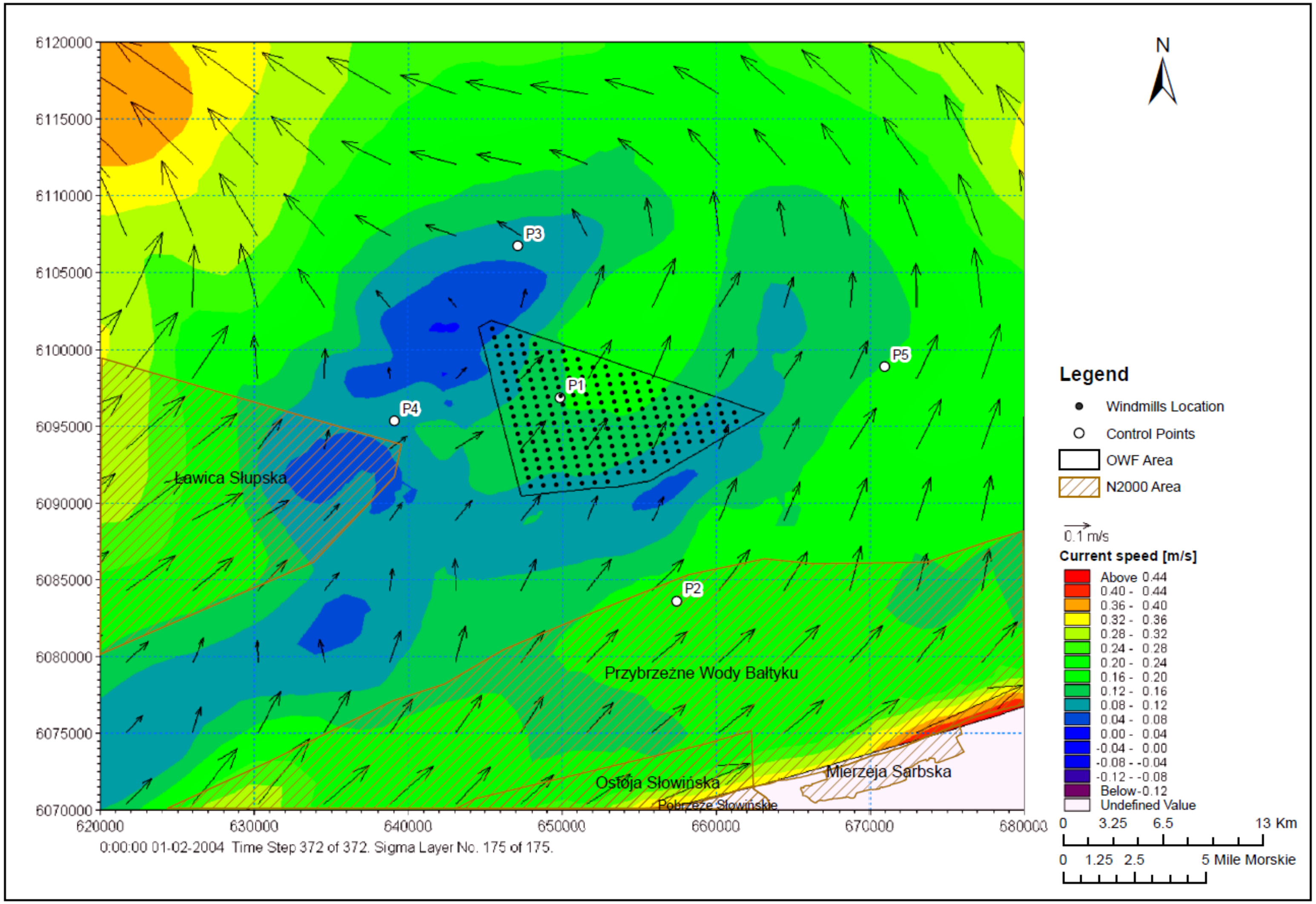
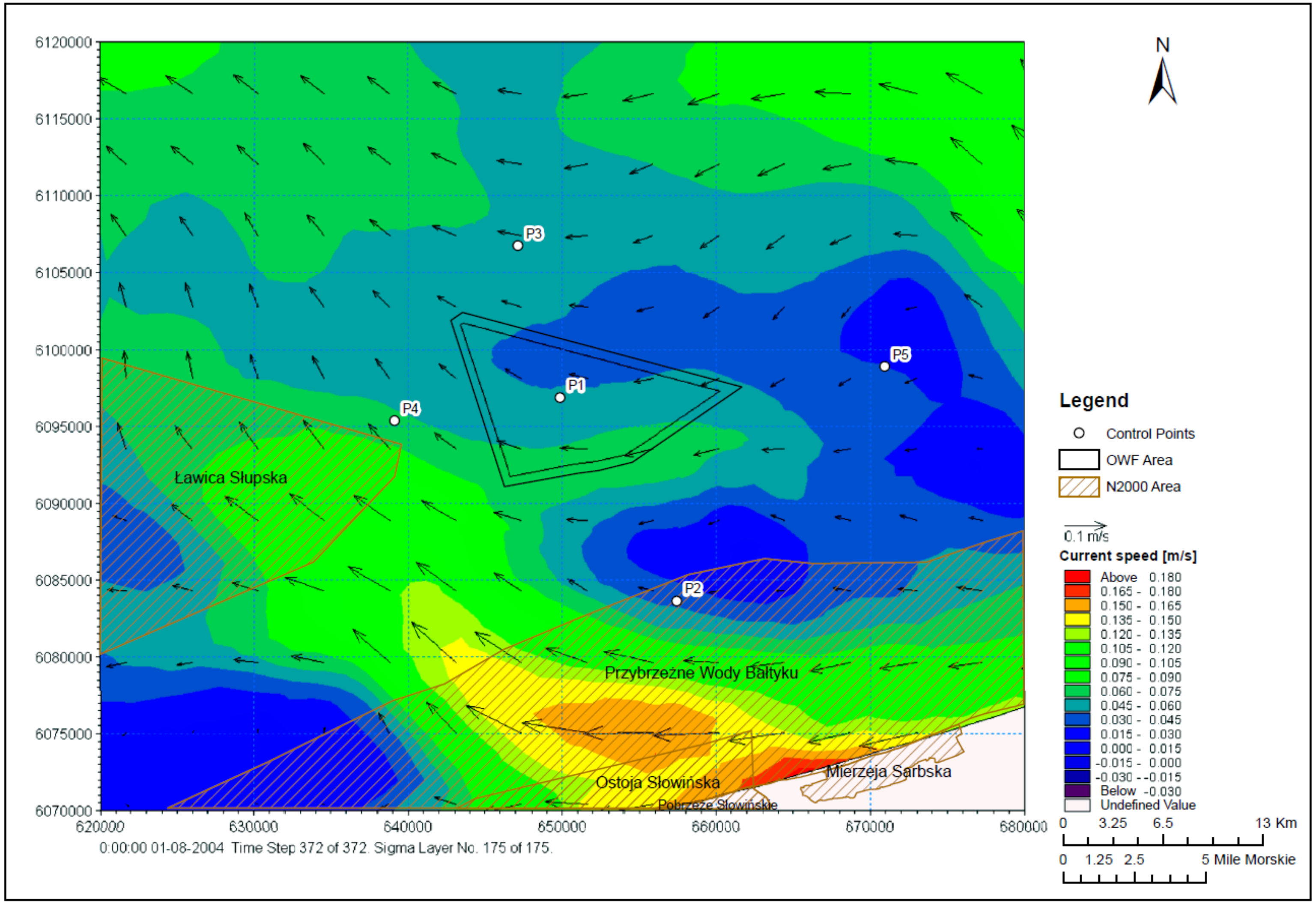


Figure 7-4 Simulated winter current speeds for the rational alternative variant (last time step only)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Przybrzeżne Wody Bałtyku
Ostoja Słowińska
Mierzeja Sarbska
Pobrzeże Słowińskie
0:00:00 01-08-2004 Time Step 372 of 372. Sigma Layer No. 175 of 175.
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Legend
○ Control Points
OWF Area
N2000 Area
0.1 m/s
Current speed [m/s]
Above 0.180
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0.150 - 0.165
0.135 - 0.150
0.120 - 0.135
0.105 - 0.120
0.090 - 0.105
0.075 - 0.090
0.060 - 0.075
0.045 - 0.060
0.030 - 0.045
0.015 - 0.030
0.000 - 0.015
-0.015 - 0.000
-0.030 - -0.015
Below -0.030
Undefined Value
0 3.25 6.5 13 Km
0 1.25 2.5 5 Mile Morskie

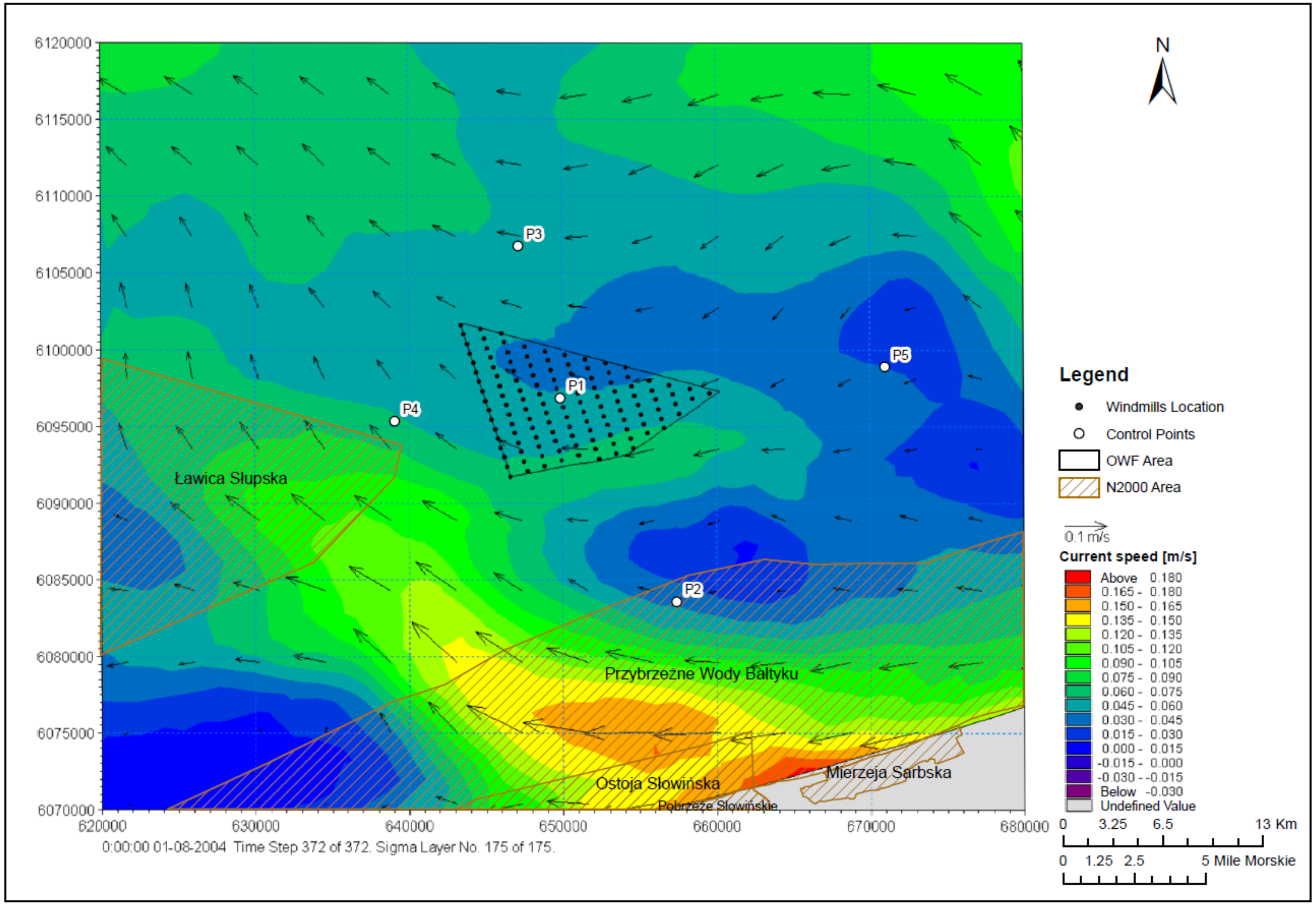

Figure 7-6 Simulated summer current speeds for the variant chosen for realization (last time step only)

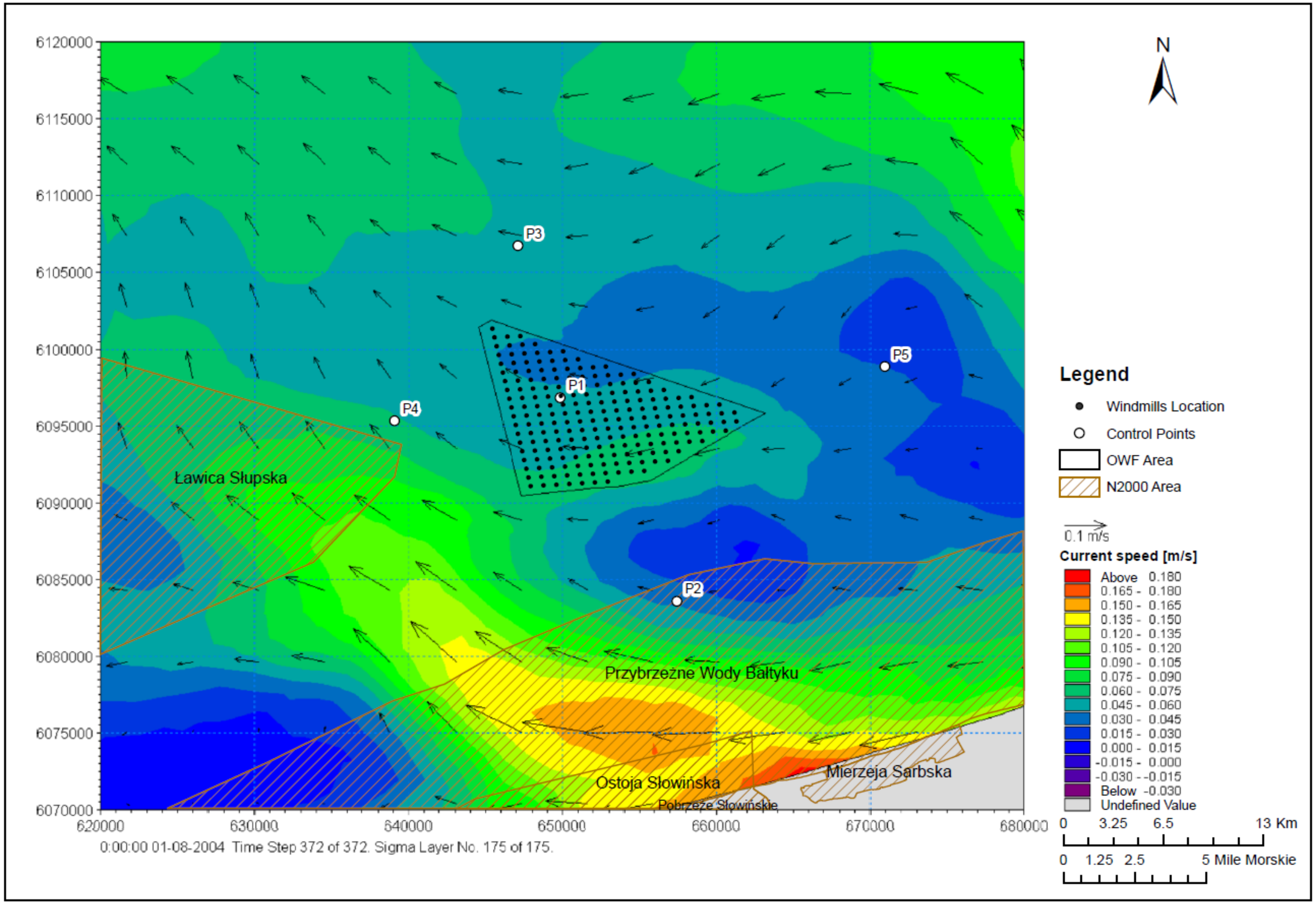

Figure 7-7 Simulated summer current speeds for the rational alternative variant (last time step only)

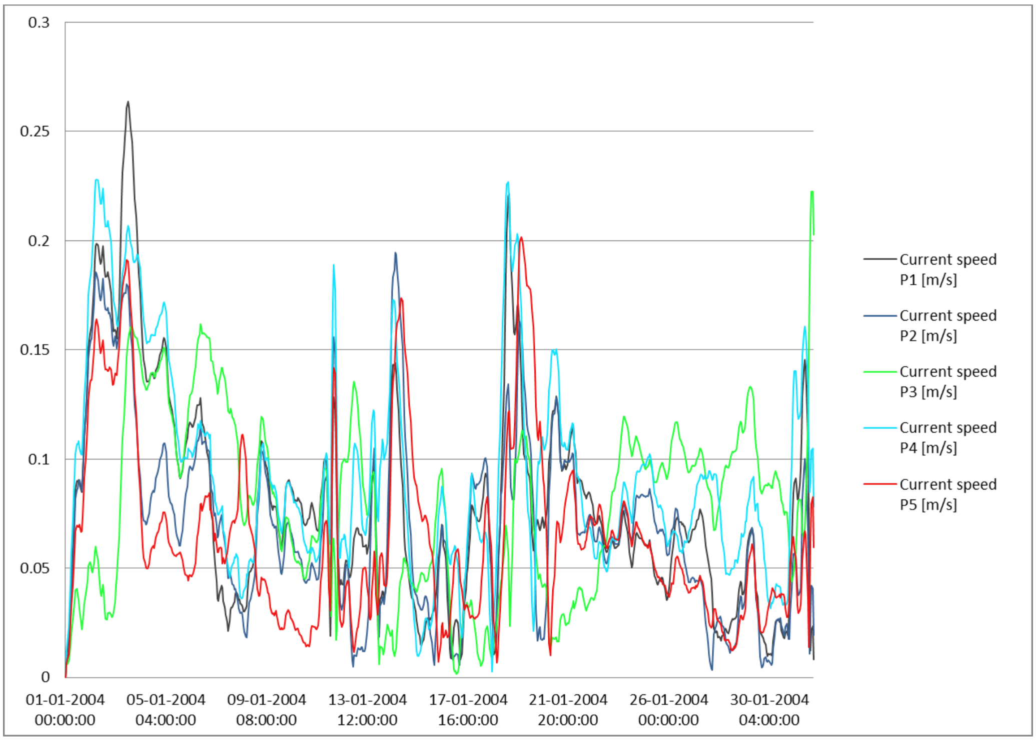

Figure 7-8 Simulated surface current speeds in the baseline situation at 5 locations – January 2004

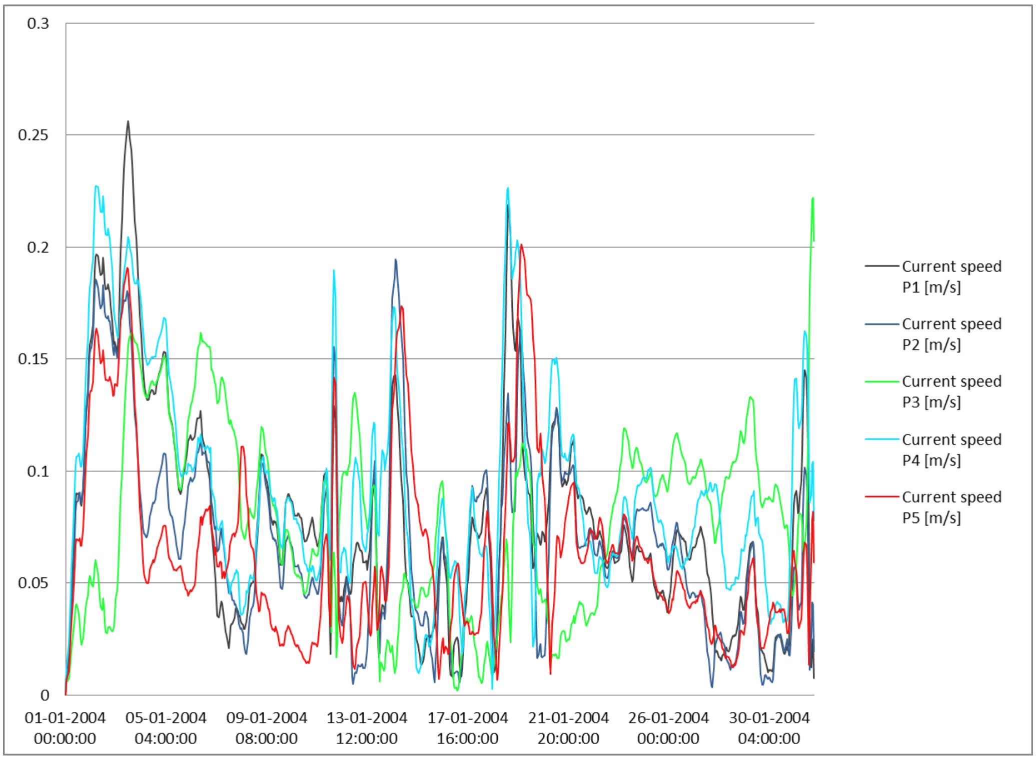

Figure 7-9 Simulated surface current speeds for the variant chosen for realization at 5 locations - January 2004

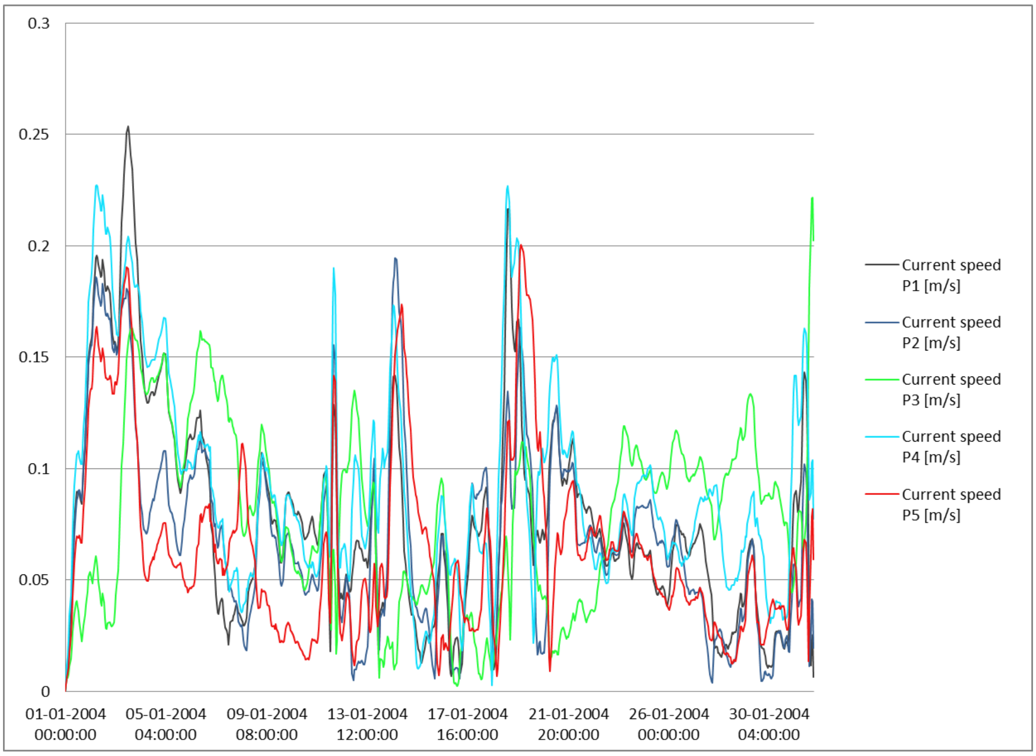

Figure 7-10 Simulated surface current speeds for the rational alternative variant at 5 locations - January 2004

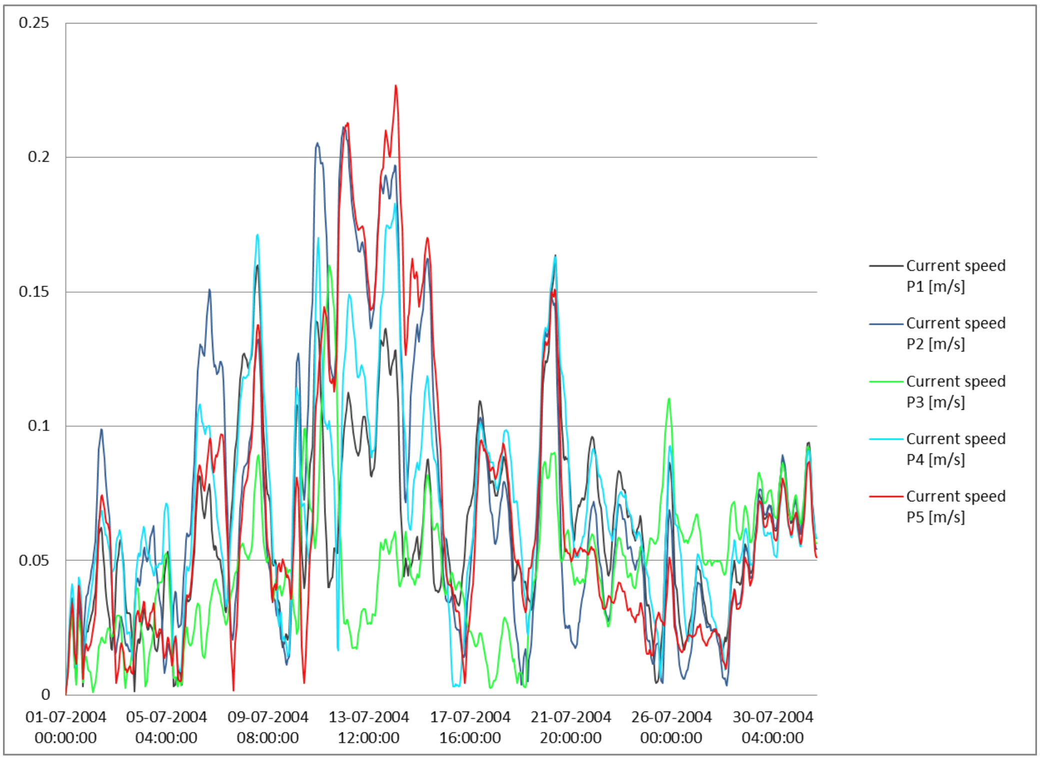

Figure 7-11 Simulated surface current speeds in the baseline situation at 5 locations – July 2004

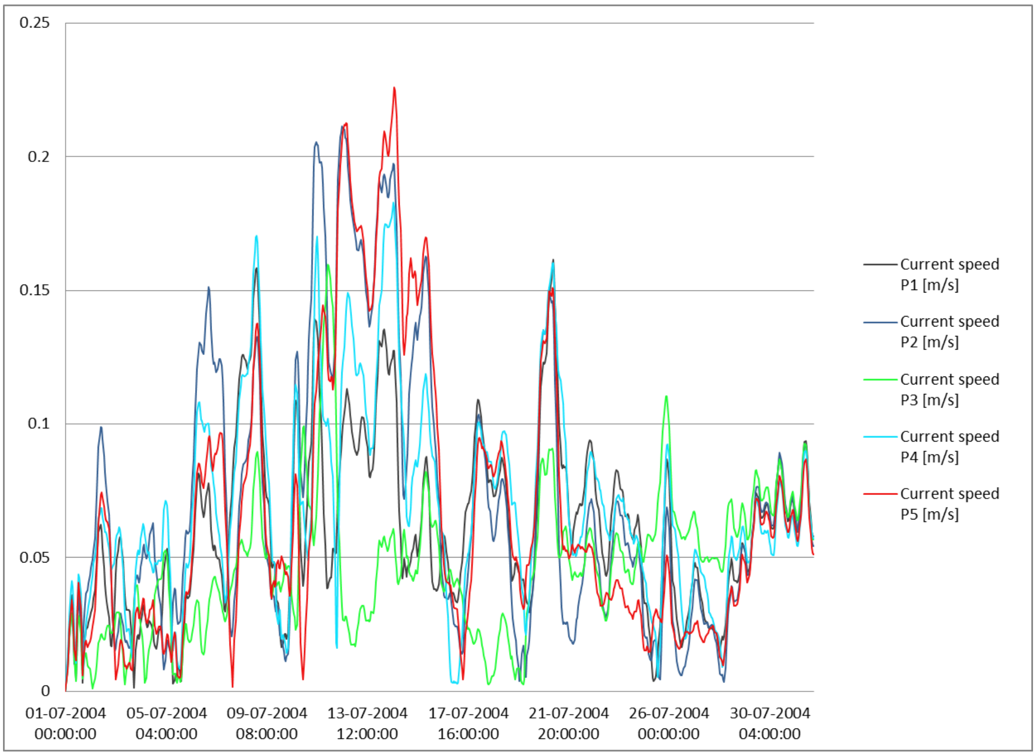

Figure 7-12 Simulated surface current speeds for the variant chosen for realization at 5 locations - July 2004

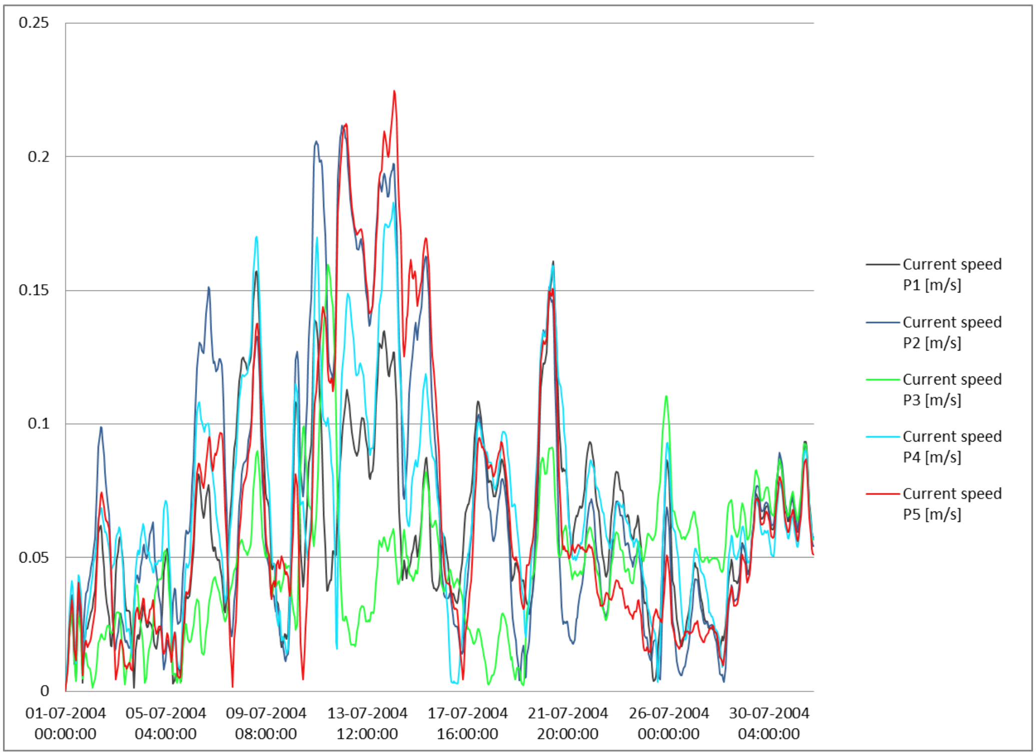

Figure 7-13 Simulated surface current speeds for the rational alternative variant at 5 locations - July 2004

7.1.3 Evaluation

7.1.3.1 Evaluation for the OWF BS III

The difference in simulated current speed with and without turbines is shown in Figure 7-14 - Figure 7-17. As can be observed the impact on currents are seen to have an order of magnitude up to approximately 0.5 cm/s during July and up to 1 cm/s during January only for the two alternatives. There is very little difference in impact between the two variants. The average impact on the current speeds in a region around the wind farm is shown in Figure 7-18 - Figure 7-21. Again, the average impact on current relative to baseline conditions is minor only and the reduction in current speed within the allocated wind farm area is balanced by a slight increase outside the wind farm.

The type and number of foundation providing the largest blocking will evidently have the largest impact on currents. In this context, the GBS foundation will provide the largest blocking. However, as already demonstrated the impact from GBS is minor only, thus one can select any of the foundation types (GBS, monopiles, tripod or Jacket) without significant impact on the current regime. As also demonstrated there is only minor difference on the impacts from the two variants.

In case mitigation measures were needed in relation to the current regime then the blocking has to be reduced and this can only be achieved by imposing larger distance between the turbines, by using constructions with as small a cross section as possible and to use shapes that are as hydrodynamically smooth as possible. However, considering the minor impact from the two variants there is no need to apply mitigating measures.

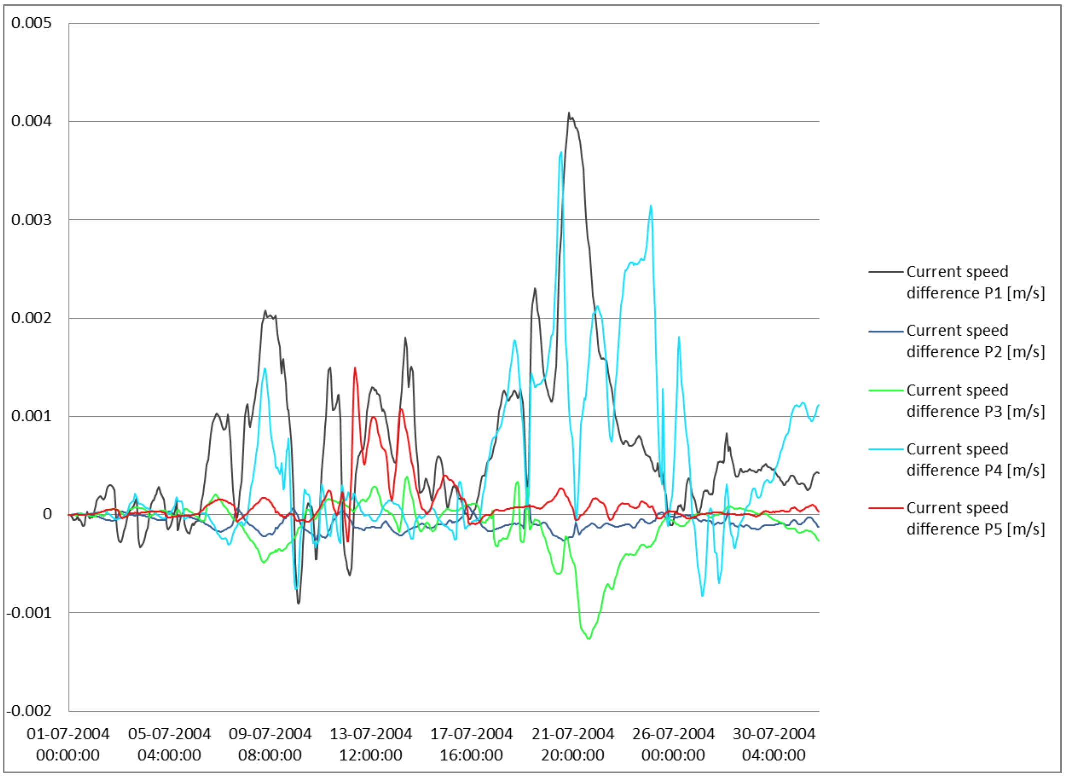

Figure 7-14 Difference in the simulated surface current speeds at the 5 locations, P1-P5, with and without turbines - the variant chosen for realization, July 2004

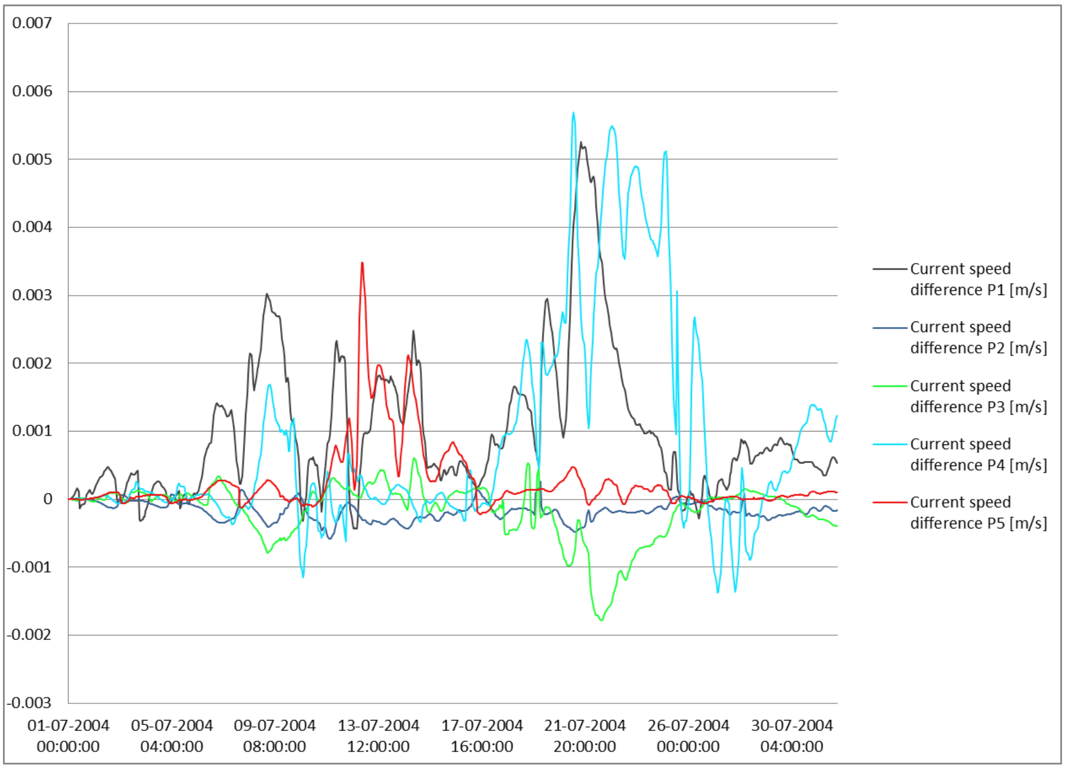

Figure 7-15 Difference in the simulated surface current speeds at the 5 locations, P1-P5, with and without turbines - rational alternative variant, July 2004

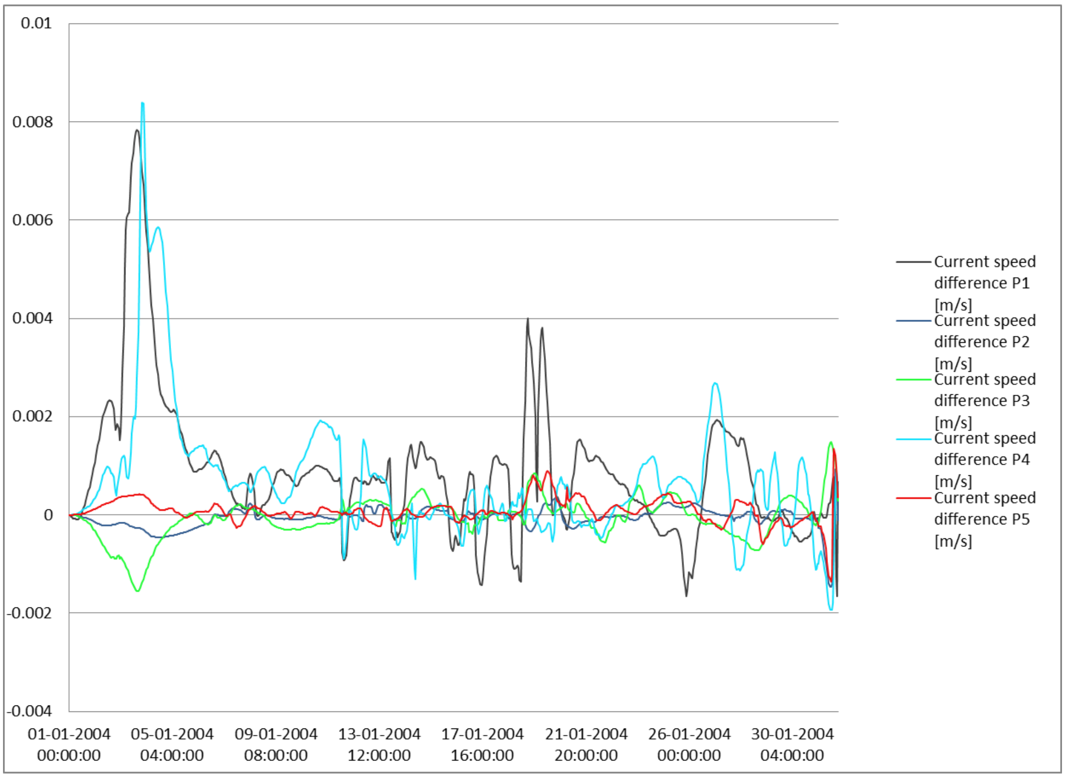

Figure 7-16 Difference in the simulated surface current speeds at the 5 locations, P1-P5, with and without turbines - the variant chosen for realization, January 2004

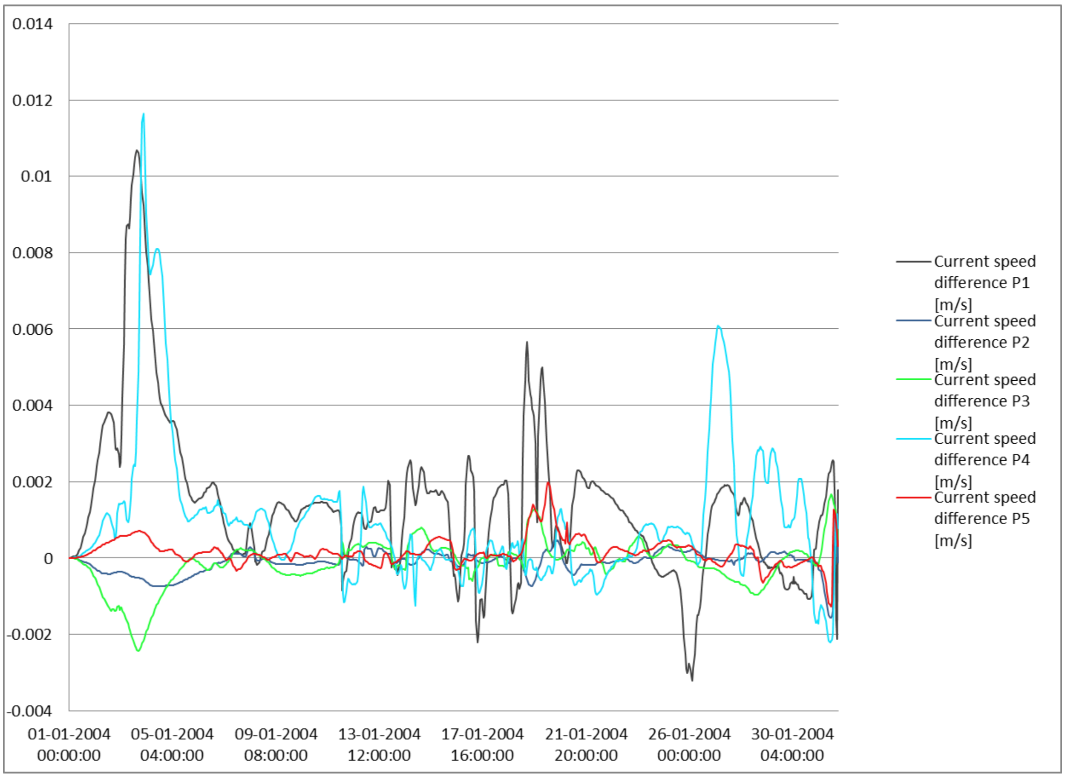

Figure 7-17 Difference in the simulated surface current speeds at the 5 locations, P1-P5, with and without turbines - rational alternative variant, January 2004

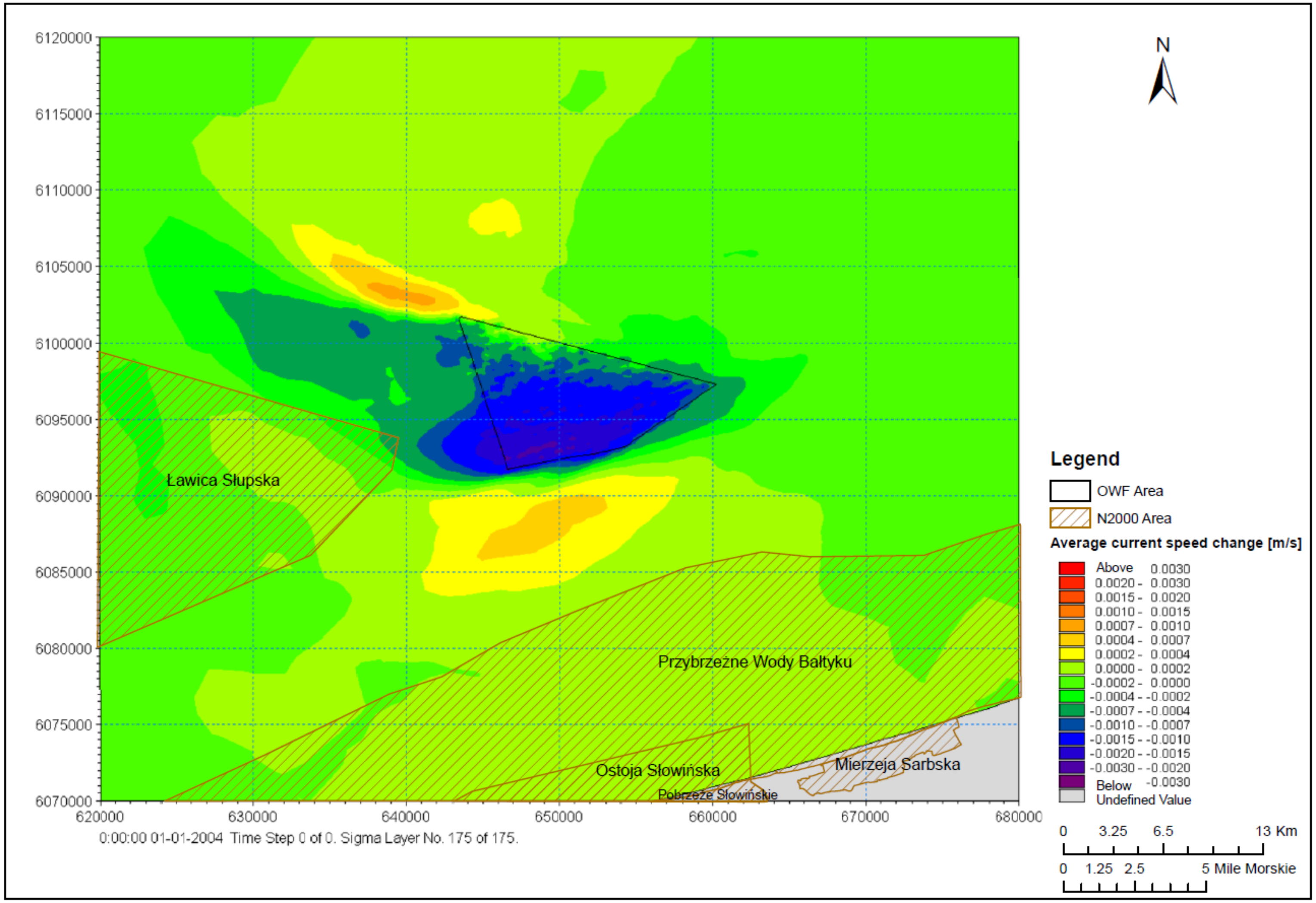

Figure 7-18 Average current speed change in the January 2004 baseline situation - the variant chosen for realization. Green- blue contours indicate a reduction in speed and the red colour indicates an increase

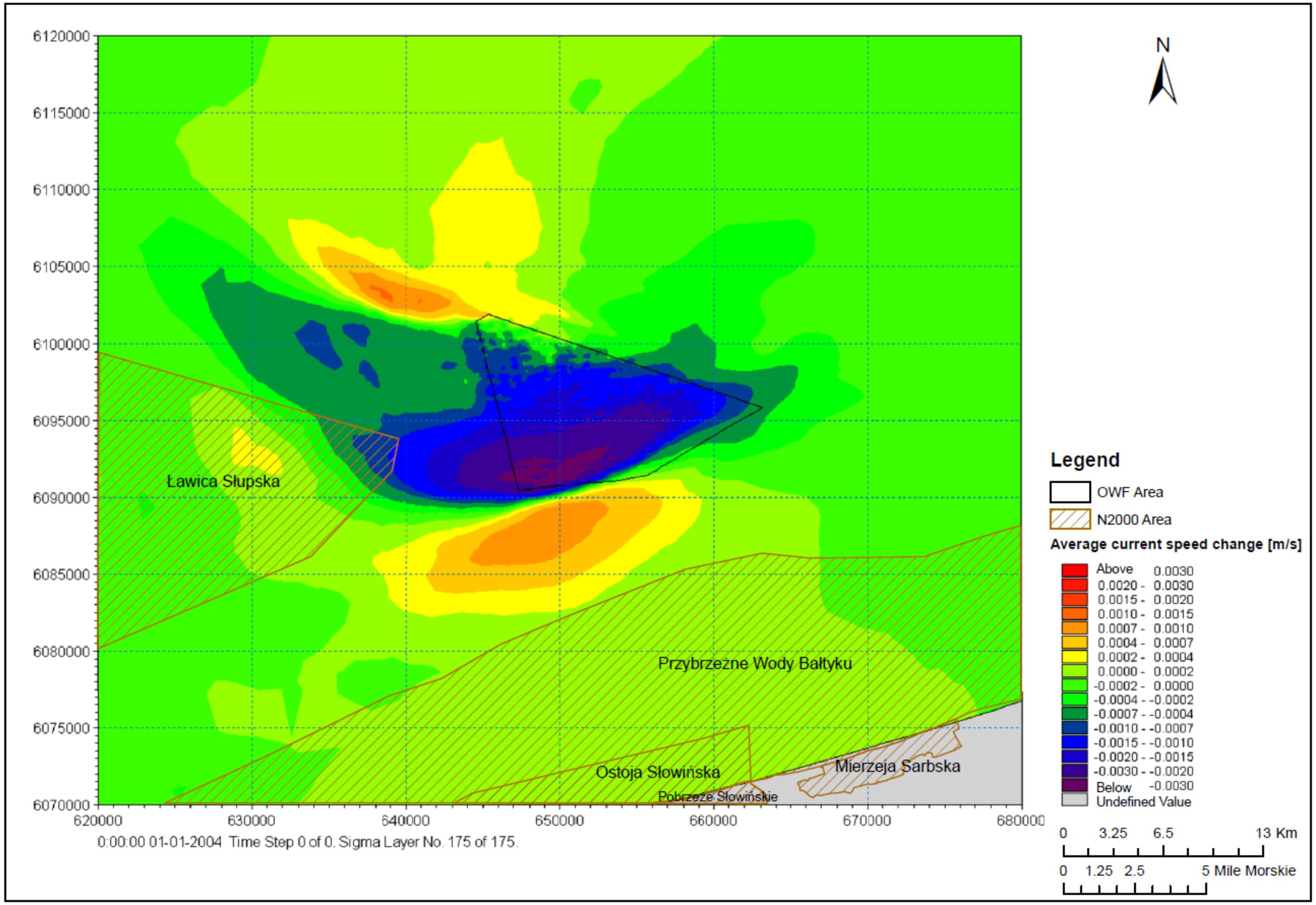

Figure 7-19 Average current speed change in the January 2004 baseline situation - rational alternative variant. Green- blue contours indicate a reduction in speed and the red colour indicates an increase

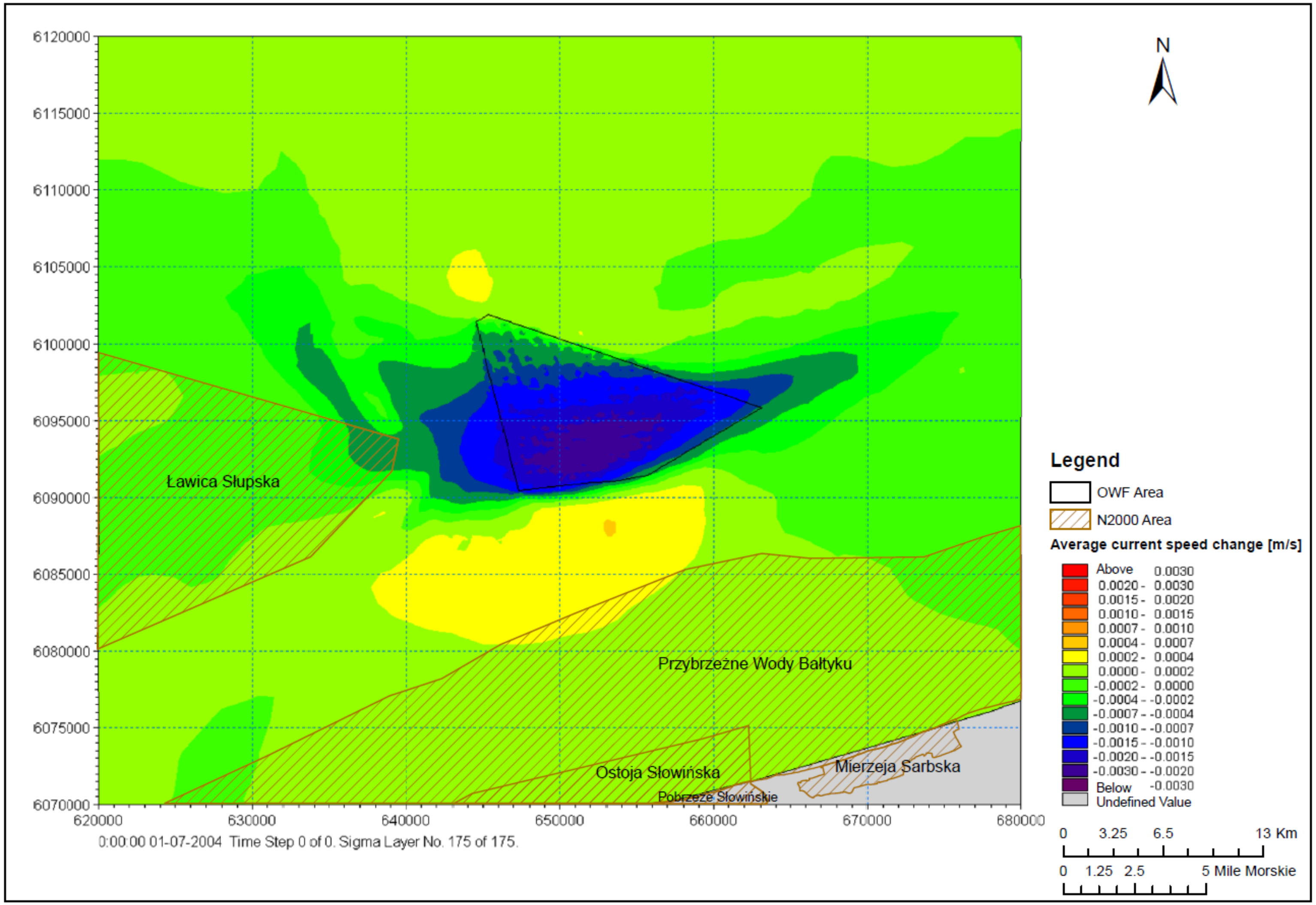

Figure 7-20 Average current speed change in the July 2004 baseline situation - the variant chosen for realization. Green- blue contours indicate a reduction in speed and the red colour indicates an increase

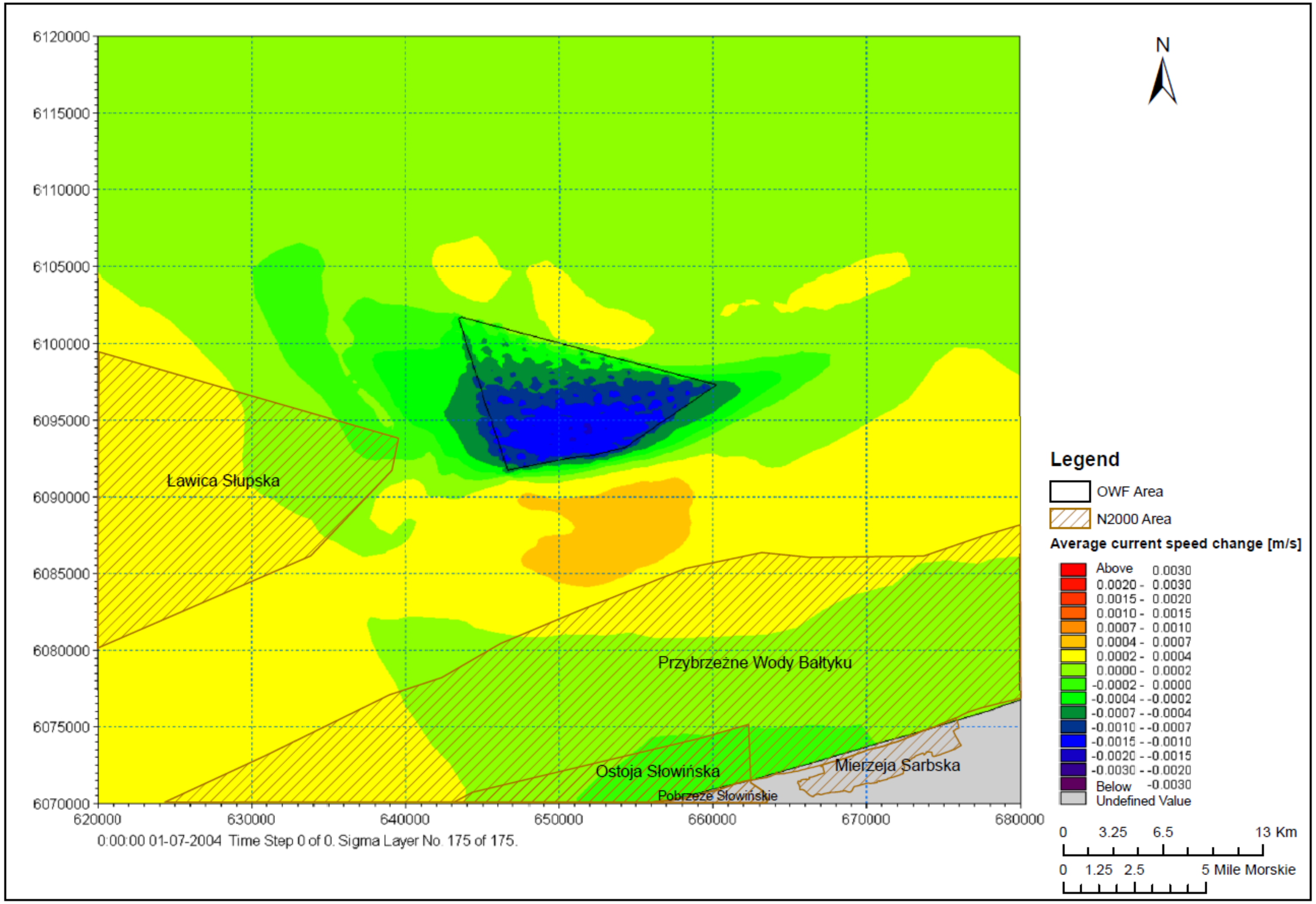

Figure 7-21 Average current speed change in the July 2004 baseline situation - rational alternative variant. Green- blue contours indicate a reduction in speed and the red colour indicates an increase

Considering the only minor impact on currents from the turbines the scale of the impact is considered insignificant as presented in Table 7-1. This conclusion applies to both variants

Table 7-1 Impact assessment in relation to currents

Impact	Scale of the exposure	Duration	Intensity	Scale of the impact
On current pattern and velocities	Local	Long-term	Low	Negligible

7.1.3.2 Cumulative impact assessment

Cumulative effects are the impacts from the current project BŚ III in combination with other plans or projects in the area, which have already been completed, approved by the planning authorities or are currently undergoing planning approval.

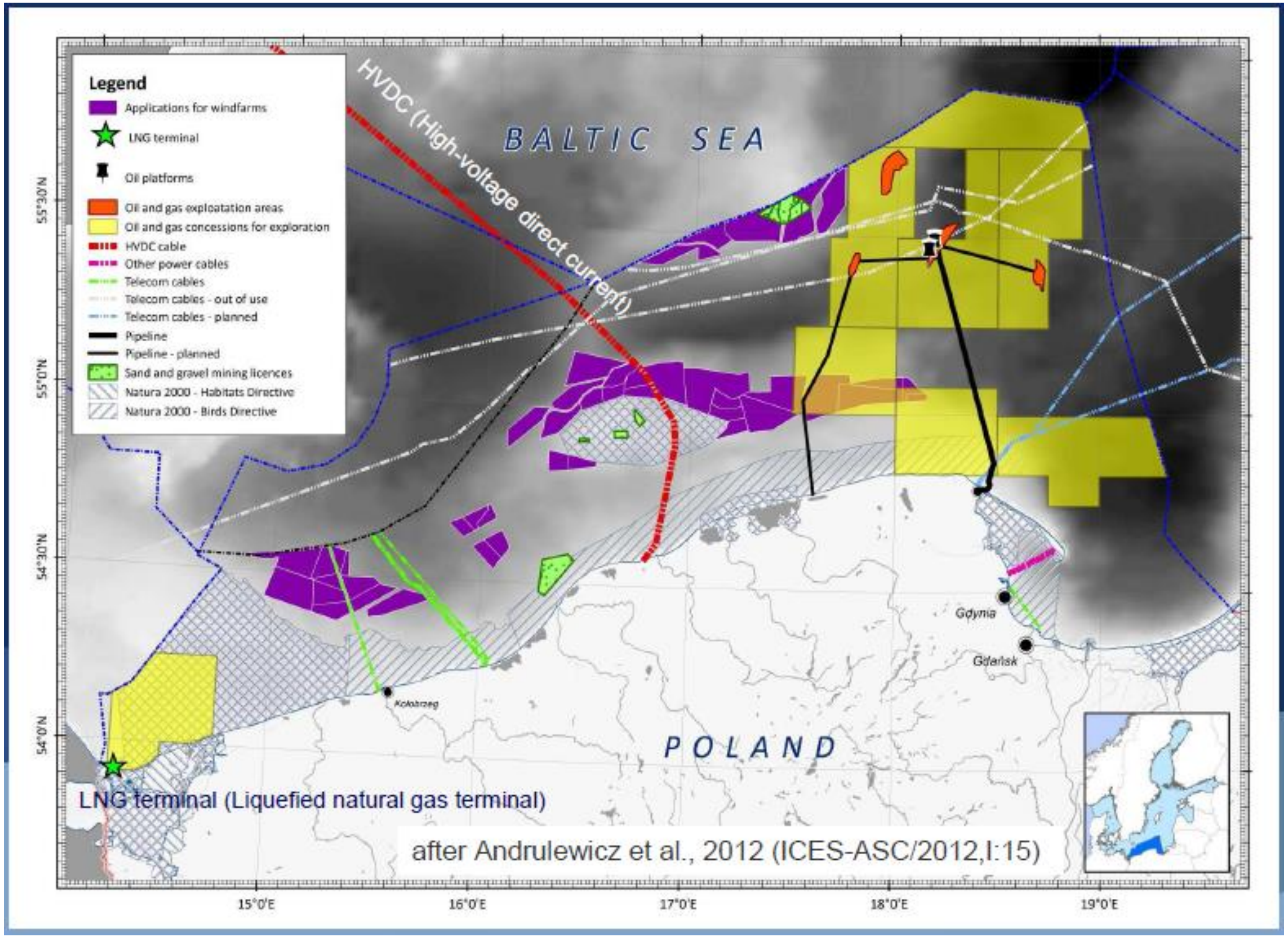

Figure 7-22 Present and planned use of the seabed space within the Polish EEZ. (source: Grygiel et. al 2013)

Projects and plans, which have been possible to identify, and which potentially can have a cumulative impact together with impacts from BŚ III are:

- Offshore wind farms

Between 2011 and 2013 a large number of applications for offshore wind farms within the Polish EEZ have been send to the Ministry for Transport, Construction and Marine Economy. In the surrounding area of the Slupsk Bank, seven wind farms could be of interest for a cumulative assessment, listed below:

- BŚ II
- Baltica 2
- Baltica 3
- Neptun I
- Neptun II
- Neptun III
- Baltica 1
- Wind farm Group

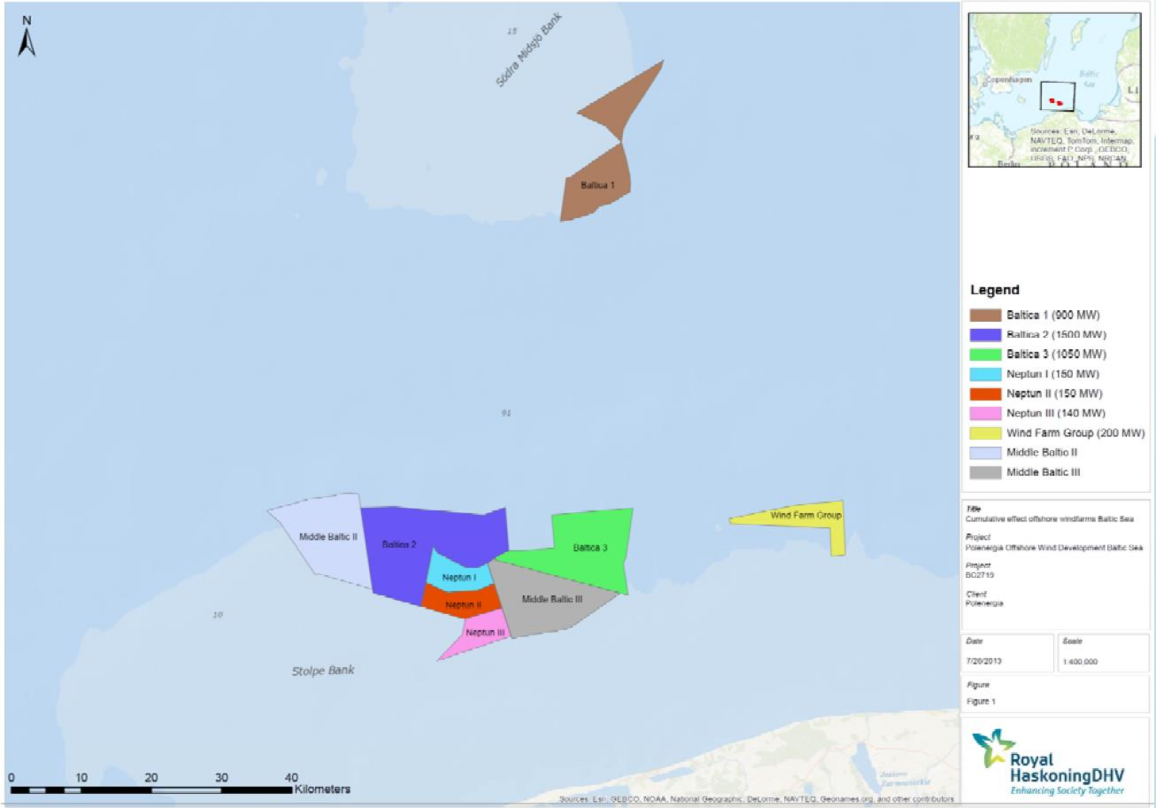

Figure 7-23 Planned offshore wind farms located in the Polish EEZ (source: Royal Haskoning DHV 2014)

Investigations have shown that only BŚ II, BŚ III, Baltica 2 and Baltica 3 are feasible wind farm projects (in addition to BŚ III). There are no operating offshore wind farms within the Polish EEZ at the moment.

In the Swedish EEZ only one offshore wind farm can be relevant for the cumulative assessment: Södra Midtsjöbanken located close to the Polish EEZ, currently in the planning phase. An Environmental impact Assessment has been prepared for the project. The maximum number of turbines will be 300 with a maximum height <200 metres including rotor (E. ON Vind 2012).

Although, several wind farms are located in the vicinity of BŚ III no accumulative effects on the current regime are expected. The main reason being that the effects from other parks are expected to have similar negligible impacts as summarized in Table 7-1

7.1.3.3 Evaluation of the impact on Natura 2000

The impact on the current regime around OWF BS III is considered negligible for both variants, thus no impact are expected in the adjacent Natura 2000 areas.

7.2 Sediment spill during dredging activities

7.2.1 Assumptions

In the construction phase up to (120+6) or (200+8) foundations will be built in the project area. Sediment spill is expected during the construction when the cables between the wind turbines are being jetted into the seabed and – in case of gravity foundation (GBS) – where the foundation areas will be dredged down to geological layers capable of supporting the foundations. Furthermore, sediment spill is to be expected when the sea cable between the wind mill park and the offshore substation is established. During this operation a portion of the fine material in the seabed will be spilled into the environment. The fate of this material is the topic of this section.

Sediment spill caused by the construction of BŚ III Offshore Wind Farm is assessed by modelling the sedimentation and spreading of sediment. Simulations are carried out by assuming a realistic day-by-day dredging schedule, where the dredgers move around in the wind farm and dredge areas for the foundations and trenches for the connecting cables. The project activities causing sediment spill are summarised in Table 7-2 together with the potential environmental impacts of the activities.

The material spilled into the water is tracked by the model until the dredging operation is finished. As long as the sediment is suspended in the water column, the concentration of sediment is increasing in areas where the sediment is transported to. The spreading and concentration are governed by current speed and direction, turbulence and settling velocity of the sediment. When the particles fall to the seabed, they may later be eroded and become re-suspended in the water column if the hydrodynamic conditions are strong enough. Increased concentration of suspended solids can be seen as a deterioration of water quality along with increased concentration nutrients and phytoplankton and reduction in dissolved oxygen. Actual levels of suspended solids that may cause harm to the environment will vary depending on the background concentration. However, the assessment of impact on biota and water quality from spreading is not included in the present report.

Table 7-2 Project activities causing sediment spill and potential impacts

Activity	Sources of potential impacts	Potential environmental impacts
Dredging for foundation and dredging for cables	Spreading of sediment spills	• Water quality • Benthic fauna • Benthic habitat • Fish

The sediment spill generated during construction of a wind farm depends mainly on the volumes of sediment that are handled (i.e. foundation by monopiles does not require any dredging). Choosing gravity foundations hence cause larger volumes of sediment dredging and therefore larger sediment spill rates. Geologically the sea bed in the wind mill area consists of layers of mud, sand and rocks as described in the geological base line report by MIG. Based on the RH report a series of assumptions are made regarding the dredging operations. These are given in Table 7-3.

Table 7-3 Assumptions for dredging operations for foundations

Scenario name	Rational alternative variant	Variant chosen for realization
Foundation shape	Round	Round
Foundation diameter base	40	40
Diameter protection layer	70	70
Total burial depth	3	3
Dredging volume pr foundation	2507*	2507*
Dredging volume protection layer pr foundation	11099*	11099*
Total volume pr foundation	13606	13606
Number of foundations	208	126
Total dredged volume	2 830 048	1 714 356
Dredging method	Grab Dredger (GD)	Grab Dredger (GD)
Spill location	Water column	Water column
Spill (%) (Fines only)	3	3
Assumed dry density (kg/m^3)	1800	1800
Total amount of spilled material (m^3)	84084	51430
Dredging time pr mill (hours)	24	24
Dredging rate (kg/s)	283	283
Spill rate (kg/s)	8.50	8.50
Number of dredgers	3	2

*Volumes calculated as a frustum $V=1/3*\pi*h*(a^2+ab+b^2)$ in which a and b are the radius at the top and bottom and h is the height

The type of dredging equipment is assumed to be a grab dredger. The dredger is assumed to work 24/7 with literally no transfer time between foundations. The spill rate is set at 3% which in DHI's experience is a slightly conservative value. The spill will be equally distributed in the water column. Similarly, a series of assumptions are made on the cable works. These are given in Table 7-4.

Table 7-4 Assumptions for dredging operations for internal cables

Dredging for cables between turbines	Rational alternative variant	Variant chosen for realization
Internal park cables (km)	200	200*
Assumed burial depth (m)	3	3
Width of affected soil	3	3
Burial method	Jetting	Jetting
Touched volume (m^3)	534545	326955
Spill percentage (fines only)	3	3
Spilled mass (tonnes)	28865	17656
Speed (m/day)	577	577
Spill rate (kg/s)	2	2
Spill location	bottom	Bottom
Number of vessels	3	2**
Dredging period (days)	69	63

* Maximum number indicated by the investor; ** Different number of vessels applied to fit dredging plan

The cables are assumed to be buried to a depth of 3 m by jetting. It is assumed that the soil in a 90 degrees triangle above the pipe is washed for fines by the penetrating water from below. The fines are released at the bottom.

It is assumed that the dredging for cables starts 2 weeks after the dredging for foundations have started thereby allowing for a two-week period to deploy the foundations.

The spill in the model is included as moving dredgers working at the foundations. Similarly, the jetting of the cables is included along the cable lines.

Only the fine sediment with diameters less than 64 µm is modelled since sediment with larger diameters are expected to settle so fast that it will not be transported out of the work area. The model is setup as a so called excess model which means that only the spilled sediment is modelled. No background sediment is included. The sediment is represented by one fraction with a settling velocity of 0.5 mm/s corresponding to medium silt and with a critical shear stress for erosion of 0.1 N/m^2. This is the shear stress beyond which the sediment will erode. The critical shear stress for deposition is set to 0.07 N/m^2. This is the shear stress below which the sediment will deposit. The simulation is run in 3 periods all for July 2004 thereby representing typical calm conditions where dredging is expected to occur. The July conditions are used to model 3 consecutive months and thus cover an entire three month dredging period. Thus it is not relevant to model a winter month as such a month will include too many days with rough seas. However, dredging will most likely take place all days year round provided that weather allows.

7.2.2 Modelling

The results are given in Figure 7-24 through Figure 7-29.

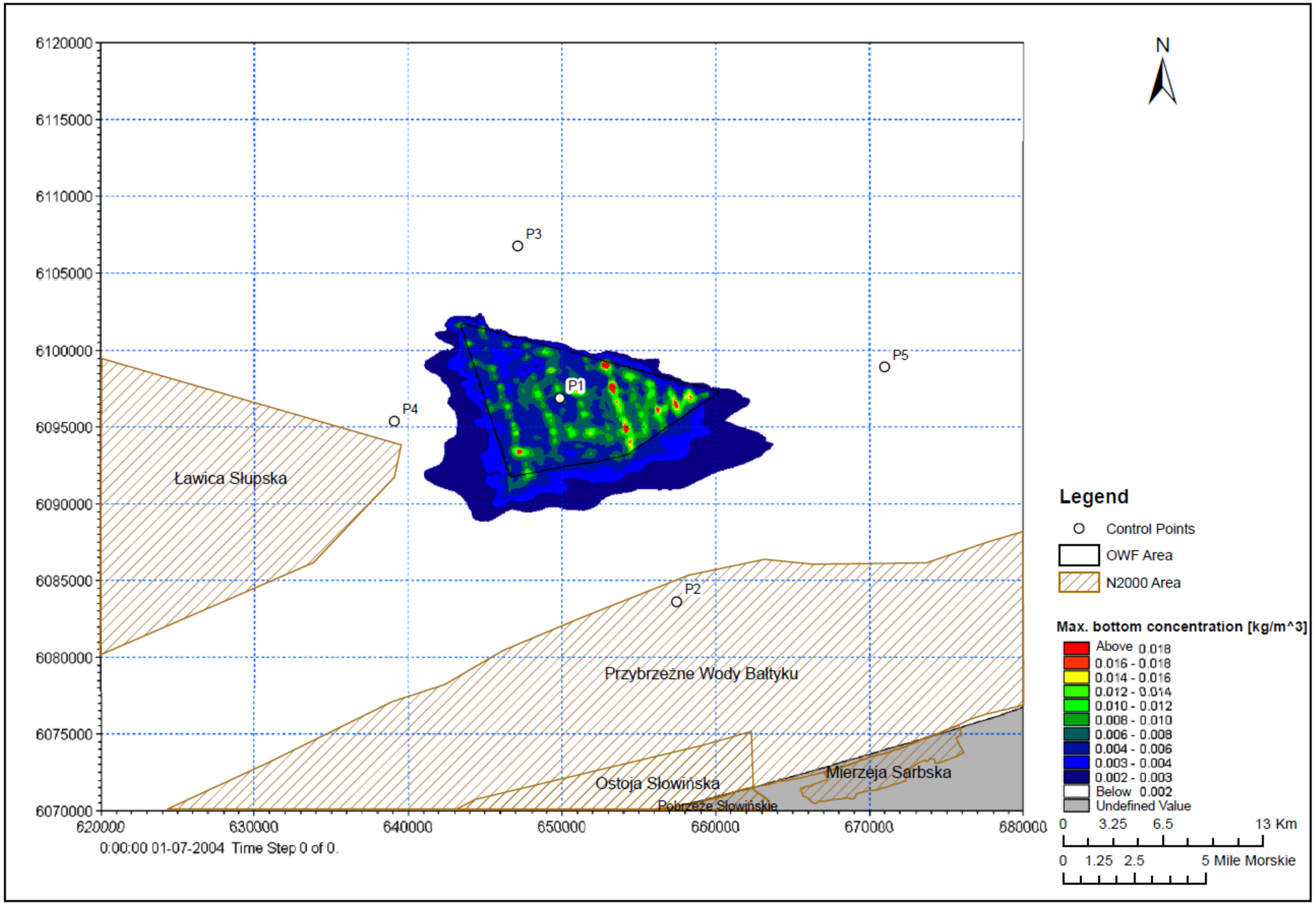

Figure 7-24 Maximum concentration at the sea bed over the entire dredging period - Variant chosen for realization

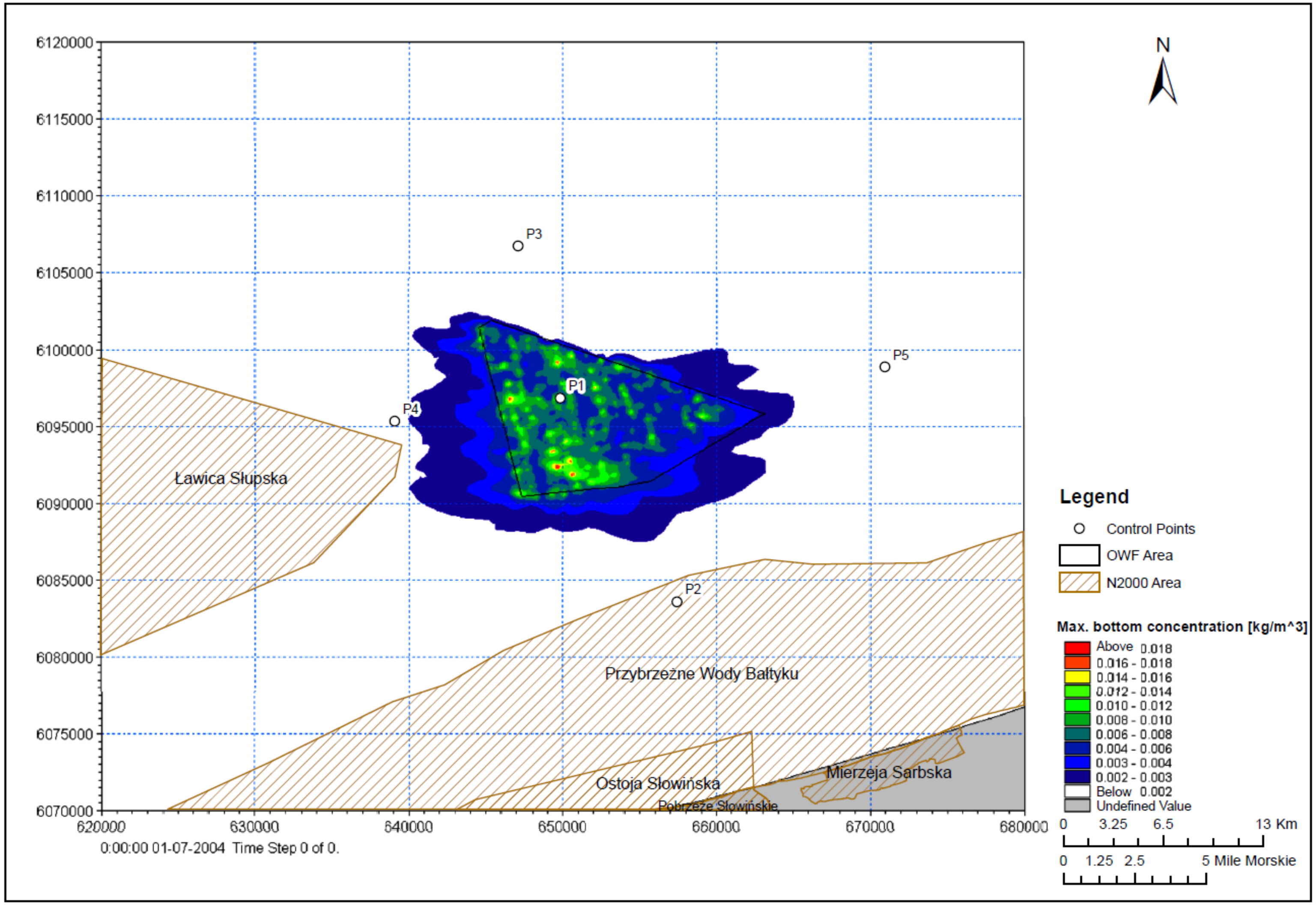

Figure 7-25 Maximum concentration at the sea bed over the entire dredging period - Rational alternative variant

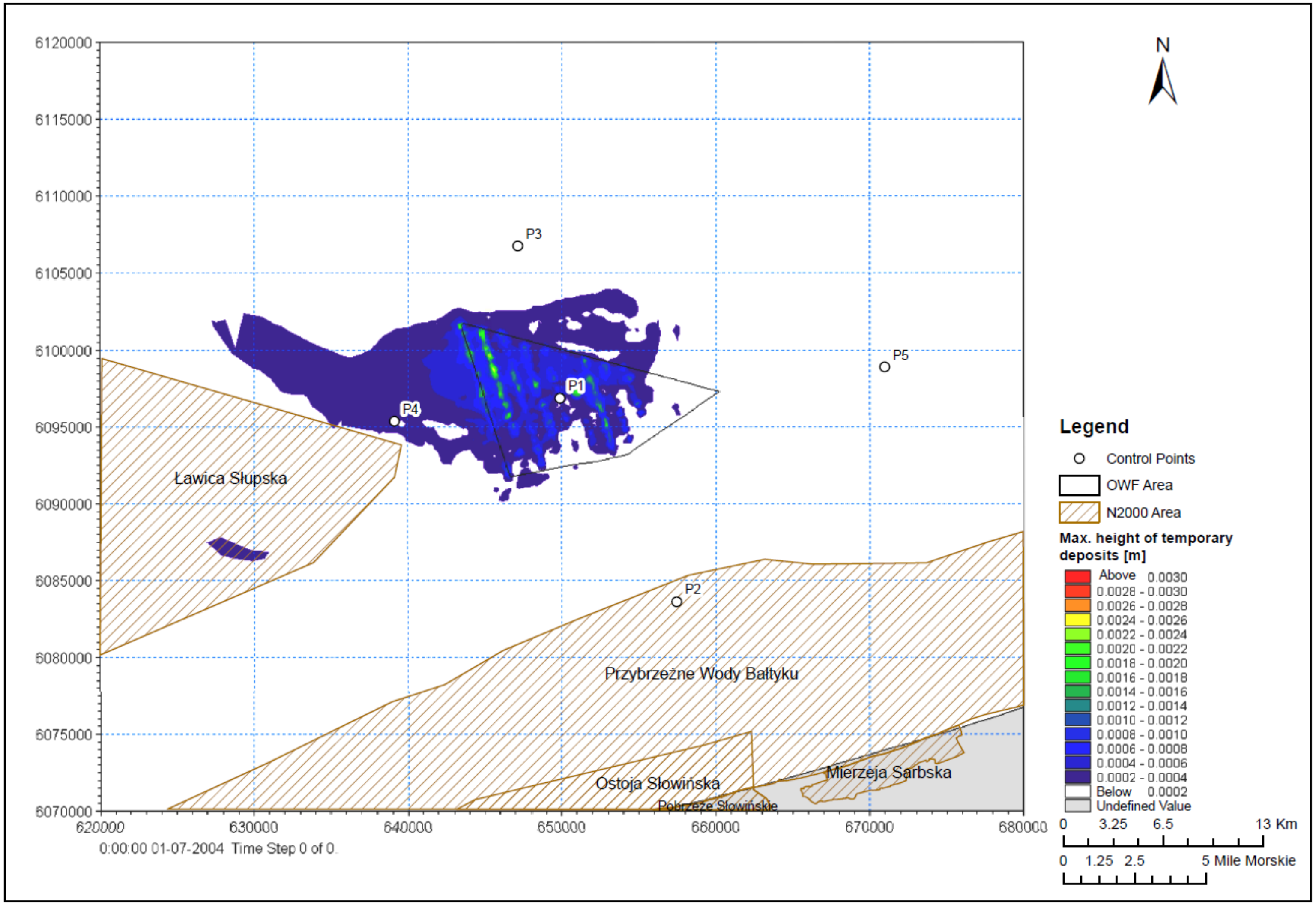

Figure 7-26 Maximum height of temporary deposits - Variant chosen for realization

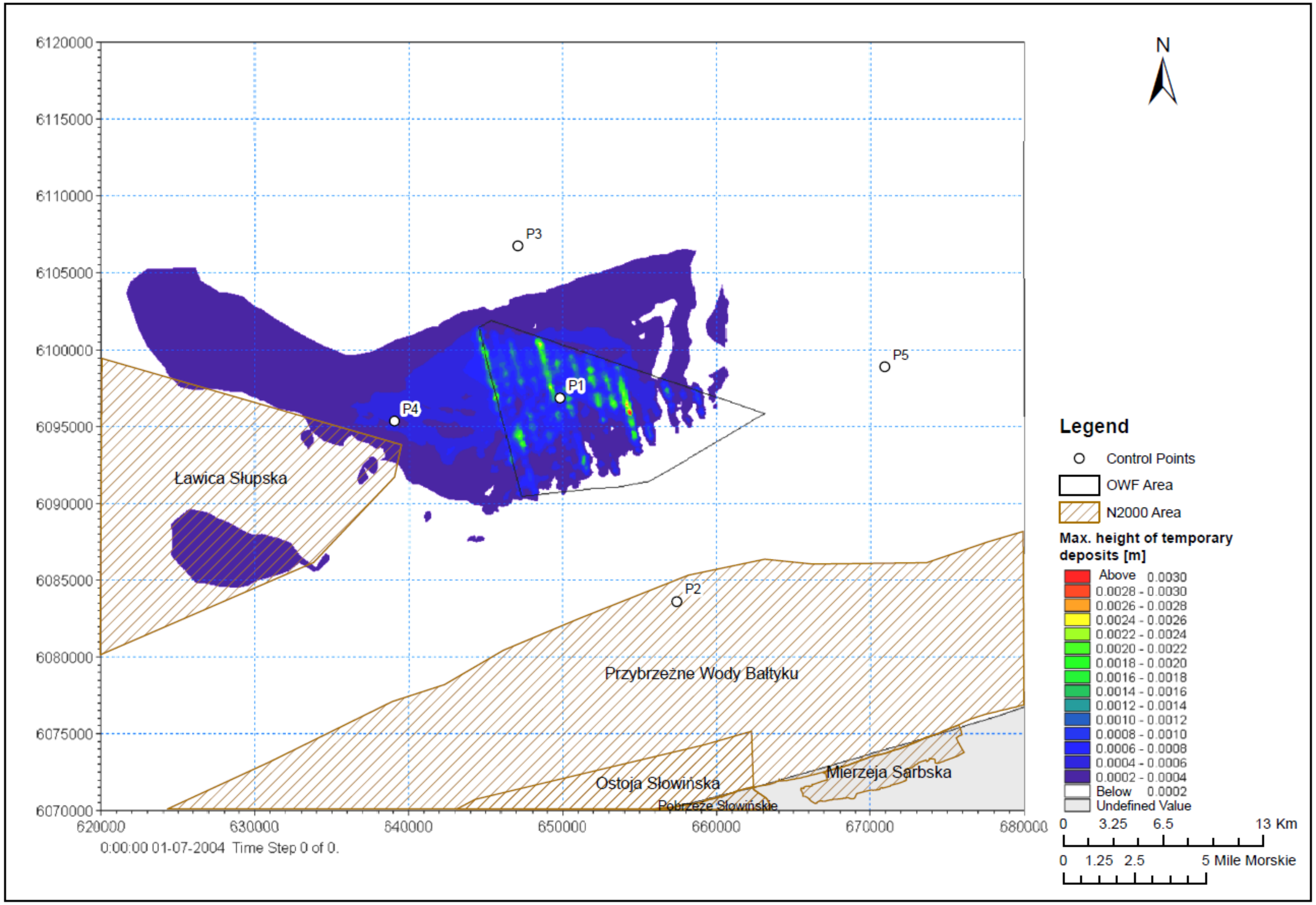

Figure 7-27 Maximum height of temporary deposits - Rational alternative variant

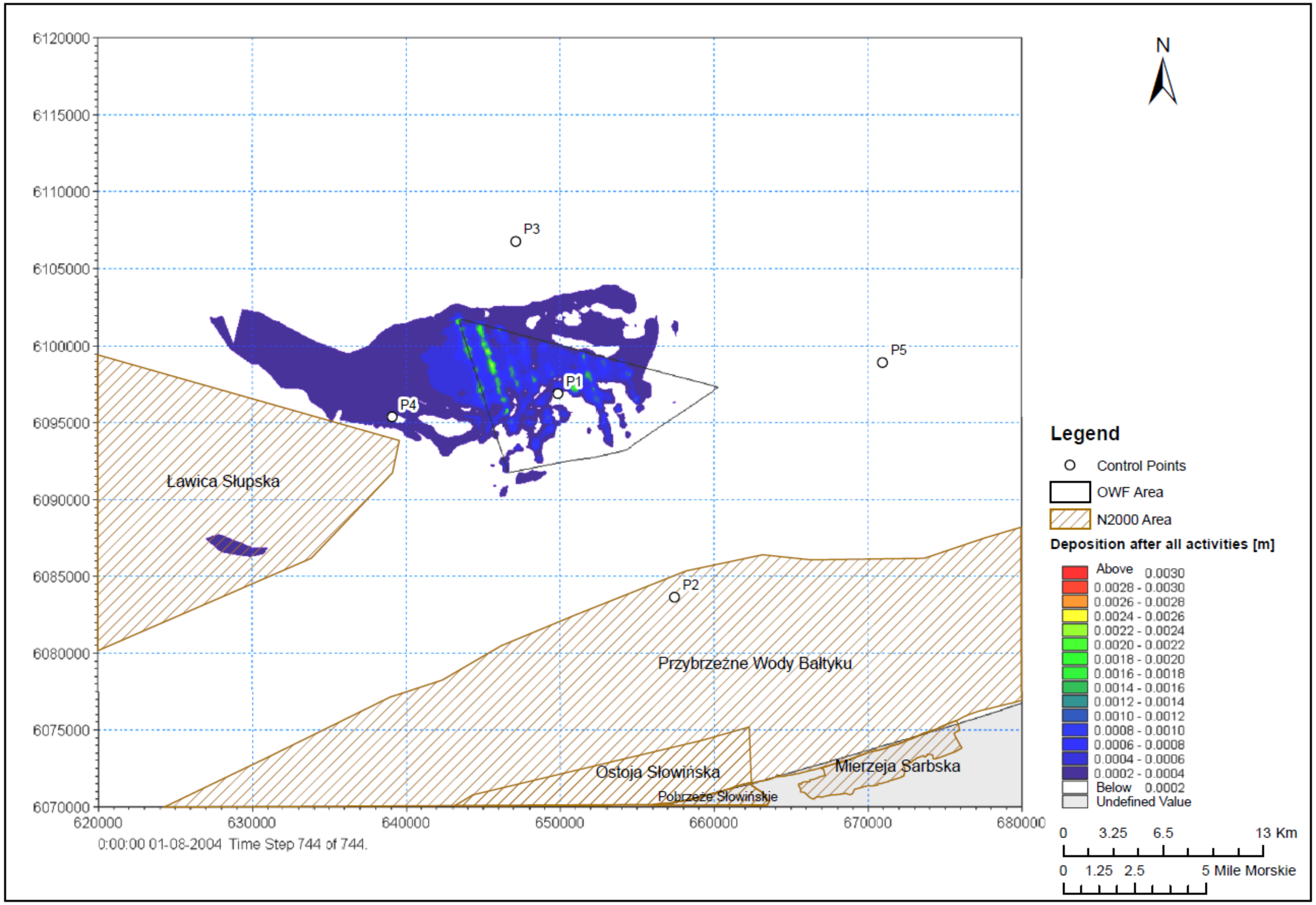

Figure 7-28 Deposition after all dredging activities have seized - Variant chosen for realization

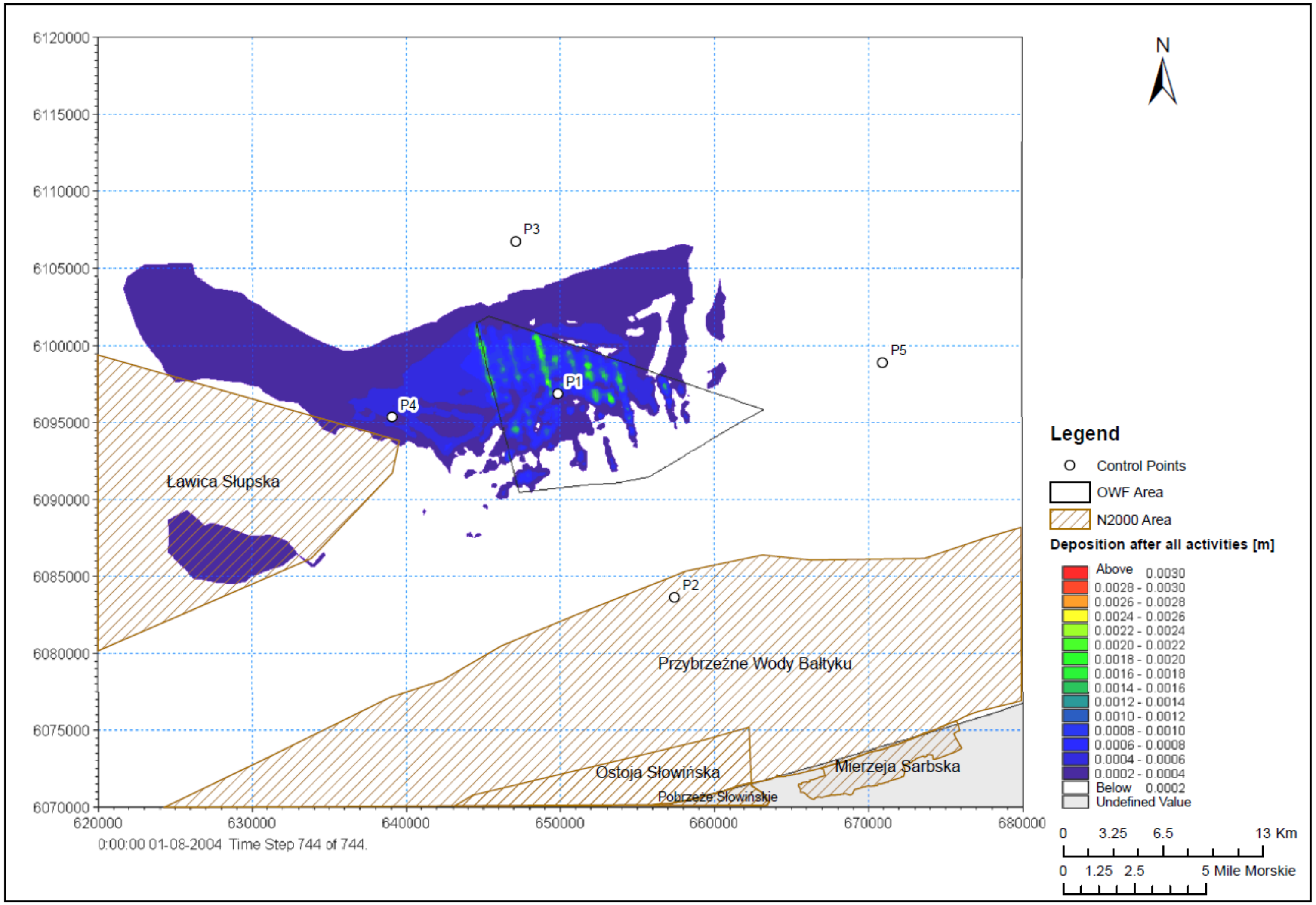

Figure 7-29 Deposition after all dredging activities have seized - Rational alternative variant

7.2.3 Evaluation

7.2.3.1 Evaluation for the OWF BS III

The maximum concentration plot shows the maximum concentration occurring in each point. It is thus not a snapshot of a real plume but a map showing what the maximum concentrations are in each point. The plot shows that the maximum excess (without background concentrations) concentration never exceeds 20 mg/l inside the windfarm and 10 mg/l outside the windfarm.

Similarly, the deposition plot shows that the deposition reaches levels up to approximately 2 – 3 mm during and after the dredging operations. This relatively low amount shows that the spilled material is spread over a relatively large area and thus the long term effect is small. During the dredging operation temporary deposits may occur. The maximum size of these deposits is given in Figure 7-26.

Results show that temporary deposits do occur and that bed thicknesses up to 3.5 mm occur during the dredging period.

The impact is evaluated in Table 7-5.

Table 7-5 Impact assessment in relation to spilled sediments

Impact	Scale of the exposure	Duration	Intensity	Scale of the impact
Sedimentation patterns	Local	Short term and Long-term	Low	Negligible

In case mitigation measures were needed in relation to the sediment spillage then the spillage has to be reduced or the spreading limited. This can be done either by using other dredging methods or by applying siltscreens. However results show that no mitigation is needed due to the small impacts.

7.2.3.2 Cumulative impact assesment

Considering the negligible impact outside the windfarm area no cumulative impacts from neighbouring wind farms are expected.

7.2.3.3 Evaluation of the impact on Natura 2000

Slight deposition is observed in the neighbouring Natura 2000 areas; however, the amounts are so low that for all practical purposes it would be indetectable. No measurable excess concentration is observed.

7.3 Dampening of waves

7.3.1 Assumptions

When waves hit a wind turbine foundation a part of the energy will be reflected. This will change the wave climate inside the wind farm and in the leeward area of the plant. The change of wave heights depends on:

- Water depth
- Incoming wave period
- The layout of the foundation and under water part of the tower
- The number and spacing between the wind turbines

As a part of the environmental impact, the effects of the wind turbines on the incoming waves have been included in the wave prediction. The calculation of the wave reflection around each wind mill foundation is parameterized using the same locations and physical properties as for currents and sediments.

7.3.2 Modelling

January 2013 has been selected in order to analyse the impact on the wave regime for the two variants. The year 2013 is also the period where wave measurements were available. The wave climate during winter is also more harsh than during the summer period as seen Figure 4-1. Wave model simulations have been conducted with and with the turbines and the difference in wave conditions with and without turbines has been assessed.

7.3.3 Evaluation

7.3.3.1 Evaluation for the OWF BS III

The average and maximum difference in simulated significant wave height conditions with and without turbines is shown in Figure 7-31 - Figure 7-33. As it can be seen the maximum impact is low (1 cm for the variant chosen for realization and 4 cm for the rational alternative variant) compared to the undisturbed wave heights and thus the impact can be categorised as negligible.

The type and number of foundation providing the largest reflection will evidently have the largest impact on waves. In this context, the GBS foundation will provide the largest reflection and as one can see the rational alternative variant will have the largest impact. However, as already demonstrated the impact on waves from GBS is minor only, thus one can select any of the foundation types (GBS, monopiles, tripod or Jacket) without significant impact on the wave regime.

Considering the negligible impact there is no need for mitigating measures.

The impact on waves is evaluated in Table 7-6.

Table 7-6 Impact assessment in relation to wave regime

Impact	Scale of the exposure	Duration	Intensity	Scale of the impact
Wave regime	Local	Short term and Long-term	Low	Negligible

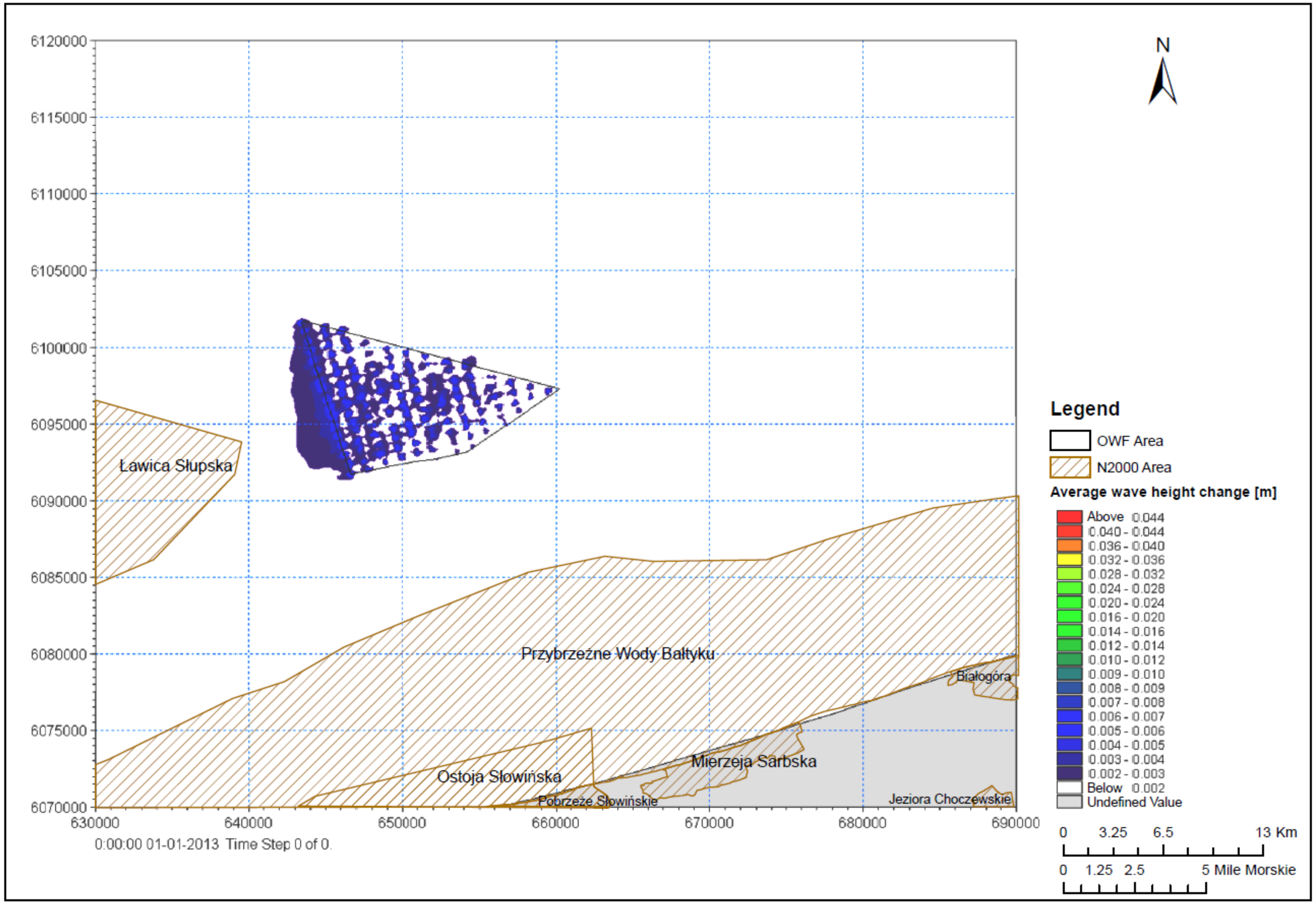

Figure 7-30 Average wave height change - Variant chosen for realization

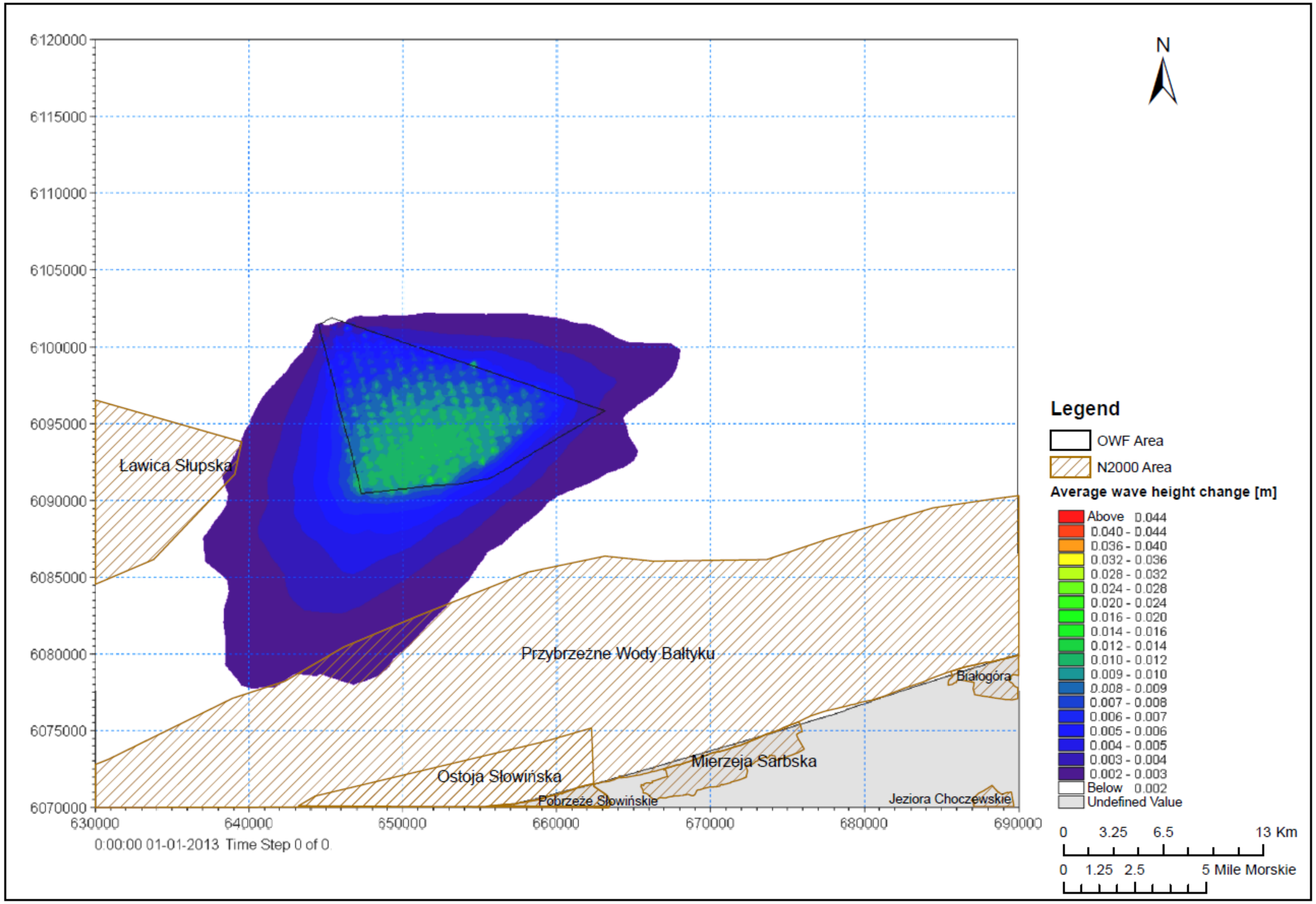

Figure 7-31 Average wave height change - Rational alternative variant

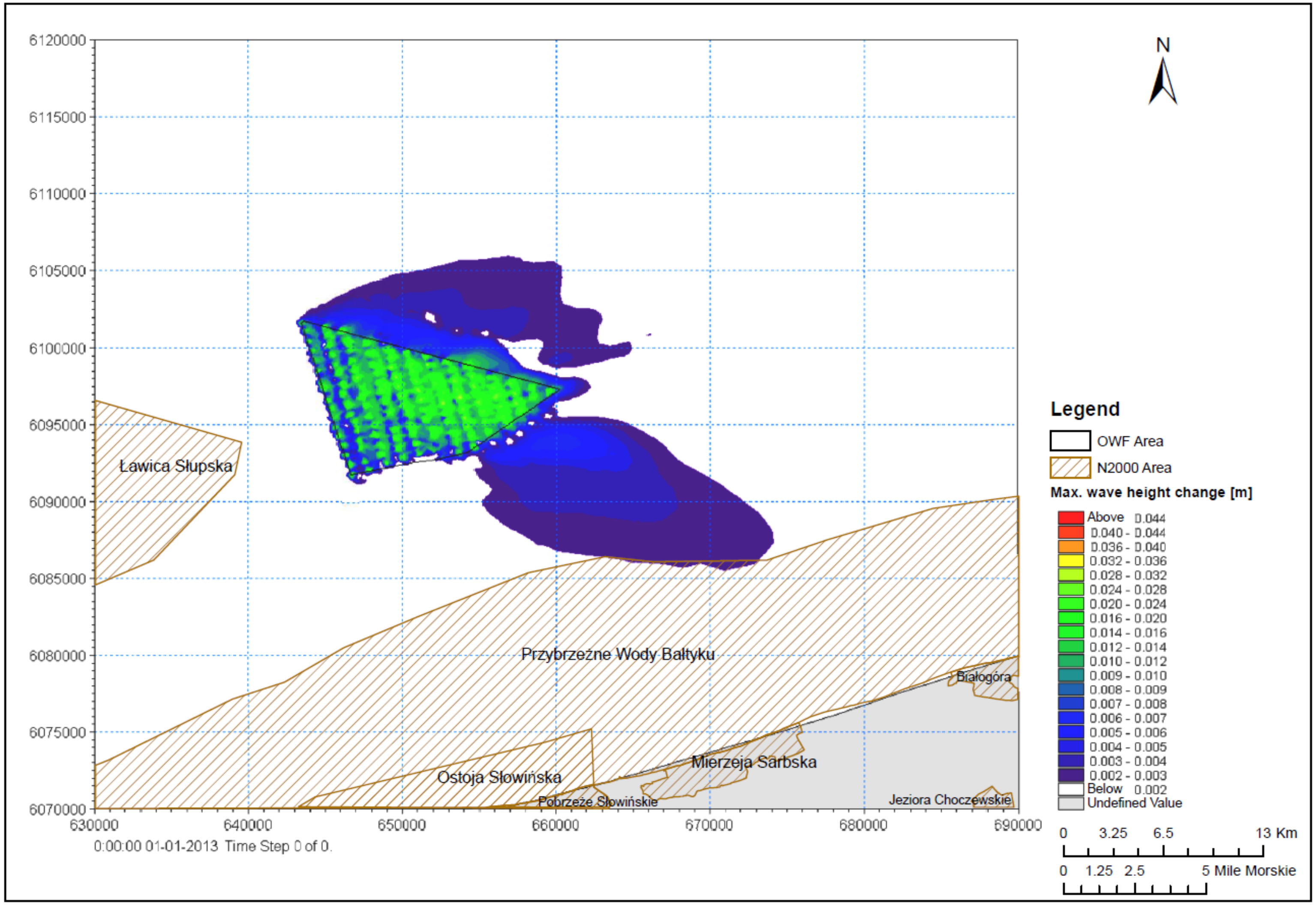

Figure 7-32 Maximum wave height change - Variant chosen for realization

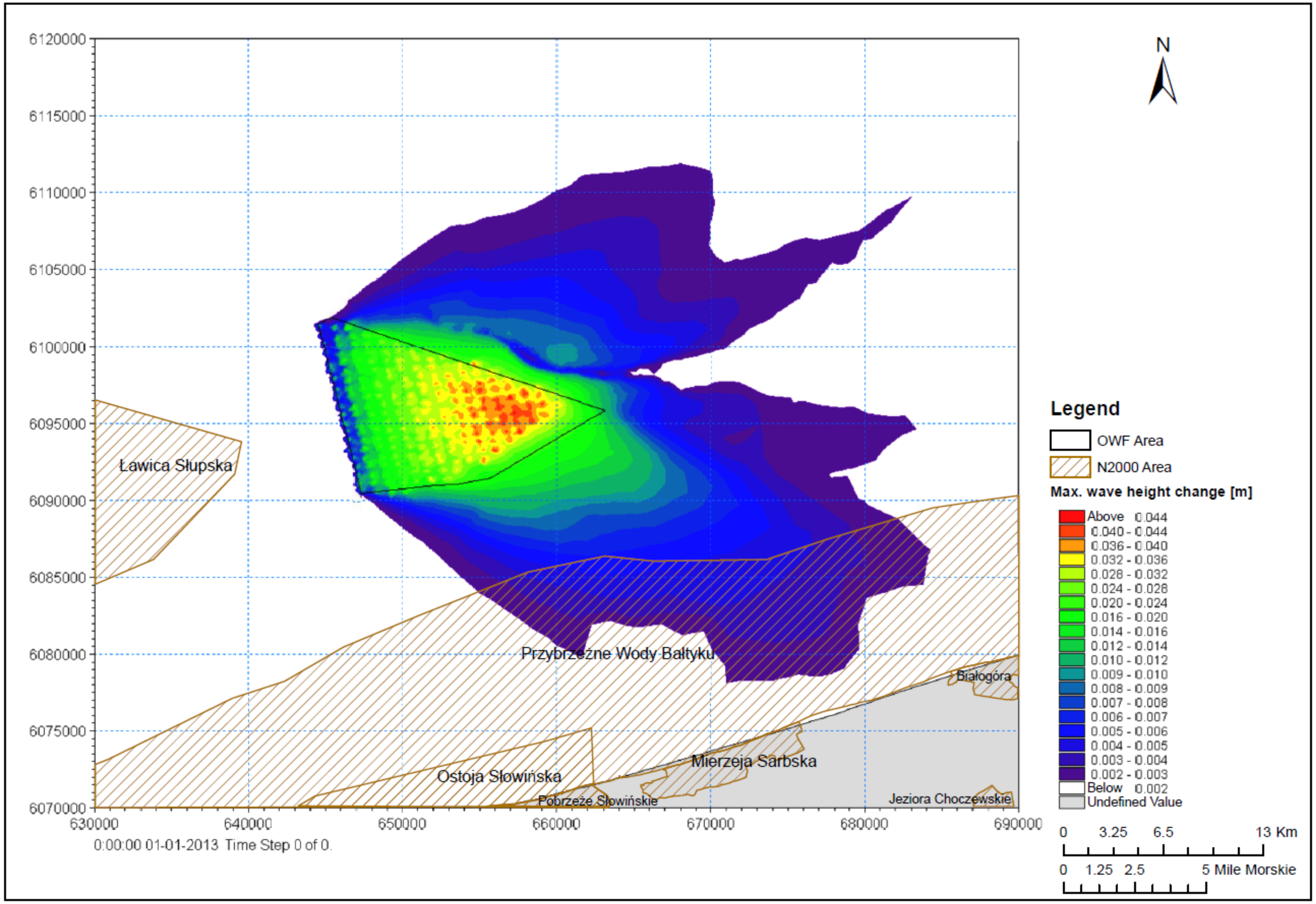

Figure 7-33 Maximum wave height change - Rational alternative variant

7.3.3.2 Cumulative impact assessment

Considering the negligible impact no cumulative impacts from neighbouring wind farms are expected.

7.3.3.3 Evaluation of the impact on Natura 2000

The impact on the wave regime around OWF BS III is considered negligible for both variants, thus no impact are expected in the adjacent Natura 2000 areas. In case of the rational alternative variant the maximum impact within the Natura 2000 area is less than 1 cm.

8 References

/1/ DHI, MIKE 3 Flow Model FM, Oceanographic downscaling Module, Step-by-step training

/2/ /2/. Royal HaskoningDHV. High Level Technical Design Options Study. Polenergia Offshore Wind Developments for Projects Middle Baltic II and Middle Baltic III - 04.2.2014

/3/ /3/ Sumer, B.M. and J. Fredsøe. 2002. The mechanics of scour in the marine environment. World Scientific, Singapore, 536 pp.

/4/ MFW Bałtyk Środkowy III Sp. z o.o., Morska farma wiatrowa Bałtyk Środkowy III – opis metodyki wariantowania, 4.12.2013

/5/ Royal HaskoningDHV, High Level Technical Design Options Study. Version 1 – initial concept, Polenergia Offshore Wind Developments for projects Middle Baltic II and Middle Baltic III., 04 February 2014

9 Figures

10 Tables