HISTORIC ENGLAND

KASSANDRA

IRONBRIDGE GORGE WHS
Pilot Study

HISTORIC ENGLAND RESEARCH REPORT 80/2022

1.0 | EXECUTIVE SUMMARY

Climate change has become one of the most significant threats to historic sites and World Heritage properties, including their integrity, authenticity, and their potential for economic and social development at the local level.

The Ironbridge Gorge WHS site was chosen as a good example to demonstrate, with an evidence-based pilot study, the connection between the future changes that are likely to affect the overall resilience of the community, the heritage assets, to be able to see the distribution of impacts these changes might have.

This report concludes the Pilot Study conducted by Kassandra of the Ironbridge Gorge World Heritage site on behalf of Historic England and brings together the exploration work and analysis of resilience to climate change carried out so far.

The aim of the Pilot Study is not to provide definitive answers, but to showcase an application of the Kassandra IDSS (Integrated Decision Support System) methodology in developing a climate change resilience model and associated decision support tools for historic places, cities and landscapes. Indeed, being a Pilot Study, there have been limitations in scope, available data and the extent of the analysis carried out, which are illustrated in detail in the following paragraphs.

Kassandra is a multidisciplinary Integrated Decision Support System that facilitates the management of climate resilience in urban or natural environment and the improvement of quality of life of its human and non-human inhabitants.

Kassandra's methodology is based on the creation a Digital Twin of the asset – based on Building Information Modelling technology – that uses analysis and simulation tools that take a long-term and whole-system view of an environment. The analysis - based on twelve parameters, hundreds of sub-parameters and thousands of relationships between these parameters - identifies a Resilience Index of the entire study area and of individual elements within it.

The output of a Kassandra study is a parametric digital twin of the study area, which shows all in one place all the data collected so far, the existing resilience to climate change of the overall site and individual items and a number of scenarios that highlight different vulnerabilities and adaptive pathways to increase the Resilience Index.

No simulation scenarios were carried out as part of this study due to the level of data provided. A description of the scenario process is included in the relevant sections and reccomendations for the way forward and possible further stages is included in the conclusion of this document.

2.0 | CONTENTS

3.0 | INTRODUCTION

3.1 The Wider Context

Many of the impacts of global warming are now simply *"irreversible"* according to the UN's latest assessment. Recently, the Intergovernmental Panel on Climate Change report from February 2022 says that humans and nature are being pushed beyond their abilities to adapt. The new study stated, however, that there is still a brief window of time to avoid the very worst.

Climate change has also become one of the most significant threats to historic sites and World Heritage properties, including to their integrity and authenticity, and to their potential for economic and social development at the local level. According to UNESCO, however, *"World Heritage properties also harbour options for society to mitigate and adapt to climate change through the ecosystem benefits... Cultural heritage can convey traditional knowledge that builds resilience for change to come and leads us to a more sustainable future."* *
Urgent adaptation pathways, based on the fullest possible available data, are therefore essential if the special significance of these sites is to be maintained and if possible enhanced.

3.2 The Mitigation approaches

Various approaches are currently being developed to identify the risk to these sites and provide methodologies for decision making processes to manage the required short term and long-term adaptations. Too often, however, these tools are either limited in scope (looking only at a limited number of parameters), or with based on lower degrees of geographical accuracy, or of limited use as the information cannot be easily visualised and communicated.
Current technology does allows us to collect, manage and analyse huge quantities of very diverse information but the challenge is how to interpret this multidisciplinary data in an easily understandable way, so that it may be of use to decision-makers and the community as a whole.

3.3 The Kassandra approach

This, in essence, is what Kassandra does; Kassandra brings together Digital Twin technology (a virtual 3D model designed to accurately reflect a physical object) with a relational database (to collect and relate different types of information in one place). Via data analysis and simulations Kassandra allows for, amongst other, the clear visualization of existing and future climate resilience levels based on parametric algorithms. It is important to note shifting the focus from risk to resilience as a benchmark allows Kassandra to breakdown the huge challenges of climate change into locally manageable tasks and provide a shared view of the risk landscape that a site faces.

Kassandra has not only already completed a study for a UNESCO World Heritage Site in Modica, Italy - which was presented as an innovative approach at the XXI Architecture Biennale in Venice in 2021 - but has already proven to be a tool that is both scalable and felxible. Indeed, other recent and current projects include studies for the governments of Dominica and Grenada (together with the University of Portsmouth), for the A4 motorway network in Northern Italy, at the historic site of Mount Stewart for the National Trust in Northern Ireland and, most recently, for various local councils in Italy.

3.4 The Irobridge Gorge World Heritage Site

The Ironbridge Gorge WHS site was chosen as a good example to demonstrate, with an evidence-based pilot study, the connection between the future changes that are likely to affect the overall resilience of the community, the heritage assets, to be able to see the distribution of impacts these changes might have.

The study has seen the contribution of various stakeholders, for which we are grateful, starting from Historic England who has commissioned this study, the Ironbridge Gorge WHS Steering Group, Telford Council, the Severn Gorge Trust, Shropshire Council and the Environment Agency.

As a Pilot Study, there have been limitations in scope and the analysis carried out, which are illustrated in the following paragraphs. Nevertheless, the study has provided some interesting and useful preliminary results, which, with a wider scope and more in-depth analysis, could provide a solid basis for the management of climate change and other aspects, across the WH site and beyond.

*(extract from "Climate Change and World Heritage"; https://whc.unesco.org/en/climatechange)

4.0 | SETTING THE SCENE

RESILIENCE:

"the capacity of individuals, communities, institutions, businesses, and systems within a city to **survive, adapt, and grow** no matter what kinds of chronic stresses and acute shocks they experience"

100 resilient cities

CLIMATE CHANGE

A LONG-TERM CHANGE IN THE AVERAGE WEATHER PATTERNS THAT HAVE AFFECT EARTH'S LOCAL, REGIONAL AND GLOBAL CLIMATES

Earth's **temperature has risen by 0.08° C per decade** since 1880, and the rate of warming over the past 40 years is more than twice that.

According to UNDRR, in the period 2000 to 2019 there was a sharp increase of **extreme weather events claiming 1.23 million lives**, affecting 4.2 billion people (many on more than one occasion) resulting in approximately US$2.97 trillion in global economic losses

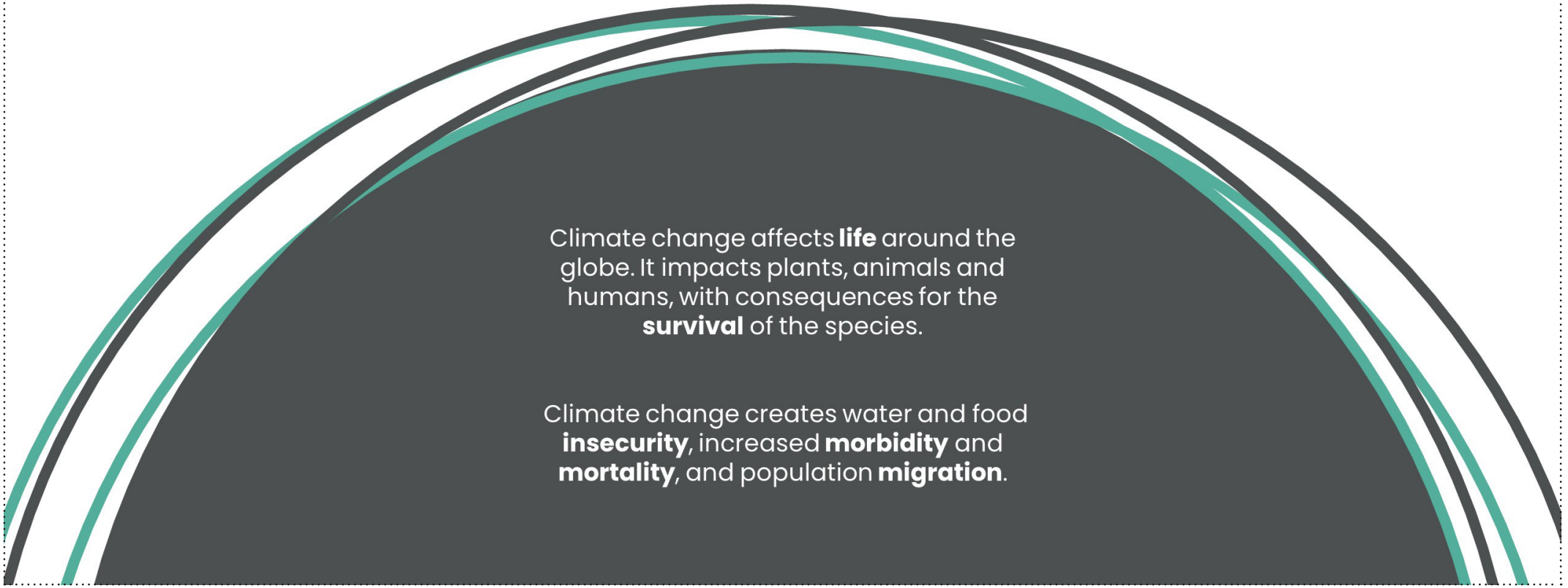
Today, 55% of the world's population lives in urban areas, a proportion that is expected to **increase to 68% by 2050**.

According to UN Habitat, cities consume **78% of the world's energy** and produce more than **60% of greenhouse gas emissions**. 70 percent of cities are already dealing with the effects of climate change, and almost all are at risk.

As stated by the World Economic Forum "the imperative for urban disaster risk reduction squarely in the hands of municipal planners, politicians and the urban community at large." **Increasing resilience is essential**.

QUALITY OF LIFE AT RISK

FROM THE EFFECTS OF CLIMATE CHANGE AND LACK OF COORDINATED ACTION



Climate change affects **life** around the globe. It impacts plants, animals and humans, with consequences for the **survival** of the species.

Climate change creates water and food **insecurity**, increased **morbidity** and **mortality**, and population **migration**.

NEGATIVE DOMINO EFFECT

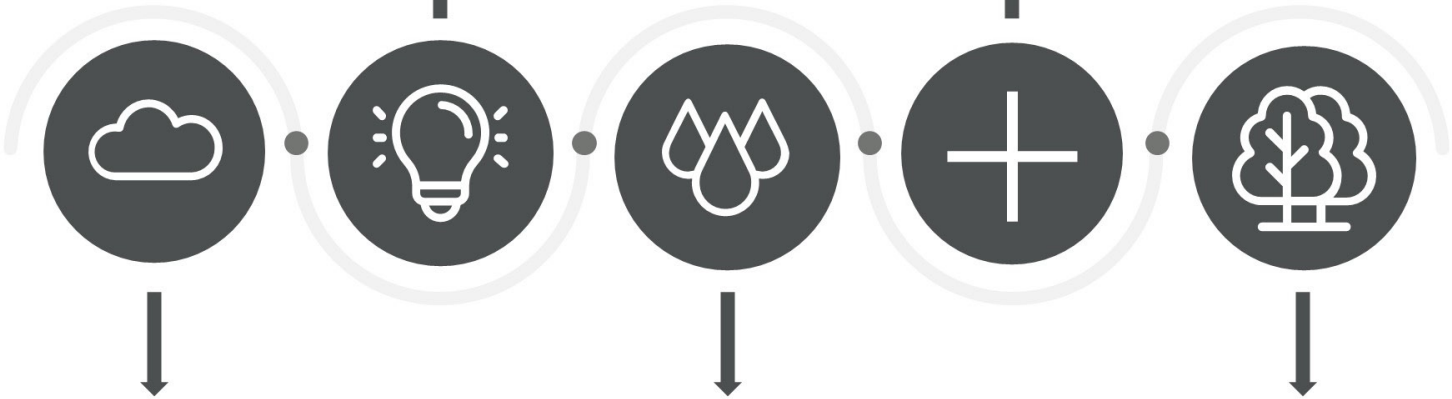
OF CLIMATE CHANGE CRISIS

ENERGY

Higher temperatures exponentially increases the energy consumption of cooling buildings

HEALTH

Climate change impacts health in a myriad of ways, diseases including zoonosis, disruption of food systems, mental health issues.



AIR

Approximately seven million premature deaths annually are due to air pollution, about four million of which are due to ambient air pollution.

WATER

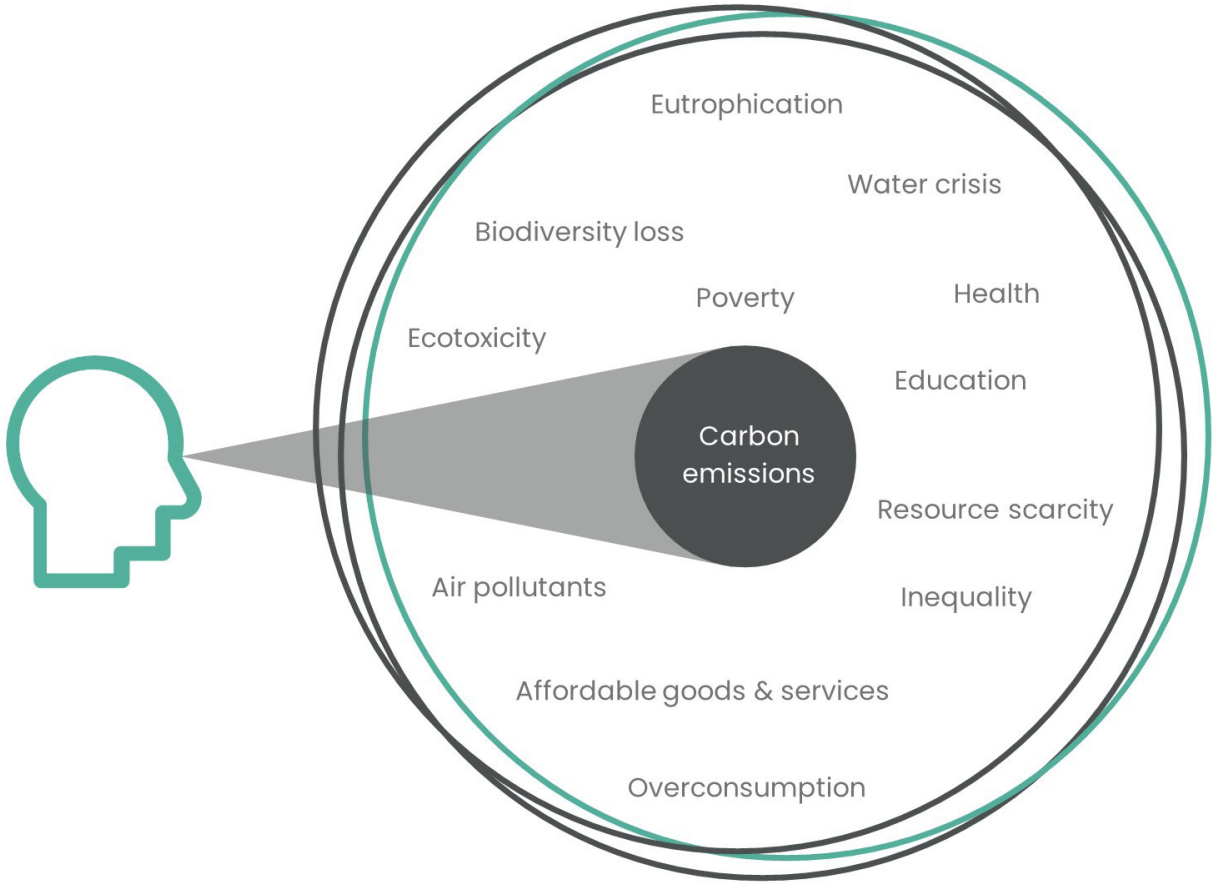
Warmer weather causes more water to evaporate, allowing the air to hold more water leading to heavier rainfall and flooding, decreasing the quantity and quality of drinking water.

ENVIRONMENT

Climate change destroys the habitats of flora and fauna across the globe and reduces biodiversity.

TUNNEL VISION

…IS LIMITING EFFECTIVENESS OF DECISIONS…



EVERYTHING IS CONNECTED

THEREFORE A MULTIDISCIPLINARY VIEW IS NEEDED

WHAT IS KASSANDRA?

And how can it help cities manage climate change?

Kassandra is the first multidisciplinary **Integrated Decision Support System** that facilitates the management of a truly **resilient smart city** and the improvement of **quality of life** of its, human and non-human, inhabitants

WHY IS KASSANDRA UNIQUE?

KASSANDRA IS THE ONLY MULTIDISCIPLINARY AND FULLY COMPREHENSIVE IDSS

ACCURACY

It is the only IDSS that reaches high levels of geographical accuracy.

VISIBILITY

It is the first IDSS capable of measuring and visualizing positive actions by an individual and at the same time of an entire community.

MULTIDISCIPLINARITY

Kassandra is the only multidisciplinary and fully comprehensive IDSS

PRIORITIZATION

It is the only system that allows for the prioritization of economic investments in areas where they will have a greatest impact on climate resilience.

QUALITY OF LIFE

It is the only IDSS directly linked to accepted Quality-of-Life indexes.

HOW DOES KASSANDRA WORK?

KASSANDRA IS A FLEXIBLE AND ADAPTABLE INTEGRATED DECISION SUPPORT SYSTEM

Kassandra creates a **digital twin** of the asset – based on Building Information Modelling technology – that uses **analysis and simulation** tools that take a long-term and whole-system view of an environment.

The analysis of Kassandra is based on **twelve parameters**, over one thousand hundred sub-parameters and the thousands of relationships between these parameters.

HOW DOES KASSANDRA WORK?

KASSANDRA CREATES A DIGITAL TWIN OF THE REAL WORLD MADE UP OF:

LITOSPHERE

Mountains, hills, plains, plateaus, valleys

ATMOSPHERE

Toposphere, stratosphere, mesosphere, thermosphere

HYDROSPHERE

Oceans, lakes, ponds, rivers, streams, glaciers, groundwater

BIOSPHERE

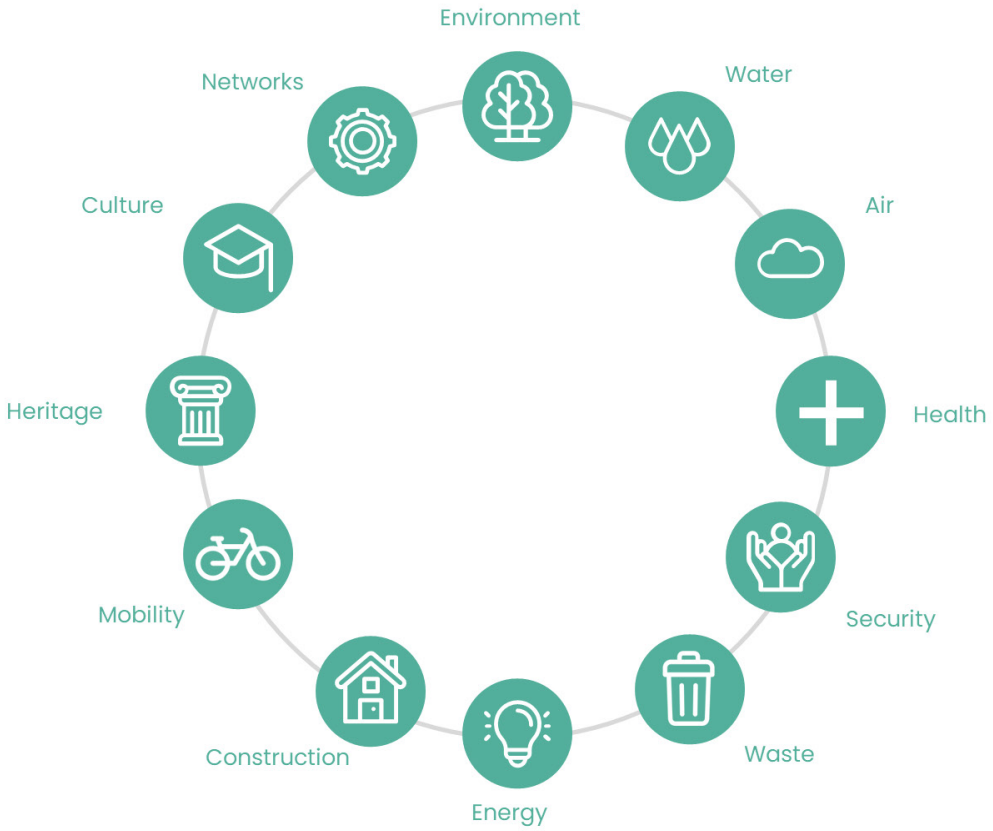
Flora, fauna, fungi, bacteria, viruses

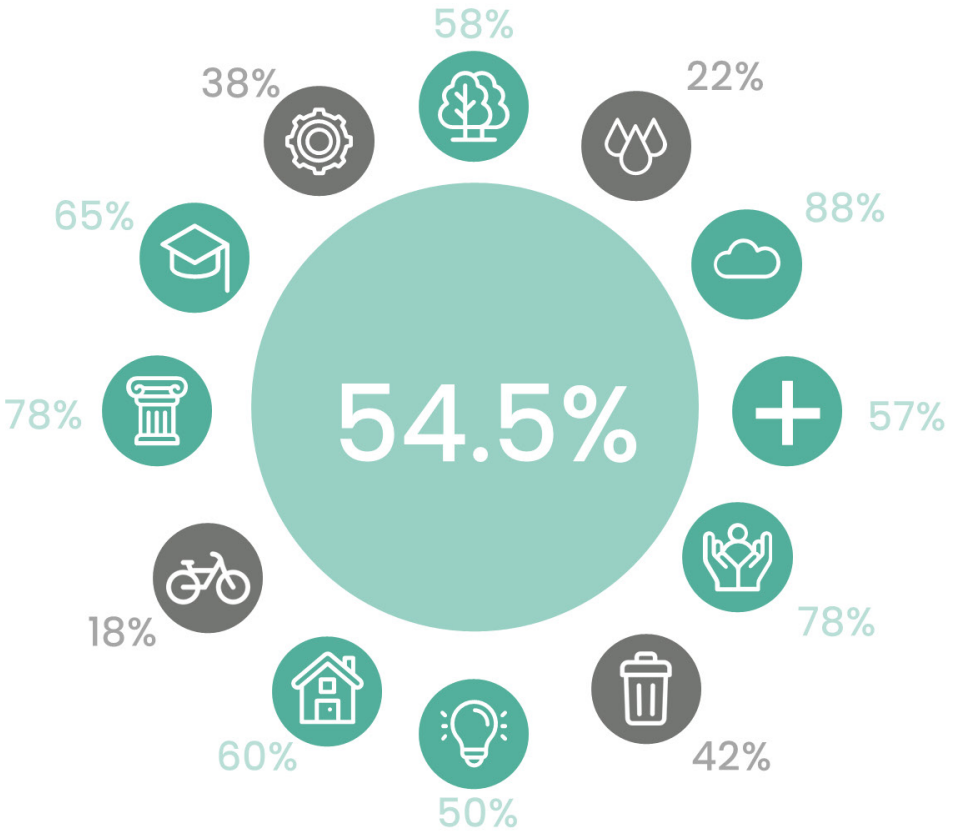
ANTHROPOSPHERE

Buildings, infrastructure, machines

HOW DOES KASSANDRA WORK?

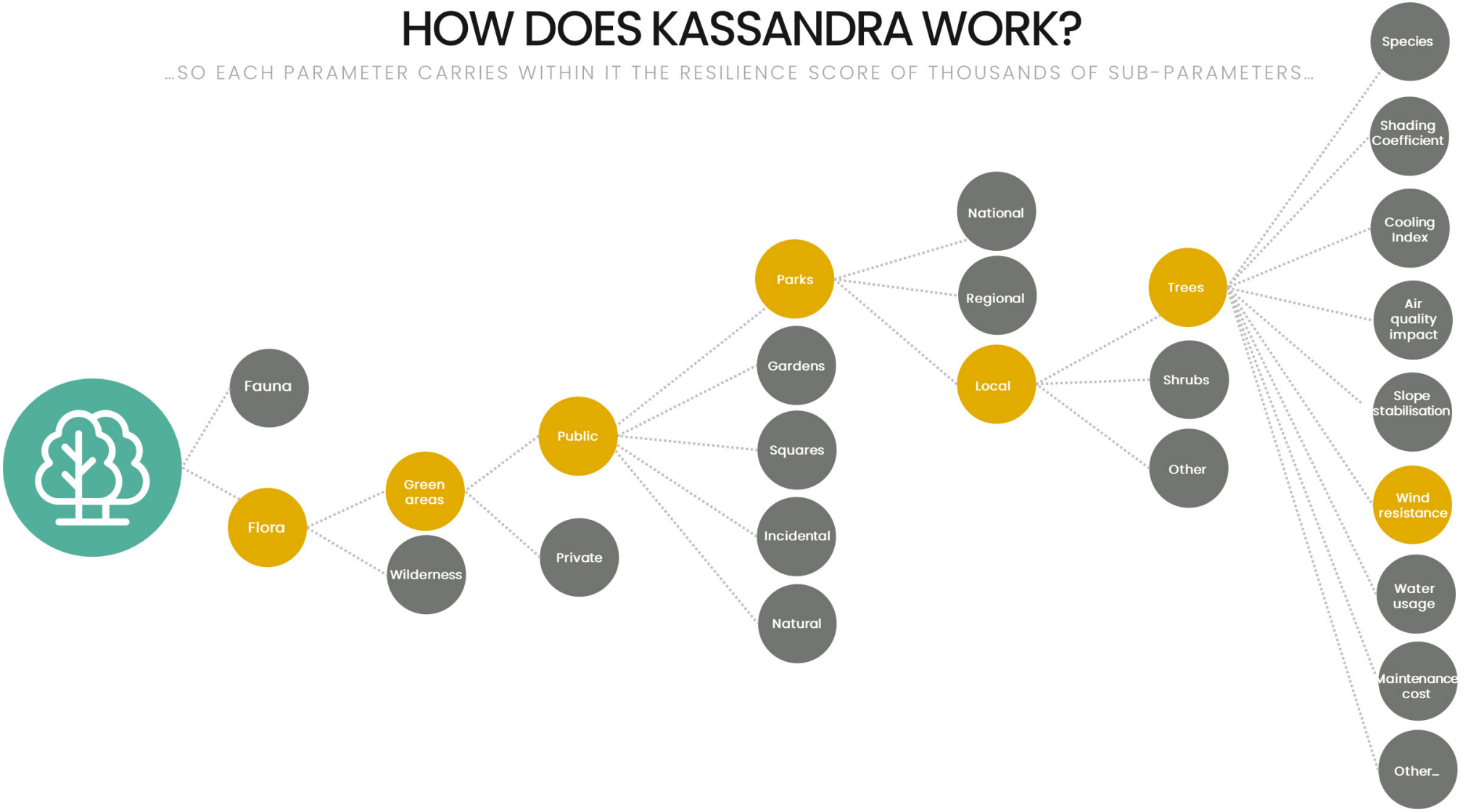
…EVERY ELEMENT AND PARAMETER IS GIVEN A RESILIENCE SCORE…





HOW DOES KASSANDRA WORK?

…SO EACH PARAMETER CARRIES WITHIN IT THE RESILIENCE SCORE OF THOUSANDS OF SUB-PARAMETERS…



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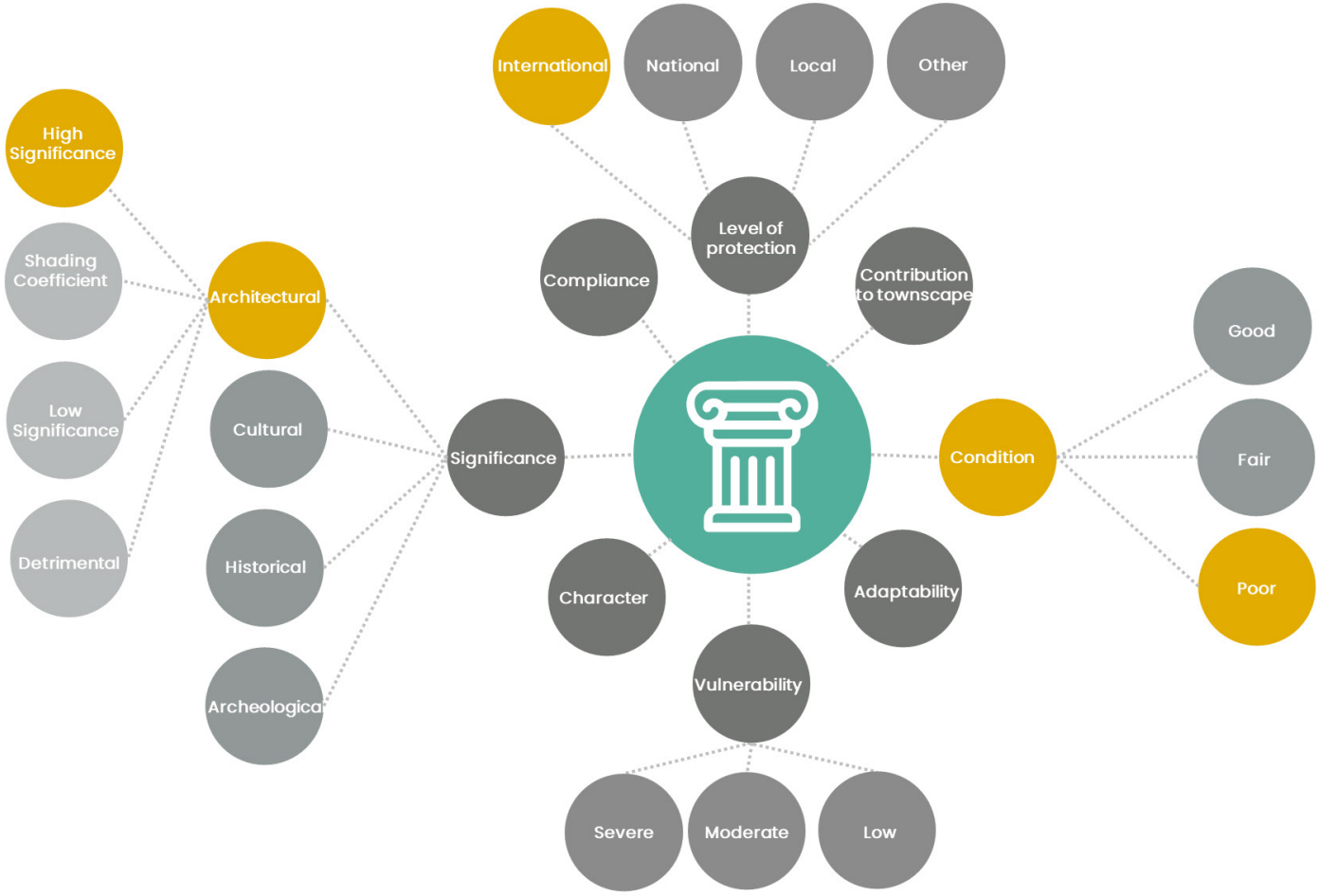
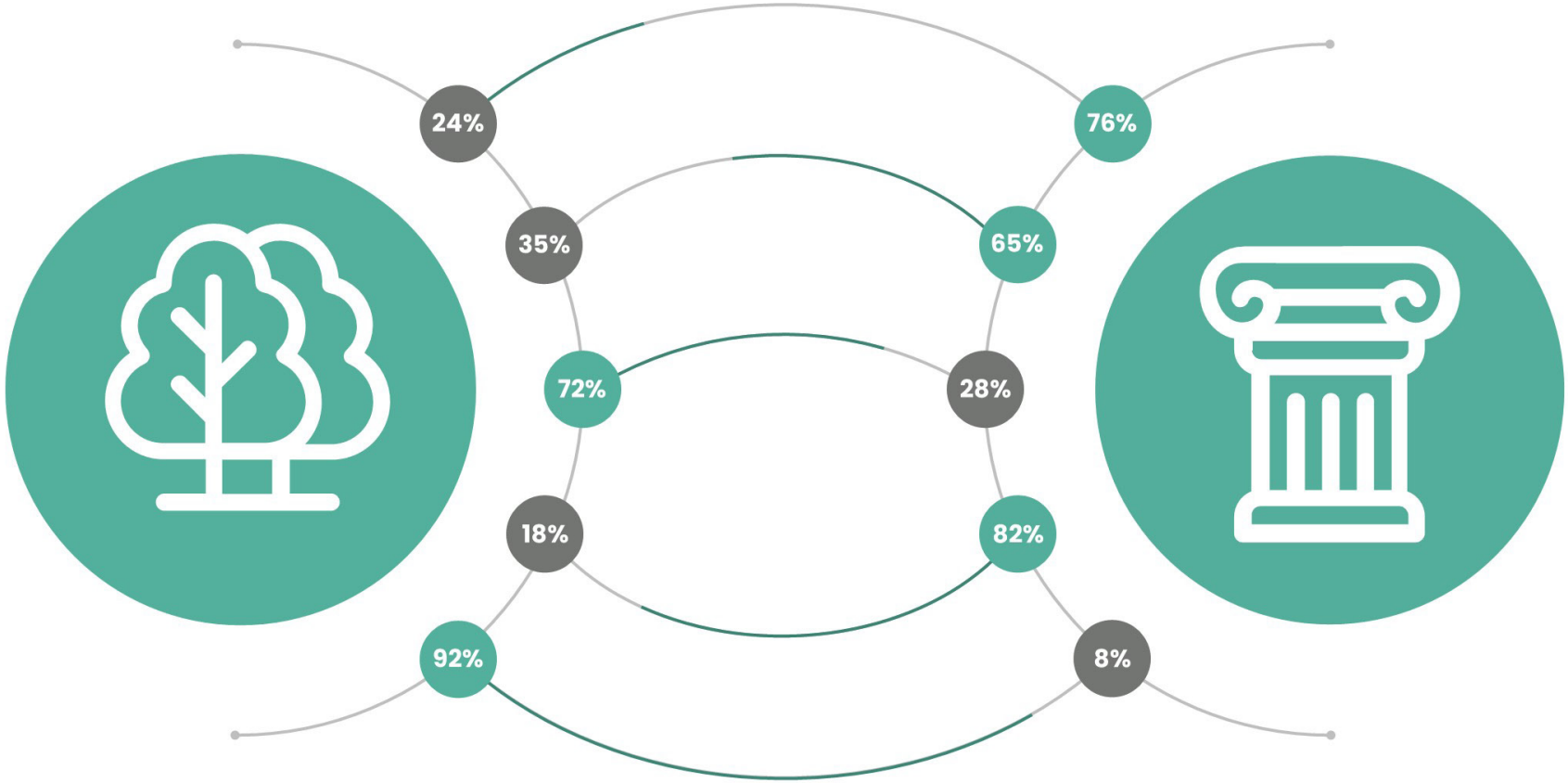


RELATIONAL APPROACH

KASSANDRA CONSIDERS THE RELATION BETWEEN PARAMETERS AND HOW THIS INFLUENCES THE RESILIENCE SCORE



POSITIVE DOMINO EFFECT

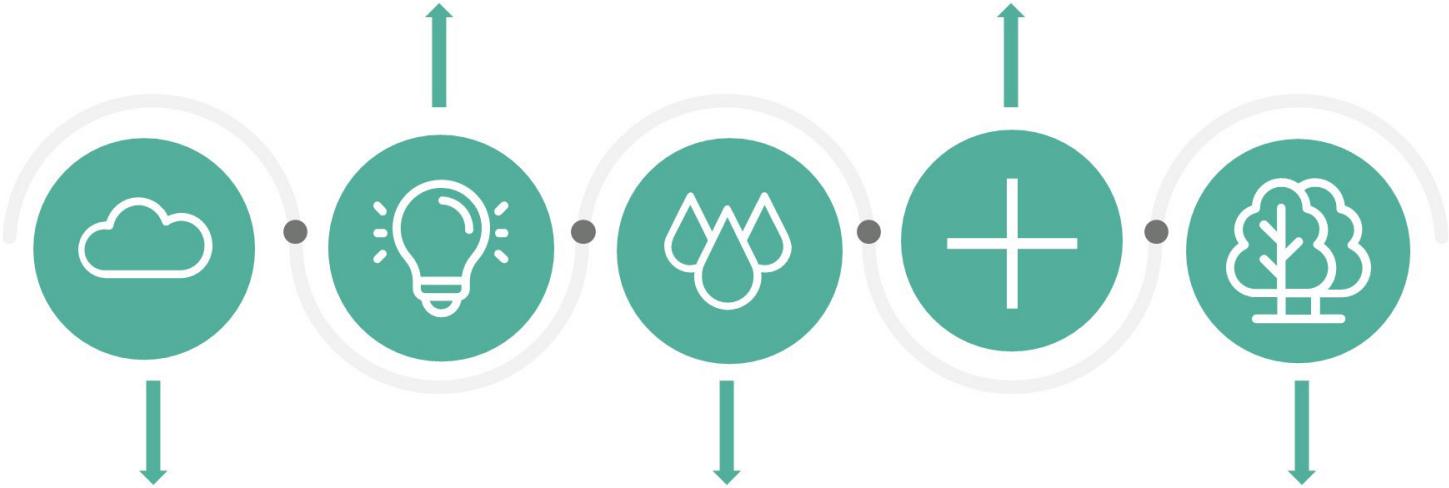
OF KASSANDRA APPROACH

AIR

Higher temperatures exponentially increases the energy consumption of cooling buildings

WATER

Climate change impacts health in a myriad of ways, diseases including zoonosis, disruption of food systems, mental health issues.



AIR

An increase in temperatures can exacerbate the presence of pollutants

HEALTH

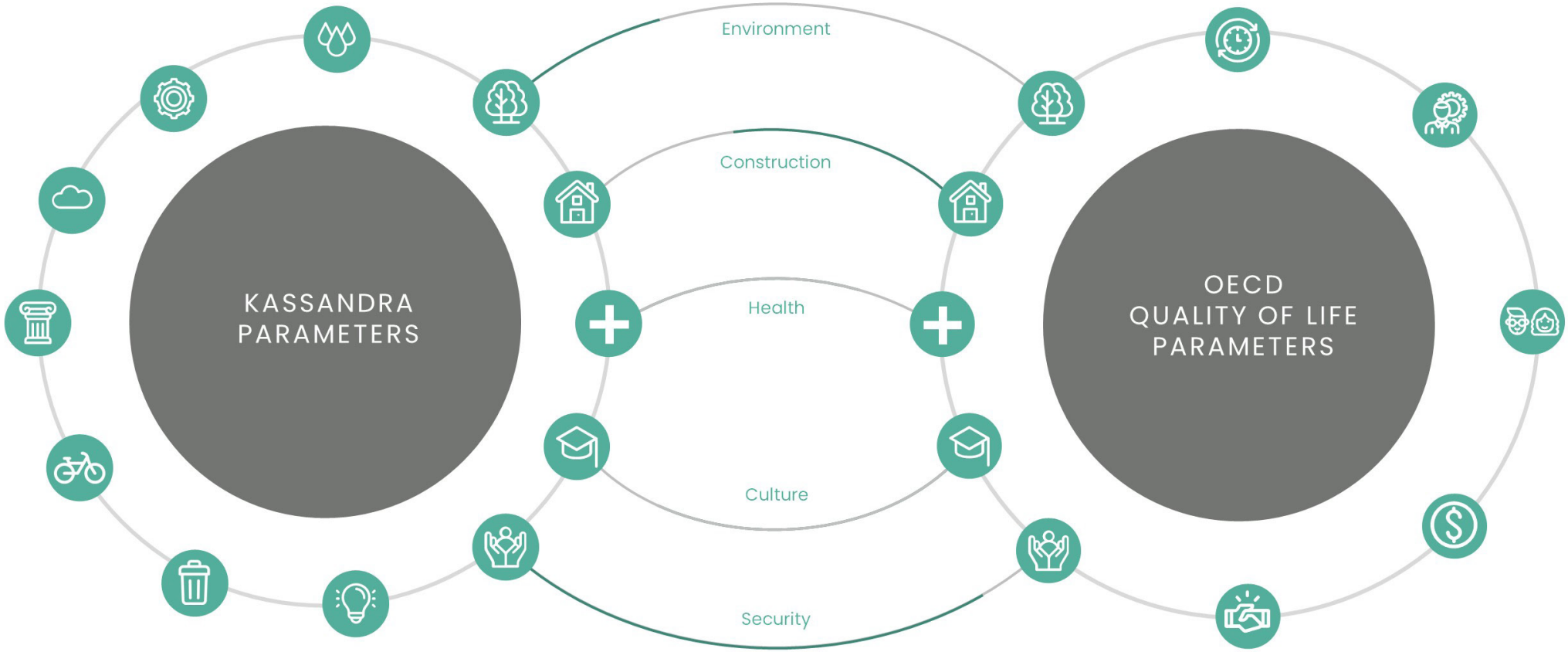
Warmer weather causes more water to evaporate, allowing the air to hold more water. Which means heavier rainfall and flooding, decreasing the quantity and quality of drinking water.

ENVIRONMENT

Climate change destroys the habitats of flora and fauna across the globe and reduces biodiversity.

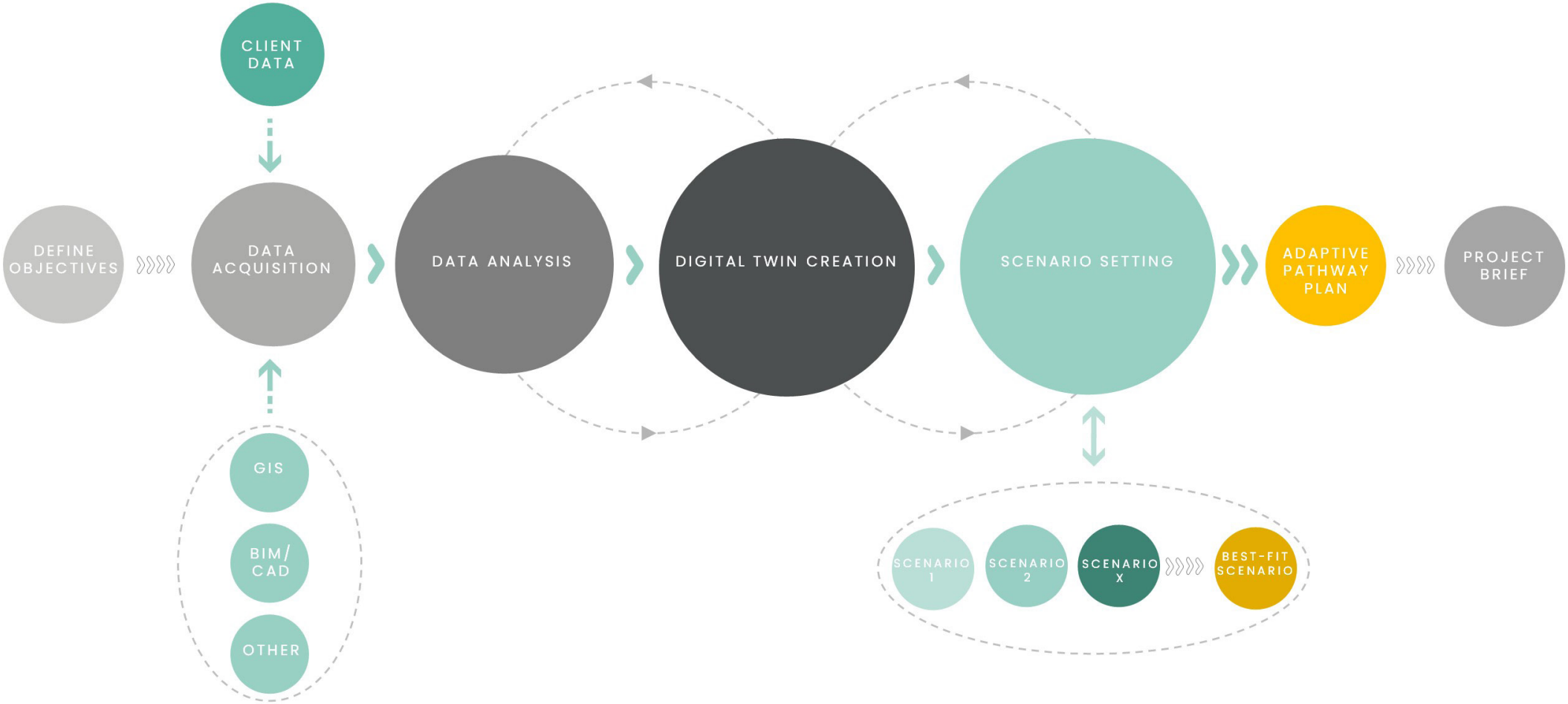
DIRECTLY IMPROVING QUALITY OF LIFE

KASSANDRA'S PARAMETERS ARE DIRECTLY LINKED TO ACCEPTED QUALITY OF LIFE INDEXES



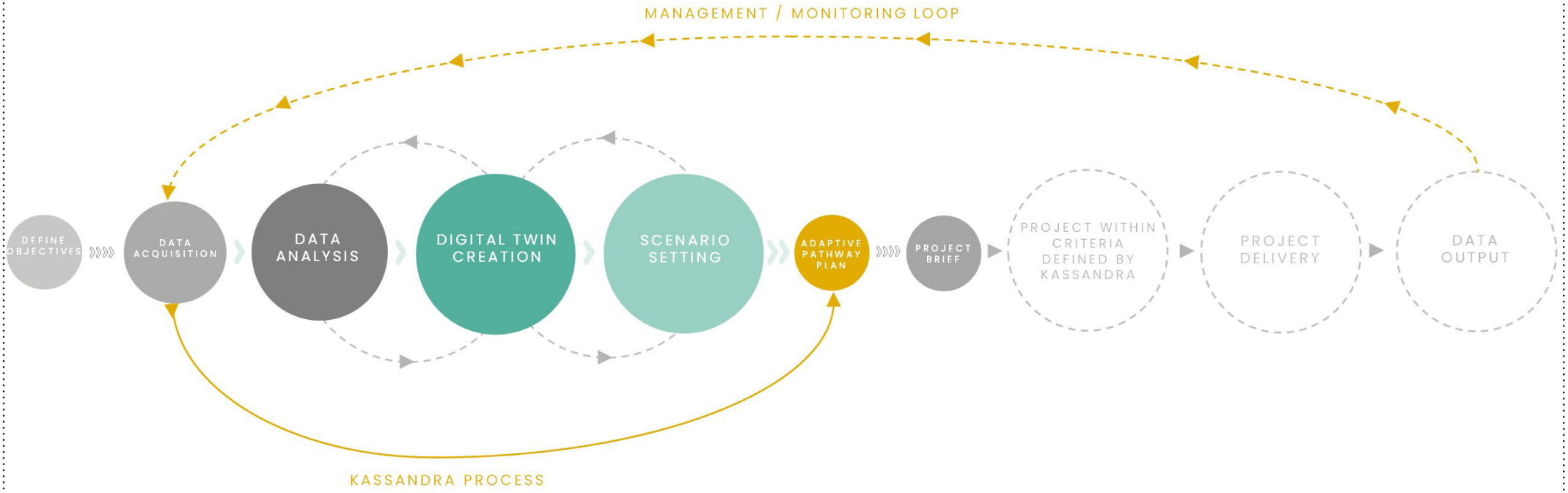
A DYNAMIC PROCESS

USING AN ITERATIVE PROCESS KASSANDRA CREATES VARIOUS SCENARIOS UNTIL AN OPTIMUM SOLUTION CAN BE IDENTIFIED



A DYNAMIC PROCESS

KASSANDRA CAN ALSO BE A MANAGEMENT TOOL COMBINED WITH SENSOR FLOWS AND ARTIFICIAL INTELLIGENCE.



7.0 | PILOT STUDY SCOPE, AIMS AND LIMITATIONS

7.1 Pilot study aims

The aim of this Pilot Study is not to provide definitive answers, but to showcase an application of the Kassandra IDSS (Integrated Decision Support System) methodology in developing a climate change resilience model and associated decision support tools for historic places, cities and landscapes.

The chosen site was the Ironbridge Gorge World Heritage Site, but the approach and application of Kassandra are far-ranging with a system that has proven to be both scalable and adaptable to provide decision support to entire estates.

The aim of the Ironbridge WHS Pilot Project is to demonstrate how Kassandra, as an Integrated Decision Support Tool, can guide and inform the stewards of heritage assets when it comes to climate change related challenges keeping the full picture always in view, as a complex and inter-related system and responding to the following requirements:

- The need to collect, collate and analyse large quantities of diverse input and output data and visualise it and communicate it in an intuitive and easily accessible way.
- The ability to simultaneously take strategic and detail decisions when faced with the need to manage change, and in this case unprecedented change brought about by Climate Change.
- The need to prioritize expenditure in areas where greater longer-term resilience is achievable.
- The need to refine decision-making processes in light of new and unprecedented challenges brought about by climate change.
- The need to identify threshold resilience levels and trigger points for decisions.

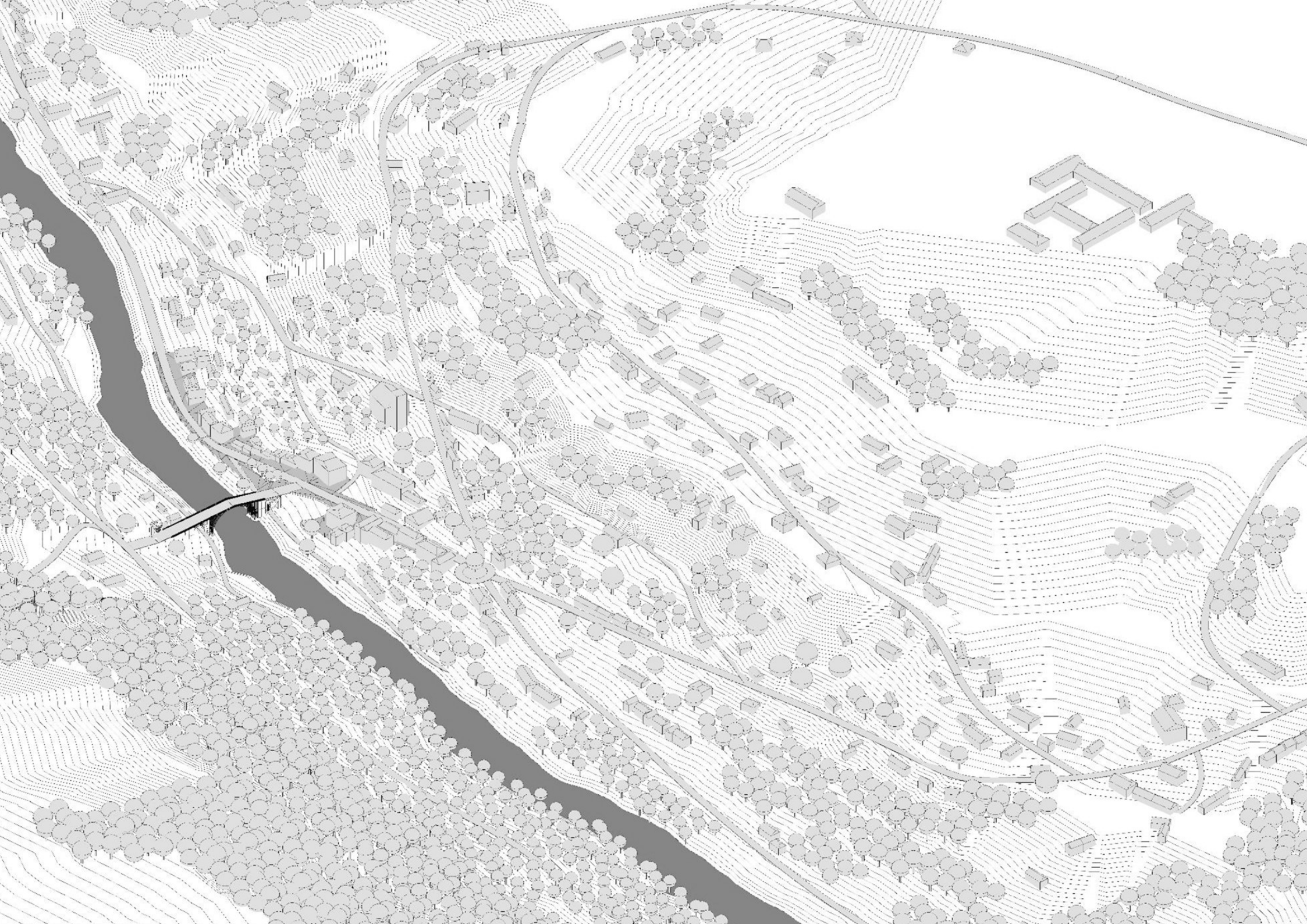
As an Integrated Decision Support system, Kassandra is conceived to address these requirements:

- It is the only multidisciplinary and fully comprehensive IDSS that reaches high levels of geographical accuracy which are essential in heritage contexts.
- Via analysis and simulation tools using parameters directly linked to accepted Quality-of-Life indexes, we are able to take a long-term and whole-system view of a historic environment and identify areas or aspect most at risk from Climate Change.
- It is the only system that allows for the prioritization of economic investments in areas where they will have a greatest impact on resilience.
- It is the only IDSS capable of measuring and visualizing positive actions by an individual and at the same time of an entire community.

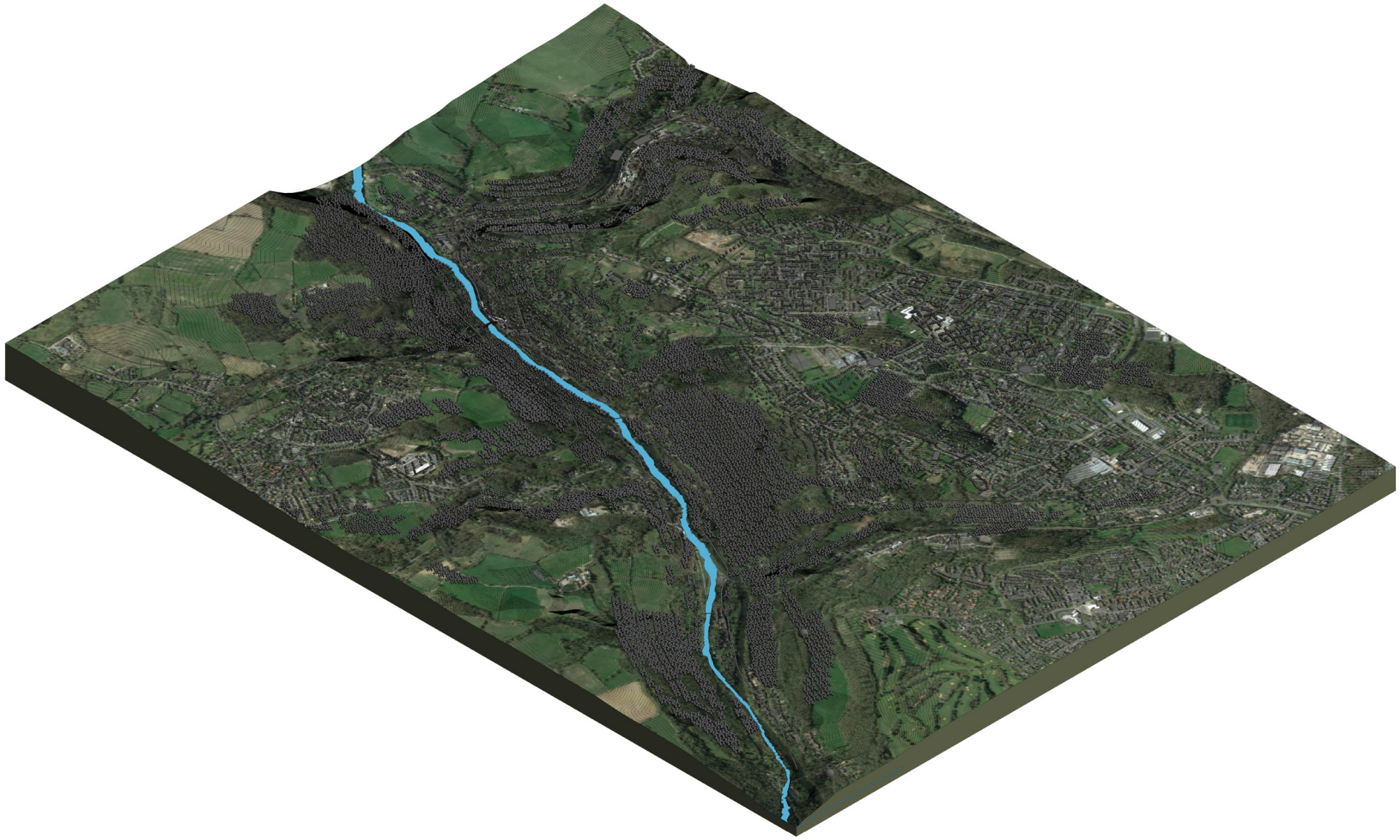
7.2 Limitations of the study

In regards to geographical limitations, whilst the boundaries of the Ironbridge Gorge World Heritage Site cover 5.5 square kilometres, we have analysed a wider area of approximately 20 square kilometres encompassing the WHS and surrounding built and not built areas, as these have an immediate effect on the overall resilience of the site itself.
For certain aspects we have looked at areas further afield as well as aspect not present within the study area, where these affect the study area directly.

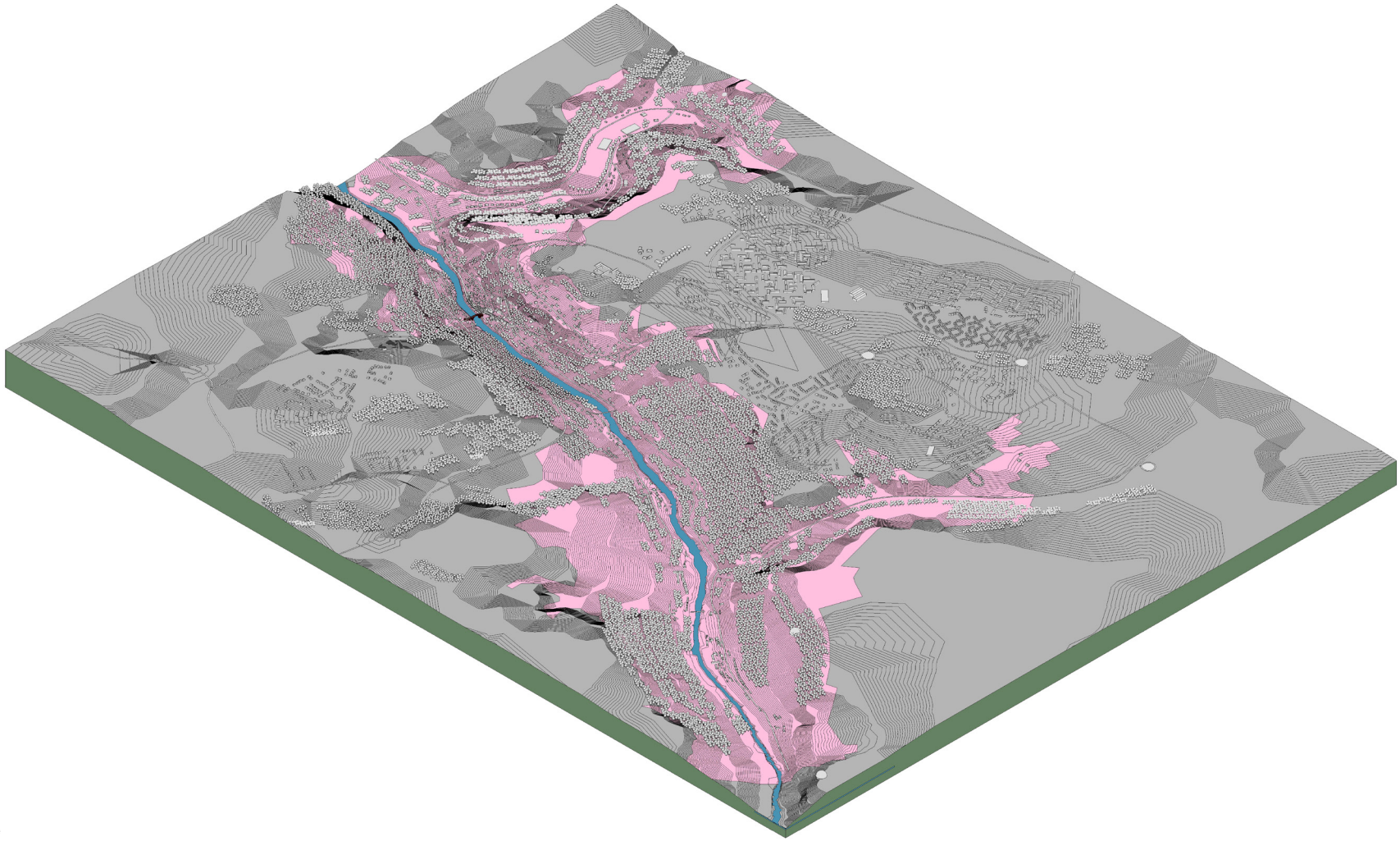
The scope of the study is also limited by the quantity and quality of data made available. Nevertheless it has been possible to showcase the Kassandra approach, methodology and output. With a wider scope, and more varied data, it would be possible to carry out detailed predictive scenarios which could give multidisciplinary scientifically-based support to many of the urgent decisions that need need to be carried out.



IRONBRIDGE DIGITAL TWIN AND AERIAL PHOTOGRAPHY



IRONBRIDGE WHS DIGITAL TWIN



World Heritage Site

8.0 | DATA ANALYSIS

8.1 Analysing resilience

Resilience has recently become an increasingly important concept in dealing with the effects of climate change, risk research and applications. The issue is how we can make a complex system able to sustain or restore its functionality and performance following a change in the condition of the system whether acute or chronic.

Resilience analysis and management constitute a main strategy to meet threat and in particular the unforeseen and potential surprises. Climate resilience is, therefore, the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate.

It should be noted that many people and organizations today make a call for a shift from risk to resilience, and considerable resources are devoted to the development of methods and models for supporting resilience analysis and management. Using resilience as a benchmark allows us to breakdown the huge challenges of climate change into locally manageable tasks and provide a shared view of the risk landscape that people face.

Kassandra's methodology provides key actors in the field with

- an understanding of the broader climate change issues that affect the site and quality of life
- an analysis of how climate change risk affects key components of the site, which components are resilient, which are not, and why
- a shared understanding of quantitative and qualitative parameters and an identification of the right metrics to monitor
- a way - focusing on the resilience of the system instead of the risk - of strengthening the system itself by building on existing capacities
- a way, working back from a plausible worst case scenario, of removing the uncertainties often associated with predictive systems
- an adaptive pathway plan with trigger points related to threshold resilience levels, turning predicting the future into monitoring change and improved decision making processes
- a shared vision of what needs to be done to boost resilience in the site, and how to integrate these aspects into policies, strategies and development efforts at every layer of the decision making process

8.2 Data limits

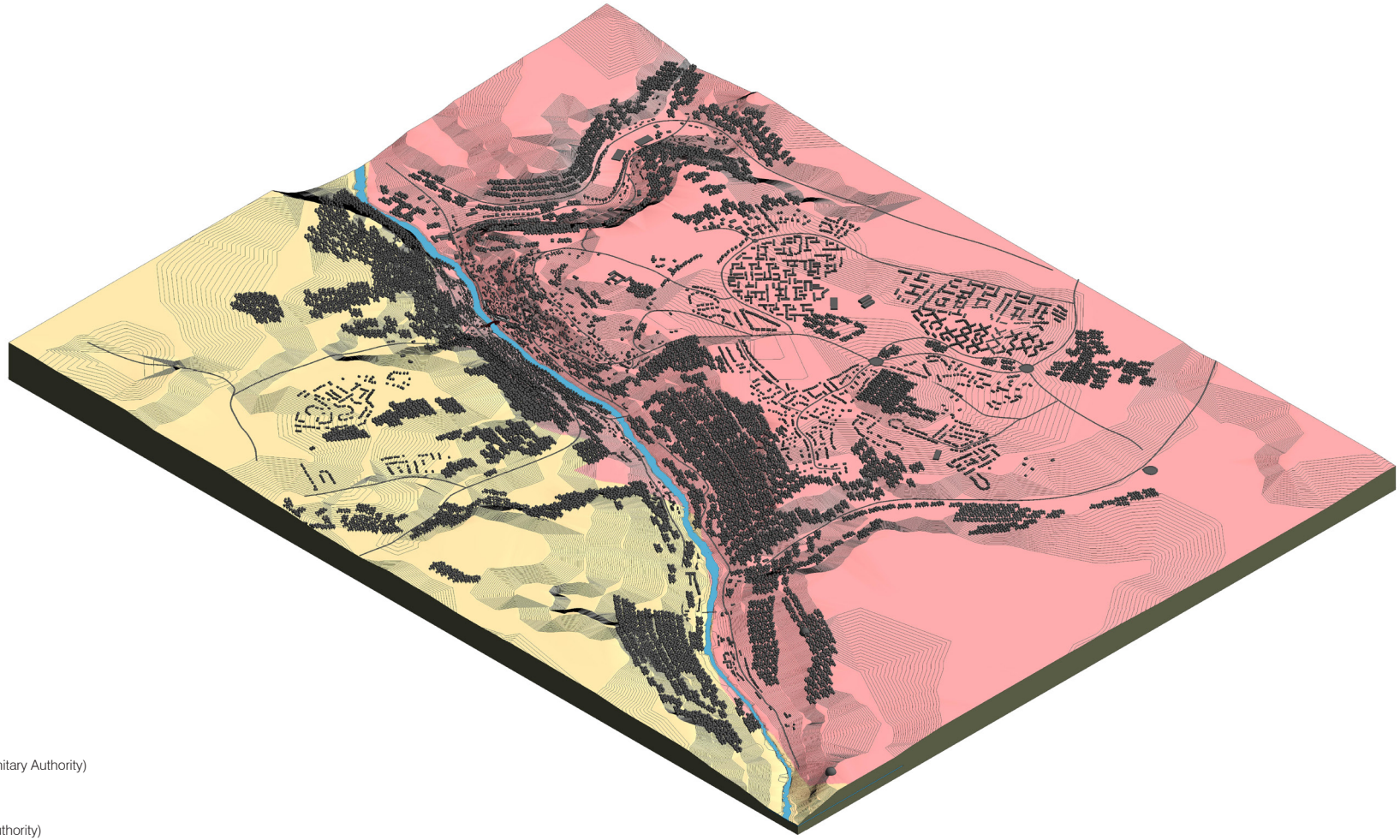
We have analysed the resilience to climate change of the study area based on Kassandra's twelve main parameters and hundreds of relative sub-parameters.

The quality and extent of information that Kassandra can provide is directly related to the amount and quality of information available at the outset in regard to the existing condition of the study site and other information associated to the area.

As can be seen in the attached bibliography, the quality and quantity of data obtained during the pilot study period has varied significantly, with some parameters covered in detail and others lacking information. Nevertheless the relational database created has provided good amounts of insightful information that can be used as the basis for a wider and more in-depth study.

Note:
For clarity, all colour schemes on the following pages reflect those of original sources.

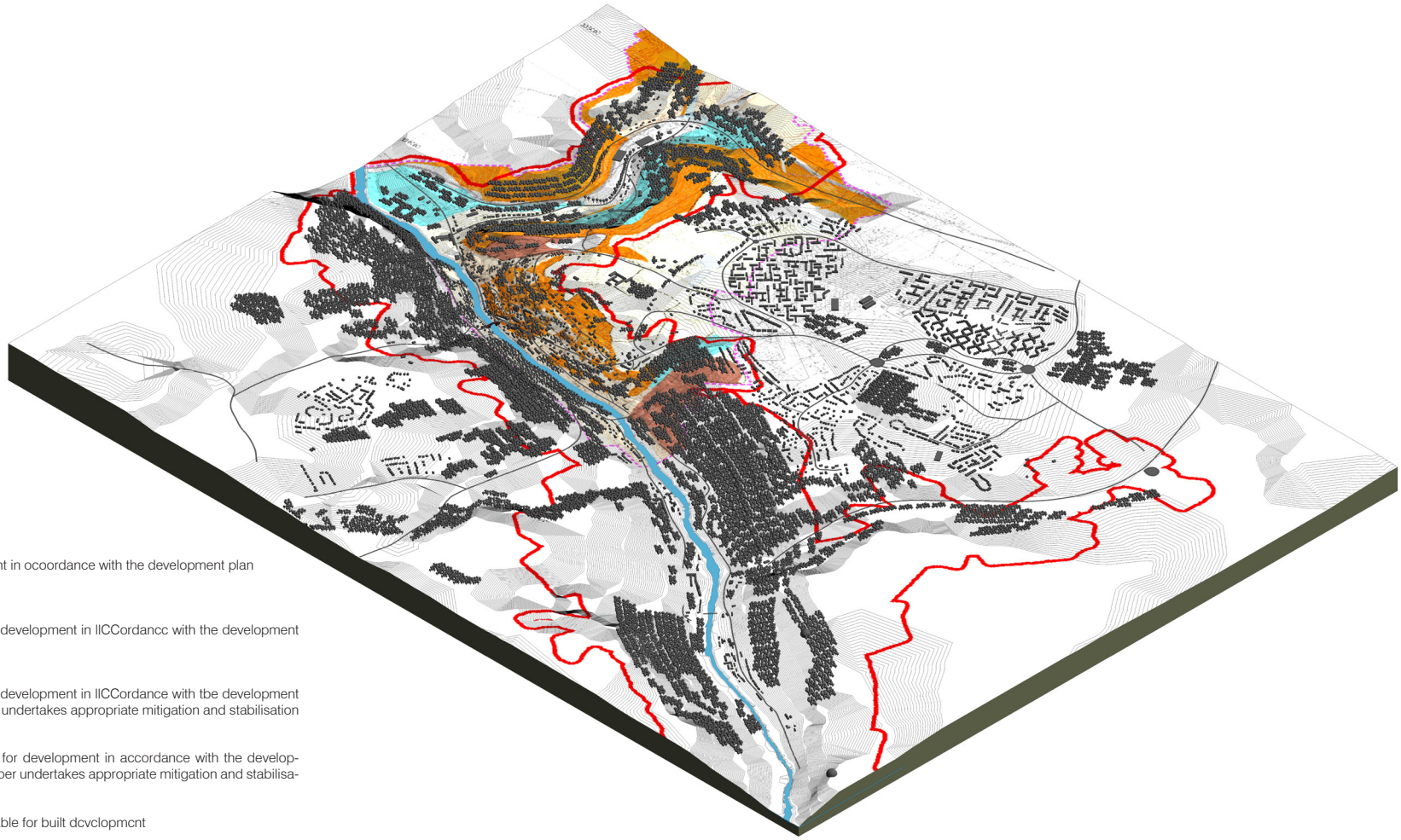
ADMINISTRATIVE BOUNDARIES



Telford and Wrekin Council (Unitary Authority)

Shropshire Council (Unitary Authority)

LAND STABILITY PLANNING GUIDANCE



Area mitable for development in ocoordance with the development plan

Area likely ta be suitable fur development in llCCordancc with the development plan

Area likely to be suitable for development in llCCordance with tbe development plen provided the developer undertakes appropriate mitigation and stabilisation

Area unlikely to be suitable for development in accordance with the development plan unless the developer undertakes appropriate mitigation and stabilisation measures

Area very unlikely to be suitable for built dcvclopmcnt

GENERAL DATA

BUILDINGS MODELLED
2335

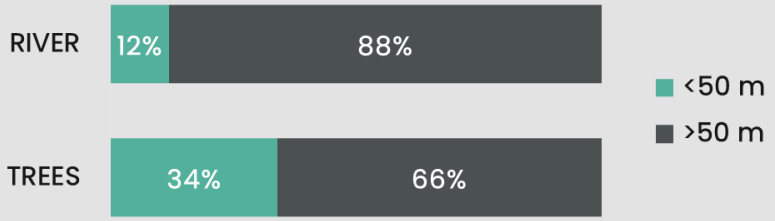
TREES MODELLED
32305

DATA POINTS COLLECTED
127700

STUDY AREA (SQKM)

20

PROXIMITY OF BUILDINGS TO:

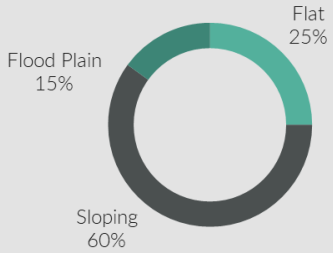


RESIDENTS

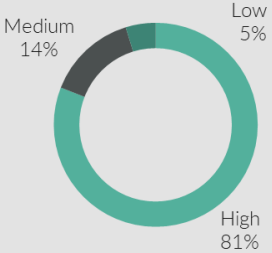
2,582

(Civil Parish population 2011)

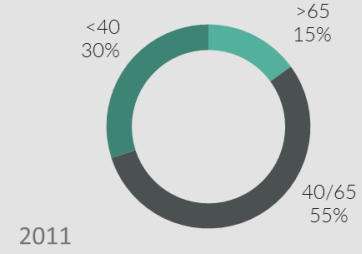
LAND MORPHOLOGY



GROUNDWATER VULNERABILITY



POPULATION



HERITAGE DATA

INSCRIPTION WHS
1986

WHS AREA
5.4 SQKM

MUSEUMS
11

VISITORS PER ANNUM
>1,000,000

HERITAGE

250
Listed Buildings

7
Scheduled Ancient Monuments

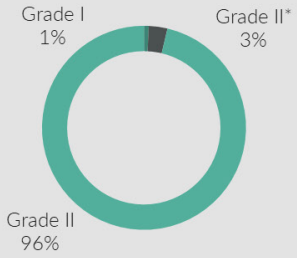
2
Sites of special scientific interest

RISKS

- Development
- Natural disasters
- Visitor/tourism pressure

UNESCO

HERITAGE GRADE



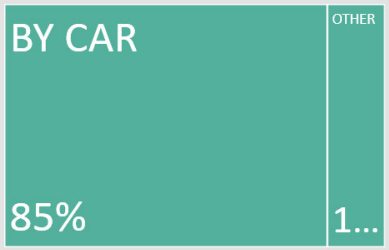
TOURISM

- 5,000 Jobs
- 7% Employment
- £13m Monthly Income

TWC

TRAFFIC/MOBILITY DATA

VISITORS MOBILITY



PARKLAND

2.6 SQKM

PATHWAYS

20 KM

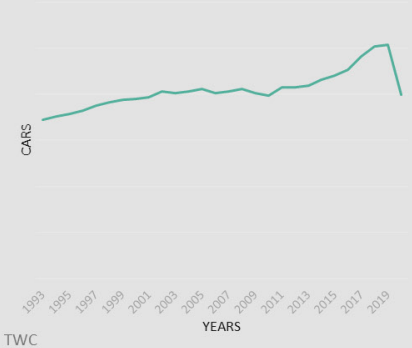
CARS per YEAR

visiting Ironbridge Gorge

154,000

Considering 545,000 visitors and 3 people per car.

TRAFFIC DATA



PARKING INSIDE WHS

7 CAR PARKS

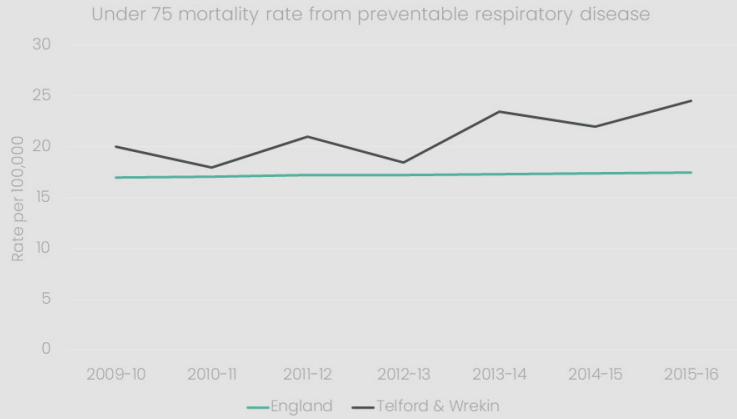
250/300 CARS CAPACITY

CO2 PRODUCED

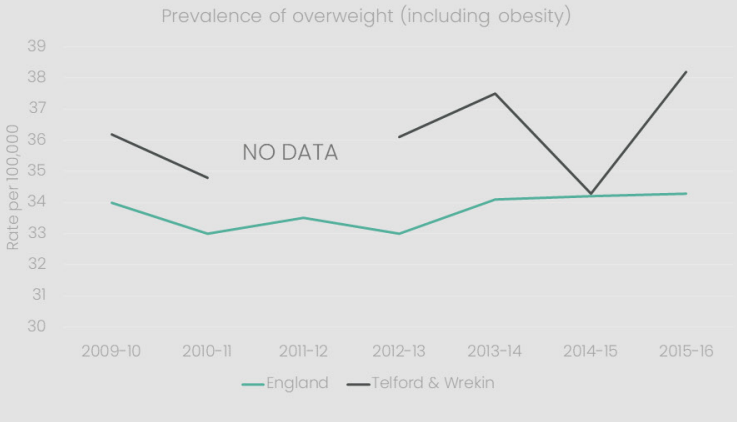
15,400 Kg

Considering a mean of 100 g produced by a car per km

RESPIRATORY DISEASE



PREVALENCE OF OBESITY



FLOODING/LANDSLIDE DATA

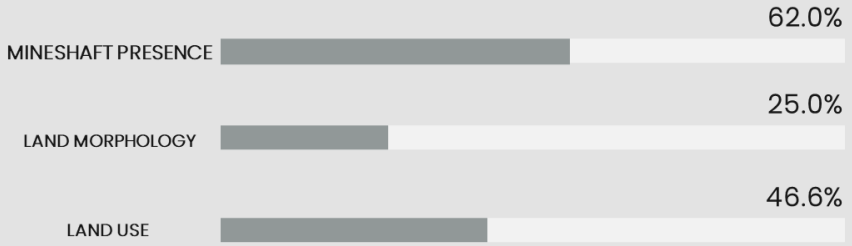
HISTORICAL RECORDED EVENTS

FLOODING: 1348 1545 1579 1599 1634 1729 1672 1740 1759 1763 1759 1795 1811 1831 1849 1852 1867 1869 1872 1877 1879 1880 1881 1886 1893 1903 1905 1924 1929 1946 1947 1948 1960 1965 1965 1998 2000 2004 2022

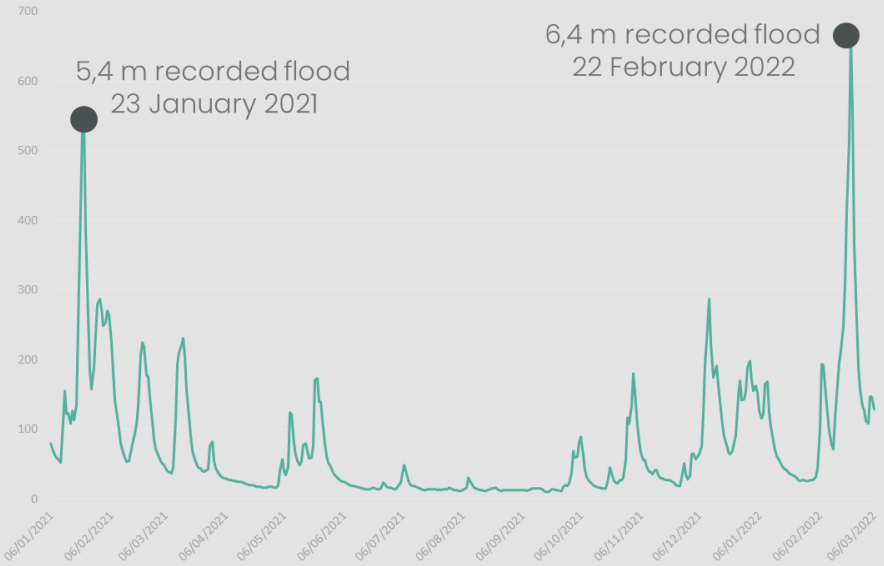
LANDSLIDES: 1700 1773 1924 1935 1952 1989 2000 2012

Chronology of British hydrological events and British Geological Survey

RESILIENCE INDEX (LAND INSTABILITY FACTORS)

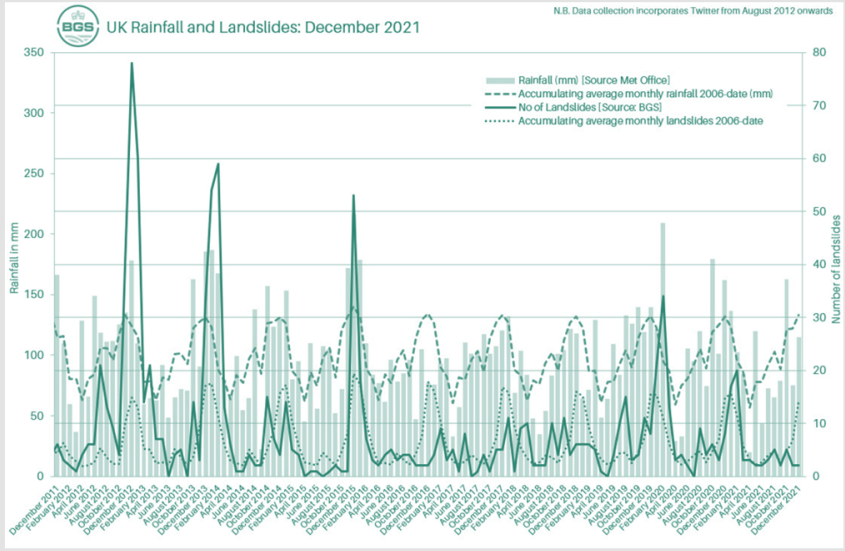


DAILY MEAN FLOW TIME (JAN '21-MAR '22)



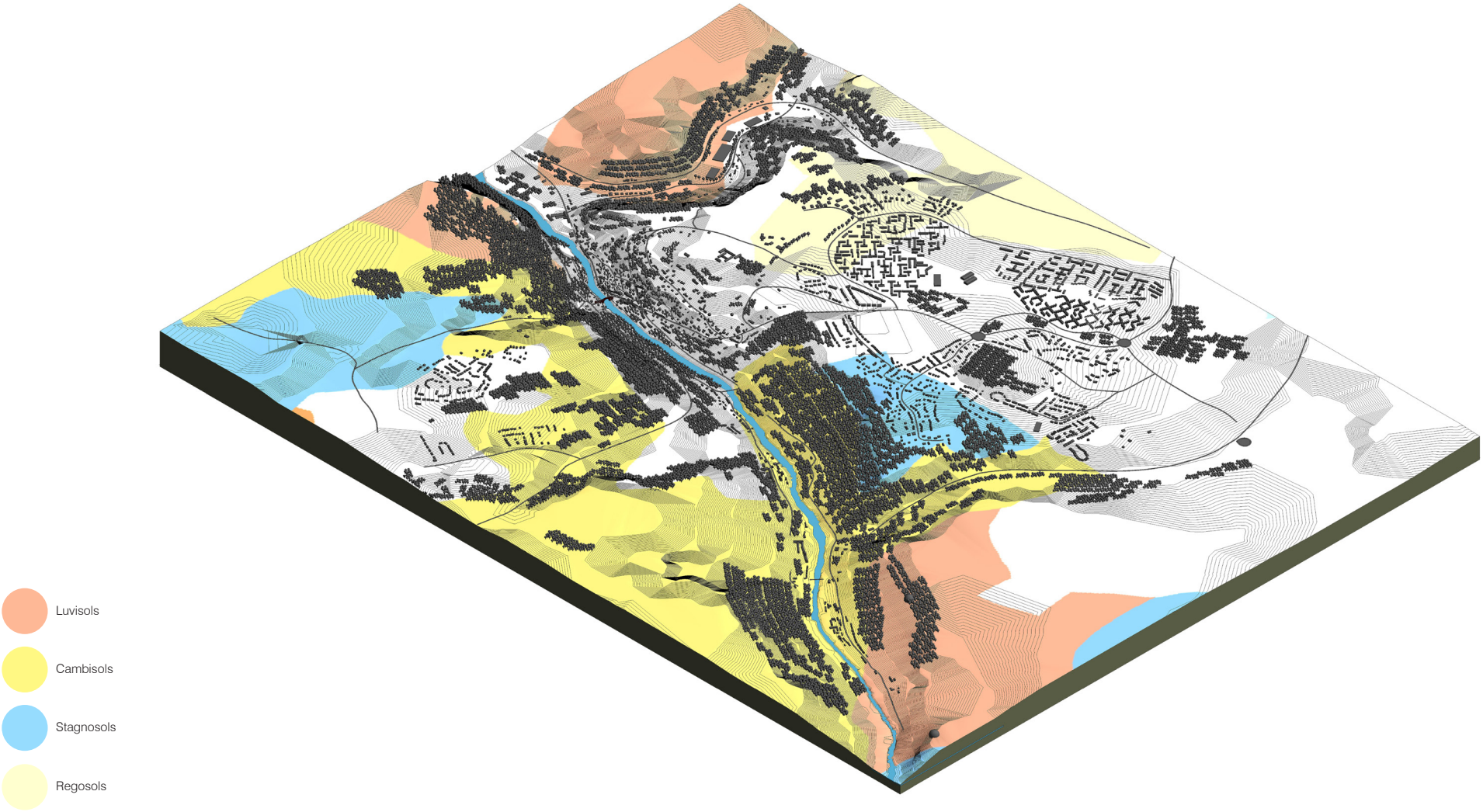
BGS

LANDSLIDE AND RAINFALL CORRELATION IN UK

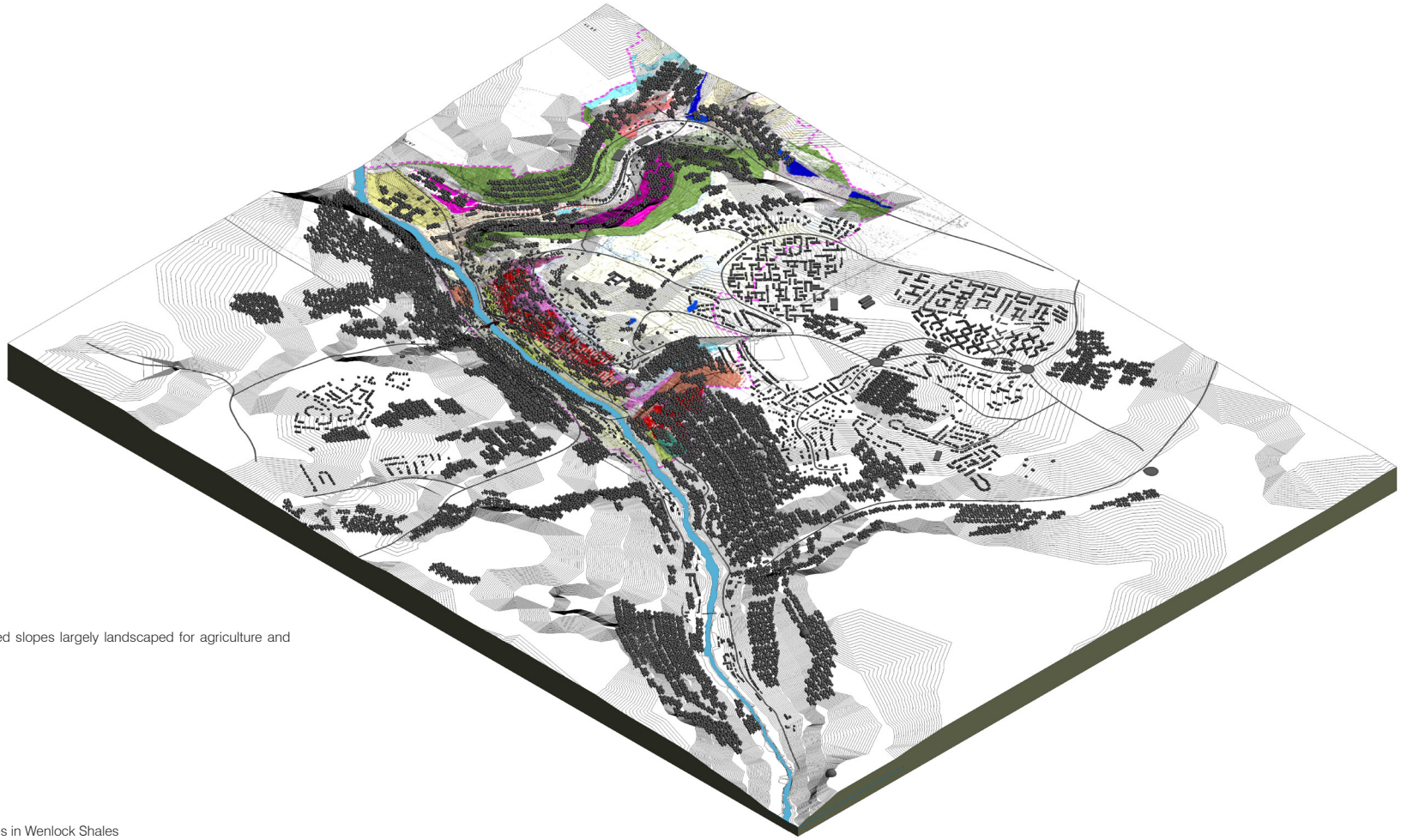


BGS

SOIL TYPES

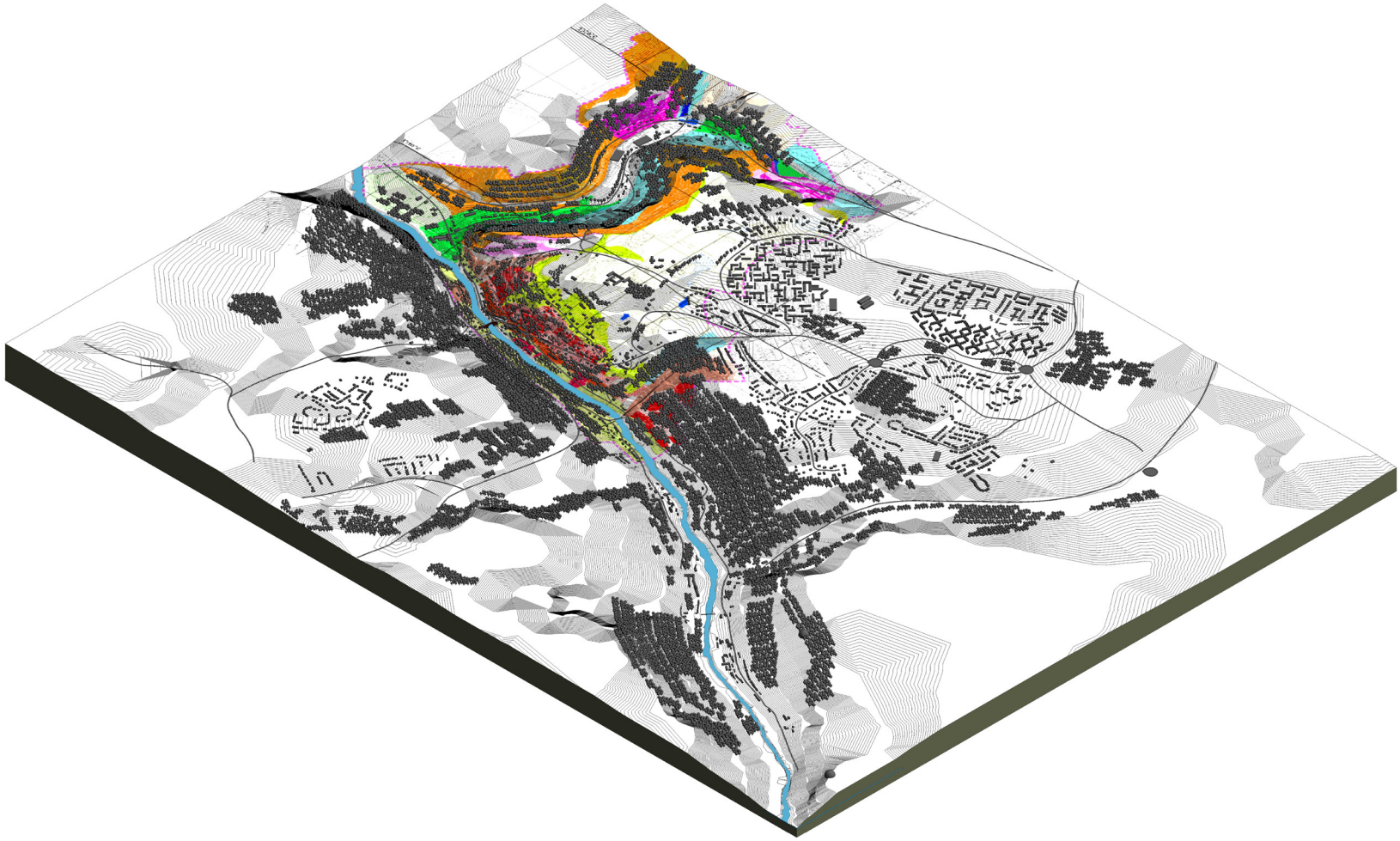


GEOMORPHOLOGY



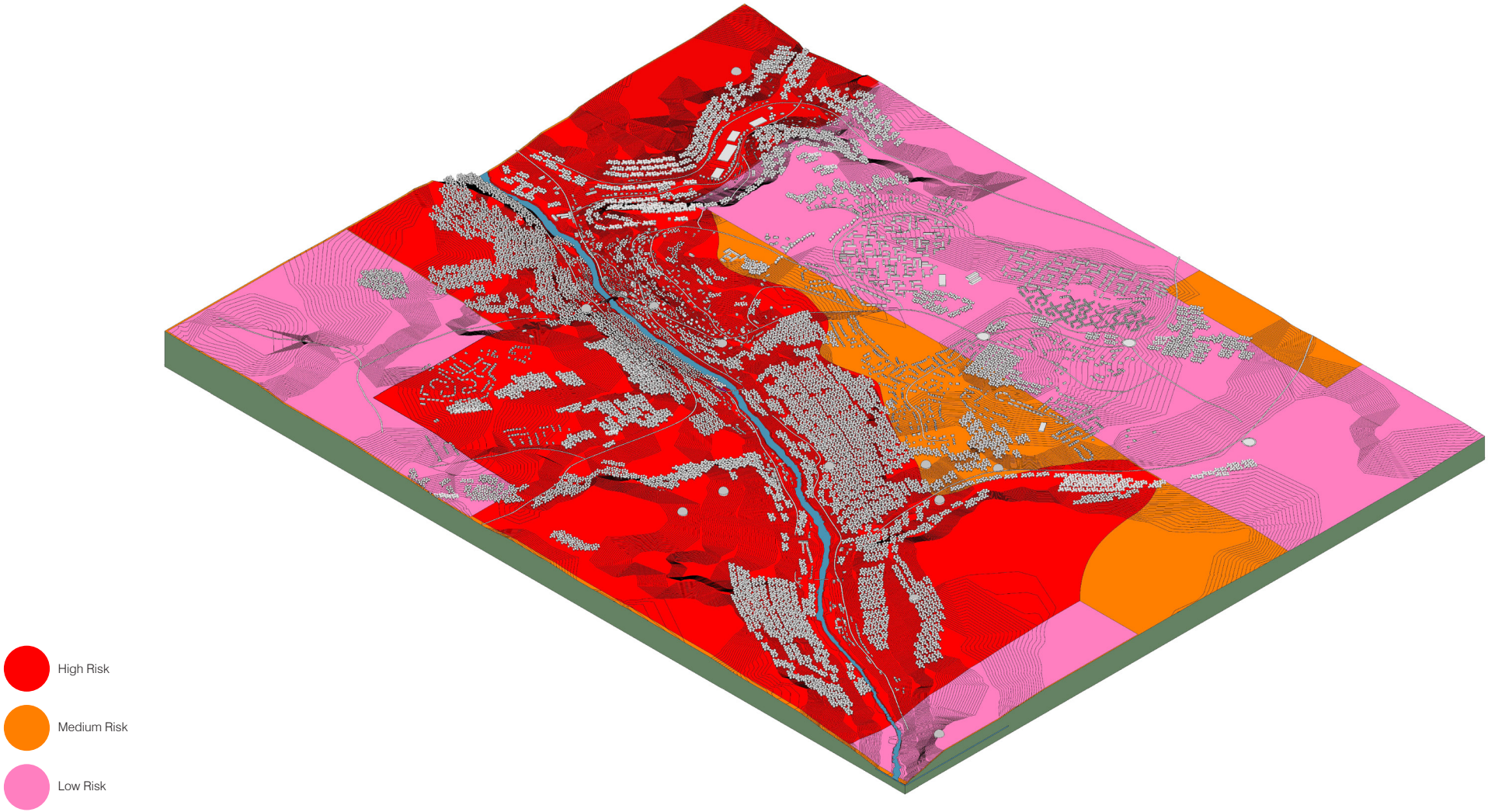
- Ponds
- River Terrace
- Shallow Valley-sides; degraded slopes largely landscaped for agriculture and development.
- Landslide accumulation zone
- Valley-side landslide complex
- Valley-side rotational landslides in Wenlock Shales

GROUND BEHAVIOUR

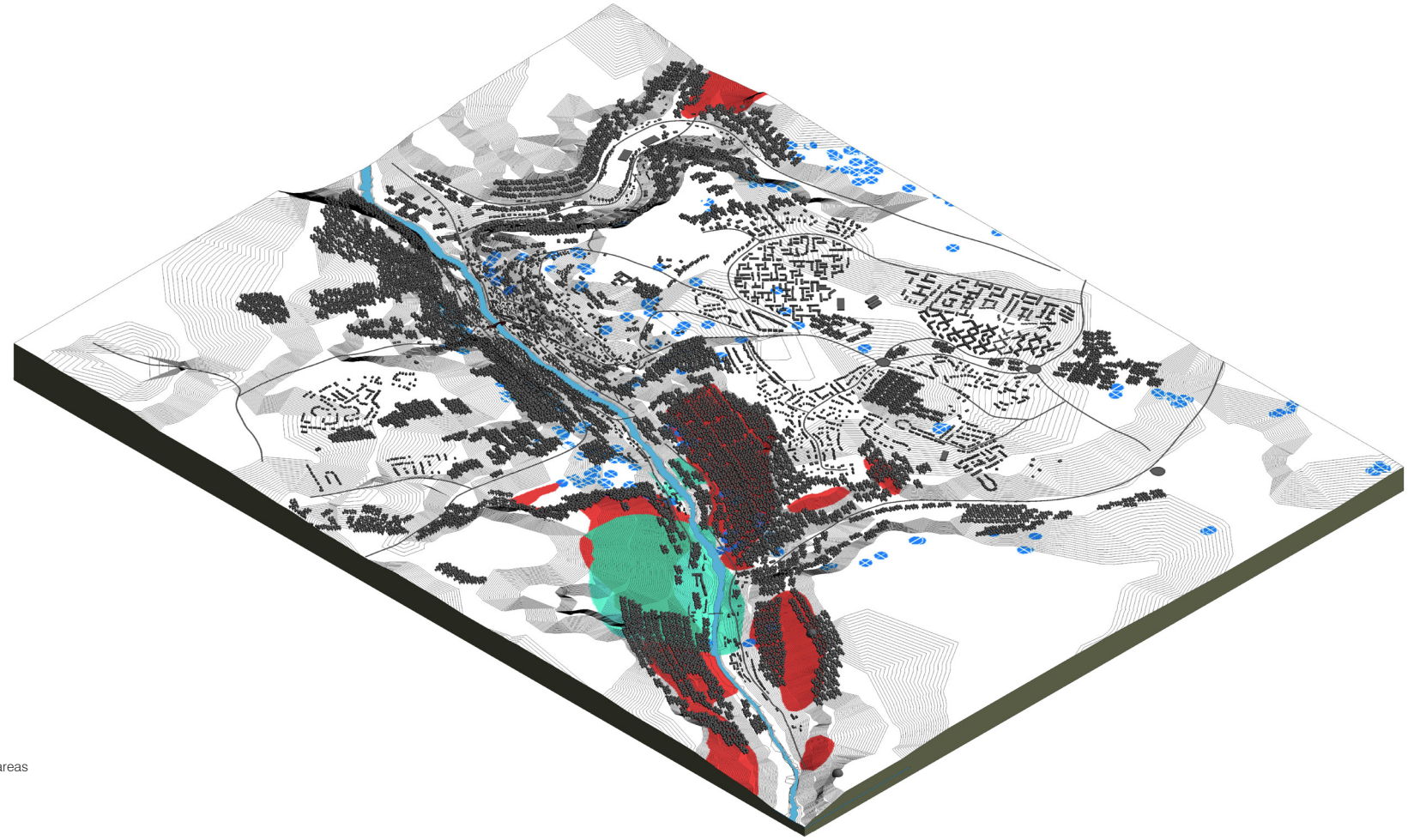


- Steep Valley Sides
- Small Stream Valley
- Worked Steep sided slopes
- Fan and Floor
- Mudslides
- Plateau Margin

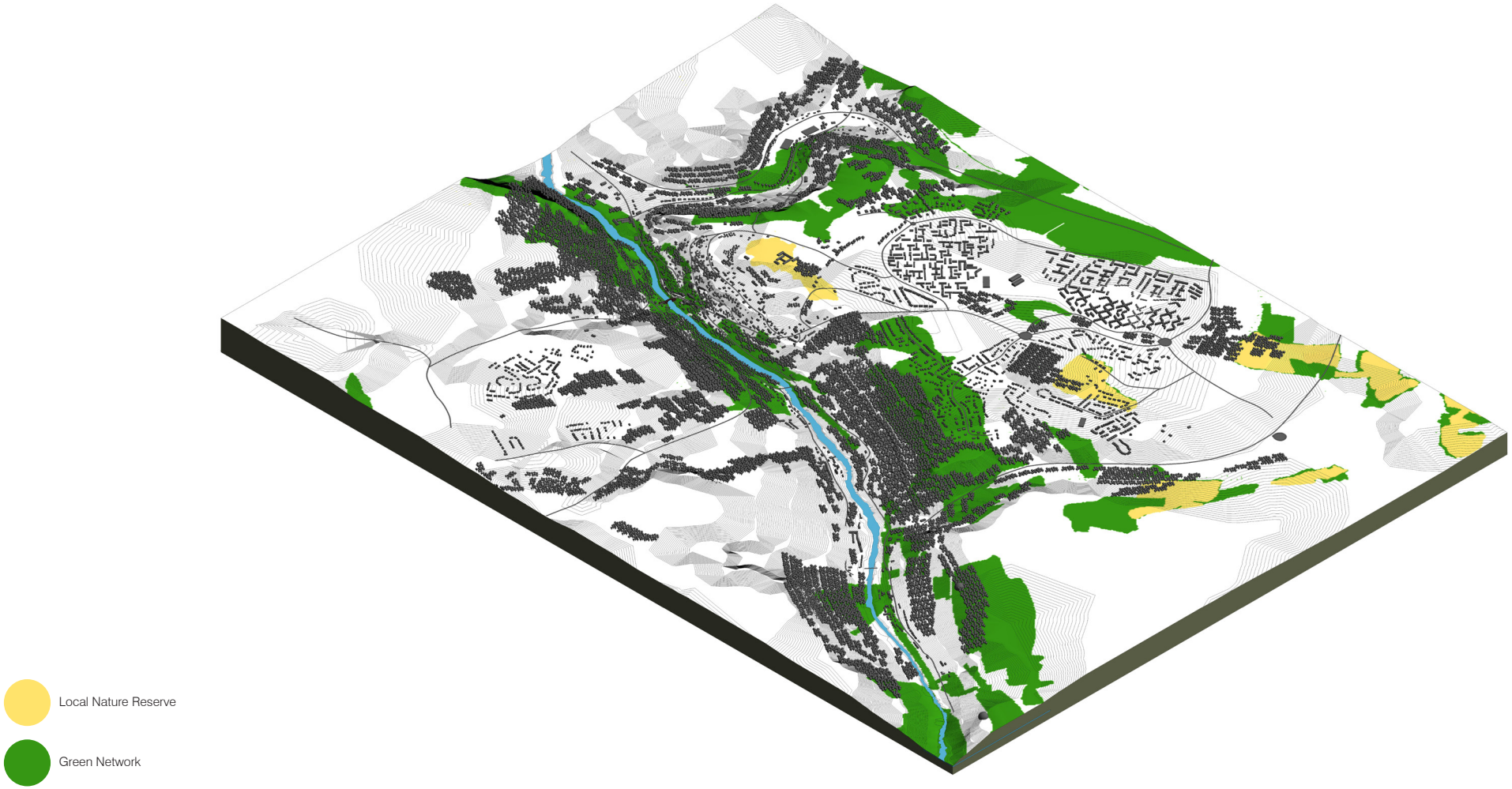
GROUNDWATER VULNERABILITY



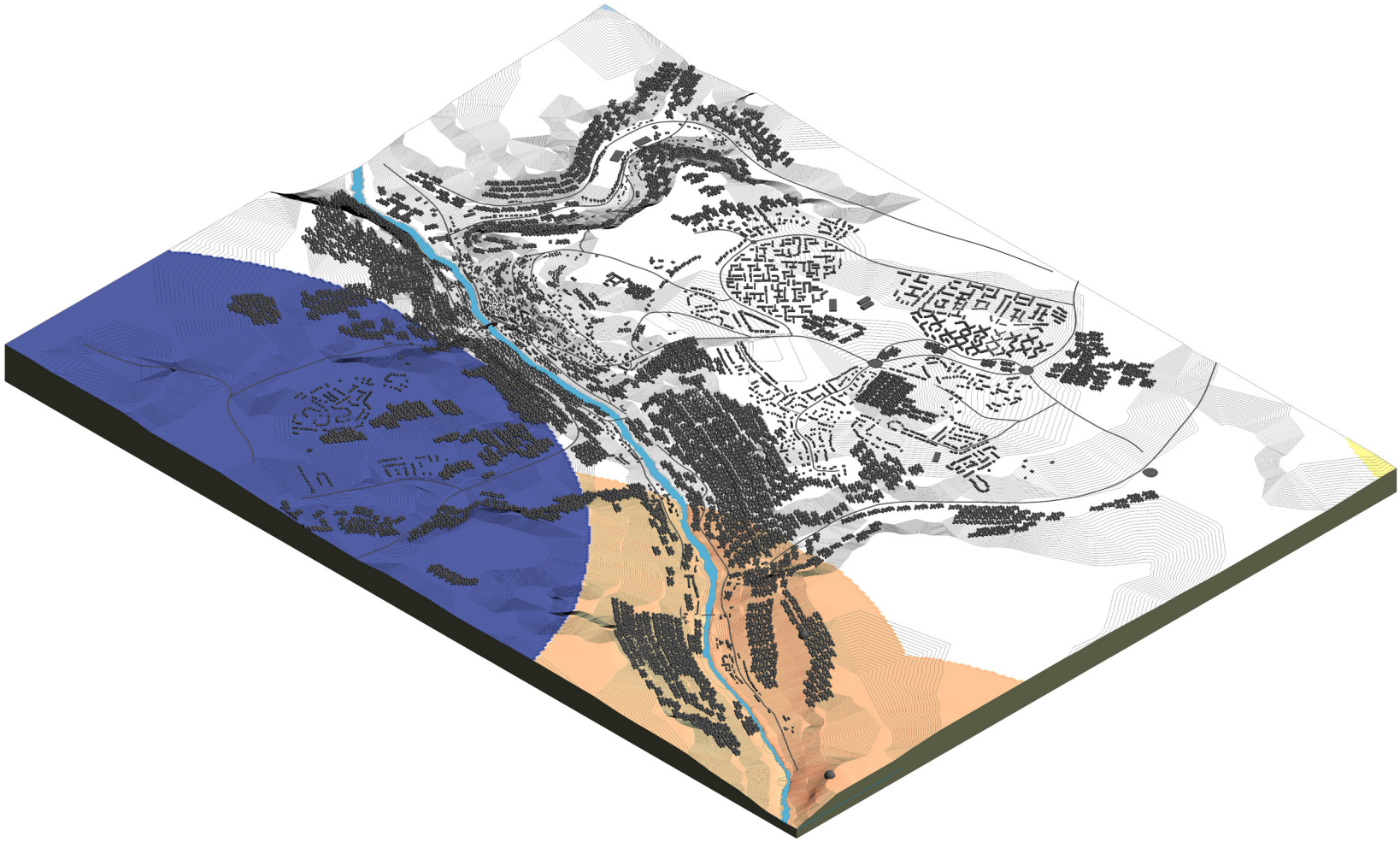
LANDSLIDE RISK



GREEN NETWORK/LNA



WILDLIFE



SAMPLE PLOT TREE DATA

1 PLOT SURVEYED

87 TREES SURVEYED

PLOT DATA

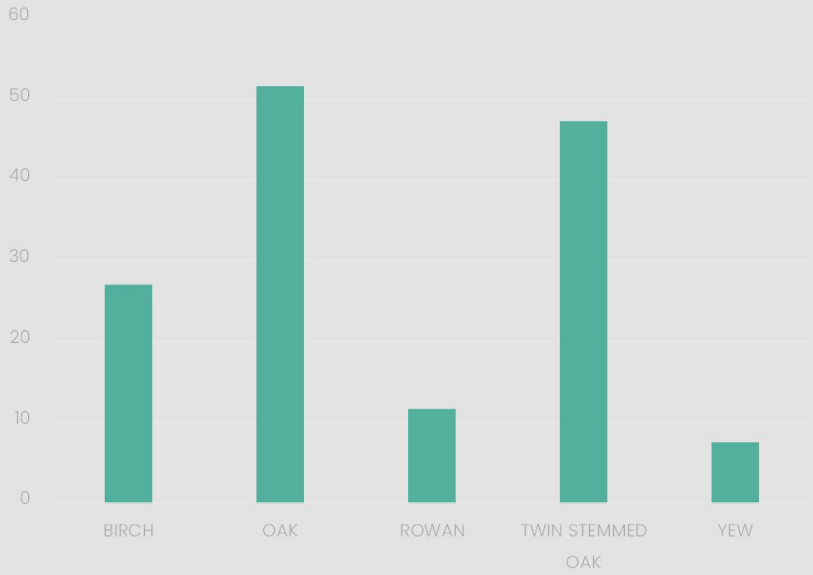
0.51 ha

27.7 per ha

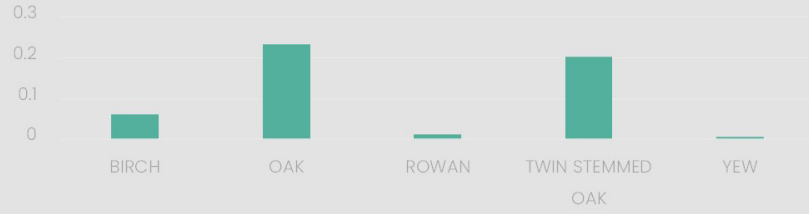
98 mc/ha
Considering 3.55 Ht Thinning Form

WORKHOUSE DEER EXCLOSURE TREE SPECIES

MEAN DBH (cm) per PLOT



MEAN BASAL AREA (sqm) per SPECIES



Data provided by Severn Gorge Trust

SAMPLE PLOT TREE DATA

9 PLOTS SURVEYED

134 TREES SURVEYED

PLOT DATA

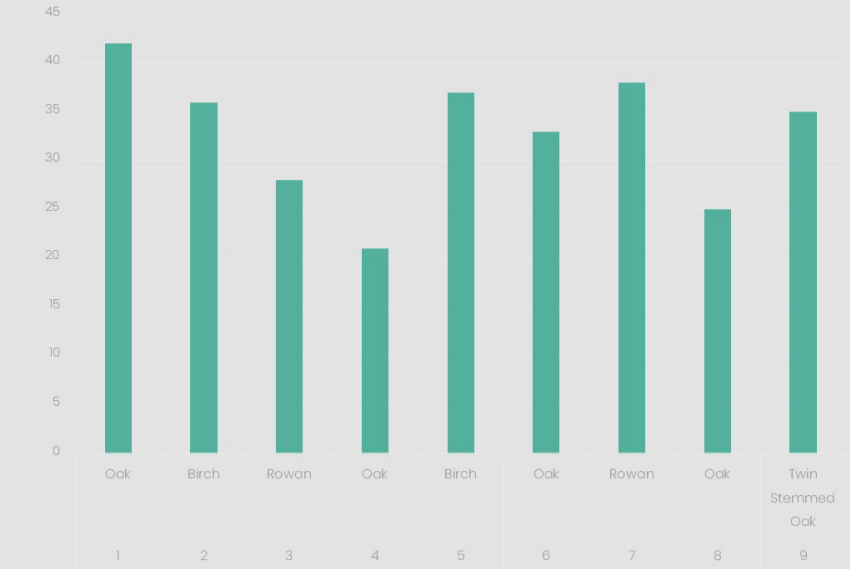
0.45 ha

30.4 per ha

242 mc/ha
Considering 8.07Ht Thinning Form

BENTHALL DEER EXCLOSURE TREE SPECIES

MEAN DBH (cm) per PLOT



MEAN BASAL AREA (sqm) per SPECIES

Data provided by Severn Gorge Trust

SAMPLE PLOT TREE DATA

5 PLOTS SURVEYED

90 TREES SURVEYED

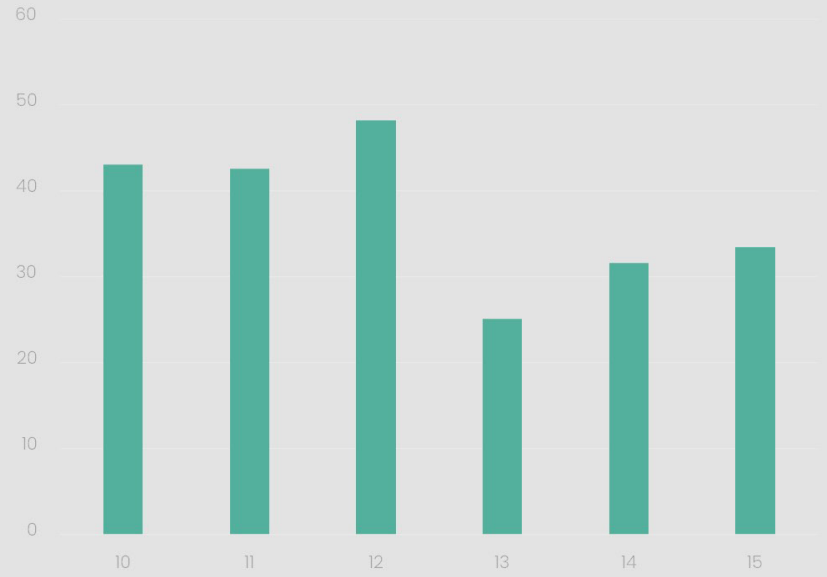
PLOT DATA

0.30 ha

37.3 per ha

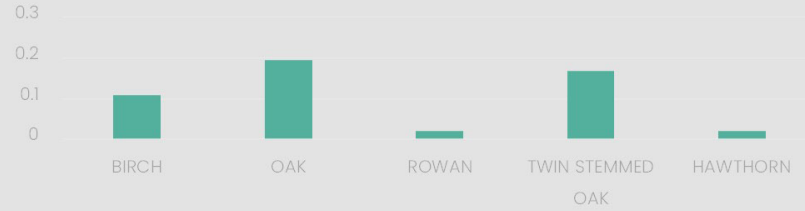
131 mc/ha
Considering 3.55 Ht Thinning Form

MEAN DBH (cm) per PLOT



WORKHOUSE WOODLAND TREE SPECIES

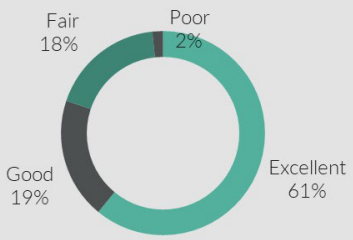
MEAN BASAL AREA (sqm) per SPECIES



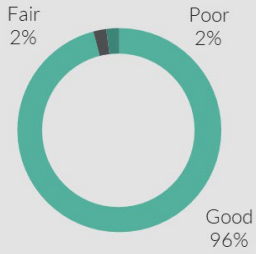
Data provided by Severn Gorge Trust

STUDY AREA TREE DATA

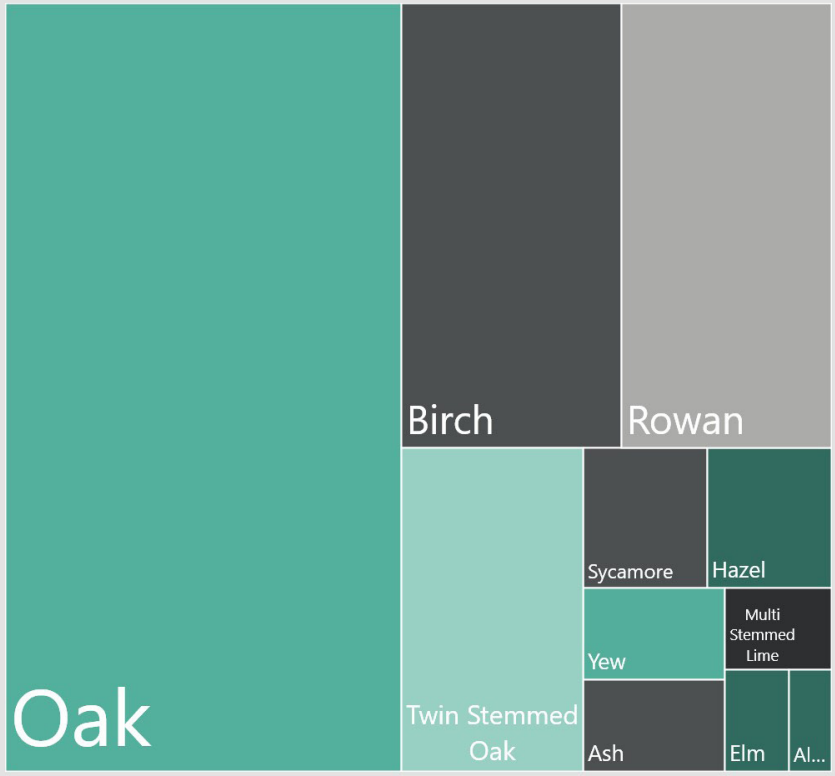
SLOPE STABILITY



WIND TOLERANCE



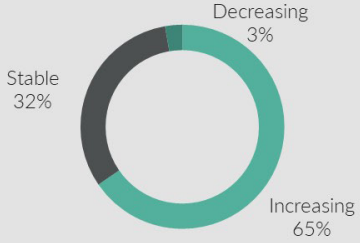
TREE SPECIES DISTRIBUTION



Data provided by Severn Gorge Trust

TREE RESPONSE TO RCP 8.5

DISEASE/PEST RISK IN RCP 8.5



9.0 | CURRENT RESILIENCE

9.1 The Ironbridge WHS current resilience to climate change

Within the scope and limitations of this pilot study, we have analysed the current resilience index of the Ironbridge Gorge WHS and the wider area, which has identified key shortcomings and areas of potential improvement.

The overall current resilience index, based on the analysed data, is just above 60% which is generally a good result. However, this varies significantly by parameters and especially with some key parameters.

The following commentary illustrates the key findings by parameter:

Water - This value of resilience is due primarily to the issues around flooding, which affect mainly one part of the study area where the score is much lower.

Energy - This value is based on interpolation of general data as no specific data for the area or buildings contained within was available.

Heritage - The otherwise high score is affected by the closeness of most heritage buildings in the study area to the river, which affects their resilience.

Environment - This score is affected by a multitude of different parameters, including number and types of species, physical condition, leaf index etc.

Infrastructure - This value reflects the visible good condition of roads but also the risk of flooding to them.

Waste - This score was based only on values derived from other parameters as no direct data on waste management was available

Air - The good score is primarily due to the number of trees present that contribute to the reduction of CO2 and low levels of NO2 and particulates

Buildings - This score derives from relation with the heritage value as no information on individual buildings was made available.

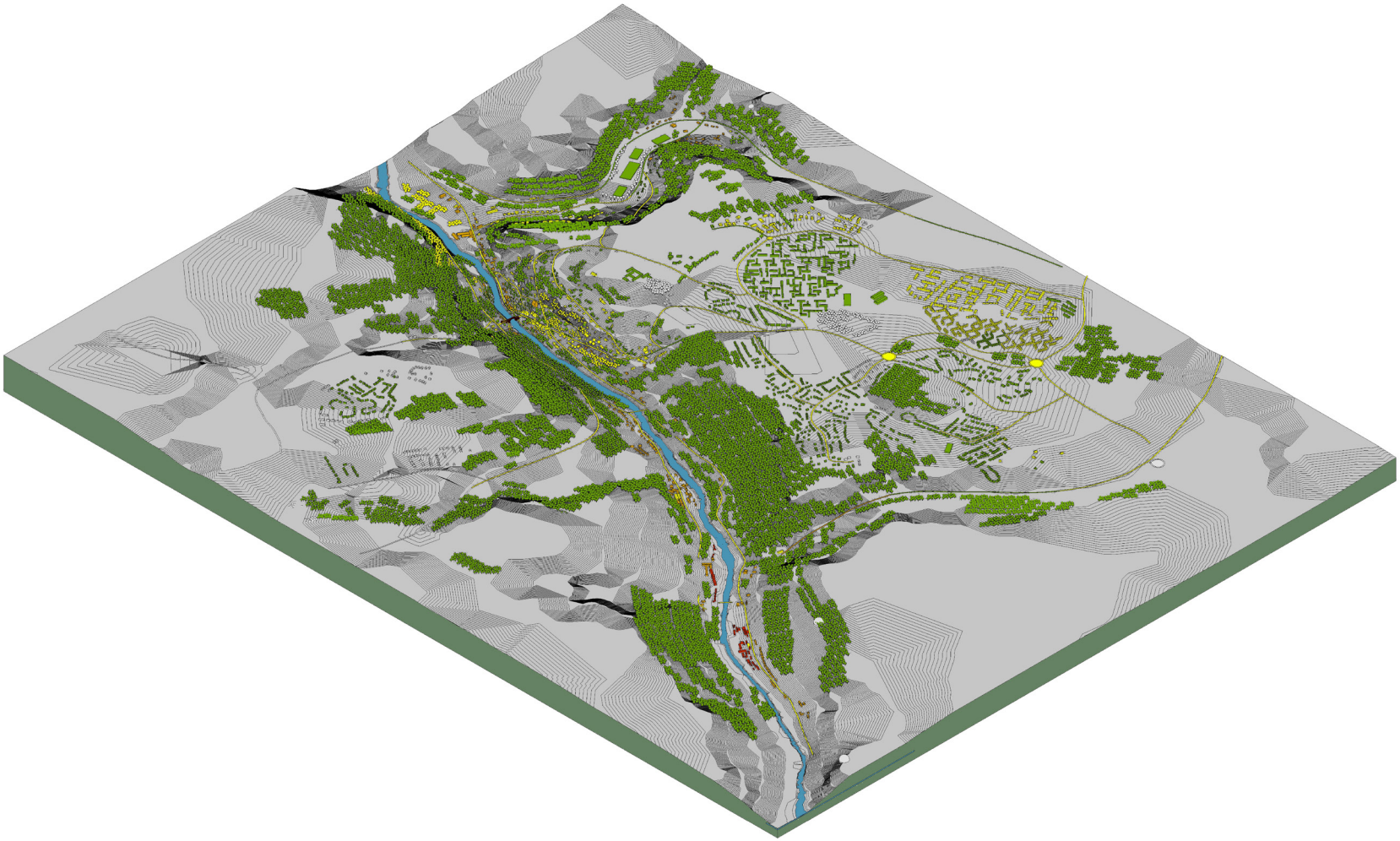
Culture - This score is due to the number of visitors and the associated values of the buildings and site.

Health - The resilience index score is due to air quality, presence of green spaces and interpolated wider area data.

Mobility - This is the parameter with the lowest score due to the shortage of public transport and alternative transportation means or presence of cycle paths.

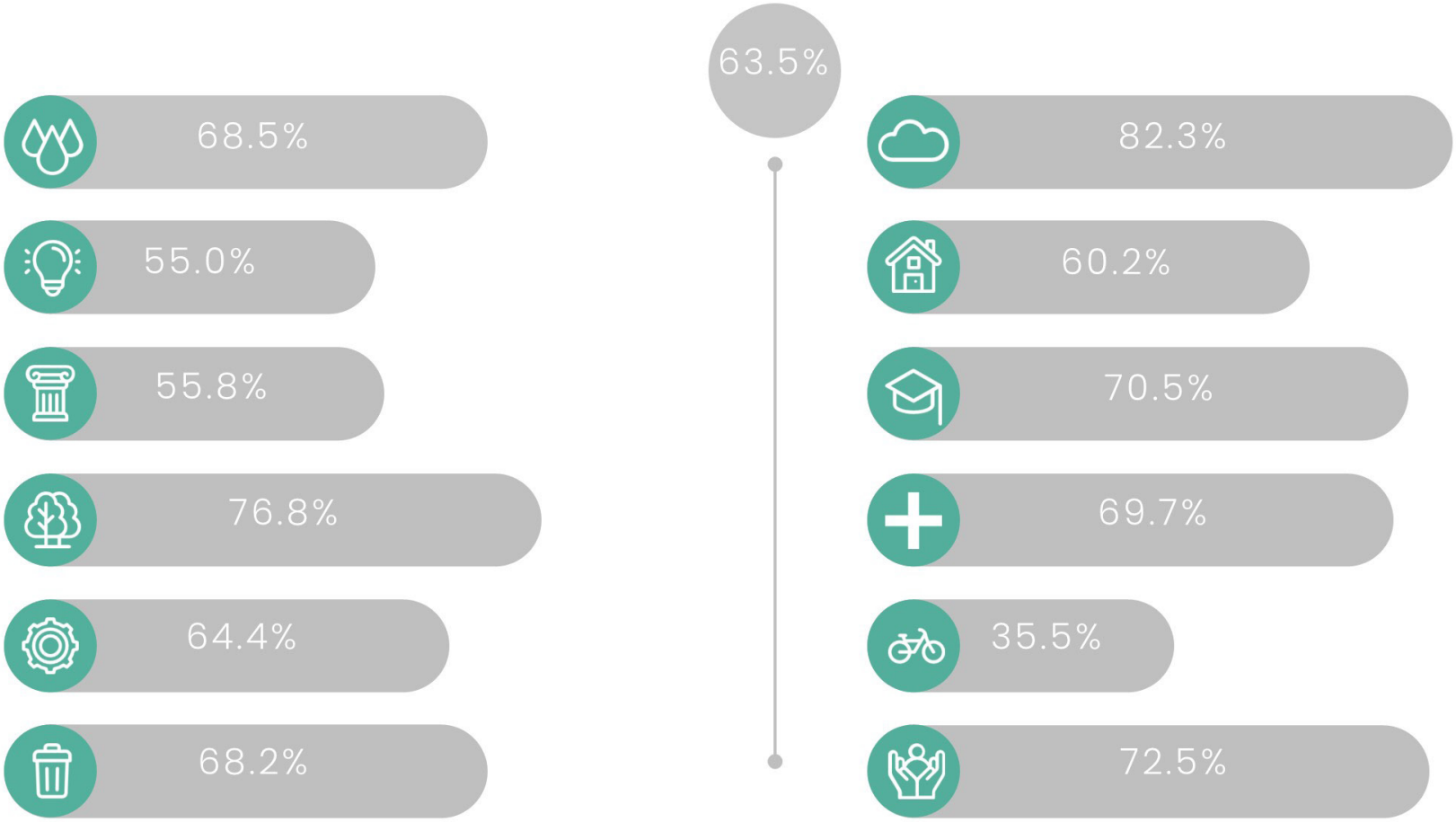
Security - This parameter has only analysed values derived from other parameters.

EXISTING RESILIENCE INDEX LEVELS

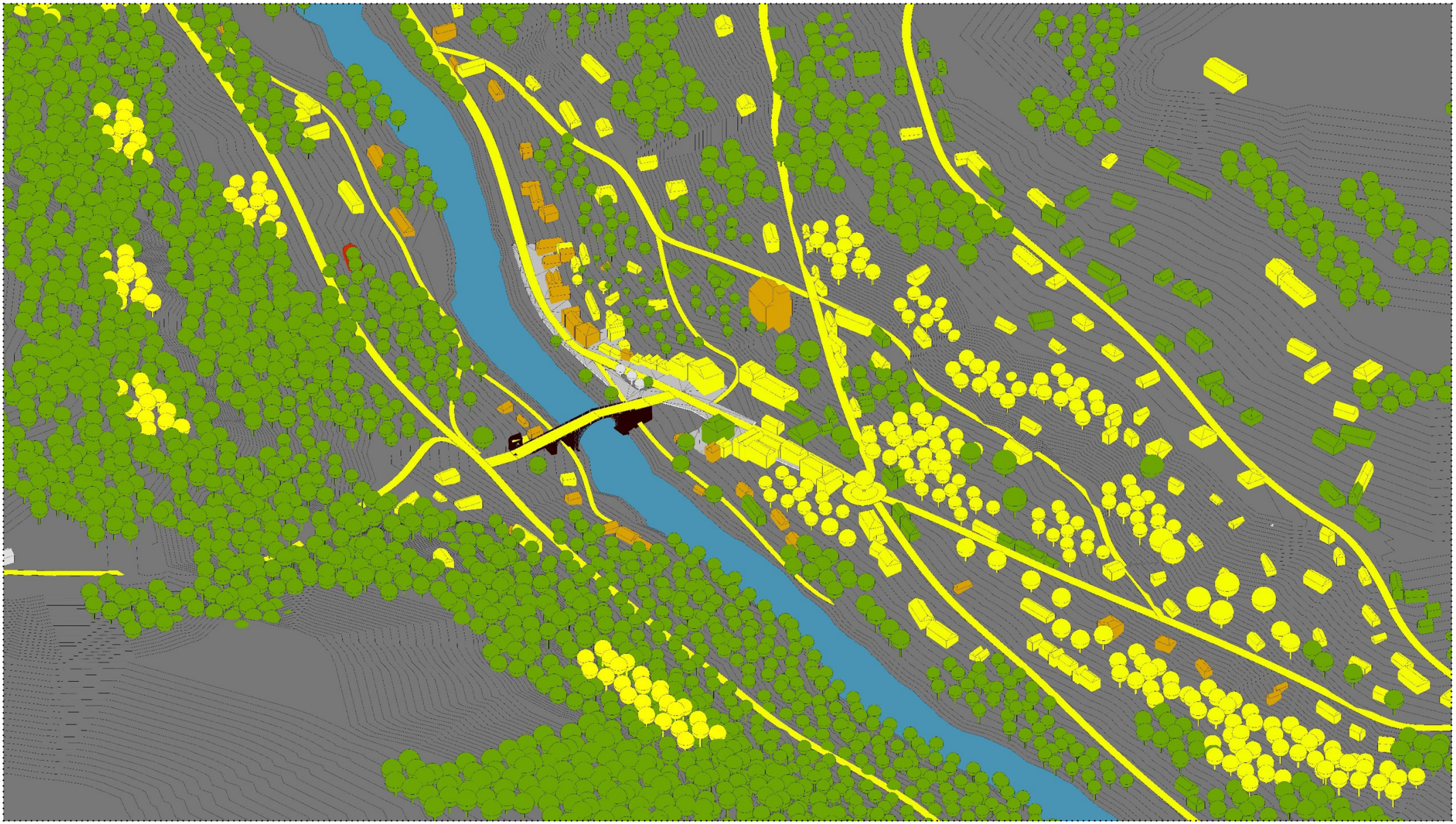


EXISTING CONDITION

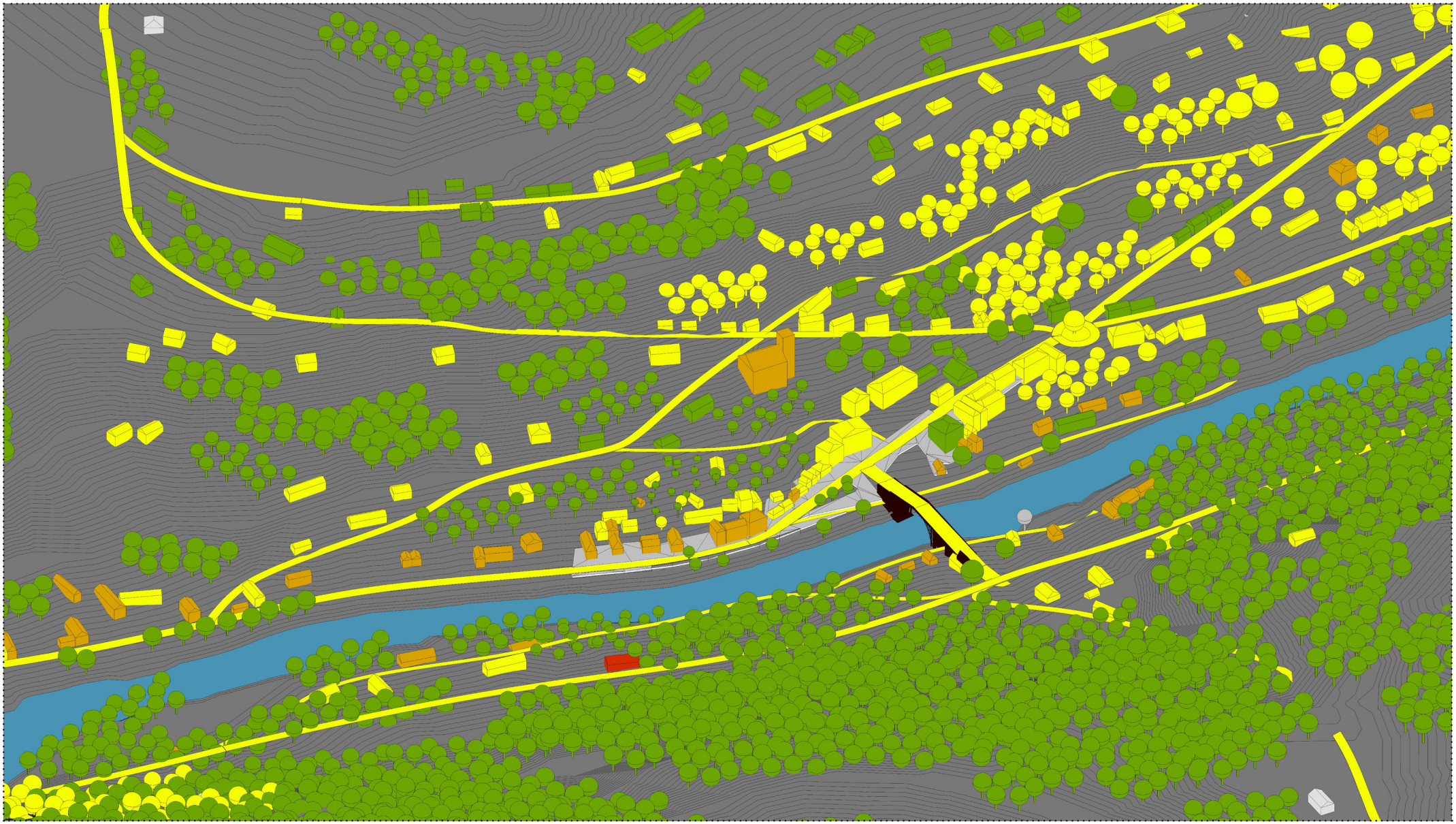
Ironbridge, England 52°37'38.08"N 2°29'07.92"W



EXISTING RESILIENCE INDEX LEVELS



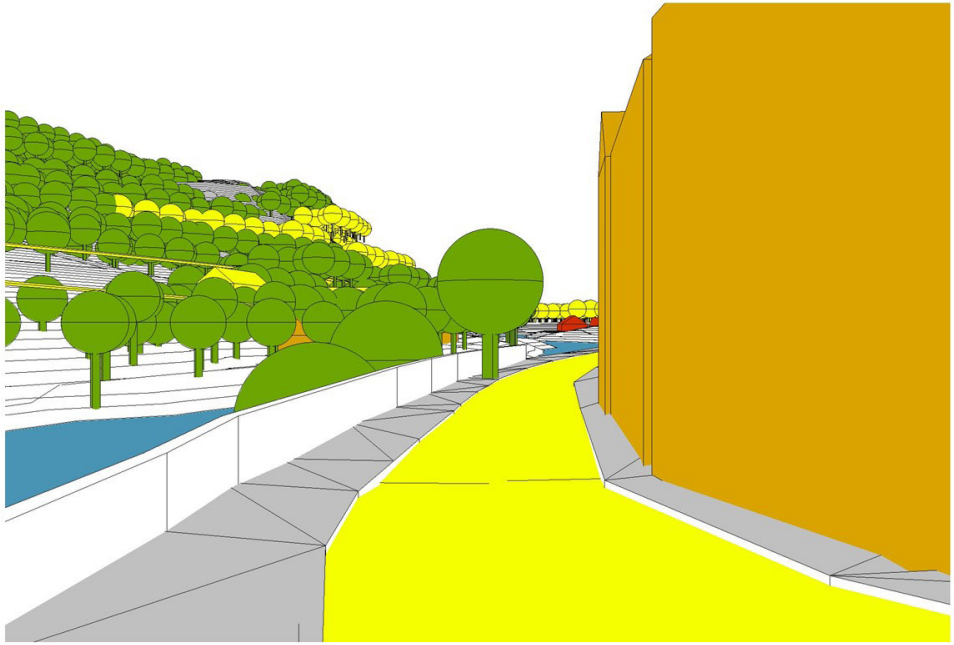
EXISTING RESILIENCE INDEX LEVELS



REAL TO DIGITAL

VIEW FROM TONTINE HILL

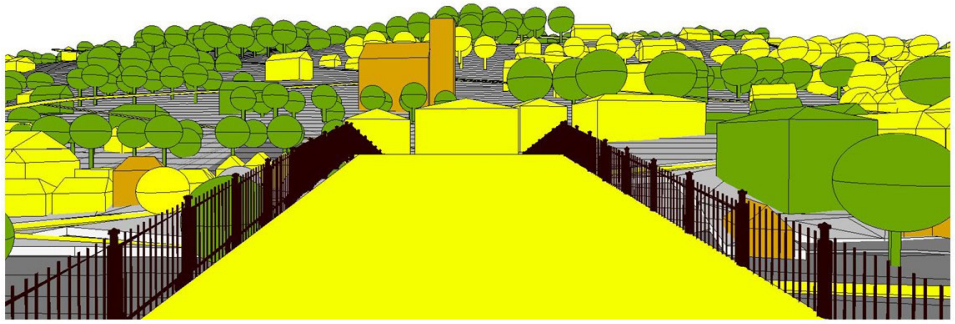
DIGITAL TWIN MODEL



REAL TO DIGITAL

VIEW FROM THE BRIDGE

DIGITAL TWIN MODEL



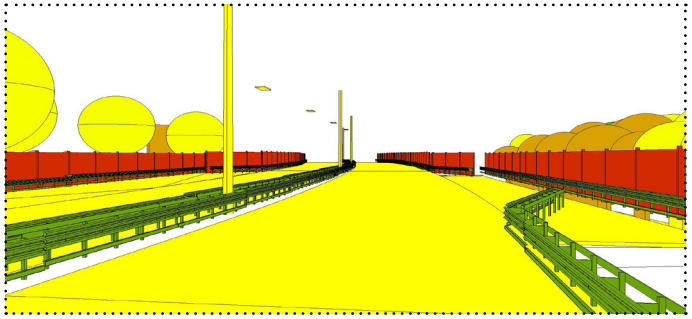
10.1 The adaptive pathway method

Once the current resilience index has been defined, which creates a baseline for the projections, Kassandra engages in a series of scenarios, by altering individual or multiple parameters and verifying the results. This is an iterative process which starts with the modelling of a plausible worst-case scenario and/or with the modification of key parameters from the current resilience index starting with the ones that are below an acceptable threshold. As the parameters are relational, thereby linked to others, any alteration to one has an effect on the whole system. This focuses effort and actions on the areas where investment can have the greatest impact on climate resilience.

The scenarios are of two types, passive or active. In the case of the former, external factors are altered, such as temperature, wind speed, visitor numbers or similar. The active scenarios simulate instead management measures, actions and processes that may be put in place to mitigate or eliminate the negative effects and increase resilience. These simulations are extremely helpful in predicting what the effect of decisions might be before projects are carried out, thereby prioritizing spending, and reducing timescales of intervention.

Together they form the basis of an adaptive pathway for the improvement of the site's resilience to climate change. This way Kassandra, in addition to acting as a unifying element in regard to data, provides a dynamic framework for decision processes.

The adjacent images illustrate various scenarios from other studies.



CVI / KASSANDRA

Comparison between CVI methodology for the assessment of vulnerability with Kassandra's resilience index identification

11.0 | CVI METHODOLOGY/KASSANDRA

Commentary on a CVI/Kassandra combined workflow

During the course of the pilot study we were asked to provide a commentary on whether it would be possible to combine the Kassandra Resilience index approach with the Climate Vulnerability Index approach recently used by Historic Environment Scotland in Heart of Neolithic Orkney.

The Climate Vulnerability Index, developed by James Cook University in Australia, is a rapid assessment tool to assess climate impacts upon WH properties. It assesses both OUV Vulnerability (Outstanding Universal Value, the central concept for World Heritage) and Community Vulnerability-based on the economic, social and cultural dependencies upon the WH property.
There are a number of differences and points of contact between the two approaches:

- It differs from Kassandra as it is based on a risk assessment approach and a high-level analysis of three key climate change drivers and certain modifiers that may vary the assessments. Kassandra, as has been seen in the previous paragraphs, is based instead on an analysis of resilience of twelve main parameters and hundreds of sub-parameters, which already include within them the factors studied by CVI.

- As a risk assessment-based approach CVI classifies the degrees of risk as the likely exposure of a site to different climate change drivers with a matrix of exposure and sensitivity, which is inherently probabilistic and does not provide, in our view, clear data for the best decision support.

- Kassandra's approach reflects in a different way the need for climate resilience metrics to cope with the inherent uncertainties associated with future climate conditions. They need to take into account the uncertainties and implications for project performance, that result from longer timescales for project implementation and the assessment of project results. To do this, as has been illustrated in the Data Analysis section of this report, Kassandra has an approach that 'collapses' the uncertainty, starting with worst-case scenario and working back from that.

- A point of overlap is that it the assessment carried out by CVI identifies the vulnerability and, to a certain extent, the adaptive capacity of a particular site. The adaptive capacity is, in resilience terms, part of the overall resilience of a site that Kassandra calculates with the Resilience Index. It is the inherent ability of a site to withstand shocks or disturbances before considering any active measures to increase resilience performance. Kassandra in this sense includes in its Resilience Index both the adaptive capacity of a site and active measures to increase the resilience level.

Climate resilience metrics require a context-specific approach that is essential for determining the project-level context of climate vulnerability and appropriate climate resilience priorities. Vulnerability and resilience could potentially be measured separately, taking into account that a resilient system is one where vulnerable elements are less present and the adaptive capacity is strongly acknowledged.

In this context the vulnerability as an internal or intrinsic risk factor (which is universally accepted) as envisaged by CVI could, if broadened to a much wider multidimensional approach, potentially be part of a Kassandra workflow, providing data to contribute to the static element of the Resilience Index.

Sources:
- https://cvi-heritage.org/
- Climate risk assessment for heart of neolithic Orkney World Heritage property. An application of the Climate Vulnerability Index, Historic Environment Scotland 2019

12.0 | CONCLUSIONS AND LESSONS LEARNED

12.1 Conclusions and recommendations

In general, the results point to a site that has considerable challenges, with areas and elements with lower resilience to climate change resilience, some of which are already known and have been confirmed by the data.

In particular, under a potential worst-case scenario such as RCP 8.5 (a high-emissions scenario is frequently referred to as “business as usual”, suggesting that is a likely outcome if society does not make concerted efforts to cut greenhouse gas emissions) there seems to be a particular low resilience to the effect of extreme weather events further and consequential risk of localised flooding and landslides which could put at risk the most significant heritage assets starting from the bridge and consequentially the Outstanding Universal Value of the site.

There is also a good indication that enhancing and diversifying tree cover with appropriate species could mitigate the risk of landslides and improve further other parameters, thereby raising the overall resilience index. Further studies would be required on both of these aspects.

A further recommendation would be that additional examination of specific focuses are required in areas of lowest resilience to identify more and better data, such as, for instance, the structure, materials and condition of individual heritage buildings, which was beyond the scope of this study.

12.2 Lessons learned

Kassandra is a live research and development project. The approach, methodology and software are constantly being updated and refined with every application and study carried out.

In the case of the outcome of this Pilot Study, we believe the initial research questions from our brief have been answered even if some results contain a higher margin of error than we would like due to insufficent data. This is a general problem that we are encountering, where information might indeed exist but is not readily available or obtainable. Having said this, the quality and quantity of data has been much better than with other projects we have done so far, and many more scenarios could still be carried out starting from what has been gathered.

In terms of approach and methodology, if we were to refine this, we would recommend starting with a workshop or series of workshops with all relevant stakeholders. We would also recommend to creating a working group with key people to be updated regularly as the study progresses. This is crucial to get insight from the local teams who have detailed knowledge of many of the aspects studied and would help break up the information silos that can sometimes exist between various parties.

We believe we have demonstrated the great potential of Kassandra has as an IDSS firstly as a data ‘consolidator’, which given the comment above is certainly important; secondly that Kassandra is a scalable and adaptable tool that can provide answers at both detail and strategic level when looking at climate resilience of a single element or a whole estate. Finally, we believe to have shown the usefulness and effectiveness of Kassandra as a data visualisation aid, capable of communicating very complex information in a direct and easily comprehensible way.

All this can surely provide the basis for better decisions, based on accurate data, which is, after all, the ultimate aim of Kassandra.

13.0 | NEXT STEPS

13.1 Next Steps

This Pilot Study on the Ironbridge Gorge World Heritage site aimed at illustrating the validity of the multi-disciplinary and interconnected approach that Kassandra proposes to improve climate change resilience and as a demonstration of the functionalities of the Kassandra Integrated Decision Support System.

Kassandra is a system that is both scalable and adaptable to different requirements and varying focuses. The Pilot Study could therefore be seen as the first iteration of analysis using the digital twin, based on the data that was made available for this limited study.

Much has already been done and the project could easily be expanded either in scope or geographically as the digital twin and analysis infrastructure already exists.

Historic England is working with Telford & Wrekin Council to develop next steps for the digital twin and potential future modelling. For example, the Coalbrook could also be modelled and analysed in order to understand the implications on the rapid risk catchment area.

Historic England is also involved in discussions with other sector organisations to promote the use of such tools for future resilience modelling.

Kassandra is developing its methodology and working with other heritage organisations to continue to develop the tool. A further development of the Kassandra web-viewer can be seen in the following page, illustrating some of the data analysed for Ironbridge WHS.
Next steps could be to run scenarios if more data was provided, or to expand the digital twin to include more data than was able to be included in the pilot.

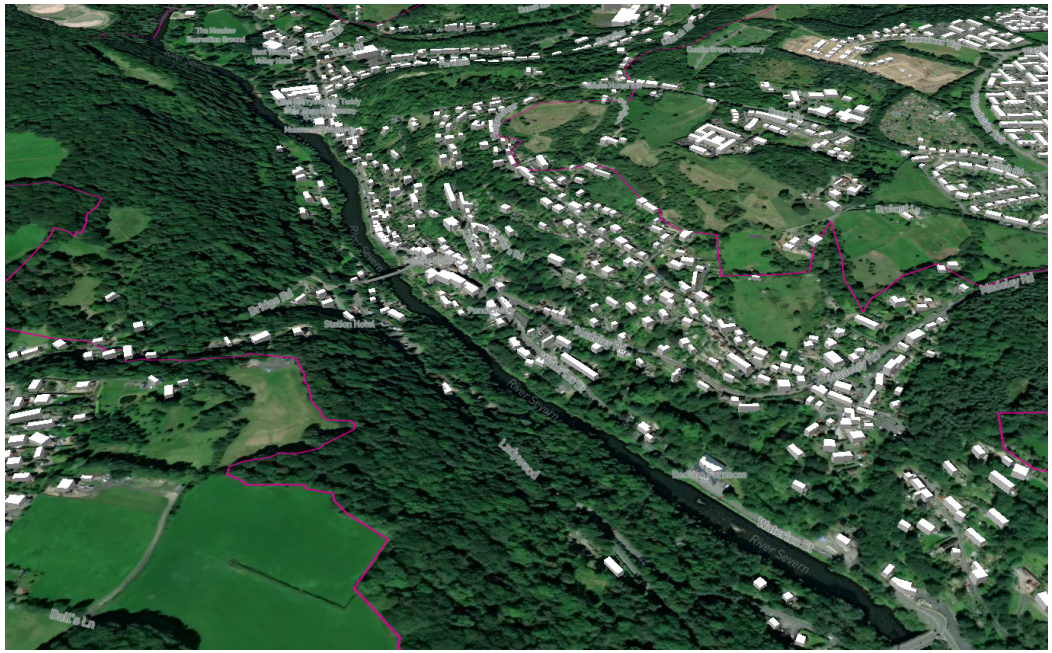
Data Gaps
Ideally it would be beneficial to bridge some of the gaps in data present to provide a more complete picture of the challenges that the WHS will face. In particular, considering the output from the scenarios, the parameters that would merit further analysis are:

- Buildings – Information on structure/materials/condition of individual built structures starting from Iron-bridge and the ones most at risk. This would be helpful to provide more precise scoring and to develop and verifying scenarios in which they might be able to be better protected from the effects climate change, thereby providing the basis for individual project brief.
- Environment – More precise information on the existing 'green' infrastructure that is present in the gorge including tree and shrub species would allows us to map more accurately the resilience from individual elements up to whole areas.
- Infrastructure – The resilience of infrastructure is key emergency situations, not only road infrastructure, but other services as well. Digital twins are very useful in the creation of emergency scenarios and the planning that derives from them.
- Waste – One of the effects of an increased population and more visitors is likely to be pressure on waste management and pollution risks. Having baseline information would be helpful to carry out scenarios looking at management options.

Wider issues
Some of the issues that affect the resilience of the Ironbridge Gorge WHS are not derived from factors within the Gorge itself. In particular the issue around flood management is unlikely to be able to be solved within the site apart from local interventions and it might be useful to consider a geographical expansion of the digital twin to encompass a wider area of the river Severn and provide a basis for scenarios and simulations.

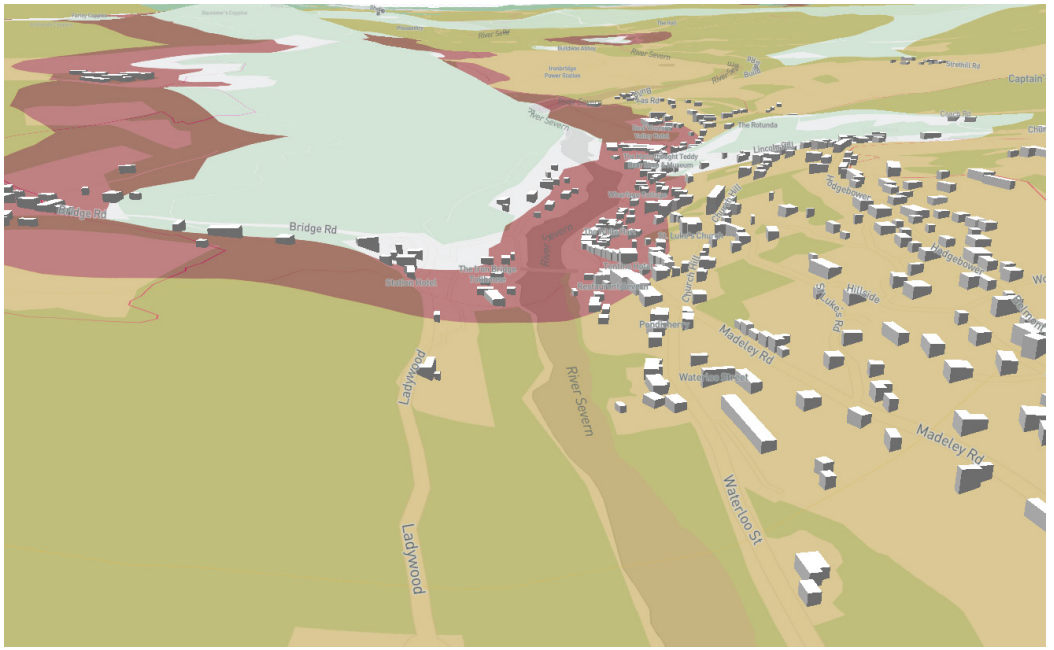
Parallel study
Determining climate resilience requires both a global and a context-specific approach that is essential for de-termining the project-level context of climate vulnerability and appropriate climate resilience priorities. This means that whilst the approach is general, many aspects of Kassandra might not be apparent as they are simply not present in Ironbridge.

A 'litmus test' of the Kassandra approach and methodology in dealing with WH sites would be to study a second very different site, perhaps a more 'urban' environment and comparing results; this would provide further corrobo-ration of the approach and a demonstration of the applicability of the system for instance across an estate in which the sites that may be very diverse and even geographically distant.


River Severn
Ladywood
Bridge Rd


Church Hill
River Severn
The Iron Bridge
The Wharfage
WHITE HART INN
HIGH STREET


Hodgebower
Church Hill
Lincoln Hill
The Rotunda
The Wharfage
River Severn
Bridge Rd


Bridge Rd
Ladywood
River Severn
Madeley Rd
Waterloo St

DATA COLLECTION & BIBLIOGRAPHY

WATER

- Environmental Agency Recorded Flood Outlines
- Ironbridge Gorge WHS Management Plan (April 2017)
- Environmental Agency Daily mean Flow Time
- Severn preliminary flood risk assessment
- Severn river basin district: River basin management plan
- Groundwater Vulnerability Map BGS Datasets

ENERGY

- Subnational electricity consumption, Great Britain, 2005 - 2020

HERITAGE

- Listed Buildings
- World Heritage Site
- Scheduled Monuments
- Historic Environment Records (HERs) – Historic England
- Climate for Culture: assessing the impact of climate change on the future indoor climate in historic buildings using simulations

DATA COLLECTION & BIBLIOGRAPHY

ENVIRONMENT

- Ironbridge Gorge Landslides Ironbridge and Coalbrookdale Ground Behaviour Study
- Severn Gorge Trust Plots Data
- Climate change: impacts and adaptation in England's woodlands (Duncan Ray, James Morison and Mark Broadmeadow)
- Projecting Tree Species Composition Changes of European Forests for 2061–2090 Under RCP 4.5 and RCP 8.5 Scenarios (Allan Buras, Annette Menzel)
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kassandra

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