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# Green Mountain Undheim

## Wind Impact Assessment - Water Reservoir

Green Mountain AS

Date: 16 June 2026

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# Contents

# 1. Introduction

NIRAS has been appointed by Green Mountain AS to evaluate the potential impact on the wind resource for the closest wind turbines to a planned elevated basin in Undheim.

## 1.1. Project

The elevated basin is planned to be located at the highest point in the terrain with the potential to affect the nearest four wind turbines located in a distance between 160 and 450 m, see Figure 1.1.

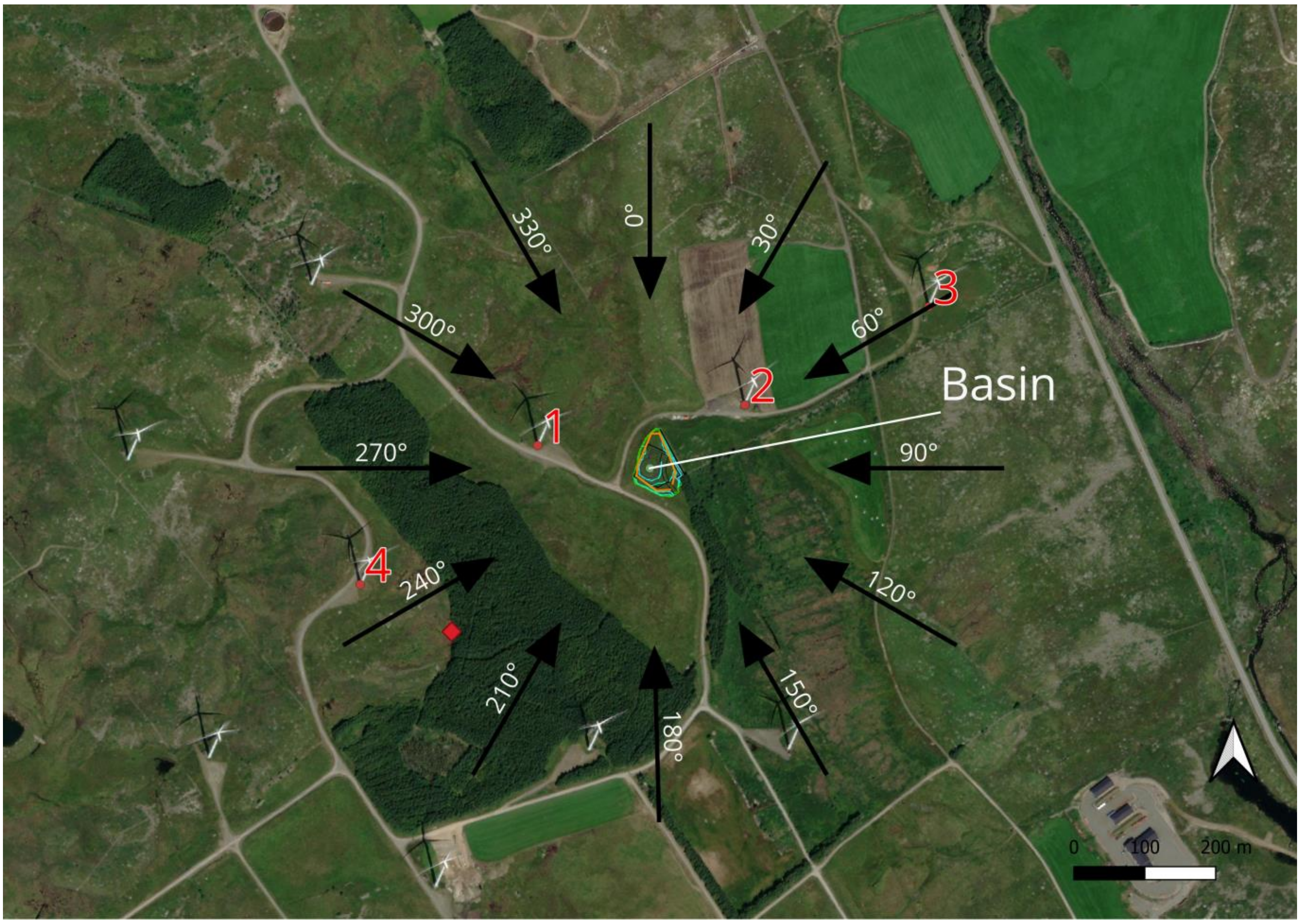


*Figure 1.1: Location of the elevated basin with the closest wind turbines numbered. The arrow indicates the wind directions. Background image: ESRI.*

To illustrate the scale, the basin and the four turbines are shown in the topography in Figure 1.2 and Figure 1.3, viewed from the east and south.

The roof of the elevated basin is at an altitude of 283 m where the lowest blade tip is at 274.5 m (WTG3) and for closest WTG at 300.5 m (WTG1).

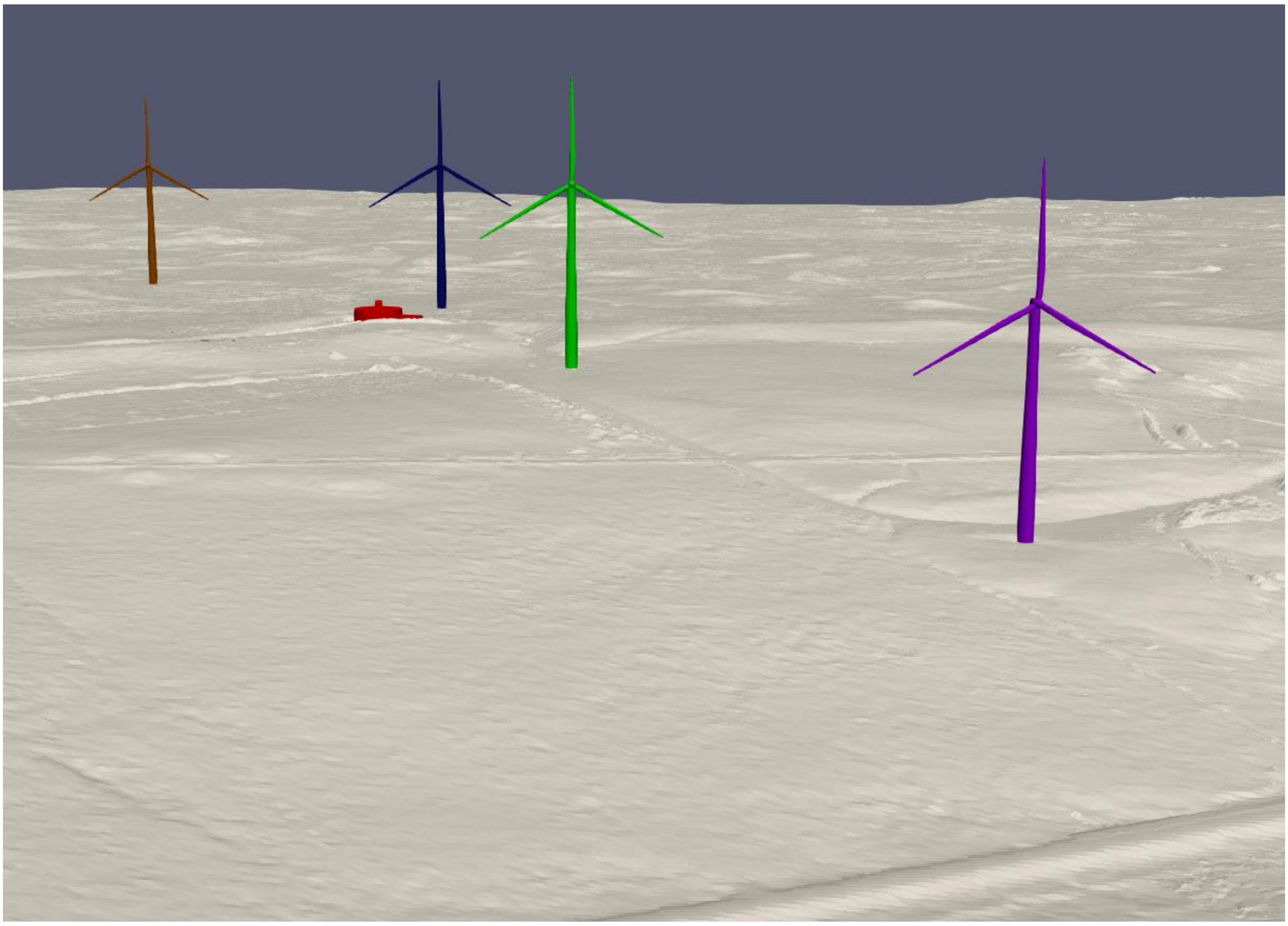

*Figure 1.2: View from east, model 1:1. Red: basin, Blue: WTG1, Green: WTG2, Purple: WTG3 and Brown: WTG4.*

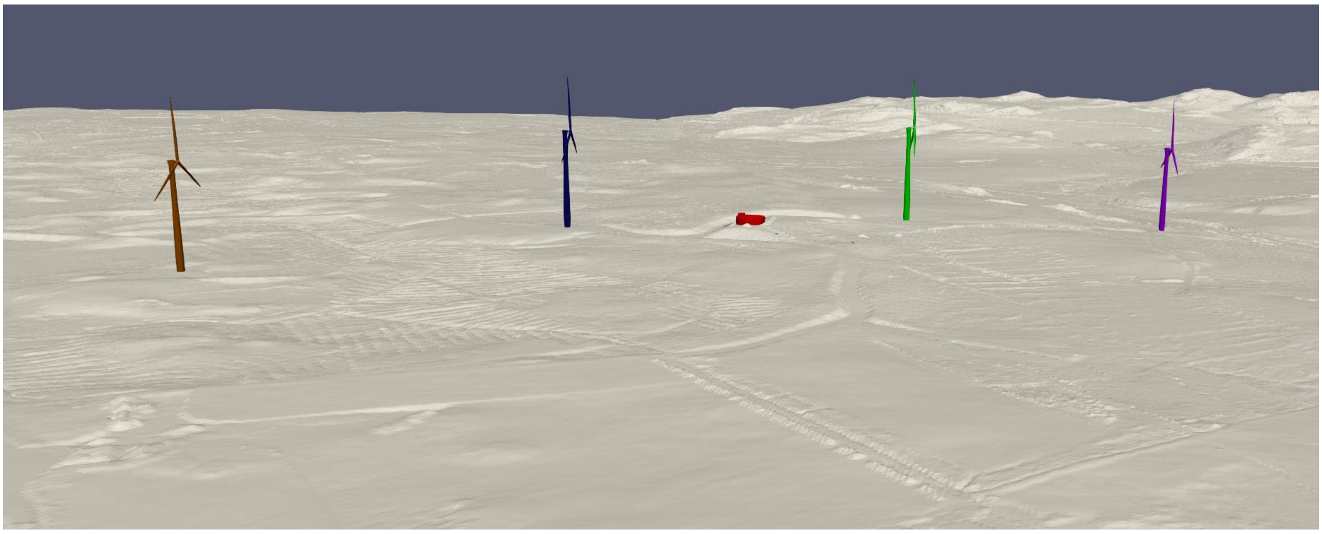

*Figure 1.3: View from south, model 1:1. Red: basin, Blue: WTG1, Green: WTG2, Purple: WTG3 and Brown: WTG4.*

### 1.2. Scope of Work

Several wind turbines are located more than 400 m from the proposed elevated basin construction area. As the elevated basin will be situated at the highest point in the area, it may influence wind conditions and turbulence at the turbine locations.

The purpose of this study is to assess that potential impact.

### 1.3. Methodology

To calculate the wind conditions around the planned elevated basin and in the surrounding area, a stationary CFD model has been used (OpenFOAM – incompressibleFluid; [1]).

Using the model, 3D wind fields were calculated for a wind speed of 10 m/s approx.10 m above ground level for wind directions from 0° to 360° in 30° increments. Simulations were performed for scenarios both without and with the planned elevated basin. For simplification and to avoid “noise” from the turbines these wasn’t included in either of the simulations.

Profiles of wind speed and turbulence kinetic energy at the four nearest wind turbines were then compared to illustrate the potential impact.

## 2. Background Data

The following subsections present the data used for the assessment and analysis of the potential impact on the wind resource.

### 2.1. Wind turbine

It is informed that wind turbines is a Siemens SWT 2.3-93 (2.3 MW with a rotor diameter of 93 m) installed with an air gab of 36.5 m resulting in a hub height at 83 m above terrain.

The estimated turbine positions and relevant elevation levels are listed in Table 2.1.

*Table 2.1: Wind turbine position, ground level and min./max. altitude of blade tip.*

| WTG | x | y | z ground | blade tip | |
|---|---|---|---|---|---|
| # | WGS84 UTM32N | | [m] | [m] | [m] |
| 1 | 313521 | 6506063 | 264 | 300.5 | 392.5 |
| 2 | 313814 | 6506120 | 266 | 302.5 | 394.5 |
| 3 | 314073 | 6506258 | 238 | 274.5 | 366.5 |
| 4 | 313271 | 6505867 | 256 | 292.5 | 384.5 |

### 2.2. Geometry elevated basin

The geometry of the planned elevated basin, “Bygning.stl”, is illustrated at Figure 2.1 and Figure 2.2.

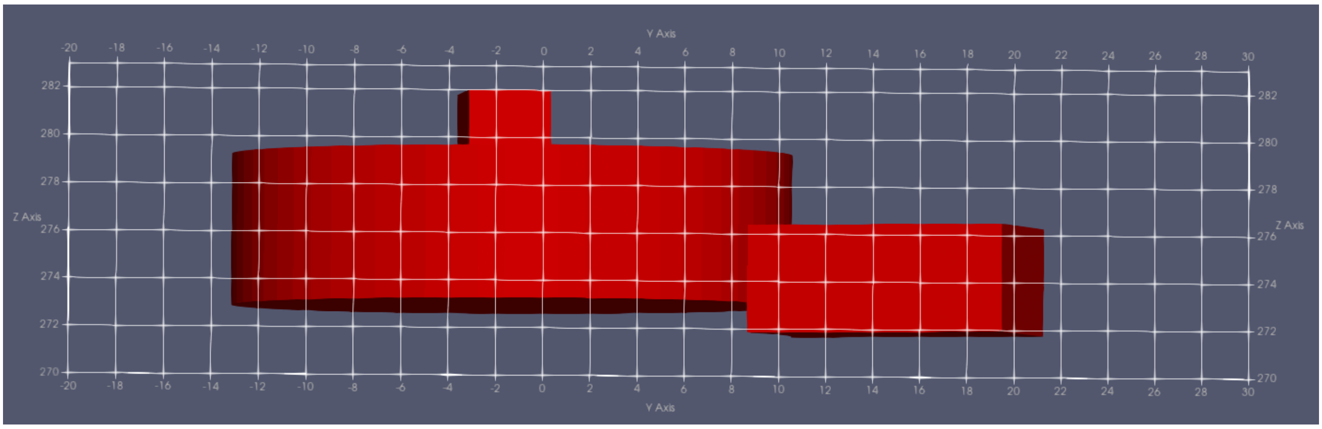


*Figure 2.1: Elevated basin, view from south.*

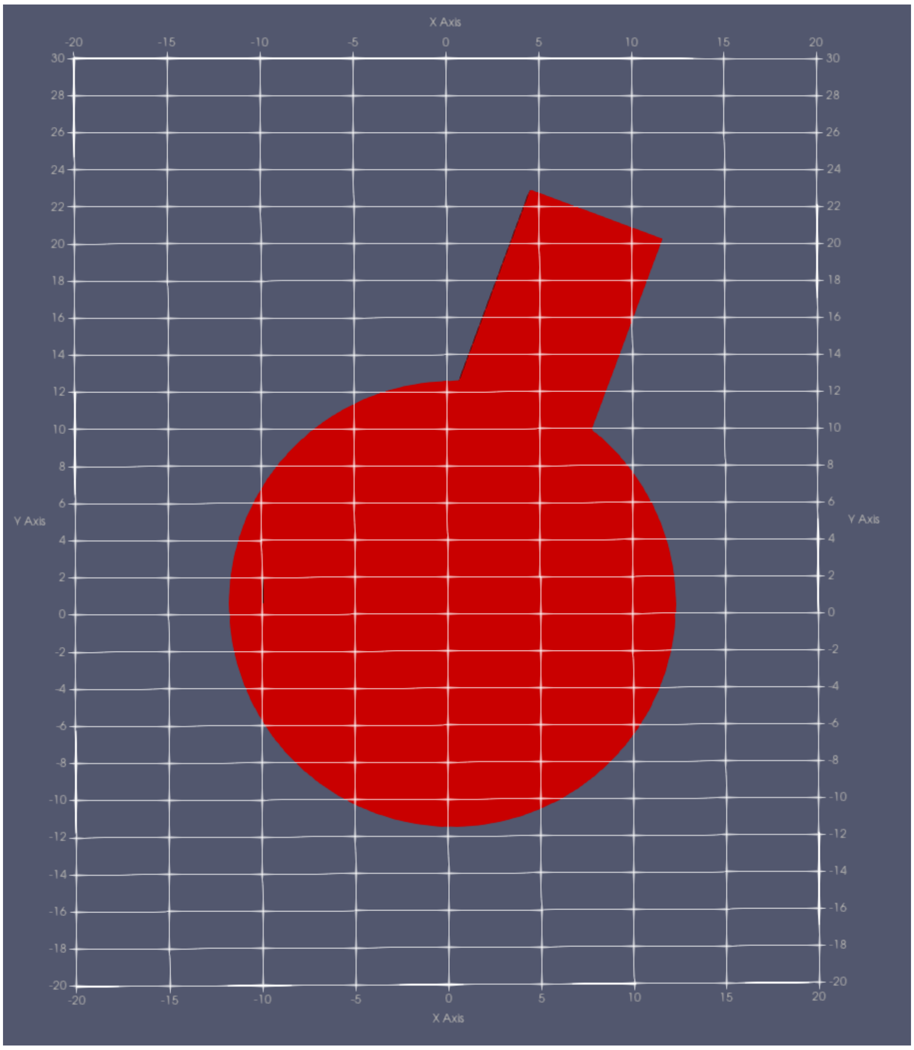


*Figure 2.2: Elevated basin, Top view.*

## 2.3. Terrain model

From the project a laser scan has been provide ("laser.stl") which has been supplemented by a terrain model from SCALGO [2] to cover the extent required for the modelling.

## 2.4. Wind

To characterise the site's wind climate, wind data at 100 m above ground level were extracted from the New European Wind Atlas [3] for the period 1989–2022.

The mean wind speed at 100 m in the period 1989 to 2022 is 9.6 m/s and the maximum 33.3 m/s, Figure 2.3.

Two prevailing wind directions are observed: northerly winds occur 25% of the time, while southerly winds occur 38% of the time, as shown in Figure 2.4and Table 2.2.

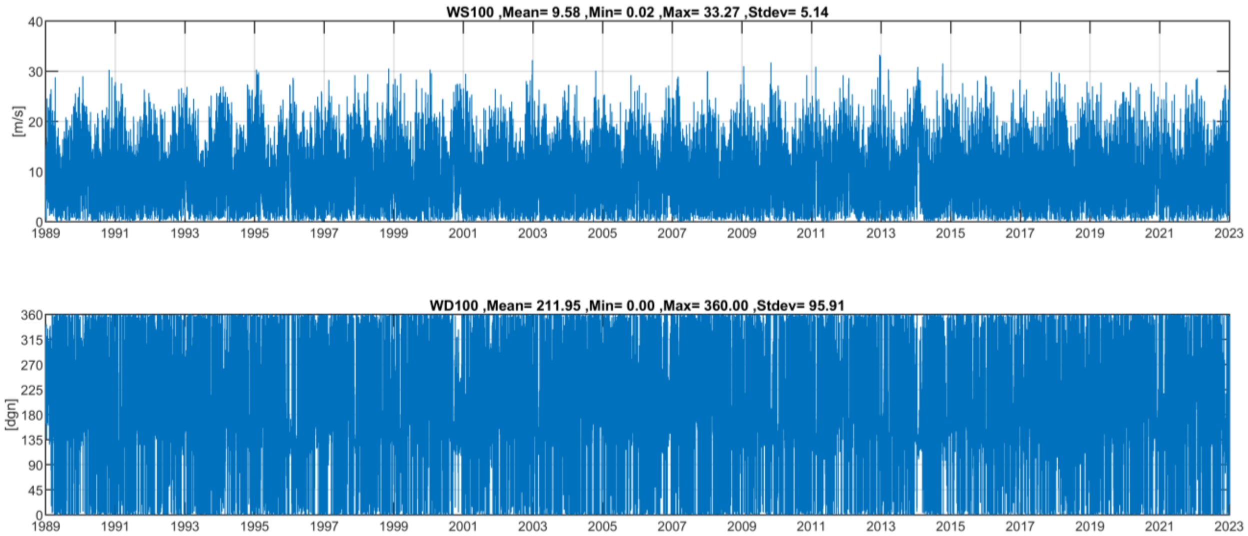


*Figure 2.3: Wind 100 m above grund level at Lat 58.6564, Lon 5.7916 [3].*

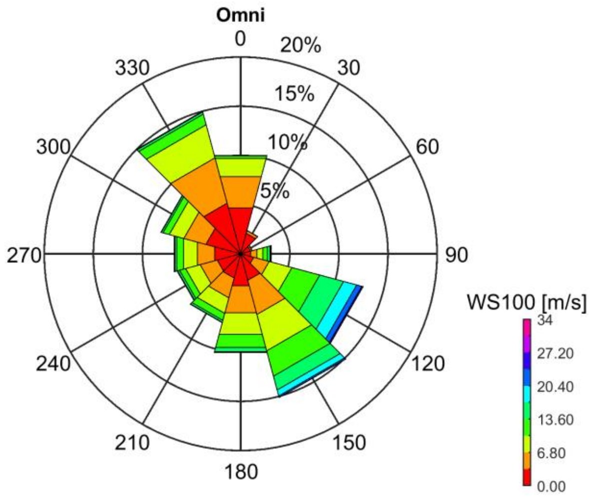


*Figure 2.4: Wind rose 100 m above grund level at Lat 58.6564, Lon 5.7916 [3].*

*Table 2.2: Scatter table wind speed vs. wind direction. 100 m above grund level at Lat 58.6564, Lon 5.7916 [3]*

| | | | Wind speed [m/s] | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | From | | 0 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | Sum |
| | | To | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | |
| Direction [°N] | -15 | 15 | 0.40% | 1.30% | 2.21% | 2.21% | 1.86% | 1.44% | 0.67% | 0.16% | 0.05% | 0.01% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 10.3% |
| | 15 | 45 | 0.30% | 0.82% | 0.84% | 0.37% | 0.11% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 2.5% |
| | 45 | 75 | 0.22% | 0.39% | 0.33% | 0.19% | 0.07% | 0.02% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 1.2% |
| | 75 | 105 | 0.19% | 0.30% | 0.36% | 0.41% | 0.40% | 0.38% | 0.34% | 0.30% | 0.23% | 0.15% | 0.08% | 0.04% | 0.02% | 0.01% | 0.00% | 0.00% | 0.00% | 3.2% |
| | 105 | 135 | 0.18% | 0.36% | 0.54% | 0.80% | 1.01% | 1.27% | 1.58% | 1.74% | 1.66% | 1.44% | 1.08% | 0.61% | 0.36% | 0.19% | 0.06% | 0.01% | 0.00% | 12.9% |
| | 135 | 165 | 0.23% | 0.71% | 1.21% | 1.78% | 2.24% | 2.31% | 2.12% | 1.64% | 1.16% | 0.81% | 0.49% | 0.28% | 0.10% | 0.04% | 0.00% | 0.00% | 0.00% | 15.1% |
| | 165 | 195 | 0.28% | 0.91% | 1.49% | 1.68% | 1.69% | 1.46% | 1.19% | 0.83% | 0.52% | 0.23% | 0.08% | 0.03% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 10.4% |
| | 195 | 225 | 0.29% | 0.82% | 1.01% | 1.13% | 1.27% | 1.08% | 0.79% | 0.48% | 0.23% | 0.10% | 0.04% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 7.3% |
| | 225 | 255 | 0.34% | 0.89% | 0.89% | 0.97% | 1.08% | 1.01% | 0.76% | 0.39% | 0.21% | 0.11% | 0.05% | 0.02% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 6.7% |
| | 255 | 285 | 0.41% | 1.01% | 0.97% | 0.97% | 1.09% | 1.01% | 0.70% | 0.44% | 0.21% | 0.10% | 0.05% | 0.02% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 7.0% |
| | 285 | 315 | 0.42% | 1.33% | 1.39% | 1.36% | 1.37% | 1.07% | 0.71% | 0.42% | 0.19% | 0.09% | 0.04% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 8.4% |
| | 315 | 345 | 0.43% | 1.48% | 2.35% | 2.70% | 2.86% | 2.43% | 1.54% | 0.71% | 0.29% | 0.12% | 0.05% | 0.02% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 15.0% |
| | Sum | | 3.7% | 10.3% | 13.6% | 14.6% | 15.0% | 13.5% | 10.4% | 7.1% | 4.8% | 3.2% | 2.0% | 1.0% | 0.5% | 0.2% | 0.1% | 0.0% | 0.0% | 100.0% |

# 3. Model setup

## 3.1. Model mesh

As a rule of thumb for simulating wind around buildings, the model must have at least one dimension as shown in the figure below.

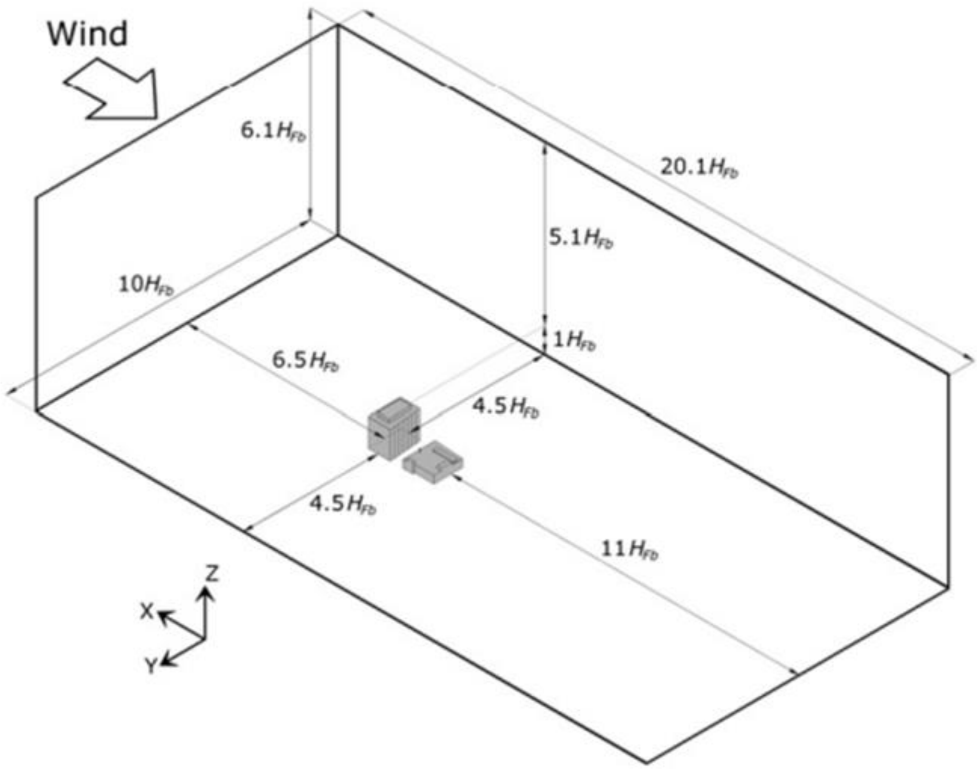


*Figure 3.1: Minimum extent of domain as function of the height of the structure, $H_{fb}$, in this the elevate basin [4].*

To simplify the simulations and avoid issues when rotating the model, the final domain was defined with a horizontal extent of 2000 × 2000 m to include the WTG locations and a vertical extent from ground level to 500 m, well above the maximum blade tip height. The elevated basin is located at the centre of the mesh, Figure 3.2 and Figure 3.3.

The base cubic mesh was sat to 25 m gradually downscaled to 0.5 m in the cells closest to the ground.

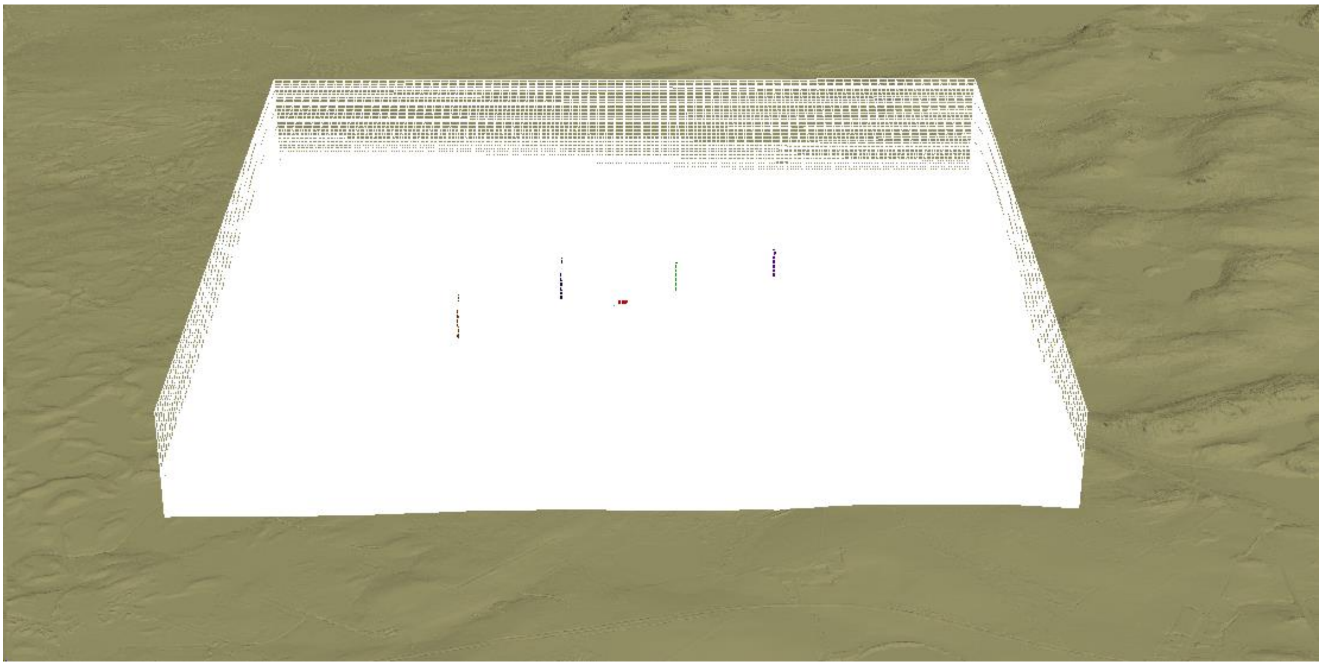

*Figure 3.2: Extent of mesh. Red: basin, Blue: WTG1, Green: WTG2, Purple: WTG3 and Brown: WTG4.*

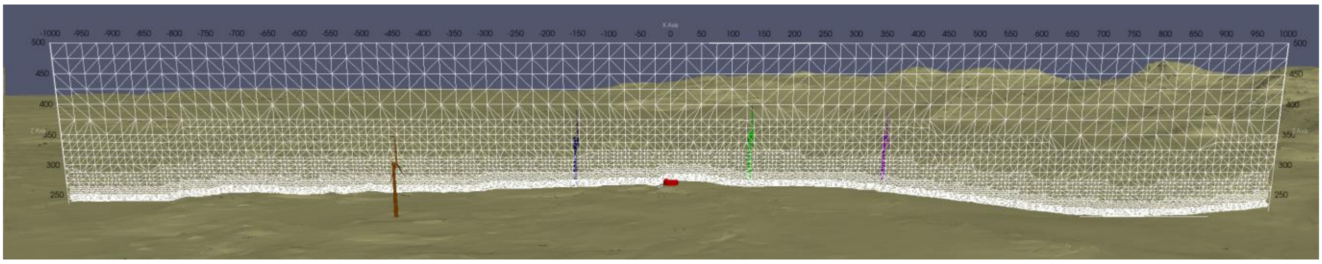

*Figure 3.3: Mesh cross section. Red: basin, Blue: WTG1, Green: WTG2, Purple: WTG3 and Brown: WTG4.*

## 3.2. CFD model input

OpenFOAM solves the Navier-Stokes equation system in terms of velocity, pressure, and turbulence for each cell in the computational grid, given by:

- $U_x$, $U_y$, $U_z$ : wind speed [m/s];
- p: pressure [$m^2/s^2$];

The turbulence is modelled using RAS (Reynolds Average Model), SST (Shear Stress Transport) in the form of a k-ε formulation, to determine

- k: turbulence kinetic energy;
- ε: dissipation rate;
- nut: turbulence viscosity;

## 3.3. Boundary conditions

To describe the applied wind, a predefined boundary condition has been used, describing an atmospheric boundary layer given by

- $z_0$: roughness – set to 0.1 corresponding to low vegetation with few major obstacles.
- $U_{ref}$: wind speed at the reference height – set to 10 m/s.
- $Z_{ref}$: height of the Uref – set to 10 m.
- $z_{Ground}$: level of terrain. Set to average for the level along the edge in the model.

The terrain in the model was assigned the same $z_0$ value as specified above. Because the assessment is based on a relative comparison, this simplified roughness representation is considered sufficient.

# 4. Results

Based on the location of the planned elevated basin, see Figure 1.1 and Figure 2.4, the largest impact on the wind is for the different nearby wind turbines expected to occur:

- WTG 1 for a wind from 120°,
- WTG 2 for a wind from 240°,
- WTG 3 for a wind from 240° and
- WTG 4 for a wind from 60°.

Vertical profiles of wind speed and turbulence are provided for wind directions at 30° intervals in Appendix 1 and Appendix 2 which for the above mentioned expected most critical wind directions is repeated in the following.

The plots first compare the profiles without (Baseline) and with the planned elevated basin (Project), followed by the corresponding difference of Project minus Baseline. E.g. a positive value means the Project increase the viewed parameter and opposite if it is negative.

For WTG 1, shown in Figure 4.1, the wind-speed difference above ground level initially indicates a reduction of approximately 0.02 m/s, increases to about 0.02 m/s at around 280 m, and decreases to approximately -0.01 m/s at 300 m, corresponding to the lowest blade-tip height. Above this level, the difference remains close to +0.005 m/s. The turbulence follows a similar but opposite trend, with a small initial increase followed by a reduction around 300 m and values approaching zero above this height. Relative to the background wind speed, an increase of 0.005 m/s from approximately 12 m/s corresponds to about +0.04%, while the change in turbulence is approximately 0.0%.

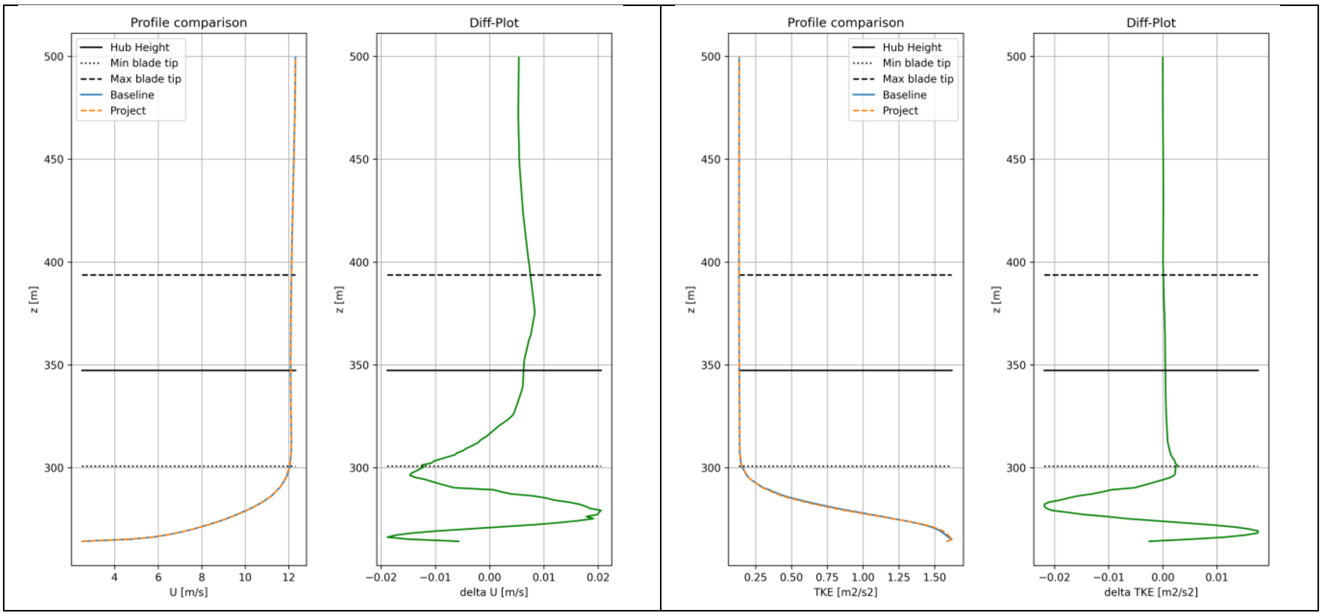


*Figure 4.1: WTG 1, wind from 120°. Left: velocity profile speed (U) and difference (delta U), Right: turbulence profile turbulence cinetic energy (TKE) and difference (delta TKE).*

Figure 4.5 shows the horizontal wind speed at the level for the roof of the elevated basin. Approximately at the hight with the largest impact in the profile. It is observed that furthest upstream (the right) the wind speed pattern is the same but close to WTG 2 a small drop occurs despite that the is upstream the elevated basin. Downstream the elevated basin the wind speed is reduced over several hundreds of metres for a width of around 30 m. But again the impact within the rotor's swept area is insignificant.

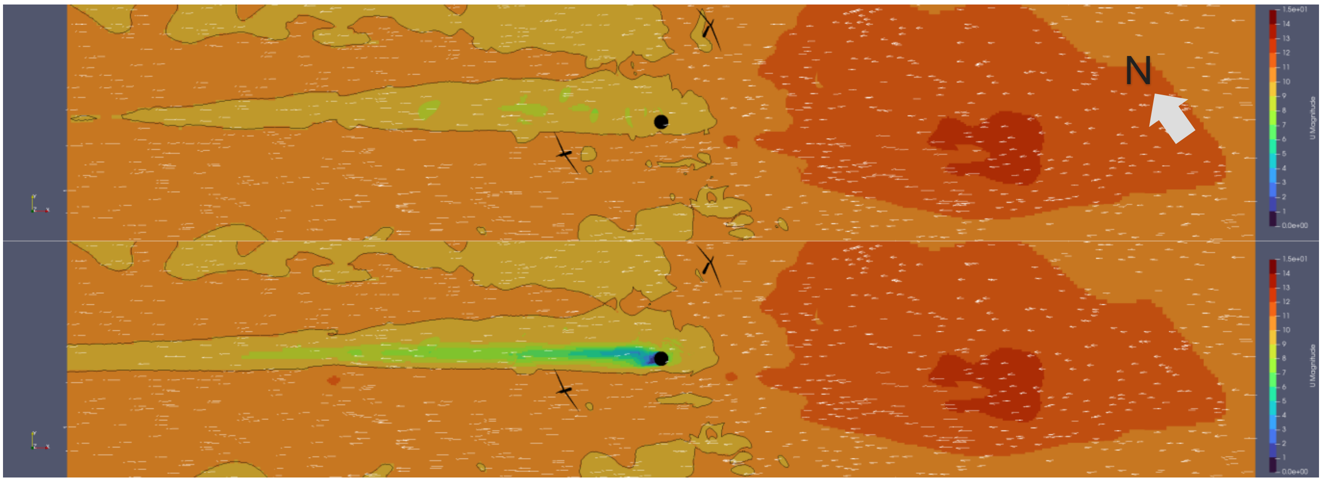


*Figure 4.5: Wind speed from 120° at roof height. Top: Baseline, Bottom: Project. The turbines are only for illustation where the basin only is included in the Project. Black line: 10 m/s contour. WTG 1 is the one to the left and WTG 2 the one to the right.*

WTG 2 and WTG 3 show larger changes in the wind profile between ground level and the lowest blade-tip height, while changes at higher elevations are close to zero, see Figure 4.2 and Figure 4.3.

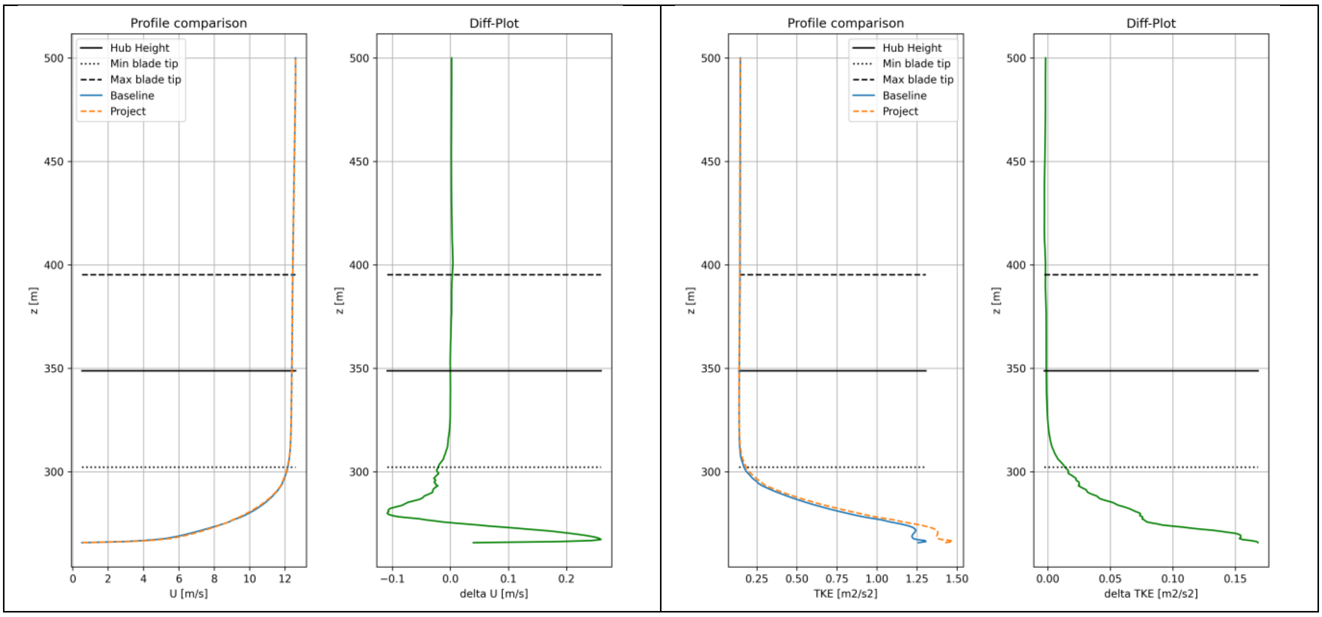


*Figure 4.2: WTG 2, wind from 240°. Left: velocity profile speed (U) and difference (delta U), Right: turbulence profile turbulence cinetic energy (TKE) and difference (delta TKE).*

![NIRAS logo]

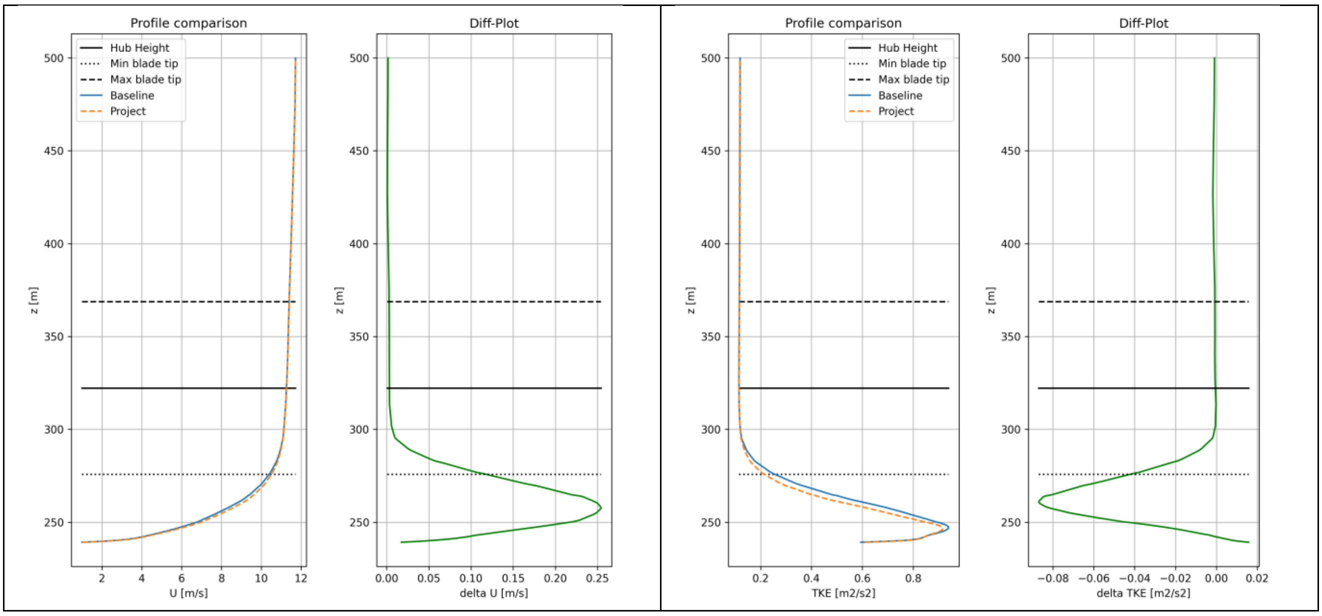


*Figure 4.3: WTG 3, wind from 240°. Left: velocity profile speed (U) and difference (delta U), Right: turbulence profile turbulence cinetic energy (TKE) and difference (delta TKE).*

WTG 2 is for a wind from 240° located directly downstream of the elevated basin and as seen on Figure 4.5 the wind is reduced at roof level but despite this the impact at the swape area is insignificant.

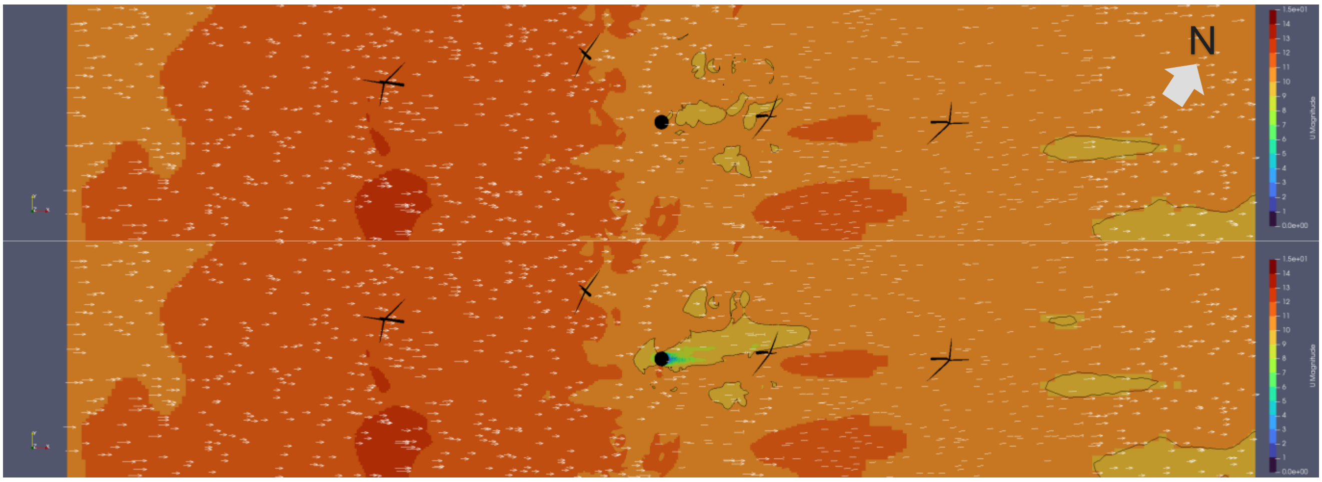


*Figure 4.5: Wind speed from 240° at roof height. Top: Baseline, Bottom: Project. The turbines are only for illustation where the basin only is included in the Project. Black line: 10 m/s contour. WTG 2 and 3 is the ones to the right with WTG 3 furthest right.*

At WTG 4, the changes are small and occur mainly between ground level and the lowest blade-tip height, becoming close to zero above this level, see Figure 4.4 and Figure 4.5.

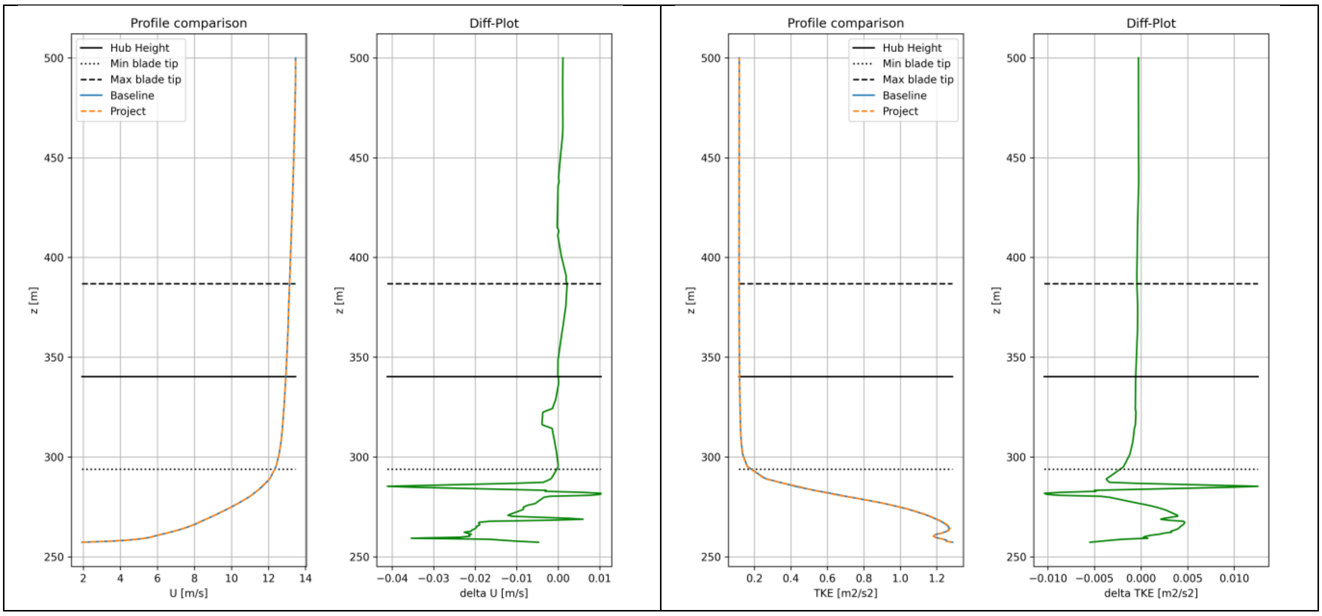


*Figure 4.4: WTG 4, wind from 60°. Left: velocity profile speed (U) and difference (delta U), Right: turbulence profile turbulence cinetic energy  (TKE) and difference (delta TKE).*

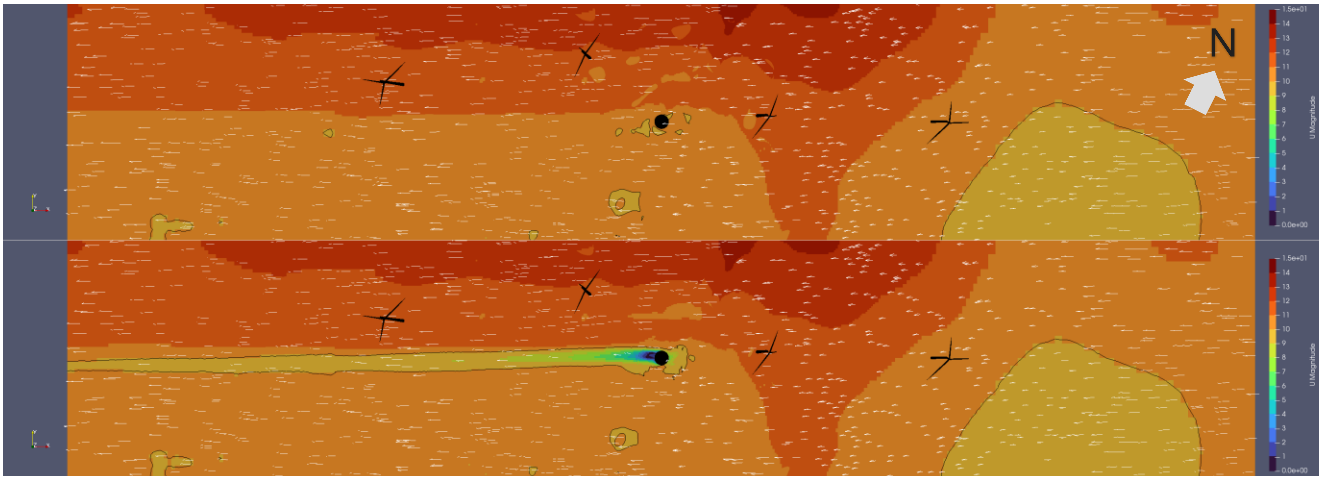


*Figure 4.5: Wind speed from 60° at roof height. Top: Baseline, Bottom: Project. The turbines are only for illustation where the basin only is included in the Project. Black line: 10 m/s contour. WTG 4 is the one furthest left.*

# 5. Conclusion

The CFD assessment indicates that the planned elevated basin has only a limited influence on the wind conditions at the four nearest wind turbines. The largest changes are generally confined to the lower part of the profiles, between ground level and the lowest blade-tip height, while the differences within and above the rotor-swept area are small and generally approach zero.

For WTG 1, the calculated wind-speed change at the lowest blade-tip height is approximately -0.01 m/s, while values above this level remain close to +0.005 m/s. This corresponds to a relative change of about

+0.04% compared with the background wind speed, and the associated change in turbulence is negligible. WTG 2 and WTG 3 show somewhat larger changes below the lowest blade-tip height, but these changes decrease rapidly with height. At WTG 4, the modelled changes are small and mainly limited to the lower part of the profile.

Based on the model results, the planned elevated basin is therefore not expected to cause a significant impact on the wind resource or turbulence conditions at the nearby wind turbines. The assessment is based on relative comparisons between simulations with and without the basin, using the same terrain, roughness, and inflow assumptions for both cases.

# 6. References


[1] openfoam.org, "openFOAM version 13," 10 03 2026. [Online]. Available: https://openfoam.org/version/13/.

[2] Scalgo, "ScalgoLive," [Online]. Available: https://scalgo.com/da/.

[3] DTU Wind, "New European Wind Atlas: Mesoscale Atlas," 15 05 2025. [Online]. Available: https://data.dtu.dk/articles/dataset/New_European_Wind_Atlas_Mesoscale_Atlas/14414096/1?file=28399449.

[4] Lateb, M., Masson,C., Stathopoulos, T., & Bédard, C, "Comparison of various types of k-epsilon models for pollutant emissions around a two-building configuration," *Journal of Wind Engineering and Industrial Aerodynamics 115,* pp. 9-21, 2013.

# Appendix 1 Wind speed profiles

Vertical velocity profile for the closest 4 wind turbines marked with lowest and highest level of blade tip.

# Appendix 2 Wind turbulence profiles

Vertical turbulence profile for the closest 4 wind turbines marked with lowest and highest level of blade tip.