BERKSWELL MILL WIND FLOW STUDY

Location: **N** 52°22'50.77" **W** 1°38'7.46"

Client: Berkswell Parish Council and the Friends of Berkswell Mill

Date of visit: 31 May 2019

Date of photo's: 31 May 2019

Date of report: 5 August 2019 (calculations June 2019); amended 19 August 2019

Author: E. van der Elst

Status: Definitive

1. Erfgoed Advies Groen

1.1 About

Erfgoed Advies (Heritage advice) Groen has traditionally been an engineering firm that specialises in the restoration of windmills and watermills. In the last five years, we have done much more in the area of heritage than just making plans for mills. However, 75% of the work still consists of mills. Of the 1,200 mills in the Netherlands, 250 mills of these mills are regular customers of Erfgoed Advies Groen and for more than 400 other mills in the Netherlands consultancy work has been done. 25% of the other work consists of other monuments such as churches, town halls, fortresses, farms and barns.

The agency is characterised by the no-nonsense approach from the engineering past. "If it is not broke, do not fix it." Only take action if necessary, try to repair as much as possible with what can still be retained, and if replacement cannot be avoided, copy the old situation as much as possible. Another characteristic of our company is the establishment of a good diagnosis, a systematic approach and a follow-up of the project.

All employees within the office have a great passion for their profession. Two of the five employees are millers in their spare time.

Erfgoed Advies Groen provides all services and documents that are required for the entire process of restoration, management and maintenance of monuments.

<u>Restoration:</u>

- Building technical research
- Building history research (archival research and colour research are often purchased).
- Vision document, schedule of requirements, cost estimate based on key figures and references.
- Predesign, 3D Visualization, elements budget
- Construction calculations (soil mechanics and foundation calculations are often purchased)
- Final design
- Specifications, budget, working (technical) drawings
- Design sprinkler installations
- Working drawings and detail drawings
- Documents application environmental permits
- Documents for subsidy applications
- Documents for the tender and the tender itself, including an official report.
- Sight supervision, building meetings including reporting and signing off
- Work visits incl. Visit reports, inspections and tests in between
- Administration of restorations
- Delivery including process report and aftercare
- Restoration report

Maintenance and management:

- Architectural inspection
- Project conservation plans
- Organization of maintenance incl. Placing on the market and following up
- RI & E safety and risk inventory
- Inventory mill biotope including wind calculations
- Flow analysis and power calculations water mills
- Calculation of rebuilding value
- Expertise in case of damage
- Re-use research
- Management plan incl. Management vision
- Review current organization management incl. Benchmark.

1.2 Certifications

Erfgoed Advies Groen has the following certifications:

- URL 2002 Certified consultancy firm for mills. Certification from the Stichting ERM (Foundation for the certification of restauration quality and preservation of monuments in The Netherlands)
- URL 2001 Certified for modules A and B for technical surveying of monuments. Certification from the Stichting ERM.
- Member of TIMS (The International Molinological Society).

2. The Study

2.1 Terms used in the report

Within the report several terms from molinological nomenclature are used. An explanation of the terms is found hereunder.

Windmill biotope:

The windmill biotope refers to the direct environment around a wind- or watermill. The relationship between the mill and its surroundings play a crucial role in the physical operation of the mill. The landscape and buildings around the mill have a direct impact on how the mill functions. For a windmill, the area that is designated as the 'direct environment' is a 400 metre radius measured from the centre of the mill.

More than just wind, the windmill biotope includes the accessibility to the mill for grain and flour transport and the millers sight of the sky (for assessing the sky, cloud formations) which allows him/her to adjust the mill for production and safety reasons. Also the mill's function as a monument is included.

Wind velocity:

A vector (speed and direction) measuring the direction and speed of the airflow. Can be measured in metres per second (m/s), knots or the scale of Beaufort. For this study the wind velocity was noted in m/s. Wind velocity is dependent on altitude due to surface drag from the Earth's surface.

The windspeed has a direct impact on how much energy the mill can induce. The difference in windspeed in front of the sails and behind the sails squared multiplied by the mass of the air and an efficiency factor equals the power the mill produces.

Milling days:

Milling days refers to the amount of days per year that the wind velocity is conducive to milling flour. Windmills start to operate effectively above a certain wind velocity. This is dependent on several factors, including the type of sail (in the case of windmills) and air temperature (density). When the wind velocity exceeds a certain speed, the mill can mill flour – this is referred to as a milling day. For the purpose of this study an average wind velocity of 3.4 m/s between 9 a.m. and 6 p.m. was used as the minimum velocity necessary to be classified as a milling day.

Wind map:

A radar graph showing the 8 compass rose and the amount of day the wind comes from each direction.

Cannister:

Where the sails are connected with the windshaft. The cannister holds the sails in place and can easily be identified as this is where the inner and outer sail cross each other.

Sail span:

The span of the inner and outer sail from tip to tip. Essentially the diameter of the turning circle at the tips of the sails.

Lowest point of the sail:

The distance between the tip of the lower sail and the ground when the sail is perfectly vertical.

2.2 Purpose of the study

The purpose of this wind flow study is to determine three things:

1. The biotope of the windmill in a situation where there are no building and trees to obstruct the wind. This scenario is based on the average wind flow and the removal of all objects from the calculation model. In the case of this study, this excludes any impact of wind turbulence caused

by natural undulation (roughness) of the surrounding area. Because the scenarios are compared solely with each other, the results are relative rather than absolute, allowing for the dismissal of this variable.

2. The current the biotope of the windmill. This model includes relevant buildings and trees within a 400 metre radius. This model allows for relative comparison of the current biotope to situation 1 in which there are no obstructions.
3. Examine the potential impact of any development around the mill with respect to wind flow and make recommendations to protect the mills operational heritage.

Finally, a recommendation (guideline) for the maximum allowable build height for buildings and growth height for trees is established. The guideline take into account the natural undulation of the surrounding area and is based on the windmill biotope formula (*see 4. Methodology*).

For the purpose of this study, the main focus of this report will be the guideline for the maximum building heights as it pertains to Berkswell Mill. However, the calculation of the scenarios are included to help the reader of the report understand the effect of wind flow on a windmill. The data forms a foundation for the guideline. Included in the report are several graphs to help the reader visualise the restrictions on building height based on relative location, distance from the windmill and natural form of the landscape.

From a cultural heritage perspective it is important to maintain the wind rights for a windmill. A monument is a valuable element in the landscape, not only for the people living near the monument, but also as a symbol of human ingenuity and our ability to create complex and beautiful things. For a mill, its operation and its position in the landscape is as important as the building itself.

3. Berkswell Mill

3.1 Brief history

Berkswell windmill is a brick tower mill constructed in 1826 for the grinding of grain to produce flour. The mill is located in Balsall Common in the West Midlands. On the tower rests a wooden boat cap. The internal gearing of the mill is powered by four sails, the outer being commons sails and the inner being self-regulating sails. The boat cap is set to the wind by means of an endless chain mechanism.

In 1927, the mill was adapted to run via a diesel engine in order to be less dependent on the wind. The last miller, John Hammond, died in 1948. With that, the mill was closed.

Berkswell Mill is a grade II Star listed building. Currently the mill is owned and managed by J. McGarry who restored the mill in 2011.

3.2 Technical aspects of the mill as it pertains to the study

Berkswell windmill is a tower mill built on a mound. The mound raises the height of the mill to allow the sails to catch more unobstructed wind as opposed to a ground-sail mill as traditionally seen in polder landscapes.

The mill is also built on the highest point in the surrounding area. This was done to ensure that none of the wind was obstructed and the wind turbulence was minimised.

Image 1: Satellite photo of Berkswell Mill and the surrounding area taken on 5-4-2018. The yellow circle is the 100 metre radius, the red circle is the 400 metre radius. Within the 400 metre radius, Berkswell Mill is located (nearly) on the highest point. The image is oriented North. (Satellite photo from Google Maps).

The height of the mound on which the mill is built is 1.00 metre above the surrounding ground level. The lowest point of the sail is 1.18 metres above the mound (2.18 metres above ground level). The sail span is 18.80 metres. Half of the sail span is 9.40 metres. Thus, the middle point of the sails (centre of the cannister) is 10.40 metres above the mound, or 11.40 metres above the surrounding ground level. The height of the cannister, sail tips and the mound are necessary to determine the effect of wind turbulence on the mill.

For reference, the ground level is 131 metres above sea level. See the graphs in chapter 5.

MILL	

Measuring	*Length*	*Unit*	
Sail span	18,8	m1	Measured over length of sail
Sail span / 2	9,4	m1	Measured over length of sail
Lowest point sail from mound	1,18	m1	Vertical
Cannister height from mound	10,4	m1	Vertical
Highest point sail from mound	19,62	m1	Vertical
Mound height	1	m1	Vertical
HEIGHTS			
Measuring	*Above sea level (m1)*	*Relative*	
Ground level	131	0	
Height of mound	132	1	
Lowest point sail	133,18	2,18	
Cannister	142,4	11,4	

4. Methodology

4.1 Elements in the study

As stated in chapter 2 of this report, the study focused on determining the relative reduction in milling days for Berkswell Mill with the arrival of new developments and on establishing a guideline for the maximum, permissible build heights for building within a 400 metre radius of the mill.

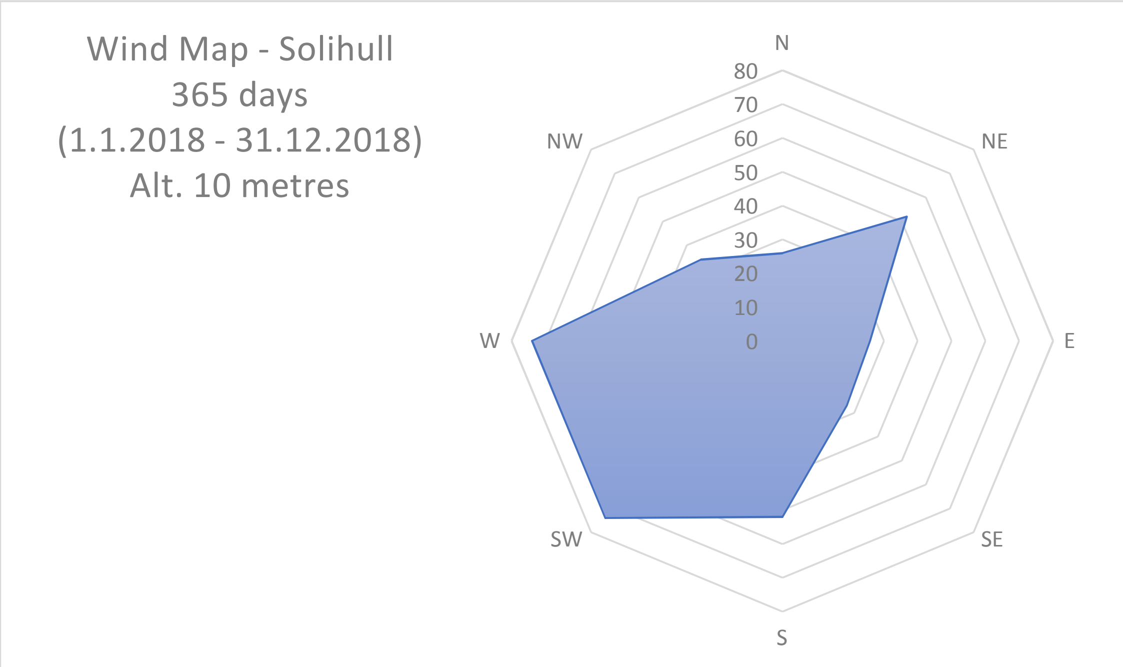
In this chapter, the methodology of both elements will be described with emphasis on the latter.

4.2 Milling days

In order to understand the effect of wind turbulence on the mills ability to produce power, the reduction in number of milling days is calculated. The first step in this process is to establish a control, a baseline in which the number of milling days in an ideal scenario is calculated. The first step is to procure wind data from the nearest weather station.

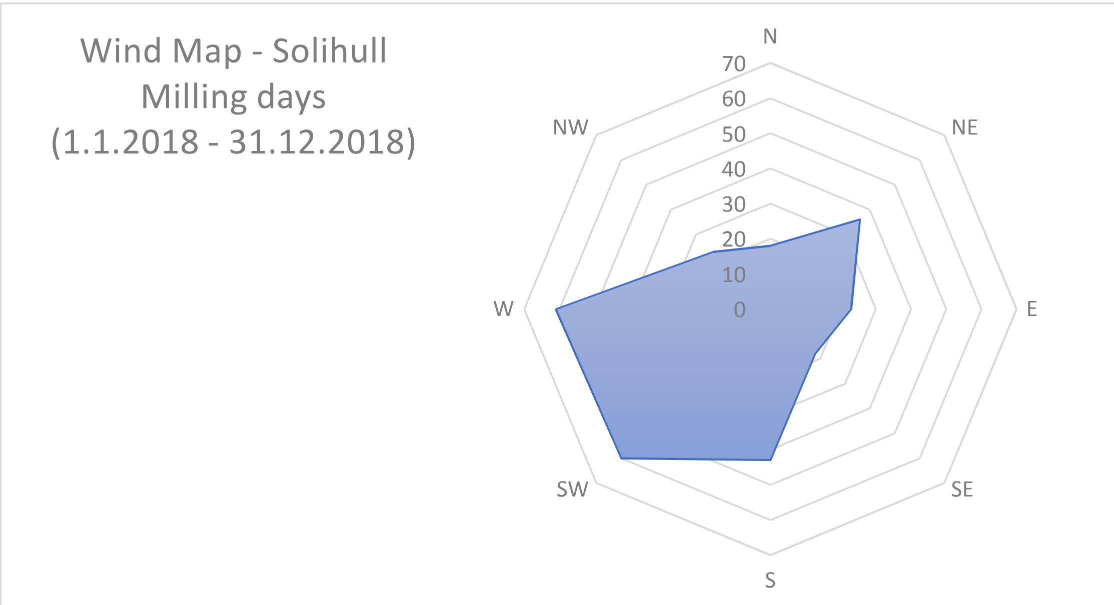
The wind data acquired for the study is from Solihull Weather Station, measured at an altitude of 10 metres above ground height.

Next, the raw data is analysed, grouped and sorted so that we can see a daily average wind speed and predominant direction. With this data a wind map can be generated to help visualise the predominant wind direction in Solihull over the period of one calendar year, in this case 2018. The average windspeed is calculated in the daytime hours only (9 a.m. until 6 p.m.).



Graph 1: The wind map for Solihull weather station from the 1st of January 2018 until the 31st of December 2018. The predominant wind directions are Southwest and West, then South and Northeast. This graph includes all 365 days of the calendar year.

Next, the data is analysed to calculate the number of days on which the average windspeed during the day was equal to or greater than 3.4 m/s.



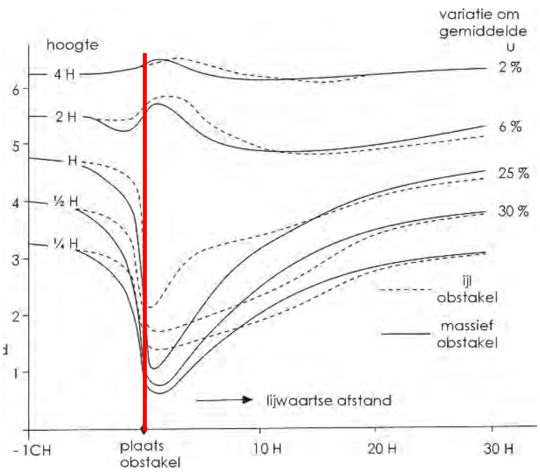
Graph 2: The wind map for Solihull weather station showing the number of days the average windspeed exceeded 3.4 m/s between 9 a.m. and 6 p.m.

With this data it is possible to calculate the theoretical number of milling days per year and in which direction it comes from in the ideal scenario.

Next, a model is created in which the wind disruption caused by an object (building or tree) can be calculated. The factors for this are:

- Distance between the object and the mill
- Height of the object
- Ground elevation of the object
- The sweep of the object (the degrees that the width of the object covers measured radially from the centre point of the mill – the closer the object, the greater the sweep – assuming the object is the same size).
- Where in relation to the mill the object is located. On the previous page, the graphs show clearly that the predominant wind directions are the Southwest and the West but with wind flows from other directions that enable the mill to operate. This is accounted for in the model, as not all directions are weighted equally.
- A reduction factor per object. If objects are in line (seen radially from the mill) the disturbance is less. If one object is blocking another, the blocked object has a negligible effect on the wind flow. This is accounted for with a reduction factor.
- For trees, the tree density is accounted for, as well as the season.

With these factors in place, the reduction can be calculated per object. The wind reduction/turbulence is calculated by taking the ratio of the object's height to the object's distance from the mill and placing it on the wind reduction graph according to Nägeli. Thereafter, the relative windspeed before the object and after the object are calculated and the reduction is the product of the post windspeed divided by the pre windspeed.



Graph 3: Graph showing the disturbance to airflow caused by objects. The red line shows the location of the object. At a certain height/distance ratio the object can actually accelerate the airflow.

This reduction is then used to calculate the reduction in milling days per wind direction.

This model can be used to calculate countless scenarios.

4.3 Biotope guideline

In the Netherlands, the standard for windmill biotopes is decided by ‘De Hollansche Molen’ (The Dutch Windmill foundation).

The standard method of calculating the maximum build heights around a mill is done with a simple formula called the ‘biotope formula’:

Hx	=	X/n+c*z

In which:

H	=	Height of obstacle (in metres)
X	=	Distance obstacle to mill (in metres)
n	=	Coefficient
c	=	Constant (0.2)
z	=	Height of the cannister from ground level (including height of mound)

The coefficient (n) is used to account for the area surrounding the mill. There are three categories:

n= 140; open terrain (flat, open, generally where polder mills would operate)

n= 75; rough terrain (hilly, naturally occurring vegetation)

n= 50; closed terrain (towns, cities, where the mill is surrounded by houses, buildings, other mills, etc.)

The distance is divided by the coefficient, meaning the lower the coefficient, the greater the rate of increase in permissible build height within a 400 metre radius.

These coefficients account for the difference in wind turbulences present in areas with natural undulation compared to a completely flat landscape (e.g. The Broads, Norfolk). An object placed in a flat landscape would cause a greater disturbance in airflow than if the same object were placed in a hilly area.

The area surrounding Berkswell Mill is designated as rough terrain, n=75.

The windmill biotope standard also dictates that the first 100 metres should be free of obstacles. All objects within a 100 metre radius must be lower than the lowest point of the sail. Starting from 100 metres an increasing line showing the maximum, permissible build height applies. This is calculated with the above formula. Hereunder an example:

Assuming the ground is flat (no undulation in the landscape, the ground level is the same within a 400 metre radius), what is the maximum build height for an object 280 metres away from the windmill? For this example, the data for Berkswell Mill (found on page 7) is used.

Again:

Hx = X/n+c*z

Hx = 280/75+0.2*11.4

By using the correct order of operations, we can calculate that the maximum permissible build height at 280 metres is 6.01 metres above the ground.

This formula can found in the book 'De Inrichting van de Omgeving van Molens', authored by the engineer J.A.M. de Nie and published in 1982. However, the graph in this book only takes into account open terrain, a coefficient of 140.

In open terrain, the rate of increase (RoI) is 0.716 metres in height per 100 metres in distance (0.716/100). For rough terrain, the RoI is 1.33/100. For closed terrain 2.00/100.

4.4 Site visit

On the 31st of May 2019, Erfgoed Advies Groen was on-site at Berkswell Mill. The purpose of the visit was threefold:

1. To speak with the client to get a good understanding of the situation and the purpose of the study.
2. To measure the mill.
3. To create an inventory of all relevant objects within a 400 metre radius. Measuring building heights and looking at tree density. From atop the windmill, 360 degree panoramic photographs were taken. As a mill biotope is unique to every mill, the surroundings have to be familiar to the person making the calculations and writing the report.

5. Results

5.1 The effect of wind turbulence

To help the reader of this report understand wind turbulence and its effect on airflow the difference in milling days between the ideal situation and the current situation with trees and buildings is presented hereunder:

> The theoretical amount of milling days for Berkswell Mill when the airflow is not obstructed by buildings or trees is 282 days per calendar year.
>
> The theoretical amount of milling days for Berkswell Mill in the current biotope is 126 days per calendar year. A reduction of 156 days.

This shows the importance of maintaining an unobstructed wind corridors in all directions to retain as much mill functionality as is currently available. The construction of the mill, with its boat cap top, enables the sails to be set to the set from any direction.

5.2 Maximum object height per wind direction

In this chapter the maximum allowable object height according to the windmill biotope formula and the elevation profile is presented per wind corridor.

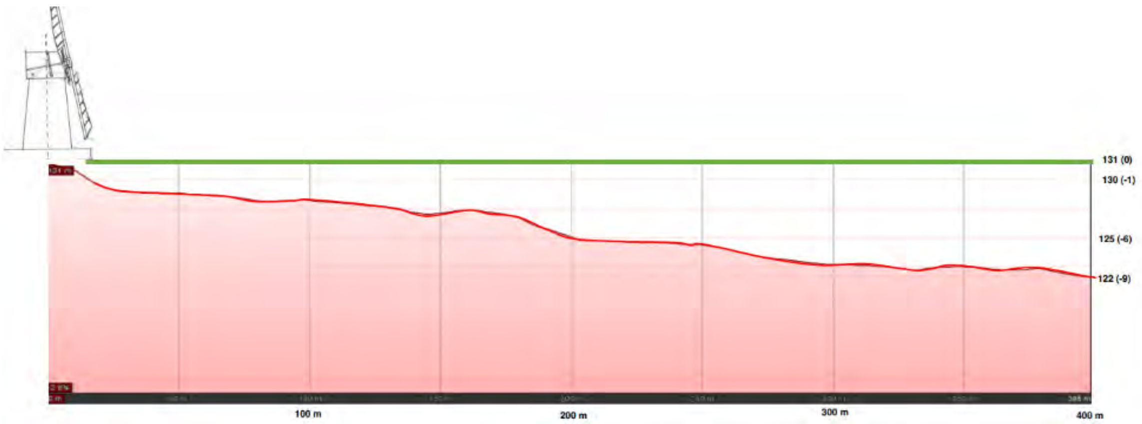
This report contains the graphs for each of the wind directions in the 16-rose compass:

N, NNE, NE, ENE**, E,** ESE, SE, SSE**, S,** SSW, SW, WSW**, W,** WNW, NW, NNW

Each of the graphs shows the following information:

- A elevation profile graph*, starting at the centre point of the mill. The starting point is 0 metres at 131 metres elevation above sea level. To clarify: the red shaded area is the ground level above sea level.
- A sketch of the mill at the 0 metre mark – not to scale.
- A solid green line showing the ground level of the mill over the 400 metre radius (not the mound height).

As an example, wind corridor EAST is shown:



400 metres

At 400 metres from the mill (x-axis), the ground level is 122 metres above sea level, or 9 metres lower (-9) than the ground level at the mill (131-122=9). According to the biotope formula, the maximum allowable build height at 400 metres is 7.61 metres (y-axis) above 131 metres. Because the terrain is 9 metres lower at 400 metres than at 0, the maximum object height at 400 metres is 7.61 + 9 = 16.61 metres. . The shaded red area is the height above sea level.

The first graph on the following page shows only the maximum building heights, valid for all wind corridors.

**Graph data from SIO, NOAA, U.S. Navy, NGA and GEBCO acquired through Google Earth Pro.*

MAXIMUM HEIGHTS ALL WIND CORRIDORS

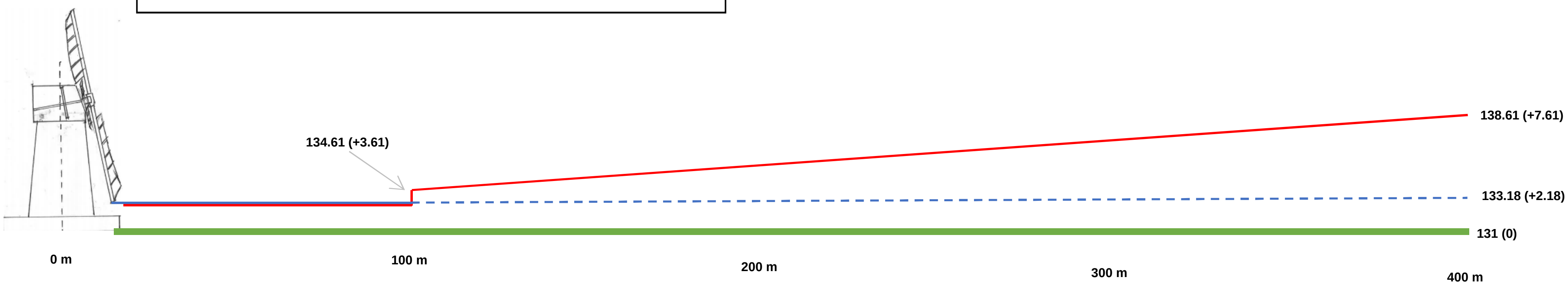
The maximum object height above ground level 131 (0) at:

100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres



Ground level (MILL)

Tip of under sail

Maximum build height

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

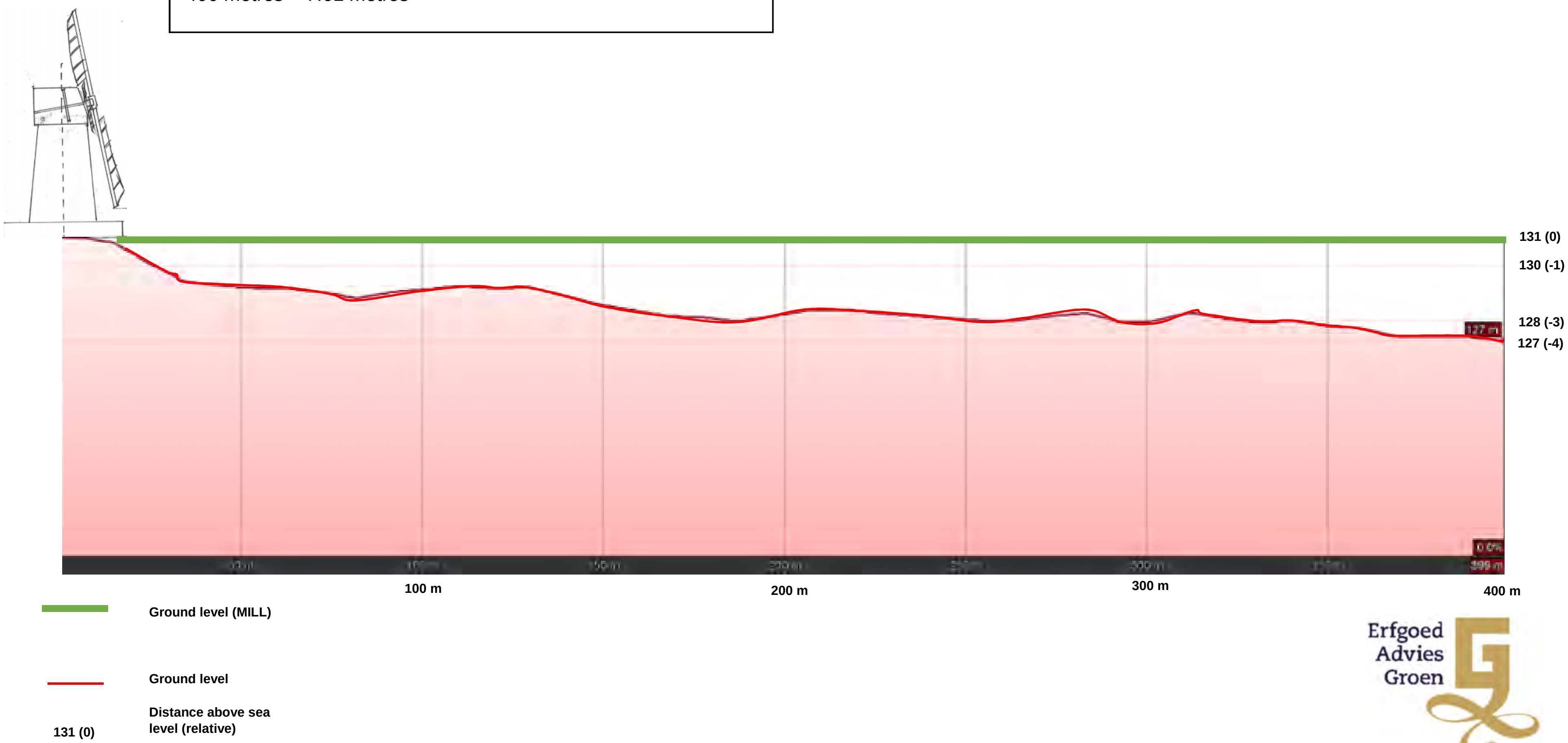
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **NORTH**



The maximum object height above ground level 131 (0) at:

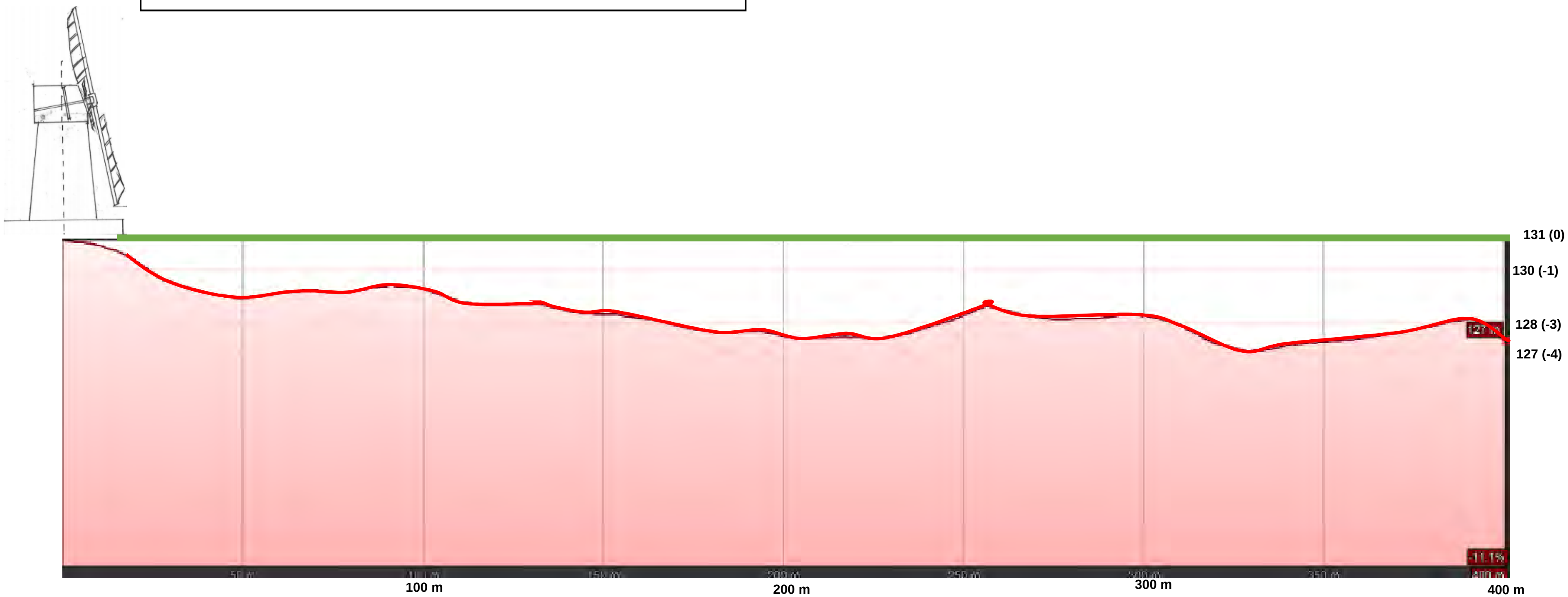
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **NNE**



Ground level (MILL)

Ground level

131 (0) **Distance above sea level (relative)**

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

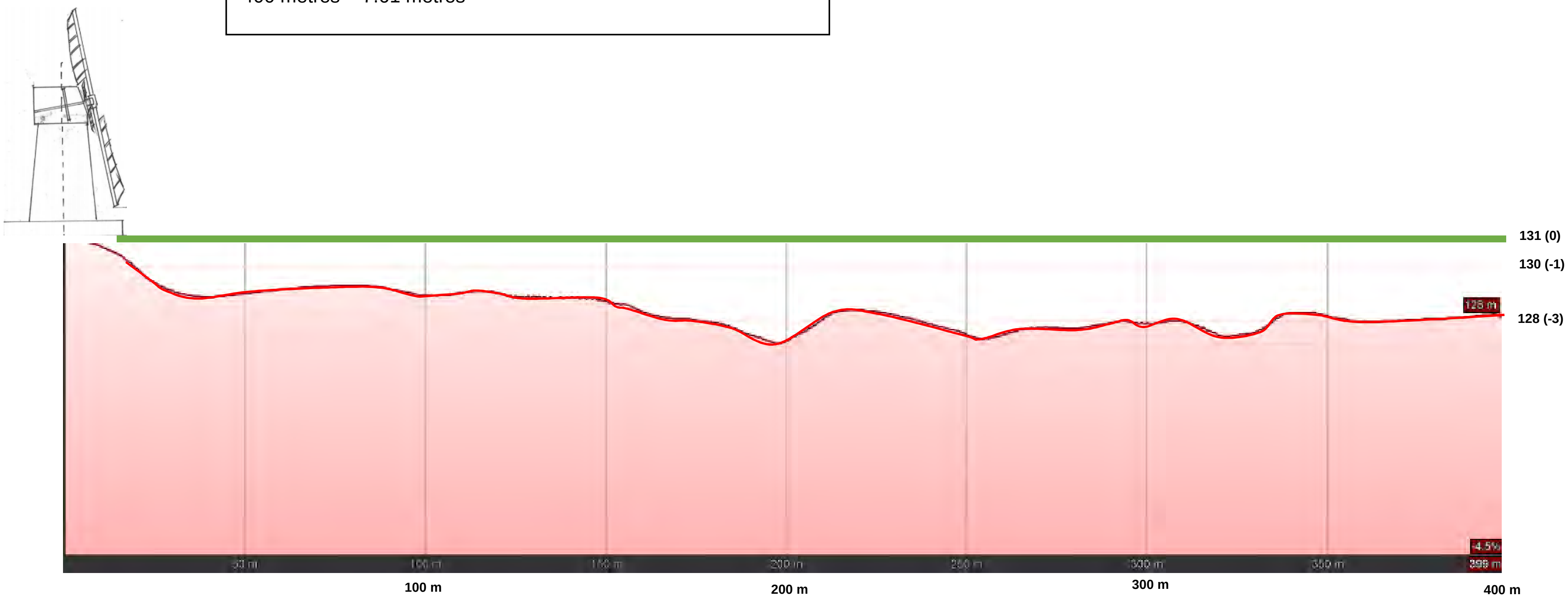
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **NORTHEAST**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

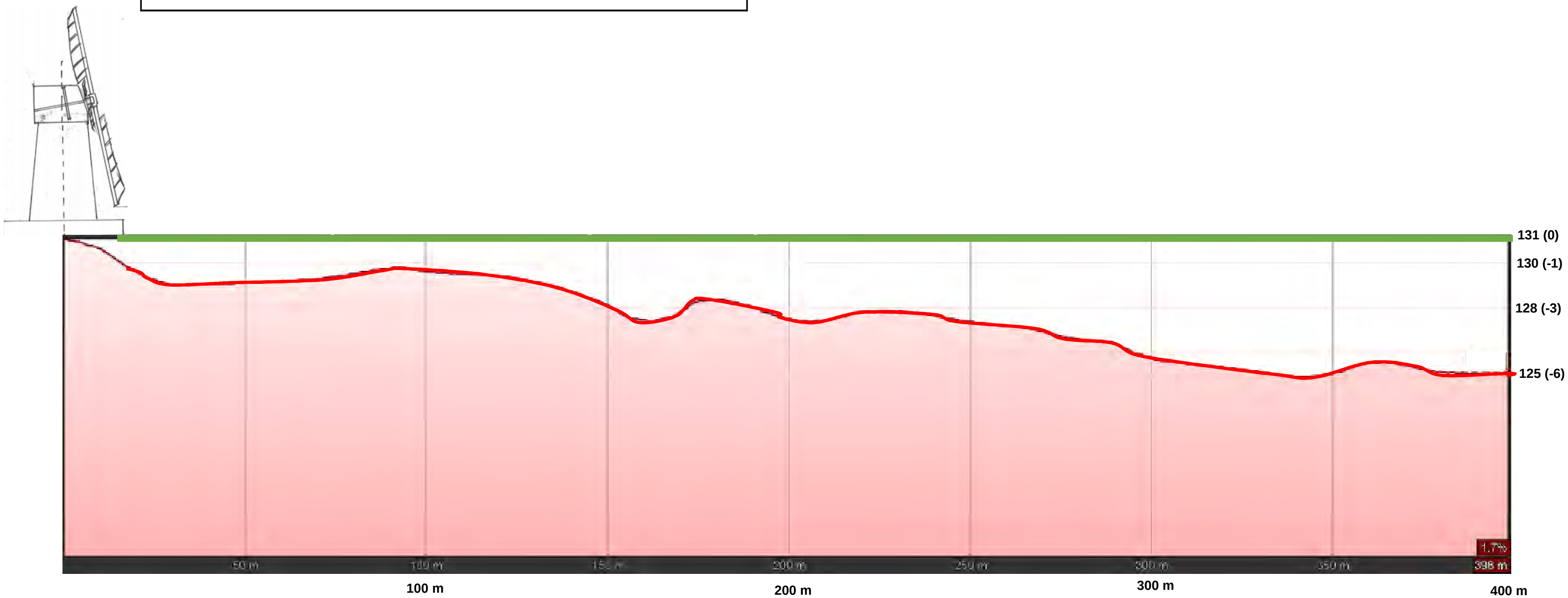
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **ENE**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

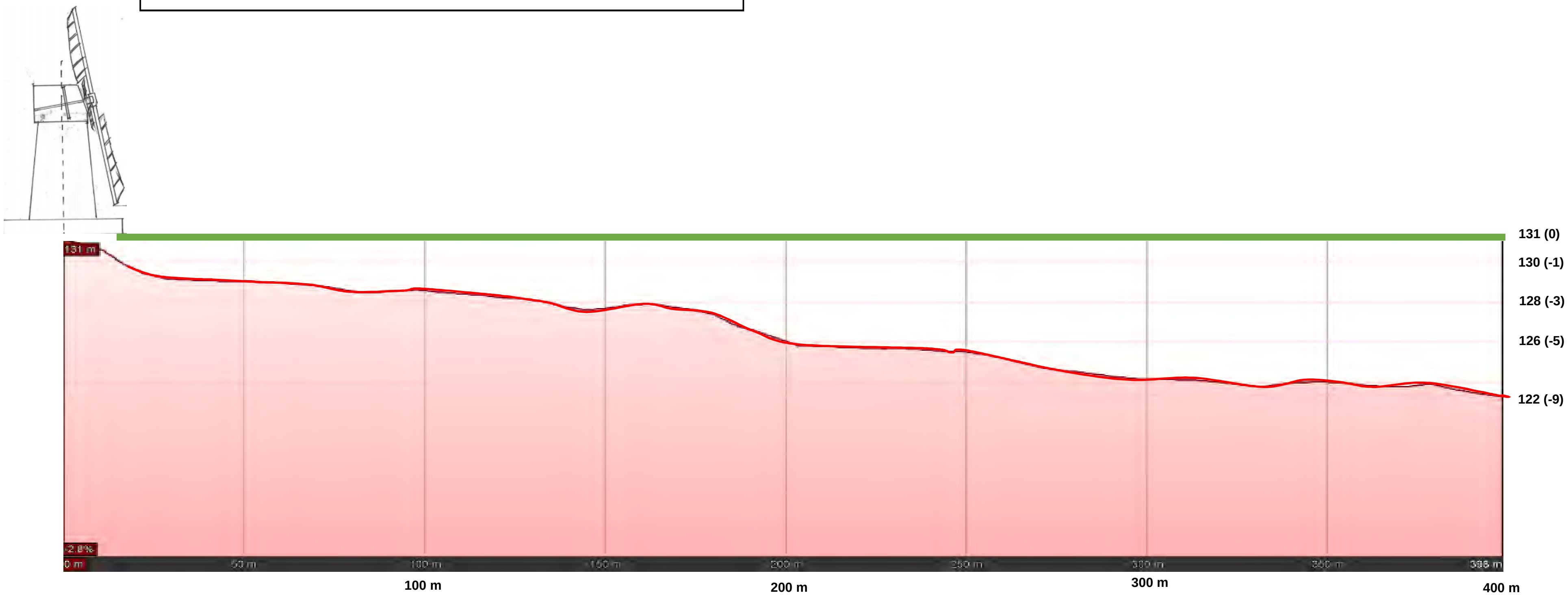
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **EAST**



(green line)	Ground level (MILL)
(red line)	Ground level
131 (0)	Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

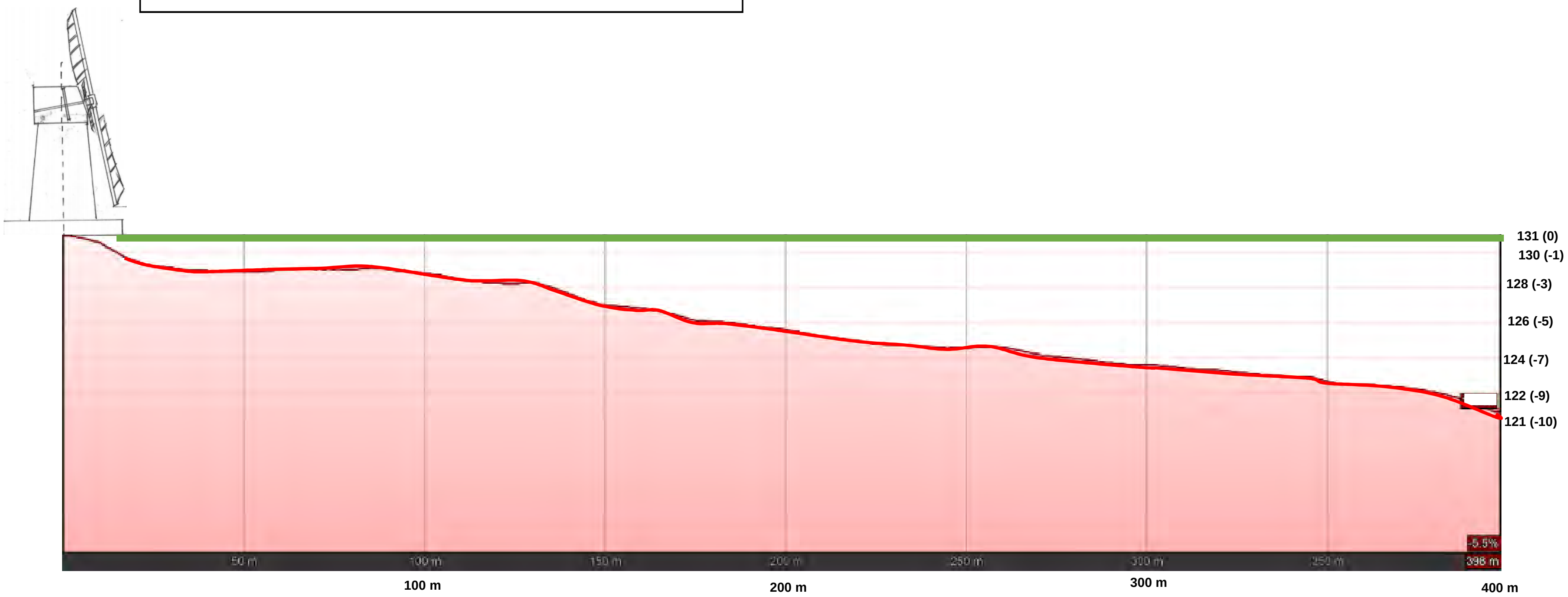
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **ESE**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

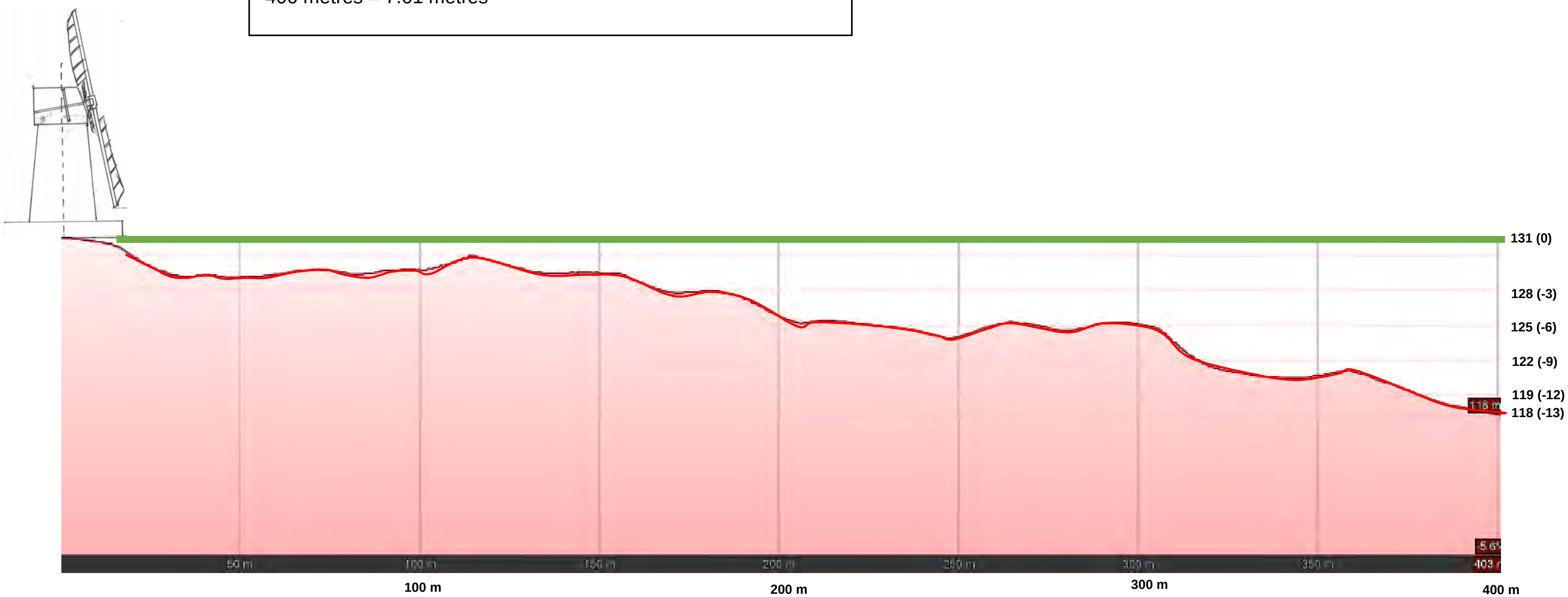
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **SOUTHEAST**



Ground level (MILL)

Ground level

131 (0) **Distance above sea level (relative)**

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

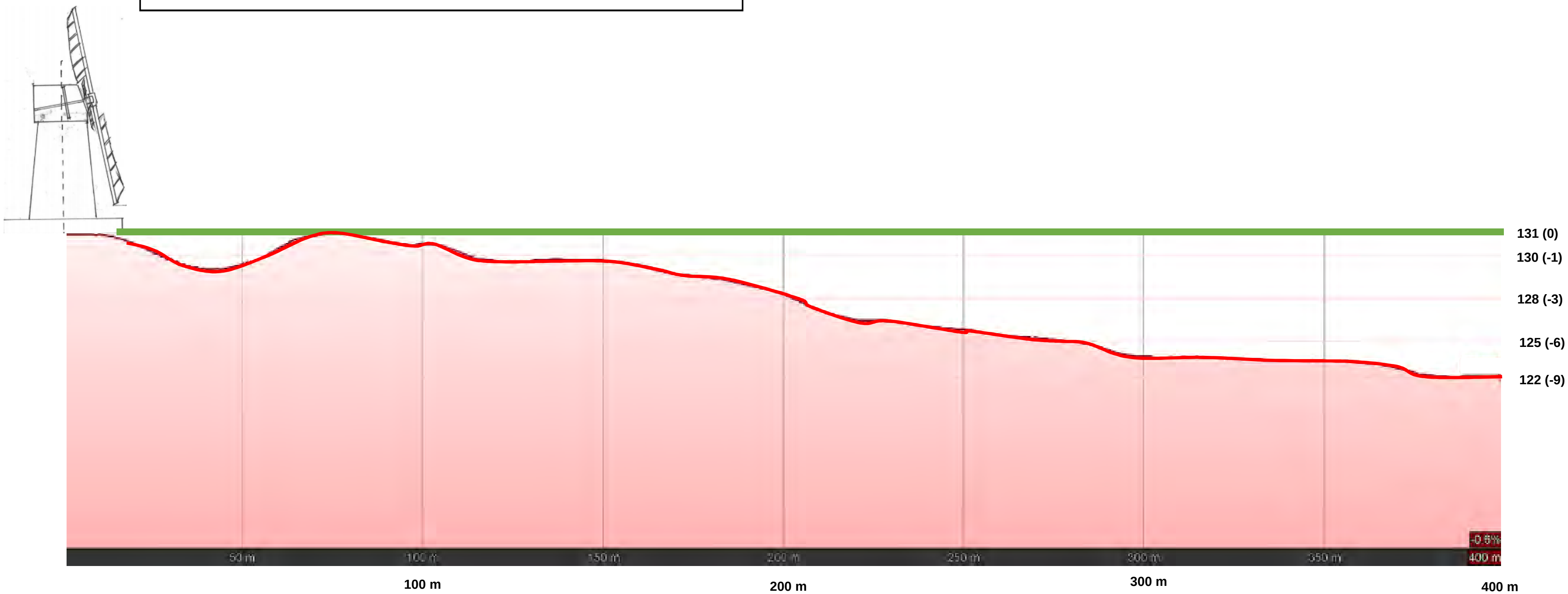
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **SSE**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

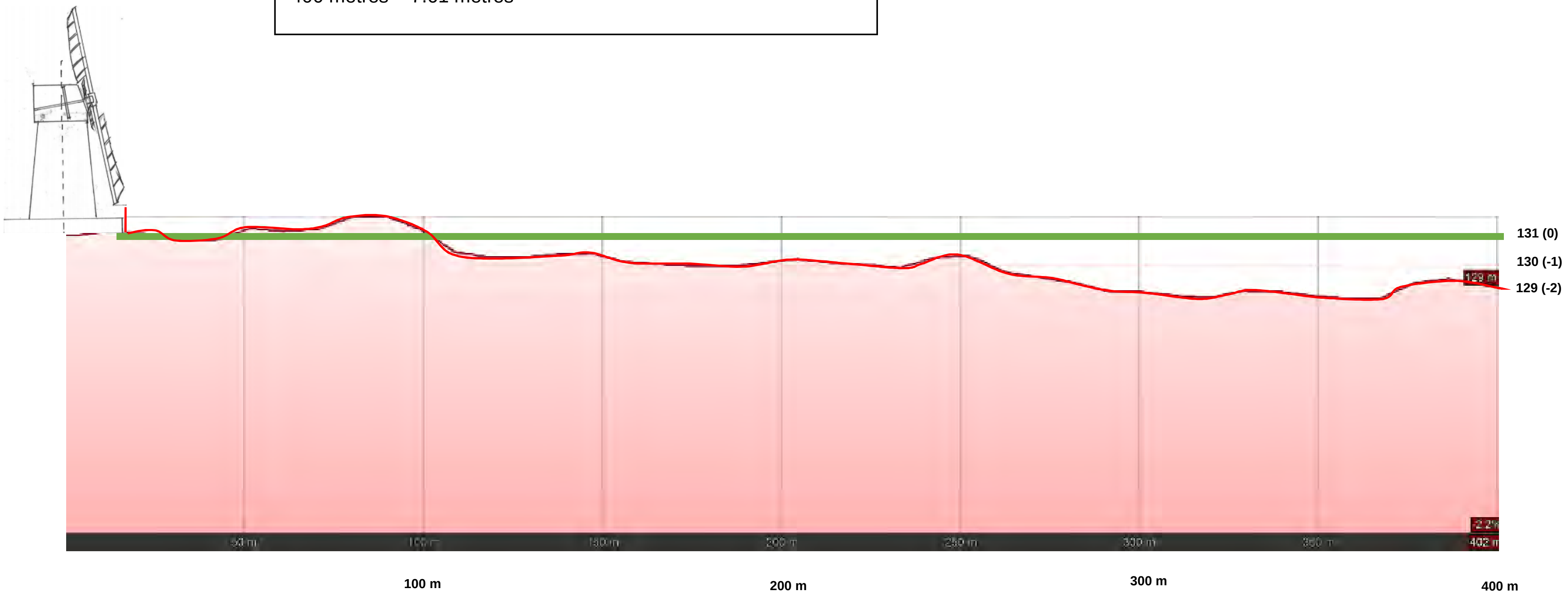
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **SOUTH**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

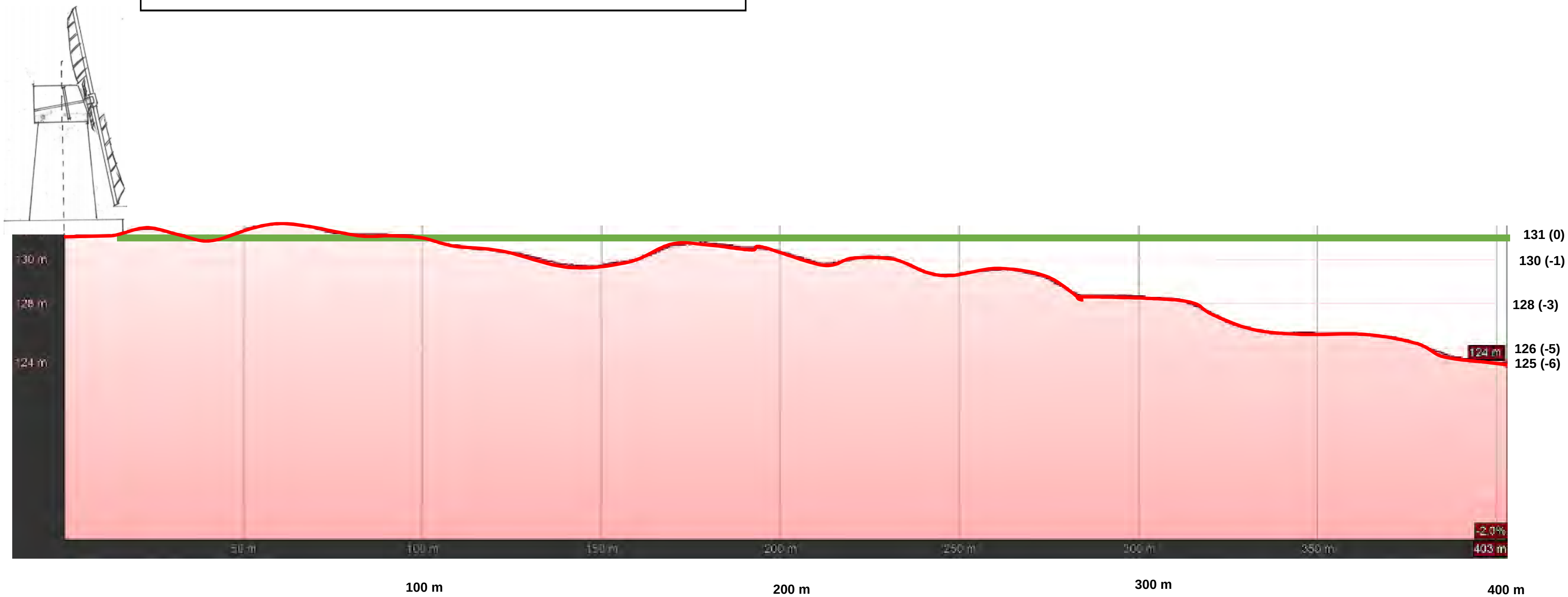
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **SSW**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

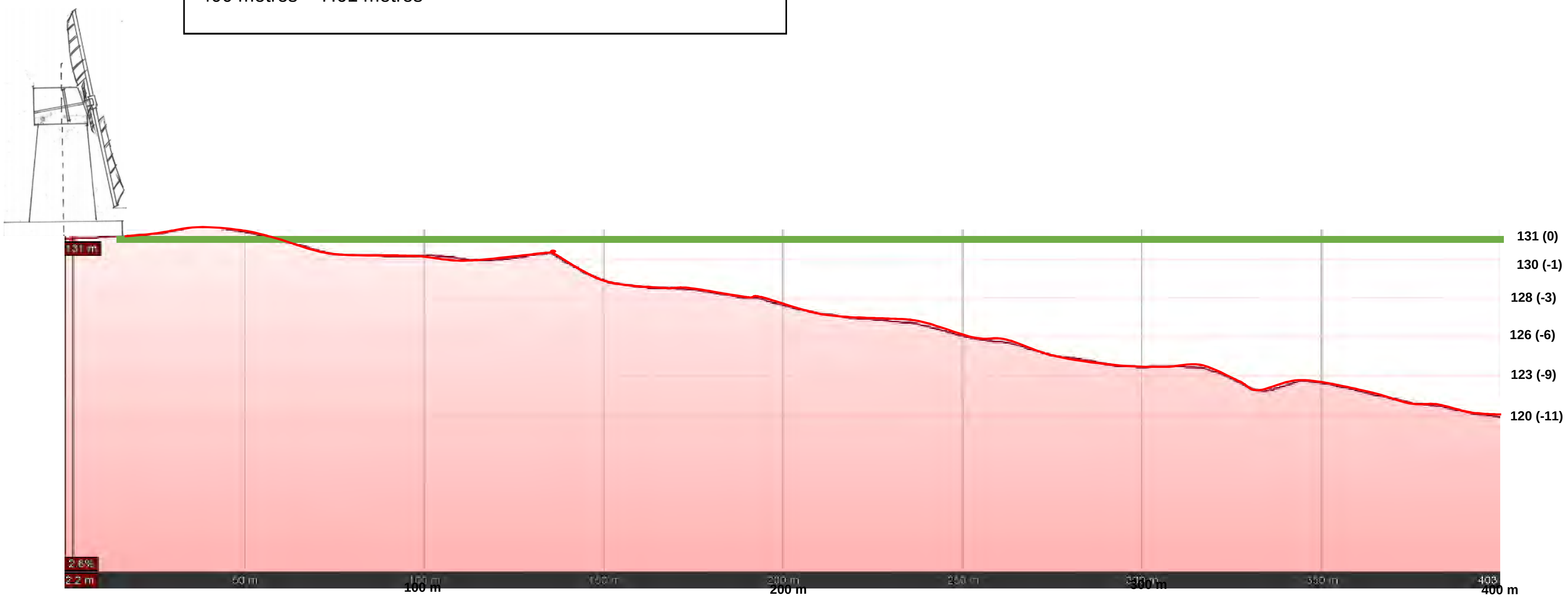
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **SOUTHWEST**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

The maximum object height above ground level 131 (0) at:

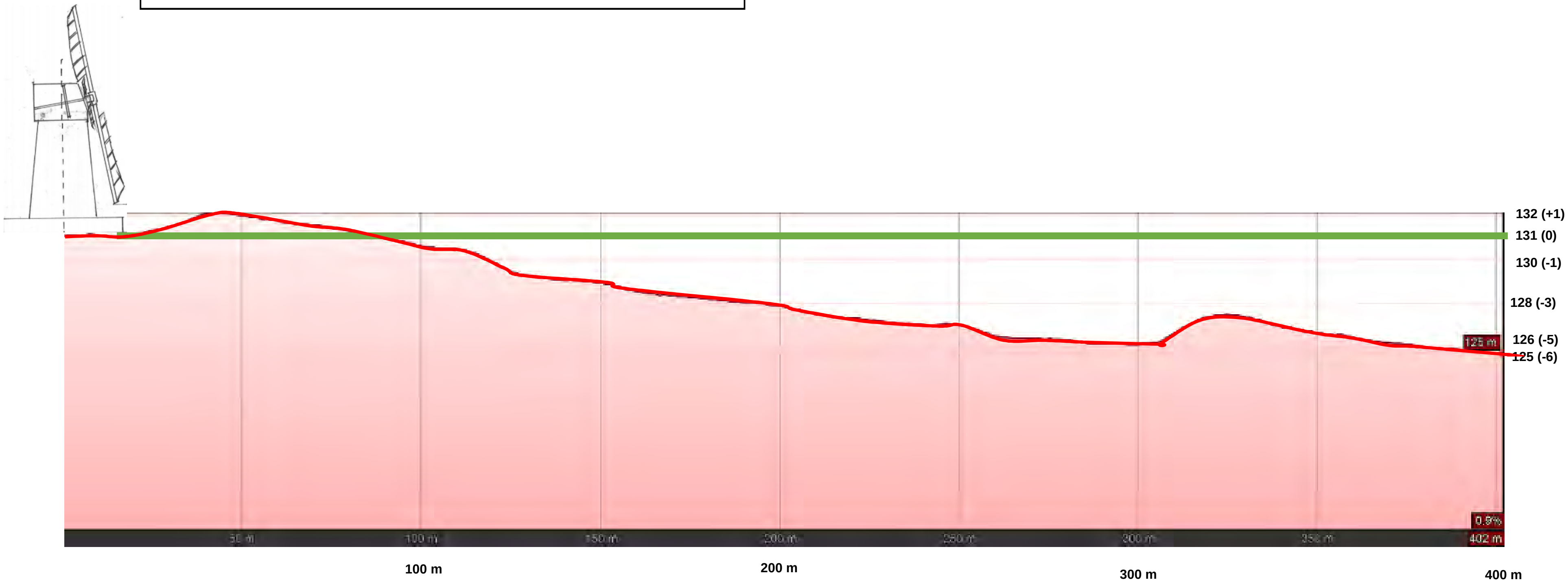
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **WSW**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

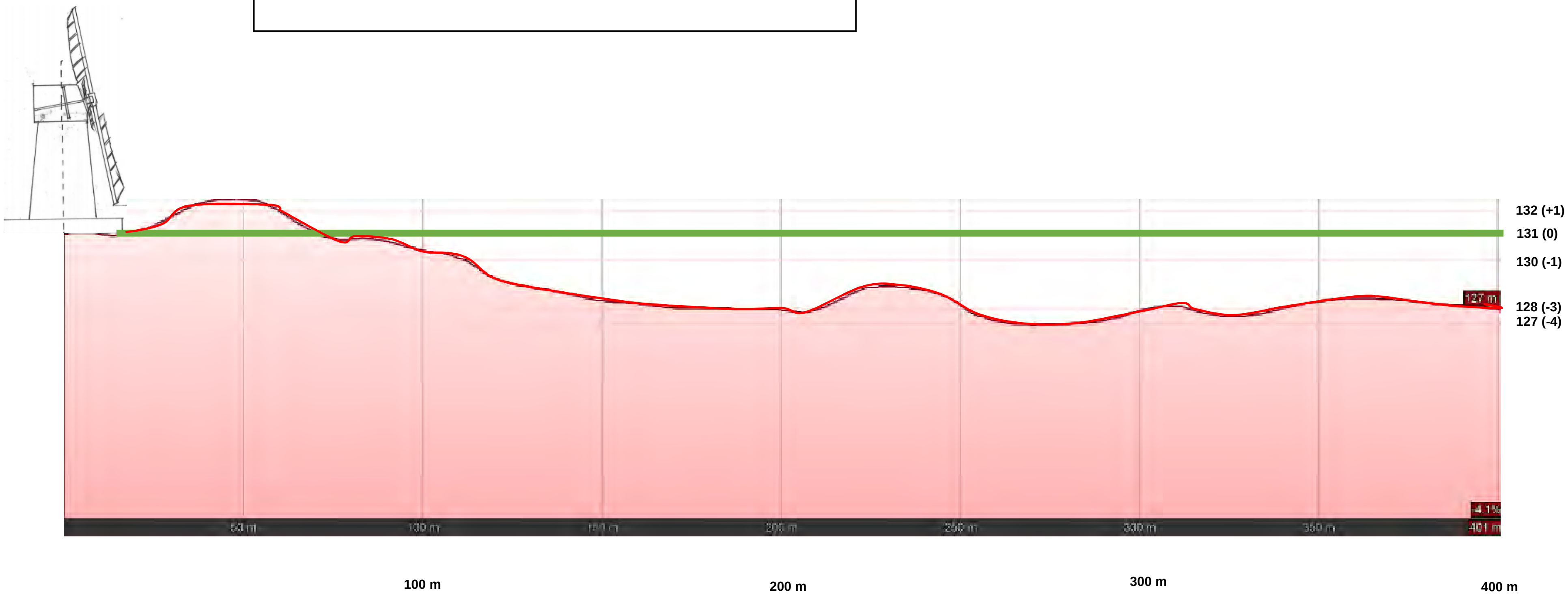
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **WEST**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

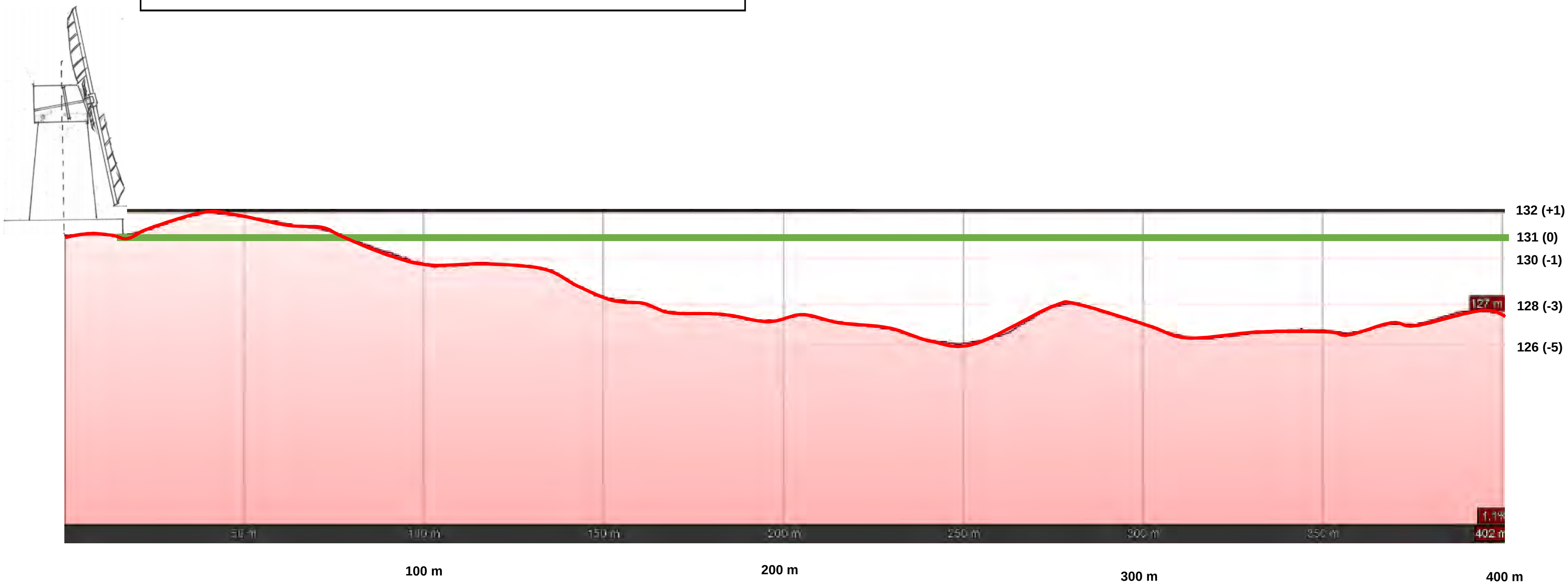
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **WNW**



Ground level (MILL)

Ground level

131 (0) **Distance above sea level (relative)**

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

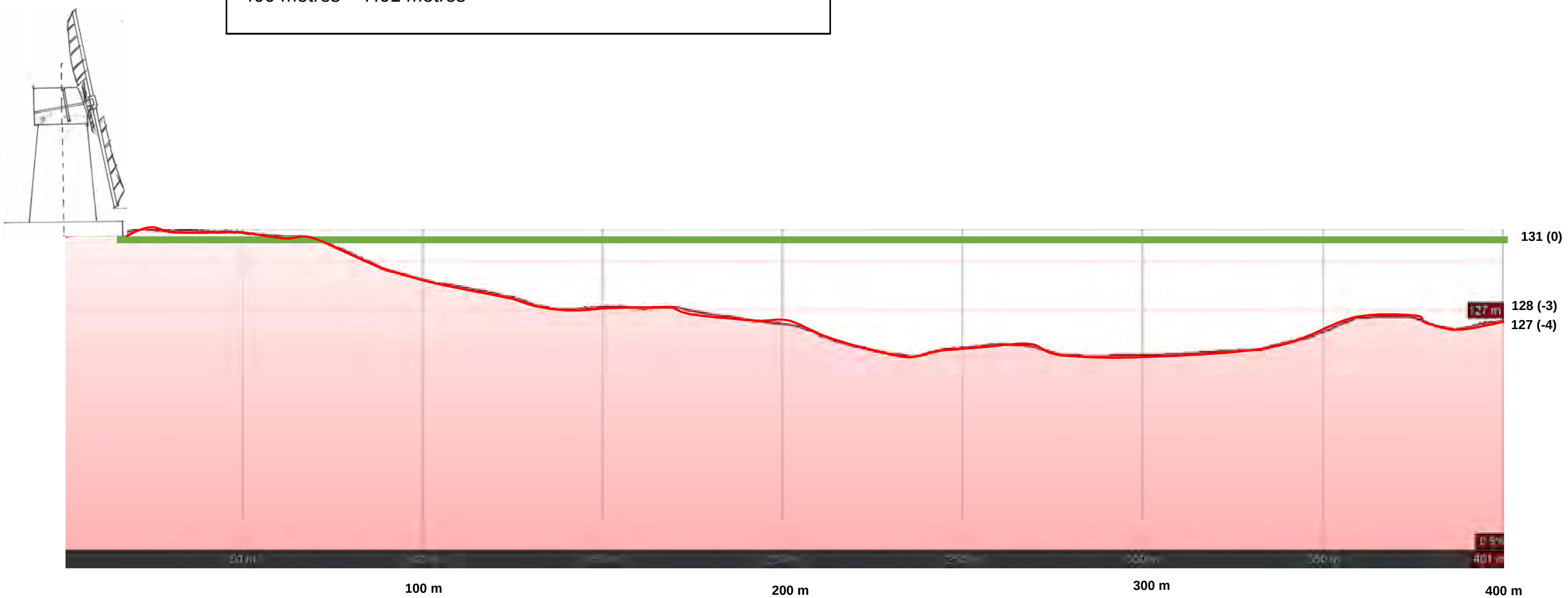
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **NORTHWEST**



Ground level (MILL)

Ground level

131 (0) **Distance above sea level (relative)**

Erfgoed Advies Groen

The maximum object height above ground level 131 (0) at:

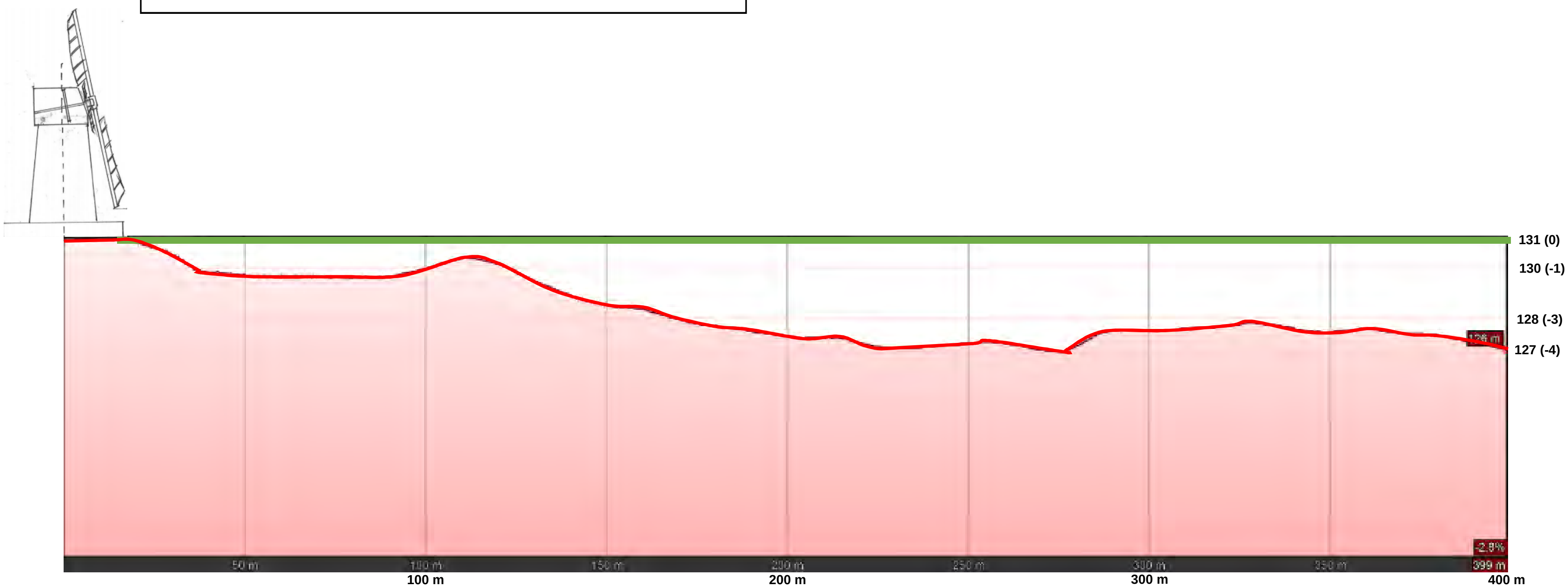
100 metres = 3.61 metres

200 metres = 4.95 metres

300 metres = 6.28 metres

400 metres = 7.61 metres

WIND CORRIDOR: **NNW**



Ground level (MILL)

Ground level

131 (0) Distance above sea level (relative)

Erfgoed Advies Groen