ASSESSING THE FINANCIAL EFFECTS OF FLOODS ON LOCAL ECONOMIES
1. Introduction

The financial effects of floods are usually assessed in the context of a project, or project options, designed to reduce the negative effects. Financial and economic analyses of the effects of floods have similar features. Both estimate the net-benefits of a project investment based on the difference between the with-project and the without-project situations. The basic difference between them is that the financial analysis compares benefits and costs to the enterprise, whereas economic analysis compares the benefits and costs to the whole economy or possibly to an economic region.

Financial analysis may also be extended to local economies where the intention is to estimate the financial rather than the economic benefits of a project – in this case the local economy is treated similarly to an enterprise. The requirement to assess the financial as opposed to the national economic benefits of flood risk management projects has arisen recently in England and Wales where the government has introduced ‘partnership funding’ for flood risk management (Environment Agency 2009; Local Government Association, Environment Agency, Defra, 2012). Local authorities and other local beneficiaries of a flood risk management project may now contribute to its costs but will normally wish to weigh the financial savings to them of the project being implemented in the same way as a national government wishes to weigh the effects of the project on the national economy. Financial analysis is therefore of interest wherever local financial contributions to project investment are being contemplated. A financial analysis of flood effects will usually help in make local decisions about potential project investments.

Financial assessment of the effects of floods is also the type of analysis that insurance companies undertake. These companies receive claims for damage suffered in floods and which focus on just those property owners. The appraisals that insurance company loss adjustors undertake of flood damaged properties are therefore based upon financial criteria rather than the economic ones. The employment of flood damage data which reflects economic criteria results in estimates of flood damage which are significantly lower than as indicated by flood loss data provided by insurance companies.

The purpose of this paper is to explain the principles behind the assessment of the financial effects of floods and to explain recent developments in methods of estimation with reference to a number of case examples. This paper is complementary to the latest economic impact assessment methods for flood risk management appraisal as set out in the Multi-Coloured Manual (Penning-Rowsell et al., 2013).

2. General principles of assessment

Cost-benefit analysis is concerned with the true value that a project holds for the society of country as a whole. It subsumes all members of society, and measures the project’s positive and negative impacts. In addition, economic analysis also cover costs and benefits of goods and services that are not sold in the market and therefore have no market price. On the other hand financial analysis is usually only concerned with an enterprise, or in flood appraisal - a local economy, and it measures the project’s positive and negative impact upon this geographically defined economy.

What this means is that an economic efficiency cost-benefit analysis is only concerned with the net value of impacts on society or the nation. So when floods cause retail outlets in a town to be closed for a week so that they lose business, this is not counted as an economic loss to the nation because shoppers will transfer their purchases to alternative flood-free retail outlets i.e. the loss is
compensated by a gain and the net effect on the national economy is zero. Technically, there may be a small national economic loss in this example if shoppers have to travel further to alternative retail outlets (i.e. more time will be used and extra travel costs are incurred). However, in a financial analysis of the negative effects of floods, the financial losses experienced by flooded retail outlets is counted as a financial loss irrespective of whether other shops gained as a result of the flooding.

An example illustrates this principle (Figure 1). In Case A two firms are operating in a country which has two regions: the ‘North’ and the ‘South’. Suppose that manufacturing firm A is flooded and its production is disrupted for several weeks. Suppose also that firm B – a competitor of firm A manufacturing the same products - is not flooded and is able to expand its production temporarily in order to supply firm A’s customers who cannot wait for their orders. The outcome is that firm A suffers a financial loss while firm B, in consequence, reaps a financial gain through increased sales. However, because both firms are located in the same country, flooding does not result in any economic loss to the country – just a temporary redistribution of trade within the country. To recap, financial losses and gains will have occurred and in a financial loss analysis, this is counted as a loss, but in an economic analysis there is no economic loss (assuming that the cost of obtaining the product to customers remains the same). However, in Case B in Figure 1, the boundaries of the country are different such that firms A and B are located in country West and East respectively. Again firm A is flooded (in country West) and production is transferred to firm B (in country East). The effect of the flood is exactly the same as in Case A but is now interpreted differently. Firm A’s financial loss becomes the West’s economic loss East’s economic loss because trade is lost by country West to firm B which is located in country East.

Figure 1 The relationship between project appraisal boundaries and financial and economic losses
There are other significant differences between financial and economic analysis. While financial analysis uses market prices to check the balance of investment costs over benefits and the sustainability of a project, economic analysis uses economic prices that are converted from the market price by excluding tax, profit, subsidy, etc. For example, the financial costs of repairing a house and its contents will include sales taxes or value added taxes, whereas in an economic efficiency analysis these elements of the cost to the householder are deducted to arrive at the economic loss value. The same applies to the cost of fuel. Taxes and subsidies are transfer payments within the economy and are not counted in an economic efficiency analysis. This is illustrated in Figure 2.

**Figure 2 Illustration of the difference between economic and financial costs**

Secondly, the economic valuation of assets such as the contents of houses which may be flooded, usually takes into account depreciation of the assets whereas, increasingly, insurance companies have a new for old policy in which depreciated contents are replaced with new ones. We might assume, for example, that on average the contents of a house are half way through their lives so that when depreciation is taken into account, the economic value of these assets will be worth 50% of their market price. On the other hand, if we calculate the financial value of these assets at their replacement value, the result will be exactly double that of the economic value.

Strictly-speaking, financial and economic analyses also differ in their treatment of external effects (benefits and costs), such as favourable effects on health. Economic analysis usually attempts to value such externalities in order to reflect the true cost and value to the society whereas financial analyses often exclude them. The inclusion of externalities raises difficult questions about their identification and measurement in terms of money. However, financial analysis may be extended in some cases to try to represent the financial value of effects on health and other intangible impacts but it is difficult in practice to separate economic and financial values in this case.

### 3. Potential impacts on local economies
The impact of floods on local economies are manifested as flood losses whereas the impact of flood risk management projects is flood damage avoidance (i.e. benefit). This section identifies the different types of potential impacts in terms of (a) the losses to local economies generated by floods which are to be measured using financial rather than economic criteria and b) the benefits of investing in flood risk management.

Typically, large-scale flood risk management measures, such as a flood protection scheme, generate benefit through avoiding flood losses and, by reducing the risk of flooding, stimulating positive developments in the local economy as businesses adjust to the changes in flood risk.

For such an analysis it is necessary to define the geographical boundaries of the local economy. This may be a local authority area i.e. the boundaries of a District Council or a Unitary Authority in England. It could also be a sub-region comprising a number of local authority areas and embracing a number of settlements. It could also be a particular area for which flood risk management measures are being considered.

In what follows below, we are primarily focused on the consequences of floods which have an impact upon the local economy and exclude those impacts which affect people (e.g. loss of life, injury, health damage etc.) although where the latter are significant they could well have an impact upon the economy.

Often likened to the impact of throwing a coin into a pond, impacts on a local economy occur as a series of ripples emanating from the core, where the core is the area which is inundated. The first of these ripples are equivalent to primary impacts which are followed by secondary impacts and so on.

3.1 Primary impacts
Principal primary impacts are as follows and are the direct consequences of floodwater coming into contact with damageable property or infrastructure:

- Direct damage to residential properties (Penning-Rowsell et al. (2013) pp86-153)
- Direct damage to non-residential properties (NRPs) (Penning-Rowsell et al. (2013) pp154-155) i.e.
  - High Street buildings (retail, retail-related and vehicle services properties
  - Offices
  - Distribution/logistics properties
  - Leisure and sport facilities
  - Industrial properties
  - Public Buildings
  - Miscellaneous properties/facilities (e.g. car parks, electricity sub-stations)
- Direct damage to utility infrastructure (e.g. water treatment and supply, sewage treatment and sewerage, electrical power production and transmission, gas production and transmission, telecommunication installations) (Penning-Rowsell et al. (2013) pp189-260)
- Direct damage to transport infrastructure (i.e. road, rail, air) (Penning-Rowsell et al. (2013) pp189-260)
- Direct damage to crops and livestock

Large-scale flood risk management measures (e.g. flood protection projects) benefit local economies by reducing or avoiding these primary losses.
3.2 Secondary impacts

Principal secondary impacts arise from the disruptive or indirect consequences of direct damage to property and infrastructure:

- Household disruption (Penning-Rowsell et al. (2013) pp86-153)
- Business disruption (i.e. private and public sector businesses) (Penning-Rowsell et al. (2013) pp171-175)
- Utility disruption (Penning-Rowsell et al. (2013) pp189-260)
- Infrastructure disruption (Penning-Rowsell et al. (2013) pp189-260)
- Loss of agricultural output and yield (Penning-Rowsell et al. (2013) pp318-365)

These forms of disruption are likely to spread beyond the area which is inundated and may, for example, spread through business supply chains or because transportation disruption affects businesses well outside of the inundated area.

Large-scale flood risk management measures (e.g. flood protection projects) also benefit local economies by reducing or avoiding these secondary losses.

3.3 Tertiary impacts

Tertiary impacts are ones which may be generated by flood risk management measures such as a flood protection scheme which can have positive impacts on local economies which may be measured in financial terms. These impacts generally play out over a number of years – say up to 10 or 15 years – after a large-scale measure has been put into place to protect businesses.

Tertiary impacts may also be ones where the damage and disruption caused by a flood leads to blight (e.g. residential and/or business blight). In cases where flood damage and disruption is so severe – and possible also serial – the economies of settlements can enter a downward spiral unless significant action is taken to prevent this from happening. The devastating impacts of hurricane Katrina on New Orleans is an example. In this case, businesses were not only physically damaged but their employees and customers were either lost in the floods or left the area entirely for many months, some of them never to return. This had an enormous negative impact upon the local economy which also suffered through a large reduction in tax revenues.

By lowering flood risk, land may become attractive for residential development which, during the construction phase, may provide a boost to the local economy depending on the extent to which construction workers and material are sourced from the local economy being analysed or from outside of it. Once the residential development has been completed, further growth in the local economy is likely as new residents increase demand for local products and services. New economic activity in the business sector may also become attracted by lowered flood risk leading to a boost in the local economy.

Significant lowering of flood risk can impact positively to increases in efficiency by which goods and services are produced, as well as increasing the overall size of production so that a local economy grows. There are a number of types of efficiency through which businesses in a local economy might gain. These include efficiencies of scale which may be an outcome of lowered flood risk where businesses decide to expand production because of increased security. Production efficiency may be
positively affected by scale economies: productive efficiency is achieved when a producer uses the least amount of resources to produce goods or services relative to others. Allocative efficiency may also be improve. This is when a society's value for a certain good or service (the amount they pay for it) is in equilibrium with the cost of resources used to produce it. It is typically achieved not by accident but when a society allocates its resources to producing what society values most.

The ‘induced’, tertiary impacts of large-scale flood risk management measures are often excluded from being counted in conventional, economic efficiency benefit-cost analyses which treat the economy as static i.e. the property base within these analyses is usually held constant during the life of the project (which may be 100 years) and no account is taken of induced economic development which is termed ‘betterment’. However, the potential for economic betterment is of considerable interest to those wishing to promote both national and local economies.

4. Impact measurement
Impact measurement is an inexact science and therefore it is preferable to refer to flood loss ‘estimates’ or flood risk management benefit ‘estimates’.

In flood project appraisal, flood losses are usually measured as potential flood losses i.e. the losses that analysts estimate are most likely to occur in a flood. Potential flood losses are usually constructed through a mix of observing and recording actual flood losses and constructing synthetic flood losses: often the former are used to calibrate the latter (Penning-Rowsell et al. 2013).

Appropriate valuation principles must be employed in order to estimate primary flood impacts or the benefits arising from flood risk management projects designed to avoid such impacts. For a financial appraisal, tax and subsidy elements should be included in costing flood damage i.e. the cost of damage to a refrigerator includes value added tax; and the cost of fuel used in travelling longer distances to avoid floods includes petrol taxes (Figure 2). Similarly, the cost of damage to the contents of homes or offices should include tax elements and should also not take into account depreciated values. The flood damage data provided in Penning-Rowsell et al (2013) and in the related MCM-Online are not estimated using financial valuation principles – they reflect the application of economic valuation principles and apply to economic efficiency cost-benefit appraisals for national level investment decision purposes. These data need to be adjusted to convert them to financial values (a relatively simple process). On the other hand, the flood damage data provided by Black et al. (2005) at the University of Dundee are based on financial valuation principles and may be employed for financial analyses. Users will note quite large differences between the costs of flood damage from these two sources. Table 1 illustrates the difference between financial and economic evaluations of residential and commercial flood damage in the Summer 2007 floods in Britain. Adjustment factors of 53% and 66% are used to convert financial (i.e. insurance) estimates to economic ones for residential and commercial properties respectively (Chatterton et al. 2010).

Exactly the same valuation principles apply to the estimation of secondary flood impacts. For example, tax elements included in estimates of the costs of disruption to businesses are included in an analysis of the impact of floods on a local economy whereas these costs are excluded when estimating economic losses.

Secondary, indirect impacts of floods are usually more difficult to measure than primary impacts. As far as household disruption is concerned, Penning-Rowsell et al. (2013) (111-117) discuss alternative methods of estimating the costs of evacuation from homes and provide average values relevant to the UK. In 2008 they found that average evacuation costs are between £7,800 and £20,100 per evacuated property at 2008 prices. Subsequent research which contributed to the 2013 volume
(Penning-Rowsell et al., 2013) is presented in terms of financial loss values and take into account the costs of temporary and alternative accommodation; extra food; extra travel and time; loss of earnings and other costs. Loss values for each for a range of flood disruption durations, up to 42 weeks, are provided.

Table 1  Estimated economic damage costs of the summer 2007 floods to residential and commercial properties and contents using alternative estimation methods (from Chatterton et al. 2010).

<table>
<thead>
<tr>
<th></th>
<th>Average insurance claim £ per property (A, B) or per individual claim (c)</th>
<th>Properties affected (A, B) or claims (c)</th>
<th>Total insurance claims £ bn</th>
<th>Economic adjustment factor %</th>
<th>Economic losses £bn</th>
<th>% covered by insurance</th>
<th>Total economic losses £bn</th>
<th>Econ as % of insurance claims</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential - A</td>
<td>£30,000</td>
<td>48,000</td>
<td>£1.44</td>
<td>53%</td>
<td>£0.77</td>
<td>76%</td>
<td>£1.01</td>
<td>70%</td>
</tr>
<tr>
<td>Residential - B</td>
<td>£24,303</td>
<td>65,000</td>
<td>£1.58</td>
<td>53%</td>
<td>£0.84</td>
<td>76%</td>
<td>£1.11</td>
<td>70%</td>
</tr>
<tr>
<td>Residential - C</td>
<td>£13,000</td>
<td>122,000</td>
<td>£1.72</td>
<td>53%</td>
<td>£0.91</td>
<td>76%</td>
<td>£1.20</td>
<td>70%</td>
</tr>
<tr>
<td>Commercial - A</td>
<td>£90,000</td>
<td>7,300</td>
<td>£0.66</td>
<td>66%</td>
<td>£0.43</td>
<td>95%</td>
<td>£0.46</td>
<td>69%</td>
</tr>
<tr>
<td>Commercial - B</td>
<td>£65,652</td>
<td>8,000</td>
<td>£0.45</td>
<td>66%</td>
<td>£0.29</td>
<td>95%</td>
<td>£0.31</td>
<td>69%</td>
</tr>
<tr>
<td>Commercial - C</td>
<td>£24,000</td>
<td>36,000</td>
<td>£0.64</td>
<td>66%</td>
<td>£0.55</td>
<td>95%</td>
<td>£0.58</td>
<td>69%</td>
</tr>
<tr>
<td>Total A</td>
<td></td>
<td></td>
<td>£2.10</td>
<td></td>
<td></td>
<td></td>
<td>£1.46</td>
<td>70%</td>
</tr>
<tr>
<td>Total B</td>
<td></td>
<td></td>
<td>£2.02</td>
<td></td>
<td></td>
<td></td>
<td>£1.41</td>
<td>70%</td>
</tr>
<tr>
<td>Total C</td>
<td></td>
<td></td>
<td>£2.56</td>
<td></td>
<td></td>
<td></td>
<td>£1.76</td>
<td>70%</td>
</tr>
</tbody>
</table>

DATA SOURCES

source of unit cost

- Residential - A: Pitt/Efra
- Residential - B: Weathernet
- Residential - C: ABI av claim
- Commercial - A: Pitt/Efra
- Commercial - B: Weathernet
- Commercial - C: ABI av claim

source of number of claims

- Residential - A: Pitt/Efra households
- Residential - B: ABI estimate households
- Residential - C: ABI claims
- Commercial - A: Pitt/Efra businesses
- Commercial - B: ABI estimate businesses
- Commercial - C: ABI claims

Economic adjustment

* residential adjusted for VAT at 17.5% and assuming 75% of claims for inventory with 50% remaining value
* commercial adjusted for VAT at 17.5% and assuming 45% of claims for inventory with 50% remaining value

The potential for business disruption costs is set out in Penning-Rowsell et al. (2013, 172-176)) and includes loss of trade/profit; and the costs of renting alternative premises, transferring to alternative premises, supply chain disruption and other costs. Some of the principles behind valuing these losses are explained in Parker et al. (1987). These include the potential for deferral of business operations (i.e. rescheduling them because of flood disruption in order to minimise impacts). One approach for estimating the financial value of potential business disruption costs is to employ uplift factors based upon previous analyses of the impacts of floods on businesses. The costs of business disruption have been researched in the UK for both the Autumn 2000 floods and the Summer 2000 floods in England and Wales (Penning-Rowsell et al., 2002; Chatterton et al., 2010). In the floods of 2000, business interruption costs comprised 31% of the total direct commercial damage claims made to insurance companies. In the floods of 2007, business interruption costs were estimated to be 27.6% of total direct business damages. The economic costs of business disruption are likely to be significantly less than these financial cost values and are likely to lie between 2 and 6% of the total...
direct damages to all non-residential property (NRPs). Potentially useful data on the disruptive effects of floods on German businesses can be found in Kreibich et al. (2007, 2011).

An alternative way of estimating secondary, indirect financial losses to businesses (I) is to employ the following equation:

\[ I = \text{LGVA} + A \]

Where:

\( \text{LGVA} \) = Lost gross value added

\( A \) = Additional costs

Gross Value Added (GVA) is a measure of the value added to the economy of each additional hour worked (measured by hourly earnings) or the value-added by a business when it assembles different inputs to create a product or service that is worth more than the inputs used (i.e. the profit).

A good proxy for GVA is average earnings per employee which, in England and Wales, is published as part of the Office of Annual Statistics (ONS) Annual Survey of Hours and Earnings. Similar kinds of average earnings data are likely to be available for many countries in the European Union. In order to employ such data, the analyst will need to perform an analysis which also requires the following kinds of data:

- Number of businesses by size and business sector (in the flooded area and the area indirectly disrupted by flooding)
- Average employees per business
- Estimated length of flood disruption
- Probability of flooding

### 4.1 Impacts on business supply chains.

One of the difficulties of measuring the impact of floods on businesses – and thus the positive impact of flood protection on businesses – is analysing and estimating the effects on business supply chains.

According to a survey by BCI, CIPS and Zurich (2013) 15 different generic consequences of supply chain disruption are identifiable, some of which had an immediate financial impact and others which had the potential for long term damage.

In order of importance they were ranked as:

- Loss of productivity
- Customer complaints received
- Increased cost of working Service outcome impaired
- Loss of revenue
- Damage to brand/reputation/image
- Product release delay
- Product recall/withdrawal
- Payment of service credits
Figure 3  The complexity of supply chain linkages within a coastal settlement
• Share price fall
• Stakeholder/shareholder concern
• Delayed cash flows
• Expected increase in regulatory scrutiny
• Loss of regular customers
• Fine by regulator for non-compliance

Whilst loss of productivity maintains its place as the most likely negative outcome from a supply chain disruption, 41% stated that customer complaints were received as a consequence of disruption, an increase from 35% in 2012. Strategic consequences are very important with 24% stating they experienced damage to their brand and reputation.

4.2 Indicative costs of supply chain disruptions.
According to a survey by Zurich, the majority (80%) of medium-sized UK businesses (with annual revenues between £5 million and £300 million) in the manufacturing, technology, food and beverage, sport, leisure and entertainment and wholesale sectors consider their supply chains to be either very important or critical to their business. On average, the businesses surveyed in 2012 reported an average of 48 critical suppliers. When describing their relationship with suppliers, a third (35%) of organisations believe they are in a strong negotiating position as their key suppliers are dependent on their business (http://www.zurich.co.uk/internet/home/sitecollectiondocuments/business/largebusinesses/zurich_supplychainreport_july2012.pdf).

The indicative costs of supply chain disruptions are illustrated in Box 1. Zurich reported that the mean cost of a disruption to manufacturing firms in 2012 was £230,000; and the costs to wholesale companies ranged from £50,000 to £500,000 whereas it ranged from £10,000 to £1m for sports and leisure companies. These costs excluded the cost of management time and loss of brand reputation and customers.

The consequences of supply chain disruption in the automobile manufacturing industry are illustrated in Table 2 below (http://www.frost.com/prod/servlet/market-insight-print.pag?docid=245127884)

4.3 Disruptive impacts of floods on utility services, schools, hospitals, transportation networks and emergency services.
Data on both the direct and indirect, disruptive costs of floods on these components of local economies can be found in Chapter 6 of Penning-Rowsell et al. (2013, 189-260).

5. Case study 1 – the local financial benefits of a proposed fluvial flood protection project

This case study focuses upon the assessment of the local financial benefits of a proposed flood protection project for a large provincial city in the United Kingdom. In this case ‘local’ includes the immediate area of the sub-region surrounding the city. The location and full details of the assessment are not revealed here for confidentiality purposes. The project represents a major improvement of existing flood defences combined with minor river system improvements. The
Table 2 Consequences of disruptive events in car manufacturing

<table>
<thead>
<tr>
<th>OEM</th>
<th>Plant Location – Province</th>
<th>Severity of Impact</th>
<th>Production Status due to floods</th>
<th>Average Monthly Estimated Loss of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toyota</td>
<td>Chachoengsao</td>
<td>Medium</td>
<td>Halted - Supply Chain Disruption</td>
<td>30,000-35,000</td>
</tr>
<tr>
<td>Honda</td>
<td>Ayutthaya</td>
<td>High</td>
<td>Halted - Assembly plant flooded</td>
<td>10,000-15,000</td>
</tr>
<tr>
<td>Nissan</td>
<td>Samut Prakan</td>
<td>Medium</td>
<td>Normal Production but likely to be affected due to Supply Chain Disruption</td>
<td>10,000-12,000</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>Chon Buri</td>
<td>Medium</td>
<td>Halted - Supply Chain Disruption</td>
<td>12,000-15,000</td>
</tr>
<tr>
<td>Auto Alliance Thailand (Ford - Mazda)</td>
<td>Rayong</td>
<td>Medium</td>
<td>Ford PV production resumed but Pick-up production halted</td>
<td>5,000-8,000</td>
</tr>
<tr>
<td>GM</td>
<td>Rayong</td>
<td>Low</td>
<td>Normal production</td>
<td>-</td>
</tr>
<tr>
<td>Isuzu</td>
<td>Chachoengsao</td>
<td>Medium</td>
<td>Halted - Supply Chain Disruption</td>
<td>10,000-15,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>80,000-100,000</strong></td>
</tr>
</tbody>
</table>

Source: Frost & Sullivan

https://www.google.co.uk/search?q=Automotive+industry+supply+chains&tbm=isch&tbo=u&source=univ&sa=X&ei=1sy6U6jeF6nM0QWX_oHgDA&ved=0CDAQ7Ak&biw=1680&bih=949#q=Frost+and+Sullivan+automobile+floods&tbm=isch&imgdii=_

proposed project will initially raise the standard of protection (SoP) to 1% (1.3% with climate change) along a 7km reach of the river. The assessment was commissioned because the local city council was interested in using the results to support discussions with potential local third party funding contributors to the project under the partnership funding policy recently introduced in England and Wales.

5.1 Background
The urban area currently benefits from a flood protection scheme that extends over 4km which was constructed about 30 years ago to protect against serious flooding which had been experienced. The existing flood defences continue to perform well although some flood protection assets now show some signs of wear and tear. Furthermore in the recent past, two flood events led to ‘near miss’ situations which highlighted the risks to the city. The current SoP is considered to be unacceptable and ranges from 2.5% (1 in 40) to 5% (1:20). Large residential and commercial areas of the city both along the river frontage and set back as far as 1.2 km from the river are at risk from overtopping and inundation by fluvial flood waters. This risk is predicted to increase due to climate change.
The city is in a state of sustained economic growth, with significant ongoing Growth Point investment by the Government, and is a prominent economic driver for its region. A higher standard of flood protection would support this position whereas a major flood could damage it including through loss of confidence in the area by key business companies.
Box 1 What are the indicative costs of supply chain disruption?

Large UK manufacturers lost more than £58 million dealing with the fall-out from supply chain disruptions in 2013; much of which could have been prevented, new research shows. The research, commissioned by Achilles – a global supply chain risk management company – revealed the total average cost of all supply chain disruptions was £105,000 per manufacturer.

The survey revealed:

• Manufacturers were hit hardest in 2013 by suppliers failing to deliver the products of the required quality, which cost the industry an estimated £20.4 million

• The second most costly disruption was suppliers failing to deliver products on time, which cost £17.2 million

• Then came the financial failure of suppliers, which cost the industry £7 million

• Suppliers exposing firms to litigation cost the industry a further £7 million

• Smaller costs included the consequences of severe weather disruption and natural disasters which carried a bill of £3.6 million, damage to reputation cost £2.4 million, suppliers failing to meet health and safety regulations cost businesses £0.79 million and suppliers being involved in industrial action cost businesses a further £0.26 million.

The most costly supply chain disruptions per manufacturer include:

• Failing to deliver on time - 61% of manufacturers experienced this; 42% of which incurred a cost. The average bill per disruption was £55,000

• Suppliers failing to deliver products of the required quality - just over half (54%) experienced this issue; 34% of which incurred a cost. The average fee was £91,000

• Financial failure of a supplier - one third (32%) experienced the financial failure of a supplier, with 46% paying a financial price. The average cost was £39,000

Despite the significant costs involved, 58% of manufacturers said they were reliant to some extent on pieces of paper to manage information about suppliers. The Chief Executive of Achilles, said: “This research shows that manufacturers are paying a heavy price for supply chain failures; many of which could be prevented.

“In our experience, efforts to improve information about the supply chain work best when whole industries – such as oil and gas – work collaboratively to agree and implement standardised requirements of all suppliers in terms of business critical areas, such as health and safety to reduce the burden of administration. They can then manage the information on a global, centralised database – implementing the same high standards not only in the UK but in every country in which they operate.

“With a significant impact on the bottom line, addressing supply chain failure should be at the forefront of people’s minds, because the cost will be felt not only by industry but also shareholders and consumers.”

* Some manufacturers would have experienced duplicated incidents, whereby one type of disruption would affect/overlap on another e.g. the financial failure of a supplier would also mean they were unable to deliver.

* The survey was carried out among procurement professionals from 108 manufacturing companies with 250+ employees. This sample is representative of the entire manufacturing sector in the UK


In a recent survey of 500 businesses conducted by Zurich, 33% said they were dependant on a single supplier, 44% had suffered from supplier financial failure at some point, and 88% of businesses had suffered some form of significant disruption in the past at an approximate cost of £200,000 per disruption. The manufacturing sector is particularly dependent on its suppliers – with 70% of manufacturers agreeing that healthy suppliers were critical, and 52% saying supplier bankruptcy was the main cause of disruption.

http://www.opportunitywales.co.uk/the-potential-cost-of-supply-chain-disruption/
5.2 Characteristics of the benefit area

The wider benefit area in this case study comprises three zones: (a) the zone within the city which will benefit directly from the proposed flood protection i.e. the area of maximum flood extent where direct damages would be experienced as well as indirect ones, (b) the zone within the city which lies immediately beyond the flood risk area where indirect disruptive impacts of flooding would be experienced and (c) the wider sub-region which could also experience adverse impacts as a result of flooding in the city.

The existing flood defences operated at near full capacity during the most significant flood events of recent years, but a mainline railway just outside the city suffered from direct flooding in the most recent floods. The railway company has been investigating solutions to deal with flooding problems here and at a number of separate locations upstream.

If nothing is further is done to protect the city’s potential benefit areas, more than 3,000 properties are at risk within the 1% AEP and in 100 years’ time this is expected to rise to nearly 6,000 properties because of climate change (not counting the possible extra development which might take place in the benefit area over this period of time). Over 70% of the properties are residential. Flood depths in some areas could exceed 1.8m and the flow velocities at critical locations could be as high as 4 m/s, resulting in significant risk to life.

Critical infrastructure at risk includes the mainline railway station located in the city, the railway line just outside the city, a large sewage treatment works and trunk sewer and important mainly lateral city road links. The trunk sewer runs in a canal embankment parallel with the river. Erosion from flooding could lead to collapse of the sewer and a major pollution incident affecting the river downstream which has environmentally sensitive sites of national and European significance. Key assets at risk include two emergency services stations, listed buildings, some Scheduled Monuments, four schools and seven surgery/health centres. All of these were flooded prior to the extant flood defences being installed. 1,000 non-residential properties (mainly commercial properties) are located within the area likely to be directly affected by a flood with a 1% AEP, rising to an estimated 1,560 in 100 years’ time.

5.3 The potential consequences of a major flood

Without intervention the condition of the existing defences would progressively deteriorate until they fail from problems such as blockage, erosion, overtopping, wash-out, breach and seepage. In the longer term, as river embankments deteriorate, the eventual outcome would lead to major harm to the city’s economy of Exeter and that of the wider sub-region. There would be regular floodplain flow due to overtopping and breaching into the lowest lying areas, flooding critical commuter routes through large residential areas of St Thomas, a major industrial/commercial estate and the mainline railway. The eventual loss of the canal banks and trunk sewer would lead to serious river pollution with significant adverse environmental effects.

A major severe flood which overtops and/or breaches existing flood would lead to a large amount of physical damage to houses, to commercial properties and to other buildings and infrastructure. The indirect impacts would spread well beyond the flood risk areas into the rest of the city and into the surrounding sub-region. For a 1% AEP the depth of flooding is predicted to reach 2m in some flood risk locations and the flow velocities are predicted to be above 4m/s – leading to a significant risk to life.

The disastrous consequences of a major flood event could take up to a year for recovery operations and repairs to be completed, with significant adverse impact on the local and sub-regional economy.
with insidious adverse social and health impacts. However, a flood would also create business for repair and rehabilitation companies including local electricians, plumbers, builders etc.

5.4 Proposed flood protection project
The preferred option comprises minor river system improvements followed by major improvements to upgrade the SoP to 1% initially. The quite separate economic assessment shows that 1% SoP is viable but that is not feasible to implement flood defences to a higher standard than this on cost grounds and because of visual intrusion. In the longer term there may be other upstream storage option which would attenuate flooding. The cost of the preferred option is in excess of £30m.

5.5 Application of assessment principles
The assessment is of the losses (i.e. costs) incurred by individual property owners whether they be owners of residential or non-residential properties rather than losses incurred by the nation. The appraisal of financial benefits employs the same valuation principles that insurance company loss adjustors employ but in this case the focus is on all properties and activities within the flood risk area as well as adverse impacts of flooding beyond the area directly at risk from flooding. The difference between (a) national economic and social and (b) local economic and social benefits are as follows:

National economic and social benefit model -

- The economic situation assesses the benefits and costs from the perspective of the national UK economy.
- Transfer payments in the economy are not counted e.g. flood damages and FAS costs are estimated with VAT (20%) excluded and where flood loss costs include a fuel cost element, excise duty on the fuel is excluded.
- The value of losses during a flood is not the value of an equivalent new product but the ‘Average remaining Value’ (ARV) (which we assume is 50% of the replacement value). This ensures that the calculated flood damages reflect the pre-flood value of the property inventory and not the cost of replacing old goods with pristine new ones which amounts to ‘betterment’ which, in the UK, has been disallowed in an economic appraisal of a flood defence project.

Local financial benefit model -

- The financial situation assesses the benefits and costs from the perspective of the individual household and local business.
- Transfer payments are counted e.g. flood damages and cost are estimated with VAT (20%) and excise duty on fuel costs included.
- When a property is flooded the damages are costed using replacement costs values rather than ARVs.

Using a 3.5% discount rate, the effect of a financial benefit appraisal is to significantly increase flood damage estimates compared to those estimated using a national economic efficiency approach.

5.6 Adapting standard flood damage data and valuing local benefits
In order to apply Flood Hazard Research Centre’s (FHRC) Multi-Coloured Manual standard flood damage data for a local economic and social benefit appraisal, it is necessary to adapt and modify all
of the 'national economic efficiency' standard damage data maintained by FHRC to reflect the different costing principles as explained above. This is a significant task which has never been done before but which has been performed for this project and project report. It involves disaggregating our suites of data into their component parts, modifying them, and then re-aggregating them. For example, five principal elements go to make up standard depth-damage curves for non-residential properties, as follows:

1. Building Structure and Fabric
2. Building Services
3. Moveable Equipment
4. Fixtures and fittings
5. Stock (i.e. raw materials, work-in-progress and finished goods).

Only 3. and 4. need to be altered because they are the only elements valued in terms of ARVs, and so it is necessary to alter just these elements rather than all five.

In other cases loss estimation methods have been modified to take account of the appraisal principles applicable to local benefit appraisal.

5.7 Residential Damage data
The existing MCM residential economic damage data were revised to reflect financial values. This was achieved by adding VAT at 20% on all items, plus a 100% uplift on internal decorations and all inventory items, plus a further 1.43 uplift on Audio/Video. The economic figures take into consideration the “average remaining value” of items, whereas the financial values must reflect “new for old”.

5.8 Non-Residential Properties (NRPs) data
Similar to the residential damage method, each of the 35 non-residential property types (high street shop, public house, office, warehouse etc.) in the MCM economic damage dataset were updated to reflect financial values. For each property type, four damage components (‘building structure’, ‘fixtures & fittings’, ‘services’ and ‘moveable equipment’) have had VAT at 20% applied to them. In addition to this, the values for ‘moveable equipment’ and ‘fixtures & fittings’ have been doubled to reflect the change from “average remaining value” to “new for old” value. This increased the economic damage figures by approximately 75% across all NRP types.

5.9 Indirect Commercial Damages
For the 2007 floods in England and Wales the following direct and indirect costs for domestic and business properties were estimated by Chatterton et al. (2010) (Table 3):

Table 3 Direct and indirect costs of flooding for domestic and business properties: Summer 2007 floods (based on data in Chatterton et al. 2010, p16)

<table>
<thead>
<tr>
<th>Economic costs £000</th>
<th>Property</th>
<th>Vehicles</th>
<th>Temporary accommodation</th>
<th>Business disruption</th>
<th>Total</th>
<th>Ratio of direct to indirect costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic</td>
<td>1,200</td>
<td>80</td>
<td>83</td>
<td></td>
<td>1,363</td>
<td>1:0.06</td>
</tr>
<tr>
<td>Business¹</td>
<td>580</td>
<td>11</td>
<td>160</td>
<td></td>
<td>751</td>
<td>1:0.27</td>
</tr>
</tbody>
</table>

¹ Because disruption was so acute in many locations, Chatterton et al. make the assumption that business disruption losses were not made good by alternative local businesses. This gives commercial indirect losses at 27% of direct NRP losses when estimated as financial losses. Disruption costs include increased over-time costs, costs of rescheduling deliveries of products and
supplies, extra costs of communicating with customers and suppliers, transferring business and employees where alternative, temporary premises can be used, and getting back into action.

5.10 Vehicle Damage data
The MCM estimates an average vehicle value of £3,100. This value takes into consideration, amongst other things; the average age of all vehicles on the road (7.5 years), annual depreciation rates and historic sales prices. In order to work out a likely vehicle damage figure for the flood risk area, it was necessary to ascertain the rate of vehicle ownership per household. Using ONS Census data the ownership rates for all six survey regions within the flood risk area were compared. An average of these six regions suggested that 61% of households own at least one vehicle. Based on several post-flood event surveys, it is assumed that, on average, 26.3% of vehicle owners will move their vehicles to safety following a flood warning. This has been taken into consideration in the final damage estimation in which economic damage data were adjusted for financial values.

Research for the updated MCM has revealed that the average vehicle will succumb to water damage at 0.3m. At this depth, water ingress is likely and insurers will usually consider vehicles a total loss on health and safety grounds. For each of the four defence options, the number of properties at risk from a flood depth of 0.3m+ (actually 0.15m+, allowing for the 0.15m threshold) was calculated and it was assumed that 61% of these households will be vehicle owning.

5.11 Electricity Substation Damage
The direct damage figures used for substations are taken from FHRC’s updated Non-Residential Property dataset from the 2013 edition of the MCM (Table 4). These have been converted to reflect financial values for the purposes of this appraisal using exactly the same methods as for NRP damages above.

Table 4 Direct damage to electricity substations. Short duration, most-likely flood scenario

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>1</th>
<th>0.75</th>
<th>0.5</th>
<th>0.25</th>
<th>0</th>
<th>0.25</th>
<th>0.5</th>
<th>0.75</th>
<th>1</th>
<th>1.25</th>
<th>1.5</th>
<th>1.75</th>
<th>2</th>
<th>2.25</th>
<th>2.5</th>
<th>2.75</th>
<th>3.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage (£)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>1004</td>
<td>1348</td>
<td>1683</td>
<td>2642</td>
<td>3288</td>
<td>4241</td>
<td>4588</td>
<td>6476</td>
<td>6502</td>
<td>6530</td>
<td>6547</td>
<td>6566</td>
</tr>
</tbody>
</table>

In addition to direct damages, it is important to consider electricity disruption costs. The costs of the summer floods of 2007 report (Environment Agency, 2008) proposes a willingness to pay figure of £10 per kWh per household. Ofgem (2011) estimates that the average UK household uses 9kWh of electricity per day. This equates to £90 per household (£10 x 9kWh). The average substation serves between 100-150 properties so a conservative estimate, assuming 100 properties served, gives a disruption figure of £9,000 per substation. A more detailed analysis would refine this figure, which is likely to be significantly higher. If the flood duration is >24hrs, alternative accommodation will be sought: these additional costs are taken into consideration in ‘evacuation costs’.

5.12 Evacuation Costs
The financial evacuation costs per affected property have been calculated at £5,277. This figure is based on research undertaken for the 2013 edition of the MCM and takes into consideration the costs of temporary accommodation (hotel/B&B etc.), prepared food, loss of earnings, additional transport costs and alternative accommodation costs (rents for a longer-duration evacuation) for the mean flood duration of 23 weeks (RPA/FHRC 2004).

5.13 School disruption
There were 8 schools in the property database in the flood risk area. By comparing a map of the area flooded in a recent flood with Google Street map and information on the names and locations of schools available on the local authority website, 8 schools and their type were identified. Any slight identification error is unlikely to be important to this school disruption benefit calculation. In addition to the 8 at-risk schools, there were a further 6 either on the edge of the benefit area or just outside of it, which could be affected by flood warnings and emergency actions and/or transport problems. Taking the average size of primary schools as 400 children, 2,800 children could be affected by school closures excluding those on the edge. The Technical College would have about 1,500 students about 75% of which would be young enough for parents to need to be on hand i.e. c. 1,175. In total, 3,975 young people could be affected by school closures of say, up to 1 week (5 working days) until temporary arrangements are made to continue with education. Damage to schools could, however, lead to significantly longer closures.

3,975 x 5 days = 19,875 school days lost. Using the Hull 2007 method (Coulthard et al., 2007) it can be assumed that there are 2 children for every 1 working day lost by a parent who has to be at home with the children, so 19,875/2 = 9,938 days lost. Assuming a conservative estimate of £50 wages lost per day by a parent, the cost of school closures would be £50 x 9,938 = £496,900. The mean cost per school is £496,900/8 = £62,113. To estimate these disruption losses in financial terms, tax elements were not deducted from the £50 per day wage figure.

5.14 Traffic Disruption
It is possible to find out the average daily traffic flows for some stretches of road likely to be rendered impassable by a flood in the risk area using UK Department for Transport statistics [http://dft.gov.uk/traffic-counts/](http://dft.gov.uk/traffic-counts/), but determining how many motorists will decide against making their journey or predicting which alternative routes may be taken, requires more time than this project allowed. To provide an example, one cross-floodplain route was identified where it could be fairly certain that: a) at least one section of the road would be closed due to a flood if the current scheme failed and b) it is relatively easy to identify where traffic is likely to be diverted to. However, it was not possible to get flow data for certain sections, nor for some key diversion routes. In order not to mislead, a far more detailed analysis of the road network and statistics on cross-floodplain motoring habits would be required in order to provide a confident cost figure for traffic disruption.

5.15 Rail Disruption
Two elements of the cost of rail traffic disruption were included in the quantitative analysis of flood damages. The first relates to the value of time lost by passengers when the rail service is disrupted. One of the principal train operating companies running services in the flood risk area operated 294 train services per week (Mon-Fri) through the city’s mainline railway station. Averaged over a working week, this amounts to 59 trains per day. The UK National Audit Office report on rail delays estimates that the average train contains 182 passengers (NAO 2008). Employing this figure and an updated Department for Transport’s (DfT) market value of time for rail passengers, this amounted to an hourly delay figure of £48.30 per passenger. This value is based on gross wage rates plus non-wage labour costs, such as national insurance and pensions etc., and applies to journeys made in the course of work (DfT, 2012). Using the NAO’s average rail flood event of 2-hours, a flood at the mainline railways station would cost at least 59 x 182 x £48.30 x 2 (hours) = £1,037,000 (rounded). Another train company also uses the City’s mainline station and runs services on each day. In total approximately 7,780 passengers use the station on a typical day and, assuming half as many passengers use the station at weekends compared with weekdays, this alone would amount to an approximate delay cost of £376,000 per hour.

The second element of cost of rail disruption is the compensation with Network Rail is obliged to pay Train Operating Companies (TOCs) under Schedules 4 and 8 of the Track Access Agreement.
operating in the UK. The available cost data are average compensation costs. The actual compensation values for each of the TOCs is restricted information and therefore the indicative

![Image](image_url)

**Figure 4** Flooding causing rail disruption (from http://www.floodzone.co.uk/articles/network-rail-unveils-new-plan-to-tackle-river-flood-disruption/)

average values used here were based on data on the delay costs and cancelled services between 2011 and 2013. High, medium and low values are available which reflect the wide variation between TOCs and the rail lines impacted. The rail line in question to and from the city is a busy main line and therefore it is considered appropriate to use the high average values in this case which for passenger services are:

- Delay compensation value £s per minute per service - £97
- Cancellation compensation value £s per service cancelled - £2,591

For the NAO's average rail event of 2 hours, and assuming that trains are delayed for one day as a result, the additional delay compensation cost paid by NR to TOCs is estimated to be £97 x 59 x 120 minutes which is £686,760. These estimates may be under-estimates if trains are delayed for more than one day by flooding and this should be taken into account in interpreting results.

### 5.16 Emergency Services Costs

Penning-Rosell and Wilson (2006) undertook a detailed analysis of emergency service costs in the UK, including those of local authorities, highway authorities, fire, police and ambulance services and voluntary services, but excluding betterment (for example where a bridge was replaced by one of a higher standard). They calculated that emergency service costs (i.e. economic costs) amounted to 7.7% of total economic damages. Paccagnan (2012) concluded that equivalent emergency service costs should be estimated as between 10% and 13% and opted for 11% of total economic costs. These estimates exclude VAT and excise duty on fuel used by the emergency services which need to be taken into account when economic costs are converted to financial costs. This suggests that circa 12% of economic losses should be taken as emergency service costs, fed into appraisal at each return period rather than a single loss addition.
5.17 Social costs: anxiety treatment

Financial analyses usually exclude these kinds of costs but where flood protection appraisal is concerned they may be reported as an added benefit. The benefits of property-level protection due to the avoidance of stress and other mental health issues are based upon a value of £2,513 per household per event, based on future climate change metrics (Ramsbottom et al./Defra 2012). The value relates to a figure of £1,065 per person and the assumption that there are 2.36 persons per house, from the 2001 census (still applicable following 2011 census). The figure of £1,065 is made up of the existing approximate £225 value used by Defra as the willingness to pay, per household per year, to avoid stress caused by flooding; and £970 as a central value of medical and productivity costs for an average four months; these are a blend of general practitioner care, cognitive behaviour therapy and non-direct counselling (JBA 2012).

5.18 Impact on the wider region

In the early 1990s, for the case of a major flood in the Thames valley, FHRC estimated the indirect (primary and secondary) effects of such a flood in the locality and the sub-region (Table 5). The research used a model of the economic structure of the sub-region and the degree of interaction (as inter-trading) between the businesses located there. Economic multipliers were used to quantify the linkages between the floodplain economy (i.e. businesses affected by the flooding) and the economy, in the local flood free area defined as within 15-20 km of the floodplain and the sub-regional economy defined as the area up to 50 km from the floodplain. The stronger the linkages, the larger the adverse economic effects of the flood in the form of lost income in the adjacent economy owing to a lack of sales to the flood-affected businesses. Using multipliers calculated from surveys of how the flood-affected businesses buy from the local area and the sub-region, it was found that every £1m of income generated by businesses located in the floodplain generated £60,000 and £90,000 of business located in the local area and sub-region respectively. Losses owing to flooding would have the reverse effect. Applying this multiplier to the primary indirect losses shown in Table generated the results given in this table for secondary indirect impacts.

Here the 3.4% indirect losses are calculated as economic losses and would be much higher e.g. c.27% when estimated as financial losses. Similarly, the secondary indirects would be significantly higher. If the primary indirect losses are estimated as 27% of direct losses (i.e. 7.94 times higher), this would be £23,059,080. Similarly factoring 0.2% and 0.33% by 7.94 would give £1,365,378 and £2,207,368.

Whether the Thames Valley local and regional economies are similar to that of city which is the focus of this case study is a moot point: it is unlikely. A quantitative estimate could not be included in the quantitative benefit and reported separately in the accompanying benefit narrative to illustrate the likely order of magnitude of these benefits.

Potential damages to the trunk sewer. It is likely that a 1:50+ year event could cause substantial damage to the Sewage Treatment Plant main waste water pipe which is embedded into the embankment of the canal. No flood damage estimates were available from the operating company and so this benefit could only be reported qualitatively.

Overall results of the benefit assessment. Qualifying economic present value of benefits (as input to the Flood Defence Grant in Aid (FDGiA) Partnership Funding calculator are calculated using a EXCEL based model in which each property, its threshold flooding height, its size and property type are identified. Employing data from a hydraulic flood model of the benefit area, the depth of flooding in each property for a range of flood probabilities is then calculated, allowing depth-damage data from
Table 5 Primary and secondary indirect impacts of flooding in the Thames valley (Penning-Rowsell and Green 2000)

<table>
<thead>
<tr>
<th>Loss type</th>
<th>Damage and losses caused by a major flood (204 year return period)</th>
<th>Potential losses</th>
<th>As %age of direct damages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct</td>
<td>£85,404,000</td>
<td>100.0%</td>
<td></td>
</tr>
<tr>
<td>Indirect</td>
<td>£2,866,040</td>
<td>3.4%</td>
<td></td>
</tr>
<tr>
<td>Secondary indirect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in locality</td>
<td>£171,962</td>
<td>0.2%</td>
<td></td>
</tr>
<tr>
<td>in sub-region</td>
<td>£278,006</td>
<td>0.33%</td>
<td></td>
</tr>
</tbody>
</table>

Losses estimated in 1992

FHRC’s flood damage database (for different property types) to be linked leading to per property flood damage predictions. The results are based upon FHRC’s MCM Short Duration flood damage data in line with model simulations of flooding and are as follows:

The present value of benefits is estimated as £262m qualifying benefits for the economic case (where qualifying refers to the Government’s rules for benefits which qualify for consideration in a FDGiA proposal).

These benefits have been subject to ground-truthing of damages associated with the miscellaneous, unclassified, Code 9 properties (see below).

The breakdown of benefits for the economic case is shown below (Figure 5).

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>23%</td>
</tr>
<tr>
<td>Non-residential</td>
<td>30%</td>
</tr>
<tr>
<td>Code ‘9’ properties</td>
<td>10%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>20%</td>
</tr>
<tr>
<td>Indirect</td>
<td>14%</td>
</tr>
<tr>
<td>Risk to life</td>
<td>4%</td>
</tr>
</tbody>
</table>

When the principles of financial analysis are applied to the appraisal to generate an estimation of local financial benefits, the results are as follows.

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>21%</td>
</tr>
<tr>
<td>Non-residential</td>
<td>33%</td>
</tr>
<tr>
<td>Code ‘9’ property</td>
<td>14%</td>
</tr>
</tbody>
</table>
Figure 5 Breakdown of qualifying benefits by receptor for the case of an economic assessment

The present value of financial benefits is estimated to be £398m, for the financial case, as illustrated in the benefit breakdown shown below (Figure 6).

A more detailed analysis of the contributions of each flood damage receptor to Do Nothing damages is shown in the histogram below (Figure 7). Non-Residential Property financial damages are more than 50% of the total.

The potential benefits of the proposed flood protection project to economic growth. In addition to the above benefits, if implemented the proposed project has the potential to contribute to economic growth which will bring further local financial benefit. Historically the city has been a prominent driver of economic growth in its region and has grown even during the recent national economic
recession. The city is becoming progressively more important as a focus for knowledge-based industries and professional and business services with a wider regional and national importance. The Government has recently invested in accelerating infrastructure in the city. The investment anticipates a significant number of new houses and commercial development. Such investment will benefit from the protection of cross-floodplain and other infrastructure and properties that will be provided by the proposed project. Conversely, without the proposed scheme these investments and developments, and economic growth generally in Exeter, will be undermined.

As can be seen from the results above, the estimated local financial benefits of the preferred option are 68.5% higher than the estimated economic benefit estimates (i.e. £398m compared with £262m). To these estimated local financial benefits we also need to add any so far unquantified benefit relating to: tourism and recreation, environment and heritage, the trunk main sewer, canals and navigation, business confidence and the wider region.

6. Case Study 2 – selected examples from an assessment of the local financial benefits of protecting a harbour

This case study considers the worst case scenario in which nothing is done to defend the piers which protect an important coastal harbour from the risks of breaching and subsequent flooding. The case study has been anonymised and only selected aspects of the assessment are included here in order to demonstrate some further elements of local financial benefit assessment – in this case in a coastal flooding location. The piers are large concrete and masonry sea walls which extend from land out into the sea on either side of the harbour to embrace it: there is a gap in the centre of these embracing piers which is the harbour entrance. Within the harbour there is large marina.
Potential impacts of pier breaching and flooding. Apart from (a) physical damage to the harbour, the marina and its contents and the residential and commercial, properties which border the harbour, and (b) the costs of moving vessels from the harbour on receipt of warning three categories of impact can be distinguished – see Figure X:

Primary losses i.e. direct effects - these are the effects associated directly with the expenditure of marina and harbour users, visitors and tourists (often affecting very specific sectors such as chandlers, restaurants and amusement and leisure businesses, retail trade and transportation). Here we refer to these as the tourist sector. Tourists including marina users who buy locally-supplied goods and services. In the case of a breach of the harbour piers these direct effects will be negative ones on the local economy i.e. reduced expenditure.

Secondary losses i.e. Indirect effects - these are the effects associated with the decrease of intermediate demand from tourism including marina users for local production factors (labour, capital and land) and to other sectors of the local economy, as local suppliers buy locally produced goods and services.

Secondary losses i.e. Induced effects - these are the effects associated with household spending of reduced income earned directly or indirectly as a consequence of the decrease in tourist spending. Resident’s income is partially spent on locally-supplied goods and services (housing, food, transportation and other products and services). A decline in resident's income will be felt locally as reduced demand in terms of sales, income and employment.
The size of the indirect and induced effects is influenced by the ability of the local economy to satisfy demand arising from the tourist sector, as well as the size and shares of tourism industries that are locally owned. The extent of indirect effects depends on the size of the area being studied (i.e. the boundaries of the geographical area under study) and on the extent to which businesses in the area supply one another with goods and services (the more likely, the more diversified and interlinked is the local economy). In general, the smaller the size of the local economy and the higher the share of initial expenditure which leaks out of the local area, the fewer are these linkages and the larger will be the indirect effects of reduced spending brought about by the do nothing scenario. However, the size of indirect and induced effects also depends on the share of capital, land and labour that is locally owned. For example, small family-owned hotels and restaurants are more likely to buy local intermediate inputs than chain hotels and tourist villages. Where production factors are locally-owned, their remuneration - profits, rents and wages - will stay locally and the local community will be affected strongly by them.

The case study was limited to an assessment of the direct and indirect effects of the do nothing scenario in which one or more of the harbour piers are breached by wave attack. Figure x takes no explicit account of the potential tertiary impacts of the do nothing scenario arising through regeneration in the sub-region in which the harbour is located.

6.1 Characteristics of the coastal local economy

The local economy of the case study area resembles that of many coastal resorts and towns around the British coast. These coastal local economies are likely to be more vulnerable to climate change than inland areas because, in addition to changes in flooding, temperature and precipitation, they are also affected by a rise in sea level, increased wave heights and accelerated erosion. British coastal local economies are often recovering from a decline in traditional tourism, and are often characterised by high rates of unemployment, low wages and income, dependency on seasonal tourist industries and social deprivation. Such local economies are often fragile and many contain disadvantaged communities. They are therefore particularly vulnerable to the adverse impacts of the physical, economic and social impacts of coastal erosion and related sea level rise and climate change.

The case study area in which the harbour is located has been a popular British holiday destination for centuries but in recent decades it has suffered a decline in its visitor economy - a situation worsened by the 2008-2012 economic recession. Indeed the case study area is notable in being one of the worst-affected British coastal town in terms of personal bankruptcies. The local economy is frail and the total number of jobs for the working age population below the regional and national average and the availability of full-time employment is limited. Wage levels, income and output are low, and the area suffers from a narrow commercial base with a sectoral reliance on low wage industries including tourism, retail and social care. Gross Value Added (GVA) per head levels are reported as some of the lowest in the UK. The economy has a number of dominant industries, the majority of which are small (90% of businesses employ 19 or less people) and in the public and tourism sectors, particularly health, accommodation and food and retail. The area has one of the highest proportions of people with main or second jobs in tourism industries in the UK: one in six people in employment work in tourism related industries.

The case study area suffers from many of the deprivation problems normally associated with large cities. The area has high benefit claimant levels and an above average proportion of older residents. There are fundamental weaknesses in the local economy and especially the tourist industry which, if not addressed, could lead to declining demand for all aspects of the tourism product including
accommodation, attractions, transport, food and drink and related tourism provision including retail and professional services.

6.2 Methods for estimating the local economic impact of changes in tourist expenditure
A variety of methods ranging from crude approximation to complex mathematical modelling is available to estimate the economic impacts of spending in tourism economies. This case study employed a limited resource input and relatively simple and straightforward methods using mainly secondary sources of readily available data to measure the effects of reduced spending in various parts of the tourist local economy which will arise from pursuing a Do Nothing scenario. More sophisticated methods would employ primary data, for example from a survey or a random sample of marina users and tourist visitors to estimate their average spending by economic segment and would use these data to inform an Input-Output model of the local economy. This kind of approach was infeasible within the resources available for the case study but it was feasible to draw upon useful existing data and evidence available to the local authority and related agencies including the harbour authority, the marina operator and the local development agency.

In accordance with HM Treasury Green Book practice annual losses over the appraisal period were discounted using the 3.5% Test Discount Rate. Losses were accumulated as their Present Values (PV) from years 5 to year 10 only as a very conservative estimate. Under the Do Nothing scenario, once losses commence they would in theory extend to perpetuity. However, it is customary to cap losses at the cost of replacing infrastructure (Penning-Rowsell et al., 2013, p83). Thus calculating PV losses over the 50 year appraisal period would serve no additional purpose, with cumulative losses in the sub sectors targeted for assessment being significantly large by year 10 to merit a case for Partnership Funding investment.

The potential for direct physical damage (i.e. primary losses) to the harbour infrastructure, boats and properties surrounding the harbour which are flood-prone was assessed separately in financial loss terms outside of this case study and are therefore excluded here. Instead, the case study focused on monetising secondary local financial losses which have the potential to arise in the Do Nothing scenario. This involved seven sectors of the local economy and 14 sub-sectors as follows:

- **Business Disruption**
  - Loss of business rates income to the local authority due to closure
  - Loss of GVA to businesses due to closure
  - Loss of Gross wages to businesses due to closure

- **Residential Property**
  - Blight of property sale values

- **Harbour Moorings and Infrastructure**
  - Loss of Moorings Revenue to the local authority
  - Loss of Moorings Revenue to marina operating company
  - Loss of Lease Fee from the marina operating company to the local authority

- **Ferry Services**
  - Loss of Current Seasonal Ferry Revenue
  - Loss of new ‘all year round’ Ferry Service Revenue
- **Car Parks**
  - Loss of Revenue to the local authority and private operators
- **Cruise Ships**
  - Loss of Tourist Revenue from Cruise Ships
- **Tourism disruption**
  - Loss of Visitor Income from Boat owners
  - Loss of General Holiday Visitor Income

Below three of these sectors (business disruption, harbour moorings disruption and tourism disruption losses) are selected to exemplify the methods used to estimate secondary losses or benefits.

### 6.4 Potential losses affecting the business community.

#### 6.4.1 Loss of Business Rates to the local Council.

In the UK businesses pay rates in exchange for local services. Properties forced out of business as a result of declining demand following increased levels and frequencies of flooding will no longer pay rates, reducing the income to the local authority (i.e. Council) and the rate support grant from the Government.

An estimated 171 properties are at risk of flooding in the Do Nothing scenario. The rateable values for each property is available from government data sources (www.neighbourhood.statistics.gov.uk 2005 re-valuation). The rateable values were generalised from Bulk Class aggregates per metre squared from this data source (the values were not updated to account of changes since 2005). The multiplier for the financial year 2012/13 is 47.1p (small business rate multiplier 46.2p). The small business rate multiplier was used to calculate business ‘poundage rates’ for each property. An assumption is adopted that half of business premises will go out of business over a 5 year period starting in year 5. This assumption is considered conservative for two reasons (i) some businesses may well go out of business before year 5, and (ii) given that the marina will have been largely lost, businesses will face operating in an environment of dereliction with the principal visitor attraction (i.e. the piers and the marina) no longer present. It is therefore conceivable that up to 80% of businesses will cease operation as a result. Potential losses from commercial property can be seen in Table 6 where they are discounted using a 3.5% discount rate to derive their Present Value (PV).

Gross value added (GVA) is of the value of goods and services produced in an area, industry or sector of an economy. The loss of GVA to the nation is measured by a post-tax figure but in a financial analysis the pre-tax figure is used since we are considering the loss to a local economy rather than to the nation. As businesses close so GVA will reduce within the local economy and may be lost altogether or leak beyond the area. Statistics were derived from the UK Office of National Statistics. As most of the commercial premises expected to close are in three economic sectors (retail; arts, entertainment, recreation and other services; and accommodation and food) the analysis is limited to the GVA for these sectors. The logic of the GVA calculation is contained in Table 7.

**Table 6 Potential losses from disruption of business properties**

<table>
<thead>
<tr>
<th>Year</th>
<th>Discount factor 3.5%</th>
<th>Loss of rates to Council £</th>
<th>PV of loss of rates £</th>
<th>Loss of GVA £</th>
<th>PV of lost GVA £</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 7 Calculation of GVA for affected businesses

<table>
<thead>
<tr>
<th>Businesses affected</th>
<th>Torbay population</th>
<th>Businesses in Torbay</th>
<th>Of GVA in Retail, Accommodation, food and services and arts and recreation</th>
<th>Of business sectoral groups in Retail, Accommodation, food and services and arts and recreation</th>
<th>Of businesses in Retail, Accommodation, food and services and arts and recreation</th>
<th>GVA per head All sectors</th>
<th>GVA per head Retail, Accommodation, food and services and arts and recreation</th>
<th>Total GVA Retail, Accommodation, food and services and arts and recreation</th>
</tr>
</thead>
<tbody>
<tr>
<td>131,000</td>
<td>171</td>
<td>4,225</td>
<td>5.55%</td>
<td>32.10%</td>
<td>1,356</td>
<td>£12,777</td>
<td>£709</td>
<td>£92,895,179</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,951,967</strong></td>
<td><strong>17,660,246</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6.4.2 Potential financial losses affecting harbour moorings. The quayside and inner harbour area are operated by the local authority and lost mooring fees are losses to the Council. Any disruption to the marina is likely to be a loss to the local economy since there is no spare capacity elsewhere in the local economic area and the marina operator would encourage boat owners to moor at their other facilities outside of the local economic area. In an economic analysis transfers or mooring income would not be counted as a loss but in a financial analysis any loss of moorings income to the local economic area is counted as a loss. The Council would lose the annual lease fee of £293,255. The financial losses relating to harbour moorings are shown in more detail in Table 8. Loss of the marina revenue away would impact on car park revenues and further add to the decline of retail and service facilities around the harbour.

Table 8 Potential losses from loss of revenues relating to harbour moorings

<table>
<thead>
<tr>
<th>Year</th>
<th>Discount factor 3.5%</th>
<th>Loss of moorings revenue to Council £</th>
<th>PV of loss of mooring revenue to Council £</th>
<th>Loss of moorings revenue to Council £</th>
<th>Loss of lease fee to Council £</th>
<th>PV of Loss of lease fee to Council £</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.966</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.934</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
NB This is based on an assumption that a decision is made on safety grounds to close the harbour in year 5

### 6.4.3 Potential losses affecting tourism

Tourism plays a significant role in the local economy. The analysis separates out holidays, business trips, visits to relatives, other study visitors. It is assumed that the decline in harbour facilities will largely affect holiday visits which account for around 80% of day visitors (urban visitors only included) and UK staying visitors. This falls to 15% for overseas visitors as study visits and business visits are prominent in this sector. The per annum spend by holiday visitors excluding travel costs is £116,074,000. Additionally £1,220,000 is spent by boat owners per annum. A calculation of spend by visitors is shown in Table 9.

#### Table 9 Calculation of spend by visitors

<table>
<thead>
<tr>
<th>Visits/Spend (£) pa - Holiday only</th>
<th>Nights</th>
<th>Trips</th>
<th>£ Spend</th>
<th>£ Spend/person/day</th>
<th>% Total visit spend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Staying visitors</td>
<td>1,450,800</td>
<td>371,700</td>
<td>96,372,800</td>
<td>66.43</td>
<td>79%</td>
</tr>
<tr>
<td>Overseas Staying visitors</td>
<td>45,300</td>
<td>9,500</td>
<td>3,788,400</td>
<td>83.63</td>
<td>15%</td>
</tr>
<tr>
<td>Day Visitors (urban only)</td>
<td>1,023,500</td>
<td>46,879,800</td>
<td>45.80</td>
<td>82%</td>
<td></td>
</tr>
<tr>
<td>Deduction for travel spend</td>
<td></td>
<td></td>
<td>31,007,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total spend deducting travel</td>
<td></td>
<td></td>
<td>116,034,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boat owners spend</td>
<td></td>
<td></td>
<td>1,220,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>8,483,722</td>
<td>21,545,961</td>
<td>1,361,739</td>
</tr>
</tbody>
</table>

The following is a summary of those employed in businesses serving holiday makers/visitors categorised by direct, indirect and induced employment according to a local research company:

- Direct: 4,390
- Indirect: 1,005
- Induced: 443
- TOTAL: 5,838

Indirect employment arises as a result of expenditure by businesses in direct receipt of visitor expenditure on the purchase of goods and services for their businesses. Induced jobs are those that are supported by the spending of wages by employees in direct and indirect jobs.

Visitor numbers will inevitably decrease as harbour facilities, services and infrastructure are in decline following a strategic decision not to improve the two piers. It is difficult to deduce without
detailed visitor survey the numbers of holiday visitors who would not visit the local area under a Do Nothing scenario. Certainly the £1,220,000 per annum spend by boat users would be lost outside of the local economy but urban tourists may choose another destination close by in the sub-region. Calculated potential losses to tourism through decreased visitor numbers can be seen in Table 10.

**Table 10 Potential losses from tourism**

<table>
<thead>
<tr>
<th>Year</th>
<th>Discount factor @ 3.5%</th>
<th>Visitor income from boat owners</th>
<th>PV of loss of Visitor income from boat owners</th>
<th>Lost general Holiday visitor income</th>
<th>PV of lost general Holiday visitor income</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.966</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.934</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.902</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0.871</td>
<td>10% reduction each year after year 5 is conservative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.842</td>
<td>1,220,000</td>
<td>1,027,207</td>
<td>11,603,400</td>
<td>9,769,751</td>
</tr>
<tr>
<td>6</td>
<td>0.814</td>
<td>1,220,000</td>
<td>992,471</td>
<td>11,603,400</td>
<td>9,439,373</td>
</tr>
<tr>
<td>7</td>
<td>0.786</td>
<td>1,220,000</td>
<td>958,909</td>
<td>11,603,400</td>
<td>9,120,168</td>
</tr>
<tr>
<td>8</td>
<td>0.759</td>
<td>1,220,000</td>
<td>926,482</td>
<td>11,603,400</td>
<td>8,811,756</td>
</tr>
<tr>
<td>9</td>
<td>0.734</td>
<td>1,220,000</td>
<td>895,152</td>
<td>11,603,400</td>
<td>8,513,774</td>
</tr>
<tr>
<td>10</td>
<td>0.709</td>
<td>1,220,000</td>
<td>864,881</td>
<td>11,603,400</td>
<td>8,225,869</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5,665,102</td>
<td></td>
<td>53,880,691</td>
<td></td>
</tr>
</tbody>
</table>

7. **Assessing tertiary impacts**

Tertiary impacts are explained in section 3.3 above. They are caused either by lack of a flood risk management initiative, in which case a local economy and the local community on which it depends can spiral downwards and, ultimately, may become abandoned or by a flood risk management initiative being taken which stimulates economic and social regeneration and growth.

The key to estimating tertiary impacts is an understanding of how businesses in a local economy will react either to a continuing flood risk in which no flood risk management intervention is forthcoming or to a flood risk management intervention being introduced to lower flood risk. This is because flood risk can influence business decisions and behaviour negatively if the risk continues or is perceived to be worsening. On the other hand a change in flood risk – by reducing it significantly – could alter business decisions and behaviour positively in the years following an intervention.

7.1 **Behavioural response of businesses to flood risk**

The theoretical range of business response behaviours may be identified as:

- Businesses may remain at their location and do nothing to lessen their own flood risk (for example, they may do nothing to invest in property-level-protection measures and/or other means of safeguarding the continuity of their business during times of flood)
- Businesses may decide that the flood risk is too great a threat and move to an alternative flood-free location (which may or may not be within the same local economy)
Businesses may decide to close, possibly as a result of unsustainable, uninsured losses incurred in a flood.

Businesses may decide to remain at their location and adopt techniques to ensure the continuity of their business during times of flood, thereby reducing the impact of flooding upon them should a further flood be experienced.

Businesses may follow the first or fourth bullet point option above, and decide to invest in order to expand their business in response to a flood risk management intervention which significantly lowers their flood risk.

7.2 Evidence on the adoption of business continuity planning (BCP)

Research undertaken in five coastal locations in Europe indicates that adoption of business continuity planning by companies located in flood risk zones is limited, and that most of business continuity planning is done by large companies (Parker et al., 2011). By contrast small and medium size enterprises currently have a poor level of adoption of business continuity planning which includes property level protection measures and other measures designed, for example, to ensure that employees can get to their workplace, that goods and services can get to customers and that supply chains are protected if flooding occurs. Among the more commonly adopted business continuity measures are flood insurance and back up of electronic data files but the indications are that many small businesses may be without such measures making them particularly vulnerable to flooding and its impacts on them. Even despite some recent serious flood occurrences, hardly any of the companies interviewed had decided to move away from their present flood risk zone location. Therefore the first of the bullet point behavioural options listed above is likely to be common and it tends to be the large businesses which adopt the fourth bullet point option. The findings regarding locational inertia are consistent with the findings in the South-West of England in which the business community has been badly affected by flooding in recent years (Devonomics, 2013).

7.3 Assessing the value of BCP in reducing business disruption and contributing to the local economy

For those businesses which decide to adopt business continuity measures, the financial cost of these measures needs to be set against the financial benefits. The financial benefits will be the GVA gain generated by reducing the number of working hours lost because of flooding. Calculating this involves estimating the number and value of working hours lost without business continuity measures and subtracting one from the other. A parallel process can be followed to calculate the value of GVA that is ‘released’ by introducing a flood risk management intervention such as a flood protection scheme – by calculating the value of the working hours lost without and with the intervention. In some cases this may involve a reduction in the duration of flooding disruption although reliable data to enable this to be estimated is hard to find.

7.4 Assessing the value of the loss of businesses to the local economy by relocation of close-down

If it feasible to estimate the number of businesses which are likely to relocate outside the local economy or close down as a result of flooding – perhaps continued flood risk with no flood risk management intervention being introduced – then the GVA relating to the estimated number and value of working hours lost to the local economy is a measure of this impact.

7.5 Assessing the value to the local economy of new investment enabled and stimulated by a major flood risk management intervention

Following a major flood risk management intervention businesses may decide to invest in expansion within the protected flood risk area when they would not have done previously. Land may also become more attractive as a location for new development and new businesses. If these prospective developments are either known or reasonably predictable then the GVA to the local economy may
be assessed by calculating the number of new jobs which will be brought into the local economy and by calculating the number and value of working days added as a consequence.

7.6 Potential additional impacts on the local economy
Over and above the impacts described above, a major flood risk management project may generate further local financial benefits (as well as national economic ones) through the advantages of agglomeration whereby clusters of businesses gain further through co-location and close linkages. The infrastructure (e.g. roads) which businesses often depend upon may also be protected helping business further. It is difficult to assess these additional impacts quantitatively. Frontier Economics (2014a, b) have developed a Toolkit comprising a step-by-step approach to assessing tertiary impacts of flood risk management interventions in England and Wales. However, they do not explicitly consider the circumstance of local economic downturn owing to continued lack of investment in flood risk management initiatives but the concepts and methods used may be adapted for this purpose. A further factor to be considered in the case of some flood protection schemes is the ‘escalator effect’ in which successive flood protection projects which raise the standard of protection lead to a major increase in the value of protected property and infrastructure but also increase the potential for catastrophic flood losses (Parker, 1995).

8. Acknowledgements
The contribution of Dr John Chatterton to the second case study in this document is fully acknowledged.

9. References

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