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Modelling decision support framework (MDSF2) for flood risk management strategies: oversight report

Report – SC120062/R1

Flood and Coastal Erosion Risk Management Research and Development Programme

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Miranda Kavanagh

Director of Evidence

Executive summary

UPDATE

Since this report was written, a project has been carried out to create MDSF2 models of the whole country. This new development makes a difference to the conclusions in the report.

The authors of the report concluded that the cost of carrying out a strategy using MDSF2 was broadly similar to carrying out a strategy using a traditional approach. The exception to this is where there is an existing MDSF2 model that can be re-used. In this case, it would be around 20% cheaper to use MDSF2.

When this report was written very few models of MDSF2 existed. So being able to re-use an existing model was considered as an exception. However, it should now be considered the norm.

The original report follows below.

The second generation Modelling Decision Support Framework (MDSF2) is increasingly used by the Environment Agency to provide present-day risk information, but this is not its real strength. MDSF2 was developed to provide a flexible and structured means of exploring alternative strategies. The Environment Agency, through the Joint FCERM R&D Programme, has therefore commissioned four pilot studies (Deben Estuary, Emsworth to East Head, Lower Aire and Taw–Torridge Estuary) to evaluate the use of MDSF2 in support of flood risk management (FRM) strategy development.

The overall purpose of the MDSF2 evaluation study is to explore the ability of MDSF2 to support strategy development and compare its performance to traditional modelling approaches. Building on the experience of the pilot sites and the use of MDSF2 in supporting the Thames Estuary 2100 and Humber Estuary strategies, the study shows MDSF2 has the potential to help improve the understanding of the drivers of flood risk and explore the impact of alternative strategies more efficiently and consistently than traditional approaches. The degree to which these potential benefits are realised is, however, constrained by the functionality and usability of MDSF2, the availability of supporting data in readily usable formats, and user experience.

In particular the report explores the following three questions:

- **Can MDSF2 be applied sufficiently efficiently to enable its use in the context of the timescales and resources that are typically available for strategy development?**

Typically, setting up an MDSF2 model is likely to take more time, but testing options and sensitivity can be more efficient than traditional approaches. MDSF2 is therefore more suited to complex strategies.

As with all tools, the efficiency with which MDSF2 can be used is highly dependent upon the experience of the user. For the experienced user MDSF2 adds little to no additional effort beyond that required to develop a well-structured traditional analysis. Less experienced users would require intensive guidance and support to successfully use MDSF2 within the development of an FRM strategy.

If in the future a situation is achieved in which MDSF2 models are used and maintained for a range of uses (National Flood Risk Assessment, NaFRA), strategies, asset management), then initial model set-up would no longer require significant time and

MDSF2 would create clear overall efficiency gains. The current national datasets are not yet sufficiently streamlined, however, which means there is often a need for extensive pre-processing or checking prior to use within MDSF2. Such use would also require restructuring of MDSF2's database structures, which currently appear overly complex reflecting the evolutionary nature of MDSF2's development.

- **Are the results from MDSF2 sufficiently accurate to make robust strategic choices?**

The accuracy required to support strategic choices is often debated. Of course, an absolute response to this question is not possible as it will vary from decision to decision. The test considered here is whether the decisions made at a strategic level would be different given more accurate (more certain) data. The pilots have found that, when applied appropriately, MDSF2 satisfies this test. This conclusion is only valid when MDSF2 is applied appropriately in the context of decision making. This includes establishing an appropriate impact cell resolution, use of local data where available, and, perhaps most importantly, applying pre- and post-processing workarounds that use knowledge of the study area and flood risk processes to overcome existing limitations in MDSF2 which are known to require improvement (e.g. to flood damage calculations, handling of pumps and point assets).

- **Does the MDSF2 functionality provide added value to better support strategic decision making?**

MDSF2 has been shown to add value to the process of strategy development. This has been particularly noted through its risk attribution functionality and its structured scenario management facility. The structured consideration of the flood system that MDSF2 uses supports clear and transparent thinking. The presentation of the flood probability, risks and attribution of risk to assets offers the decision maker useful insights into the type of strategic options that should be explored and hence leads to better, more efficient FRM strategies.

Ultimately, these three aspects answer the question: Is MDSF2 fit for purpose?

MDSF2 could be used to support specific types of FRM strategies now as long as the current limitations are clearly understood and known workarounds are applied. The situations where MDSF2 is currently best suited are outlined in the table below, with the caveats that are also noted in this table.

Applicability of MDSF2 as a function of risk and receptor type

Dominant receptor type	**Type of system/risk**			
	Fluvial flood risk	Estuarine flood risk	Coastal flood risk	Coastal erosion
Properties	**X**	✓	✓	**O**
Agriculture	**X**	✓	✓	**O**
Other (utilities and transport infrastructure)	**X**	**X**	**X**	**X**

Key: ✓ – MDSF2 would be preferable
O – MDSF2 is acceptable but not preferable without significant improvements
X – MDSF2 is not appropriate without significant improvements

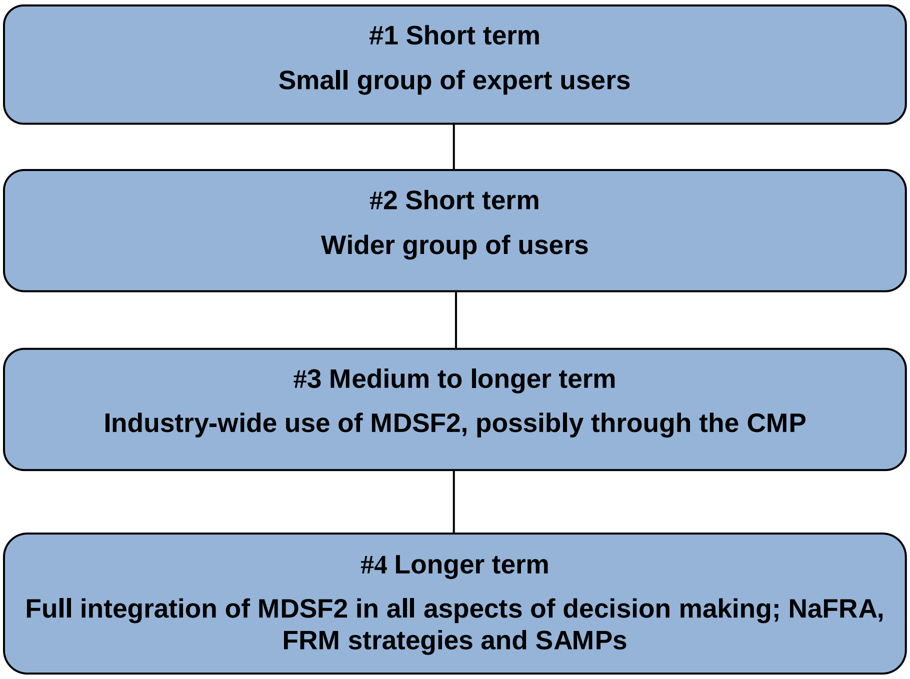
Important caveats:

- **This assessment is subject to short-term recommendations being implemented.**
- **Ease of use significantly depends on:**
  - **experience of staff involved;**
  - **presence of an existing MDSF2 model;**
  - **complexity of the study area.**

Recommendations

MDSF2 should be rolled out – but slowly

While MDSF2 has significant potential to improve FRM strategies, there are improvements that need to be made to enable this to happen. The following figure sets out the recommended phases of improvement, linked to increasingly wider levels of use.



Improvement phases for MDSF2 in FRM strategies implementation

CMP = Central Modelling Platform, SAMPs = System Asset Management Plans

Only limited additional functionality should be included in MDSF2

The degree to which additional functionality is embedded into MDSF2 and what is left to external traditional tools and processes has been debated throughout the study. In general it is recommended to focus MDSF2 on its core functionality of calculating and presenting risk, while ensuring that its outcomes can be used as input for other tools as needed.

Specific improvements required

The key short-term improvements that are required to enable a small expert group of selected users to use MDSF2 (phase 1 in the figure above) are as follows:

- Advice required for installing and running MDSF2 on other platforms (not the CMP).
- Support a better/easier representation of strategic risks through incorporating present value damage capping.
- A revised better approach to calculation of agricultural damages.
- Provide present value damages at the flood area level.

In the medium term the intention would be to extend the use of the standalone MDSF2 and encourage its application by a wider group of Water and Environment Management framework consultants. This would require better and more relevant support, and enhanced functionality to support option appraisal (partnership funding data and automated calculation of present value benefits) and option development (incorporating deterioration curves, enhanced use of fragility curves and assistance in the representation of climate change), and enhanced transparency. This wider roll-out will also require clear arrangements concerning liability for delays or errors through use of MDSF2 as an Environment Agency owned tool.

Beyond this in the medium and long term MDSF2 can be improved to maximise the potential for reuse of data for multiple purposes to encourage its wider acceptance.

Acknowledgements

We would like to acknowledge the work undertaken by the pilot teams and those that have supported this project. This includes Black & Veatch who undertook the Lower Aire pilot, HR Wallingford who have provided insight from the work developing MDSF2 and from its implementation on both the Humber Estuary Strategy and Thames 2100 projects, and Andy Emblin of the Environment Agency's Southwest region who undertook the Taw–Torridge pilot. In addition the pilot teams have been supported by Environment Agency staff who were involved in the original strategies.

Contents

Figures and Tables

1 Introduction

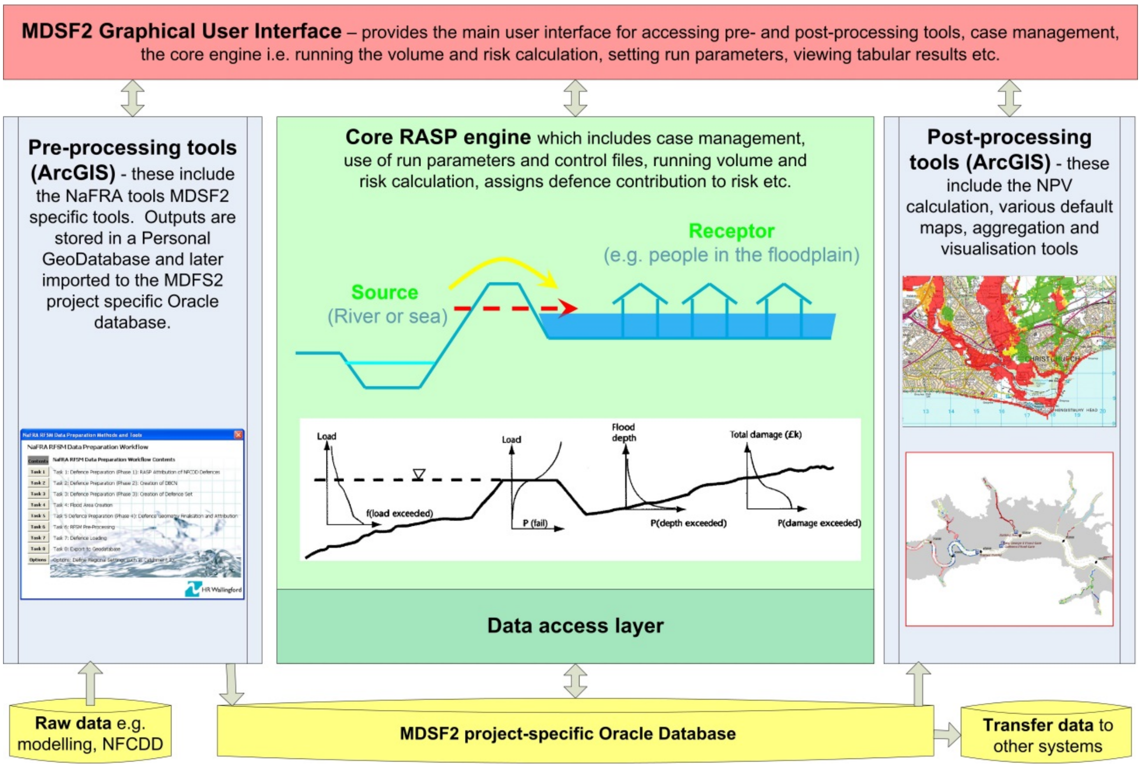
The second generation Modelling Decision Support Framework (MDSF2) is increasingly used by the Environment Agency to provide present-day risk information; but this is not its real strength. MDSF2 was developed to provide a flexible and structured means of exploring alternative strategies. The Environment Agency, through the Joint R&D Programme, has therefore commissioned four pilot studies (Deben Estuary, Emsworth to East Head, Lower Aire and Taw–Torridge Estuary) to evaluate the use of (MDSF2) in support of flood risk management (FRM) strategy development. The supporting funding has been provided under the Environment Agency's 'pay-to-pilot' scheme.

Royal HaskoningDHV in association with Sayers and Partners were commissioned to support the pilot applications and take an overview of their findings (the so-called Oversight work package). Both the Pilot and the Oversight work packages form part of the wider project titled 'MDSF2 in Flood Risk Management Strategies – Evaluation Study (SC120062)'.

1.1 MDSF2: a brief overview

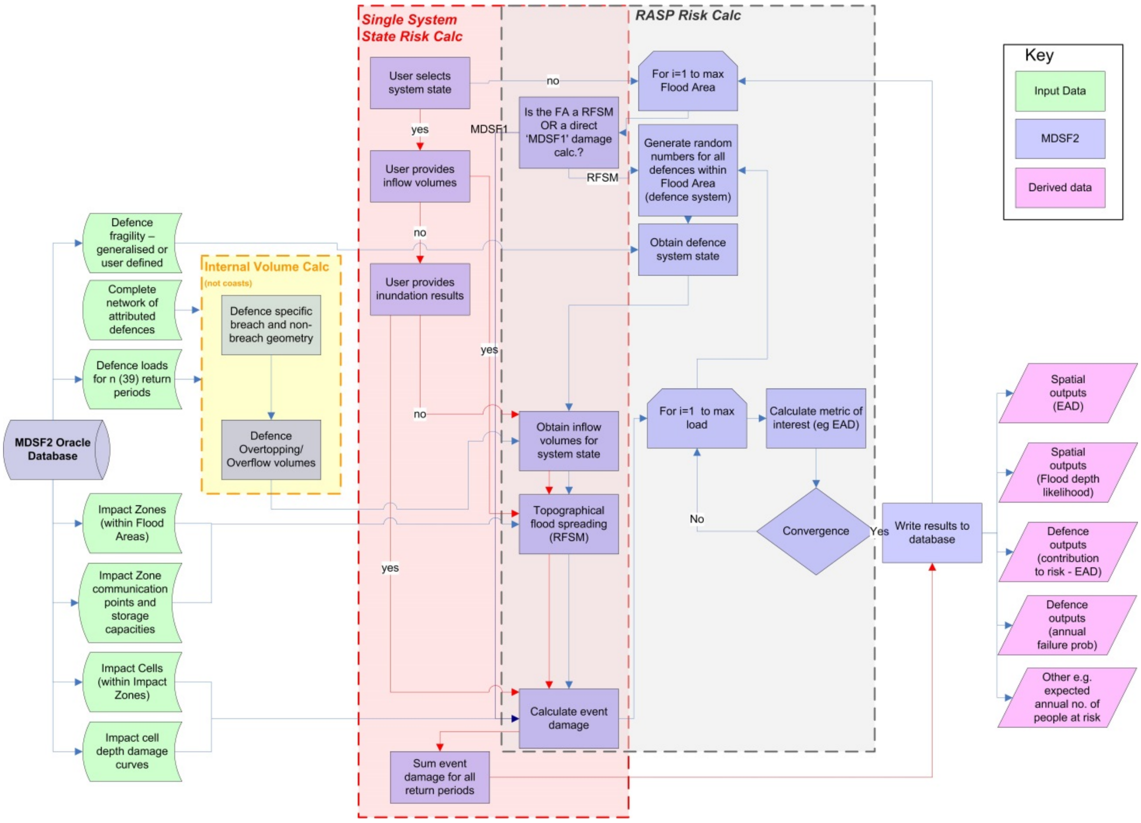
The risk analysis method implemented within MDSF2 comprises a probabilistic description of the hydraulic loadings (sources) and flood defence system (pathways) and combines this information with a model to simulate the inundation process (pathways) and subsequent impact (receptors). The modelling system originates from the Environment Agency's Risk Assessment for Strategic Planning (RASP) R&D Project (Environment Agency 2003, as summarised by Sayers and Meadowcroft 2005). One of the methods (the so-called High Level Method, Hall et al. 2003, subsequently extended by Gouldby et al. 2008 and others) forms the basis for the MDSF2 system and the National Flood Risk Assessment (NaFRA) products.

An overview of the architecture of the MDSF2 software is shown in Figure 1.1. The analysis process and the relative roll of embedded and external calculation is shown in Figure 1.2.



Source: Adapted from MDSF2, Environment Agency (2009a).

Figure 1.1 MDSF2 software logical architecture



Source: Adapted from MDSF2, Environment Agency (2009a).

Figure 1.2 MDSF2 – overview of the risk analysis engine and post-processing

1.2 Project aims

The overall purpose of the MDSF2 Evaluation Study is to explore the ability of MDSF2 to support strategy development and compare its performance to traditional modelling approaches. If it is found to be, or have the potential to be, fit for this purpose, the study should identify, and where possible prioritise, enhancements that would further improve MDSF2.

The purpose of the Oversight work package (reported here) has been to provide guidance to four separately commissioned pilot studies (Emsworth, Deben, Lower Aire and Taw–Torridge) and use the insights from these pilots to identify MDSF2's ability to support strategy development, identify any barriers to its use and prioritise future developments to overcome these. More specifically, the Oversight work package is tasked with answering the following three questions:

- Can MDSF2 be applied sufficiently efficiently to enable its use in the context of the timescales and resources that are typically available for strategy development?
- Are the results from MDSF2 sufficiently accurate to make robust strategic choices?
- Does the MDSF2 functionality provide added value (e.g. through its scenario management facility and its risk attribution capability) to support strategic decision making?

1.3 Report structure

Following this introductory section the Oversight report is structured as follows:

- **Section 2** introduces the four project pilot sites and their specific attributes and also the Humber Estuary Strategy pilot.
- **Section 3** summarises the responses from the pilot teams to a questionnaire set by the Oversight team.
- **Section 4** discusses the key findings from the pilots that are relevant to taking MDSF2 forward.
- **Section 5** discusses the experiences of the pay-to-pilot approach.
- **Section 6** draws overall conclusions on the project and its findings.
- **Section 7** provides recommendations for how MDSF2 could be improved to allow for its mainstream use in the development of FRM strategies.

2 Overview of the pilot studies

The locations of the four pilot study sites are shown in Figure 2.1 and are as follows:

- **Deben Estuary, Suffolk** (led by Royal HaskoningDHV and Sayers and Partners)
- **Emsworth to East Head**, **West Sussex** (led by Royal HaskoningDHV and Sayers and Partners)
- **Lower Aire, near Leeds, Yorkshire** (led by Black & Veatch)
- **Taw–Torridge Estuary, Devon** (led by the Environment Agency)

In addition to the four primary pilot sites, the opportunity was taken to use the relevant ongoing application of MDSF2 in support of the Humber Estuary Strategy (Arup, HR Wallingford, Black & Veatch, ABPmer). Previous experience from the application of system models within the Thames Estuary 2100 studies (University of Newcastle, Halcrow and HR Wallingford) is also drawn upon where appropriate.

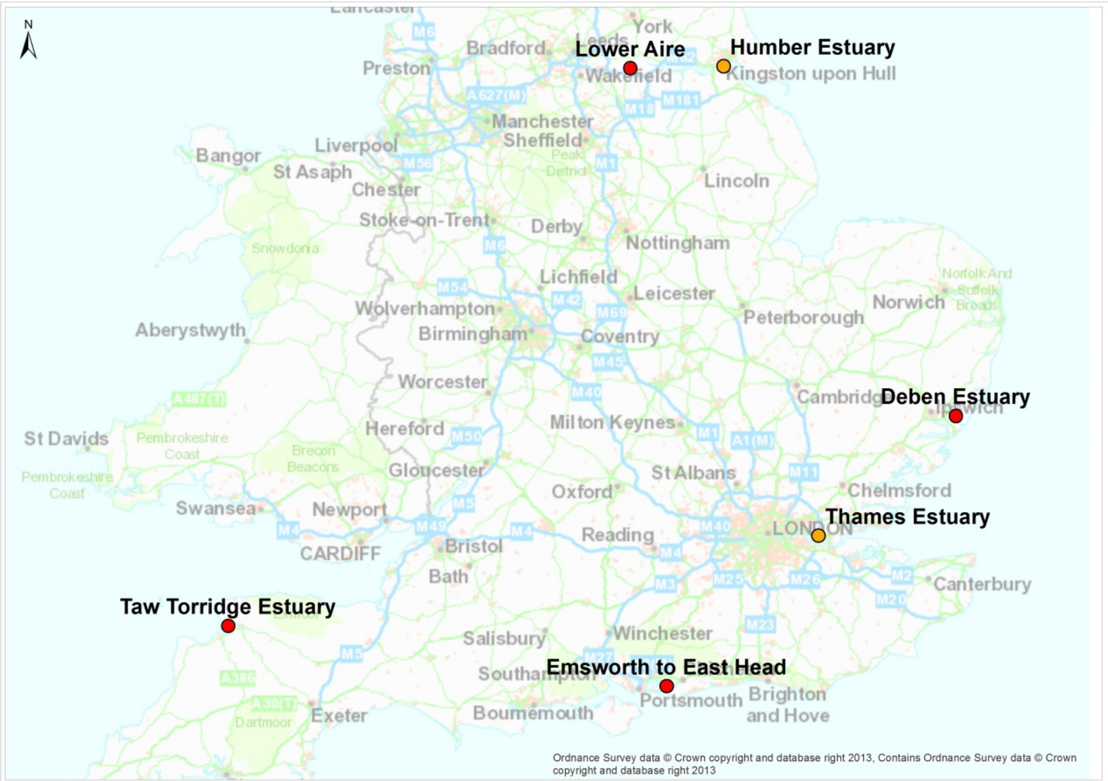


Figure 2.1 Location of pilot sites (red) and MDSF2 strategies (orange)

The following sections give brief descriptions of the pilot sites and their relevant attributes. Detailed standalone reports for each pilot site, together with a questionnaire completed by each pilot team, are available on request.

2.1 Deben Estuary

The Deben pilot study compares the insights from the MDSF2 analysis against the more traditional analysis presented in the recently developed Deben Estuary Plan

(DEP) and the pilot team’s own detailed understanding of the estuary and the associated risks.

The DEP is being developed by a partnership of the Deben Estuary Partnership, the Environment Agency and Suffolk Coast and Heaths AONB. The DEP is a tidal FRM strategy that stretches from Felixstowe Ferry (at the mouth of the estuary) to the railway line bridge upstream of Woodbridge (close to the tidal limit).

The Deben Estuary is predominantly rural and is characterised for the most part by agricultural land protected by raised earth embankments. The exceptions to this are the three main settlements: the town of Woodbridge at the upper end of the estuary and the villages of Waldringfield and Felixstowe Ferry. In these areas, flood protection is provided by a mix of vertical walls, flood gates and embankments. Figure 2.2 shows the flood areas within the Deben Estuary.

The preferred FRM strategy identified in the DEP consists of a combination of policies across 15 flood areas, including a ‘do nothing’ policy in eight flood areas as all potential FRM activities were found to be robustly uneconomic. For the remaining seven flood areas, a combination of adaptation with realigned defences and hold the line is preferred.

The live issues within the Deben Estuary are associated with understanding the role of specific defences and whether or not limited resources can be targeted and/or low-cost innovative strategies developed.

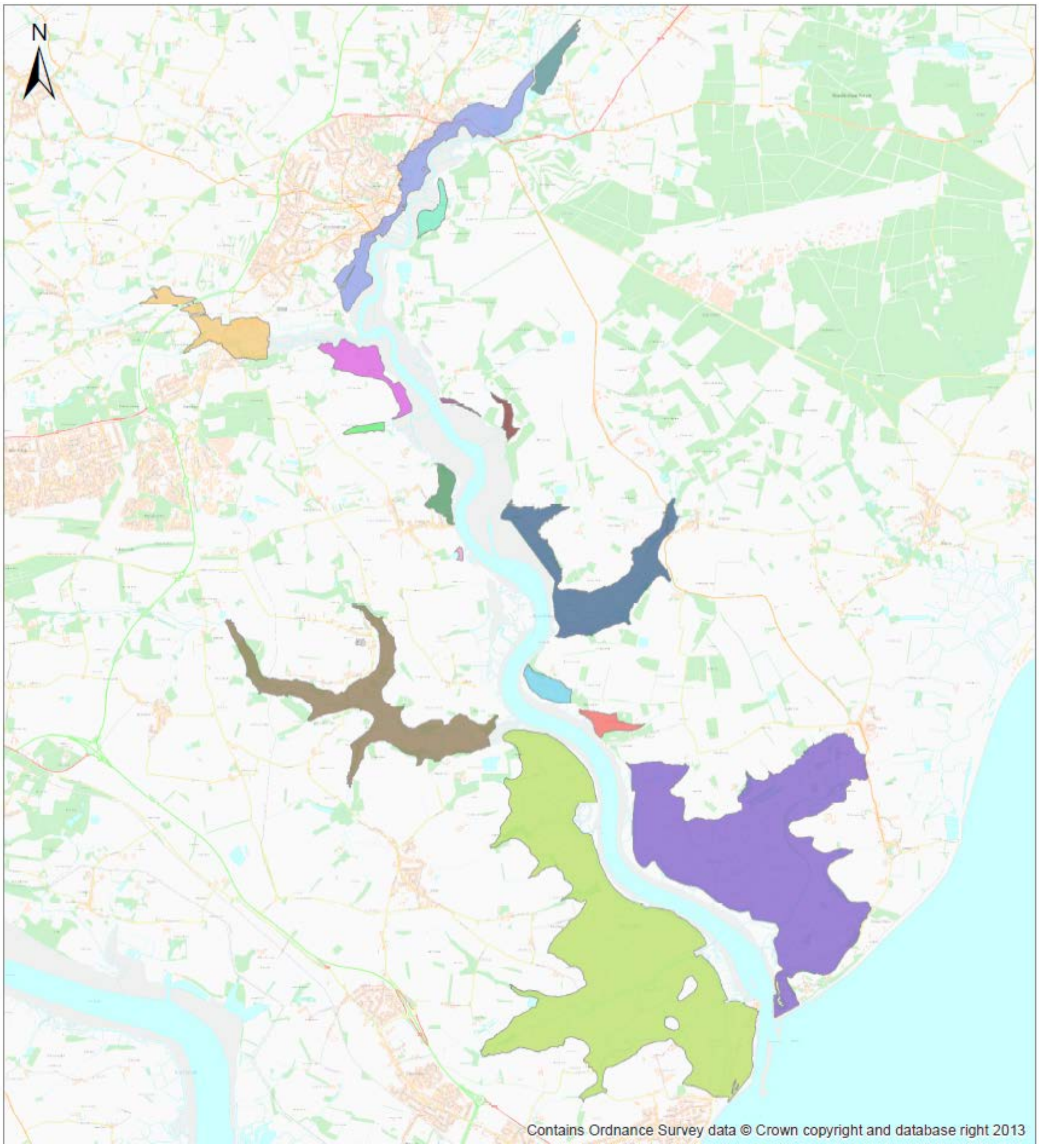


Figure 2.2 Deben Estuary pilot location map

2.2 Emsworth to East Head

This pilot compares insights from the MDSF2 analysis with the initial work that has been undertaken to develop a strategy for Emsworth to East Head in Chichester Harbour, as well as the pilot team's own understanding of the harbour and the associated risks through involvement in other studies in the area.

The Emsworth to East Head strategy work has been undertaken internally by the Environment Agency. It has used the outputs from the Chichester Harbour TUFLOW model initially developed by Halcrow in 2010/11 and rerun in 2012 by the Environment Agency's Regional Modelling and Hydrology Team. This work has considered the tidal flood risk to the eastern part of Chichester Harbour and developed basic options for management of the tidal flood defences.

The areas at flood risk in Chichester Harbour are predominantly rural with a significant amount of agricultural land. The settlements of West Thorney, Chidham, Bosham, Fishbourne and West Itchenor are the locations where the majority of properties are 'at risk'. In addition, Thorney Island is owned by the Ministry of Defence (MOD) and there has been some discussion regarding the potential withdrawal of the MOD from Thorney Island and, if this goes ahead, the potential for realigning the Thorney Island defences. Figure 2.3 shows the flood areas for the Emsworth to East Head pilot study.

At present the main strategy is no longer being progressed by the Environment Agency, reflecting a low priority for funding. The work to date has not developed a clear preferred strategy; however, improvements to defences adjacent to the main settlements and potentially realigning part of Thorney Island have been suggested as potential options and these are explored as part of the MDSF2 pay to pilot.

Figure 2.3 Emsworth to East Head pilot location map

2.3 Lower Aire

This pilot has compared an MDSF2 analysis with the results from the Lower Aire Flood Risk Management Strategy (Environment Agency 2013a). The pilot considers flood risk from both tidal and fluvial sources.

The study area includes 21 flood cells and 109 km of raised flood defences (Figure 2.4). The predominant defence type is earth embankments, with raised walls and floodplain storage also present. In many places two defence lines are present; a lower embankment adjacent to the river typically protecting agricultural land and a higher set-back embankment providing a higher level of protection to more developed areas.

The preferred approach identified in the strategy is a combination of different options for the various flood cells. This includes ‘do nothing’, ‘sustain standard of protection’, ‘improve standard of protection’ and ‘withdraw maintenance’. This pilot replicated four options using MDSF2 for comparison with the results of the original strategy: do nothing, do minimum (maintenance until assets reach the end of their residual life), sustain existing FRM asset (sustain existing asset height and extents) and sustain existing standard of protection (asset maintained and improved to ensure standard of protection does not reduce due to climate change).

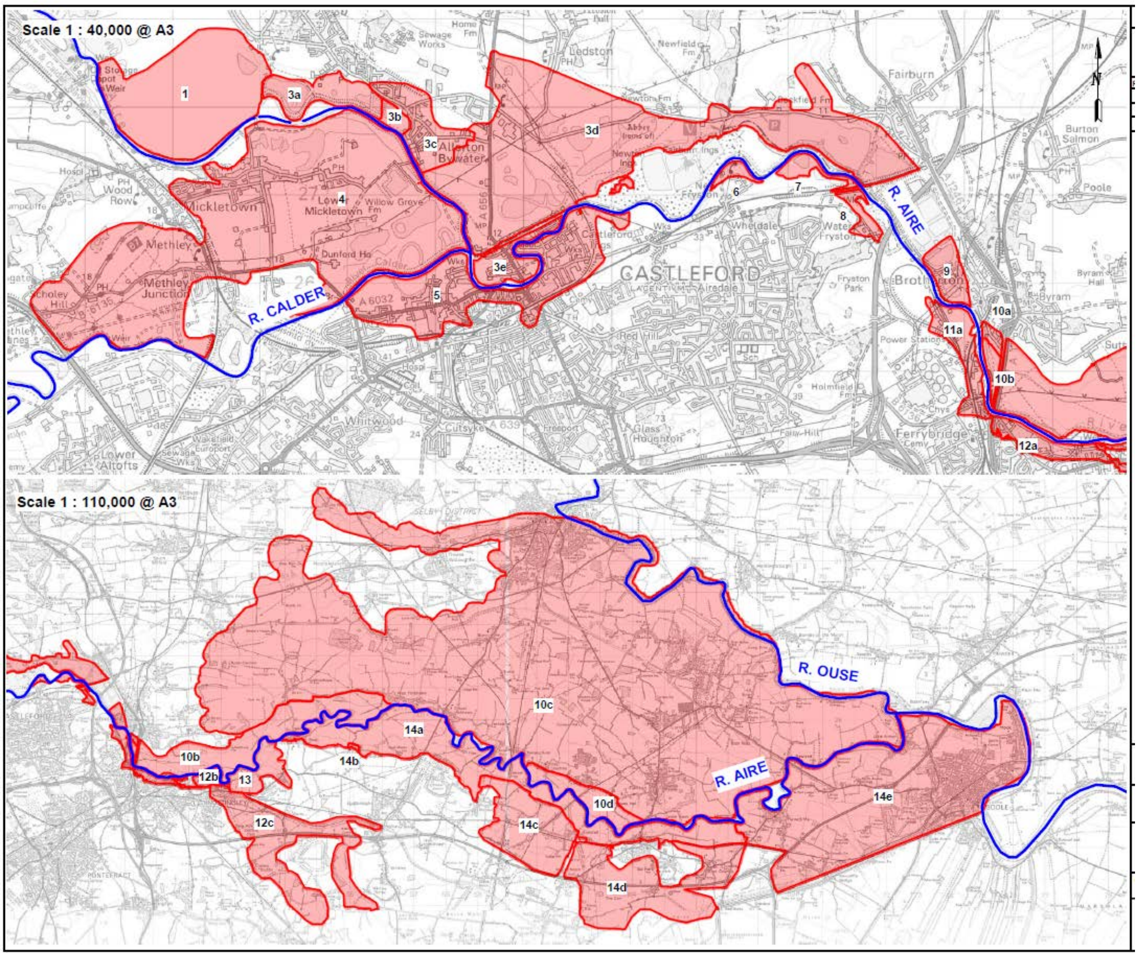


Figure 2.4 Lower Aire pilot location map

2.4 Taw–Torridge Estuary

This pilot study focuses on the lower reaches of the River Caen, Devon, an area that is subject to tidal, fluvial and coastal flooding (Figure 2.5). The area modelled in MDSF2 represents part of the area considered by the Taw–Torridge Flood and Coastal Risk Management Study, carried out by Black & Veatch. The pilot has compared an MDSF2 analysis of this area with the results of the former study.

The model domain contains a variety of land uses/types; on the western side of the River Caen is the sand-dune system of Braunton Burrows, to the east it is largely rural but does include MOD-owned land at Chivenor airfield, and further upstream is the town of Braunton, where numerous assets are currently protected by formal flood defences.

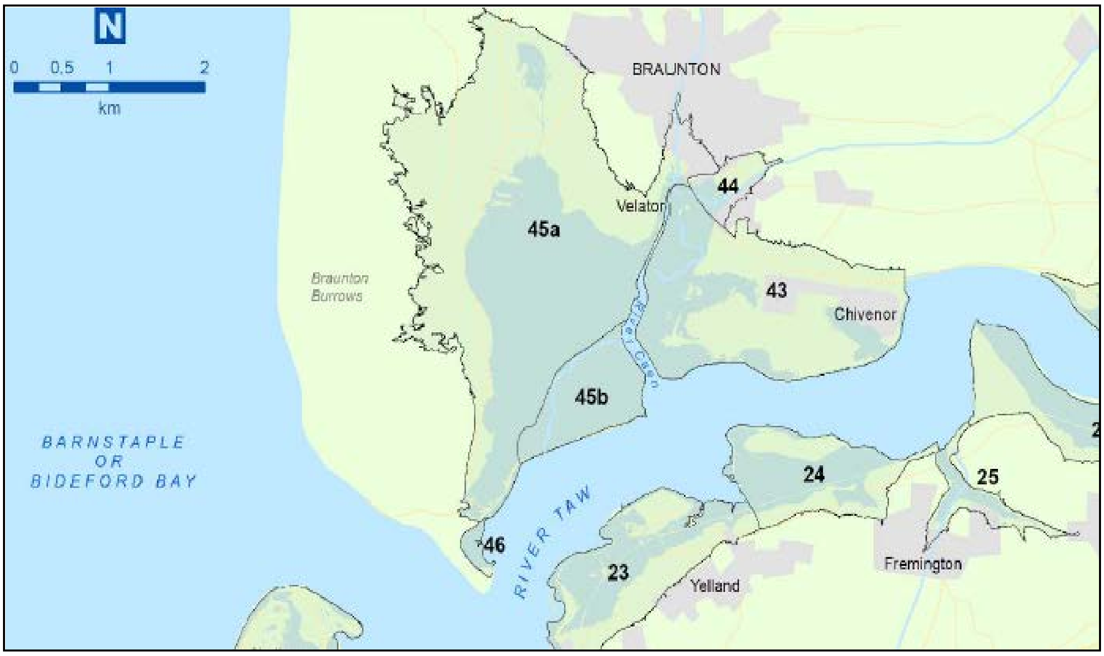


Figure 2.5 Taw–Torridge pilot location map

2.5 Humber Estuary Strategy

This pilot (undertaken outside the project) focuses on the ongoing application of MDSF2 in support of the Humber Estuary Strategy. The study area extends from west of Goole through to the estuary mouth and includes the Rivers Aire, Don, Hull, Ouse and Trent (Figure 2.6). The estuary is subject to fluvial, tidal and coastal flooding with 235 km of flood defences protecting people, property, industry and agriculture. With rising sea levels and socio-economic growth initiatives, it is anticipated that this area will be subject to increasing pressures over the next 100 years.

The regional modelling teams had extensive involvement in identifying the most relevant datasets and the selection of appropriate modelling techniques. The MDSF2 model set-up for the Humber provides a useful insight into the relationship between investment in modelling and the nature of the strategic choices made. This MDSF2 study explores three FRM options: ‘do nothing’, ‘do minimum’ and ‘do something’ (defence raising in response to climate change and socio-economic change).

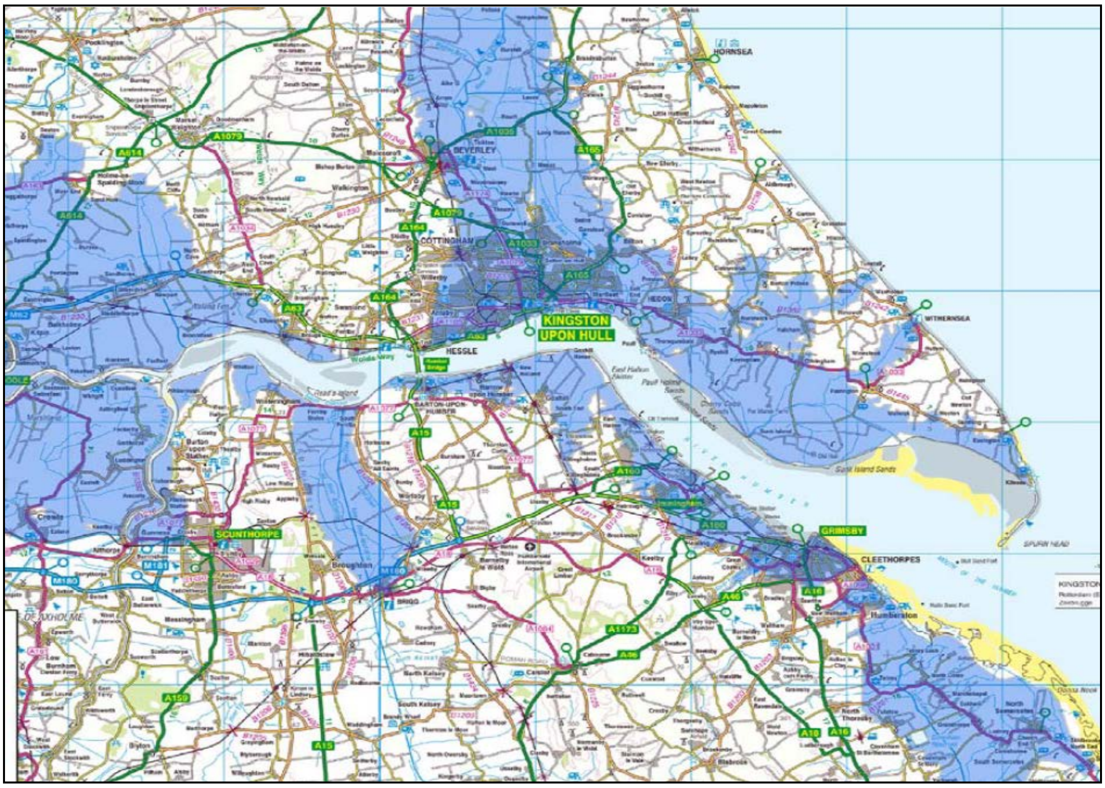


Figure 2.6 Humber Estuary Study location map (HR Wallingford 2011)

3 Pilot questionnaire responses

3.1 Introduction

To ensure the experiences from the four pilot teams were gathered in a systematic and structured manner, a questionnaire was developed to capture their views.

The questionnaire was developed to ensure that the evidence gathered from the pilot studies:

- provides meaningful insights into the practicality of using MDSF2 to support strategy development (including its accuracy and efficiency);
- highlights the potential benefits (added value) of using MDSF2, and clearly identifies any barriers (cultural, technical and financial) to achieving these benefits, including software implementation issues such as deployment through the Central Modelling Platform (CMP);
- enables experience to be recorded in a transparent manner.

The following sections present an overview of the responses received.

3.2 Question 1: Practicality of using MDSF2 to support FRM strategies

3.2.1 Is MDSF2 appropriately accurate?

Deben Estuary

Overall, the probability of inundation results were regarded to be a credible representation of the chance of flooding. The areas identified as key risks were, as expected, primarily associated with areas of property concentration (i.e. Woodbridge). The attribution of the risk to specific defences was plausible and explainable.

Agricultural damages were, however, much less than expected. This was largely attributable to the limitations of the approach to agricultural damages in MDSF2. Given the political importance of agriculture in this area, and the need to provide innovative low-cost solutions in agricultural areas, this shortcoming is significant and severely limits the applicability of MDSF2 in these rural flood areas (as neither the amount, distribution or attribution of agricultural risk is credible).

A lack of automatic capping within MDSF2's present value calculation limits the usefulness of these results (particularly in the 'do nothing' case). Manual capping of present value damages was applied and these results are presented for the 'do nothing' option in Table 3.1. The total present value damages from the Deben Estuary Plan are included for comparison. Reasons why the MDSF2 results are lower include the known limitations of the approach to agricultural damages and the inclusion of other sources of damage in the Deben Estuary Plan results, such as infrastructure. No further information was available to allow more detailed comparison.

Table 3.1 Deben Estuary 'do nothing' present value damages

MDSF2 pilot			Deben Estuary Plan
Property damages	Agricultural damages	Total damages	
£56,549,000	£3,000	£56,552,000	£142,979,000

Emsworth to East Head

The probability of inundation results appear reasonable based on comparison to past modelling and local understanding within the pilot team. It was, however, recognised that comparison of the MDSF2 results (which incorporate a realistic chance of defence failure) to the existing 'defended' TUFLOW results (assuming perfect performance of the defence system) was difficult.

The application of MDSF2 within the pilot added considerable value to the level of existing knowledge on damages and the results appear to offer a realistic representation of risk (largely derived from residential properties). The attribution to specific defences also appeared sensible and could be explained.

A lack of capping within MDSF2's present value calculation limited the usefulness of the results (particularly in the 'do nothing' case). The pilot team was able to implement capping externally to MDSF2 with relative ease and this led to a 60% reduction in present value damages under the 'do nothing' option between the uncapped and capped present value damage results.

Lower Aire

A ranking of flood areas in terms of expected annual damages (EADs) between MDSF2 and the original strategy showed comparable results. However, the benefits of the 'do something' options ('sustain FRM assets' and 'sustain standard of protection') within MDSF2 were far lower than those calculated for the strategy. The team did note that the original strategy damages did include risk to life but this did not explain the differences. They also note that it may be the case that the issues found in the calculation of agricultural damages could be to blame as well as MDSF2 using superseded depth–damage data for properties from 2005.

Unfortunately, the pilot team were unable to get the MDSF2 visualisation tools to run in the timescales available to them and hence were unable to explore in any detail the reasons for the differences, nor comment on the utility of these tools.[1]

Taw–Torridge Estuary

A detailed comparison of the probabilistic flood risk results given by MDSF2 with existing results from traditional approaches concluded that the results were 'satisfactorily similar'. The Rapid Flood Spreading Model (RFSM) visualisation tool was highlighted as 'very important' in building confidence in the MDSF2 results. This is because the visualisation tool enables the maximum flood depth for a specific storm event and defence system state (failed or not) to be determined. Hence provides a comparable output to that obtained from traditional deterministic approaches.

The estimated EADs were very low (so low that they were at first misinterpreted by the pilot team as being expressed as £k, while they were actually just £). This reinforces the limitations of the agricultural damages method currently used by MDSF2 and also

[1] The project was designed to enable a blend of users (consultants and Environment Agency) with varying levels of experience in using MDSF2 to pilot the software.

emphasises the need for units to be included when results are presented. Overall present value damages calculated by MDSF2 were far higher than the original study for the options considered, and although not suggested by the pilot team it may be the case this is due to the lack of capping.

The study area included a number of secondary lines of defence. How best to represent these multiple lines within MDSF2 led to a number of discussions.

Humber Estuary

It was found that the priority risk areas matched the pilot team's perceptions of where they should be now and in the future.

Concern was expressed over the agricultural damage calculations suggesting a significant underestimate of damages. In particular the pilot team questioned:

- The difference in perceived value of agricultural land and the estimates of damage. When implemented at the onset of flooding (0 m, rather than the default 0.5 m suggested in the MDSF2 manual), agricultural damages still contribute less than 1% of the overall damages.
- The approach to capping. Although the agricultural damages were small, they were still capped in 40–50% of impact cells under the 'do nothing' option.
- The aspects of agriculture losses that are not captured.
- Whether there is a better method to value agriculture losses.

Difficulties in defining the accuracy of MDSF2 were also highlighted, as there is nothing really to compare it against. For instance, fragility curves and defence failures are not considered in the same way by traditional approaches and therefore results will differ. Note: the benchmarking activities within the National Flood Risk Assessment (NaFRA) Improvements Project will potentially be able to address this issue in the future (Environment Agency 2013b).

Summary

Despite the difficulties in formally addressing accuracy of MDSF2, most pilots confirmed the probability of inundation results and the prioritisation of risk areas to be explainable and in line with local knowledge. Within the Taw–Torridge pilot, in-depth comparisons of RFSM visualisations with TUFLOW outputs found these to be adequate for strategy development.

The main concerns reflected (i) the treatment of agricultural damages (and the perception that MDSF2 systematically underestimated these), (ii) the lack of present value capping, and (iii) the desire to represent the whole system of defences probabilistically, including multiple lines of linear defence.

3.2.2 Is MDSF2 sufficiently efficient?

Deben Estuary

This pilot team found that setting up the MDSF2 present-day model was time consuming; however, they suggested that this would reduce over time through user experience.

Multiple data preparation issues were experienced, in particular with the input asset data and differences between data held nationally and data used locally for the strategy. Combining this information and then formatting it for use in MDSF2 took a considerable proportion of the total time spent on model build. This is not necessarily unique to MDSF2, and most FRM strategies encounter these problems to some extent. Once set up, however, MDSF2 became very efficient to run and modify to reflect alternative strategies. The pilot team found it easy to change defence attributes and water levels to include climate change impacts. Where more radical strategies were proposed, such as realignment of defences, this changed the spatial schema used within MDSF2 and took longer to set up.

The source–pathway–receptor structure of the databases was appreciated and found to be useful in the representation of alternative strategies. Reflecting some changes within the databases, such as deterioration under different management scenarios, was considered more laborious than necessary, and the team suggested potential benefits to embedding the standard deterioration curves (as available in Environment Agency 2009b as well as user-defined curves) within MDSF2 to enable future conditions to be automatically calculated within the software.

Finally, the team noted that MDSF2 has the potential to be much more efficient and suggested that once developed MDSF2 models should be managed and retained in some way, so that the effort to start will only be an update of the input data.

Key issues arising from the Deben application were as follows:

- **Installation of the software**: Installation instructions are hard to follow.
- **Computer power**: Processing capacity significantly affects efficiency; minimum system requirements should be specified to avoid extended processing times.
- **MDSF2 requires some (but not much) additional data compared to traditional approaches**: Additional, more structured, asset data is required to facilitate the Risk Assessment for Strategic Planning (RASP) approach, including defence type, and storm event loading data for 40 return periods (including wave overtopping).
- **Appraisal control**: The expected annual and present value damages for different periods could easily be obtained through the graphical user interface (GUI); however, the lack of capping and low agricultural damages were significant concerns.
- **Additional guidance is needed**: Guidance for some of the tools needs to be improved. For example, users suggested:
    - If possible, rationalising the data structures, leaving only those that are actually used.
    - Providing information on which of the numerous fields in the asset data are critical and how they are used in the analysis. It is likely that a user will not have information for all fields so knowing if they can be left blank would be very useful.
    - Providing feedback on the ‘calculate present value damage’ (PVD) tab to show tasks that have been added.
- **Better training and understanding of the methods**: The current guidance and training is not focused at helping users develop strategies, and as a result following the guidance is not as helpful as it could be. Bespoke training that focuses on the use of MDSF2 in the development of

strategies (that assumes users have been on the basic MDSF2 training) would significantly improve the efficiency of application.

Emsworth to East Head

This pilot had a very similar experience to the Deben Estuary pilot. Issues were found in getting the asset data into the correct format for use and setting up the present-day model took the majority of the time. Ambiguity over the data field names used in MDSF2 (and the multitude of redundant field names) was a cause of confusion and effort required in matching input data with MDSF2 structures. Once the initial model had been built, adjusting this to represent the alternative strategies and points in time over the appraisal period was relatively straightforward, including major interventions such as realigning Thorney Island (although without supporting hydrodynamic modelling a number of significant assumptions had to be made).

Key issues arising from this pilot application were as follows:

- **Installation of the software**: Installation instructions are hard to follow. Problems with the installation of VBA caused the pre-processing tools not to work.
- **Computer power**: RAM was an issue. A new laptop was required with additional capacity to enable MDSF2 to be used.
- **Additional guidance is needed**: The User Manual assumes a certain level of understanding of MDSF2 and does not step through the process in easy to follow sections that are relevant to strategy development. Instead, it is necessary to read all tasks and steps to gain an understanding of the process as a whole and how the tasks and steps relate before starting. It is recommended that the MDSF2 User Manual is improved to aid usability.
- **Appraisal control**: The appraisal period was easy to control through the GUI. The lack of damage capping is an issue.
- **Better training and understanding of the methods**: Users will need to have a training session on the concepts of MDSF2. It is also necessary to ensure that they are sufficiently competent in the use of GIS to be able to understand what is required as part of the pre-processing.

Lower Aire

In this pilot several technical software difficulties were encountered that led to significant delays and overall the conclusion was that the MDSF2 was an inefficient means of producing results. It was felt that in the same time with a traditional approach greater understanding could be gained.

It was accepted that this may, in part, reflect the need for (i) better software support (particularly clarity on software and hardware requirements) as well as on the application of MDSF2 to FRM strategies (to ensure efficient and appropriate implementation of alternative strategies), and (ii) better guidance on how to use the visualisation tools to help assess the quality of results obtained.

Key issues arising from this pilot application were as follows:

- **Guidance on data fields**: There is a lack of clarity as to which data fields are important and which are not.

- **Lack of resolution**: Less detail comes out of MDSF2 for a similar amount of effort when compared to traditional approaches. (This may be affected by the fact that 50-m grid impact cells were chosen and so results were coarser than from the other pilots which used 10–20-m size cells.)
- **Better manuals and guidance**: The need for better manuals and guidance is clear and this will improve efficiency of the process.

Taw–Torridge

This pilot team did not formally answer this question; however, other responses and discussions suggest that they had similar conclusions to the Deben and Emsworth to East Head pilot teams. The main conclusion was that MDSF2 is efficient, once a base model has been developed, in developing alternative strategies through changes to assets and the source data (water levels).

This pilot made the following observations:

- Developing climate change scenarios in fluvial areas, without access to a hydraulic model or past study results, was initially considered challenging but advice from the Oversight team was useful in highlighting how to do this quickly and efficiently – highlighting the importance of expert support/training in the application of MDSF2 to strategies.
- The appraisal assumptions such as appraisal period were easy to modify.
- The pilot was able to implement the concept of ‘collect once use many times’ in some aspects (e.g. with the national fluvial loads dataset). Improvements made by this study have been incorporated into the national dataset for future use. However, this was not possible for other datasets such as asset information.
- This pilot was run using the Environment Agency’s CMP. This was generally reliable but there were issues including loss of network drives at times.
- The pre-processing tools were easy to use, but any error messages cannot be solved without support from HR Wallingford.
- The case management tools mean the data associated with alternative strategies is easier to manage than with traditional methods, but the GUI needs improvement to make it more accessible.
- The post-processing tools are good but there is a clear need to report present value damage for each unique flood risk area, as this is the scale at which decisions are generally made in FRM strategies.
- In terms of run time this pilot had more issues with running the import and symbolisation post-processing task (Task 8, Step 1) rather than running the MDSF2 model in the GUI.
- There is a clear need for further training and guidance.

Humber Estuary

This pilot found that significant effort is required in data preparation prior to input into MDSF2 (particularly asset data and wave overtopping rates). In many cases this simply reflected the ability of MDSF2 to highlight data inaccuracies and the demands it places on understanding aspects such as asset fragility that are either ignored or masked in traditional approaches. The pilot team felt that better data preparation guidance would reduce the time this phase takes, enabling users to understand priority data needs and focus on these.

Significant time was spent on quality assurance and interpretation of results – however, it was unclear if this is more than or less than traditional approaches.

The following observations were made:

- MDSF2 does require additional and different data in comparison to traditional approaches; this includes additional detailed asset information (not always available from the Asset Information Management System, or AIMS), fragility curves, defence deterioration rates, overtopping rates for all 40 return period events, culvert inflow volumes and volume caps.
- It is not straightforward to modify the appraisal period, discount values and capping values, and it is not easy for the user to know if they have implemented such changes correctly. This should be possible via the user interface and feedback should be provided to inform the user they have been successful.
- Graphical illustration tools displaying risk profiles over time should be added.
- Detailed guidance is required on how best to use MDSF2 for strategy studies, setting out what is and what is not possible.
- Pre-processing tools (tools that support the development of the MDSF2 model) to support strategy study data preparation are needed. For example:
    - incorporating local water level, volume and volume cap information from hydraulic models;
    - perturbing data to reflect changes or interventions such as deterioration, climate change, defence raising or strengthening;
    - screening the National Receptors Dataset (NRD) data;
    - preparing indirect damage data;
    - scaling damages for social equity;
    - preparing damage caps for all damage types and flood sources.
- Current post-processing tools (tools that support the interpretation of the results from the MDSF2 analysis) are NaFRA focused, and strategy focused tools are required. These could include, for example:
    - mapping present value damage raw and capped for each damage type and flood source;
    - mapping interventions and risks through time;
    - mapping annual probability of failure through time for assets;
    - mapping already failed risk for assets (in addition to failed/breach and non-failed/overtopped);
    - calculating present value damage at any spatial resolution (defined by user polygon);

  - preparation of data for the Flood Defence Grant in Aid (FDGiA) calculator (this capability has been developed and applied on the Thames and the Humber strategy studies);

  - appraisal tools such as whole-life cost, benefit cost, incremental benefit cost, robustness, infraction analysis and multi-criteria analysis (this functionality has been prototyped on the risk model output for the Thames Estuary (McGahey and Sayers 2009)).

- The time to run MDSF2 depends on a variety of factors: the processing power of the computer being used, the size of model domain (number and size of impact cells) and amount of flooding (greater in future scenarios or with poor defences). This information can be used to develop guidance in the recommended standard installation guide.

- MDSF2 has the potential to be more efficient assuming appropriate training and guidance is available (User Manual and technical support).

- The pilot also highlighted that MDSF2 uses superseded versions of ArcGIS (v9.3) and Oracle, so keeping pace with such software packages will be an issue.

Summary

In general MDSF2 was found to be an efficient tool for exploring alternative strategies once the present-day base model had been established.

The basic structure of MDSF2 and how it uses snapshots to set out the components of each option being considered is a positive. Along with the use of the source–pathway–receptor structure this enables clear and systematic development of strategic alternatives.

Establishing the base model was considered time consuming by all. This in part may be due to the inevitable learning curve that the pilot teams underwent. Projects such as the Continuous Defence Line (CDL) development (due for completion 2014) should help reduce set-up time by providing datasets (such as the CDL) that are co-owned locally and nationally. Equally, using MDSF2 databases for both NaFRA and strategies would be an obvious efficiency (as long as the data management process is well structured).

The efficient application of MDSF2 was hampered by the lack of guidance that is relevant to FRM strategies (at present only the guidance developed for NaFRA was available). Equally the lack of clear guidance on installation and computer processing requirements (software and hardware) caused protracted issues, both on standalone machines and using the CMP.

3.3 Question 2: Practicality of using MDSF2 to support FRM strategies

3.3.1 A better understanding of how the flood risk system performs

Deben Estuary

This pilot felt that MDSF2 gave a good range of outputs, particularly from the import and symbolisation post-processing tool that can be used to interpret the results of the MDSF2 analysis. Of these outputs some are of more use than others, dependent upon the spatial scale of the output and the nature of the flood risk area being considered.

The attribution of risk (EAD by breach and overtopping) was the most useful output, allowing data errors to be highlighted and ‘do something’ interventions to be targeted. Other useful outputs included the overviews of results (such as EAD and other metrics) at the flood area level. The reporting of metrics at the impact cell level was less useful visually; however, the probability of inundation result in eight probability bands at this level is crucial as the main output representing flood likelihood.

Emsworth to East Head

This pilot felt that MDSF2 provides additional understanding of the system and how it performs when compared to traditional approaches. The attribution of risk was seen as the most useful part of the visualisation package, enabling alternative strategies to be developed. The other useful outputs included the impact cell probability of inundation plot and flood area results such as the different components of the overall EAD.

Lower Aire

This pilot was not able to obtain results from the import and symbolisation post-processing tool, and therefore could not answer most of this part of the questionnaire. The pilot team concluded from what they could see that the MDSF2 would not give any more insight than a well thought out and conducted strategy.

Taw–Torridge Estuary

This pilot felt that, while the standard outputs of MDSF2 are valuable, particularly the attribution of risk to individual assets, there seems to be even more data that is hidden and not displayed in visual outputs. Therefore, there should be the potential for additional outputs that specifically support strategy development, such as present value damage for individual flood risk areas.

They also found the RFSM visualisation particularly helpful in understanding flow pathways within specific flood areas. This pilot did use the confidence scoring approach and found that useful in understanding the validity of the MDSF2 results.

Overall they found that the outputs are good and useful. However, to make progress training will be required to help users understand probabilistic flood risk results in their ‘full richness’, and this will require a shift in mind-set.

Humber Estuary

This pilot team found several of the outputs and visualisations helpful in enhancing their understanding of the behaviour of the flood risk system. For example:

- Long section plots of input data were used to identify data issues and outliers (e.g. ground levels and asset crest levels).
- The RFSM visualisations can be used to understand flow pathways.
- Asset risk attribution can be used for error identification, identification of flow paths and development of potential alternative strategies.

A means of attributing (and visualising) the present value (appropriately capped) risk of individual flood defences was highlighted as a useful addition in helping a cost–benefit analysis for each defence to be undertaken.

Summary

MDSF2 offers a good range of outputs that allow the user to understand how the flood risk system performs. This is primarily through the import and symbolisation tool, which gives numerous standard outputs. Of these the most valuable were found to be the attribution of the asset line with each asset's contribution to EAD (in total as well as associated with breach and overtopping), and the metrics at the flood area level. In addition the RFSM visualisation tool was found useful in allowing comparison with traditional modelling outputs and enabling confidence to be built in the results of MDSF2. Finally, the long section visualisation tool enables rapid review of key input datasets, allowing for validation and error identification.

3.3.2 A better understanding of the performance of alternative strategies

Deben Estuary

This pilot found that the attribution of risk to individual assets, the impact cell EAD and the probability of inundation outputs helped the performance of alternative strategies to be understood.

The process for obtaining present value damage by flood area should be improved, probably with a specific post-processing tool rather than requiring the user to manually extract and process data from the Oracle database. This was considered to be one of the key improvements required from MDSF2.

The scenario management system was considered useful and logical once understood. Initial issues were encountered due to users not understanding terminology and guidance on its use needs to be clear, with worked examples.

Concerns were raised over the implementation of asset deterioration, which at present is manually applied by the user through modifications to condition grades. It was felt this needed better support and guidance, with worked examples to ensure correct application by future users.

Finally, the current approach for the calculation of agricultural damages raised concerns and the pilot team felt it inadequate for use in FRM strategies. In addition support is needed for the calculation of other damage sources. These improvements are needed to gain credibility and for MDSF2 to be accepted as giving a full picture of the benefits of alternative strategies.

Emsworth to East Head

This pilot found the use of the source–pathway–receptor model, snapshots and futures gives a simple and usable framework for the development of alternative strategies. Once the present-day MDSF2 model is developed it can easily be modified to produce new workspaces that represent different futures and combinations of strategic options across an appraisal period.

It was felt that MDSF2 allows rapid development of an alternative future (such as 'do nothing' or 'do minimum') through modifications of the source loading conditions. Alternative futures may need to be developed principally as a result of anticipated climate change (water levels/river flows/overtopping rates) and changes in defence attributes (defence deterioration through modified condition grades and defence improvements through improved condition grade, raised crests and new defence types). Implementing autonomous future changes appropriate to FRM strategies, such as climate change, was relatively easy once the new water levels or overtopping rates had been calculated (or estimated) through an external process.

MDSF2 at present performs well in the calculation of property damages. Among the other damage types considered the approach to agricultural damages is too simplistic. The present-day EADs from agriculture were only £246. Considering that significant areas of agricultural land are at risk from inundation, this is not realistic. There are several other types of damage typically considered by an FRM strategy such as transport disruption, loss of tourism revenue, infrastructure damage, environmental effects and risk to life that MDSF2 does not consider. Consideration should be given to either including them in MDSF2 in some way or improving the outputs from MDSF2 to assist in their calculation externally to MDSF2. In addition, 'opportunities' such as positive changes through provision of priority habitats could be considered.

The failure of MDSF2 to implement present value damage capping and present this information at the flood area scale was a concern. (Note: It is understood that this has been addressed already in the next update of MDSF2 v1.6.0 due to be released in 2014 – but this has not been tested here.)

Lower Aire

The need for improvements to the agricultural damages calculation approach was highlighted. In addition the need for MDSF2 either to calculate or support the calculation of damages from other flood sources was also raised.

Another area in which the pilot team suggested MDSF2 could be improved would be provision of outputs that are ready to feed into the current FDGiA calculator which must be completed for all FRM strategies.

This pilot also found that MDSF2 currently has an issue with capping of present value damage. This is a crucial process and without it the results of the economic analysis provided by MDSF2 are not fit for purpose. (Note: It is understood that this has been addressed already in MDSF2 v1.6.0 – but this has not been tested here.)

Taw–Torridge Estuary

This pilot team found that the understanding of strategy performance was improved by asset EAD attribution, and also used the RFSM visualisation. However, they felt that the real drivers of risk were not absolutely clear and believe there is much more information that could aid understanding but is buried in the Oracle database.

They felt that the ‘flexibility and functionality of MDSF2 to set up combinations of options through time is probably unrivalled’.

Humber Estuary

This pilot team recognised the benefits of the existing tools but does recommend a large number of areas where new tools could be developed to assist the development of alternative strategies. These potential new tools include:

- improved data preparation tools to support the use of local data, particularly for assets;
- data modification tools to assist development of strategy by changing input data such as water levels (source) and asset data (pathway);
- a strategic option costing module (no other pilot suggested this as a need).

This pilot found that the scenario management system is not intuitive and can be cumbersome, going against the findings of the other pilot studies.

Summary

Use of the source–pathway–receptor model, snapshots and futures has been found to give a simple and usable framework for the development of alternative strategies. This gave a logical approach to understanding the way in which they perform. In addition the ability of MDSF2 to indicate which assets contribute most to flood risk in a certain area is also very useful.

Several issues compromise the ability of the user to understand the performance of an alternative strategy. These are primarily the issues with the current approach for calculating agricultural damages, the need for present value damage information to be readily available at the flood area level, and the need for information to inform FDGiA calculations.

3.3.3 Selecting the best course of action

Deben Estuary

The overall conclusion of this pilot is that MDSF2 is useful but does need improvement before it can be widely used. The ability to represent FRM approaches beyond modifications to raised defences needs to be improved with guidance so that users do not shy away from this. For example flood storage, property level protection and channel maintenance/dredging are all harder to represent directly in MDSF2. To support a better targeting of investment, present value damage (PVD) should be provided for individual flood areas (and ideally individual assets) in an easily accessible manner; at present it is only available for the whole study area.

Emsworth to East Head

This pilot found that the greater understanding of the drivers of risk provided by MDSF2 may lead to better strategic decisions as well as reducing appraisal and strategy development costs. However, the need for PVD to be provided readily by flood area was highlighted as a concern; at present it is only available for the whole study area.

Lowe Aire

This pilot raised concerns over the accuracy of the economic analysis in supporting decision making. This stems from the poor agricultural damages methodology, the lack of an accessible method to cap PVDs and a perceived lack of resolution with MDSF2. It should be noted that the pilot chose to use impact cells that were 50 x 50 m, while other pilots reduced their impact cells to 10–20 m. This highlights the need for any future guidance to give advice on appropriate impact cell sizes.

As in the other pilots, the need for PVD to be presented at the flood area level was highlighted as important (at present it is only available for the whole study area).

Taw–Torridge Estuary

This pilot team concluded that MDSF2 does have the potential to improve FRM strategies. To realise this potential will require improvements in functionality and proper training for users. They also suggest that MDSF2 may facilitate in-house Environment Agency-led FRM strategies.

Once again the asset EAD attribution tool was praised. The team suggest that considering the amount of scrutiny being applied to the costs and benefits of FRM, this feature alone could lead to MDSF2 becoming the tool of choice, enabling far more cost-beneficial FRM strategies to be developed.

This pilot also raised the need for PVD to be presented at the flood area level (at present it is only available for the whole study area).

Humber Estuary

This project felt that as MDSF2 is primarily focused on raised defences, guidance is required to enable users to simulate other interventions such as channel maintenance and flood storage so that they are not excluded from the list of potential options.

The ability of users to identify important assets through the EAD attribution was highlighted as useful. In this context it revealed that the most important assets in some flood areas were actually located away from the main urban areas and that an inland cross-floodplain barrier would be more effective than raising the primary sea defence – creating innovation in the development of strategy intervention measures.

Finally, the project identified a list of potential outputs that could be derived from MDSF2 in the post-processing tools that would be appropriate for strategy development. These included:

- calculation and mapping of Defra outcome measures;
- maps of flood probability for individual return period events with the full set of system states;
- graphs of risk through time (EAD and probability of inundation);
- data ready for the FDGiA calculator;
- ability to click on impact cells and obtain depth–probability information;
- RFSM visualisations for all flood areas at once;
- ability to click on an asset and view the defence type, fragility curve and loading condition for a user-selected event. This recommendation has had considerable user support within the Humber study.

Summary

MDSF2 provides a rich picture of the present and future risks under alternative strategies. The user can readily vary the form (within limits) and timing of interventions, and MDSF2 quickly calculates the impact on risk. It also provides useful insights on the confidence in the estimates. This information can help ensure limited investments are well directed and help understand if a strategic decision to act (or to do nothing) is robust and whether the decision would change if better information became available (providing the evidence to decide when the data and analysis are 'good enough' to make a robust strategic choice).

The pilots confirmed that MDSF2 gives a better understanding of the drivers of risk through outputs such as attribution of assets with their contribution to EAD. This should enable better decisions to be made from this increased understanding leading to better use of available funds to manage flood risk. However, there are areas where improvements can be made to assist this process. This includes providing PVD at the flood area level, the approach to calculating agricultural damages being improved and providing guidance on the representation of FRM options beyond raised defences. In addition, the lower spatial accuracy of MDSF2 through impact cell sizes is also a concern.

3.4 Question 3: Barriers to achieving the benefits of MDSF2

3.4.1 Cultural barriers to use

Deben Estuary

The pilot team felt that MDSF2 is a significant change of approach and philosophy. Significant effort will be needed to win the hearts and minds of some consultants and risk management authorities. There will be prejudices due to the long history of development with MDSF2 (and its perceived links to NaFRA) and from what people have heard/seen in older versions of the software.

They also felt that the economic calculations need to be more transparent, with data outputs for intermediate stages to build confidence in the final results.

If all consultants were to use one mandatory platform, without opening up the development process, this may lead to loss of innovation in methods (to some extent).

Emsworth to East Head

This pilot felt that in order to use MDSF2 well the user must adopt a probabilistic systems mind-set which is quite different to a traditional deterministic view. MDSF2 also needs to be more user friendly to encourage its use and more transparency is needed in the calculations.

Smaller impact cells (10 m instead of the 50 m used by NaFRA) were considered necessary to ensure adequate spatial accuracy. It needs to be highlighted that MDSF2 does not have to use the default setting used in NaFRA (e.g. impact cell size) and the possibility to use local data needs to be made clear so that people do not use the fact that MDSF2 is used for NaFRA to question its accuracy for strategy studies.

Using MDSF2 as a standard across the industry may actually increase innovation in FRM strategies by freeing time away from 'just getting the analysis done' to 'developing the strategy'.

Lower Aire

This pilot felt that there is an element of a black box with MDSF2 at times and it is not clear if something is being done or not. For example, with capping even though the procedure described by the manual was used it was not working and this was not at all clear – no error messages were given and the error was discovered by chance.

The pilot team believe that MDSF2 gives far less detailed results than traditional approaches which report damages at the property level, and so this will be a barrier to its use (but this also relates to the choice of impact size cell in this pilot). Also MDSF2 needs to be up to date with latest damage calculation guidance and data; currently property damage data is out of date and the agricultural damages method does not follow current guidance.

Taw–Torridge Estuary

This pilot team highlighted the potential issue of Environment Agency project managers being naturally risk averse and therefore they could be reluctant to commission a strategy using MDSF2 as they would feel more comfortable with tried and tested methods. In addition the team felt there is a stigma associated with NaFRA and the results it gives which could tarnish the use and acceptance of MDSF2. This would need to be overcome through demonstration of the results MDSF2 can provide and the efficiency it can deliver.

They also felt that there is a lack of transparency over how MDSF2 really works. A key part of this is the different approach to modelling flood risk compared to traditional approaches.

Humber Estuary

This project team recognised the need for a change of mind-set, and that it will be a challenge to convince industry that the probabilistic outputs are the way to go and deterministic must be seen as a thing of the past. They also thought that there needs to be a change of focus, with MDSF2 being converted from the NaFRA-centred application it is at present to a strategy focused product with associated strategy focused guidance so users are not put off. They also felt that, while transparency has been improved with MDSF2, more can be done.

Finally, they emphasised the need for training prior to use of MDSF2 to ensure users are prepared for using it for real.

Summary

Moving to the use of MDSF2 as a standard and accepted approach will require existing practices to be changed. The strategy project teams, clients and the Large Project Review Group (LPRG) will all need to be convinced of its fitness for purpose and cost effectiveness. It is almost inevitable that there will be some level of resistance to this change in the way FRM strategies are developed.

The pilots confirmed that MDSF2 does present a challenge as its full uptake will require a change in mind-set for both practitioners and decision makers. The change from a deterministic assessment of flood risk to the probabilistic assessment which MDSF2 provides will require education of all parties and confidence to be built in its accuracy. Transparency in both the calculation methodology and the results it gives will be important. In addition, clear guidance for the use of MDSF2 in the specific context of FRM strategies is required.

3.4.2 Technical issues: software implementation

The pilot teams that used MDSF2 on local machines had a common set of issues, namely:

- Installation of MDSF2 is not straightforward and the supplied guidance was not clear. Assistance was required from technical support to ensure correct installation and this cost the project time.
- MDSF2 did not install on Windows 7, and therefore pilots were forced to run the software on virtual machines with Windows XP. This reduced the computing power available for running MDSF2 tasks and made the process less efficient.
- ArcGIS v9.3 has been superseded and is not currently being used by consultants; however, the pilot teams were able to use this version of the software as they held a copy on disc. MDSF2 will need to keep pace with updates to the software that it relies on.
- The minimum performance requirements for MDSF2 should be explained to potential users, as this significantly affects the efficiency with which MDSF2 can undertake model runs and analysis. This was supported by feedback from the Humber Estuary team.
- The Lower Aire team raised the issue that there is potentially a very large licence fee for Oracle. The Deben and Emsworth to East Head teams used a freely available version that does not have total functionality but was sufficient for the purposes of running MDSF2. As with ArcGIS, the developers of MDSF2 need to be aware of the potential for changes to Oracle and the danger of relying on functionality that may become obsolete in later versions.

The Taw–Torridge Estuary pilot team used the CMP to run their pilot and so they did not experience any installation issues. Overall they felt that the CMP was generally reliable; however, technical issues did hinder progress. These issues included inability to access saved data and MDSF2 models and temporary loss of access to the CMP. They felt that support from the Environment Agency's CMP support team was poor.

4 Discussion of key themes and findings

4.1 Ease of representing the reality of strategies

MDSF2 uses a logically structured case management system. A strategy is broken down into snapshots which represent the state of the flood risk system at a given point in time within the appraisal period. This is typically the present day, the end of the period and intermediate points when key changes to the system state occur. Each snapshot is defined through the source–pathway–receptor model; these three areas represent the key elements of the flood risk system that are used to represent system state at the specified point in time. Overall this is considered a suitable structure for the representation of alternative strategies and is compatible with the approach generally taken by traditional methods: it makes explicit what is already implicitly present in traditional methods. However, future users will need training and guidance to understand the philosophy behind this structure.

The following sections discuss the way in which MDSF2 represents the source, pathway and receptor elements of the system, establishing where the approach is currently adequate for FRM strategies and identifying areas for improvement.

4.1.1 Source

The source datasets define the loading placed upon flood defence assets. For fluvial and tidal defences the sources are water levels associated with different storm return periods. For coastal defences the sources are overtopping rates associated with different storm events.

MDSF2 currently allows users to import water levels for a minimum of three events for each snapshot considered. The tool then uses interpolation and extrapolation to determine water levels for the remainder of the 40 storm return period events that MDSF2 uses in its calculations. This process is relatively simple; however, it does require users to assign water levels to asset IDs outside the assistance of any MDSF2 pre-processing tools.

Use of wave overtopping data within MDSF2 requires more effort: for an FRM strategy the user is expected to supply rates for both the failed and un-failed asset states, and to do so for all 40 events. This would require significant external wave overtopping analysis. For the Humber Estuary team this was considered a worthwhile exercise, while in the Deben Estuary pilot a simple linear interpolation of available results (five return period events) was used for their small length of coastal assets. Guidance is needed to allow users to interpolate between a number of wave overtopping rates credibly or to calculate the full range of return periods easily (e.g. through an updated EUROtop). Whatever approach is adopted it will need to be proportionate and appropriate to the level of accuracy required for strategic decision making. If no further information is available linear interpolation would be good enough at the strategic scale.

MDSF2 does allow the user to import erosion contour data. However, none of the pilot teams were able to successfully implement this aspect of the tool (the Deben Estuary pilot attempted this for a small area but were unsuccessful).

The final element of the source component is the ability to represent the impacts of climate change. This needs to be undertaken through changes in water levels, overtopping rates and erosion rates. In the tidal and coastal pilots this was easily achieved by simply applying sea-level rise predictions from the existing guidance to the present-day water levels and re-estimating overtopping rates in coastal areas. The impact of climate change on fluvial systems is typically presented as changes in peak flows. To represent this in MDSF2 the user must translate changes in flow to changes in water levels. Applying these changes, given better guidance, would be straightforward and easily automated (either by providing additional tools to support MDSF2 or supporting consultants to quickly develop in-house tools).

4.1.2 Pathway

The pathway component of the flood risk system comprises both the flood defence assets and the hydraulic representation of the flood risk areas. The following sections discuss the way in which MDSF2 represents these elements of the system.

Flood areas

The definition of flood areas is relatively straightforward in MDSF2 and the main point of note is the representation of the floodplain through the use of impact cells. There were varied responses regarding how well this enabled alternative strategies to be represented and this related primarily to the size of impact cell used. Although smaller impact cells (10–20 m) did lead to longer model run times they are crucial in giving sufficient detail for the purposes of strategy development.

Assets

The representation of flood defence assets – location, condition and crest level as a minimum – is crucial at a strategy level. Achieving this basic requirement remains more difficult than it should be. For example:

- The **asset dataset** contains a large number of fields. Not all fields are crucial to the MDSF2 calculations and users found it frustrating that the guidance did not describe their exact meaning nor indicate which fields were essential and how they affect the calculation process. Basic online guidance would significantly improve this. It is recommended that the MDSF2 asset data structures are revisited and rationalised before updating the MDSF2 User Manual and embedding a help tool.
- **Point assets**. None of the pilots included pumps or other complex point assets within the analysis. Although some of the areas included point assets, in all cases it was argued that these could be legitimately excluded from the analysis. In part this appears to be a true reflection of the context of the strategies in the pilot areas and in part it is associated with the limited guidance and function on how to deal with point assets easily with MDSF2.
- **Condition grade** is used as one of the key factors in determining how a defence reacts to being loaded. This has both advantages and disadvantages. The disadvantage is that condition grade is a very coarse measure of performance. The advantages, however, are that condition grade is generally available and easily linked to default fragility curves (Environment Agency 2009b). In order to achieve appropriate representation of actual defence performance, it will be important to facilitate local definition or validation of the fragility curves, especially for

high risk assets. This will require clear guidance for the translation of practical local knowledge into the defined format of the fragility curves.

- Defence **deterioration** is a complex process and in general poorly understood. At present MDSF2 requires the user to represent this through changes to condition grade at user-defined points in time. A stronger link to the generalised deterioration curves (Environment Agency 2009b) within MDSF2 would hopefully reduce variability in how this process is represented by users of MDSF2. This should be combined with clear guidance on how users can adapt the generic curves to incorporate their local knowledge.

- **Breach repair** conditions are poorly represented in MDSF2. There is an inherent assumption that breaches, if they occur, are automatically repaired and that the defence returns to the same condition grade as it would be in if the breach had not occurred. The validity of this assumption is questionable and may lead to MDSF2 (marginally) overstating the risk but not recognising the impact that breach repairs can have.

- **Interventions other than structural measures** such as improved channel conveyance, property level protection and flood storage can be incorporated into MDSF2 but it is not easy. There would be benefit in allowing the user to incorporate these types of intervention with greater ease. Various approaches to help do this are available; for example, a simple approach for providing modified water levels due to channel intervention has been applied as part of a SAMPs project to estimate the benefits of maintenance at a national level (Roca et al*.* 2009). However, the ability to rapidly modify attributes such as condition grade, crest level and standard of protection led to most pilots concluding that MDSF2 can provide significant efficiencies in developing alternative strategies.

4.1.3 Receptor

The receptors for which there are default data preparation tools in MDSF2 are properties and agricultural land. These represent a limited subset of the range of receptors that are typically considered in an assessment of flood damages for an FRM strategy. MDSF2 has a generic receptor capability and thus any receptor with a depth–harm relationship can be incorporated in the analysis. For example, on the Humber Estuary depth–damage data was introduced from the Multi-Coloured Manual for critical infrastructure (oil refineries, power stations, works, industrial estates, docks) to assess the sensitivity of these receptors.

It is recommended that default data preparation tools are introduced to support a wider range of receptors such as the assessment of critical infrastructure. There is the clear potential for this to be included within MDSF2, enhancing a user's understanding of what is at risk and enabling strategic decision making.

Equally, MDSF2 only reflects direct damages. Guidance on reflecting indirect damages (either as an embedded process or as an external process) would be useful together with, for example, equity weighting and other treasury rules.

In addition, the representation of the two types of receptor already considered could be improved. For example:

- **Properties**: One of the pilots included property level flood protection measures as part of a strategy. This was represented through modifications to the properties dataset before import into MDSF2. This type of intervention is becoming increasingly common and there is the potential for a formalised method within MDSF2 to allow property level protection measures to be applied to specific properties.

- **Agricultural land**: The assessment of agricultural land uses the agricultural land classification to determine a basic depth–damage relationship. This is simplistic and does not capture the reality of damage to agricultural land. For example the Taw–Torridge pilot calculated expected annual damages for agriculture of only £122, despite a significant area being identified as at risk of inundation by MDSF2. An approach that reflects the guidance given by the Multi-Coloured Manual should be developed so that MDSF2 gives more realistic estimates of agricultural damages.

4.1.4 Futures

Futures that include changes beyond the physical impacts of climate change (sea-level rise, increased rainfall intensity and increased peak river flows), such as economic growth, urban development and changes to funding regimes, are hard to incorporate. Although at present FRM strategies do not consider these factors, it is likely that they will become increasingly relevant and warrant inclusion when making strategic decisions on FRM. Decision aids from the recent Environment Agency R&D project ‘Accounting for Adaptive Capacity in Options Appraisal’ (Environment Agency Project SC110001) could also be usefully included (or linked to as an external process outside MDSF2 but with associated guidance).

4.2 Completeness of the assessed risk and strategic decision support

MDSF2 provides expected annual damages (EADs) and present value damages (PVDs) as well as information on flood probability and risk attributed to individual assets. Visualisation aids help communication of these outputs.

The EAD is supplied readily to the user by asset and flood area through the MDSF2 GUI. However, the PVD is only readily available for the whole area modelled. Additional analysis by the user is required to determine the PVD for individual flood areas or at an individual asset scale, which is typically needed in FRM strategies. Aggregation to a flood area scale could be easily embedded into MDSF2. Asset-scale PVDs are more difficult to extract (and have not been extracted as part of the pilots) but this would also be useful.

The visualisation of the results of MDSF2 as provided by the import and symbolisation post-processing tool gives a very useful suite of outputs to enable the user to explore the data.

At the moment MDSF2 provides information on the changing risks. It is assumed that the user will export this information to support benefit–cost ratios analysis. This is straightforward and not perceived as a barrier to uptake. In the longer term consideration could be given to inclusion of an automated costing module and presentation of Benefit Cost Ratio, incremental Benefit Cost Ratio, Net Present Value etc. It would also be straightforward, and convenient, to include partnership funding calculators and alternative decision rules in this. Many of these aspects were explored in FLOODsite and methods and prototype tools were developed and applied to the Thames Estuary (McGahey and Sayers 2009) and more recently in the scoping of the FaCET tools (Environment Agency 2013c).

The results of the pilots show that MDSF2 gives robust results for damages to property, primarily in terms of EADs. There are, however, several areas where improvements are required to allow for a more complete assessment of risk; for example, indirect damages could be considered for inclusion or (perhaps more appropriately) guidance provided on how to use the MDSF2 to assess indirect damages.

Of those damages assessed in the pilots the agricultural damage calculation was shown to be lacking in quality and significant improvements are needed there. Overall the approach to the calculation of damages for properties was considered satisfactory. Some specific recommendations for improvements to these two aspects are given below.

Direct property damages

There are several areas for improvement. Firstly, the depth–damage data has not been updated since 2005 although new data has been released. There is an imminent update to the dataset and this should be included in any updates to MDSF2.

Secondly, the capping of PVDs calculated by MDSF2 requires the user to manually assign a write-off value for each damage type to each impact cell. When MDSF2 was developed, a valuation field was incorporated and automatically populated with the NPD property valuation data. When the National Receptors Dataset (NRD) was released, MDSF2 was updated to use the NRD data; however NRD does not include valuation data, so the field was no longer populated. It would be helpful to reintroduce this capability with an alternative source of valuation data.

Agricultural land

Although of limited significance to the national economic damages, agricultural losses can be significant in determining more local strategies. The current default data preparation does not differentiate between saline and fresh water damages. To introduce this distinction is straightforward (through the damage table) but little guidance is provided on how to assess agricultural damages credibly using the existing MDSF2 framework. Investing significant effort to radically change the approach to agricultural damages is not recommended, but additional advice on how to make the most of the current approach would make a significant difference.

As with properties, write-off values and capping of PVD should be made easier.

4.3 Are the results ‘good enough’?

In some ways MDSF2 is significantly better than traditional approaches, in particular in its treatment of raised defences and the potential for one or more breaches. MDSF2 also provides a structured view of the whole risk system. The assumptions and limitations are clear and well understood. In other aspects, particularly the relatively narrow range of damage types that are reliably calculated, MDSF2 is some way behind a standard approach.

Overall the results produced by MDSF2 at present are only good enough (when supported by appropriate local modelling) to enable the development of FRM strategies that are dominated by direct property damages. When strategic choices are controlled by issues of loss of life, agricultural or indirect damages MDSF2 can be a useful supporting tool but is not sufficiently complete to be the central approach. Concerns have also been raised regarding the omission (or oversimplification) of some damage types and the lack of certain key functions (such as capping etc), and these need to be improved prior to wider roll-out.

The approach to agricultural damages is particularly simplistic and inferior to a traditional approach. It is possible for more advanced users to introduce additional damage types and use the results of MDSF2 to calculate damages from other sources such as transport disruption and damage to critical infrastructure. However, if MDSF2 is to be used widely this process needs to be made easier, either through providing outputs that can be easily used to calculate such damages or possibly incorporating the calculation of these damages into MDSF2 itself. It is not always the case that these damages contribute a significant proportion of the total damages, but unless they are quantified certain stakeholders can be reluctant to buy into the strategy. This is particularly the case with agricultural damages and local landowners.

There are some areas where MDSF2 is better than traditional approaches. MDSF2 provides a structured view of the whole risk system. The assumptions and limitations are clear and well understood. The representation of raised defences is much better in MDSF2 than traditional analysis (and avoids gross assumptions about undefended and defended situations). In general the 'translation' of strategic options into the model domain is more straightforward (and realistic) in MDSF2. MDSF2 is not, however, a detailed hydraulic or morphodynamic model (it fails to capture floodplain channel interactions that may be important in some areas) and relies upon appropriate external modelling.

4.4 Can NaFRA be used as a 'hot-start'

Significant effort has been devoted to developing and improving the National Flood Risk Assessment (NaFRA) dataset over a number of years. Using a NaFRA database developed with MDSF2 as a so-called 'hot-start' for a more local strategy should offer a significant time saving. Using NaFRA datasets as a hot-start for MDSF2, however, relies upon the NaFRA modelling having access to and using a good base dataset that takes into account appropriate local knowledge. Two of the pilot studies (Deben Estuary and Emsworth to East Head) attempted to make use of the NaFRA databases as a hot-start. In both cases the quality of the data within the NaFRA databases was so poor that this was not possible without significant effort. Also in both cases the NaFRA data was developed using the NaFRA toolsets (rather than MDSF2), and hence the structure of the data was also different. Overall these issues are likely to make using a NaFRA database developed with the old NaFRA approach as a hot-start for MDSF2 an inefficient choice.

NaFRA and MDSF2 already draw upon a common managed dataset – a finding confirmed in the pilots. To provide a more seamless interaction between NaFRA and more local strategy studies using MDSF2 databases – that transfers value added information from one to the other – will require investment in management processes. If this linkage can be established and maintained efficiently it is likely to deliver significant savings and improved data quality to both NaFRA and strategies.

4.5 Visualisation aids

The visualisation aids provided in the post-processing tools of MDSF2 give a wide range of outputs that can be used to interpret the results of the analysis. The visualisation aids that are appropriate for use by strategy studies are:

- post-processing import and symbolisation (Task 8, Step 1);
- long section visualisation;

- Rapid Flood Spreading Model (RFSM) visualisation;
- validation layers.

The merits and usefulness of these visualisation aids are discussed in the following sections.

4.5.1 Import and symbolisation

The outputs produced by the import and symbolisation tool provide a wide range of ways to interpret the results of the MDSF2 analysis for each snapshot that is modelled. These are given at three spatial scales: the individual impact cell, the flood area and the asset.

Results shown at the impact cell scale are of varying use. Information regarding the level of risk is most appropriate at this scale. The impact cell probability of inundation gives the best overview of the level and distribution of flood likelihood for each snapshot. It was found that the eight-band option was always preferable to five-band, giving extra detail that aids interpretation. Figure 4.1 shows the probability of inundation visualisation for the Deben Estuary at the present day.

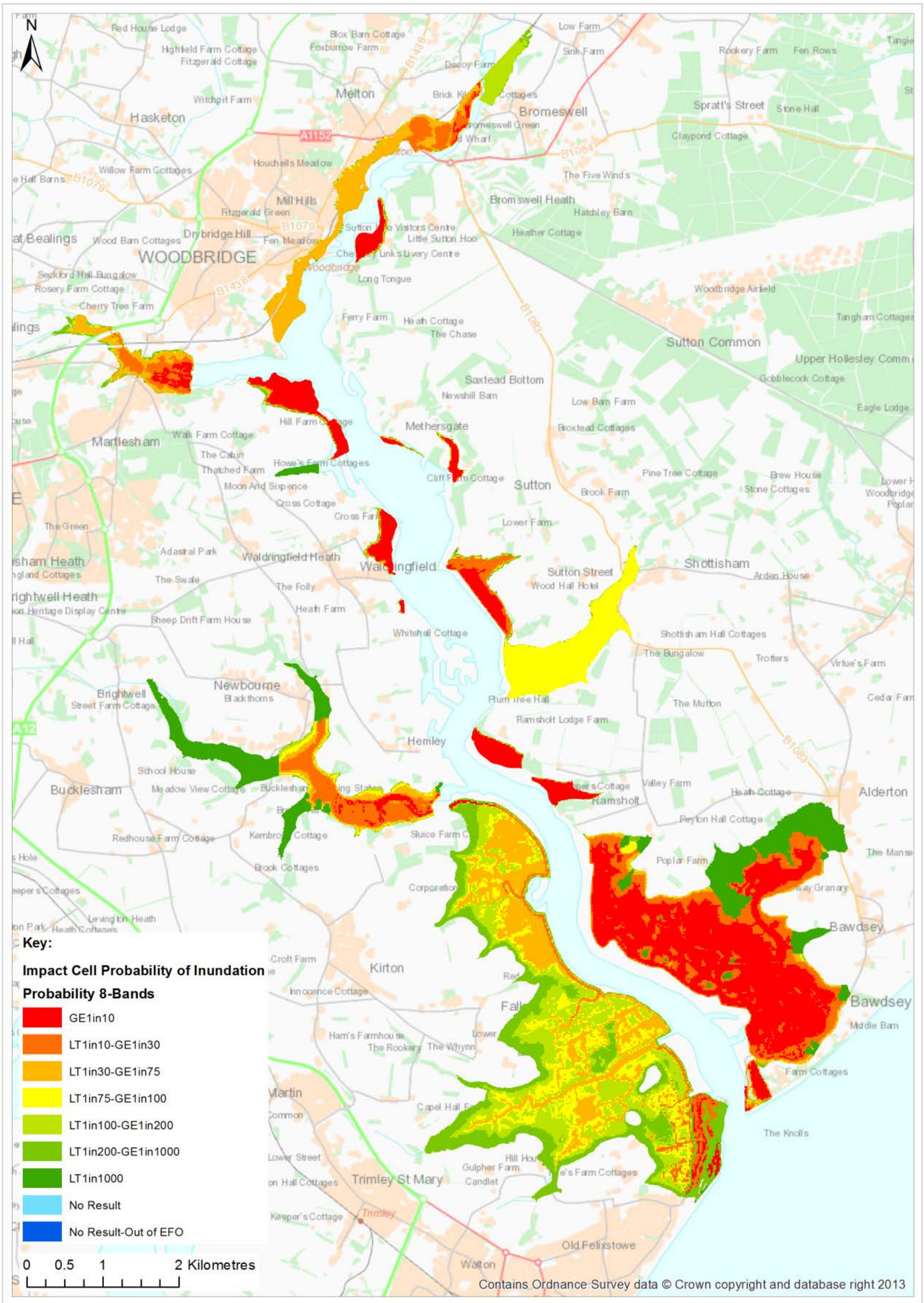


Figure 4.1 Probability of inundation visualisation – MDSF2

Figure 4.2 shows deterministic results from the traditional approach of the Deben Estuary Plan for the present-day defended scenario. This shows the results for five return period events overlaid to represent the probability of flooding across the estuary with no defence failure. The MDSF2 result shows higher levels of flood risk because defence failure is considered, while for the deterministic approach defence failures such as breaches must be manually included.

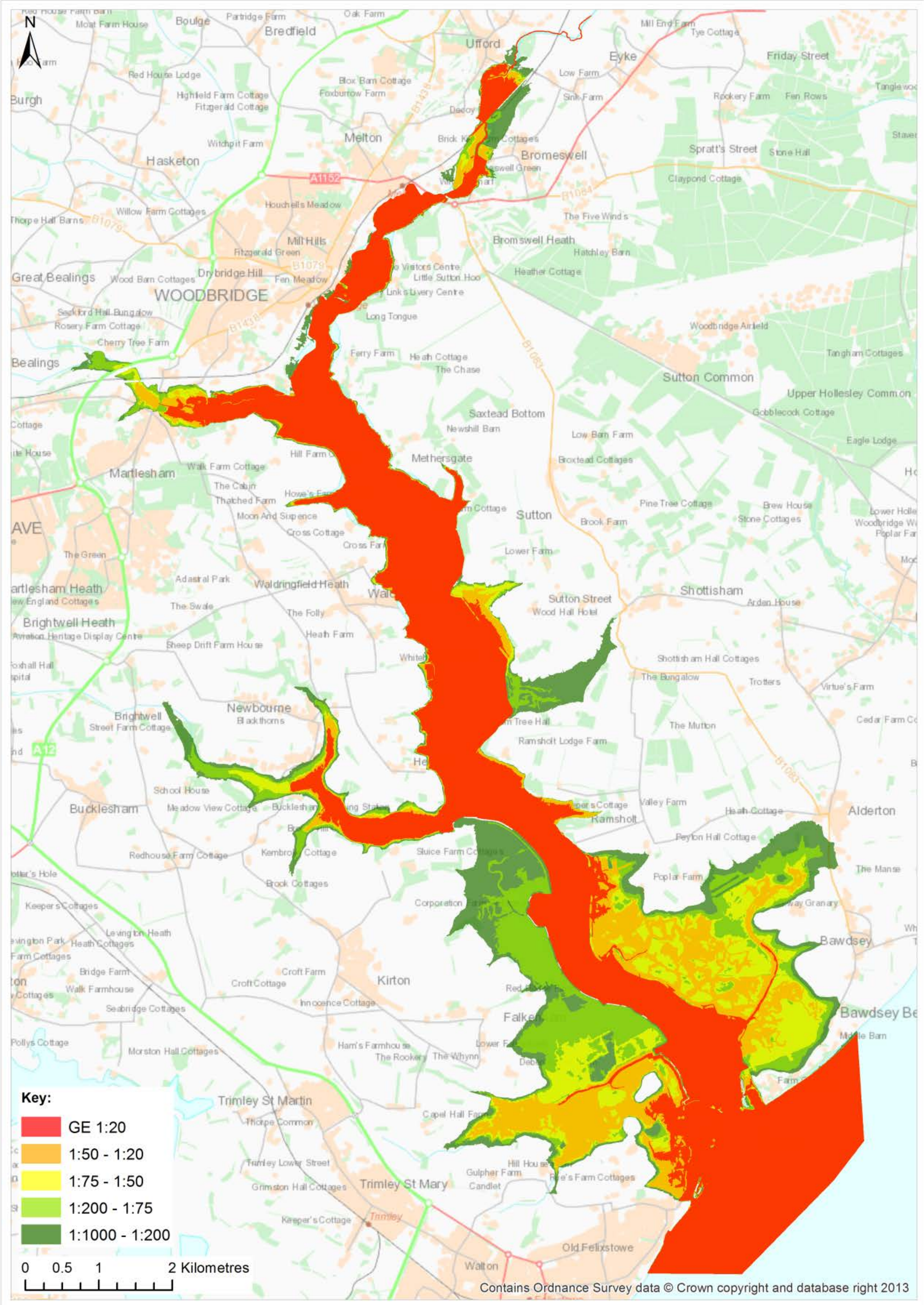


Figure 4.2 Probability of inundation visualisation – deterministic results

However, the other results shown at the impact cell level are of less use. Especially in rural locations EAD by impact cell is hard to interpret as the cells with damage are spread out and it is necessary to zoom in considerably to inspect them.

EAD is better and more easily understood at the flood area level, and this is also provided in MDSF2. The flood area is the appropriate level at which to consider damages as it is the performance of the defences protecting the whole flood area that affect the risk it experiences and the damages that may occur. This is why the flood area is the scale at which most decisions are made in an FRM strategy.

Numerous metrics are also supplied including property numbers by flood area separated into residential and non-residential. These help with understanding the composition of the damages in a certain area. Overall the symbolisation of results is useful to give a starting point to enable understanding of both risk and economic damages.

MDSF2 gives the user the ability to analyse the contribution of individual defence assets to the EAD. The ability to easily identify the worst-performing assets and investigate the reasons for this (low crest level or poor condition or poor data) gives the potential for alternative and potentially more cost-effective options to be developed for individual flood areas. This could also be used to highlight the assets for which it would be worthwhile to develop a more locally accurate representation of fragility and deterioration. Figure 4.3 shows an example of this type of visualisation for West Itchenor in the Emsworth to East Head pilot study.

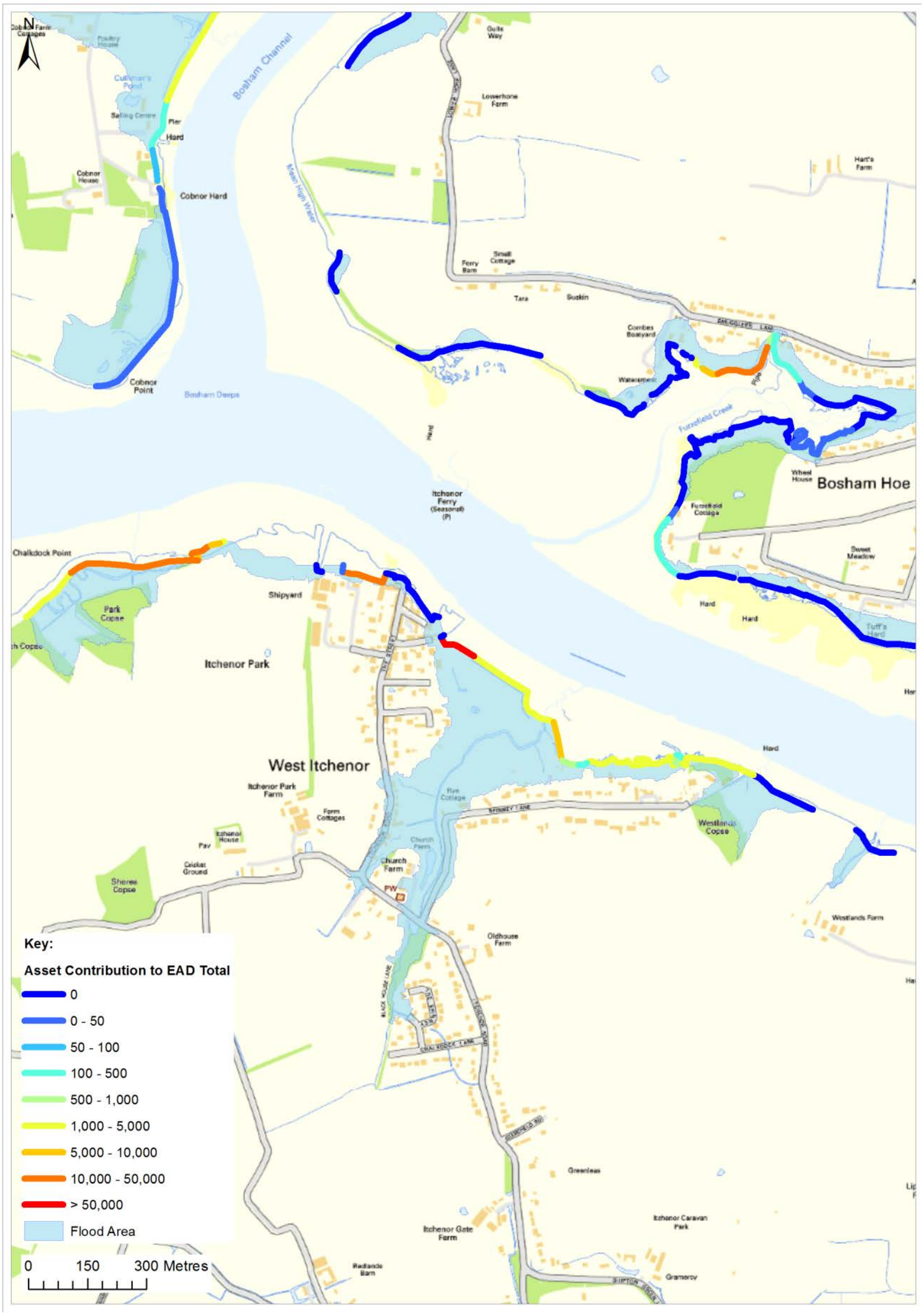


Figure 4.3 EAD by asset visualisation

4.5.2 Long section visualisation

The MDSF2 long section visualisation tool provides a useful means of exploring the validity of the defence and water level data. This has the ability to display long sections showing crest levels and extreme water levels (see Figure 4.4). This has use in understanding the variation in crest level across a flood area and could be used to help develop options for a strategy if the intention was to achieve a certain standard of protection. The greatest value will be gained when data is sourced from national datasets, for example a NaFRA hot-start model.

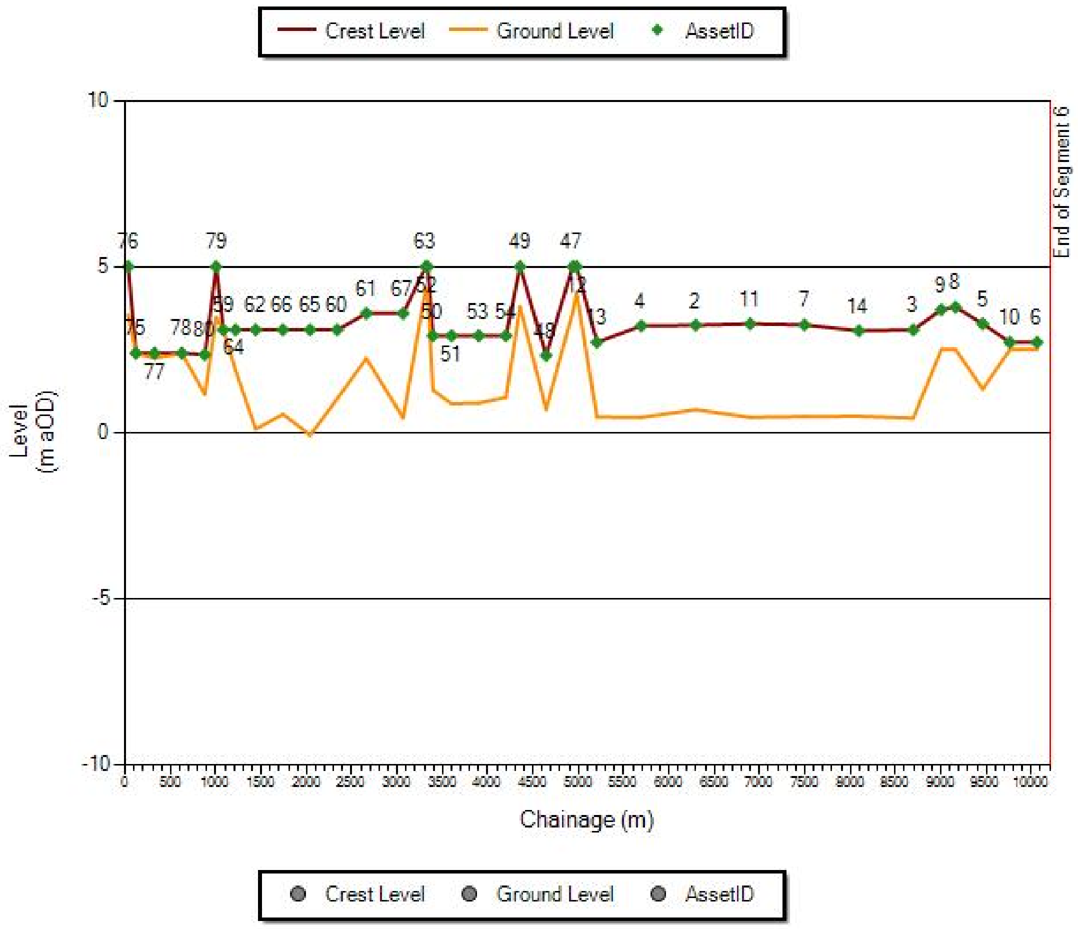


Figure 4.4 MDSF2 long section visualisation

4.5.3 RFSM visualisation

The RFSM visualisation provides value in two ways. Firstly, it can give results for variables that also come out of traditional deterministic modelling. This has been used successfully to build confidence in the results of MDSF2 with stakeholders and project teams. In addition, it provides a way to facilitate the shift in expectations from the traditional results people are used to, to the probabilistic results of MDSF2. This has been the case on the two projects which have implemented MDSF2 in live FRM strategies (Humber Estuary and Thames Estuary).

The second use is in understanding flow pathways within a flood area and showing how flood water propagates from failure of key poorly performing defences. This improves the understanding of the flood risk system and enables pragmatic decisions to be made about alternative strategies to manage the risks. The Humber Estuary team found that in one instance the flood risk and damages to an area was resulting from poor defences that were located a significant distance from the key receptors rather than those immediately adjacent to those receptors.

An example of the RFSM visualisation for Woodbridge in the Deben Estuary is shown in Figure 4.5 for a 1:200 year event at the present day.

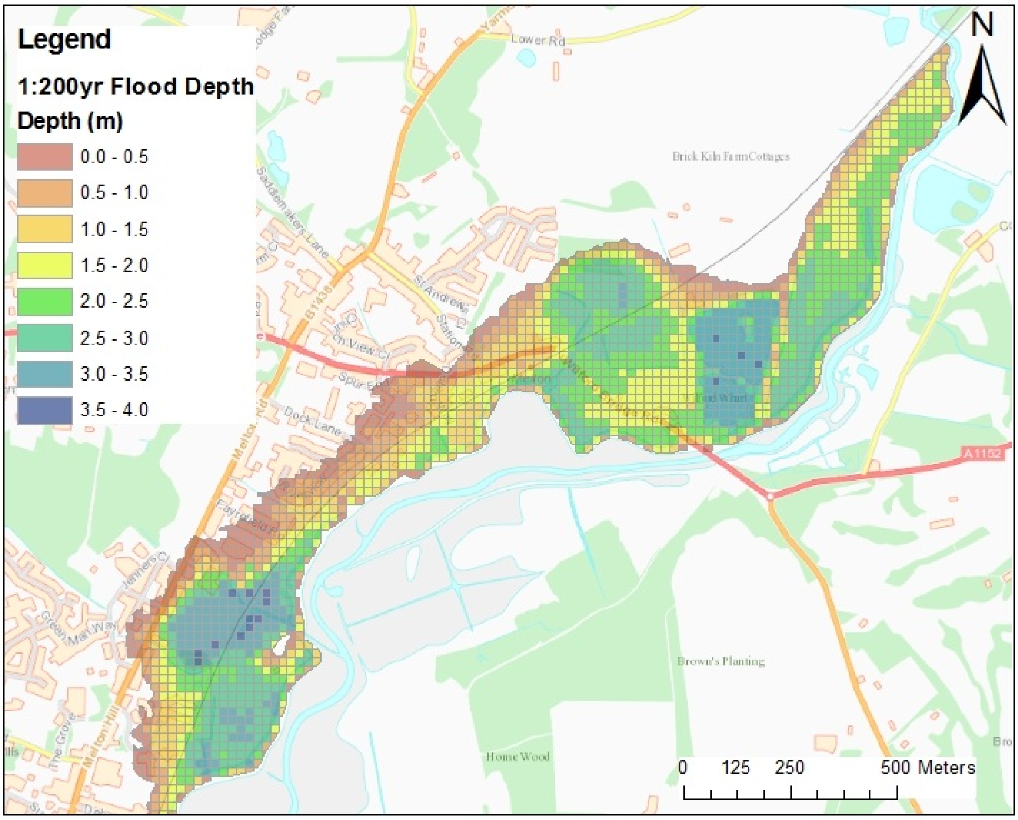


Figure 4.5 RFSM visualisation for Woodbridge

4.5.4 Validation layers

The validation layers that are generated by MDSF2 as the user completes the pre-processing steps provide a valuable visualisation of what the individual steps have done and are key in identifying data errors.

4.6 Usability of guidance and support

4.6.1 Written manuals

The User Manual for MDSF2 was written primarily to support the use of the software for production of the NaFRA products. Therefore it is not unexpected that there are deficiencies when trying to use this to undertake analysis appropriate for an FRM strategy.

One key aspect that requires further guidance is the consideration of futures and potential alternative strategies. Clear instructions on how to set up futures with the use of snapshots is required.

In addition the manual needs to be improved to assist those using non-standard datasets. Issues have primarily arisen where the format of input datasets required by MDSF2 is not clear and significant time has been spent modifying input data so that it is recognised by the software. It is recommended that the User Manual is updated to address these aspects.

Overall, the manual should be reviewed and restructured with a strategy user in mind. This should include worked examples to illustrate the application of MDSF2 in a strategy context.

4.6.2 Online support

The software support from HR Wallingford has been useful in providing help to users. Queries have arisen primarily with software installations, software error messages and data preparation.

This software support has been reinforced by support from the Oversight team in guiding the application of MDSF2 for strategy development. In particular, the Oversight support has been useful in translating the real world into the model domain and in providing guidance on how best to represent alternative strategies.

The advice provided has covered issues such as:

- growth factors, economic damage capping methods and present value calculations;
- how to implement defence deterioration through modification to condition grades and fragility curves;
- how to prepare property level depth–damage information;
- application of climate change and its impact on tidal water levels;
- representation of defence, modifications and managed realignment;
- importing wave overtopping rates.

The project team (Oversight and pilot teams) used Yammer as an online message board to raise queries and store solutions for all pilot teams to access as and when needed. This was a useful resource for pilot teams to consult before raising queries further; however, much of the technical query solving was still undertaken using emails.

Going forward it is likely that this more strategy focused support will be increasingly important as issues with the use of the software (hopefully) reduce, and people use MDSF2 to support FRM strategies for real.

5 Experience of pay to pilot

Pay to pilot is a process whereby the research programme provides funds to trial innovative approaches in real world situations. The aim is to reduce the risk for operational teams when trialling new projects and to encourage uptake of products from the research programme.

Although the operational teams within the Environment Agency for the consultant-led pilots have had limited involvement, this project has produced locally accurate MDSF2 models that they can use in the future. In addition the process has allowed them to gain some insight into MDSF2 and how it works.

In terms of encouraging uptake the project has raised the profile and potential benefits of MDSF2 within both the Environment Agency and the supplier community. The Environment Agency pilots have provided the pilot teams with the opportunity to enhance their understanding of MDSF2 and strategy development.

The pay-to-pilot structure of this R&D project has worked very well. Both the take-up and the practicality of the research rely upon close collaboration between the ‘true’ end users and the research teams.

Pay to pilot has provided a good environment for discovering the potential of a new approach where the project teams can be honest and critical about both the benefits and issues with MDSF2. Consultants would be very reluctant to pilot approaches such as MDSF2 on a real project where they were liable for the consequences of it not working and the potential issues around communicating the results.

In particular the Emsworth and Taw–Torridge pilots have added significant value to the pre-pilot understanding of the risks and offer a platform that could be taken forward by the local teams. In the other pilots the FRM strategies are already well established but nonetheless the piloting process has enabled an MDSF2 to be established that could now be taken forward. For example, in the Deben Estuary specific insights into the particular defences to modify could be used to shape a more efficient, highly targeted strategy with lower costs.

6 Conclusions

6.1 Overall conclusion

The pilot studies have shown that MDSF2 has potential for use in supporting FRM strategies. The main benefits of MDSF2 centre on the added value it can provide by improving the understanding of the drivers of flood risk and helping to explore the impact of alternative strategies more efficiently and consistently than in traditional approaches. The current version of MDSF2 already has this ability under particular circumstances: for particular types of strategies, if the right data is available and if used by competent users.

There are, however, certain 'must have' improvements that are required to unlock MDSF2's benefits for a wider range of strategy types and more practitioners, and to facilitate the initial effort needed to set up models. If these improvements are carried out, there is a good potential that MDSF2 can be rolled out as a tool of choice to enhance the development of strategic FRM planning.

The following sections elaborate on the specific aspects of this overall conclusion.

6.2 Can MDSF2 be applied sufficiently efficiently?

In response to the question 'Can MDSF2 be applied sufficiently efficiently to enable its use in the context of the timescales and resources that are typically available for a strategy?' the answer is **'Yes', with the following qualifications:**

- Typically, initial model set-up will take more time but subsequent exploration of alternative options will be more efficient with MDSF2. This was experienced by all pilot studies.
- In the current situation data is often not yet fully available in the required format, so significant time is needed for model set-up. The pilots experienced issues particularly with flood defence asset data from the Asset Information Management System (AIMS). However, with increased use and improved national data management this effort will reduce and MDSF2 could even become more efficient than traditional approaches.
- In the current situation MDSF2 can only be used efficiently by experienced users, or by less experienced users with intensive guidance and support. Capacity building (partly through use in practice) will increase the group of practitioners that can use MDSF2 efficiently.

It has not been possible to make a direct comparison of resource input and costs between the original strategy and the pilots because the required information was not available and the context was not comparable (e.g. the fact that the pilot teams had very limited MDSF2 experience). Instead, an estimate for the cost of undertaking a MDSF2 analysis for a tidal estuary strategy and the equivalent traditional analysis has been made for illustrative purposes (see Table 6.1). This comparison is based upon use of a fairly experienced team who are able to undertake both approaches with limited external support. Overall the cost of undertaking a MDSF2 and a traditional analysis are largely similar; however, the distribution of the costs between tasks does differ. With MDSF2 the modelling and economic analysis is all contained within MDSF2 and therefore part of the same tasks, while the traditional approach has distinct hydraulic modelling and economic appraisal tasks, undertaken by different staff. The MDSF2 approach is slightly cheaper but uses more staff days, while the traditional approach is the opposite; this is the result of slightly more experienced and therefore more expensive staff being required for the traditional approach. These estimates would be affected by the experience of the team in using MDSF2, the presence of a readily usable MDSF2 model and the complexity of the study area.

Table 6.1 Cost comparison

Task	Estimated cost (£)			Estimated time (days)		
	MDSF2	Hot-start MDSF2	Traditional	MDSF2	Hot-start MDSF2	Traditional
Inception	900	900	900	2	2	2
Modelling (incl. MDSF2)						
MDSF2 model development	4,200	2,100		10	5	
Option development	2,200	2,200	1,800	4	4	3
Interpret results and write up	2,900	2,900		6	6	
MDSF2 modelling	2,600	2,600		5	5	
Hydraulic modelling			6,600			12
Economic appraisal						
Undertake analysis			1,400			3.5
Interpret results and write up			2,400			4.5
Project management	900	650	900	2	1.5	2
Total	13,700	11,350	14,000	29	23.5	27

For the experienced user MDSF2 adds little to no additional effort beyond that required to develop a well-structured traditional analysis (asset information, properties, supporting modelling etc). Exploring future modifications, for the experienced user, is straightforward and more efficient than traditional approaches in many instances. Complex FRM strategies that rely upon realignment of defences, or use of secondary defences (such as the Lower Aire pilot) or topographic change, require additional pre-modelling – but no more than would be the case using a traditional approach.

This does not mean applying MDSF2 is as efficient as it could be. MDSF2 requires information in a specific format with particular field names, and demands a specific stepwise process of data preparation. This process is not well documented (with limited guidance on the physical meaning of many of the fields or indication of how they will be used in the analysis). All four of the pilots suffered from this problem, and spent time deciphering whether fields were truly required for calculations or only for information purposes. This slows the process of establishing a credible model and can lead to poor targeting of effort as a result of missing of steps perceived as unimportant (which must later be returned to) or conversely spending effort on refining aspects that may be less important.

For the uninitiated user MDSF2 can take some time to get used to and to get the best out of. As experience is gained, the usefulness and efficiencies of applying MDSF2 will increase. This was demonstrated by the Deben and Emsworth to East Head pilots which were carried out by the same organisation with partly overlapping teams: lessons learned in the Deben pilot could be translated directly into strong guidance for the Emsworth to East Head team, leading to much more efficient working. The ideal user is someone who is actively involved in the strategic decision making process, has an understanding of the physical process, engineering and economic analysis elements of FRM options and is competent in the use of GIS. A tall order, but this reflects the 'systems' view that MDSF2 presents and we as flood risk managers must address. In reality these skills are often spread around a team and the MDSF2 user will need to work closely with others to get the full benefit from its use.

Making modifications to reflect future change is more complex and ad hoc than it needs to be. MDSF2 currently makes no use of the standardised deterioration curves (e.g. enabling future condition grades to be automatically determined), receptor changes are slow to incorporate and climate change is more complex than necessary.

Significant improvements to efficiency could be gained through:

- **Establishing a 'collect once use many times' approach to data.** This is starting to happen but still the accuracy of the local information in the majority of the pilots was not reflected in the national datasets provided to establish the MDSF2 models. This wastes significant time and leads to continual reinvention of datasets.
- **Providing additional guidance or some limited tools** (either within or external to MDSF2). To support users in modifying the databases to reflect future change would significantly improve efficiency (as developed, for example, to support Long Term Investment Strategy (LTIS), the National Flood Risk Assessment (NaFRA) Future toolset).
- **Providing support and training on the application of MDSF2 to FRM strategies.** The efficiency of the application of MDSF2 relies upon the experience of the user. Bespoke support and training on how to use MDSF2 in support of strategy development is required.
- **Providing better guidance on installation.** A better standard installation guide appropriate for wider readership and use needs to be developed. This would cover, for example, alternative platforms and environments, software requirements, hardware specifications, testing advice, troubleshooting advice, statistics on model size and runtimes.

Efficiency will increase if the concepts and approaches used in MDSF2 become commonplace. These include deterioration curves, fragility curves, RASP (Risk Assessment for Strategic Planning) defences analysis and probabilistic flood risk analysis. Increases in efficiency also require the methods to remain reasonably constant as users gain this familiarity. As all parties involved in the process (MDSF2 user, project manager and decision maker) become more familiar with these approaches, the process will become more efficient in numerous areas.

6.3 Are the results from MDSF2 sufficiently accurate?

In response to the question 'Are the results from MDSF2 sufficiently accurate to determine support strategic choices?' the answer is **'Yes, but with the following qualifications:**

- The user has to choose the appropriate model resolution.
- Where needed, the user has to make use of MDSF2's functionality to draw on local information instead of the default national-scale information.
- The current version of MDSF2 needs workarounds to overcome known limitations in the damage calculations – this will need to be improved within MDSF2 (which is partly starting to happen).

The accuracy required to enable robust strategic choices to be made is often debated. The rule of thumb is that if the decision would not change given more accurate information, then the accuracy of the evidence is sufficient. It has not been the intent of this study to explore the 'absolute' accuracy of MDSF2 but rather to explore its fitness for the specific purpose of strategy development.

In general the pilots found the assessment of receptors well captured where the damage is well defined by a depth–damage relationship such as properties (provided the resolution of the impact cell was sufficient; this was the case for all pilots apart from the Lower Aire). Damage terms that require a more complex understanding of the resulting damage (e.g. agricultural, critical infrastructure) are less well reflected. In the Deben and Humber estuaries agricultural damage was a significant component of the decision making – an issue that is likely to be reflected elsewhere. However, the calculated damages were far lower than expected using the standard MDSF2 approach.

The level of accuracy of the Rapid Flood Spreading Model (RFSM), breach or other embedded flow calculations were considered sufficient and did not need to be improved in the context of strategic-level decisions on this study. It would however be useful if MDSF2 could report a prioritised list of system state scenarios (and their associated probabilities) that could be modelled externally (using a fully hydrodynamic model) if additional confidence was required.

The modelling of defence asset performance is based on nationally generic fragility curves, but it is possible in MDSF2 for users to define these for each asset. This could add value where strategic decisions are sensitive to high risk assets. However, there is a need for clear guidance that will enable users to translate their local knowledge into the defined but often unfamiliar format of the fragility curves. A similar approach should be followed for the deterioration curves: using the available generic curves as a default but providing clear guidance to enable users to incorporate their local knowledge.

6.4 Does MDSF2 add value?

In response to the question 'Does MDSF2 add value to support strategic decision making?' the answer is **'Yes'**, in particular through its risk attribution functionality and its structured scenario management facility.

Strategy development costs money and takes time. To become accepted as an approach of choice, any additional cost and time needed for use of MDSF2 must be acceptable against the background of any added value that MDSF2 provides.

The structured consideration of the flood system that MDSF2 supports (based on the source–pathway–receptor framework) supports clear and transparent thinking. The presentation of the flood probability, risks and attribution of risk to assets offer the decision maker useful insights into the type of FRM strategies that should be explored and hence lead to better, more efficient (better targeted) FRM strategies. The Deben Estuary and Emsworth to East Head pilots, and feedback from the Humber Estuary Strategy, all show how this structure can be used to develop targeted interventions through easily identifying the weakest flood defence assets. In addition to providing information of flood risks within the floodplain, MDSF2 can help users to visualise the supporting data (river long sections, crest levels etc.).

Significant value is added to underlying datasets in the process of strategy development. MDSF2, if well managed, could play an important role in capturing this value for future use (as the strategy is updated, but also for NaFRA and, possibly, for other functions such as local asset management).

6.5 Fit for purpose – yes or no?

MDSF2 could be used to support specific types of FRM strategies now as long as the current limitations are clearly understood and workarounds are applied. There are several benefits to using MDSF2 instead of traditional approaches, in particular its ability to structure the representation of the whole system and highlight critical defences. This better understanding in turn enables more intelligent targeting of actions. This does not mean, however, that improvements are not needed, they are.

The locations of the pilot sites were chosen by the Environment Agency and are mainly tidal estuaries with the exception of the Lower Aire (a fluvial system). This study has not included an open coast pilot study where erosion is a significant issue, nor a complex fluvial urban setting for example. Although further piloting would be useful, the general conclusions and recommendations are likely to remain valid.

These pilot studies have shown that MDSF2 is good and has the potential for providing significant benefits to strategic decision making in FRM. However, it is not ready yet to be released widely and could not be used as it stands in some situations.

The situations where MDSF2 is currently best suited are outlined in Table 6.2. This is subject to the caveats that are also noted in this table.

Table 6.2 Applicability as a function of risk and receptor type

Dominant receptor type	**Type of system/risk**			
	Fluvial flood risk	Estuarine flood risk	Coastal flood risk	Coastal erosion
Properties	**X**	✓	✓	**O**
Agriculture	**X**	✓	✓	**O**
Other (utilities and transport infrastructure)	**X**	**X**	**X**	**X**

Key: ✓ – MDSF2 would be preferable
O – MDSF2 is acceptable but not preferable without significant improvements
X – MDSF2 is not appropriate without significant improvements

Important caveats:

- **This assessment is subject to short-term recommendations being implemented.**
- **Ease of use significantly depends on:**
    - **experience of staff involved;**
    - **presence of an existing MDSF2 model;**
    - **complexity of the study area.**

6.6 Communicating flood risk and its management – will MDSF2 ease or make worse?

- **Managing the assumptions of both internal and external partners.** Throughout the project there have been difficulties in getting agreement from area teams and the technical support group on the most appropriate modelling techniques to use. A lack of understanding regarding the techniques used by MDSF2 has on several instances led to inaccurate assumptions regarding the validity of MDSF2 outputs. The current use of MDSF2 for NaFRA for instance does prejudice views on the validity of the outputs, as it can be seen as a tool for national-scale analyses. In addition the move from deterministic to probabilistic outputs presents a clear communication challenge. Additional time and effort will be required to ensure all the techniques are fully explained and understood.

- **Difficulties in aligning the FRM strategy update projects with NaFRA**. While running MDSF2 as part of both FRM strategy update projects and NaFRA would realise efficiencies for the Environment Agency, some of the techniques and processes which ensure that the outputs are NaFRA compliant are not necessarily the best approach to use for FRM strategies. This could lead to the situation where the Environment Agency has two published datasets, from the same source, but with different outputs. Communicating these differences will become increasingly difficult. Appropriate management processes will be needed to ensure common results are communicated.

- **Moving to a probability of inundation** result will require appropriate communication to support practitioners, clients, stakeholders and eventually the general public to fully understand (and not mis-understand) the results. Communicating flood risk is always an issue, and if the industry moves to probabilistic outputs the challenge may increase.

6.7 Modelling and managing data – will MDSF2 ease or make worse?

MDSF2 adds few (if any) significant data challenges. It does, however, force the user to confront data deficiencies in source, pathway and receptor terms that are more easily ignored in traditional approaches. For example, the Humber Planning and Strategic Overview team identified added difficulty due to the area of study covering three Environment Agency regions, and four area teams, noting that 'significant time' had to be invested to identify the most up-to-date and accurate datasets to use in the study. They suggested this resulted in it not being possible to adopt a consistent approach across the estuary, and this may lead to inconsistencies in the outputs of the study. In particular problems have been identified in establishing defence crest heights and a water level profile. None of these issues, of course, are specific to MDSF2.

The modelling challenge of implementing MDSF2 at an appropriate resolution (assuming suitable impact cell sizes are used) is not lesser or greater than for a traditional approach. Too often there is an overemphasis on obtaining highly spatially accurate flood flow modelling, usually forgetting that much of the input data contains significant uncertainty and the central issue of being good enough to make a 'strategic choice'. Gross uncertainties typically exist in traditional modelling that do not exist (or are lessened) in MDSF2 – assumptions regarding the performance of defences (assuming undefended or perfect defence performance), estimating expected annual damages (EADs) based on very limited sets of events etc. MDSF2 does of course introduce some gross uncertainties not present in a traditional analysis, primarily associated with the representation of the dynamic flows (e.g. channel–floodplain, velocity and duration of flooding). For the purposes of FRM strategies, it is likely that the assumptions made within MDSF2 are less important than those typically made in traditionally modelling.

7 Next steps and recommendations

7.1 Overview

While MDSF2 has significant potential to improve the way in which FRM strategies are carried out, there are improvements that need to be made to enable this to happen. The number of improvements that are necessary to enable MDSF2 to be used depends upon the flood risk context in which it is being applied and the experience of the users. Therefore, a timeline of improvement phases has been developed that sets out which improvements are necessary to enable increasing levels of use. The phases of improvement are summarised in Figure 7.1 and the recommendations that it is necessary to implement in each phase are discussed in detail in the following sections.

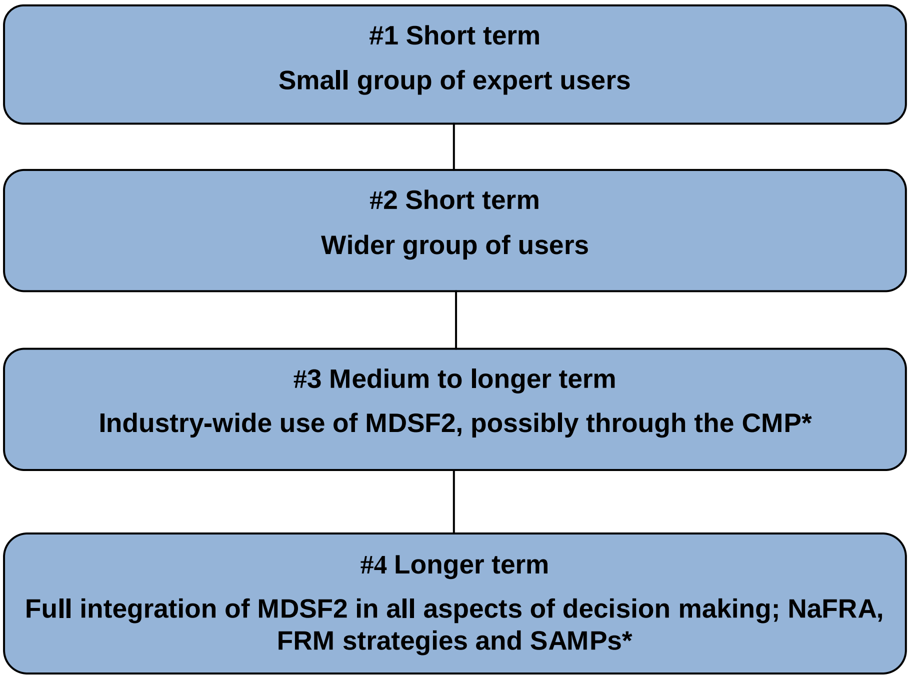


Figure 7.1 Improvement phases for MDSF2 in FRM strategies implementation

*CMP = Central Modelling Platform, SAMPs = System Asset Management Plans

In addition to the technical improvements that MDSF2 will require over the phases of development outlined above, it is necessary to consider the commercial reality of how MDSF2 may be used. One aspect of this is who owns the risk of MDSF2 not working. MDSF2 is an Environment Agency owned software, but does this mean it is liable if the software does not work and this leads to delays on a project? This will need to be clearly defined in any contract where MDSF2 is used. Furthermore, if MDSF2 is to be used through the CMP, then the reliability of this platform and its performance will be a concern to consultants. As this is an Environment Agency system any delays and subsequent costs would be the responsibility of the Environment Agency. Finally, to encourage the use of MDSF2, tender documents must be developed so that consultants are provided with incentives where appropriate.

7.2 Short term

In the short term a small expert group of selected users, appropriately supported by the Oversight team and HR Wallingford would use MDSF2 as standalone software. They would be able to use it for any type of strategy, but would use workarounds for other situations than tidal/coastal strategies where risk is dominated by property and agricultural damages. To enable this to occur would require limited improvements in three areas: installation support, basic risk calculation and presentation of results, as outlined in the subsections below. (Note: We understand a number of bug fixes are already being implemented in the next version of MDSF2 to address issues such as importing external model flood depths. The following suggestions assume these have been done.)

7.2.1 Advice required for installing and running MDSF2 on other platforms (not CMP)

The pilot studies have experienced issues installing MDSF2 as standalone software. A standard installation guide for MDSF2 that clearly explains this process is necessary such that time is not wasted. This should include clear explanation of the supporting software requirements and how the software should be installed.

7.2.2 Support a better/easier representation of strategic risks

While MDSF2 goes some way towards representing strategic risk through the calculation of flood risk damages there are areas that require improvement. There needs to be an embedded approach for present value damage capping. This could easily draw upon the property valuation field and the user could supply valuations per hectare for agricultural land to enable MDSF2 to do this on an impact cell basis.

This is estimated to cost around £5,000 to £10,000 and would be required immediately to enable use of MDSF2 for FRM strategies.

7.2.3 Revised approach to calculation of agricultural damages

There are deficiencies in the depth–damage relationship used for agricultural land and this should be improved. The current traditional methods are based on the probability of inundation and the associated impact on productivity. It should be possible to incorporate a calculation methodology in MDSF2 that follows this philosophy. Finally, MDSF2 must be updated to include the most recent depth–damage datasets for properties from the Multi-Coloured Manual, the latest version of which has just been released.

This is estimated to cost around £15,000 to £30,000 and would be required immediately to enable use of MDSF2 for FRM strategies.

7.2.4 Present value damages at the flood area level

Currently MDSF2 only gives the present value damage results for the whole study area and if the user wishes to know this at the flood area level the data has to be extracted from the Oracle database. An automated process to present this part of the results as standard is required, and is estimated to cost £10,000.

7.3 Medium term

In the medium term the intention would be to extend the use of the standalone MDSF2 (including support) and encourage its application by a wider group of Water and Environment Management framework consultants for any type of strategy, supported by external hydraulic models as appropriate. To enable this to occur the following recommendations would need to be implemented.

7.3.1 Provide better, more relevant support

It is apparent that software support alone is not enough for the use of MDSF2. Support provided in this project by the Oversight team (who are familiar with the demands of a strategy and the methods in MDSF2) was vital to the efficient use of the software. Without this guidance, effort would have been wasted and misdirected. This second stream for support should be maintained going forward.

This would involve the development of a dedicated MDSF2 User Manual for strategies (including worked examples) and establishment of a strategy support team. The support should cover broader strategy advice, data preparation and software use. Additionally, training videos could be developed to further enhance this guidance. It is estimated that it would cost around £25,000 to develop guidance with a call-off contract of ongoing support.

7.3.2 Support basic appraisal functions

The results that MDSF2 currently provides give a certain amount of understanding, but post-processing is required to enable appraisal decisions to be made. Additional functionality should be added so that MDSF2 better supports strategic appraisal of FRM options. This should include:

- Present the information required to enable the partnership funding calculator to be completed including properties at risk in the relevant flood risk categories and deprivation bands.
- Give present value benefits in comparison to the 'do nothing' option for the whole area and at the flood area scale.
- Export the most likely defence system states for each storm loading condition to facilitate 'credibility checks' and prioritise external model runs if needed.
- Enable benefit streams to be exported to support benefit–cost ratios/net present value outside MDSF2. (In the medium term as confidence builds in the use of MDSF2 this process could be reversed and costs imported.)

It is estimated that this would cost around £20,000.

7.3.3 Support easier modifications to sources, pathways and receptor databases

At present MDSF2 requires the user to manually adjust the attributes of the model to produce the sources, pathways and receptor tables for each of the snapshots considered. This could be assisted through tools that facilitate typical changes a user would like to make such as:

- Representing defence deterioration through changes to its condition grade, this could be linked to standard deterioration curves for each defence type.
- Providing clear guidance to enable the user to incorporate local knowledge, helping to translate this to the unfamiliar format of fragility and deterioration curves.
- Representing the impact of climate change on tidal and coastal water levels. This would not be appropriate for fluvial levels as, while tidal levels are modified through sea-level rise, climate change is anticipated to impact on peak fluvial flows instead of levels, so local modelling is required.
- Modification to damage-depth relationships, for instance to represent property level protection measures being installed.

It is estimated that this would cost around £10,000 to £15,000.

7.3.4 Improve transparency

Despite recent advances in 'opening up' the results, there continues to be a danger that MDSF2 is seen as a black-box system, with little understanding of how the results are actually generated. Transparency in the methodology and source of results is required so that results are trusted and so that this does not cause practitioners to question the validity of MDSF2 as a whole. This could be achieved through providing outputs from intermediate steps in the calculation process and providing clear documentation explaining the approach MDSF2 takes to generate the results. It is estimated that this would cost around £20,000 to £30,000, focused on strategy related visualisations.

7.4 Medium to longer term

In this step, MDSF2 will be the modelling framework of choice accessed through the CMP and supported by external models as appropriate. Support continues to be provided, largely through self-sustaining industry groups.

7.4.1 Use MDSF2 to embed strategies as a legitimate part of the 'collect once use many times' cycle

MDSF2 uses several datasets such as the National Receptors Dataset (NRD) that are easily characterised in a way that satisfies national use and local use. MDSF2 can help in ensuring the principle of 'collate once use many times' is met (by returning data to national databases in a standard format – which could be an easily automated procedure). This is a key gain and would help ensure that future projects do not re-assess basic datasets such as defences and receptors etc, and effort is devoted to adding vale and not reinvention. A process to fully capture the added value data from an MDSF2 strategy application and ensure its return to the national datasets should be developed. This will be an ongoing process to ensure data improvements in FRM strategies are preserved and available for future use. This process could be extended to also cover application of MDSF2 at a national scale and for asset management. This process could also help the Environment Agency to implement Building Information Modelling (BIM)Level 2 compliance, which is required by 2016. This is an ongoing process and therefore a cost estimate is not appropriate.

7.4.2 Improve the efficiency of data preparation

Challenges with data preparation are not a new issue, and not limited to the use of MDSF2. The key dataset which the pilot studies struggled with was flood defence asset information. The quality of this data has been a long-standing problem for the Environment Agency and it is used throughout the organisation. Knowing what assets exist, where they are, their attributes such as height and generic type and finally what condition they are in is crucial for any assessment of flood risk. Therefore the challenge for any approach is to ensure that the national dataset for flood defence assets (Asset Information Management System, AIMS) is as good as it possibly can be with as much local knowledge and information as possible. This does not necessarily require a one-off effort: a more efficient and risk-based approach would be to ensure there is a culture, supported by processes, of entering new information in AIMS as it becomes available, from local asset management and from scheme and strategy development. This should be managed such that the data is compatible with the many uses it has for the Environment Agency including FRM planning through strategies. This will be an ongoing process to ensure highest quality data can be used and because it is an ongoing process a cost estimate is not appropriate.

7.4.3 Access to Oracle

At present Environment Agency users cannot access data in the Oracle database for MDSF2 applications using the CMP. As this stage envisages that MDSF2 will be used via the CMP, this will need to be solved. Access could be provided via an SQL server, or the MDSF2 graphical user interface (GUI) could be improved to enable more data to be extracted from Oracle.

7.5 Longer term

In the longer term full data integration from the National Flood Risk Assessment (NaFRA) to strategies to SAMPs can be envisaged. This could be facilitated through the common use of the MDSF2 framework. This will not require any specific further actions; however, it will be a process of continuing to ensure that MDSF2 uses the most up-to-date damages data, and that the processes of improving transparency and reuse of data continue.

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List of abbreviations

AIMS	Asset Information Management System
AONB	Area of Outstanding Natural Beauty
CMP	Central Modelling Platform
DEP	Deben Estuary Plan
EAD	expected annual damages
FDGiA	Flood Defence Grant in Aid
FRM	flood risk management
GIS	geographic information system
GUI	graphical user interface
MDSF2	Modelling Decision Support Framework 2
MOD	Ministry of Defence
NaFRA	National Flood Risk Assessment
NERC	Natural Environment Research Council
NRD	National Receptors Dataset
PVD	present value damage
RASP	Risk Assessment [of Flood and Coastal Defence] for Strategic Planning
RFSM	Rapid Flood Spreading Model
SAMP	System Asset Management Plan
VBA	Visual Basic for Applications

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