Appendix C
Flood risk assessment

Flood Risk Analysis

Introduction

This appendix provides further technical details on the approach adopted in the flood risk analysis and the proposed response. The appendix focuses on some of the key decisions and any underlying assumptions. In particular:

- The basis for the embankment design
- Climate change and the impact on decision making
- Embankment vulnerability over time
- Phasing works – when do we take action
- What Standard of Protection is provided by the preferred strategy

The basis for embankment design

The proposed strategy does not presuppose that embankments are required. However where embankments are proposed it is essential that the embankments remain stable when loaded, and can be accessed and maintained safely.

The embankments considered within this report vary in height depending on location and future climate change. However typically banks will be 2 to 4m high, and are significant engineering structures.

It is essential that these large banks do not breach during periods of high water, when the bank is loaded. Because the embankments will protect assets against high water levels in the estuary close to its mouth, there is a very large volume of water available to flood land behind the defence should a breach occur. Since flood levels on the estuary are driven by the tide, some limited overtopping of defences may be acceptable providing large robust defences are adopted. High tides are likely to occur for short periods and well maintained defences are robust against short periods of overtopping.

The situation in the strategy area is analogous to a dam where breaching can cause rapid and uncontrolled flooding should a dam fail. Because of these risks dam construction and maintenance is regulated by the Reservoirs Act 1975, and is very precautionary. These regulations do not apply to linear river defences, but the risks must be considered in a similar way because of the risk to life.

Within this context the general design of the embankment is a bank with a 5m top width (to safely allow maintenance vehicles along the crest) and 1(vertical) to 4 (horizontal) embankment slopes (i.e. 14 degrees to horizontal). A 3m high embankment would therefore have a footprint width of 29m.

The crest level of the embankment has been selected to ensure that the risk of breaching in the 1 in 200 year event (0.5% AEP) is negligible. This is achieved if the embankment is at least in fair condition and the depth of flooding over the embankment does not exceed 200mm during the tidal peak in the 200 year event (0.5% AEP). A detailed analysis has been undertaken to confirm this assessment. The 1 in 50 year event (2% AEP) level conincides with 200mm below the 1 in 200 year level. Therefore if embankment levels are maintained at the 1 in 50 year (2% AEP) level then the risk of breaching is minimised. The implications of selecting this standard are discussed later in the Appendix

Climate Change and the Impact on Decision Making

Sea level rise associated with climate change is the key issue in the future, and has major impact on the approach adopted in this strategy.

In broad terms managed realignment options have been identified where it is possible to reduce the length of embankment to be maintained in the future. This is achieved by 'cutting the corner off' large meanders, or retreating defences to just protect key built assets. However there are considerable costs associated with building new realigned banks and this has to be compared with the costs of maintaining the defences on their current alignment. Generally higher sea level rise estimates will promote realignments because the reduce length of embankment will be cheaper to maintain in the future than the 'hold the line approach' in which the banks are longer.

Within this framework it is essential that the preferred strategy is flexible. We have adopted what we consider to be the most appropriate approach today, but this will be subject to change as climate change causes sea levels to rise and future predictions of sea level rise become more accurate.

Embankment Vulnerability Over Time

Once constructed, embankments must remain fit for purpose during their life. At the end of their life they will need to be rebuilt or demolished (and potentially relocated where appropriate).

It is essential that embankments are maintained appropriately to ensure their structural condition is retained. Maintenance activities may include:

- Removal of scrub or trees
- Repair of ruts along the bank
- Identification and removal of animal holes (e.g. badger/rabbit burrows)
- Bank flailing

Despite Regular maintenance the overall condition of embankments will deteriorate over time as the bank consolidates. We have used best available information to determine how quickly this deterioration will occur, and at what stage the condition of the defences becomes unacceptable. This assessment is based on information from the Based on National Assessment of Defence Needs and Costs (Risk Assessment for Strategic Planning) [NADNAC (RASP)] condition grade deterioration curves. There remains considerable uncertainty but the embankments may deteriorate from new to fair within 30 to 45 years. In our central design case we have assumed that major reconstruction of the tidal embankments will be required approximately every 35 years, although we have considered the implications of longer or shorter periods. This approach should ensure that the defences are in appropriate condition should the defences be overtopped in the future.

Phasing the Works

Our approach to phasing builds on the points made above. In particular:

- The maximum overtopping depth must be retained at less than 200mm in the 1 in 200 year event, even taking the implications of sea level rise into account
- The defence condition must not deteriorate to poor if the stability of the system is to be retained.

Based on the two points above it is logical to reconstruct the embankments about every 35 years and build them such that that the 200mm restriction is maintained throughout the following 35 years. This maximises the value of the works and minimises the future costs.

Level of flood risk

In considering options to manage flood risks, strategies need to consider what level of flood risk is acceptable. In this context we are considering the actual standard of protection to homes, businesses and agriculture and the frequency of flooding in the future. Economically the standard of protection should be optimised to minimise costs whilst maximising the benefits (i.e. the flood damage avoided).

However there are other considerations. Those communities protected from flooding by embankments may be able to accept that the defences may be overtopped occasionally, but it is our view that the risk to life and property associated with uncontrolled breaching of defences must be minimised. As described above, the situation is analogous to a dam break, and in some ways is worse because there is a replenishing supply of water from the Bristol Channel should the defences fail. International experience has highlighted the risks associated with uncontrolled breaches. In the post flood analysis of the flooding of New Orleans in 2005 the University of California at Berkeley concluded that ‘the majority of the flooding came from unanticipated and unintended breaches in the levees’.

Based on the above assessment the key levels of flood risk adopted are summarised below. In many flood risk situations the frequency of overtopping is often the same or similar to the flood risk to the properties protected by the defences. However because of the large storage capacity of the land behind the defences this helps to improve the level of flood risk considerably as shown.

Asset	**Level of flood risk (Minimum)**	**Comments**
Overtopping of Principal Defences	1 in 50 year (2% AEP)	
Agricultural Land (incl. Farm Houses)	Typically 1 in 100 years (1% AEP) to 1 in 300 years (0.33%)	Some limited flooding from 1 in 50 years.
Principal Urban Areas	Generally 1 in 500 years (0.2% AEP)	Includes Bridgwater where preferred strategy indicates tidal barrier as main method of flood protection.

Some sensitivity testing has been undertaken. A higher rate of overtopping could be adopted, but this would increase the risk of breaching to an unacceptable level. Higher standards of defence were considered, but the 1 in 50 year standard was considered appropriate given that this minimises the risk of breaching to a low level and because a high standard of protection is provided to key assets by the defences (helped by the storage capacity of agricultural land) and that there is little further economic benefit to be derived by raising the defences further.

In considering sea level rise the design has ensured that the 1 in 50 year standard of overtopping is maintained at all times in the future. Therefore generally the standard provided to key assets is above that indicated in the table. There is no mention here of the need to ensure that rural defences overtop first – urban defences will be higher than 1 in 50.

Rate of deterioration

The rates of detoriation used were derived from the following

Extract from Guidance on determining asset deterioration and the use of condition grade deterioration curves

Based on National Assessment of Defence Needs and Costs (Risk Assessment for Strategic Planning) [NADNAC (RASP)] condition grade deterioration curves

Table 4: Deterioration with normal maintenance

			Time (years) to reach condition grade from new																
Environment Agency	**Defence**	**Description**	***Best estimate (m)***						***Fastest estimate (m)***						***Slowest estimate (m)***				
primary asset descriptor	**class**		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
Raised defence (man-made)	4	Type 1, FP, B&M (m)	0	13	40	67	80		0	10	30	50	60		0	17	50	83	100
	5	Type 1, CP, B&M (m)	0	13	40	67	80		0	10	30	50	60		0	17	50	83	100
	6	Type 1, RP, B&M (m)	0	13	40	67	80		0	10	30	50	60		0	17	50	83	100
	7	Type 1, FP, Piles (m)	0	15	30	45	60		0	11	23	34	45		0	19	38	56	75
	8	Type 1, CP, Piles (m)	0	15	30	45	60		0	11	23	34	45		0	19	38	56	75
	9	Type 1, RP, Piles (m)	0	15	30	45	60		0	11	23	34	45		0	19	38	56	75
	10	Type 2, FP, Turf (m)	0	13	27	36	40		0	10	20	27	30		0	17	33	45	50
	11	Type 2, FP, Rigid (m)	0	13	25	42	50		0	9	19	31	38		0	16	31	52	63
	13	Type 2, RP, Rigid (m)	0	15	30	50	60		0	11	23	38	45		0	16	33	54	65
	14	Type 2, FP, Rip-rap (m)	0	13	25	42	50		0	9	18	29	35		0	14	28	46	55
	15	Type 2, CP, Rip-rap (m)	0	14	28	46	55		0	10	20	33	40		0	15	30	50	60
	16	Type 2, RP, Rip-rap (m)	0	15	30	50	60		0	11	23	38	45		0	16	33	54	65
	19	Type 2, RP, Flexible (m)	0	15	30	50	60		0	11	23	38	45		0	16	33	54	65

			Time (years) to reach condition grade from new																
Environment Agency	**Defence**	**Description**	***Best estimate (m)***						***Fastest estimate (m)***						***Slowest estimate (m)***				
primary asset descriptor	**class**		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
Raised defence (natural)	20	Type 3, High Ground (m)	NOT APPLICABLE TO HIGH GROUND CASES																
Culverted channel	21	Type 4, Culverts (m)	0	15	30	45	60		0	11	23	34	45		0	19	38	56	75
Raised coastal defence (man-made)	26	Type 5, CP, Concrete (m)	0	8	25	42	50		0	7	20	33	40		0	12	35	58	70
	27	Type 5, RP, Concrete (m)	0	10	30	50	60		0	8	23	38	45		0	13	38	63	75
	29	Type 5, CP, B&M (m)	0	9	28	46	55		0	7	20	33	40		0	12	35	58	70
	30	Type 5, RP, B&M (m)	0	10	30	50	60		0	8	23	38	45		0	13	38	63	75
	31	Type 6, FP, Perm (m)	0	10	20	33	40		0	8	15	25	30		0	13	25	42	50
	34	Type 6, FP, Imperm (m)	0	10	20	33	40		0	8	15	25	30		0	13	25	42	50
Raised coastal defence (natural)	37	Type 7, Dune (m)	0	13	20	27	40		0	10	15	20	30		0	17	25	33	50
	38	Type 7, Shingle (m)	0	13	20	27	40		0	10	15	20	30		0	17	25	33	50
Raised defence (man-made)	40	Type 1, W, CP, Gabions (m)	0	4	13	21	25		0	3	10	17	20		0	5	15	25	30
	41	Type 1, W, FP, B&M (m)	0	13	40	67	80		0	10	30	50	60		0	17	50	83	100
	42	Type 1, W, CP, B&M (m)	0	13	40	67	80		0	10	30	50	60		0	17	50	83	100
	44	Type 1, W, CP, Piles (m)	0	15	30	45	60		0	11	23	34	45		0	19	38	56	75
	45	Type 2, W, FP, Turf (m)	0	17	33	45	50		0	13	27	36	40		0	20	40	54	60
	46	Type 2, W, FP, Rigid (m)	0	15	30	50	60		0	11	23	38	45		0	19	38	63	75
	48	Type 2, W, FP, Rip-rap (m)	0	15	30	50	60		0	11	23	38	45		0	19	38	63	75
	49	Type 2, W, CP, Rip-rap (m)	0	15	30	50	60		0	11	23	38	45		0	19	38	63	75
	50	Type 2, W, FP, Flexible (m)	0	15	30	50	60		0	11	23	38	45		0	19	38	63	75
	51	Type 2, W, CP, Flexible (m)	0	15	30	50	60		0	11	23	38	45		0	19	38	63	75
Raised coastal defence (man-made)	55	Type 5, W, CP, Concrete (m)	0	9	28	46	55		0	7	20	33	40		0	12	35	58	70

			Time (years) to reach condition grade from new																
Environment Agency	**Defence**	**Description**	***Best estimate (m)***						***Fastest estimate (m)***						***Slowest estimate (m)***				
primary asset descriptor	**class**		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**		**1**	**2**	**3**	**4**	**5**
	57	Type 5, W, CP, B&M (m)	0	9	28	46	55		0	7	20	33	40		0	12	35	58	70
	58	Type 6, W, FP, Perm (m)	0	10	20	33	40		0	8	16	27	32		0	12	24	40	48
	59	Type 6, W, CP, Perm (m)	0	13	25	42	50		0	10	20	33	40		0	15	30	50	60
	60	Type 6, W, FP, Imperm (m)	0	10	20	33	40		0	8	16	27	32		0	12	24	40	48
	61	Type 6, W, CP, Imperm (m)	0	13	25	42	50		0	10	20	33	40		0	15	30	50	60