Environmental Impact and Sustainability Assessment

Group 6

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Introduction

The investigation and assessment are conducted as one part of the Hydrogen Cyanide and AMS Plant Replacement Project. The client is Coates Chemicals.

Objective

This report is mainly used for assessing the feasibility of constructing the new designed plant and provide a reference for further construction. A systematic information review about history, geology, meteorology, and environment of the bounded area is completed to learn a detailed local context. Then relative sustainability metrics which integrates three indicators is applied and is compared with regulatory standards and the obtained local context. Additionally, cost benefit is assessed for an economic determination.

Liability statement

The environmental impact assessment in this report was all based on the study of investigation data from third party. And the sustainability assessment is done following the IChemE form and code. The author of this report is not responsible for the referenced information.

Site information

Figure 1. Site remote sensing image - Google Earth

Table 1. Site coordinates

Coordinates	Point	1	2	3	4
	Westings	1°16'38"	1°16'32"	1°16'39"	1°16'33"
	Northings	54°35'3"	54°35'3"	54°34'59"	54°34'58"

Table 2. Site information

Site Name	Lucite International
Site Address	New Road, Billingham TS23 1LE
Certificate of Title	Current Certificate of Title
Site Area	Approximately 13500m^2 (1.35 ha)
Site Owner	County Durham, British land
Occupier/Operator	Lucite International UK Ltd
Local Government	Billingham Town, County Durham
Current Zoning	Chemical Industry

Local context

History

According to the historic maps (1850s, 1890s, 1950s and 1970s) found in Digimap, there used to be no architectures in 1850s and 1890s. The empty area supposed to be agricultural used land. However, in the historic map of 1950s, a big number of buildings had been constructed in this region, which means that this region experienced a large-scale development during 1890s - 1950s. According to (Cities of Science - North East - An Explosive History, 2007), rapidly ascending demand for explosives resulted in the massive expansion of Billingham after the outbreak of First World War. The Billingham town was selected as ammonia production site in 1917 to supply ammonia to the army. Nevertheless, the plant wasn't finished until the end of the war. Then, this plant was taken over by the Brunner Mond Company, which transformed it into fertilisers manufacturing plant. The plant continued to use the origin ammonia process and then converted the produced ammonia to ammonia sulphate fertiliser, which was known as AMS process. It marked that Billingham entered the chemical industrial age. In December 1926, four chemical companies include Brunner Mond were merged and Imperial Chemical Industries (ICI) was formed. As one of the biggest monopoly chemical groups over the world, ICI promoted the rapid development of the chemical industries in Billingham. In the following decades, ICI successively developed Perspex, polythene, nylon etc. at Billingham. To satisfy the need of anhydrite, which was an essential raw material of fertiliser manufacturing, ICI used to mine at Billingham. The 240 metres deep mining work left about 200 miles of underground tunnels beneath parts of Billingham. The mine was shut down in 1971 and was sealed in 1978 (A Brief History of Billingham - Heritage Stockton, 2019). The industrial monopoly of ICI in Billingham remained until late 1990s, when ICI sold all plants to other international groups, such as Huntsman, Mitsubishi, BASF etc. By the comparison of historic maps in 1950s, 1970s and the contemporary one, the distribution of the site has been fixed since 1950s or even earlier.

Geology

According to the Geology maps (Rock, Soil), the geological properties of the site are simple and unitary. The rock formation here were all glaciolacustrine deposits which were Devensian. The major petrographic composition of this deposits were clay and silt. The origin ground consist of clay and silt were not suitable for construction because of its high moisture and low hardness. Therefore, further borehole test needed to be conducted to collect more information for formation solidification.

Climate & hydrology

Locate in the North-eastern England, the site is temperate marine climate. This type of climate is mild because there is no big fluctuation on climate all year round. As shown in the average high and low temperature chart (Weather Spark), the hottest month of the year in Billingham is July, with an average high temperature of 20 ℃ (68℉). The coldest month of the year in Billingham is January, with an average low temperature of 2 ℃ (36℉). No high-temperature or freezing hazards are identified here.

Overall, the monthly precipitation in Billingham is quite stable and rain falls throughout the year. The month with the most rain in Billingham is August, with an average of 53 mm (2.1 inches). And the month with the least rain in Billingham is February, with an average rainfall of 33 mm (1.3 inches).

The hourly average wind vector recorded in chart is measured at 10 meters above the ground in the Billingham. The average hourly wind speed significantly varies by seasonal variation throughout the year. The windiest month of the year in Billingham is January, with an average hourly wind speed of 25400 m (15.8 miles) per hour. And the calmest month of the year in Billingham is July, with an average hourly wind speed of 16600 m (10.3 miles) per hour. Additionally, the prevailing wind direction in Billingham is from west throughout the year.

The most possible hazard in Billingham is flooding. According to the flooding map, there is no flood potential in the bounded area. But the Billingham Beck with high flood potential from the sea locates in the right south of the southern site boundary, which should be carefully noted. Flooding was regularly happened in winter.

Ecology

A Local Nature Reserve, Billingham Beck Valley Country Park located on the south of the site. Although there was regular flooding in the winter, summer hay cutting and grazing has made it a wetland meadows. These wetland meadows provided good ecologic environment for plants and wildlife. The mature ecologic systems here have the adjustive ability to purify the environment.

Emission standards

Table 3. Air emission standards (Environmental Permitting (England & Wales) Regulations 2016)

Substance	Emission period	Limit (average)	Standard
Carbon monoxide	8 hour running average across a 24-hour period	10 milligrams per cubic metre	AAD Limit Value
Nitrogen dioxide	1 hour	200 micrograms per cubic metre	AAD Limit Value
Nitrogen dioxide	Annual	40 micrograms per cubic metre	AAD Limit Value
Particulates (PM10)	Annual	40 micrograms per cubic metre	AAD Limit Value
Particulates (PM2.5)	Annual	20 micrograms per cubic metre	AAD Limit Value
Sulphur dioxide	24 hour	125 micrograms per cubic metre	ADD Limit Value

Sustainability metrics

All data used here was based on maximum productivity.

Environmental indicators

Resource

(a) Energy

Table 4. Energy Imports

	Energy Value	Conversion factor	Primary Energy Value	Quantity Used/y	Usage rate GJ/y
Electricity	3,600kJ/kWh	1	7,764,759 kJ/h (Max) 888,288 kJ/h (Min)	2167 kWh (Max) 248 kWh (Min)	18,635,422 kWh (Max) 2,131,892 kWh (Min)
Natural Gas	3,8207 kJ/kg	1	235,355,120 kJ/h (Max) 26,924,626 kJ/h (Min)	53,222,400 kg (Max) 6,088,643 kg (Min)	564,852,288 kWh (Max) 64,619,102 kWh (Min)

Steam	2737.6 kJ/kg	1	31,482,400 kJ/h (Max) 1,182,643 kJ/h (Mini)	99,360,000 kg/y (Max) 3,732,480 kg/y (Mini)	272,008 GJ/y (Max) 10,218 GJ/y (Mini)

Table 5. Energy outports

	Energy Value	**Conversion factor**	**Primary Energy Value**	**Quantity Used/y**	**Usage rate GJ/y**
Electricity	3,600kJ/kWh	1	540,000 kJ/h (Max) 61,776 kJ/h (Min)	150 kWh (Max) 17 kWh (Min)	1,290,000 kWh (Max) 147,576 kWh (Min)
Steam	2797.2 kJ/h	1	190,050,160 kJ/h (Max) 21,753,824 kJ/h (Mini)	587,027,520 kg/y (Max) 67,193,280 kg/y (Mini)	1,642,033 GJ/h (Max) 187953 GJ/h (Mini)

Table 5. Energy

Total Net Primary Energy Usage rate = Imports – Exports	725,887 GJ/y (Max) 83,042 GJ/y (Min)
Percentage Total Net Primary Energy sourced from renewables	43%
Total Net Primary Energy Usage per kg product	1,231 kJ/kg
Total Net Primary Energy Usage per unit value added	3 kJ/£

(b) Material (excluding fuel and water)

Table 6. Material 1

Total raw materials used, including packaging	898506 kg/h
Raw material recycled from other company operations	2190 kg/h
Raw material recycled from consumer	0
Raw material used which poses health, safety or environmental hazard	7385 kg/h

Table 7. Material 2

Total raw materials used per kg product	135 kg/kg
Total raw materials used per unit value added	409 kg/£
Fraction of raw materials recycled within company	0
Fraction of raw materials recycled from consumers	0
Hazardous raw material per kg product	1 kg/kg

(c) Water

Assume coolant will be replaced three times a year, and every circulation of coolant last 15 minutes. Total water mass flow rate in coolant is 180766 kg/h

Table 8. Water

Water used in coolant solution	135 te/y
Water directly used in cooling	3122440 te/y
Water used in process	669991 te/y
Total	3792566 te/y
Water recycled internally	153063 te/y
Net water consumed = Total used-recycled	3639503 te/y
Net water consumed per unit mass of product	62.57 kg/kg
Net water consumed per unit value added	0.1543 te/£

(d) Land

Table 9. Land

Land occupied by operating unit	12500 m2
Other land affected by unit's activities	1000 m2
Total land	13500 m2
Total land for value added	0.000573 m2/£

Emission

(a) Atmospheric impacts

Table 10. Atmospheric impacts

Substance	**Mass flowrate**
CO2	4973 kg/h
N2	11447 kg/h
H2O	1217 kg/h
NO2	50 kg/h

Table 11. Atmospheric acidification burden

Substance	**Potency Factor PF**	**Emission**	
		Tonnes W	**EB value = W x PF**
NO2	0.7	438 te/y	306.6
Total		306.6	

The unit of Environmental Burden is te/y sulphur dioxide equivalent

Table 12. Global warming burden

Substance	Potency Factor PF	Emission	
		Tonnes W	EB value = W x PF
NO_x	40	438 te/y	17520
CO_2	1	43563 te/y	43563
Total		61083	

The unit of Environmental Burden is te/y carbon dioxide equivalent

Table 13. Photochemical ozone burden

Substance	Potency Factor PF	Emission	
		Tonnes W	EB value = W x PF
NO_2	0.028	438 te/y	12.26
Total		12.26	

The unit of Environmental Burden is te/y ethylene equivalent

Table 14. Atmospheric environmental burden

Atmospheric acidification burden per unit value added	0.000013 te/£
Global warming burden per unit value added	0.002588 te/£
Human Health burden per unit value added	0
Ozone depletion burden per unit value added	0
Photochemical ozone burden per unit value added	0.00000053 te/£

(b) Aquatic impacts

Table 15. Aquatic impacts

Substance	**Mass flowrate**
CO2	62.66 kg/h
Ammonia	31.42 kg/h
H2O2	2.42 kg/h

Table 16. Ecotoxicity to aquatic life

Substance	Potency Factor PF	Emission	
		Tonnes W	EB value = W x PF
Ammonia	0.24	275 te/y	66
Total		66	

The unit of Environmental Burden is te/y formaldehyde equivalent

Table 17. Eutrophication

Substance	Potency Factor PF	Emission	
		Tonnes W	EB value = W x PF
Ammonia	0.33	275 te/y	90.75
Total		90.75	

The unit of Environmental Burden is te/y phosphate equivalent

Table 18. Aquatic environmental burden

Aquatic acidification per unit value added	0
Aquatic oxygen demand per unit value added	0
Ecotoxicity to aquatic life per unit value added	0.0000028 te/ £
Eutrophication per unit value added	0.0000028 te/ £

(c) Impacts to Land

Table 19. Impacts to Land

Total hazardous solid waste disposal	0
Total non-hazardous solid waste disposal	0
Hazardous solid waste per unit value added	0
Non-hazardous solid waste per unit value added	0

Economic indicators

Table 20. Profit, value and tax

Sales	60527692 £/y
Cost of goods, raw materials and services purchased	32109979 £/y
Value added	28417714 £/y
Gross margin	22601217 £/y
Net Income Before Tax (NIBT)	22601217 £/y
Taxes	4225729 £/y

Table 21. Value

Value added	28417714 ع.ب
Value added per unit value of sales	411 ع.ب
Value added per direct employee	568354 ع.ب
Gross margin per direct employee	473924 ع.ب
Return on average capital employed	10 %
Taxes paid, as percent of NIBT	17.9 %

Investments

(a) Direct

Table 22. Direct investments 1

Average capital employed	40822197 ع.ب
Increase (decrease) in capital employed	unknown
Research and Development expenditure	459570 ع.ب
Average number of direct employees (full-time equivalents)	50 /y
Number of new employees appointed	15 /y
Number of employees with at least 2 years of post-school education	30 /y
Total wages expense	4816497 ع.ب
Total benefits expense	481650 ع.ب
Payroll expense = wages + benefits	5298147 ع.ب
Total training expense for direct employees	636145 ع.ب

Table 23. Direct investments 2

Percentage increase (decrease) in capital employed	12 %
R&D expenditure as % sales	4 %
Employees with post-school qualification	30 /y
New appointments/number of direct employees	10 /y
Training expense as percentage of payroll expense	13 %

(b) Indirect

Table 24. Indirect investments

Number of indirect jobs wholly dependent on operating unit	10 /y
Investment in education (non-employee) at all levels	59000 ع.ب
Other philanthropy and charitable gifts and donations	180000 ع.ب
Ratio of indirect jobs number of direct employees	20 %
Investment in education employee training expense	95253 ع.ب
Charitable gifts as percentage of NIBT	0.93 %

Social indicators

Workplace

(a) Employment situation

Table 25. Employment situation

Number of employees who have resigned or been made redundant	Unknown
Number of direct employees promoted	Unknown
Working hours lost through absence	Unknown
Indicative wage and benefit package for highest-paid 10% of employees	Unknown
Indicative wage and benefit package for lowest-paid 10% of employees	Unknown
Benefits as percentage of payroll expense	Unknown
Employee turnover (resigned+redundant/number employed)	Unknown
Promotion rate (number of promotions/number employed)	Unknown
Working hours lost as percent of total hours worked	Unknown
Income+benefit ratio (top 10%/bottom 10%)	Unknown

(b) Health and safety at work

Table 26. Health and safety at work

Lost time accident frequency (number per million hours worked)	Unknown
Expenditure on illness and accident prevention/payroll expense	Unknown

Assessment

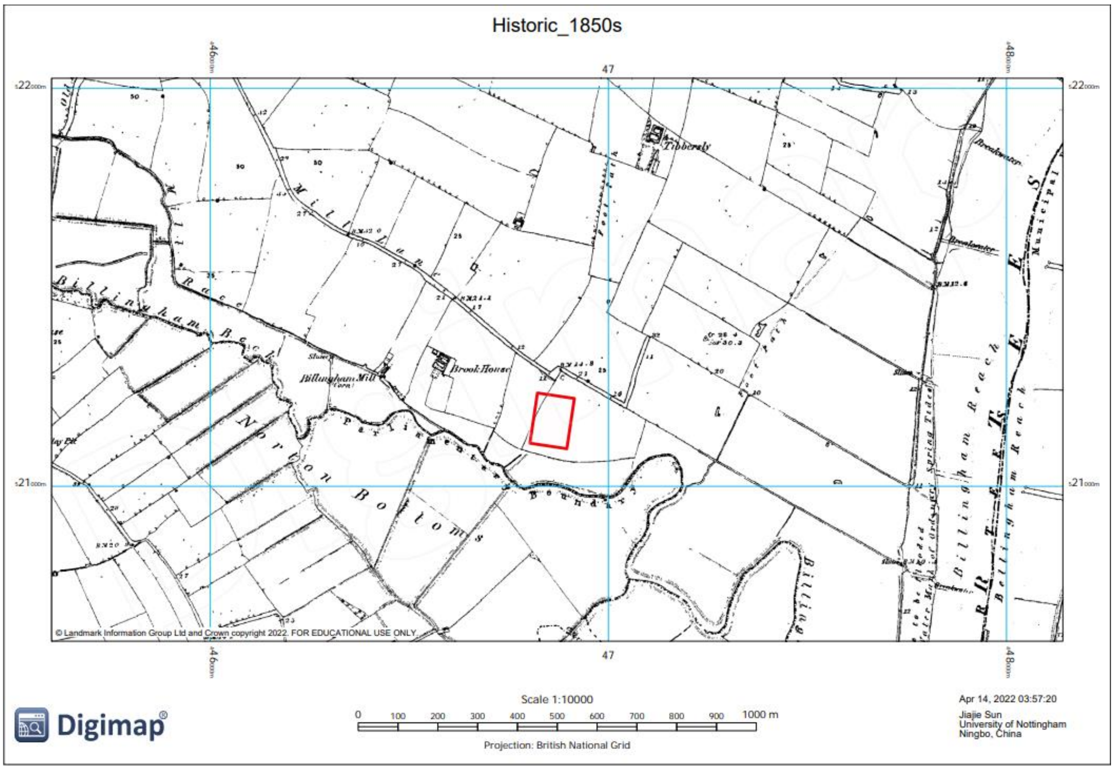
The selected site locates in an industrial zoning which has been used for chemical industries since 1917. The ground foundation under the site is soft, which means that pre-treatment for the ground is needed before construction. The climate here is typical temperate marine climate. Thus, there will be high percentage of rainy day and relatively low temperature difference, which is not conductive to pollution diffusion. There is no flooding risk in the site, but the potential flooding area is quite close to the site. Both exhaust gas and wastewater are well treated in the designed project, producing very low environmental burden (Atmospheric acidification burden per unit value added 0.000013 te/ £ , Global warming burden per unit value added 0.002588 te/ £ , Photochemical ozone burden per unit value added 0.00000052 te/ £ ,

Ecotoxicity to aquatic life per unit value added 0.0000028 te/£, Eutrophication per unit value added 0.0000038 te/£). All emissions fulfil the regulatory emission standard (Environmental Permitting (England and Wales) Regulations 2016). The annual earnings before tax (EBT) can be 23601217 £/y. Thus, this plant is economically sustainable.

Reference

1. "Cities of Science - North East - An Explosive History". Citiesofscience.co.uk. Archived from the original on 27 September 2007. Retrieved 22 January 2022.
2. A Brief History of Billingham - Heritage Stockton, 19 March 2019
3. Weather Spark
   Available at: https://weatherspark.com/y/42252/Average-Weather-in-Billingham-United-Kingdom-Year-Round#Figures-WindDirection
4. Environmental Permitting (England & Wales) Regulations 2016
   Avalable at: https://www.legislation.gov.uk/

Appendix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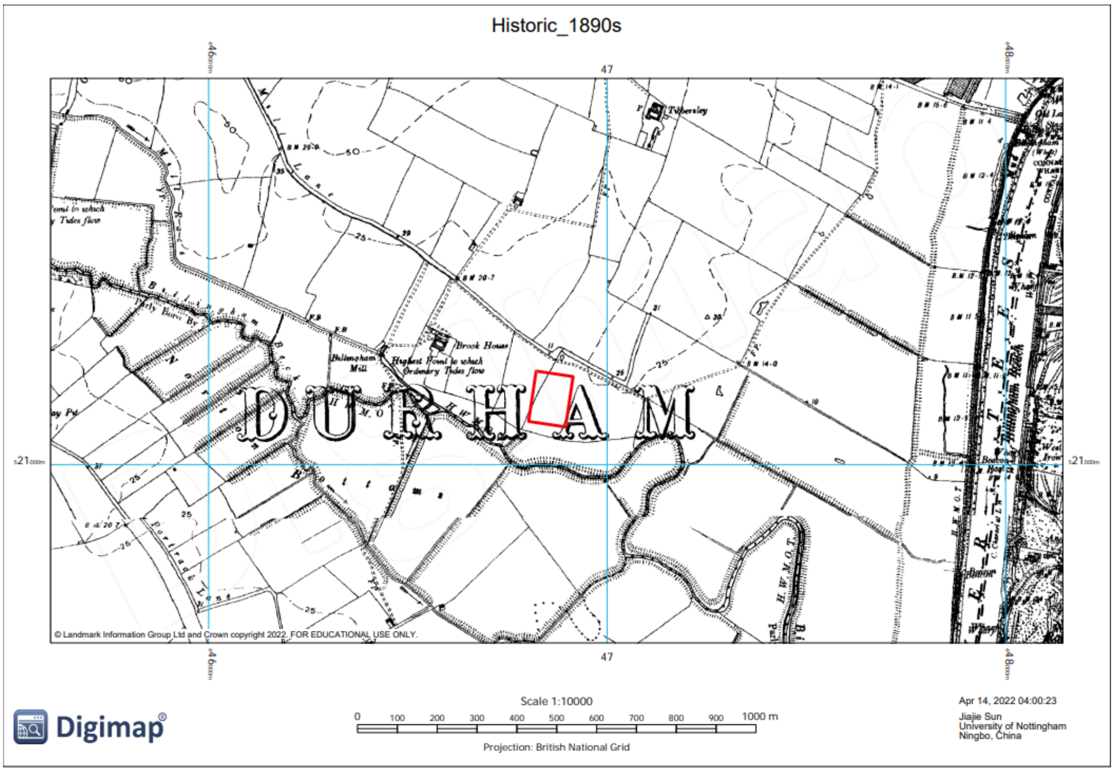
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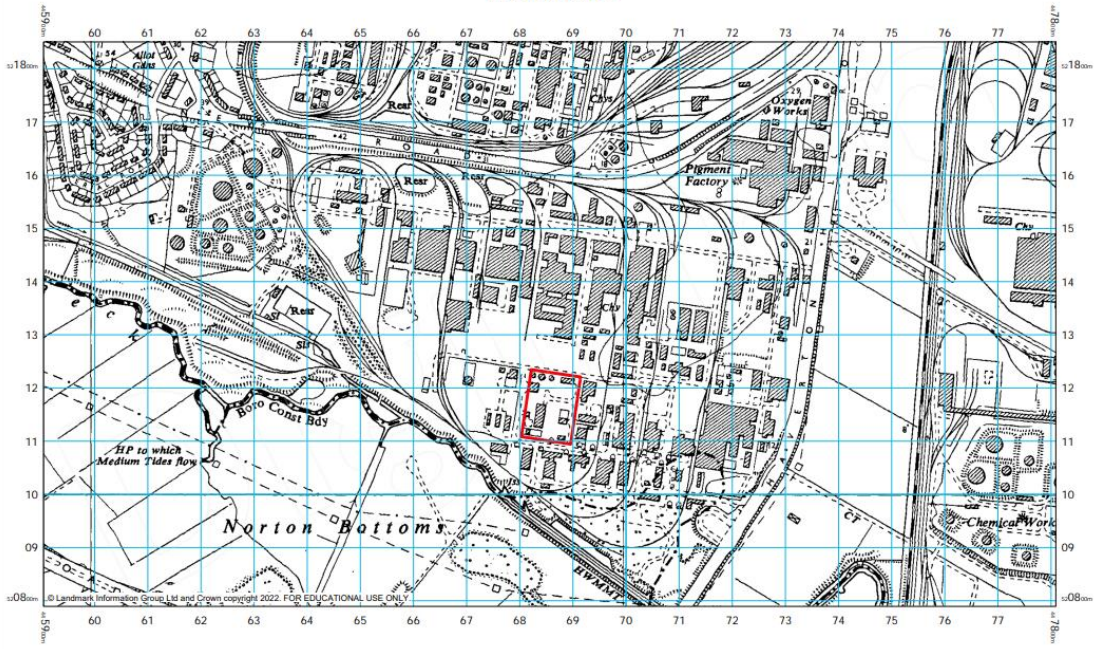

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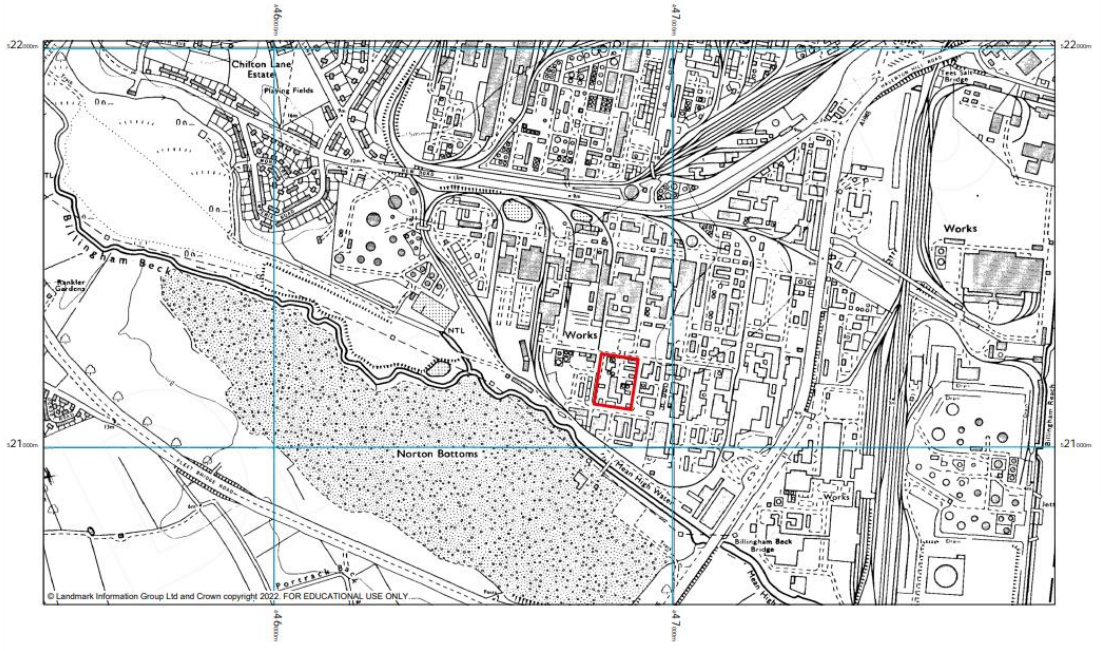

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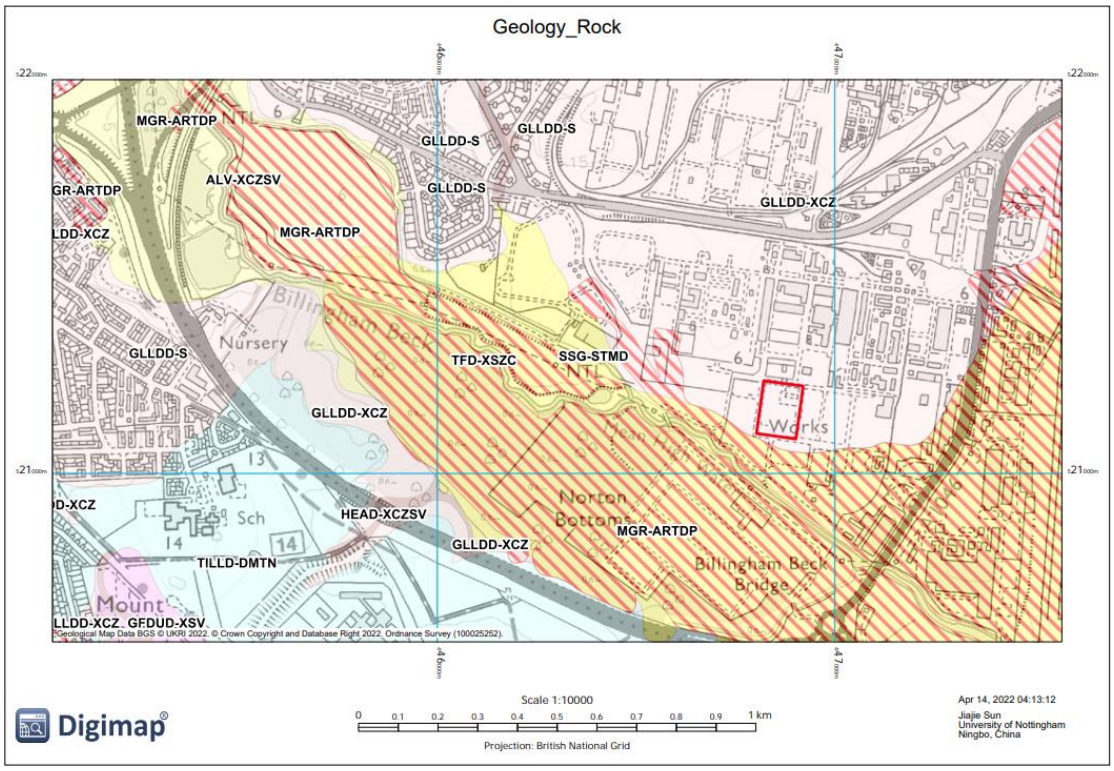
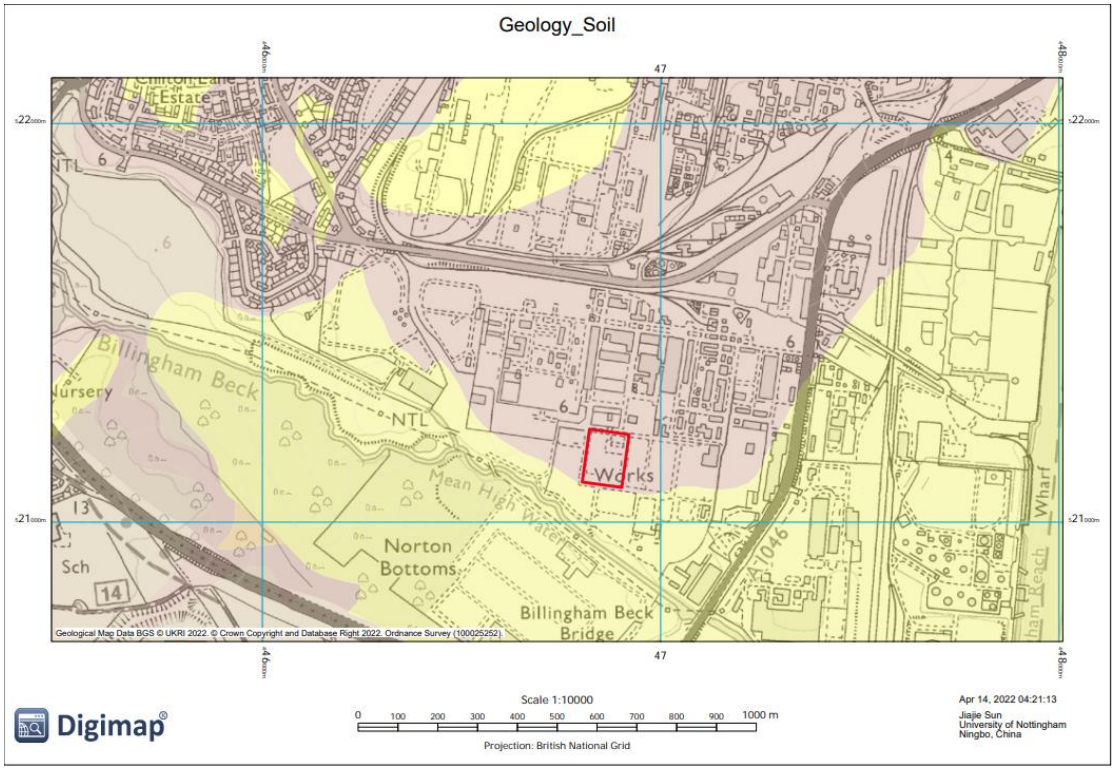
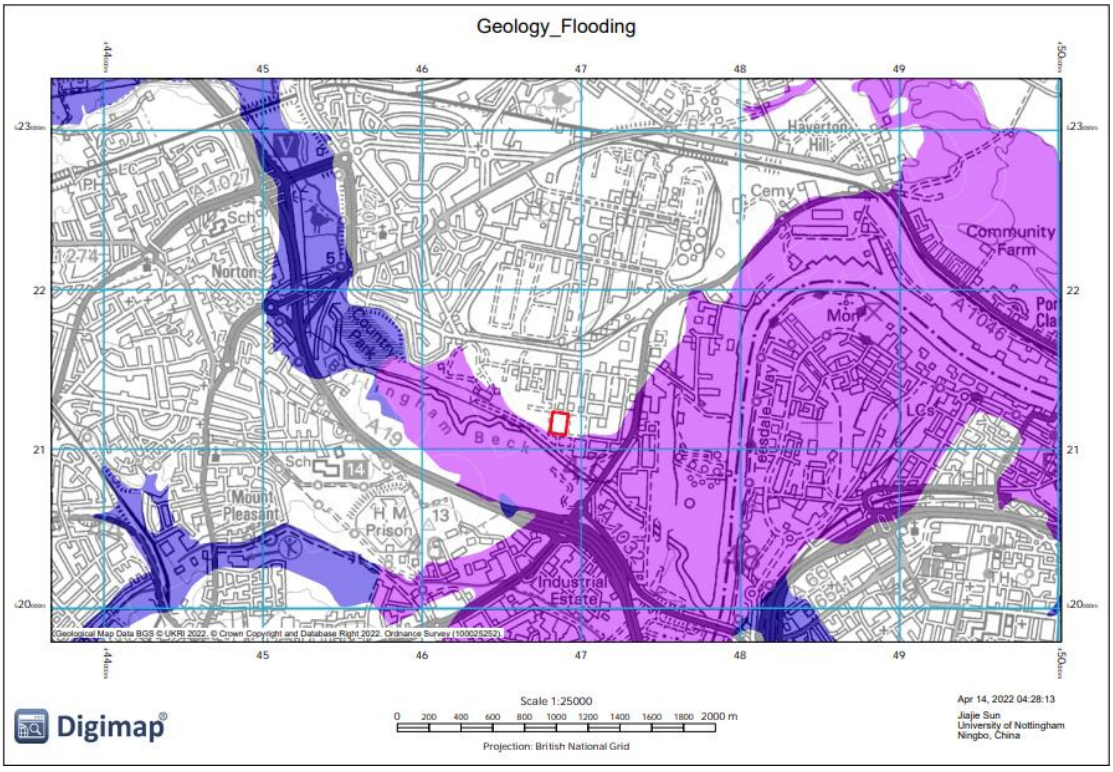


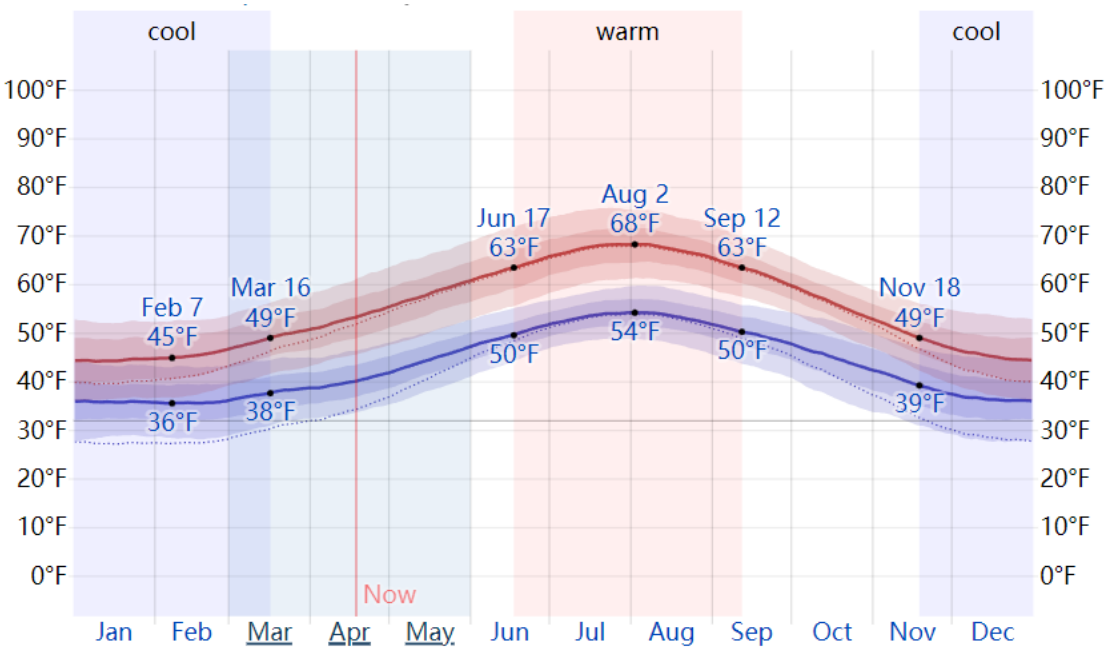
Bedrock	
Sherwood Sandstone Group - Sandstone And Mudstone(SSG-STMD)	
Mercia Mudstone Group - Mudstone, Siltstone And Sandstone(MMG-MDSS)	
Superficial Deposits	
Tidal Flat Deposits - Sand, Silt And Clay(TFD-XSZC)	
Head - Clay, Silt, Sand And Gravel(HEAD-XCZSV)	
Till, Devensian - Diamicton(TILLD-DMTN)	
Glaciolacustrine Deposits, Devensian - Sand(GLLDD-S)	
Glaciofluvial Deposits, Devensian - Sand And Gravel(GFDUD-XSV)	
Glaciolacustrine Deposits, Devensian - Clay And Silt(GLLDD-XCZ)	
Alluvium - Clay, Silt, Sand And Gravel(ALV-XCZSV)	
Artificial Ground	
Made Ground (Undivided) - Artificial Deposit(MGR-ARTDP)	



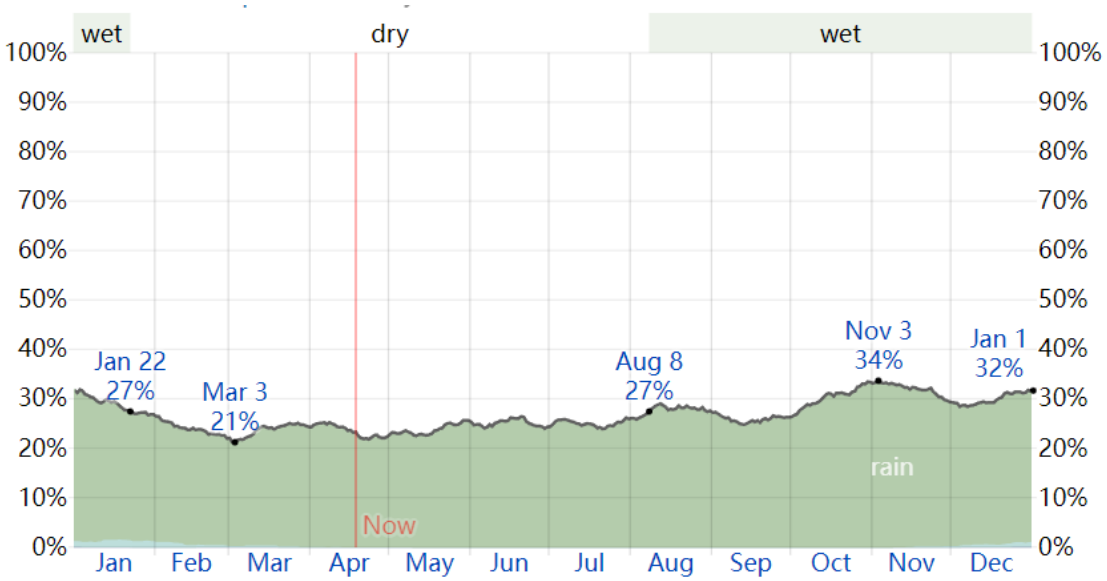
Loam > Clayey Loam	
Loam > Clayey Loam, Locally Chalk	
Loam > Sandy Loam	



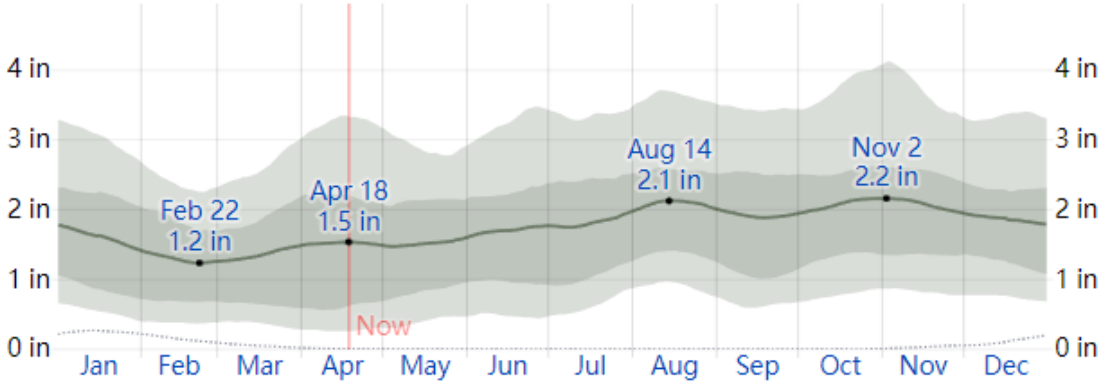
Coastal	
Higher flood potential from the sea	
Lower flood potential from the sea	
Fluvial	
Higher flood potential from rivers	
Lower flood potential from rivers	



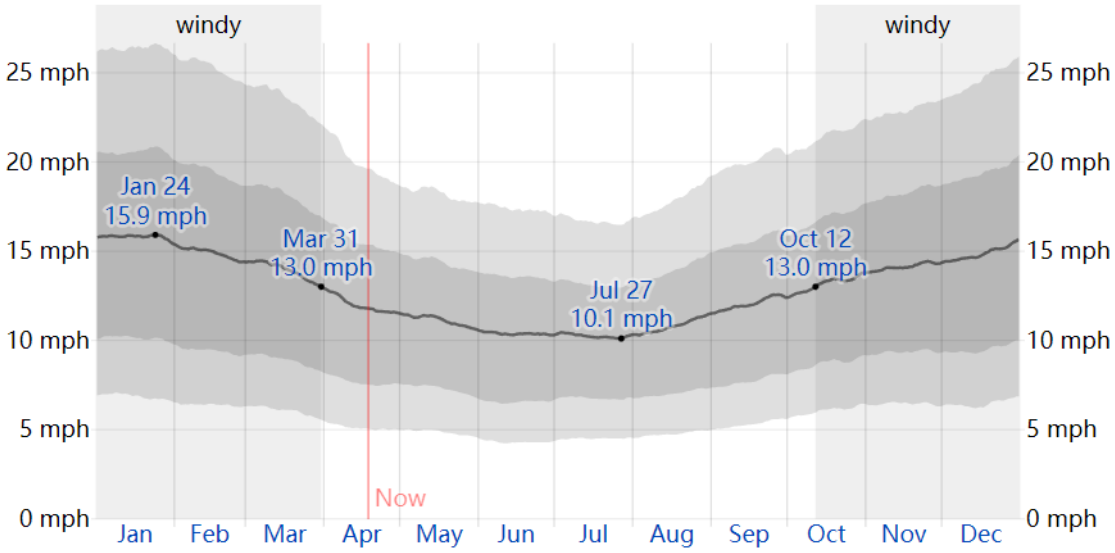
The daily average high (red line) and low (blue line) temperature, with 25th to 75th and 10th to 90th percentile bands. The thin dotted lines are the corresponding average perceived temperatures.



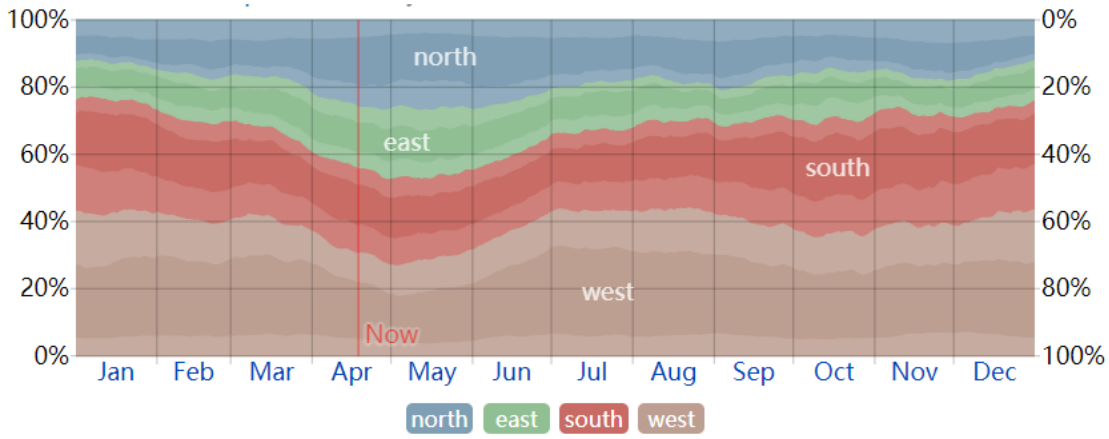
The percentage of days in which various types of precipitation are observed, excluding trace quantities: rain alone, snow alone, and mixed (both rain and snow fell in the same day).



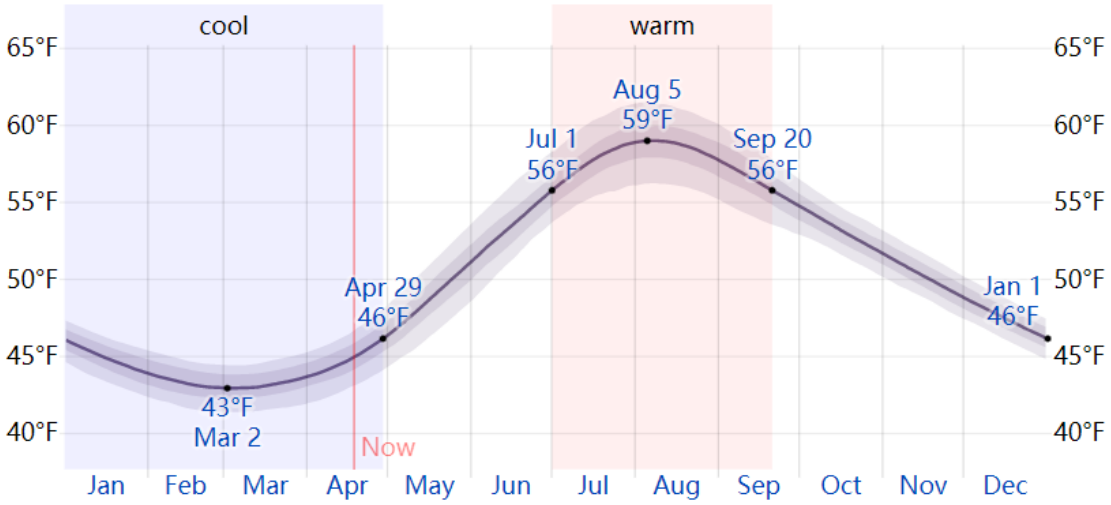
The average rainfall (solid line) accumulated over the course of a sliding 31-day period centered on the day in question, with 25th to 75th and 10th to 90th percentile bands. The thin dotted line is the corresponding average snowfall.



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.



The percentage of hours in which the mean wind direction is from each of the four cardinal wind directions, excluding hours in which the mean wind speed is less than 1.0 mph. The lightly tinted areas at the boundaries are the percentage of hours spent in the implied intermediate directions (northeast, southeast, southwest, and northwest).



The daily average water temperature (purple line), with 25th to 75th and 10th to 90th percentile bands.