Defra

RESEARCH CONTRACT
RESERVOIR SAFETY ADVICE

SUPPLEMENT TO REPORT BY SIR DAVID COX ON

REVIEW OF METHODOLOGY FOR EXTRAPOLATION OF EXTREME RAINFALL IN FEH

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Document History Record

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1. General

This note is a supplement to the Cox report, partly to provide an indication of the scope and magnitude of work that is indicated by the recommendations and to comment on how these recommendations could most usefully be implemented.

2. Magnitude and scope of further research

The magnitude and scope of work indicated by the recommendations was developed in a workshop with Sir David Cox, Howard Wheater and KBR staff (Alan Brown, Marcus Francis) on 3rd April 2003; this summary is given in the form of the attached Table 2, using the key in Table 1. The recommendations from the Babtie report are also included for completeness.

The Cox report recommends significant further research is required to fully resolve hydrological issues relating to estimation of extreme floods. The workshop identified this could be carried out as six small contracts (1 to 6 man-months), plus three larger contracts

Major contracts: Package of recommendations		Indicative Man months
2.1b	Rainfall-runoff models for major storm events	18
4.2b	Re-evaluate PMP	24
3.1, 3.3, 4.2c, 5.1	Data collection of extreme rainfall events, Combined approach to extreme storms using extrapolation of observed events and storm maximisation (PMP) techniques. Detailed update of FEH and determination of correction factors, for rainfall in excess of 2000 years	42

The overall cost is likely to be of the order of £1.0M, based on a notional average cost per man-month of £10k. It should be stressed that the estimates of man months and cost are only indicative.

Before any of these are taken further detailed technical specifications should be developed to ensure that any further research work has clearly defined objectives and deliverables, preferably in the form of milestones where subsequent work depends on the successful completion of the previous milestone. All contracts should also have a steering group, appointed at the same time as the research contractor is appointed and whose first task would be to review the research contractor's Inception Report.

Table 1: Key to Table 2

Issue	Key to be used in scoring issue	Remarks
Who should lead the work?	CEH Univ – Academia Eng – Engineering Consultant MO – Meteorological Office	Entry should be one or more of these i.e. all who, in principle should be invited to bid
Can it be readily resolved?	Scale of 5 to 1, 5 : Provide workable outcome[1] in one contract, with no recommendations for further research 4: Intermediate between 5 and 3 3 : Provide interim guidance for workable outcome[1] subject to further research 2: Intermediate between 3 and 1 1: No workable outcome, only recommendations for further research	
Man months	Approximate number to implement recommendation	
Priority	Scale of 5 (high) to 1 (low)	
Phasing	Can it be done on its own, or should it be part of the same package as other recommendations? : List other recommendations with which it should be carried out as one research project, as the issues interrelate.	

1. Workable outcome is resolution of discrepancy between FEH and FSR and/or other change in UK dam safety regime that could be issued in an Engineering Guide, that would allow application by the dam industry in defining dam safety works (and thus allow approval by Ofwat of consequential capital funding)

Table 2: Recommendations by Babtie and Cox Reports for further work in relation to flood estimation

Recommendation Number		Text	Remarks		Can it be readily resolved?	Indicative Man-months	Improving the accuracy of extreme flood estimation: Phasing?	Improving the accuracy of extreme flood estimation: Priority
Babtie Report - Sept 2000			**Remarks by Defra in 2000**	**Current Status**				
1		Revision of the DDF parameters c and E	Will confirm with CEH the scope and timetable for this investigation	Outstanding				
2		Validation of the FEH design rainfall estimates	Will confirm with CEH the scope and timetable for this investigation	Outstanding				
3		Research into the extrapolation methodology	Will confirm with CEH the scope and timetable for this investigation	Review by Cox				
4		More UK rainfall records to be brought into digital form	Notes this recommendation, which is relevant not only to flood estimation studies but also to much wider hydrological interests. It has drawn it to the attention of the relevant other Government departments, with a view to agreeing what needs to be done and how that might be funded	Outstanding				
5		Issues surrounding PMP (inconsistency between PMP and 10,000-year rainfall)	…..gradually move away from the current combined approach (of T year and PMF) in favour of an exclusively T year approach, but with flood safety itself becoming absorbed into the more integrated approach to all aspects of reservoir safety called for in the following recommendation".	Section 6.2.4 of KBR Report on Integrated system				
6		Overall risk assessment strategy	Will invite tenders for the conduct of this work as soon as a specification has been drawn up	Completed by KBR				
Cox Report - April 2003			**Remarks by Workshop on 3rd April as to scope**	**Any similar ongoing research?**				
		General						
2.1	a	The relative contribution of various kinds of uncertainty in rainfall-runoff models (both loss model and routing) to the FEH estimates should be assessed in some typical cases.	Sensitivity study of elements of rainfall- runoff model (scoping study to see if important issues, and if so scope what needs to be done to resolve)	a) CEH research project to re-calibrate the FSR rainfall-runoff model for use with FEH rainfall inputs, but only for events up to 200 year return; b) work in Australia differentiates annual probability of PMP from that of PMF, to account for varying conservatism in rainfall-runoff model.	1	1	On own	5
	b		Detailed study of variability of elements and parameters in rainfall runoff models in major storm events		4	18	Follow a	3
2.2	a	The potential impact of climate change on estimates should be considered, in the first place by simple sensitivity analyses imposing various trends in mean and dispersion of daily rainfall and examining the effect on current estimates both by PMP and FEH methods. This might lead on to assessment in the light of models of climate change.	Sensitivity study (PMP may be more sensitive to climate change than Index rainfall)		1	3	On own	3
	b		Review results of study on "Climate change impacts on safety of UK reservoirs" by Babtie (2002) which was based upon UKCIPS98. Sensitivity study to update in view of UKCIP02, taking into account the improved resolution of the Regional Climate models reducing grid mesh sizes from 300km to 50km.	Would be an extension/update of work by the Babtie group (2002)	1	3	On own	2
		Available information						
3.1		Further analysis of major rainfall events should be made, in particular to examine the spatial pattern of rain at times at or near to those events and the storm type and also to examine possible biases arising from the mode of selection of the storms analysed.	Collection of data on all major events (> 100 year) for input into 5. Based on rainfall gauges, but supplemented by radar. Analyse spatial dependence for effects of elevation, obstruction etc that are not accounted for properly by FEH georegression on index rainfall.	Extending the work of Collier et al (2002)	1	15	With 5.1	3
3.2	a	The recording and use of information about minor spills should be considered.	future events can be collected as part of new incident database;					
	b		Historic events: questionnaire to dam owners, followed by detailed follow up to obtain best estimate of hydrograph and return period	Build on report by Bayliss and Reed (2001) for Met Office (www.nwl.ac.uk/feh/historical_floods_report.pdf)	1	6	On own	4
3.3		In a few typical cases the uncertainties involved in estimating small probabilities (large return periods) should be assessed, with particular reference to the relative importance of largely random errors of estimation and systematic errors. One role of such uncertainty measures is discussed in the Appendix	Student project as part of 5? Need access to FEH dataset. This would involve the close examination of the FEH rainfall model, the derivation of the parameters and the assessment of error at each step in the process.		1	3	With 5.1	4
		Role of PMP						
4.1		Further analysis of the relation between FEH and PMP should be made paying attention to the selection of sites for analysis, to explaining the apparent systematic difference between FEH and PMP and to the dependence of the ratio on explanatory features such as elevation. Extreme discrepancies should be examined.	Extend Babtie report to see if can any relationship between difference FEH/PMP and elevation or other variables can be identified. Examine distribution for bias and consider need to increase sample size.		2	3	On own	4
4.2	a	The appropriateness and feasibility should be examined of a combined approach involving both PMP and FEH procedures. Some comments in more detail are in the appendix	Estimate uncertainty in existing estimates of PMP, plus assign return period to PMP	Builds on preliminary estimates by Collier (Section 7 of 1995 Report for DOE; Radar based estimation of PMP; Met Office); which estimated PMP as about 2×10^5 years	3	6	On own	5
	b		Re-evaluate magnitude and return period of extreme rainfall using storm maximisation techniques and/or more up to date techniques for the general case (Provisional, depending on 'a')		5	24	After 'a'	3
	c		Examine appropriateness and feasibility of combined approach involving both PMP and FEH		3		With 5.1	
		FEH method						
5.1	a	The contributions from the various steps in the FEH procedure to the uncertainty in the final answer should be assessed in a few typical cases.	Steering Group must include statistical steer. These recommendations under section 5 concern general methods in contrast to 3.1 and 3.3 which are focussed on analysis of historical storm events.		5	24	With 3.1, 3.3 and 4.2c	4
	b	The possible effects of features such as elevation, etc. beyond those absorbed in the index level should be analysed.						
	c	The nature of spatial dependence at high rainfall levels and its effect on the plotting positions used in FORGEX should be reviewed.						
	d	The precise mode of extrapolation to high levels should be re-examined.						
5.2		Rain gauges closest to a sample of Category A and B reservoirs and with more than, say, 25 years of data should be examined to compare the FEH predictions of maxima with those actually encountered.						
				Total man months - Cox report		106		

3. Implementation: Comment by KBR

The issue of prioritisation is a difficult issue. The tests as to whether Defra should fund some or all of the research are

- will it resolve the current confusion between FEH and FSR (and Probable Maximum Precipitation (PMP), Probable Maximum Flood (PMF))?
- to what extent is the output necessary for dam safety management?

KBR's views in relation to extreme rainfall is that concentrating on the extrapolation of observed rainfall (even when using pooling techniques) is of limited value unless it is considered in conjunction with

a) assigning return periods and evaluating the uncertainties in storm maximisation and other techniques to estimate the magnitude and return period of extreme rainfall
b) consideration of probabilities of particular runoff conditions in conjunction with a given rainfall, in order to assess the magnitude and return period of floods.

This is a logical development of the PMP/PMF concept into a risk based approach to dam safety

The relative importance of floods compared to other threats such as internal erosion is a difficult area. KBR have recently completed a research project to see if a system could be devised to compare these, on a dam specific basis. A trial of the prototype system on ten dams showed that for Category A and B dams the threat from internal threats was typically ten times higher than from floods, as shown on Figure 1.

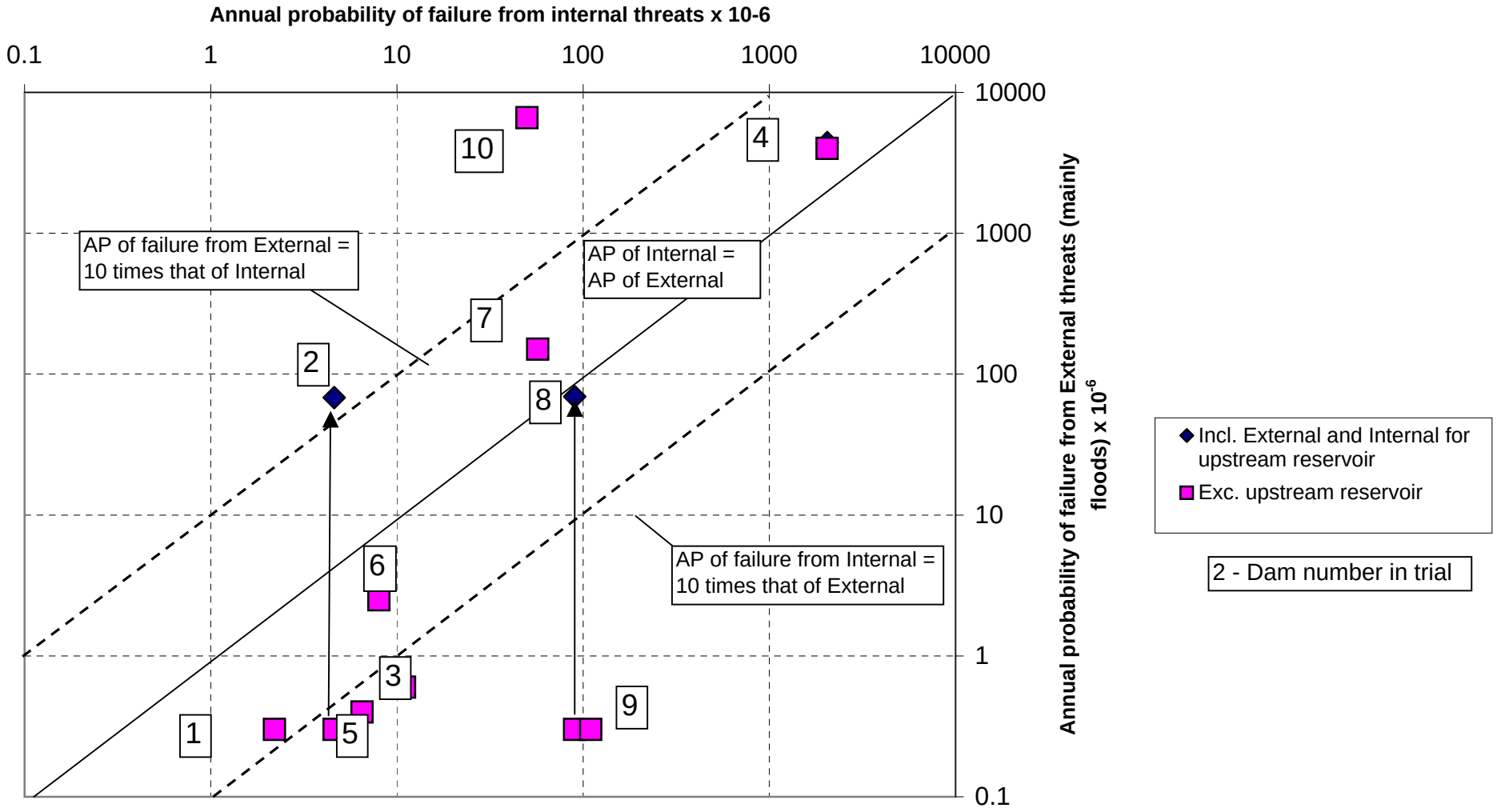
However, the significant uncertainties over some of the key assumptions in the prototype system should be noted, including:-

Assumption in trial of prototype Integrated System		Remarks
Annual probability of flood magnitude equal to best estimate of PMF	10^{-6}	The published literature suggests PMF could vary 10^{-4} to 10^{-9}
Annual probability of failure of the best 1% of UK dams due to internal erosion	10^{-7}	

All that can be concluded is that although for Category A and B dams internal threats pose the largest threat, the uncertainties in estimating the probability of failure due to overtopping are such that overtopping failures cannot be ruled out and further research is justified (although not at the expense of research on internal threats).

Potential funding where the recommended work overlaps with that of other agencies, such as the Environment Agency, Defra Flood Management, ESPRC and UKWIR is noted. It is possible that some of the research recommended may be considered to overlap with one of the six research themes of the joint EA/Defra Flood Management research programme.

Figure 1 : Output from Integrated System : Comparison of Internal threats vs. External threats



Packaging and prioritisation of the various recommendations is not straightforward; although the problems of funding large research projects are noted it is undesirable to subdivide the work as this leads to interface issues remaining unresolved. The value in Milestones is noted, as providing more flexibility for subsequent stages depending on the outcome from previous stages.

Packaging of the research work, and the associated technical specifications need to be drawn up carefully by an appropriate technical organisation.

4. Conclusions

The review by Sir David Cox concluded that

a) although the approach in FEH is "in principle well thought out ……It was, however, neither designed nor intended for use at such extreme levels… likely that medications are needed for the extreme rainfalls"
b) significant additional work is required if the issue of reliable prediction of extreme rainfall (and by inference floods) is to be resolved

It is essential that before any further work is undertaken that

- there is consultation with the dam engineering profession to agree priorities and timing.
- clear terms of reference and scope of deliverables are defined
- the Interim guidance is redefined

KBR suggest that

a) it is desirable that any future research on floods should be suitable for use in a risk based approach, including consideration of confidence limits on the data, following the development of risk based methods for management of dam safety
b) a preliminary task prior to any major study would probably be to complete Tasks 2.1a and 4.2a. These should include a comprehensive literature review and possibly consultation with overseas practioners (e.g. Australia and Canada where work on this issue is further advanced)
c) in parallel with progression of the recommendations of the Cox Report it would be desirable for experience to be gained with use of a risk based approach to dam safety in evaluating the relative threat to dams from floods and internal threats such as internal erosion