# Resilient Edinburgh
# Climate Change Adaptation Framework
## For Edinburgh 2014 – 2020
### Evidence base and risk analysis

THE EDINBURGH PARTNERSHIP

SUSTAINABLE DEVELOPMENT




EDINBURGH WORLD HERITAGE





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EDINBURGH



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# INTRODUCTION

Climate change is one of the most serious threats facing Scotland and the world today. Due to past emissions, a certain degree of climate change is now unavoidable. Effects of changing weather patterns on Edinburgh will vary depending on the severity of global warming but, even when only a relatively modest increase in temperature is assumed, the impacts are likely to be significant. It is widely accepted that the effects of climate change are already being felt in Scotland.

A Climate Change Adaptation Framework for Edinburgh has been prepared, setting out Edinburgh's strategic approach to building resilience to the impacts of climate change. Climate change adaptation provides a unique opportunity for the Council and its citywide partners to work together to ensure that Edinburgh continues to be a climate resilient city.

This document provides the evidence base on which the Adaptation Framework is built. It summarises the background research that provided the reasoning behind the assumptions reached in the Framework, including the scientific evidence of past climatic change and predicted future climate trends for the East of Scotland, their impact on Edinburgh and the way essential services are delivered.

Finally the risks to the city from climate change impacts are assessed and graded.

The Evidence Base consists of three parts:

1. The predicted future climate change trends for the East of Scotland. These were extrapolated for Edinburgh.
2. A summary is provided of the results of a Local Climate Impact Profile (LCLIP) which was initially done in 2008 and updated in 2012. The LCLIP helped identify Edinburgh's key vulnerabilities to severe weather, the impacts and responses by the Council and key city stakeholders, and an assessment of what future climate change could mean for the city.
3. The potential risks to the city from these impacts were identified and weighted as to their likelihood and severity.

# PREDICTED CLIMATE TRENDS

## Global Climate Change

There is now scientific consensus that climate change is happening. The Intergovernmental Panel on Climate Change concluded that the "scientific evidence for warming of the climate system is unequivocal" (IPCC AR4, 2007). All major reconstructions of global surface temperatures show a warming trend over the last century, with most warming occurring since the 1970s and the ten warmest years on record after 1998 (NASA).

The global climate is changing with far-reaching implications for Scotland. Greenhouse gases already emitted into the atmosphere mean that some climate change is unavoidable regardless of future emissions.

## Climate Trends for the East of Scotland

The climate in the East of Scotland is set to get warmer and wetter. This will increase the risk of storms, flooding and the potential for extended periods of drought. As global average temperatures increase, we will also experience rises in sea level around the East Scotland coast.

The UK Climate Projections 2009 (UKCP09) provide the latest climate change scenarios for the UK. Some of the general trends for Scotland which can be drawn from UKCP09 are as follows:

- warmer, drier summers
- milder, wetter winters
- rising sea levels – the sea level in Edinburgh is projected to increase by 10 to 18cm by 2050 and 23 to 39cm by 2095.
- more very hot days – extremes of temperature increase in intensity as well as frequency
- more intense downpours of rain - extremes of precipitation increase in intensity as well as frequency
- snowfall will become less common.
- the growing season is now nearly 5 weeks longer in Scotland (1961 to 2004) with the greatest change occurring at the beginning of the season.

According to projections from current baselines, if we continue to discharge medium-high amounts of greenhouse gases into the atmosphere then, in the East of Scotland, it is possible that:

- average daily temperatures will rise between 1 and 2 degrees by the 2050s. The largest temperature increase, up to 2$^{o}$C will be in the winter months.
- summer rainfall will reduce by as much as 10% by 2050s.
- winter rainfall is predicted to show a consistent increase of up to 10% by the 2050s. Winters will be milder and wetter, with increased risk of storms and flooding.
- snowfall in Scotland will by the 2080s be 40-60% less. Around the East Scotland coast snowfall will reduce by up to 80%.
- weather patterns could become more extreme e.g. high temperatures recorded occasionally today could become the norm by 2080

- there will be a greater frequency and intensity of extreme events – storms, floods, heat waves and drought
- the growing season may become longer by between 20 and 60 days by 2080.

Effects of changing weather patterns on Edinburgh will vary depending on the severity of global warming, but even when only a relatively modest increase in temperature is assumed, the impacts are likely to be significant.

From the data, the following changes to Edinburgh's climate are predicted:

- warmer, drier summers
- milder, wetter winters
- extreme rainfall
- severe weather events
- rising sea levels

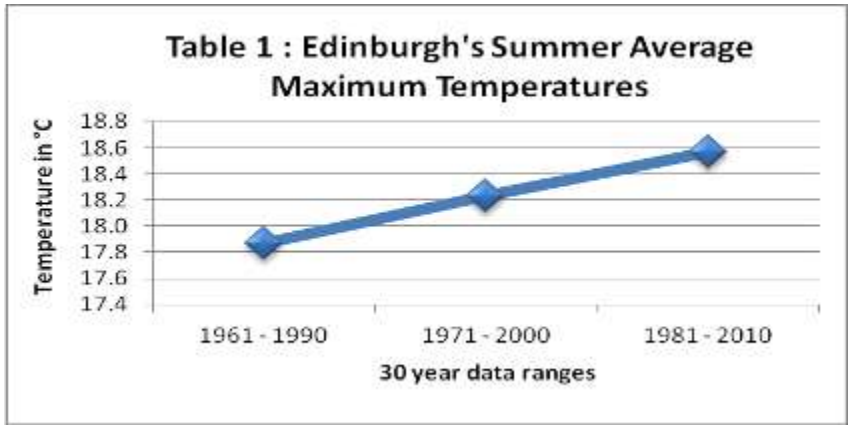
It is likely that the extreme weather events that Edinburgh is currently experiencing will become more frequent in the future.

## Warmer, Drier Summers

Weather predictions for South East Scotland show a distinct warming trend. Summers will be warmer, up to 1.4 $^{O}$C, and drier, with the potential for extended periods of drought.

Met Office data[1] shows a distinct warming trend for Edinburgh in line with climate change predictions. Table 1 shows a daytime temperature rise of 0.75 $^{O}$C comparing 1961-1990 averages with those of the 1981 to 2010 period.

As well as warming, climate change trends predict drier summers for South East Scotland, with periods of intense rainfall shifting from summer towards autumn.



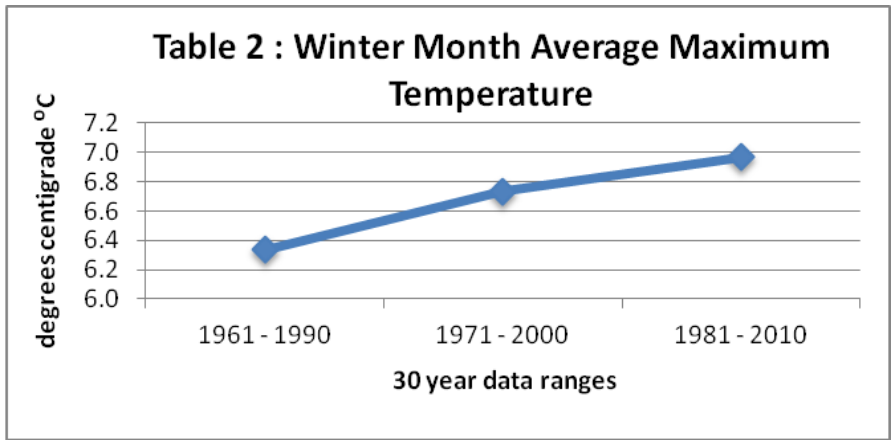

## Milder, Wetter Winters

Edinburgh's winters are predicted to become milder. The winter temperature data for Edinburgh from 1961 to 2010 (Table 2) shows a clear rising trend that is consistent with climate change predictions.

Weather data suggests Edinburgh is already experiencing up to 4% wetter winters, with increased rainfall intensity in autumn and winter.

[1] Met Office Climate Averages,

This trend towards wetter winters is expected to continue into the future. The wettest year on record at Edinburgh's Royal Botanic Gardens was 2008 with a total of 907.9mm (981.4mm in 12 months in 2007/08 or 141% of the average) [2].

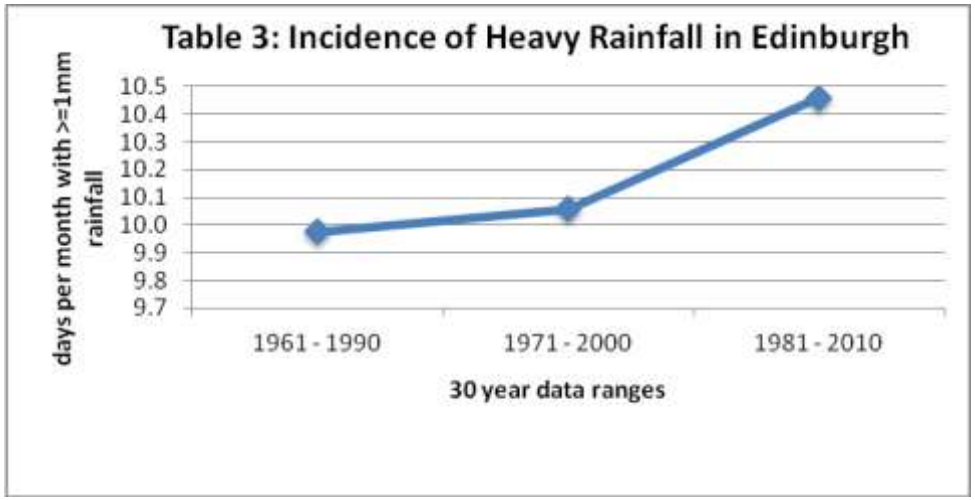



## Extreme Rainfall

The incidence of heavy rain (days when the quantity that fell was equal to or greater than 1mm) in Edinburgh has grown by 5% comparing the period 1961-1990 with that of 1981-2010, as in Table 3.

Rainwater volumes have also increased in Edinburgh over the same period. On average an extra 6mm of rain per month fell in the more recent period in comparison with the earliest one. The implications of this include greater potential for flash floods, rivers bursting their banks and drainage systems being overwhelmed in the city.

[2] Royal Botanic Gardens Edinburgh – Edinburgh Weather Station, webpage last updated 1 March 2012




## Severe Weather Events

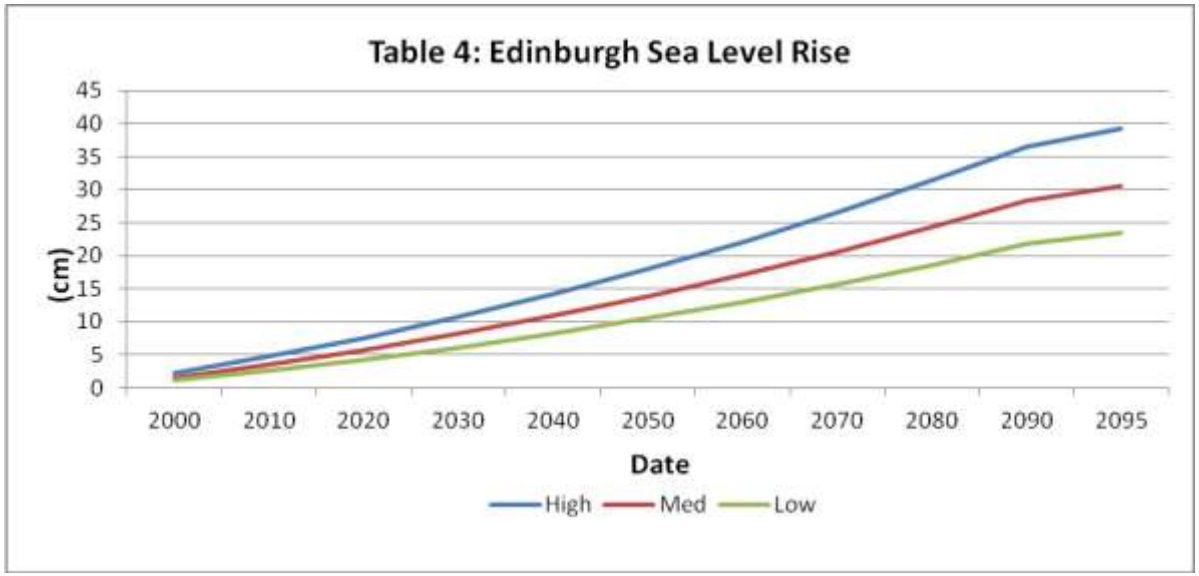
There have been high profile consequences of severe wind and storm events in Edinburgh in recent years. Edinburgh, in common with Scotland as a whole, is prone to severe gales in the winter months. The predicted trend is for a greater frequency of extreme events, including storms.

## Rising Sea Levels

As global average temperatures increase, we will experience rises in sea level around the coast. Two major factors contribute to sea level rise. Firstly, as the sea warms it expands. This is called thermal expansion. Secondly, melting of land-based ice adds further water to the world's seas.

While Edinburgh has suffered from a number of river floods, coastal flooding has not been a significant issue up to now. However there are concerns that climate change could lead to more widespread coastal flooding, resulting from a combination of rising sea levels,

increased frequency of storm surges, and rougher sea conditions. Table 4 shows UKCP09 projections for future sea level rise around Edinburgh's coast, based on the three scenarios of future levels of greenhouse gas emissions[3].




[3] UK Climate Projections – Sea Level Rise, updated 11 March 2011

# EDINBURGH'S LOCAL CLIMATE IMPACT ASSESSMENT

In 2012, the City of Edinburgh Council participated in an Adaptation Scotland pilot workbook for local authorities on climate change adaptation. Our Local Climate Impacts Profile (LCLIP) was updated as part of this process. The aim of a LCLIP is to help local authorities establish and prepare for the impacts of climate change and extreme weather events on the delivery of local authority services. The original LCLIP was compiled in 2008. The City of Edinburgh Council was one of four Scottish local authorities that took part in this Adaptation Scotland led project. The LCLIP now covers a 13 year period between 1997 and 2011.

Using existing regional research and recorded local weather events, the Council assessed the potential impact of climate change on its buildings, local infrastructure and the way it manages its services. The LCLIP provides an assessment of Edinburgh's vulnerability to extreme weather events.

Local authorities provide many services that will be affected by climate change. Climate change impacts – such as wetter winters, drier summers, increased flooding and extreme weather events – have implications for service areas including:

- emergency planning;
- waste collection and disposal;
- strategic and land-use planning;
- building control;
- estates management;
- protection and management of biodiversity and greenspaces;
- provision and management of leisure facilities and open spaces;
- events management
- transport infrastructure and fleet services;
- social services.

## Weather Data

Relevant weather data from 1997-2011 was researched to verify severe weather events described in media reports and service information. Data was supplied by the Royal Botanic Garden Edinburgh weather station[4], the Gogarburn Edinburgh weather station[5] and the Met Office website[6], and the online Weather Underground website[7] and the Climatological Observers Link[8] - an organisation for amateur meteorologists - were used as additional sources (though averages and records from these sites are not official values).

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[4] www.rbge.org.uk/science/plants-and-climate-change/edinburgh-weather-station

[5] http://www.tutiempo.net/en/Climate/EDINBURGH_GOGARBANK/31660.htm

[6] www.metoffice.gov.uk/

[7] www.wunderground.com/history/

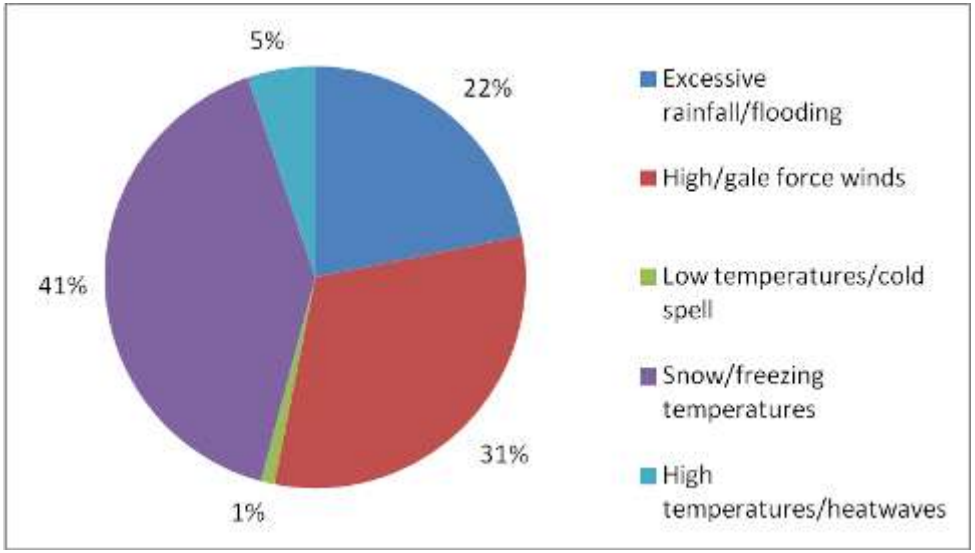
[8] www.met.rdg.ac.uk/~brugge/col.html

Correlation of media reports, service information and weather data enabled the assessment of the consequences of severe weather events for services.

## Media Search

- 472 media references to weather events and impacts were identified and recorded in the period 1997 to 2011.
- Media reports reflected the study area's urban character and Edinburgh's role as a major tourist centre
- Incidents of flooding, high winds and severe frost were the most regularly reported weather events with their associated impacts on infrastructure, property, transport movement, biodiversity and communities.
- Media reports not rated as highly relevant in identifying significant weather events included references to localised flooding, hot summer weather, warm weather and others that did not have an immediate consequence for services.
- Many media reports reiterated previously reported events and it was noted that there was increased reporting of weather events since the original LCLIP and a tendency in some media reports to sensationalise weather incidents. Some reports referred to weather warnings that did not materialise.
- A number of media reports referenced the perceived impact of "weather" (*e.g.* the hot summer of 2003, extended summer rainfall during 2007, the severe winter of 2011, the heatwave of September 2011 or short periods of torrential rain/downpours) on sporting, cultural and tourist events and visitor numbers.

## Weather events identified by Edinburgh LCLIP media search 2007-2011




The original LCLIP media search showed the increasing prevalence of precipitation-related severe weather events, in the form of excessive rainfall/flooding and frost/ice/snow.

The second LCLIP (2008-2011) found a major increase in severe weather incidents and impacts on Council services from snow and freezing temperatures. This is due to the severity of the winters of 2008/09 and 2009/10.

Specific incidents of excessive rain and subsequent flooding have also risen from 15% in the original LCLIP to 33% in the second. Incidents of high winds and gales have remained the same at 19%.

## Project Findings

The LCLIP found five types of weather event that impacted on the Council and the city:

- a warming trend;
- more frequent intense rainfall;
- extreme weather events;
- heavy snowfall and subsequent thawing
- other – including lightning strikes.

Over the first 10-year period (1997-2007) flooding and high winds were the most regularly reported weather events with their associated impacts on infrastructure, property and transport movement. From 2008-2011 (the period of the second LCLIP) incidents of intense rainfall, flooding, high winds and snow and thawing were the most regularly reported with associated impacts on infrastructure, property and transport movement. The severe winters of 2008/09 and 2009/10 in particular affected Council services. The Council's response to these extreme winter weather events was significant in terms of the resources deployed but, despite this, the city still experienced significant disruption. In response, a winter weather preparedness strategy and short-term measures were developed. These should reduce disruption caused by such severe weather events.

Other severe weather events had a more limited impact on Council services, principally because these services have already adapted or are planning to adapt. Impacts tended to result from infrastructure failure exacerbated by the weather. Emergency Planning arrangements were found to be effective for weather-related incidents both experienced to date and predicted.

### 1. Warming Trend

Weather data for South East Scotland shows a distinct warming trend[9] with the largest temperature increase (up to 2$^{o}$C) in winter months. Nine of the 10 hottest years on record have occurred since 2001, according to the Met Office's temperature data. However recent years have seen a spate of cold winters, with 2009-10 being recorded as the coldest in 31 years. This has caused major disruption to the city and to Council services.

### 1.1 Biodiversity

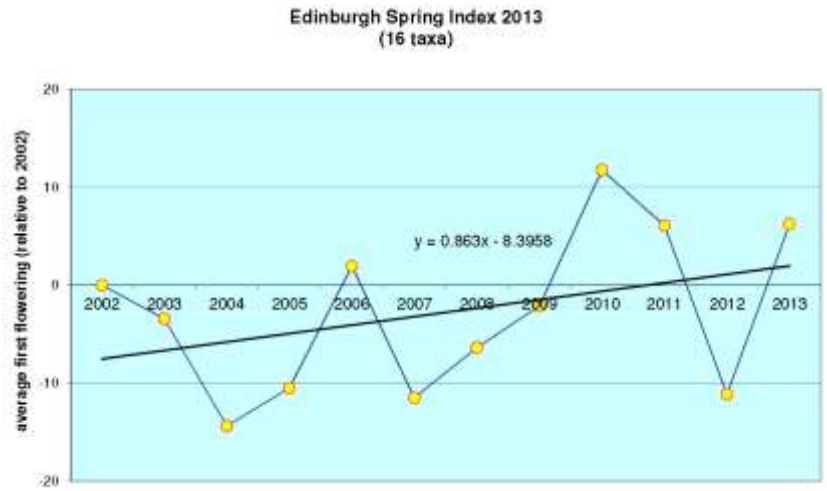
Climate change is having a direct impact on biodiversity in the UK. This is evident in the shift in timing of seasonal events such as budburst, flowering, egg laying and the arrival of migrant birds. Climate change is also acting as a further stress on some ecosystems already under pressure.

Nationally, a consistent warming trend is now associated with changes in the flowering and breeding patterns of wildlife. According to the Woodland Trust's Nature Calendar, Britain's native trees are fruiting on average 18 days earlier than 10 years ago. Flowers are coming into bloom in gardens and the countryside earlier, birds and animals are breeding earlier and their distribution is changing. In general, levels of bioproductivity may be increasing although the breeding success of individual species has been variable in recent years.

The Royal Botanic Gardens' 'Edinburgh Spring Index' provides

[9] *State of Scotland's Environment 2006* SEPA, Part D – Environmental Challenges, Figure C4: Change in mean temperature…1961-2004

further evidence of earlier flowering dates of all taxa flowering before the Spring Equinox, relative to 2013.




Climate change may be a contributory factor to the regular presence of kingfishers on the Water of Leith, and on other watercourses in Edinburgh, as the recent succession of mild winters will have supported recovery of the local population.

Climate change is thought to be partly responsible for other species extending their range into Edinburgh, such as the northward spread of the nuthatch. These insect-eating birds have recently bred in the Lothians for the first time and there have been an increasing number of sightings in Edinburgh woodlands, parks and gardens.

Some effects of a slowly warming climate are becoming evident in the delivery of Council services. The Edinburgh Local Biodiversity Action Plan 2010-15 (LBAP) includes a new section and various actions on climate change mitigation and adaptation.

A practical example of this is the work the Council is doing to protect and preserve the honeybee. One fifth of honeybee hives died in the winter of 2008/09. The causes of the current rate of loss are thought to be a combination of factors including climate change.

The LBAP is implementing a series of actions to: provide more bee-friendly plant species and habitat features; increase our knowledge of the city's bee species through recording; and, raise awareness of the decline in bee populations.

As projected trends in temperature and rainfall become more evident in Edinburgh some form of intervention or active management may be necessary to maintain the city's current natural habitats and wild species and to accommodate new species moving into the area.

### 1.2 Pests

Figures on the number of requests for local authority pest control services have been published by Audit Scotland for 2003 to 2005 only. These show that the total number of requests increased by 50% over that two-year period in Edinburgh, compared with a 19% increase for Scotland. However, this is a very short time period to draw any strong conclusions. The large number of requests in

2003-04 may partly be a reflection of the very hot summer in 2003.

Where the Council's pest control service used to deal sequentially with mice in the winter, ants in the spring, gulls in the early summer and wasps and bees in the summer they are now requested to deal with mice year-round, ants from January to September and gulls in the spring, with resulting pressures on staffing resources.

Recent warm summers have also led to a rise in Edinburgh of complaints about wasps with unusually large nests being formed due to the plentiful food supply of aphids and greenfly. Wasps are now the most frequently reported pests in Edinburgh, with requests exceeding those for mice in 2006-07. More conclusive evidence of trends for all pests will emerge as a longer data series builds up.

This may also be the case for other pest species. The longer growing season also means that city buildings are more likely to have some degree of fungal growth on walls and plant growth in gutters. Wetter winters may increase damp problems in Council housing and other properties.

Pest control figures need to be interpreted with caution as the rising trend may be affected by reduced tolerance on the part of the public, rather than (or in addition to) real changes in the frequency of incidents. Other factors may also influence the number of requests for Council intervention – for example, revisions to charging policies or the use of private pest control contractors.

There was a peak in mice and rat complaints in 2005-06, which was echoed in higher requests for private pest control services. This may have been related to rates of house building and other development, which disturbs existing populations and stimulates breeding.

Because of the warmer winters, the growing season now starts on average three weeks earlier than it did in 1961 and extends two weeks further into the autumn. The resulting increased bioproductivity has had significant impacts on pest control, grounds maintenance and management of green waste. The pattern, nature and severity of pest problems have meant a heavier workload for the Council's Pest Control service.

The Parks and Greenspace services were considering at the time of the initial LCLIP what adaptations would be required. These include how to go about replacing a tree stock that may come under increasing stress/disease and how to adapt maintenance regimes to the ever-lengthening growing season. One option that was under consideration was to naturalise a number of parks to reduce the need for regular and extensive mowing and provide habitats more suitable for species migration/conservation. This may free resources to extend grass cutting in those parks more suited to formal lawns.

### 1.3 Parks and Gardens

The extended growing season has resulted in increased green waste, affecting not only the green waste recycling service but also the parks maintenance teams who are responsible for routine tasks such as grass cutting. The Council through its Living Landscapes project is looking at ways to reduce green waste and allow greenspaces to return to a more natural state through reduced grass cutting and maintenance.

If the current warming trend continues consideration will need to be

given to adapting maintenance and watering regimes to suit longer, warmer, drier summers and to the choice of trees, shrubs and flowers planted in parks and greenspace across the city.

There are also implications for the city's biodiversity if a warming climate changes the current suitability of local habitats for wildlife and increases the occurrence of pests and diseases. The implications of climate change for pests and diseases in the city's parks and gardens are difficult to predict. This is because there is a fine balance between pests and disease-causing organisms and the trees, shrubs and flowers that they affect. The majority of insect pests affecting the city's gardens are likely to benefit from climate change as a result of increased summer activity and reduced winter mortality.

Climate change could have implications for the spread of well-known plant diseases such as Dutch Elm Disease. Warmer, wetter conditions could enable the beetles which carry the disease to complete more breeding cycles in a year. Until now, Edinburgh's relatively cool climate has been a factor helping to inhibit the spread of the disease. Similarly predicted warmer and wetter weather could help the spread of Acute Oak Decline and Ash Dieback, which is an example of how quickly a newly emerged disease can gain countrywide significance.

In addition, some insect pests that are currently present at low levels, or that are not considered a threat at this time, may become more prevalent. As the climate warms some pests may migrate into the city from more southerly parts of Britain.

Summer droughts and prolonged wet periods may adversely affect the health of many trees and shrubs currently planted across the city. This will increase their vulnerability to disease.

Because the impact of climate change on some pests and diseases cannot be predicted it will be important to maintain a high level of vigilance to ensure the continuing health of the city's parks and gardens, particularly during periods of environmental stress.

### 1.4 Property

The longer growing season means that city buildings are more likely to have fungal and plant growth in gutters etc. This combines with more frequent instances of heavy rainfall to impact on building maintenance, particularly as regards historic buildings.

An increase in wet and dry weather cycles is going to accelerate stone decay. As the majority of buildings in central Edinburgh are stone, this would impact on the integrity of the historic urban fabric and could potentially pose a risk to passersby as well.

## 2. Extreme Rainfall and Flooding

Weather data suggests that Edinburgh is experiencing progressively drier summers and wetter winters, with increased rainfall intensity in autumn and winter. The period of most intense rainfall appears to be shifting from summer towards autumn. This trend toward drier summers and wetter winters is expected to continue into the future.

This is shown in the LCLIP, at least in relation to wetter winters and increased rainfall intensity in the autumn. However, instances of intense and prolonged summer rainfall have caused localised disruption and damage, with flooding resulting from a combination of surface water and surcharged drainage.

The wettest year on record at Edinburgh's Royal Botanic Gardens was 2008 with a total of 907.9mm (981.4mm in 12 months in 2007/08 or 141% of the average) and the wettest month has been August 2008 with 202.3mm; that is 326% of the average for August (230.6mm in a 31 day period in July/August 2008).[10]

Heavy rainfall has caused significant disruption to the city in recent years. The East of Scotland has seen an increase in average rainfall intensity by 7.6% on 1961 levels[11].

Extreme rainfall, often resulting in flooding from a combination of surface water and surcharged drainage, has led to localised disruption and damage. Localised flooding has an impact on infrastructure, property and transport movement, leading to road and rail closures, and damage to homes and businesses. Impacts tend to result from infrastructure failure exacerbated by the weather.

The East of Scotland has seen an increase in average rainfall intensity (*i.e.* mm per day) by 7.6% on 1961 levels[12].

In April 2000 severe weather caused widespread flooding. Very wet weather accompanied by strong north-easterly winds brought floods to north-east Scotland. This caused flooding throughout Eastern Scotland, and Edinburgh was one of the most severely affected areas. A total of 112mm of rain fell over 48 hours. The monthly average rainfall in Edinburgh for April is 42.2mm. River flows were the highest ever recorded on the Water of Leith and the Braid Burn.

The flooding affected some 750 residential and business properties in the Edinburgh area including Murrayfield Stadium, two residential care homes and a school. Scottish Fire and Rescue Service received over 500 calls - 296 within a six-hour period.

Firefighters evacuated more than 150 people from their homes, including nearly 100 elderly residents from nursing homes in the Gorgie and Peffermill areas of the city. Around 700 Council staff worked to reopen flooded roads, clear mud and debris from roads and pavements and respond to calls from residents. 8,000 sandbags were filled to minimise the damage. 2,500 people lost power when an electricity sub-station was engulfed by more than a foot of water. Several main roads throughout the city were closed, including an eight-mile stretch of the city bypass. Later in the same year, on 8 November, four houses were flooded and a flood alert was initiated resulting in emergency flood works.

The costs of flood damage at the time were estimated at £25 million. The immediate cost to the Council was estimated at just over £1 million for land drainage works and repairs to highways, removing fallen trees and debris plus the evacuation of a care home. In 2001 the Council received Scottish Government funding of £150,792. This grant reimbursed the Council for the immediate costs of ensuring public safety after the two flooding incidents in 2000.

[10] Royal Botanic Gardens Edinburgh – Edinburgh Weather Station - http://www.rbge.org.uk/science/plants-and-climate-change/edinburgh-weather-station, webpage last updated 1 March 2012

[11] *Handbook of Climate Trends* SNIFFER January 2006 – Precipitation related variables, Table 19: Changes in average rainfall intensity

[12] *Handbook of Climate Trends* SNIFFER January 2006 - Precipitation related variables, Table 19: Changes in average rainfall intensity

While major flooding events such as that experienced in April 2000 are rare, climate models predict more prolonged and intensive periods of rainfall. In 2006 the council published a flood risk strategy[13] to plan ahead and the council's State of the Environment Audit 2008[14] brings together a wide range of evidence on recent environmental trends.

## 2.1 Water of Leith and Braid Burn

Edinburgh has also suffered from riverine flooding in recent years. An estimated £25m worth of damage to around 600 homes and businesses was caused when the Water of Leith and the Braid Burn burst their banks in 2000.

Much of the burn's natural flood plain has been constrained by residential development. It had burst its banks five times in the last 16 years. One of the most recent example occurred in August 2008 leaving Old Dalkeith Road and Inch Park flooded, with localised flooding in residents' gardens.

[13] *Flood Risk Strategy for the City*, City of Edinburgh Council Executive, 14 November 2006

[14] *Edinburgh's Environment: State of the Environment Audit Baseline Report* The City of Edinburgh Council May 2008

After April 2000 the Council decided to progress two major flood prevention schemes along the Water of Leith and the Braid Burn. Both schemes are funded by the City of Edinburgh Council and the Scottish Government.

The Water of Leith Flood Prevention Scheme comprises a series of walls and embankments along the river banks to protect properties from flooding. There are other associated works such as landscaping, pumping stations and drainage. Upstream storage has been created. This has the benefit of reducing high flows during storms. As funding was not available to implement the Scheme in full, it was agreed to deliver it in phases. Phase 1 is largely complete. Proposals for Phase 2 are currently under review.

The Braid Burn Flood Prevention Scheme was completed in October 2010 and provides protection to approximately 900 properties. It comprises physical defences in the form of flood walls and embankments at vulnerable locations along the route. Two temporary flood storage reservoirs have been constructed at Inch Park and Peffermill. These will hold back water in the event of a flood and allow it to flow back into the burn as flood water levels fall. At Inch Park, more than £100,000 was spent on environmental improvements, including hundreds of trees and thousands of shrubs, with reed beds designed to create a habitat for waterfowl.

The Council has also identified unbuilt areas of land which fulfil an important flood function and which should be allowed to flood in order to protect other, built-up areas from floodwater. These are shown on the Edinburgh Local Development Plan Proposals Map as areas important for flood management.

## 2.2 Balcarres Street

Since 2000, mainly short duration storms or periods of extensive

rainfall have led to a number of localised flooding incidents, due to excess surface water and surcharged/choked sewers, drains and culverts. Flooding caused by blockage is more frequent in many locations than that caused by severe weather.[15]

Two of the most recent incidents took place in the Morningside area of the city in 2011. The flooding was a result of exceptional adverse weather conditions.

On 8 July there was severe flooding due to thunderstorms over Edinburgh. 36mm of rain was recorded in two hours at Bonaly, the seasonal average for July is 5.6mm. On 17 October the severe weather resulted in an intense downpour for about four hours. A maximum rainfall of 20 mm over a two hour period was recorded again at Bonaly.

The intensity of rainfall exceeded the amount the drainage systems could be expected to take without above ground flooding. The significant localised flooding which occurred as a consequence was not caused by any defects in the drainage systems or faults in its maintenance. Business premises and homes were flooded, and flooding of the road led to damage to cars, waste bins and travel disruption. Surface water ran down through gardens, round houses and collected in basements and back gardens causing damage on Greenbank Road.

Surface water from a large area of Morningside runs downhill and collects at the low point in Balcarres Street. The layout and level of the buildings on the street has resulted in a development that is vulnerable to flooding of this kind, and leaves limited options to improve the situation. The drainage system in place is known as a combined sewer which carries foul and storm water. The sewer system has had problems downstream and the only surface water outlet is the Jordan Burn culvert, which has limited capacity. The sewer is the property of Scottish Water.

Since it is not possible at present to prevent flooding in all circumstances, and since it is likely to be some time before a permanent improvement could be achieved, it was recommended that the Council provide flood defense equipment to help householders in Balcarres Street. The estimated cost at the time of supplying and installing temporary flood defense products and improving gullies was approximately £30,000 and was met from existing Flood Prevention Revenue and Roads Capital Budgets.

Specific short term actions include the procurement and installation of dismountable defenses.

Any permanent solution is likely to involve significant investment and can only be developed through cooperation between the Council and Scottish Water under the process set out by the Flood Risk Management (Scotland) Act 2009. There is now a duty on both parties to work together to develop solutions and Flood Risk Management Plans. The Council has carried out a pluvial flood risk screening study which identifies which areas are at risk.

While major flooding events are rare, climate models predict more prolonged and intensive periods of rainfall. Local Flood Risk

[15] *Flood Assessment Reports*, City of Edinburgh Council, 2001, 2003, 2005, 2007

Management Districts are currently being established to produce a Flood Risk Management Plan for the Forth Estuary District. It is likely the Council will be the Lead Authority for the District and will be required to produce a Plan for the District, in co-operation with Scottish Water and the other authorities by December 2015. The Plan must show the measures which are required to deal with flooding from all sources.

The Council has already carried out modelling work which indicates the areas at risk of flooding from surface water. Scottish Water is due to start modelling work in all the major cities to develop measures to address sewer and surface water flooding. This will be carried out in conjunction with the Local Authorities, who may be expected to contribute to the costs. However it is recognised that it is not economically possible to prevent flooding of roads in all events, especially in areas like Balcarres Street where the urban area has expanded while still draining into old systems.

### 2.3 Coastal Flooding

Climate change could lead to more widespread coastal flooding, resulting from a combination of rising sea levels, increased frequency of storm surges, and rougher sea conditions. Research by the Scottish Environment Protection Agency (SEPA) indicates that areas of Leith are at risk from high sea levels and storms surges.

A severe storm surge in 1953 inundated many coastal areas of South-East England and the Netherlands with devastating consequences. This raised water levels by 2.97 metres at Kings Lynn, although in Scotland the uplift was considerably smaller – just 0.82 metres at Leith, for example. Nevertheless, climatic change is likely to generate more frequent and more severe storms of this type.

In late March 2010 the East of Scotland was hit by a storm comprising easterly gales, heavy rain and blizzards. A tidal surge coincided with the highest spring tides of the year. The Firth of Forth was worst affected, damage being caused to the coast of Edinburgh, Fife and East Lothian. In Edinburgh there was storm damage to coastal defences from Cramond through Portobello to Eastfield. Work to ensure damaged areas were made safe involved a significant response from a range of Council services, all met out of Council budgets. This work is not eligible for Central Government support under the Bellwin Scheme or at a level to be paid by the Council's Emergency Funds. £214,000 of the estimated cost was met by the Council's Services for Communities Department and £344,000 by City Development capital budgets. A number of infrastructure projects were delayed in order to accommodate the additional expenditure within the Coast Protection budget. An estimated £23,000 worth of damage was caused to private property.

In early January 2014 SEPA issued a warning that high tides coupled with a storm surge would affect the Forth estuary and may affect low lying areas. While this did not materialize, it did result in some localised flooding.

Rising sea levels and storm surges will increase the risk of flooding in low-lying areas. Future climate scenarios predict sea level rise relative to the land in some areas; by 2080 the current estimates range from between 0 and 600 mm sea level rise, leading to increased risk of flooding around Scotland's coasts. Although Edinburgh has escaped significant coastal flooding, the risk cannot be ignored. Due consideration must be given to minimising the risk to existing and future developments in low-lying coastal areas – especially to the most vulnerable groups of people and to the most vulnerable land uses (*e.g.* essential public infrastructure). The

effects of rising sea levels on coastal habitats and sites of natural and cultural interest also need to be taken into account.

Under the Coast Protection Act 1949 the Council has a duty to ensure coastal defences are inspected regularly and repair work is carried out as required. The Council has ownership of the coastal defences between Cramond and Newhaven and Seafield and Joppa. It identifies and carries out repairs to these sections of the coast, within available resources and funding. The type of coastal work carried out includes maintenance or repair works to damaged sea walls, land acquisition by compulsory purchase, prohibition of excavation or removal of any materials from the seashore and making contributions towards the costs of others carrying out coastal protection work. The Council also works closely with Arcus to manage water levels in Leith Docks during high tides. The Water of Leith must be able to discharge enough flood water into the sea to prevent flooding occurring further upstream.

The cost to the Council of coastal defence essential repairs over the period 2008-2011 was estimated at £740,000. Repair and maintenance works are not eligible for grant assistance from the Scottish Government. However new works have to be promoted as a coast protection works scheme, and may be eligible for grant assistance.

The Council supports the Forth Estuary Forum's approach of pursuing an integrated approach to coastline management. This will entail the production of a Shoreline Management Plan by 2015, which will provide guidance on the maintenance of coastal defences and the control of development along the coast.

## 3. Extreme Weather Events

There have been a number of high profile impacts resulting from severe weather events in Edinburgh in recent years, including the cancellation of the Hogmanay celebrations, closure of the Winter Wonderland in Princes Street Gardens, damage to infrastructure and biodiversity, street closures due to falling masonry and trees, and loss of revenue to business. Edinburgh, in common with Scotland as a whole, is prone to severe gales in the winter months. Over recent years, some weather data gathered on the Forth Road Bridge indicates that high wind events have increased over the very short term[16]. Climate change trends predict a greater frequency of extreme weather events rather than a change or increase in the severity of strong or gale force winds.

In 2006 Edinburgh's Hogmanay Street Party was cancelled in the interests of public safety due to storm-force winds and heavy rain in the city centre. Wind gusts of 92mph were recorded. The total cost of the cancellation of the Street Party was met by £2 million worth of insurance cover – a learned outcome from the cancellation of the 2003-04 event due to similar adverse weather conditions.

Strong winds during December 2006 caused the cancellation or closure of some of Edinburgh's Christmas festivities. Edinburgh's Winter Festivals attract a local, national and international audience with an estimated economic impact of over £33 million. They are funded through a variety of sources including the Council's revenue budget, commercial sponsorship and income generation. The reported success of the 2007-08 Winter Festivals demonstrated that

[16] *Edinburgh's Environment: State of the Environment Audit Baseline Report* The City of Edinburgh Council May 2008

Edinburgh's Hogmanay recovered well following the cancellation of the previous year's Street Party. Public and marketing confidence are of vital importance to the success of such high profile events indicating the need to plan for events that are weather resistant.

In April 2010, fallen trees caused road closures and traffic disruption while the debris was removed. Falling scaffolding and loose tiles led to the closure of an area of the High Street and the Royal Mile was closed after a 60ft tree fell on a car and masonry fell onto the street.

In May 2011, high winds caused the closure of Edinburgh bus station, the Forth Road Bridge, the Zoo and Botanic Gardens as wind gusts exceeded safety levels. Princes Street Gardens were closed due to safety concerns about falling branches. The Forestry Service responded to over 350 emergency tree incidents involving hundreds of fallen and damaged trees. With the support of Roads Services, Ranger Services and neighbourhood task force teams, roads and pedestrian walkways were kept open and safe throughout this period. A major clear up phase was completed by the end of June.

In December 2011, high winds again led to the closure on safety grounds of Edinburgh Castle, the Forth Road Bridge, Edinburgh Zoo, the Botanic Gardens and Princes Street Gardens Winter Wonderland. Roads were closed because of falling debris and trees, there was further travel disruption and double decker buses were taken off the road. Fallen masonry led to the closure of a city centre street, cars and property were damaged by debris from roof and chimney stacks, offices and schools were closed early and police advised against non-essential travel in the afternoon.

The Council's Shared Repairs Service provides an emergency service to deal with situations where there is a risk to public safety or public health. The Council can use its legal powers to issue a statutory notice and carry out the emergency repair. When particularly bad weather is forecast by the Met Office extra provisions are made.

## 4. Winter Weather Preparedness

Edinburgh experienced two bouts of particularly severe winter weather in 2009/10 and 2010/11 including the coldest average daily temperatures since 1947 and the highest number of days with snow lying since the winter of 1963. December 2010 was reported as the coldest since Met Office records began.

The severe weather emergency in December 2009 to January 2010 was considered to be exceptional in terms of volume of snow, low temperatures and overall duration. This severe weather was reported as the worst in decades. Prior to the severe weather of 2009-10, the Council had a relatively stable response to winter weather conditions. The established gritting fleet and routes worked well and because there were few prolonged spells of severe weather, additional resources from outwith the Council were never considered.

This severe winter weather caused major disruption to the city and to Council services. The Council's response to these conditions was

very significant in terms of the resources deployed but, despite this, the city experienced significant disruption. The Council's response developed significantly over these two winters.

For 2009-10 a number of unprecedented steps were taken in order to augment the normal response. This included:

- redeployment of further staff from non-essential work
- use of those serving Community Service Orders
- deployment of contractors on an emergency basis
- provision of food parcels for vulnerable people
- contact arrangements to keep in touch with vulnerable people
- targeting of snow-clearance resources to schools, care homes and other important sites
- use of 4x4 vehicles to enhance access for care and support services for vulnerable people

As a result of these additional measures there were typically 350 people deployed on snow clearing duties.

Following a report in May 2010, the Council invested in a further eight mini-tractors and secured five additional lorries capable of being converted for winter maintenance work. These measures significantly enhanced the fleet at minimal extra cost. Additionally, the Council's salt storage capacity was increased by 38% so that before the winter period began, the Council had some 7,215 tonnes of salt in storage.

A tailored "Severe Weather Emergency Plan" was developed and implemented in November 2010 following heavy snowfall. As a result the Council's response was more formally managed during those early days than during the previous winter. Of particular significance was the speed with which private contractors were deployed – within two days of the first snowfall. The Council's response included all the measures listed above, augmented by:

- The number of people on snow-clearing duty increased from 350 to 650 largely due to enhanced use of private contractors, and the additional plant, vehicles and equipment.
- Military assistance was requested and provided for a short period in December 2010.
- Exceptional measures were taken to relieve measures in relation to refuse collection. These included permission to use garden waste containers for domestic waste, distribution of over 40 skips and large containers to supermarket car parks etc across the city and hand collection of refuse sacks in some hard-to-reach areas.
- Use of grit-dumps to maximise availability of grit in areas where permanent grit bins could not be reached or where demand was particularly high.
- The securing of additional salt supplies from the Scottish Government's strategic reserve.
- The communications plan was intensified with daily Member's Briefings throughout the period, supplemented by more detailed briefings from Neighbourhood Managers and significant usage of Twitter and other social media.

## Lessons Learned

- This severe winter weather caused major disruption to the city and to Council services. The Council's response to these conditions was very significant in terms of the resources deployed but, despite this, the city experienced significant disruption. The Council's response developed very significantly over these two winters. However some communities nevertheless experienced significant disruption.
- A key factor in carrying out any review of the Council's preparedness for severe winter weather is to assess the likelihood of similar events recurring in future years. This is impossible to predict at the moment. Met Office records show these two winters reversed a trend of nearly 10 years of milder winters.
- A "just-in-time" approach is not feasible if a trend of freezing winters were to develop. Financial resources were not the constraint limiting the Council's response, rather the scale of the response was constrained by the availability of plant, vehicles, equipment and manual labour. When Edinburgh experiences severe weather, it is highly likely that much of Scotland will be facing similar conditions (or much of the UK). In these circumstances, the supply of plant etc is quickly exhausted. There are also significant challenges in deploying a large manual labour force quickly – so this too needs to be planned in advance. Salt supply also needs to be taken into consideration.
- A Corporate Severe Weather Resilience Plan was developed. It details the Council's arrangements for responding to any form of severe weather emergency and to ensure the continued delivery of essential Council services during periods of severe weather and their aftermath.

## 5. Further Work

Edinburgh World Heritage, together with climate scientists and conservation experts, are working on a climate modeling tool for the whole city. This tool could be applied to other cities to assess risks and impacts on the built fabric, particularly in their historic centers, to help understand future climate impacts and develop an effective adaptation strategy.

# KEY CLIMATE RISKS FOR EDINBURGH

Effective climate risk management requires that the likelihood and consequences of impacts are understood and assessed at the service delivery level within local authorities. The Council's Local Climate Impacts Profile is a step towards identifying potential threats. To further this process, a high level analysis of existing climate risks for Eastern Scotland has been conducted, based on the known climate trends outlined in this Framework and the existing service responsibilities of the Council. This should act as a precursor to more rigorous service-based risk assessment and will be vital in identifying and developing appropriate actions for responding to the climate risks. Following guidance in Adaptation Scotland's Adaptation Workbook for Local Authorities risk is determined by a climate change impact's likelihood and impact.

## Likelihood

| Likelihood | Score | Recurrent Impact |
|---|---|---|
| Rare | 1 | Unlikely to occur during next 25 years |
| Unlikely | 2 | May arise once in 10 to 15 years |
| Possible | 3 | May arise once in 10 years |
| Likely | 4 | May arise about once a year |
| Almost Certain | 5 | Could occur several times a year |

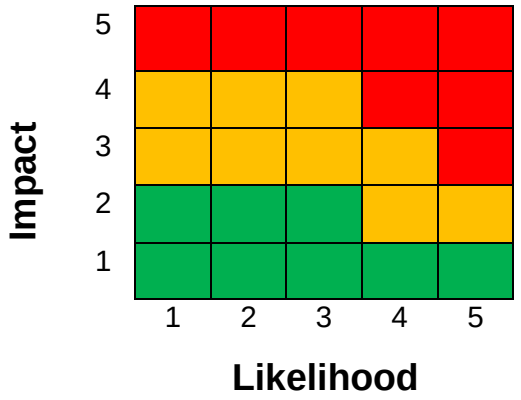
## Impact

| Impact | Score | Nature of Impact |
|---|---|---|
| Negligible | 1 | Appearance of threat but no actual impact on service provision |
| Minor | 2 | Isolated but noticeable examples of service decline. Minor environmental damage |
| Moderate | 3 | Service provision under severe pressure. Appreciable decline in service provision at community level. Isolated but significant instances of environmental damage that could be reversed. Small number of injuries |
| Major | 4 | Services seen to be in danger of failing completely with severe/widespread decline in service provision and quality of life. Severe loss of environmental amenity. Isolated instances of serious injuries |
| Catastrophic | 5 | Widespread service failure with services unable to cope with wide-scale impacts. Irrecoverable environmental damage. Large numbers of serious injuries or loss of life |

## Assessing risk

Once the risk has been scored it will fall within one of these areas, where, as an indicator:

- **red area** requires urgent attention
- **amber area** requires active management
- **green area** is acceptable, subject to monitoring



| | Climate Change Impact | Likelihood x Impact | Risk | Climate Change Impact | Likelihood x Impact | Risk |
|---|---|---|---|---|---|---|
| Property and Housing | Warmer, Drier Summers | | | Milder, Wetter Winters | | |
| | Increased energy consumption for cooling | 5 x 2 | | Building damage | 5 x 2 | |
| | Increased growth pest infestations and vermin | 5 x 2 | | Reduced heating demand | 5 x 2 | |
| | Increased 'heat island' effect | 5 x 2 | | Dampness/mould issues increase | 5 x 2 | |
| | Increased bioproductivity promotes growth of problem species e.g. buddleia | 2 x 4 | | Increased pest infestations and vermin | 5 x 2 | |
| | Increased water demand | 5 x 1 | | | | |
| | Damage to buildings/fittings due to subsidence and heave | 2 x 2 | | | | |
| | Severe Weather Events and Extreme Rainfall | | | Sea Level Rise | | |
| | Building damage | 5 x 4 | | Damage to sea defenses | 1 x 1 | |
| | Increased vulnerability of key heritage and cultural assets to damage | 5 x 4 | | Flooding/damage to coastal property and possible loss of property value | 1 x 1 | |
| | Increased insurance costs | 5 x 4 | | Increased vulnerability to storm surges | 1 x 2 | |
| | Increased incidence of inundation and flood damage | 5 x 4 | | | | |
| Land Use Planning | Warmer, Drier Summers | | | Severe Weather Events and Extreme Rainfall | | |
| | Policy response to enable local wildlife to adapt better to climate change. Planning must make it easier for species to move through the landscape to new habitats | 5 x 3 | | Design guidance to ensure developments will be built to withstand increased rainfall, more intense rain storms and more frequent flooding, including from surface water | 5 x 4 | |
| | New building design requirements in response to excessive summer temperatures and increased 'heat island' effect | 5 x 3 | | Development and strategic planning responses to ensure increases in rainfall intensity will result in changes and improvements in fresh and waste water infrastructure | 5 x 4 | |
| | Enabling policies required to reduce pressure from increased tourism and recreational demand | 5 x 3 | | Measures such as flood and coastal defences and enhanced drainage systems will be required to reduce risk posed by flooding. | 5 x 4 | |
| | High development churn rates due to subsidence and heave | 2 x 2 | | Disruption to transport – minimise need to travel through better town planning | 5 x 4 | |
| | Sea Level Rise | | | Disruption of services – decentralise provision of energy and water supplies | 5 x 4 | |
| | New and existing developments close to coast may need to be adapted | 5 x 2 | | More flexibility in choice of building materials and designs may be required | 5 x 3 | |
| | Development Plans will need to reflect impact of long term sea level rise | 5 x 2 | | | | |

| | Climate Change Impact | Likelihood x impact | Risk | Climate Change Impact | Likelihood x Impact | Risk |
|---|---|---|---|---|---|---|
| Road Services and Transport | Warmer, Drier Summers | | | Milder Wetter Winters | | |
| | Failure of essential road infrastructure e.g. melting tarmac | 5 x 2 | | Increased road deterioration | 5 x 3 | |
| | Extreme Weather Events and Extreme Rainfall | | | Failure of drainage infrastructure | 5 x 3 | |
| | Failure of drainage infrastructure | 5 x 4 | | Disruption to work programmes and operational issues caused by water logged ground conditions | 5 x 3 | |
| | Increased incidence of localised and widespread flooding | 5 x 4 | | | | |
| | Increase road deterioration | 5 x 3 | | Sea Level Rise | | |
| | Disruption to work programmes and operational issues caused by waterlogged ground conditions | 5 x 3 | | Failure of coastal defences | 3 x 2 | |
| | Increased number of emergency call-outs | 5 x 4 | | Storm surge inundation | 3 x 4 | |
| | Significant increases in maintenance costs/requirements for new infrastructure | 5 x 3 | | | | |
| | Economic and reputational ramifications of major transport disruption to Edinburgh | 5 x 2 | | | | |
| Biodiversity and Greenspace | Warmer, Drier Summers | | | Milder, Wetter Winters | | |
| | Trees, vegetation and grass in parks and open space dying during prolonged periods without rainfall | 4 x 2 | | Habitat changes | 5 x 3 | |
| | Deterioration in river and wetland environments | 4 x 2 | | Severe Weather Events and Extreme Rainfall | | |
| | Reduced water quality | 4 x 2 | | Damage to vegetation and trees | 5 x 4 | |
| | Increased fire risk – grasslands and moorlands | 4 x 2 | | Mature trees liable to be blown down during storms with potential to cause damage or injury, road traffic accidents and road closures. This will be especially important if storm events occur during prolonged wet spells in summer months when broadleaf trees are in leaf. | 5 x 4 | |
| | Longer growing season | 5 x 3 | | | | |
| | Species and habitat stress | 5 x 3 | | | | |
| | Introduction of new species | 5 x 3 | | Deterioration of public parks | 3 x 4 | |
| | Damage to tree roots – subsidence and heave | 5 x 3 | | Increased soil erosion and land instability resulting in increased risk of landslides and accelerated coastal erosion | 3 x 3 | |
| | Deterioration in river and wetland environments | 4 x 3 | | | | |

| | Climate Change Impact | Likelihood x impact | Risk | Climate Change Impact | Likelihood x impact | Risk |
|---|---|---|---|---|---|---|
| **Environmental and Community Health** | Warmer, Drier Summers | | | Milder, Wetter Winters | | |
| | Changes in incidence of vector borne diseases | 5 x 4 | | Increased risk of mould and fungal illness and associated respiratory problems | 5 x 4 | |
| | Increased risk of heat stroke, dehydration and respiratory problems | 5 x 4 | | Higher levels of air pollution when there is no wind | 2 x 4 | |
| | | | | Severe Weather Events and Extreme Rainfall | | |
| | Increased incidence of food poisoning | 5 x 4 | | Public health and safety risks increase | 5 x 4 | |
| | Reduced water quality – sea, river and standing water | 5 x 4 | | Disruption to essential community services for vulnerable individuals | 5 x 4 | |
| | Increase in air particulates leads to worsening air quality | 5 x 4 | | Long- term mental health issues | 5 x 1 | |
| **Waste Services** | Warmer, Drier Summers | | | Milder, Wetter Winters | | |
| | Changes in incidence of vector borne diseases | 5 x 4 | | Increased pest infestations and vermin | 5 x 2 | |
| | Increased pest infestations and vermin | 5 x 2 | | Potential for leachate escape from landfills and contaminated land | 2 x 1 | |
| | Increased odour issues | 5 x 2 | | | | |
| | Increased bioproductivity promotes green waste volume | 2 x 4 | | Sea Level Rise | | |
| | Severe Weather Events and Extreme Rainfall | | | Loss of recycled materials | 5 x 4 | |
| | Lost work days | 5 x 4 | | Increased insurance and repair costs | 5 x 4 | |
| | Disruption to transport and supplies | 5 x 4 | | Increased vulnerability to coastal landfills and contaminated land | 1 x 1 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Economy | Warmer, Drier Summers | | | Milder, Wetter Winters | | |
| | Increased demand for outdoor events | 5 x 3 | | Changes in demand for weather related goods/services | 5 x 2 | |
| | Additional staff heat and health risks | 5 x 2 | | Severe Weather Events and Extreme Rainfall | | |
| | Heat stress to service provision | 5 x 2 | | Cancellation/disruption of events | 5 x 4 | |
| | Closure of water reliant recreational activities | 5 x 2 | | Lost work days | 5 x 4 | |
| | Sea Level Rise | | | Disruption to transport and supplies | 5 x 4 | |
| | Loss of land and property values | 5 x 2 | | Increased insurance and repair costs | 5 x 4 | |
| | | | | Loss of land/property values | 3 x 2 | |