

Leeds (River Aire) Flood Alleviation Scheme Executive Summary for Steering Group 13 July 2009

1.0 Purpose of Executive Summary

- 1.1 The purpose of this report is to seek views from the Leeds Flood Alleviation Scheme (FAS) Steering Group and subsequently Leeds City Council Executive Board on our preferred option and seek agreement on an approach to take the scheme forward.
- 1.2 We will be submitting the business case (Project Appraisal Report - PAR) for the Leeds Flood Alleviation Scheme on 24 August 2009 for presentation to our National Review Group (NRG) at the start of October 2009. This report provides an executive summary of the options considered and the rationale supporting our preferred option.

2.0 Introduction and Background

- 2.1 There are no formal flood defences along the River Aire in Leeds. The onset of flooding varies through the city, but can happen in an event with as low as a 1 in 5 year (20% annual chance event) flood. The city has been fortunate not to suffer any recent severe flooding comparable to that experienced in Sheffield and Doncaster in June 2007. In autumn 2000, the city was only centimetres away from major inundation. There have been further 'near misses' in 2002, 2004, 2007 and 2008.
- 2.2 The Aire catchment has a rapid response to rainfall.
- 2.3 In addition to flooding directly from the river, many recorded flood incidents are due to localised surface water.
- 2.4 The Leeds FAS extends over nineteen kilometres from Newlay at the upstream end, to Woodlesford at the downstream end. It passes through the central business district in Leeds city centre. A plan of the scheme is provided at the end of this summary.
- 2.5 The number of residential and non-residential properties affected by flooding during a 1 in 200 year (0.5%) flood is shown in Table 1. Around a third of the non-residential properties are offices, including Asda's headquarters and numerous large employers in the financial, legal and service sectors.

	Residential	Non-Residential (Commercial, Retail and Industrial)	Total
Directly	255	495	750
Indirectly	3607	188	3,795
Totals	3,862	683	4,545

Table 1: Number of Properties Currently at Risk from a 1 in 200 year (0.5% annual chance event) flood

- 2.6 There are many additional services which are severely affected if Leeds floods. These include major A roads, utility services and rail services to the whole of the north east. 140,000 passengers pass through Leeds station each day. In the 2000 floods Leeds station narrowly avoided closure.
- 2.7 We have used the mandatory Flood and Coastal Defence Project Appraisal Guidance (FCDAG) suite of documents (Defra 2001 and associated updates) to appraise the scheme.
- 2.8 We have carried out a high level environmental assessment to highlight any key impacts and actions that will be required.

3.0 Downstream Implications

3.1 Woodlesford

- 3.1.1 Leeds acts as one large flood cell with significant overland flow. The exception to this is the Woodlesford area. If the Leeds FAS is implemented the flood risk at Woodlesford would be increased due to higher river levels. We have included the provision of defences in the Woodlesford area to ensure that there is not a detrimental impact from these higher levels.

3.2 St Aidan's Wetland Nature Reserve (Former Open-cast Site)

- 3.2.1 The Leeds FAS has minimal effect on river levels at Lemonroyd weir (87 mm increase in a 200 year event, 54mm in a 100 year event and 50mm in a 50 year event). This is insignificant, and is within modelling tolerances. It will have an insignificant effect on the use of St Aidan's washland as a water holding area.
- 3.2.2 The Leeds FAS is not dependant on St Aidan's washland being completed and in use. The washland is being provided in connection with events that happened 20 years ago, not as a result of the Leeds scheme.
- 3.2.3 St Aidan's will store about 7 million cubic metres of water in a 100 year event on the River Aire. This will reduce levels immediately upstream of the inlet by 840mm, at Swillington Bridge by 100mm and at

Lemonroyd weir by 630mm. This will have benefits downstream in the event of flooding from the River Aire. The Leeds FAS will have insignificant effect on these benefits.

4 Options Considered

4.1 Raised Defences

- 4.1.1 Raised defences involve the construction of embankments or new flood defence walls. These will wherever possible be set back to maintain the waterfront as a public amenity area. Where it is not possible to construct flood walls due to buildings along the river edge, the buildings will be strengthened and used as part of the flood defence.
- 4.1.2 We identified this option as the preferred approach in our draft Upper Aire Flood Risk Management Strategy (FRMS). We have carried out a significant amount of work developing this option during the four year appraisal period. We have completed geotechnical, structural and environmental investigations, and site inspections. We have carried out extensive consultation including environmental scoping, individual landowner consultation, joint public consultation and key stakeholder consultation, including Leeds City Council, British Waterways and Yorkshire Water. We have used the results of this work to identify an outline form and alignment of the defences.
- 4.1.3 A Design Vision and Guide sub-group in 2008/9 identified a number of sensitive areas (Hotspot Sites) and developed outline designs to illustrate how the raised defences can be incorporated in the waterfront area. The group identified 14 sites and gave them green, amber or red status as the solutions for these sites were developed in more detail. 11 are now green or amber. With further discussion and detailed design we are comfortable that the remaining sites can be green, (Fearn's Wharf, Rose Wharf and Thwaite Mill).
- 4.1.4 The Strategic Design Alliance, in liaison with teams across City Development with input from the Environment Agency developed the Design Guide and Vision (The Vision). The Vision aims to analyse the existing river corridor environment, highlight important features and suggest how design can be used to mitigate the potential negative impact of defences and where possible highlight enhancement opportunities.

4.2 Upstream Storage

- 4.2.1 In our draft Upper Aire strategy we concluded that our preferred option was linear defences providing a 1 in 200 year event standard of protection. This is in accordance with Defra appraisal guidance. The strategy studied over 20 sites in the valley but concluded that few sites were available for storage of large volumes of flood water. However, recognising an aesthetic need to minimise the impact of raised

defences, we carried out further conceptual investigation of an upstream storage option. We considered storage at two locations; Holden Park (Keighley) and Rodley.

4.2.2 At Holden Park the approximate storage volume available is 6 million cubic metres. We would need to address a number of issues if this option is taken forward to detailed design including a trunk road, railway line, trunk sewer and associated environmental impacts.

4.2.3 We considered upstream storage at Rodley at a very conceptual level to enable a storage alternative to be considered. The approximate storage volume at Rodley is 1.5 to 2 million cubic metres. It would need a dam as part of the storage area. The dam height would be approximately 5m above the typical existing ground level. We would need to address a number of issues if this option is taken forward to detailed design.

4.2.4 These include consultation with landowners and assessment of the environmental impacts such as impact on landscape from a sizeable structure, impacts on the existing nature reserve, water quality issues and change of land use. We would also need to consider the impact on a Yorkshire Water sewage works and the Aire Valley railway line. We would only retain water during significant flood events and the volume retained would be that over and above the capacity of the channel downstream of the storage.

4.3 Arup Conceptual Options

4.3.1 Arup have suggested a number of alternatives that might lower the proposed flood defence heights through Leeds City. These comprise:

- Replacing Knowsthorpe weir with moveable gates;
- The addition of either an 18m or 28m wide bypass channel along Great Wilson Street / Hunslet Road;
- Connecting the river and canal together into a single wide channel upstream of Knowsthorpe weir;
- Localised re-profiling of the main channel upstream of Knowsthorpe weir to remove obvious high points in the river bed;
- Re-location of the floodwall downstream of Knowsthorpe weir to the landward side of the canal.

4.3.2 We asked Arup to carry out hydraulic modelling on our behalf to provide an indication of the potential benefits these options could deliver in terms of reduced wall heights. If we include one or more of these options in the FAS we will need to carry out a feasibility study including consideration of costs, buildability and environmental impacts. The reductions in water levels achieved appear in section 5.3.

4.4 Use of demountable or removable defences

Our policy is to avoid the use of demountable or removable defences wherever possible. This is due to problems deploying the defences, particularly where advance warning of a flood is limited. Extensive use is not planned, however their use will be considered further if necessary in particularly sensitive areas as part of the detailed design. This will be on a risk assessed basis.

5 Defence Heights

All the options above will require raised defences of varying heights. The following provides an indication of the reduction in wall heights that could be achieved using one or a combination of the options outlined above.

5.1 Raised Defences

5.1.1 Table 2 provides wall heights at specific locations for both a 1 in 100 year (1%) and 1 in 200 year (0.5%) flood with and without allowance for climate change.

Location	1:100	1:100 + Climate Change	1:200	1:200 + Climate Change
Asda	0.45	1	0.71	1.29
Brewery Wharf	0.78	1.26	1.01	1.52
Royal Armouries	1.67	2.08	1.87	2.29
Knowsthorpe Weir	0.39	0.65	0.52	0.77

Table 2: Wall Heights in metres for Varying Standards of Protection

5.1.2 Wall heights are all inclusive of freeboard (510mm). Freeboard is an allowance for tolerances including those in the modelling process. These include super elevation at bends and wave action. The freeboard required is calculated on a scheme by scheme basis. Provision of freeboard is not optional and we cannot consider its removal as a means for reducing wall height.

5.2 Upstream Storage

5.2.1 Upstream storage at either Rodley or Holden Park would reduce the flood levels downstream through Leeds as shown in Table 3 below for a 1 in 200 year (0.5%) flood including climate change. These are indicative heights.

Reduction	Rodley Storage	Holden Park (Keighley)
Minimum	0.11m	0.10 – 0.20m
Maximum	0.36m	0.40 – 0.60m
Average	0.24m	0.20 – 0.30m

Table 3: Reductions to Wall Heights using Upstream Storage

5.3 Arup Conceptual Options

5.3.1 Table 4 provides an indication of the potential reduction in the 1:200 year + climate change water level we could achieve if we construct one or more of the options listed in 4.3.1. Please note that these figures are based purely on water level without taking into account freeboard allowances for wall heights. We could only achieve reductions to wall heights through the central section of the scheme between Victoria Bridge and Knowsthorpe Weir.

Location	Change in Water Level (m) Compared to Baseline (1:200 year + cc)				
	Lowering of Knowsthorpe Weir	Lowering of Knowsthorpe Weir + 18m bypass Channel	Lowering of Knowsthorpe weir + 28m bypass channel	Lowering of Knowsthorpe weir + 28m bypass channel + local re-profiling of channel	Lowering of Knowsthorpe weir + 28m bypass channel + local re-profiling of channel + Merging of Canal and River
Asda	-0.1	-0.6	-0.7	-0.9	-1.1
Brewery Wharfe	-0.2	-0.5	-0.5	-0.8	-1.1
Armouries Museum	-0.2	-0.4	-0.4	-0.7	-1.7
Knowsthorpe Weir	-0.8	-0.8	-0.8	-0.8	-1.1

Table 4: Potential Water level reductions from Arup's Options compared with the 1:200 year + climate change water level

5.4 Climate Change

5.4.1 The current climate change guidance (Defra) suggests that over the next 100 years, river flows will increase by approximately 20%. This will result in an increase to the frequency and depth of flooding. The channel through Leeds is very narrow, as is the flood plain. As a result any increase in flows would have a significant affect on water levels.

5.4.2 For the Leeds FAS climate change will result in the current day 1 in 200 year (0.5%) flood becoming a 1 in 75 (2%) annual chance event in a 100 years time.

- 5.4.3 We can provide for the affects of climate change in two different ways. Precautionary, i.e we deal with it now based on predictions of water levels in the future, or through a managed adaptive approach, i.e. deal with it later through a range of options. The latter involves providing for the standard of protection required today and then increasing the capacity of the scheme at a future date.
- 5.4.4 Table 5 summarises the different options we have assessed for dealing with climate change.

Option	Climate Change Mitigation
Using Raised Defences	<p>Do it now - Precautionary approach: The initial standard of protection provided is equivalent to a 1 in 750 years (0.13%) annual chance event. This falls to a 1 in 200 years (0.5%) annual chance event at the end of the 100 year appraisal period.</p> <p>Do it later - Managed Adaptive approach: An initial standard of a 1 in 200 year (0.5%) annual chance event is provided. The height of the wall is then increased in the future, after 30, 40, 50, 60 or 70 years.</p>
Using Upstream Storage	<p>Holden Park</p> <p>Do it now - Precautionary approach: Holden Park storage is constructed at the start with raised defences. A standard of protection of 1 in 200 years (0.5%) annual chance event is provided at the end of the 100 year appraisal period*.</p> <p>Do it later - Managed Adaptive approach: raised defences are constructed to provide an initial standard of protection of 1 in 200 years (0.5%) annual chance event. Holden Park storage is then constructed after 30, 40, 50, 60 or 70 years.</p> <p>Rodley</p> <p>As Holden Park but constructing a storage area at Rodley instead of Holden Park</p>

Table 5: Options Assessed for dealing with Climate Change

* The appraisal period is the period over which the performance of the defences is considered.

5.5 Land Management

- 5.5.1 Current research indicates that there is no evidence to prove catchment scale land use and management is an effective tool to manage flood risk, (Research & Development Update: Review of the impact of land use and management on flooding. Environment Agency, 2008).
- 5.5.2 For large catchments, existing modelling studies suggest that a large extent of land-use or land management change is required to produce a relatively modest reduction or delay in downstream flood peaks.
- 5.5.3 We will continue to promote land management as an adaptive approach to build climate change resilience into catchments as part of

the implementation of the Aire Catchment Flood Management Plan (CFMP) and the Upper Aire Flood Risk Management Strategy.

6.0 Costs

6.1 Raised Defences

6.1.1 We have carried out extensive appraisal work as outlined in 4.1. This has enabled us to produce an outline for the most appropriate type and alignment of the defences at each location along the scheme. Working with a Framework contractor we have developed costs for these proposals.

6.1.2 In addition to the labour, plant and material elements associated with the physical defences the costs also include provision for overheads, design and further surveys, risk, compensation, environmental mitigation, consents and licences, work to existing bridges and the existing drainage network required as part of the scheme. This is not an exhaustive list. We have also developed costs for construction of a scheme with one metre lower defences. We have used this information to calculate costs for varying standards of protection.

6.1.3 Table 6 shows the costs and associated benefits for construction of a scheme with raised defences at varying standards of protection. The costs shown below do not take into account climate change as appraisal guidance requires that economic analysis is carried out in the first instance to establish the optimum standard of protection before considering the implications of climate change.

	Standard of Protection (1 in X years)			
	100	200	500	750
Cost (£M) *	125	140	145	150
Benefits (£M) *	295	380	440	450
Benefit Cost Ratio	2.4	2.7	3.1	3.0

Table 6: Costs for Raised Defences (excluding climate change) * figures rounded to the nearest £5m

6.1.4 It can be seen that as the standard of protection and benefit values rise the cost does not increase at the same rate. This is because the scheme is complicated with significant costs involved in establishment, design and foundation works. Reducing the wall by 1m would save approximately £6 million of labour, plant and material costs.

6.2 Upstream Storage

6.2.1 The estimated costs for provision of an upstream storage area at either Holden Park or Rodley are shown in Table 7. We have developed these costs based on a conceptual design and they are not to the same level of certainty as the raised defences costs. However, we

consider the costs to be of sufficient detail to enable economic analysis and comparisons.

Location	Cost (£m)
Holden Park	45 – 50
Rodley	45 – 50

Table 7: Upstream Storage Costs

6.2.2 Although the storage capacity of Rodley is smaller than Holden Park the costs are approximately equal due to the comparatively large dam required at Rodley.

6.3 Arup Conceptual Options

6.3.1 In the work carried out to date Arup have not included calculation of costs for their alternative suggestions. An initial review of the works that would be required to construct a bypass channel (18 or 28m wide) suggests costs would far exceed the additional £6 million that it would cost to provide the equivalent protection through increased wall heights. Therefore, for completion of our business case we cannot justify more detailed analysis of this alternative option. For this option to proceed, the requirements for planning policy, land take and infrastructure changes would probably only make it suitable as an adaptive approach to climate change if significant delays to construction of a flood defence scheme were to be avoided.

6.3.2 We do not expect the remaining options proposed by Arup (lowering of the weir, merging of the canal and river and re-profiling of the channel) will deliver a reduction in wall height of greater than 1m. However, as with the bypass channel, we the cost of constructing these alternatives is estimated to be significantly in excess of a raised defence option therefore we have not progressed with a more detailed analysis at this stage. Approximate costs are shown in table 8, below. Please note that these costs are an initial guide only and do not include contaminated land remediation, supervision, demolition, land purchase/compensation or service diversions.

Option	Total (£million)
2.4km of 28m wide channel	24
New road bridges (2)	20
New Footbridges (6)	8
Fish belly lock gates	20
Total	72

Table 8 Costs of Arup alternatives

7.0 Results of public consultation

7.1 The scale of the Leeds FAS and the implications of the scheme on the community, their representatives, public sector organisations, businesses and the local media has led to the requirement for a wide spread and on-going public awareness and consultation campaign. The key findings from the public consultation (based on 135 returned questionnaires) carried out in May and June 2009, including public events in central Leeds, Swillington and Kirkstall are summarised below:

- 75% of respondees agree or strongly agree that Leeds should have flood defences.
- 55% thought the proposals were an acceptable way to protect Leeds.
- 54% wanted to see a combination of upstream storage and a by-pass channel.
- 63% of people agreed or strongly agreed that the outline designs fit in with the waterfront environment.
- 60% felt the Design Vision should set the overall design approach for defences.

8.0 Environmental Considerations

8.1 We have involved environmental specialists in the development of the preferred option. We carried out investigations to highlight potential impacts that will need to be eliminated, minimised, mitigated or compensated for. These investigations included:

- visual impact and heritage assessment (including access and recreation);
- archaeological desk top study and watching brief on the site investigation;
- ecological walk over survey and watching brief on site investigation;
- strategic ecological impact assessment;
- geo-technical investigation.

8.2 We have consulted key stakeholders and taken on board feedback to the Scoping Consultation Document in the development of the outline design. Landscape and access impacts have been a key issue. Particular focus on these issues during meetings with key stakeholders has helped us to develop workable outline designs. The key report in partnership with the Environment Agency – The Landscape Design Vision and Guide - documents key outcomes.

8.3 Along the scheme length there are no locations where existing riverside access to the river edge is blocked. We have set back

defences or raised ground levels to maintain existing footpaths and retain views and included improvement to access.

- 8.4 We fed the high level Environment Risk Management Plan into the costs for taking the Leeds FAS forward.
- 8.5 The FAS proposals can also bring some new benefits along the river; these appear in an outline enhancement list. We also identified opportunities to work with others during detailed design. Examples include riverside habitat planting improvements, improvements to cycleway surfacing, incorporation of public art, fish passes, new river crossings and the creation of 11ha of Biodiversity Action Plan habitat. We are investigating the possibility of introducing small hydro-power structures on weirs and solar or wind power on pumping stations. If feasible these would help to offset the carbon footprint of the scheme.

9.0 Selection of preferred Option Standard of Protection

- 9.1 Having collated the cost data, we carried out calculations to determine the most economic standard of protection (SOP). This process is called optimisation. During this process we consider not only the benefit cost ratio but also incremental benefit cost ratio between the different standards of protection. The appraisal process requires this to be carried out in advance of works to determine how climate change should be addressed.
- 9.2 As we identified that the upstream storage and Arup alternatives were significantly more costly, we carried out the optimisation process for the raised defences (walls) option.
- 9.3 Our analyses of how the scheme should take account of the impact of climate change concluded that the most economic solution is a precautionary approach achieved by providing raised defences at a height for 1:200 years with climate change.

10.0 Impact on British Waterways assets.

- 10.1 We have worked with British Waterways to identify impacts on their assets and develop appropriate solutions. Key areas for further development are; Granary Wharfe canal basin, Knostrop cut construction of defences between the river and canal and new flood gate, and potential requirement for flood gates at Thwaites Mill.

11.0 Impact on Yorkshire Water assets.

- 11.1 Following a meeting attended by ourselves and Yorkshire Water on the 22 June 2009 we concluded that:

- A 1:5 pluvial (surface water) and 1:200 fluvial (river) condition is a suitable basis for outline design of the scheme;
- We will continue to work closely with Yorkshire Water as the scheme develops to detailed design;
- Yorkshire Water were comfortable with the outputs from the outline design; subject to them incorporating the Asset Standard for Pumping Stations and that opportunities to reduce the number of pumping stations are looked at as the design progresses;
- Working with Yorkshire Water we will look at respective maintenance and construction programmes with a view to achieving efficiencies;
- Once built, Yorkshire Water would ultimately take over the operation and maintenance of the pumping stations subject to agreement of a commuted sum.

12.0 Impact on Leeds City Council assets.

12.1 We carried out an assessment on the bridges that would be affected by our preferred option. We costed these works, which include bridge strengthening works and jacking of bridges (predominantly footbridges the main exception being Gotts Bridge) to raise levels and these are included in the projected scheme costs.

12.2 LCC drainage department have been involved in the ongoing consultation on the surface water outline design in conjunction with Yorkshire Water. As noted in 11.1 further work will be carried out to identify opportunities for reducing the number of pumping stations.

12.3 Provision of defences on the River Aire will increase river levels on Holbeck. We are therefore developing a proposal for defences on this tributary. We have held discussions with the Holbeck Urban Village project team and have identified three potential options.

- Raised defences
- Culvert
- Culvert with dry weather flow

We are continuing to work with key stakeholders to review the environmental, technical and economic aspects of these three options. We have made an allowance within the PAR for costs associated with the highest cost solution at this time.

13.0 Benefit Cost Ratio and Outcome Measure Score.

13.1 The preferred option (1 in 200 year with precautionary climate change) has a benefit cost ratio of approximately 3.5. Under current arrangements the scheme will need to compete with other flood defence projects elsewhere in the country.

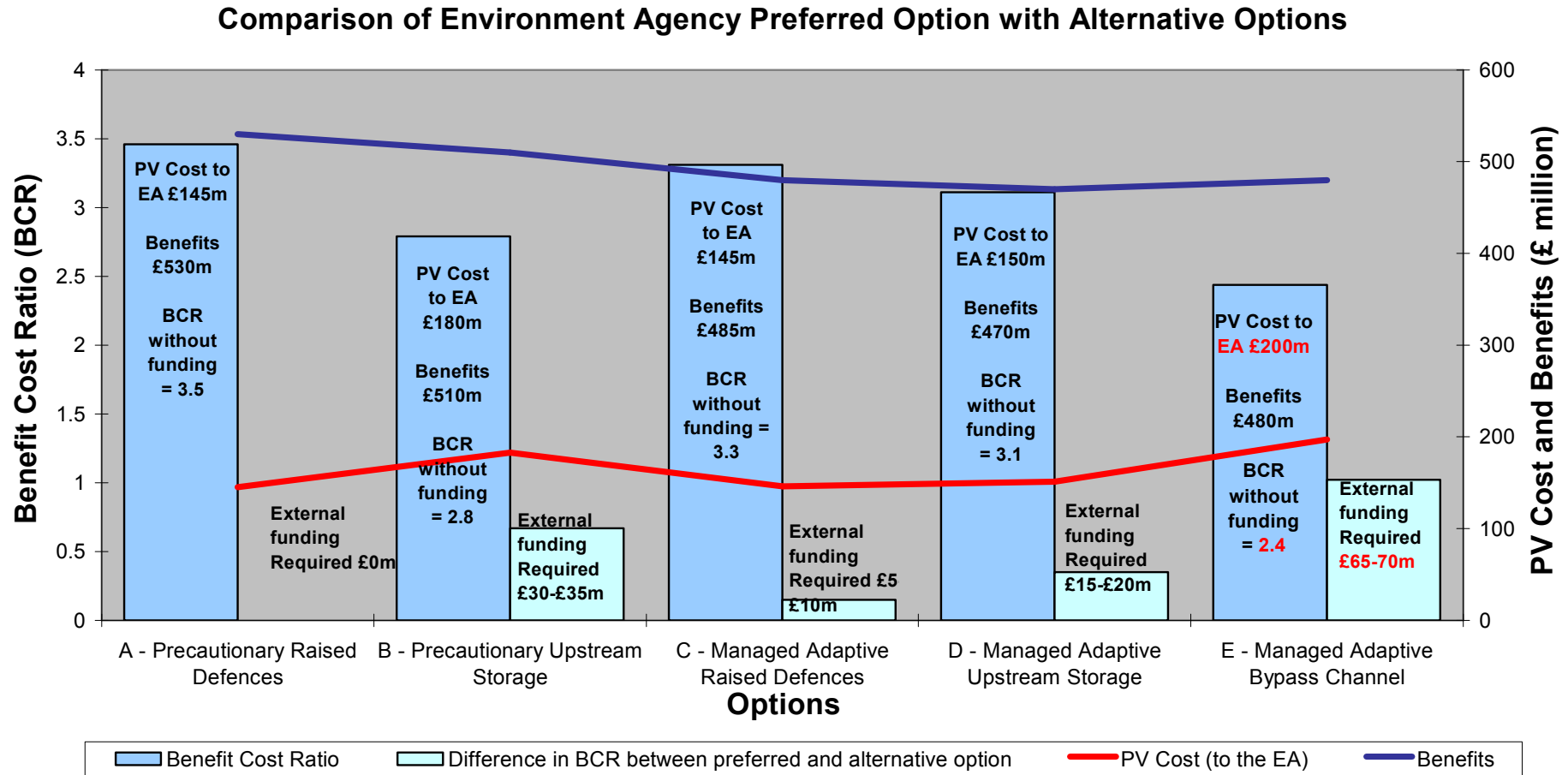
- 13.2 As part of this process we calculate an outcome measure (OM) score and this is used in prioritising the allocation of funding. The score is based on a number of factors including benefit cost ratio and contribution of the scheme to delivery of national targets, for example properties moved from a high to medium flood risk category. Scores are also relative to the present value cost of delivering the scheme.
- 13.3 The OM score for the preferred option is quite low. An increase in scheme costs and subsequent reduction in the OM score could impact on the schemes likelihood of receiving funding.

14.0 Confirmation of Our Preferred Option.

- 14.1 Our preferred option which would form the basis of an application for funding is the provision of a 1 in 200 year (0.5%) flood standard of protection with a precautionary approach to climate change. We would provide this standard using raised defences.
- 14.2 We suggest that we proceed with submission of the PAR with our preferred option as outlined above and a statement from LCC that they support the scheme with either our preferred option or an alternative option with a managed adaptive approach to climate change. We would also outline the concept of an alternative option. We envisage that an alternative scheme is one that would not necessarily provide the best value for money in accordance with appraisal guidance but is perceived to have additional benefits in terms of the wider regeneration and development plans for Leeds. Figure 1 illustrates some of these alternatives in relation to our preferred option
- 14.3 We would find it difficult to promote a 1 in 100 year standard of protection due to the significant reduction in benefit cost ratio.
- 14.4 To help achieve approval of the business case and subsequent funding of an alternative option, we need commitment from Leeds City Council that they would secure external funding at a level that would deliver an equivalent benefit cost ratio as our preferred option identified in accordance with appraisal guidance. Figure 2 illustrates the decision process for establishing a proposed standard of protection.

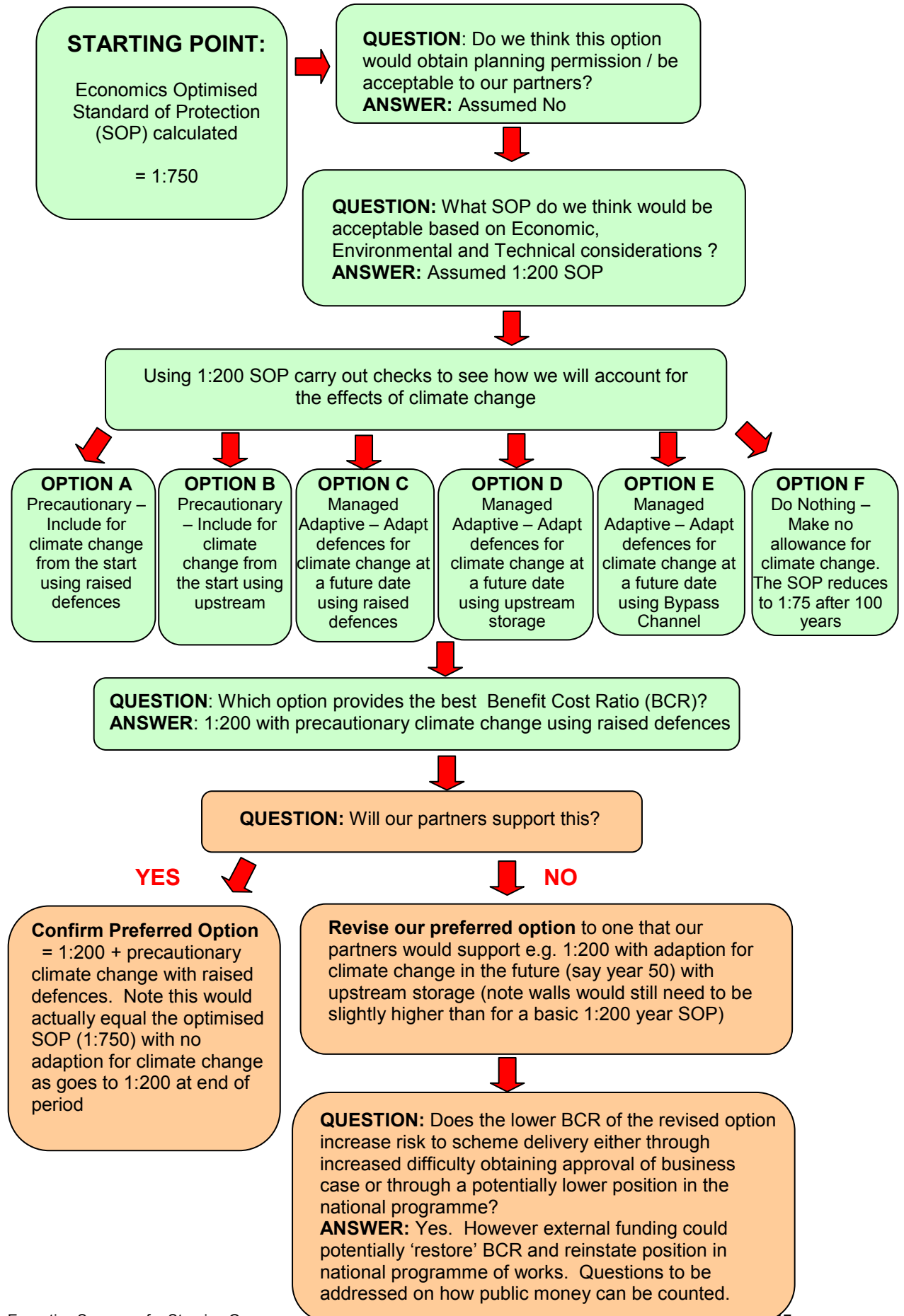
Figure 1: Environment Agency Preferred Option compared to Alternatives

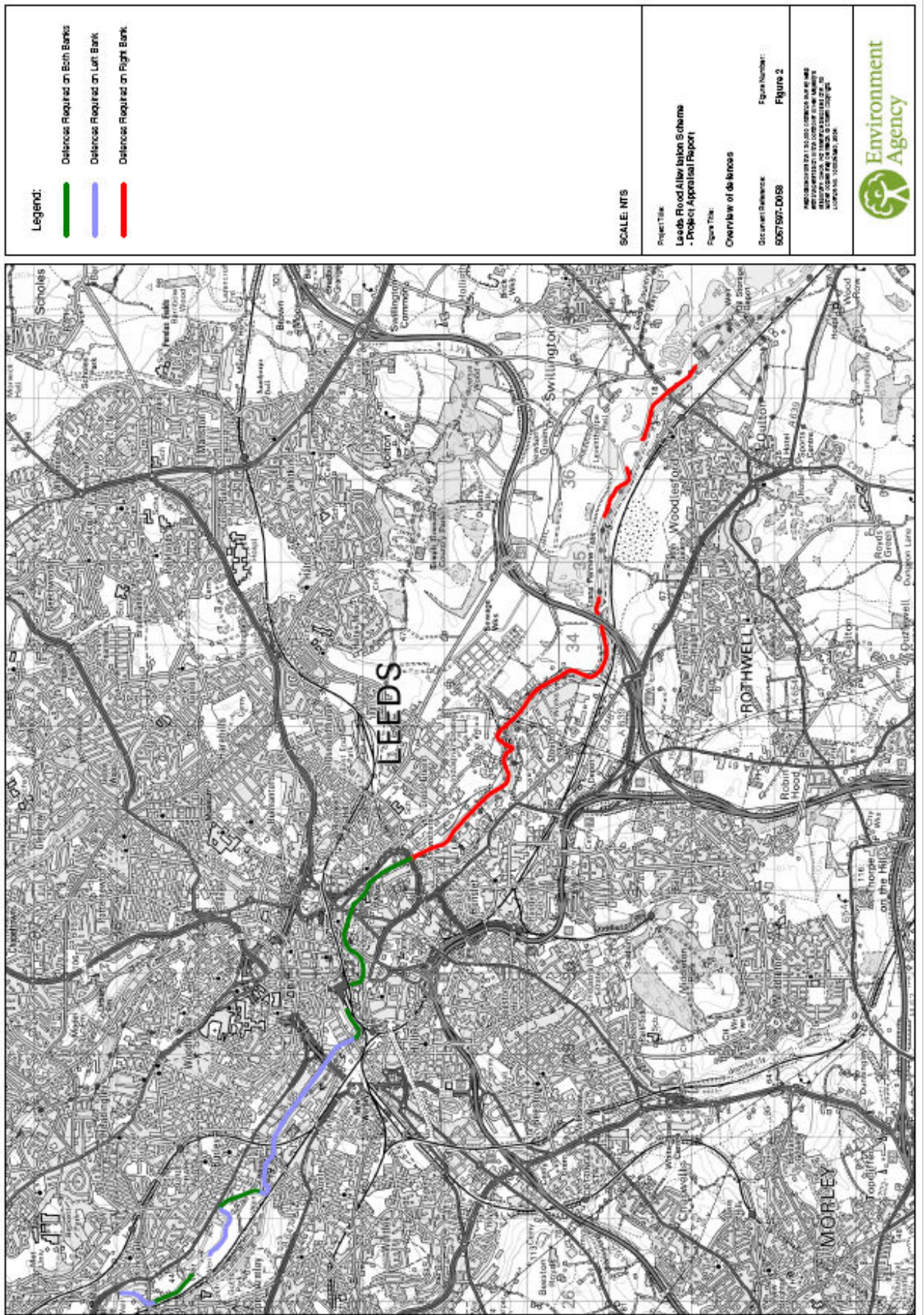
Figure 2: Decision Process for Leeds Flood Alleviation Scheme Standard of Protection



Notes:

1. PV = Present Value
2. CC = Climate Change
3. Option E costs are based on a high level cost approximation.
4. External funding required is calculated as the contribution needed to achieve an equivalent Benefit Cost Ratio as the Environment Agency's preferred Option.





Notes:

1. We are currently carrying out an internal review of the PAR and therefore there may be changes to figures from those shown in this executive summary.
2. We have prepared this executive summary to address specific concerns and queries raised by the Steering Group. It is not the executive summary that we will submit as part of the PAR as this is required in a specific format with specific content and would have provided insufficient or in some instances inappropriate information. A copy of the executive summary submitted to NRG as part of the PAR would be available for information after the 24th August 2009.
3. The likelihood of a particular flood happening is best expressed as a chance or probability over a period of 1 year. For example, if there is a 1 in 100 chance of flooding in a given year, this can also be described as having a 1% chance of flood each year. As such, if a flood occurs, it does not mean that another flood will not occur for 99 years.
4. The Environment Agency / Arup report on the By-pass option is still in DRAFT status and has not been formally approved.
5. This Executive Summary will be issued in DRAFT format on the 7 July 2009 and will be presented at a meeting of the Steering Group on the 13 July 2009. We will issue a FINAL version following discussion of comments.