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Adapting flood risk management for an uncertain future:

Flood management planning on the thames estuary

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ADAPTING FLOOD RISK MANAGEMENT FOR AN UNCERTAIN FUTURE: FLOOD MANAGEMENT PLANNING ON THE THAMES ESTUARY

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Flood, Planning, Adaptation

Abstract
A flood risk management plan is being developed for the Thames Estuary, covering the next 100 years. In 2007 flood risk management options (the 'High Level Options') were developed for a range of different climate change scenarios. The objective was to provide initial flood risk management options for the estuary, and identify how the uncertainties of future climate change could be managed.

Since then the options have been further developed to take into account other drivers including the deterioration of the existing flood risk management assets. Whilst the Plan will lead to preferred options for managing flood risk, it is recognised that the assumptions used to develop these options could change. The paper demonstrates how the options would be adapted to change.

Whilst the main options have been developed to manage flood risk for the whole estuary, there are choices to be made at the local or Policy Management Unit (PMU) level. Hence the approach applies to both the estuary-wide and PMU levels.

The main steps of the approach to adaptation are as follows:

1. The main drivers of flood risk management have been identified. These include, for example, climate change and socio economic change.
2. For each driver, a number of indicators have been identified which describe the impact of the driver. For example, indicators of climate change include sea level, which is rising, and fluvial flood flows.
3. For each indicator, thresholds have been identified where interventions are needed to maintain the required level of flood risk (for example, in the case of climate change, a particular sea level at Southend or a particular fluvial flow on the Thames).
4. Possible interventions for each threshold have been identified, for example the need to raise some of the defences when a certain water level is reached as the sea level rises.
5. The lead time for implementing each intervention at each threshold has been estimated. This is the time needed to plan and construct the intervention.
6. The rate of change of each indicator will be monitored. This is used to predict future change in the value of the indicator. From the predicted future change, the threshold value when an intervention will be required and the lead time, it is possible to estimate when a decision to implement an intervention must be made. This is referred to as a 'decision point'. The identification of a decision point is illustrated on Figure A.1.
7. Figure A.1 also shows conceptually how to take account of uncertainty in decision making.

8. The decision to implement the intervention is taken at the decision point that takes account of uncertainty.
9. The same process is followed at estuary-wide level for all key indicators. This leads to the development of an option, which consists of a number of interventions throughout the century to respond to the different drivers. Figure A.2 shows an option developed for a small number of drivers, together with the decision points and lead times.
10. The indicators are monitored. If there are significant changes in the indicators compared with the assumptions in the Plan, the Plan must be reviewed. The review may either lead to the conclusion that the option is still satisfactory, although the timing of the interventions may change, or the change in the indicators is such that an alternative option is required.
11. As there is a chance that the Plan could change, responses should be as adaptable as possible to avoid undertaking work that may not be needed in the future.

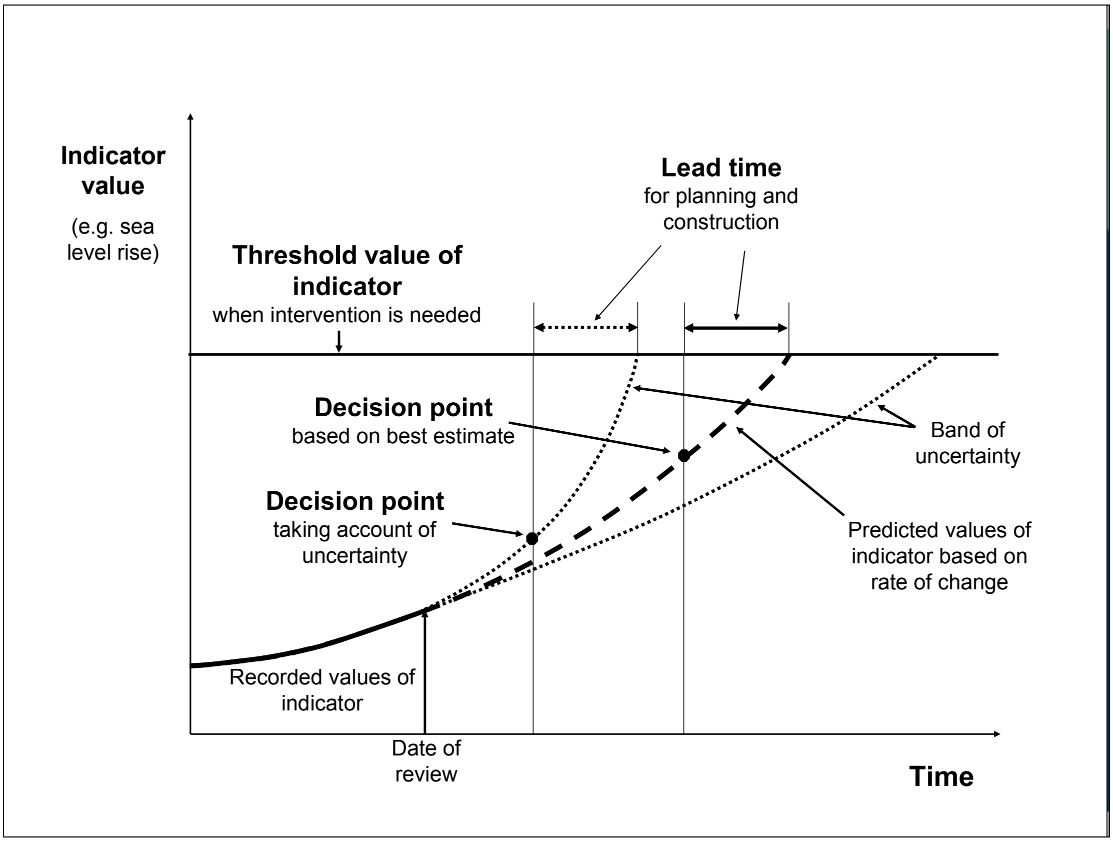

Figure A.1 Decision making with an uncertain future

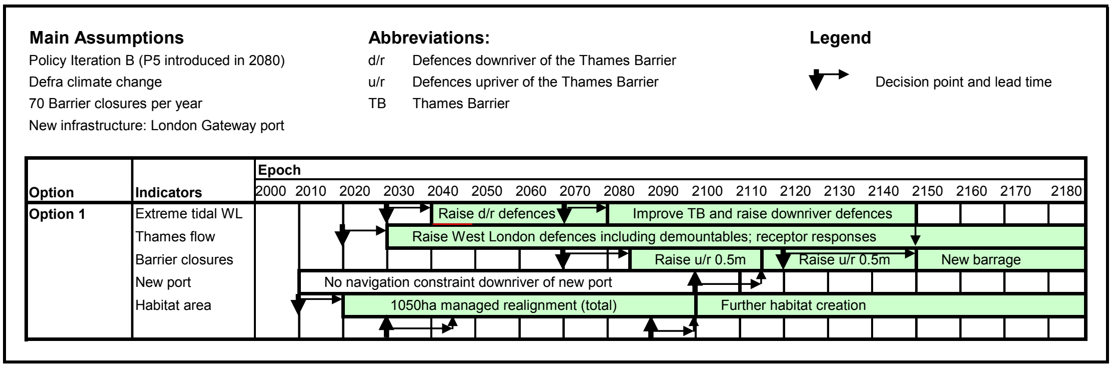

Figure A.2 An option, showing interventions and decision points

Background

Following the 1953 floods the Thames Barrier and associated defence improvements were planned and built over a 30 year period to protect London and the Thames Estuary from tidal flooding. Given the challenge of climate change and the long timescales required to plan major improvements to the system, the Environment Agency has set up the Thames Estuary 2100 (TE2100) project. The project will develop a Flood Risk Management Plan for the Thames Estuary for the next 100 years.

The project has included managing uncertainty as part of its approach to developing the Plan. This has been based on existing guidance from UKCIP (Willows & Connel 2003) and has been further developed through the ESPACE Project (European Spatial Planning Adapting to Climate Events) to develop and refine transnational methods.

As part of the Plan, flood risk management options (the 'High Level Options') were developed in 2007 for a range of different climate change scenarios. The objective was to provide initial flood risk management options for the estuary, and identify how they could be adapted if the rate of climate change (particularly sea level rise) changed (Ramsbottom & Lavery 2007).

Since then the options have been further developed to take into account other drivers including the deterioration of the existing flood risk management assets. Whilst the Plan will lead to a preferred option for managing flood risk, it is recognised that the assumptions used to develop the options could change. The paper demonstrates how the options would be adapted to change.

The flood risk management system

Structural elements of the flood risk management system on the Thames Estuary are shown on Figure 1. The system includes the Thames Barrier, over 300km of fixed tidal defences, nine other major barriers and control structures, and numerous smaller structures.

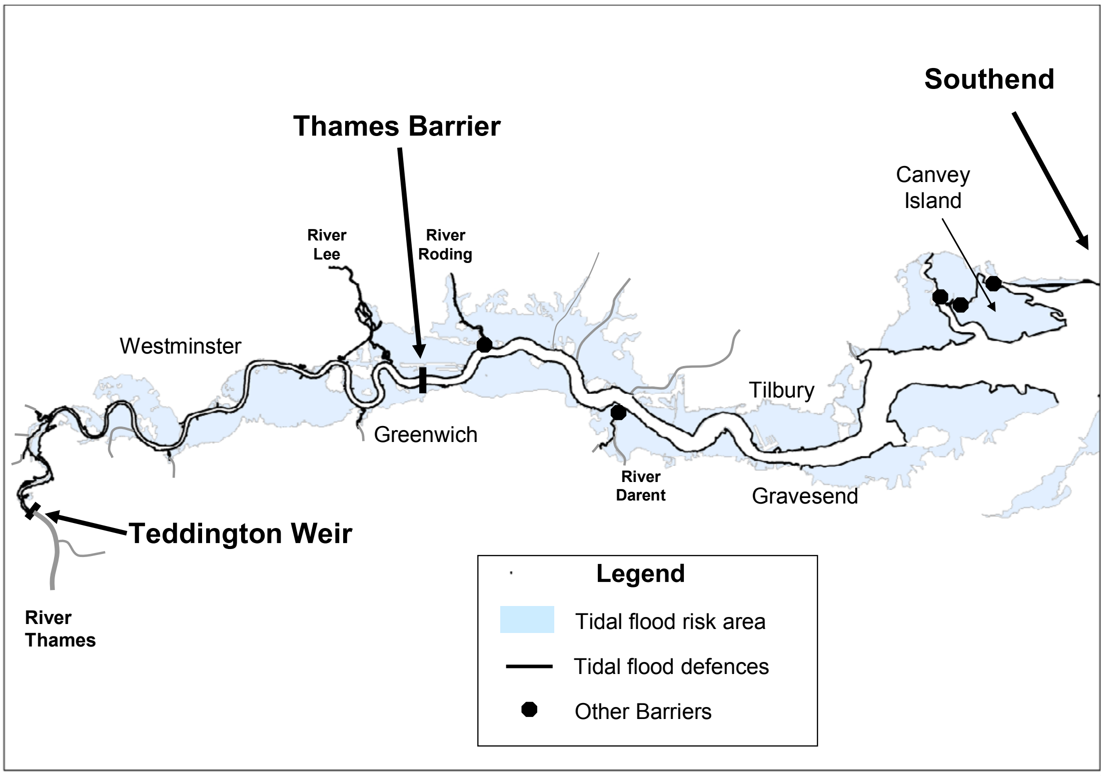

Figure 1 The Flood Risk Management System

The options include separate changes to the 'upriver defences', which are the tidal defences upriver (west) of the Thames Barrier, and the 'downriver defences', which are the tidal defences downriver (east) of the Thames Barrier.

Future change and adaptation

The Plan is designed to adapt to future change. Some of the main future changes which are taken into account in the development of the Plan are summarised below.

Climate

Climate change presents perhaps the greatest challenge in terms of future uncertainty. The impacts include expected rises in Mean Sea Level, peak surge tide level, wave heights and fluvial flows (Church & White 2006).

Socio economic

The Foresight Flood Risk project (OST 2004) identified the critical uncertainty that socio economic development presents to the future of flood risk. On a national scale it was more influential in changing the scale of future flood damages than the effects of climate change.

Asset deterioration

The deterioration of existing assets means that much of the existing flood management infrastructure will require replacement over the next 100 years, at a cost of several billion pounds. The rate of deterioration is therefore a vital factor in future planning.

The physical environment (including estuary morphology)

The estuary has an essentially fairly stable history over the last century or so in terms of its physical development. The outer sandbanks in the estuary protect it from the worst effects of wave attack. However sea level rise could disturb this picture and it will be essential to monitor the state of the estuary into the future.

Public behaviour

At present the awareness of flooding on the estuary is low, and the present high standard of protection means that there is little need for the public to be aware of the risk. However with an uncertain future, it may be desirable for this situation to change so that the public can be better prepared for the risk of future flooding.

The types of adaptation envisaged within the Plan to cope with future change include the following (where an option is defined as a series of interventions to manage flood risk over the next 100 years):

Changes to the timing of new interventions

The Plan will have a preferred option for managing flood risk throughout the century given the envelope of change that is considered to be most likely based on current information. However the actual rate of change is likely to differ from the rates assumed in the Plan, and this could lead to changes in the timing of interventions.

Ability to change between options

If the rate of change of a critical factor is predicted or is observed to change significantly above the expected rate of change when the preferred option is selected, it may be necessary to switch to an alternative option that is able to cope with larger changes.

Adaptation of engineering responses

Engineering responses should be designed so that they can be adapted to changing circumstances, for example by providing foundations for new defences that can take higher future loadings, or designing barriers and other control structures that can be modified in the future.

Land use planning that provides flexibility in the selection of options

Each flood risk management option will require land for new defences, enlarged defences, new areas of habitat creation, and in some cases flood storage. It is essential that the planning system is aware of the land required for the preferred option and the alternative options so that the land can be safeguarded.

Adaptation to new infrastructure

New infrastructure on the Thames Estuary could have a major impact on flood risk management. For example, the proposed new port at Shellhaven will require free access for navigation, which will affect any outer barrier or barrage options. New transport links could provide the opportunity to combine a new crossing of the estuary with a new barrage. The Plan should be flexible enough to accommodate major changes such as these.

Procedure for developing the plan

A set of options including a preferred option is a key output of the TE2100 Plan. The preferred option is needed to set the direction for flood risk management. The alternative options are needed in case the preferred option is no longer able to manage flood risk because the actual rate of future change is greater than expected. The method for developing the options at estuary-wide level is described in the following steps.

1. The main drivers of flood risk management are identified.

2. For each driver, indicators are identified which describe the impact of the drivers and can be monitored.

3. For each indicator, the thresholds where interventions are needed to maintain the required level of flood risk are identified. For example, in the case of climate change, a particular sea level at Southend or fluvial flow at Teddington.

4. A range of possible interventions for each threshold is identified.

5. The lead time for implementing each intervention is estimated. This is the time needed to plan and construct the intervention, in order to determine when decisions should be taken.

6. Options are developed for the following cases:

    7. Best available estimate of future change.
    8. Different 'what if' assumptions regarding the rate of change of key indicators.

For each option, interventions needed for each threshold are identified. The overall option consists of all the interventions needed to manage all the thresholds.

9. A preferred option is identified for the best estimate of future change available at the time that the options are developed. This is achieved by appraisal of the options developed under 6a above.

10. The options are developed at estuary-wide and Policy Management Unit (PMU) level. The process of linking them is as follows:

    a. Estuary-wide options are developed and a preferred option is selected.
    b. PMU options are then developed which include the relevant components of the estuary-wide options.
    c. There may be some feedback from the PMU options into the estuary-wide options which could lead to refinement of the estuary-wide options. This should not affect the overall estuary-wide approach.

11. At this stage there is:

    a. A preferred option for the best available estimate of future change.
    b. Alternative options for different assumptions of future change.

This information will be provided by the TE2100 Plan.

Drivers and indicators of change

Drivers are defined in this context as the factors that create the need for flood risk management and therefore the TE2100 Plan. The main drivers of the TE2100 Plan include the following:

- **The existing** (present day) **flood risk.** Much of the tidal Thames floodplain is protected from flooding by flood defences. As the floodplain is intensely developed, it is essential that the Plan includes management of the existing flood risk.
- **Flood Risk Management Policy.** This determines the direction in which flood risk in the floodplains will change (e.g. increase, reduce, stay the same).
- **Climate change.**
- **Deterioration** of the existing defence system.
- **Probability of failure** of the Thames Barrier and other barriers.
- **Socio economic development** on the floodplains.
- **New infrastructure** that directly affects flood management.
- **Physical change** to the estuary.
- **Loss of habitat.**
- **Creating a better place.** The Environment Agency's Corporate Strategy entitled 'Creating a Better Place' seeks to achieve an improved environment, taking account of a wide range of issues including improving river environments and landscapes, enhancing biodiversity, and working with natural processes.
- **Public behaviour.** This includes public awareness of flood risk under conditions of an uncertain future.

Measurable indicators for the above drivers include the following:

- Mean Sea Level
- Peak surge tide level
- Frequency of closure of the Thames Barrier
- Developed area or asset value of development
- Intertidal habitat area
- Condition Grade of the flood defences
- Extent of erosion/deposition
- Public awareness of flood risk and how to respond

The options are based on assumptions about each of these indicators. For example, Defra guidance on climate change is assumed. Information on such indicators as frequency of closure of the Thames Barrier and area of intertidal habitat has been obtained from studies carried out as part of TE2100.

Option development

Interventions are developed for each of the key drivers. In some cases there is overlap between the key drivers and the indicators. For example, the amount of habitat loss depends on sea level rise and physical change in the estuary.

Figure 2 shows portfolios of responses to manage the rise in peak surge tide level. A single event frequency is used in this illustration. Peak surge tide level is the main driver for the choice of tidal flood risk management interventions downriver of the Thames Barrier.

An important threshold is the maximum annual number of Thames Barrier closures before the reliability of the Barrier is compromised. Once the maximum number of closures has been reached, the mitigation intervention is to raise the upriver defences. As the number of closures of the Thames Barrier is primarily driven by an increase in Mean Sea Level, this means that the raising of upriver defences is also driven by increases in Mean Sea Level. This is shown on Figure 3.

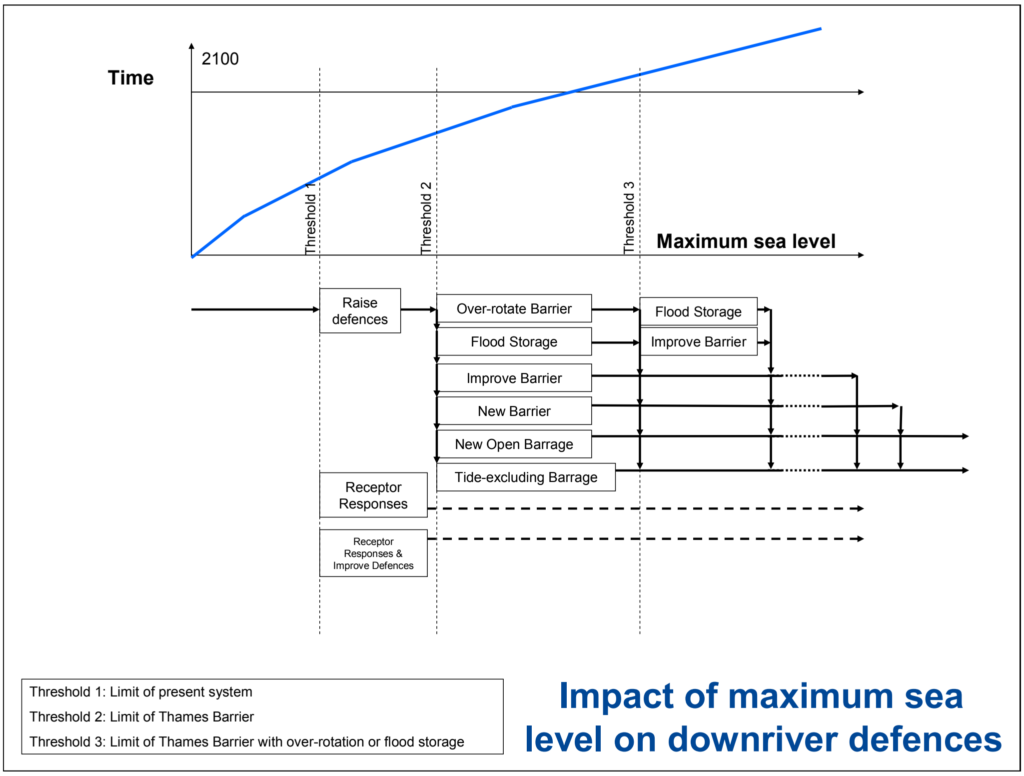

Figure 2 Responses to manage increases in surge tide peak level

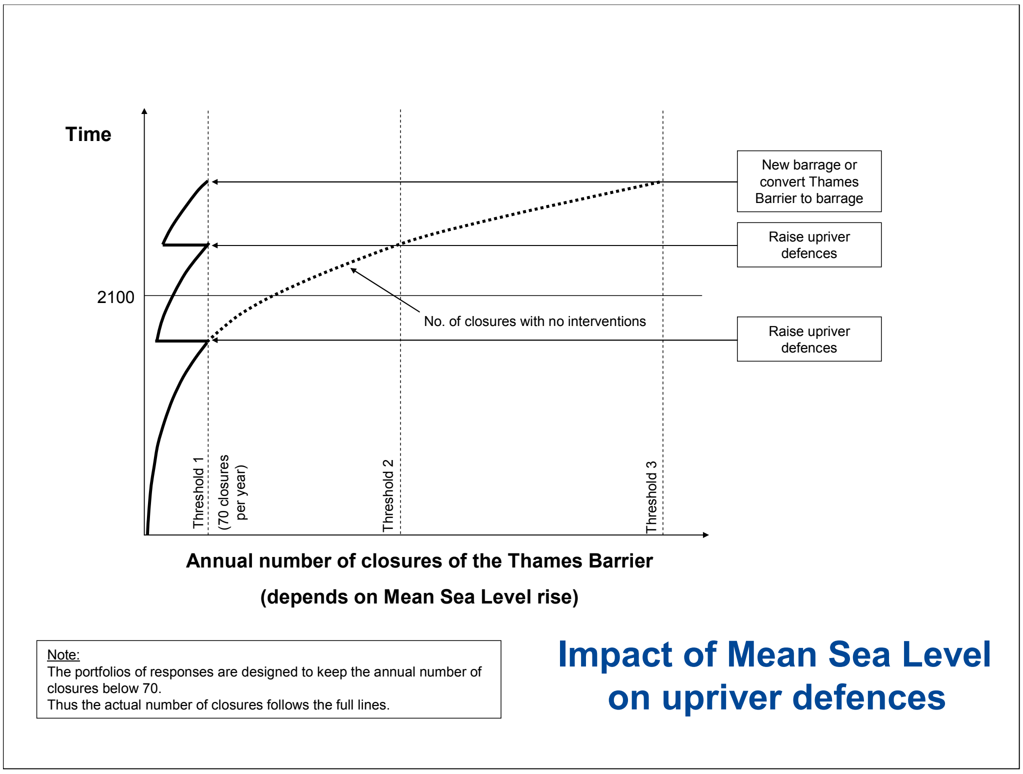

Figure 3 Responses to limit the increases in Thames Barrier closures

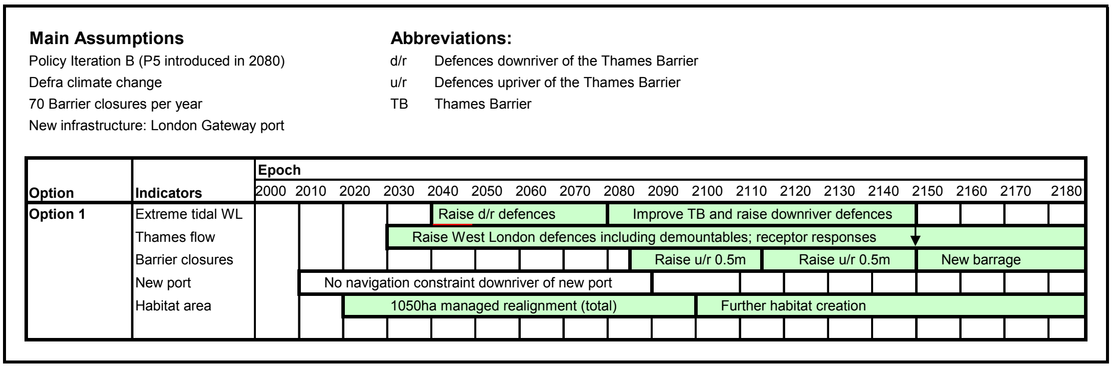

Figure 4 An option developed from several drivers

Responses for different drivers can be added together to create a complete option. An example is shown on Figure 4. This shows the main assumptions made, and the portfolios of responses for a range of thresholds arising from different drivers and indicators. The complete option consists of all the responses shown, including raising downriver defences, improving the Thames Barrier, raising upriver defences, improvements in West London, habitat creation, and a future new barrage.

Several alternative options have been developed, and selection of the preferred option(s) is carried out by appraisal. The option shown above involves improving the existing flood defence system.

Implementation of the plan

The Plan is based on assumptions about the way in which future drivers will change. The process of implementation is as follows:

1. The key indicators are monitored.

2. If the actual values of the indicators do not correspond with the assumed values, the preferred option will be affected. This can affect the timing and choice of interventions

3. The timing of a decision to implement an intervention must be made based on:

    a. The rate of change of the indicator (which is unlikely to be linear).
    b. The threshold value when an intervention is required.
    c. An estimate of how the indicator will continue to change, in order to estimate the date when it reaches the threshold value.
    d. The lead time.

This process is illustrated in Figure 5.

4. The choice of intervention will be guided by the options developed in the TE2100 Plan. It is based on the preferred option but may change to an alternative if the rates of change are significantly different from those assumed in the development of the Plan.

5. Thus the timing and possibly the choice of interventions will be guided by the rates of change of the indicators which represent the key drivers of flood risk.

6. The monitoring should be regularly reviewed, and the Plan updated if and when significant deviations occur between actual change and the assumptions made in the Plan.

The above procedure is simplified by the fact that the Thames Estuary is a constrained system where most of the floodplain is already developed. Hence the number of choices available is limited.

The monitoring results are then used to calculate new decision points using the process shown in Figure 5.

Figure 7 shows an example of the possible impacts of actual future change on the option shown above. In this example the decision points come forward in time as a result of an increase in peak surge tide level and an increase in Mean Sea Level. Other indicators are assumed to be the same as in the Plan.

Figure 6 shows the option developed in Figure 4, but with the decision points added.

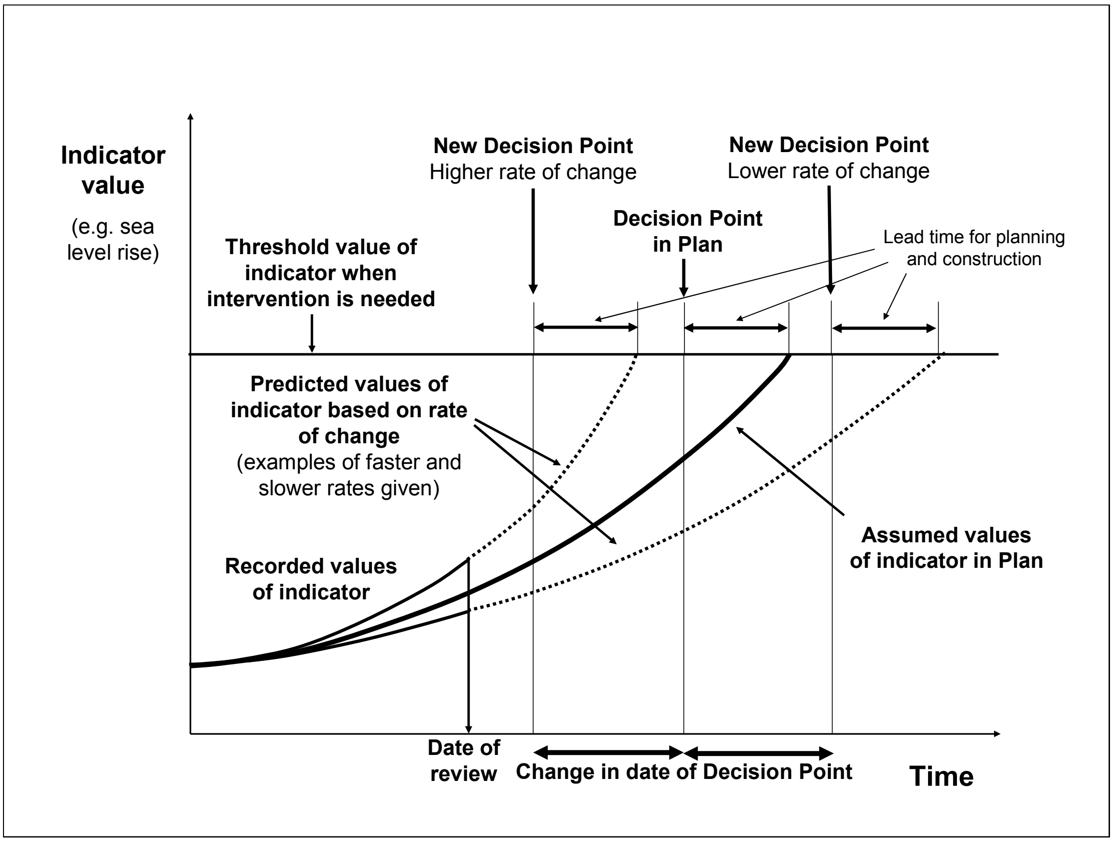

Figure 5 Timing of decisions

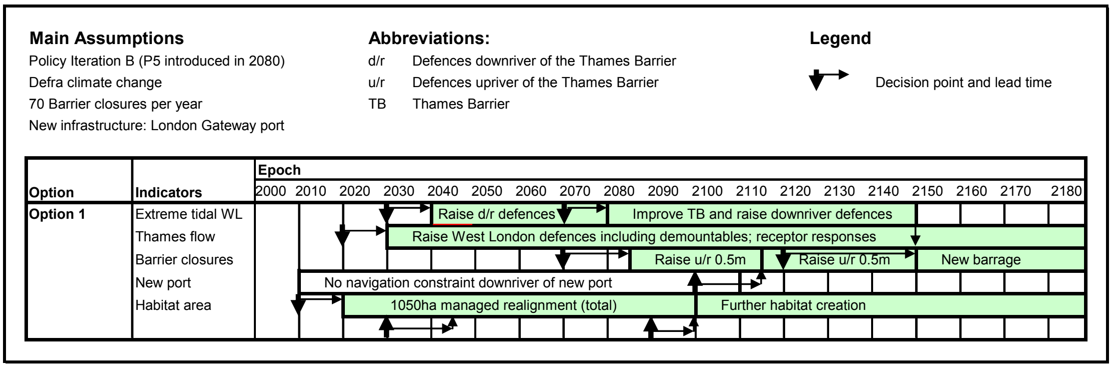

Figure 6 Option with decision points

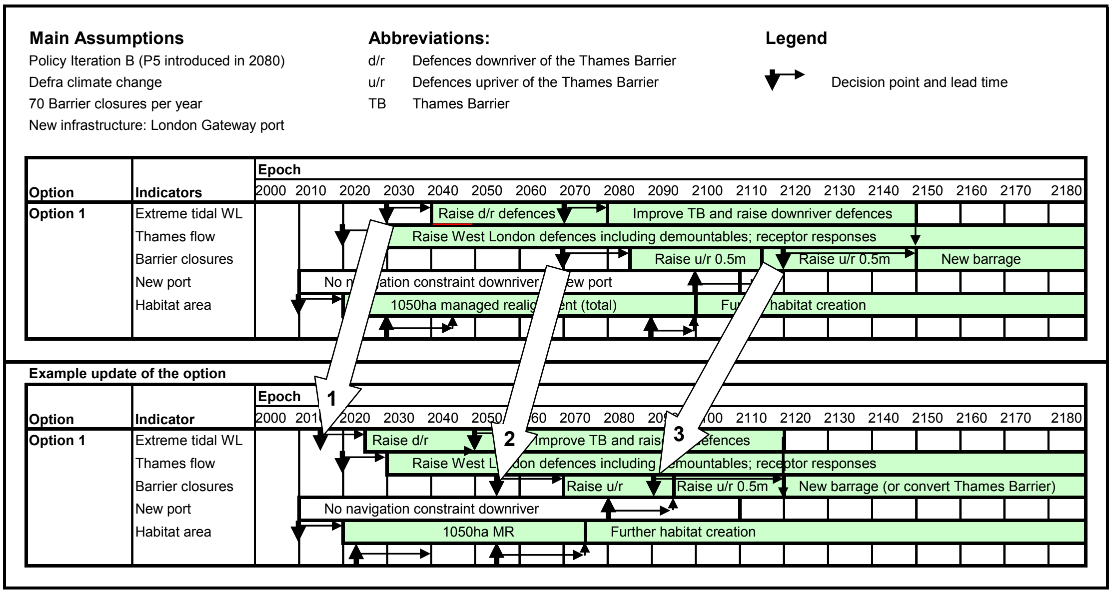

Figure 7 Example update of an estuary-wide option

The main impacts of changes following the update of the Plan in this example are as follows:

- The decision to raise downriver defences comes forward from 2030 to 2015 (Arrow 1).
- The decision to improve the Thames Barrier comes forward from 2070 to 2050, following the raising of downriver defences.
- The decision to raise upriver defences comes forward from 2070 to 2055 (Arrow 2).
- The decision to construct a barrage comes forward from 2120 to 2090 (Arrow 3).
- Decisions regarding managed realignments come forward.
- The West London interventions have not been changed.

The next step is to consider whether the preferred option is still the best. In this illustrative example, an option based on improving the existing defence system is shown. Alternative options investigated in the Plan include:

- Tidal flood storage.
- Tidal flood storage plus over-rotate Thames Barrier, and associated defence raising.
- Convert Thames Barrier to an open barrage (including locks), and associated defence raising.
- Raise upriver defences as the sea level rises, to avoid increasing the number of Barrier closures.
- New Barrier and associated defences, with or without the Thames Barrier.
- New Barrage and associated defences.
- Greater use of secondary defences (in combination with an estuary-wide defence system).
- Greater use of resilient development (in combination with an estuary-wide defence system).
- Greater investment in contingency and emergency planning (in combination with an estuary-wide defence system).
- Greater emphasis on floodplain management and land use planning to manage flood risk (in combination with an estuary-wide defence system).

The preferred option and the alternatives are reviewed and. if necessary, re-appraised, in order to decide whether the existing preferred option is still the best choice, or an alternative should be adopted.

If an alternative is adopted, some of the works in the preferred option will no longer be required. For this reason, any design and construction work should take account of the possibility of future change.

Monitoring

Monitoring of the indicators is required in order to assist with decision making at estuary-wide and PMU level. The indicators to be monitored include:

- Mean Sea Level
- Surge tide peak level (based on updating predictions of extremes)
- Peak river flood flows (based on updating predictions of extremes)
- Condition of assets
- Probability of failure of the Thames Barrier
- Accuracy of flood forecasting
- Floodplain development
- Physical condition of the estuary
- Intertidal area
- Public attitudes

Some of these indicators are monitored already. In addition, existing close links should be maintained with those responsible for assessing and predicting future change, particularly climate change and socio economic change. This is because changes may not show in monitoring results until it is too late to make an appropriate response.

The general approach to adaptation

The approach to flood risk management presented in the TE2100 Plan includes a method of developing options together with a regular updating process in which options and decisions are reviewed taking account of changing circumstances.

Interventions will be introduced as the need arises, taking account of the lead time needed for planning, design and construction. These include both flood defences and floodplain management. In some cases it may be recommended that pre-design work is commenced early to reduce lead times and the vulnerability of the Plan to rapid change.

The flood defences involve engineering construction works to provide continuous flood defence systems for the estuary and tributaries. They require land for the works, including land for future improvement and adaptation. Floodplain management includes non-structural responses and some structural works, such as safe havens.

A preferred option will be identified by the appraisal process. This will set the direction for flood risk management on the estuary, but will be reviewed as change occurs.

If future changes are within the envelope that can be accommodated by the preferred option, it is likely that the choice of option will be unchanged. There may however be changes in the timings of future interventions, which depend on the rate of change of the drivers of flood risk management.

If future changes lie outside the envelope of change that can be accommodated by the preferred option, an alternative option will be selected. This could lead to significant changes in the interventions.

The evolutionary approach of responding to change is intended to minimise the risk of implementing responses that become redundant long before they reach the end of their design lives.

Adaptability of individual responses

As part of the process of adaptation, it is necessary to consider how individual responses can be adapted to future change. Some examples of how responses could adapt to change are as follows:

- Tidal flood storage that is no longer required because of a new downriver intervention (e.g. a barrage) could be adapted to provide regulated tidal exchange, thus creating intertidal habitats.

- A new defence for which the future raising requirement is not known could have foundations designed to permit future raising, or an alternative alignment identified for a future defence.
- Secondary defence designs should include landscaping so that they are integrated with the environment and do not form barriers between communities. This should also provide the space needed for future adaptation.
- Barriers should be designed for conversion to a barrage when their limits of operation are reached.
- Pre-event measures and flood warning should be flexible to allow for future change. This includes updating of information, and briefings to advise partners of change.
- There is a need to ensure that flood risk management and land use planning are integrated so that changes in land use planning does not conflict with the requirements of flood risk management. This may require a more formal approach to land use planning on the Thames floodplains.

Conclusions

1. Long-term planning for future flood risk management should take account of possible future change, including changes in the climate and socio economic conditions.

2. As future change is uncertain, a flexible approach is needed.

3. An approach has been developed for the Thames Estuary TE2100 Plan which involves monitoring of key indicators of change and identifying when key decisions must be made based on the lead times needed to plan and implement interventions.

4. In addition to monitoring, close links should be maintained with those responsible for assessing and predicting future change, particularly climate change and socio economic change. This is because changes may not show in monitoring results until it is too late to make an appropriate response.

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