APPENDIX A : EMERGENCY PLANNING GENERALLY

Summary of this Section

This section provides a commentary on

- Introduction for Undertakers (reservoir owners) on emergency planning in general terms.
- How emergencies at dams may vary from this, as an introduction for both Undertakers and local responders classified as ‘category 1’ under the Civil Contingencies Act (2004).

A.1 Principles of Emergency planning

A.1.1 General

Emergency planning is increasingly recognised as one of the measures, which when applied systematically, may be used to manage (reduce and mitigate) the risk from high hazard installations.

Emergency planning may be subdivided into:

Type of plan	Covers	Strategy reference documents on risk management
“on-site”	Actions the owner of the high hazard may take on his land to prevent or mitigate a failure	HSC Policy Statement on “our approach to permissioning regimes”
“off-site”	Measures taken on third party and public land to mitigate the effects of the failure	Civil Contingencies Act 2004, and associated documents

A.1.2 Extendibility

Emergency planning needs to recognise that in reality there are often several alternative emergency scenarios that may arise resulting from the same hazard. This although the emergency planning is likely to cover one specific scenario, it should be capable of adjustment to other scenarios. This is illustrated with an example as below.

In the nuclear industry, emergency planning is based on the reasonably foreseeable accident, and a detailed Emergency Planning Zone (DEPZ) of a defined area, i.e. a one kilometre radius. This zone should be capable of being extended, by using general contingency plans to deal with larger less likely accidents (Chapter 9 of DTI, 2004). This is known as extendability planning. The text in Chapter 9 includes the following

- “a balance should be struck between ensuring that plans are sufficiently extensive to cope with serious emergencies, and avoiding a waste of resources that could occur through over-planning for most improbable emergencies” (para 9.6.1)
- “The improbability of a larger accident means that the absence of a detailed plan would not significantly increase the risk to the public” (Para 9.2.2)
- “planning in detail to meet every conceivable emergency was impractical” (para 9.2.3)
- the Nuclear Installations Inspectorate have specified a beyond design basis accident scenario against which to plan, as this would materially improve the ability of organisation such as the police and county emergency planning department. Various extendibility exercises were carried out and “showed that detailed plans could be extended to deal with larger events” (para 9.2.4-9.2.5)
- in applying one or more of the relevant countermeasures beyond the detailed planning zone, efforts should first be directed at those most at risk (para 9.4.3)
- extendibility planning is an important part of civil nuclear emergency response arrangements. General contingency plans need to be examined and enhanced as

necessary, to ensure that an appropriate response can be mounted should an emergency occur with more wide ranging effects than would be foreseen in reasonably foreseeable accident scenarios" (para 9.6.1)

A.1.3 Maintenance of emergency plans

To be effective as a risk management measure any emergency plan should be treated as a live document which requires regular maintenance, including

- training of staff (which should be before, and separate from, any exercise)
- exercising, including feedback and improvement of the plan in the light of how well the exercise achieved its aims and the objectives of the plan
- periodic review and updating.

If this maintenance is not carried out regularly then the plan will not only be ineffective, but fail to comply with the requirements of the Direction issued by the Secretary of State under the Reservoirs Act 1975 (as amended by the Water Act 2003).

Commentary on the minimum maintenance requirements for each element of the reservoir flood plan is included in the main Guide. However, it is recommended that the maintenance of the reservoir flood plan should be integrated into the process for the overall maintenance of an organisation's emergency plans. This should include processes for feedback and improvement, and audit that the maintenance is occurring. The role of panel engineers under the Reservoirs Act 1975 includes that given in Section 1.5 of the Guide.

Revisions of plans may vary from issuing corrections to contact lists, to a major review and reissue of a plan. Other factors may also require a revision and some examples include:

a) Lessons learned from the experience of real emergencies.
b) Lessons learned from exercises.
c) Restructuring and other changes in organisations.
d) Changes in key personnel.

It is an essential part of emergency planning to appreciate that the future can never be fully predicted. Thus an essential part of the preparation and maintenance of emergency plans is to learn from both historic and contemporary incidents. Attention is drawn to the Incident database for UK reservoirs, which is due to commence operation in 2006 (Brown & Gosden, 2004) and for which lessons learnt reports will be available from the Database Manager at the Environment Agency to those with a bona fide interest. Papers on lessons learnt from individual incidents also form an invaluable source of information (examples including Bridle, 2004).

Further guidance on maintenance of emergency plans is given in Emergency Preparedness (HM Govt, 2005) para 5.128 to 5.175.

A.1.4 Training and exercising

The effectiveness of any plan depends on the people implementing the plan. Training and exercising are therefore key parts of the plan.

Training is broadly about raising the awareness of members of the group or organisation on the contents of the plan and the emergency they may face. This gives them confidence in the procedures, and their abilities to carry them out successfully. It is important participants understand the objectives of the plan and their part in delivering those objectives.

The plan itself should include a reference to an exercise programme, which will maintain its currency and validity. It is noted that exercising can, and should, be carried out at many levels;

five possible levels are summarised in Table 1.1. Generally, participants in exercises should have an awareness of their roles and be reasonably comfortable with them, before they are subject to the stresses of an exercise. Exercises will validate plans; develop staff competencies and enhance training; and will test well-established procedures. An exercise should be designed to test the procedures and roles, and not the people. More information on this subject is contained in 'Emergency Preparedness' (HM Government, 2005) and 'The Exercise Planners Guide' (Home Office, 1998).

Table A.1 : Possible methods of exercising of an emergency plan

Type	Description
Call-out simulation	Contacting agencies and individuals with key roles in the plans to verify contact details are correct and that the required response can be mobilised. This should be done during and outside normal working hours (e.g. at 02.00hrs).
Seminar	Focus on one aspect of the response, to inform staff of contemporary developments and thinking (this might be better considered as training)
Tabletop	Based on simulation, usually of a realistic scenario and a time line. The players are expected to know the plan and are invited to test how the plan works as the scenario unfolds. Can include media awareness, for example use of trainee journalists, under direction of their tutor, to play news hungry journalists
Control post	Team leaders and communications teams positioned at the control rooms that would be used during an actual incident or live exercise
Live (Operational, or field)	Live rehearsal for implementing the plan. Particularly useful for testing logistics, communications and physical capabilities. Range from small scale test of one component through to a full scale test of the whole organisation

Note: Other than contact verification these are as described in The Exercise Planners Guide, Home Office, 2004. Similar descriptions are given in para 5.153 of Emergency preparedness (HM Govt, 2005).

A.2 Planning for dam break flooding

A.2.1 Differnces between fluvial and dam break flooding

Although the response to the threat of imminent dam break or an actual breach will be similar in many ways to one for fluvial floods, flooding caused by a dam break is likely to differ from conventional river and coastal flooding because of factors such as the

- difference in the speed of development of the emergency, the sudden rise of water and the time available for evacuation
- for large dams the increased force of the water is likely to lead to total destruction of buildings near the dam, reducing to partial structural damage and inundation damage with distance downstream
- the increased impact on infrastructure such as roads, railways, airports, electricity, gas water and other essential services
- the front of the flood wave may in the form of a standing wave, and include large scale debris (in the extreme in the form of a debris flow or lahar)

Nevertheless it is likely that the management of any response to the threat of imminent dam break would have significant similarities with the response to fluvial flooding. It is therefore instructive to learn the lessons from major fluvial flooding events, for example the various review reports published by the Environment Agency (1999) following the Easter 1998 floods. These resulted in improved multi-agency co-ordination and response. The Civil Contingencies Act and other flood events should lead to further improvement in multi-agency co-ordination.

The timing and sequence of evacuation should take into account the likely effect of the dam break flood, which will vary from inundation damage only, through to areas likely to be subject to total destruction of buildings.

A.2.2 Proportionate cost

An important principle in managing risk is that the cost of any risk reduction measures should be proportionate to the reduction in risk achieved.

There are approximately 2600 reservoirs registered under the Reservoirs Act 1975, but these have a wide range of physical size and consequences in the event of failure. Information is not currently available on the consequence class of individual dams. Nevertheless it is considered likely that the distribution of consequences in terms of the likely loss of life (LLOL) for the population of reservoirs under the Reservoirs Act is likely to be within the two lines shown on Figure A.1. It is noted that the population at risk would be significantly greater.

The practical implications of the consequences varying by several orders of magnitude is that what constitutes a proportionate cost for preparing and maintaining any reservoir flood plan should similarly vary by several orders of magnitude. The level of analysis and output from the inundation analysis which it is suggested may be proportionate in relation to the reduction in risk achieved is included in Figure A.1.

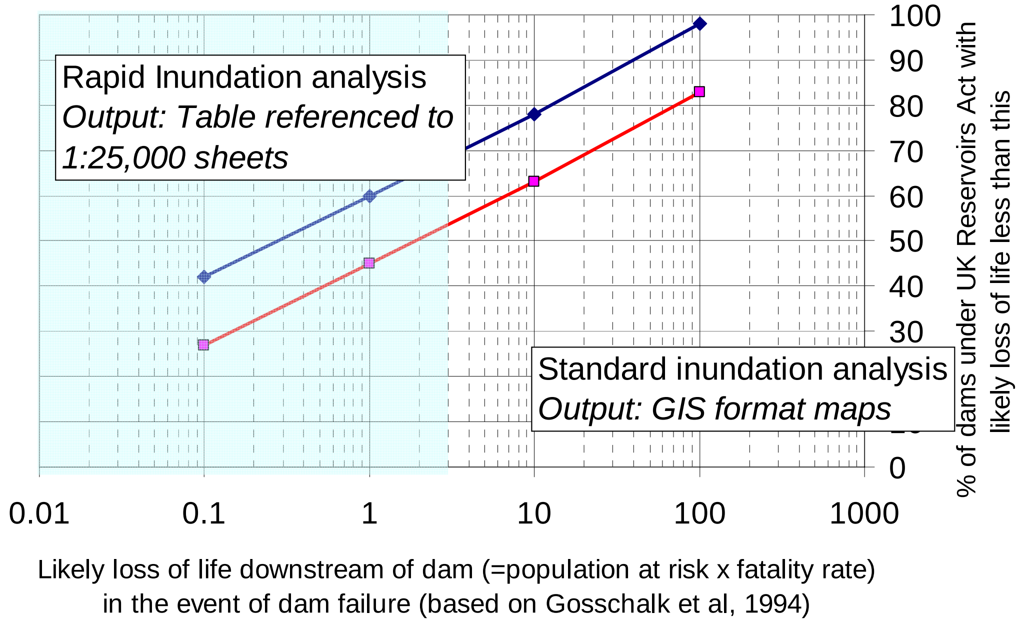

Figure A.1 : Need for a proportionate approach to management of the risk of dam failure

A.3 Role of the emergency services and local authority

The Civil Contingencies Act 2004, Part 1, now provides a statutory framework for civil protection at the local level, which applies across the whole of United Kingdom (by contrast with the Water Act which applies only to England).

Published together with the Civil Contingencies Act are two volumes of guidance which together cover the six phases of Integrated Emergency Management, namely
a) ‘Emergency Preparedness’ (statutory requirements)
b) ‘Emergency Response and Recovery’ (non-statutory guidance to complement ‘a’.

Reference should be made to the eight page summary published to accompany these documents; namely "Civil Contingences Act 2004: a short guide (HM Govt 2005).

The key points relevant to reservoirs are

a) The Civil Contingencies Act 2004 defines Category 1 responders (emergency services, local authorities, NHS bodies) and Category 2 "co-operating bodies" (e.g. utility companies)
b) Category 1 and 2 organisations will come together to form 'Local Resilience Forums' (LRF) (based on police areas) which will help co-ordination and co-operation between responders at the local level
c) The LRF has a duty to asses risks and record the results in a "Community Risk Register"
d) some Reservoir Undertakers will be Category 2 Responders and will therefore, have a duty to share information and co-operate with Category 1 Responders in this activity.

Comment on, and an example of, a possible template for an off-site plan for dams are given in Appendix D.

APPENDIX B : DETAILED ISSUES REGARDING HYDRAULIC MODELLING

Summary of this Section

This section provides detailed guidance on the hydraulic modelling aspects of an impact assessment.

B.1 Possible scenarios for release of water from reservoirs

Table B.1 summarises the range of situations in which releases of water from a single reservoir could occur, and likely associated flow conditions downstream. When considering flood conditions inflows from downstream catchments could be

e) modest, if the flood was a high intensity local storm upstream of the reservoir, or
f) very high if the storm was geographically intensive.

When considering a cascade with more than one reservoir there are clearly many possible combinations of release of water.

In addition to the uncertainties in both the cause of release of water and downstream flow conditions, there is also the issue of the location of the failure, with candidate locations including

- the point on the dam which retains the greatest depth of water
- Along culverts or other structures penetrating through the watertight element of the dam
- Along tunnels within abutments
- Other locations, determined by the geology of the dam foundation or other features

Table B.1 : Possible scenarios for releases from reservoirs

	Scenario for release of water[1, 2]	**Discharge in valley prior to releases**	**Remarks on extent of flooding**
1	Rainy day “dam failure”	Extreme flood, could be up to PMF flow	Reservoirs are designed to be safe against floods of between 150 year return period and the probable maximum flood (PMF) (AEP of the order of 1x 10^{-5} to 10^{-6}), depending on the consequences of failure. This is up to 1000 times less likely than the “extreme” (1000 year) flood envelope published on the Agency website. Thus even with no reservoir failure, flooding due to extreme floods (the natural flood envelope) may extend significantly outside the areas indicated by the Agency as liable to flooding, such that significant evacuation may already have occurred
2	Rainy day “no dam failure”	As for ‘1’	The no-failure flood impacts of potential interest include a) Flooding of access routes to the reservoir for bringing in personnel and material for operation and potential works necessary to prevent failure, although this is already available, to some extent, by inspection of the Environment Agency mapping of an Extreme (1000 year return period) flood b) baseline for determining the incremental loss of life in the event the dam failed
3	Sunny day dam failure	In-bank	a) Flooding would be unexpected. In the case of some small reservoirs, the inundation resulting from dam failure could be within the Agency “extreme flood” (1000 year) envelope. For large reservoirs the dam break flood inundation area could be significantly greater than the natural PMF envelope. b) This scenario could be triggered by internal erosion, earthquake, landslides into reservoirs etc.

	Scenario for release of water[1, 2]	Discharge in valley prior to releases	Remarks on extent of flooding
4	Gate failure (mechanical or operational)	Varies	a) Effects would be worse for sudden structural failure (or accidental opening) at a time of low flows. b) This scenario includes the various scenarios associated with hydroelectric schemes, such as penstock failure
5	Extreme event e.g. operation of fusegates or siphons	As for '1'	May be into side valley i.e. unexpected
6	Valve and pipework failures	Varies	a) Principal impact is likely to be limited to the vicinity of the reservoir but can still have serious consequences to installations such as water treatment works which are commonly sited immediately below a reservoir, with the potential for release of chemicals. b) Potential for total discharge of reservoir contents with additional implications for secondary usage of reservoirs, such as boating. c) Valves include operational and bottom outlet/ scour valves
7	Emergency drawdown[3]	Varies	Flow rate covered under On-site plan..
8	Routine testing of outlets[3]	Varies	a) Flow rate and timing of operation covered under On-site plan. b) For some large reservoirs on small catchments operation of the bottom outlet may lead to releases in excess of the bankfull watercourse capacity, and thus flooding. Where flooding is significant, the additional cost of modelling of outlet releases may be proportionate to the reduction in risk that could be achieved (see Note 3) c) Equipment failures during testing can have serious consequences (Scenario 6 above)

Notes

2. These are for a single reservoir. Where the reservoir is in a cascade then in principle there are many credible combinations of one of the above for each reservoir with different scenarios at other reservoirs in the cascade. In particular, the potential for failure of, or impact on, other reservoirs, with or without a rainfall event driver, should be considered. This may include water retaining structures falling outside the Reservoirs Act provisions (including canals) and reservoirs in different ownership.
3. When generating a FN curve as part of quantitative risk assessment (i.e. a cumulative curve of the probability of occurrence and fatalities for each of the possible failure modes) the number of scenarios would be significantly increased, in that separate inundation analysis may be required for each failure mode.
4. Modelling of flows significantly less than those resulting from dam failure would incur significant additional cost as it would generally require detailed field survey to obtain the channel geometry, including below water level. However the length of channel for which detailed survey would be required is likely to be less than the length over which the impact of dam failure needs to be considered.

B.2 Program Types

B.2.1 Hydraulic modelling

Hydraulic modelling programs may be classified chiefly by:

- Whether they solve physically based flow equations or apply a hydrologic routing technique;
- Whether they deal with steady or unsteady (time varying) flows;
- Whether they model free surface flow or are physically constrained.
- The number of spatial dimensions they simulate (1-D, 2-D or 3-D);

Hydrologic routing techniques, such as Muskingum-Cunge, are essentially black-box modelling systems which need to be calibrated against observed data and cannot be relied upon to extrapolate to extreme events from normal conditions. Such models can be calibrated against detailed hydraulic models to generate simple stable models for use in real time forecasting systems but are not appropriate for the analysis of extreme flood flows, except in limited circumstances where relevant observed flows are actually available.

Steady flow modelling is fundamental to all hydraulic analysis since unsteady flow solutions depend on the establishment of initial steady flow conditions. A steady flow solution is adequate in cases where only a constant flow rate is known or flows are controlled to fixed rates. Steady flow conditions (flow lines parallel to the channel bed) can be approximated at the peak of a flood, so a steady flow model can be sufficient where it is safe to assume that the peak flow varies little through a river reach.

The assumption of steady flow may be appropriate for reservoir safety assessment where releases are effectively constant, as might be the case with the failure of pipework or gates on a large reservoir. However the assumption of a constant peak flow down a valley following the breaching of a dam is generally unreasonably conservative and such circumstances should be modelled assuming unsteady flow.

Hydraulic modelling programs applicable to dam-break modelling must therefore solve physically-based flow equations and deal with both steady flows and time-varying flows. It is also clear that free surface flow must be modelled.

The principal degree of complexity remaining is the number of spatial dimensions to be modelled. The principal characteristics of 1-D, 2-D and 3-D modelling systems are set out in Table B.2. Hybrid models have also been developed which, for example, use 1-D models to provide boundary conditions for 2-D models. The recent introduction of the Conveyance Estimation System (CES, Defra/EA, 2004) also introduces an element of 2-D modelling to the conventional 1-D model as it makes use of the flow depth when calculating roughness rather than using a fixed Manning's 'n'.

It is important to appreciate that the 1-D, 2-D or 3-D classification applies to the underlying hydraulic computational engine. Graphical interfaces with GIS tools can allow 1-D models to be built from 3-D data and help to present the results in a 3-D format, including the creation of animations of the passage of floods. Programs providing these facilities are vastly superior in ease of operation to "traditional" programs but suffer just as much from the "garbage in – garbage" out syndrome and can lend a spurious sense of reality to the results.

B.2.2 Flood Mapping

Mapping the results of the mathematical modelling into plan format is a separate, second process. Increasingly, but invariably, this software is integrated with the hydraulic modelling software

Table B.2 : Comparison of different levels of modelling of spatial dimensions

<table>
<tr><th></th><th>1-D models</th><th>2-D models</th><th>3-D models</th></tr>
<tr><td>Description</td><td>Flow in a defined path between two points</td><td>Grid of points, with flow depth and velocity calculated on each interconnection</td><td>As 2-D, but in vertical dimension as well</td></tr>
<tr><td rowspan="2">Assumptions and limitations</td><td rowspan="2">• Cross-sections must be normal to the direction of flow.
• Modeller determines the flow direction
• Water surface is horizontal across a cross-section.
• Only distance along the flow path is modelled directly – cross sections are reduced to parameters attached to model nodes.
• Flow velocity output is a single value representing an “average across section”</td><td>• Calculate flow direction in two dimensions.
• Can be 2-D horizontal or 2-D vertical – the third dimension becomes a parameter attached to a model node</td><td>• Calculate flow direction in all three dimensions</td></tr>
<tr><td colspan="2">• 2-D and 3-D models with free surface flow must deal with singularities arising from wetting and drying of model cells.
• Hydraulic structures such as weirs and bridges cannot be modelled directly and are often represented as 1-D links connecting nodes in 2-D and 3-D models
• Geometric data requirements increase in proportion to the power of the number of dimensions</td></tr>
<tr><td>Available model types</td><td>• 1-D, steady flow programs are the most widely available type and are often referred to as backwater models
• 1-D, unsteady flow, programs are the next most common type and are the basic minimum for dam-break flood analysis.
• Model interfaces vary considerably in capabilities.</td><td>• 2-D steady and unsteady flow models may be available as stand-alone programs or as part of hybrid 1-D/2-D systems</td><td>• 3-D unsteady flow models are often described as “Computational Fluid Dynamics” (CFD).
• Models appearing to be 3-D may really be multi-layer 2-D models</td></tr>
<tr><td>Applications</td><td>• Design of channels and structures
• Assessing channel capacity.
• Flood mapping.</td><td>• Situations where flow direction is initially unknown
• Large flat floodplains.
• Flow through urban areas.
• Estuaries and coastal areas.
• Flow around bridge piers for scour calculations.</td><td>• Water quality and sediment transport studies where vertical mixing processes are important.
• Modelling of complex hydraulic structures such as side channel spillways</td></tr>
</table>

B.3 Program Requirements for Dam-Break Analysis

The basic minimum requirements for a program to be able to deal with routing dam-break floods in simple valleys (i.e. no flow bifurcations, simple flood plains) are that it should be able to:

- Model 1-D unsteady flow
- Represent channel cross-sections using top-width tables or coordinates
- Represent variable friction factors across a section
- Represent basic hydraulic controls such as weirs
- Report results including flow, level and velocity at cross-sections

The inflow hydrographs could be generated separately and specified as inputs to the model. Routing through intermediate reservoirs, with or without breaching, can also be accomplished using similar separate tools, if required.

However, more complex situations require the ability to model flow bifurcations in general and, particularly, flow leaving the main channel towards flood areas remote from the channel, or to overtop local obstructions and rejoin the channel at some point downstream. Reservoirs which are relatively long may also require, ideally, to be modelled as channels to allow properly for the change in hydraulic behaviour of the system as they empty. In general, the ability of software used for dam-break flood routing to represent dams and the formation of breaches is of great value.

Discharges from narrow valleys into wide coastal plains and bunded reservoirs, and other cases with no single obvious flow path, may be difficult or impossible to represent sensibly with 1-D modelling systems. The use of 2-D and 3-D models in this situation is being actively developed but their use is currently constrained by computing power limitations and the availability of suitable geographic data. It is also not yet clear whether such techniques would add significantly to the emergency planning process, given the underlying uncertainties in the assessment of breach location and discharge.

B.4 Commercially available software

B.4.1 Hydraulic modelling

There is a wide range of hydraulic modelling software which is commercially available that may be suitable for dam break analysis as indicated in Table B.3. It is noted that the presence on, or absence from, this list of a software item, including versions with different numbers of nodes etc, does not imply its suitability for dam-break analysis. The purpose of a list of software is to assist users of the guide in understanding the range of software that may be suitable for dam break analysis and to provide them with contacts should they wish to obtain further information.

In some cases the price of software is based upon the maximum size of the model the software can manage, which is usually measured in model nodes or cross sections. Model sizes which can be accommodated are often constrained by hardware and/or operating system factors as much as by cost.

Software support is sometimes included in the cost of purchase for the first year. For later years, the cost of support is typically 10-15% of the list price.

In the case of software made available free under US freedom of information rules, such as HEC-RAS, the US Army Corps of Engineers does not offer technical support to external users, but this can be purchased from third parties who may also offer other services of interest.

B.4.2 Flood Mapping

As for modelling there is a wide range of software available. As well as engineering software, there are proprietary survey and GIS packages which can map the estimated water surface (at sections) onto the ground model. It is preferable for the flood mapping software to be integrated with the modelling, as where separate software is used this can give rise to problems and inaccuracies in the mapped surface.

Table B.3: Summary of Flood Routing Software

Model	Principal Contact	Nodes	Cost (£)	Website
		1D Models		
Hec-Ras	US Army Corps of Engineers	n/a	Free	http://www.heB.usace.army.mil/software/hec-ras/
Mike 11	DHI	250	4,100	www.dhi-uk.com
		450	6,800	
Hydro 1D	Mott MacDonald	In-house software		http://www.mottmac.com/
InfoWorks RS	Wallingford Software	100	5,300	www.wallingfordsoftware.com
		400	7,990	
		1,000	13,300	
		2,000	20,000	
		10,000	25,300	
ISIS	Wallingford Software	100	2,000	www.wallingfordsoftware.com
		1,000	8,500	
		10,000	14,200	
BOSS DAMBRK	Boss International	300XS	600	www.bossintl.com
		2,000XS	800	
SOBEK	WL | Delft Hydraulics			http://www.sobek.nl/
DAMBRK-UK	Unsupported (historic software)			http://www.bvl.bv.com/
FLDWAV	US National Weather Service, Purchase via US National Technical Information Service (NTIS)	?	$120	http://www.fema.gov/fhm/dl_fdwv.shtm http://www.ntis.gov/
		2D Models		
JFLOW	Developed By Jeremy Benn Associates	In-house software		http://www.jbaconsulting.co.uk/
TUFLOW	WBM Pty Ltd	Unlimited?	3,300	http://www.tuflow.com/
Mike21	DHI	5,000	3,300	www.dhi-uk.com
		25,000	6,000	
		50,000	8,000	
Hydro-2D	Mott MacDonald	In-house software		http://www.mottmac.com/
DIVAST	Environmental Water Management Research Centre, Cardiff University		3,000	http://www.engin.cardiff.ac.uk/research/summary.asp?GroupNo=3
DelftFLS	Delft Hydraulics			www.wldelft.nl
SMS	U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory		$9,250	http://www.ems-i.com/
TELEMAC-2D	Electricité de France, UK Agent HR Wallingford			http://www.telemacsystem.com/gb/default.html
		3D Models		
Hydro-3D	Mott MacDonald	In-house software		http://www.mottmac.com/
Mike 3	DHI	15,000	4,000	www.dhi-uk.com
		80,000	9,300	
		160,000	16,800	
Delft 3D	Delft Hydraulics		23,600	www.wldelft.nl
FLUENT	FLUENT	No limit	33,000	http://www.fluent.co.uk
SSIM	?			
TRIVAST	Environmental Water Management Research Centre, Cardiff University			http://www.engin.cardiff.ac.uk/research/summary.asp?GroupNo=3
TELEMAC-3D	Electricité de France, UK Agent HR Wallingford			http://www.telemacsystem.com/gb/default.html

Notes:

1. The presence on, or absence from, this list of a software item, including versions with different numbers of nodes etc, does not imply its suitability for dam-break analysis. The purpose of the list is to assist users of the guide in understanding the range of software that may be suitable for dam break analysis and to provide them with contacts should they wish to obtain further information.
2. Prices shown are based on 2005 information and include conversions from other currencies. Some software requires the purchase of a range of components and/or software from third parties in order to operate as advertised.

B.5 Ground model

B.5.1 Ground elevation data

The principal alternatives for digital elevation data are summarised in Table B.4, in order of increasing accuracy.

In relation to Land-Form apart from the accuracy of the contours themselves, features falling entirely within contour intervals are not identified in this data and there is therefore a risk that model building and flood mapping will be unreliable in areas of complex topography. The Ordnance Survey has also launched a "Land-Form Plus" product which combines their historic Land-Form data with data based on LiDAR where available. The cost of this product depends on the proportion of the data derived from the higher quality source. Land-Form Plus should be used with caution as LiDAR data is not available everywhere, and, even where LiDAR is available, it may not yet have been incorporated in the OS mapping. Additionally, there is a risk of substantial discontinuities in level along a valley, which can have a serious effect on hydraulic modelling as well as generating anomalies in the final mapping.

IfSAR data has significant advantages over the OS Land-Form data as it is a continuous grid of measurements. The remote sensing method used has drawbacks, however, in that it cannot penetrate dense woodland and can fail to reach the bottom of a valley in steep topography. The data is presented in two forms: with and without embankments. In both, the data has been adjusted to achieve hydraulic connectivity throughout a river catchment. For example, a meandering stream through dense woodland can appear as a straight ravine cut through a block of land more than 20m higher than the surrounding fields. In the "with embankment" form, embankments are cut by vee-shaped notches; in the "without embankment" form, embankments are removed entirely. On balance, IfSAR data used with a proper understanding of its limitations is likely to provide a better basis for a dam-break analysis than is Land-Form. It should also be appreciated that the IfSAR data is the basis for the Environment Agency flood zones, subject to local adjustments in the published data whereby Zone 3 (100 year flood) outlines have been replaced by, or augmented from, outlines from the Environment Agency's detailed flood mapping programme.

Raw LiDAR data generally identifies the solid surface of ground and buildings, though it can pick up the top of a tree on occasions. Filtered LiDAR is raw LiDAR with structures etc. removed automatically based on algorithms which identify unnatural changes in elevation. It is recommended that unfiltered data be used for building hydraulic models for dam-break analysis; the modeller then has the option of removing buildings from the cross section if desired. The option remains to use the filtered data when determining the inundated area.

A general warning is attached to all ground models derived exclusively from remote sensing, and particularly to simple gridded data: significant linear features such as walls are likely to be omitted entirely; and broader but unnatural linear features such as flood protection embankments are likely to be shown with top levels generally too low, and even with spurious gaps.

A final point on the ground model/ground survey issue is that it is risky to plot the extent of flooded areas using a different ground model to that used to build the hydraulic model. Where existing hydraulic models have been acquired which incorporate ground survey over areas for which LiDAR (say) is the principal data source, it may be appropriate either to delete the extended sections in the hydraulic model and use the LiDAR data or to combine the LiDAR data with the ground survey in the hydraulic model to generate a single ground model.

Table B.4 : Summary of sources of ground data used in fluvial modelling

Product	Quoted Accuracy	Coverage	Relevance to inundation maps produced by Undertakers	Costs and format £
Ordnance Survey (OS) 'Land-Form Profile'	+/- 1.0m from 5metre contours +/- 1.8m in mountain and moorland areas. Produced from 1:10,000 scale digital height data set.	National. Typically based on photogrammetric contouring from 1:40,000 scale aerial photography. The 5m contour intervals produced are said to be at the minimum spacing achievable with the technology used. Heights are interpolated from the 5m contours	Use for rapid method (as given on 1:25,000 scale, Explorer maps)	Min. order from OS £100, otherwise £4.10 per 5km*5km tile. Plus £4.10 per tile annual licence fee. CAD drawings or DTM data on CD.
Ordnance Survey (OS) 'Land-Form PROFILE Plus'	Variable, 0.5m urban to 2.5m in mountain and moorland where incorporates Lidar; 5.0m where based on original Land-form PROFILE	Product being rolled out from April 2005, where not yet available OS will supply as Land-form profile.	Variable accuracy down valley; thus uncertainty relating to isolated properties	
IfSAR Digital Terrain Model (DTM) (Interferometric Synthetic Aperture Radar)	+/- 0.7m in general flat terrain. +/- 1.0m in wooded and steeply sloping areas.	England and Wales, (being extended to Scotland). Funded by insurance company and Environment Agency (EA). Heights are a 5m grid of levels as DSM (surface mapping i.e. tops of trees, buildings) and DTM (filtered to a bald earth model)	Readily available source of data for more detailed analysis from approved suppliers.	10km*10km tile with 10m postings £1762.50; with 5m postings £4230.00. Licence fee £36.00 for one year, more in perpetuity ASCII data on CD.
LiDAR DTM (Light Detection And Ranging)	+/- 0.25m by fixed wing aircraft. +/- 0.05m by rotary wing aircraft.	Flown by EA on project specific basis along river courses and Highways Agency (HA) along motorway corridors. Has been flown by private contractors along rail network in Scotland	.	Approx cost to acquire new 2m postings data through: EA, £410 per km². Contractor, £600 per km². ASCII data on CD.
Photogrammetric mapping	+/- 0.05m hard surfaces +/-0.12m soft surfaces Best contour interval 0.25m from 1:3,000 scale photography.	Flown by EA on project specific basis along river courses, and Highways Agency along motorway corridors.		Approx cost to acquire new data through private contractor, £2200 per km². CAD drawings on CD.

Product	Quoted Accuracy	Coverage	Relevance to inundation maps produced by Undertakers	Costs and format £
Ground Survey (spot heights to enable contouring at 0.25m interval)	+/- 0.01m hard surfaces +/-0.03m soft surfaces	Commissioned by EA and HA on project specific basis	For very high hazard dams this may be appropriate at motorway embankments, bridges and other constrictions across the valley.	Approximate cost to acquire new data through private contractor, £4500 per km^2 Suburban areas, >£5000 per km^2. CAD drawings on CD.

B.5.2 Transportation embankments, structures and channel cross sections

Ground survey is the only technique which can identify linear features properly and can give the "true" dimensions of structures, such as the width and inverts of bridge openings and weirs. Ground survey is also the only practical technique generally available for surveying cross sections of river channels below water level, though techniques are available for surveying the under-water parts of sections using ultrasound and radar

It should be noted that no direct mention is made of channel survey in the data requirements, except for the suggestion of obtaining previous hydraulic models. This is because dam-break floods are expected to so far exceed typical river flows that the river channel capacity is irrelevant.

Levels of the top of embankments can normally be obtained from Lidar, though the limitations of ground elevation data mean that the data must be used selectively to ensure that the embankment is not represented as being too low, or even breached. Embankments which are small in height in relation to dam break flows (say less than 25% of dam break flood depth downstream of the embankment) may be neglected, as they will almost certainly breach, and the ponding immediately prior to breach should be below the peak flood level.

Dimensions of openings in embankments may be obtained with sufficient accuracy for dam break analysis by site inspection and hand held remote sensing, and can be compared with mapped channel widths for further support.

B.6 Model Cross Section and Reach Specification

The following text is based on a base model comprising 1-D, unsteady flow modelling. If a 2-D model is used it is assumed that it will also meet the basic criteria for 1-D modelling. It is assumed that suitable digital elevation data and digital mapping has been acquired. The modelling process is no different in principle to that followed in any river modelling exercise. It is however assumed that channel section data and detailed surveys of structures in the flood plain are not, and normally will not be, available.

The first requirement is to establish the possible flow paths, bearing in mind that the flows to be modelled will probably be far greater than historical flows, at least close to the dam. At the same time significant features on the flow paths need to be noted, which will typically be:

- Structures crossing, or running along, the flood plain;
- Different types of land use (principally natural open ground, farms and parks, woodland, low density development, urban housing and industrial units);
- Changes in width of flood plain or longitudinal gradient;
- Areas where high water levels might lead to overspills into different watercourses;
- Tributaries (particularly where backing up of floods into tributary flood plain areas may be significant).

The locations of reach boundaries necessary for estimating fatalities and other output data should be identified at this stage.

A suitable reach and node numbering system should be established prior to building any model. It is generally best to number model nodes consecutively running downstream and to allow for the addition of more cross sections as modelling progresses. A possible format is AAANNN.SSSSS where AAANNN identifies uniquely the river reach, being modelled and SSSSS is the section number (initially 00100, 00200, 00300, 09900). It is acknowledged that some software packages do not allow this particular form of numbering, due either to limits on numbers of characters or to assuming section references approximate to channel distances, and that various different system have been used historically. However the modeller's fundamental aim must be to make it reasonably easy to find a node either in an on-line model or in a printout.

At this stage it is best to assume that the flood flow path will follow the river round any convolutions in its path. This is one of the areas in which the choice of digital elevation data can have a significant effect but it seems sensible to assume that the path of the river reasonably represents a natural drainage route. Short-circuiting due to the overtopping of the land in the middle of a loop in the river can be modelled by adding spill units to the model.

Typical hydraulic modelling guidelines suggest a minimum cross section spacing of ten to twenty times the flow width. It is suggested that this can be translated to ten to twenty times the flood plain width for dam-break applications. An initial section layout taking account of the significant features along the flow paths and the minimum section spacing suggested can next be developed. The most likely locations for problems with hydraulic models are those with rapid changes in section and gradient, and areas with particularly steep gradients. It is generally advisable to break the channel into reaches of reasonably uniform character. Where the results of the analysis show widely varying degrees of damage within a zone, the zone would need to be subdivided into zones of broadly similar velocity and depth. Treatment of transportation embankments across the valley may be as shown in Table 3.4. The ground model will be influenced by such embankments to a variable degree. It is therefore advisable to use all such features as ends of reaches.

As with any 1-D modelling exercise, cross-sections must be drawn normal to the likely direction of flow and looking downstream. It is advisable to draw the sections generously in the first instance to ensure that the full extent of the floodable valley is represented. They should then be trimmed back to the highest point at either side of the flow path. It may well be noticed at this point that the lowest point in the section is not at the mapped location of the river channel. This is perfectly normal, as the ground model probably does not include points within the width of the river channel and flood plain levels are frequently lower than the river banks. It can however indicate that the river is in the wrong place on the map.

The simplest way of allocating roughness factors across a section is to specify left and right floodplain and channel friction factors which can be implemented by setting markers on the cross section for left and right bank locations. These locations need not bear any relation to the actual watercourse bank locations but are used as a device for implementing a variation in friction factors. Right and left bank levels may be displayed on longitudinal sections of the channel, so setting these locations sensibly may have other advantages.

B.7 Model Boundary Conditions and Steady State Conditions

The downstream boundary condition is best defined either as a weir or spill unit connected to a fixed head at a lower level, or a normal depth boundary using the typical valley gradient downstream from the modelled area and the geometry of the furthest section downstream. When using a weir-type arrangement in this situation, it is advisable to use a low discharge coefficient (1.0 or less, where a broad crested weir would have a coefficient of 1.7).

The inflow to the model at this stage should, ideally, be based on a T-year flood at the dam location with provision for a minimum flow setting. The modeller should be prepared to set the minimum flow at a level between the 100 year flood and the 1000 year flood in order to achieve an initial steady state solution, though lower flows should be sought if possible.

The model should then be built up from the downstream end, ensuring that a steady state solution can be achieved after each component is added. The diagnostics output from a steady state run in InfoWorksRS, for example, includes a list of links (lengths of river between cross-sections) for which the program has needed to automatically interpolate additional cross-sections to achieve a steady state together with recommendations for the number of additional sections needed. It is generally sensible to get the number of additional sections required down to no more than one, though the presence of higher numbers is not a guarantee of failure when moving to unsteady flow conditions, and having no requirement for extra sections does not guarantee success.

Sections may be added either by using interpolation tools in the modelling software or by creating new sections properly from the ground model. The latter approach is to be preferred where possible. Review of the detailed results from the steady state run will often show a few sections with relatively high Froude numbers. Insertion of additional sections one at a time nearer to the ends of links with high Froude numbers is likely to be more effective than is inserting uniformly distributed additional sections. If the required section spacing becomes absurdly small, an alternative solution should be sought. Inserting a spill unit, as described for the model boundary, is a possible solution. This might allow a short length of relatively steep valley, which will be entirely drowned out at the peak of the dam-break flood, to be omitted from the model, for example.

It is advisable to test the model at each stage to ensure that it also runs in unsteady state mode with, say, a 1000-year flood inflow. It can be useful to use the final results from a long unsteady run at the specified minimum flow, in place of the initial steady state solution.

B.8 Model calibration and verification

Construction of an hydraulic model would normally include

- calibration of the model against a number of observed historical events of known annual probability (return period), adjusting the model assumptions as necessary such that the model matches the observed behaviour
- verification of the calibrated model by estimating the behaviour under defined conditions, comparing these against further observed events

It is generally not possible to apply this process to dambreak models, because the flows that would occur are so much greater than normal fluvial events. Nevertheless the principle of review of the model for reasonableness should still be carried out. This should include

a) comparison with the Environment Agency estimated 1000 year flood outline
b) assessment of whether all reasonable flow paths have been included in the model, including the possibility of some flow bypassing bends in the river, the effect of infrastructure embankments and occasionally cross catchment transfers

B.9 Flood Risk Mapping

Various processes have been used to map flooded areas and damage parameters from the hydraulic analysis results but the principal issue to be addressed here is the nature of the output.

Historically, flood maps were presented principally as outlines on hard copy maps or as polygons in an electronic format. Water levels and flood depths could only be determined indirectly from the data provided.

The increasing use of digital elevation data, and the ready availability of a range of ground modelling and GIS software, makes the areal mapping of flood depth and velocity relatively straightforward. It is therefore recommended that the full dam-break analysis process should yield a grid of flood depth and velocity over the area identified as being at risk from inundation. The elevation data used in the flood mapping process should be the same as that used to build the model and the results should be presented at the same spatial resolution as the elevation data.

The accuracy of elevation data is variable, as shown in Table B.4, and the quoted accuracy is typically within a range that is very significant when considering the impact of flooding. It is therefore considered that the results should be understood in terms of predicted flood depth at a location and that flood level should not normally be quoted.

It is recommended that, where a choice must be made, flood depth should be extracted in intervals of 0.05m. This is not intended, or expected, to reflect the accuracy of the calculations, but is proposed to avoid practical problems with the interpretation of the areal extent of flooding experienced when using wider intervals.

It is acknowledged that the velocity results available from the 1-D modelling process are, normally, averages across cross sections and that velocity is not defined for flood storage areas.

APPENDIX C : SCENARIO PLANNING IN RELATION TO POSSIBLE EMERGENCIES AT A DAM

Note: This appendix presents examples of an approach that might be adopted to assess measures to prevent or delay dam failure. The examples are indicative of a approach, but are likely to be incomplete in respect of any particular dam, which should be sassed by a competent dam engineer employed by the undertaker.

C.1 Prompt sheet for assessment of measures to prevent or delay failure

	Issue	Questions to be answered	Assess
1.1	Indicators	What are the symptoms?	
1.1	Potential failure modes	Could this lead to failure of the dam, and if so by what failure mode or modes?	
2	What are the candidate measure(s) to reduce the risk of failure? (descriptions)		
3	For each option to prevent/ delay failure:		
3.1	Objectives		
3.2	Resources required		
3.3	Timescale before likely to have a measurable effect?		Note 1
3.4	How likely is this measure to prevent failure?		Note 1
3.5	Reliability of assessment	Is there any additional information which would improve the reliability of this assessment, and if so a) what is it ? b) is it practicable to obtain?	Note 1
	Assessment of risk of damage or detriment to	Include both consequences and likelihood	
3.6	Dam		Note 1
3.7	personnel implementing measures	Note 2	Note 1
3.8	third parties		Note 1
3.9	environment		Note 1

1. Assess each option in some way, so as to prioritise options and resources. Suggested scales could include 1 to 5, where 5 implies the option is worth pursuing and 1 indicates significant reasons not to pursue this option, and/or high/medium/low
2. Sources of useful information on health and safety guidance include
   www.safetyindesign.org/ (includes various design guides)
   www.hse.gov.uk
   www.opsi.gov.uk
   www.cic.org.uk/services/publications.shtml
   www.wwt.uk.com

Relevant Guides include
a) HSG224/2001 Managing construction for health and safety: The Construction (Design and Management) Regulations 1994 Approved Code of Practice and Guidance
b) CIRIA C604 CDM Regulations – work sector guidance for designers (2004)

C.2 Sinkholes above reservoir level

	Issue	Questions to be answered	Assess
1.1	Indicators	A sinkhole has appeared in the upper part of the dam, above reservoir level.	
1.1	Potential failure modes	Sinkholes may be caused by a variety of reasons, including a) Concentrated leaks which may be controlled by the permeability of the upstream shoulder (or other fill zone), which means that, rather than a sudden catastrophic failure ongoing erosion occurs, leading to a gradual enlargement of the hole in the core area, which then migrates upwards b) Collapse of a culvert or other conduit Failure could occur due to a) enlargement of the erosion hole such that the sinkhole emerges below reservoir level, when the reservoir could enter the hole; or b) The leakage path breaking through horizontally into the reservoir	
2	What are the candidate measure(s) to reduce the risk of failure?	Options include f) lowering the reservoir g) dumping fill into the hole	
3	For each option	**For Option 'b' – dumping fill into sinkholes**	
3.1	Objectives	To introduce fill into the concentrated leakage path, which will slow or stop the ongoing erosion.	
3.2	Resources required	a) A source of suitable fill. Options comprise cohesionless fill or sacks of bentonite which could be dropped into the hole, in anticipation they may expand on wetting and seal the hole b) Plant to transport the fill to the top of the sinkhole c) Plant to place the fill safely into the hole	
3.3	Timescale before likely to have a measurable effect?	As soon as fill dumped. Fill could be brought to site within a few hours	4
3.4	How likely is this measure to prevent failure?	This is likely to depend on • whether the fill reaches the bottom of the hole, or arches in the upper part of the hole • if the fill reaches the concentrated leak, whether it will be washed straight out, or delay/stop the erosion	3
3.5	Reliability of assessment	Reasonable	3
3.6	Risk to dam	Bringing heavy plant onto the dam crest may trigger instability of the crest	M
3.7	Risk to personnel implementing measures	These will include • Those risks involved in placing fill at the top of steep slopes • Possible sudden enlargement of the hole visible at the crest, if wider below • Collapse of ground over unseen cavity below	M
3.7	Risk to third parties	Conflict between pedestrians on public footpaths/ roads and vehicles bringing in fill	L
3.8	Risk to the environment	Less than risk of doing nothing	L
		Total	10

C.3 Spillway blocked by trash

	Issue	Questions to be answered	Assess[1]
1.1	Indicators	During a flood a large tree has washed down and is lodged on the spillway crest, partially blocking the spillway. The reservoir level has risen and is now well above the spillway crest. There is further debris in the reservoir which is likely to be driven towards the spillway by the wind and cause further blockage.	
1.1	Potential failure modes	1. Overtopping, due to reduced spillway capacity 2. Internal erosion elsewhere at the dam, initiated by the high reservoir level	
2	What are the candidate measure(s) to reduce the risk of failure?	b) Excavate emergency spillway on a flank c) To clear the debris, and thus restore the spillway capacity (and prevent worsening blockage). Options include • lifting the trash with a large excavator situated on the spillway abutment • winching the tree (conditional on being able to safely attach a chain) • in extremis light explosive charge (but this incurs the risk of damage to the dam, or moving the debris further down the spillway and blocking the chute) If there is no vehicle access to the side of the crest, it may be necessary to bring two excavators to site (one to lift the other into place), or locally demolish the crest wall to form vehicle access	
3	For each option	**For Option 'b' clear the debris**	
3.1	Objectives	Remove tree blocking spillway	
3.2	Resources required	Excavator (or large mobile crane) to drag tree Chains and hook Chainsaw to cut up tree once in a position where it is safe to do so	
3.3	Timescale before likely to have a measurable effect?	Immediate once cleared, but will take time to clear	3
3.4	How likely is this measure to prevent failure?	depend on the weight of the tree relative to the power of the excavator	2
3.5	Reliability of assessment		2
3.6	Risk to dam	Bringing heavy plant onto the dam crest may trigger instability of the crest	H
3.7	Risk to personnel implementing measures	These will include • inadequately sized excavator overturning • chains snapping and whipping back from the break	H
3.7	Risk to third parties	Conflict between pedestrians on public footpaths/ roads and vehicles bringing in plant/ materials/ labour	M
3.8	Risk to the environment	Less than the risk of dong nothing	L
		Total	7

C.4 Serious internal erosion incident

	Issue	Questions to be answered	Assess[1]
1.1	Indicators	A new leak has developed, which is carrying fines with the flow rate increasing rapidly with time. If no action is taken it is likely that the leak will develop into a breach of the dam.	
1.1	Potential failure modes	Internal erosion leading to structural failure	
2	What are the candidate measure(s) to reduce the risk of failure?	Illustrate for modest 100,000m^3 capcaity reservoir and 5m high dam and to lower the reservoir by one metre in a day would require about 0.6m^3/s. Options are a) Bring additional pumps to site, to augment the existing drawoff capacity and reduce load on the dam. This would need 14 x 100mm pumps, five x 150mm pumps, or two 300mm pumps. b) Bring siphon pipes to site, to augment the existing drawoff capacity and reduce load on the dam. No crane is readily available, so assume will have to be manhandled. Require 18 number 100mm siphon pipes, discharging at least 3m below the reservoir level (4m below dam crest) c) Install reverse filter on top of leak, to try and block fines escaping whilst allowing flow through	

3	For each option	**Option 'a' – pumps**	Assess[1]
3.1	Objectives	Lower reservoir by providing pumps	
3.2	Resources required	Five 150mm pumps, complete with power pack, fuel for the first 48 hours, intake and discharge hoses	
3.3	Timescale before likely to have a measurable effect?	Quick once installed, but will take time to bring to site and get working	2
3.4	How likely is this measure to prevent failure?	The likelihood of success is likely to depend on obtaining sufficient size and number of pumps and getting them working in time.	3
3.5	Reliability of assessment		2
3.6	Risk to dam	Surface erosion at pump outlets	L
3.7	Risk to personnel implementing measures	Handling heavy equipment	M
3.7	Risk to third parties	Conflict between pedestrians on public footpaths/ roads and vehicles bringing in plant/ materials/ labour; Increased discharges may cause local flooding downstream	M
3.8	Risk to the environment	Increased discharges, possibly with sediment if dam surface is eroded	M
		Total	7

3	For each option	**Option 'b' - siphons**	Assess[1]
3.1	Objectives	Lower reservoir by providing and installing siphon tubes	
3.2	Resources required	a) 18 number 20m long four inch diameter siphon pipes b) Bungs to block pipe between filling with water in reservoir and manoeuvring into position over dam crest c) Sheet onto which downstream end of siphons discharge, to reduce erosion damage d) Personnel to install siphons	
3.3	Timescale before likely to have a measurable effect?	Quick once installed, but will take time to bring to site and get working	3
3.4	How likely is this measure to prevent failure?	The likelihood of success is likely to depend on obtaining sufficient size and number of pumps and getting them working in time.	3
3.5	Reliability of assessment		2
3.6	Risk to dam	Surface erosion at siphon outlets	M
3.7	Risk to personnel implementing measures	Handling heavy equipment; working in water (to fill siphons), leptospirosis	H
3.7	Risk to third parties	Conflict between pedestrians on public footpaths/ roads and vehicles bringing in plant/ materials/ labour; Increased discharges may cause local flooding downstream	M
3.8	Risk to the environment	Increased discharges, possibly with sediment if dam surface is eroded	M
		Total	8

APPENDIX D : POSSIBLE TEMPLATE FOR A SITE SPECIFIC OFF-SITE PLAN

Preface to this Appendix

Local Authorities have a statutory duty to prepare off-site Plans under several EU-derived regulations:

- Control of Major Accident Hazard Regulations (COMAH)
- Pipeline Safety Regulations (PSR)
- Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR).

The regulations include provision for local authorities to charge the owner of the hazard for the cost of preparing and maintaining these plans. This is for a variety of reasons, including that the owner of the hazard does not have legal powers to take actions off his land or to co-ordinate the emergency services.

Under the Reservoirs Act 1975 (as amended by the Water Act, 2004) there is no obligation on external agencies to prepare such plans. There is, however, no reason why an undertaker could not promote preparation of an off-site plan for his reservoir(s), if the costs were proportionate in terms of the risk reduction achieved. Nevertheless it is important that undertakers develop a good working relationship with category 1 local responders.

However, there is an obligation on local responders (who collectively constitute the Local Resilience Forum (LRF) on a non-statutory basis), under the Civil Contingences Act 2004 and associated statutory guidance (Chapter 4 of HM Govt, 2005), to assess the risk of an emergency occurring, and to use such assessments to inform their emergency planning arrangements. Local responders should therefore

a) assess the risk of a dam failure in their area (drawing upon the expertise of the Environment Agency as lead in this area), and include this in the Community Risk Register
b) consider what form of risk management is needed, based on an evaluation of all the risks in the Community risk register
c) where off-site planning is considered appropriate, consider whether it should be generic, or site (or cascade) specific (or a combination of the two approaches), who should be party to the plan, who should lead the development and maintenance of the plan, and finally how the (potentially substantial) costs associated with this should be paid for.

Key issues for each Local Resilience Forum in evaluating the justification for preparation of any generic or site specific off-site plan for a dam include

i) how the risk posed by the dam(s) compares to other risks in the Community Risk Register, and how many dams there in each risk category
ii) the resources that would be required to maintain and validate the plan(s), particularly the detailed factual appendices, for example for dam specific plans in populating
    - Appendix D with a comprehensive schedule of transport and utility infrastructure that crosses the inundation area and is likely to be severed
    - Appendix E in preparing maps of escape routes
iii) how this compares to the reduction in risk that would be achieved

It is instructive to compare the risk from dams with other risks from flooding. Once such example is for areas protected by flood walls, for example the London embayments or coastal flood defences. In this situation floods (coastal or fluvial) larger than the design standard would overtop the flood walls and inundate the protected area, which is likely to lead to loss of life and damage (as in the 1953 east coast floods, and Hurricane Katrina in New Orleans). The probability of this would typically be around 0.1% to 1% per annum, which is typically 100 more likely than dam failure. It is noted that currently there are generally no off-site plans for this hazard, either generic or site specific.

This appendix contains a generic template for a site specific off-site plan for a dam breach which has been developed by local responders based on existing multi-agency plans for dam breaches and major flood incidents on main rivers, to illustrate some of the issues that may be covered by an off-site plan for dam failure. Emergency preparedness (HM Government, 2005) also includes in Annex 5C and 5D suggested minimum contents for generic and specific plans. The plan does not seek to replicate the contents of local responders' generic plans (e.g. set out all of their generic responsibilities) and should be used in conjunction with these. Furthermore, the template is not prescriptive, but will help to guide the development of any plan seeking to treat the off-site consequences of a dam failure by the relevant agencies.

Whilst the plan has been developed as a basis for a site-specific plan, its core elements can be readily applied for use in developing more generic plans. Local responders would still need to take a view on what information specific to particular sites needed to be garnered and prepared relative to specific risks posed.

D.1 General

D.1.1 Aim of Plan

This plan provides a framework of procedures to facilitate a co-ordinated multi-agency response to the off-site consequences of a dam breach. In order to facilitate the above, the plan:

- provides clear definitions of the roles, responsibilities and actions of each agency at particular stages of the response;
- provides a response escalation procedure to cover actions from the initial alert, full plan invocation through to stand-down and post-incident recovery;
- set-out the multi-agency co-ordination and control arrangements at each level of response;
- specifies the manner in which information is communicated to the public in an accessible and consistent fashion;
- provides contact details to facilitate an efficient call-out of resources;
- identifies both areas and establishments (e.g. homes with vulnerable individuals), which are 'at risk' and which might require additional or specific assistance.

D.1.2 Scope of Plan

This plan confines itself to addressing the off-site consequences of flooding from *(Name)* Reservoir as a result of a dam breach. As such, it is focused on the areas downstream of the reservoir as depicted in the inundation map in Appendix B.

The LRF has agreed that (name of organisation) will co-ordinate the development and maintenance of this plan. This plan should be developed and used in conjunction with:

(i) the three elements of a flood plan (impact assessment, on-site plan, external interface plan) maintained by the undertaker;
(ii) any specific procedures maintained by individual partner agencies;
(iii) each organisation's generic emergency plans;
(iv) the local authority's rest centre and post-incident recovery plans.

D.1.3 Risk Assessment

Impact

A breach of the dam (or dams if this is a potential 'domino' location) is likely to cause significant consequences including

g) death and injury to those caught in the flood wave
h) the flooding, structural damage and total destruction of significant numbers of properties

i) possibly severing (or inundating and causing damage leading to shut down) of key parts of the local infrastructure, including transport (road, rail, canals) and utilities (power, gas, water, telecommunications) (see Appendix D)

As well as direct impacts in the inundation area, there will be significant indirect impacts, including compromising the ability of key agencies to respond and deploy their resources where these are needed, and the potential to cause discomfort to a wider population than that immediately affected and complicate the response.

A serious incident would require local responders to implement special arrangements for the:

- evacuation, transport, accommodation and treatment of large numbers of evacuees or casualties from the dambreak inundation area
- temporary replacement or repair to local infrastructure
- direct or indirect involvement of large numbers of people
- handling of a large volume of enquiries from the public and the media.

The degree to which there are casualties and fatalities will depend on the specific circumstances surrounding the dam breach (i.e. is it predicted or in progress ?) and whether there is sufficient lead time to facilitate a safe evacuation of communities located either close to the dam or further downstream.

Probability

The likelihood of *(name)* dam failing has been assessed by *(Name)* as being *(rating).*

Overall Assessment

The *(name)* Community Risk Register gave an overall rating of *(rating)* for this risk and called for *(details of controls).*

D.1.4 Plan Validation and Training

To ensure that this plan can be successfully implemented, it is essential that key players within participating organisations are trained to understand the key issues, their roles and responsibilities, how the plan is triggered, and how a multi-agency response will be co-ordinated. To this end, training requirements are set out in Appendix D.5.G.

In accordance with the overall assessment of risk associated with this dam, the LRF has determined that this plan should be validated through an exercise regime which is set out in Appendix D.5.G.

D.2 Roles and Responsibilities

In a dam breach incident, each agency may have responsibilities as set out below

Note

a) this list is a summary of those elements of "Emergency Response and recovery" (HM Govt, 2005) relevant to reservoir safety; that document should be taken as the governing document

b) the numbers following each agency name are the clause numbers in Emergency Response and Recovery

D.2.1 Multi-Agency Strategic Co-ordinating Group (4.1-4.111)

Co-ordinate and facilitate an effective multi-agency response, on behalf of the Local Resilience Forum. This may include

a) the decision when to initiate a large-scale public evacuation (based on information including advice from the undertaker and his technical advisors)

D.2.2 Police (3.1 – 3.5)

3.1 Overall co-ordination of the activities of those responding at and around the scene of a sudden impact emergency. This may include

a) receiving details of the initial alert from the reservoir undertaker/owner and invoking the off-site plan – in conjunction with and on advice from key partners (e.g. local authority), the undertaker/owner and reservoir engineers as appropriate – following advice that the dam has breached or is in imminent danger;
b) establishing cordons, evacuating public from properties at risk and ensuring that risk assessments occur in conjunction with partner agencies prior to access being granted to areas inside the cordon;
c) controlling and diverting traffic to prevent bow waves from flooding properties and vehicles breaking down in floodwaters;
d) providing advice and assistance to the public, including assisting in the dissemination of warnings;
e) co-ordinating the media response for the emergency phase of the incident in line with local 'emergency media protocols';
f) advising the public when it safe to return to their homes.

3.3 Facilitate enquiries carried out by the responsible accident investigation bodies
3.4 Act on behalf of HM Coroner in regard to fatalities
3.5 Co-ordinate search activities for survivors or casualties

D.2.3 Fire and Rescue Service (3.6-3.8)

3.6 Rescue of people trapped by fire, wreckage or debris. Assist other agencies in

a) removal of large quantities of flood water
b) casualty handling

3.7 Manage gateways into the inner cordon

D.2.4 Health bodies (3.9-3.11)

3.9 Co-ordinate on-site NHS response; which may include co-ordinating

a) provision of patient transport facilities to evacuate vulnerable individuals from properties at risk to hospitals, rest centres or other accommodation.

3.10 Sustain life, and transport the injured

D.2.5 Local Authority (3.25 – 3.29)

3.25 Exercise a community leadership role. This may include

a) setting-up and staffing rest centres to accommodate and feed evacuees;
b) organising the provision of vehicles to transport evacuees to rest centres;
c) setting-up a public information helpline identifying vulnerable individuals and establishments potentially affected by the incident and ensuring that appropriate measures are in place to address the needs of individuals affected;
d) identifying and implementing the closure of roads and diversion routes in conjunction with the Police and supplying appropriate signage;
e) providing sandbags to mitigate the flooding of properties;
f) clearing debris from the highway and blocked street gullies;
g) making emergency repairs to bridges and evaluating whether bridges affected by floods should remain open for use;
h) providing environmental health advice and support before and after the floodwaters have subsided in relation to: the decontamination of businesses; fitness of properties for re-occupation after cleaning and disinfection (e.g. food businesses); clean-up, clearance of sludge and drying-out in houses and flats; disease, e.g. arising from sewage mixing with water supplies; rodent infestation and animal welfare;
i) examining the safety of buildings which have experienced flooding where there are potential concerns for their structural integrity, identifying areas for remedial work and authorising repair or demolition where buildings constitute a threat to public safety.

3.26 Provide emergency mortuary capacity

D.2.6 Environment Agency (3.31 – 3.33)

3.31 Protect and improve the environment. This may include

a) supporting the operational response roles of other agencies by providing materials, equipment and staff, where resources allow;
b) operating and maintaining flood defences on main rivers lying both upstream and downstream of the dam;
c) providing updated information to the public using the Floodline service;
d) providing information to the public on the clean-up and restoration of properties.

The Environment Agency (EA) also has a statutory role under the Reservoirs Act 1975 regarding enforcement on bodies of water falling within the Reservoirs Act 1975, i.e. those that are greater than 25,000 cubic metres.

D.2.7 The private sector - Essential service providers (3.50-3.54)

These are crucial players that will work closely with emergency services and local authorities to deliver timely restoration of services and to minimise the impact on the wider community. These may include

Water Company

a) maintaining the safety and integrity of the clean and waste water systems, and dealing with flooding in public sewers
b) operating their assets connected with flood alleviation measures
c) providing information to the public on water quality and sewer flooding issues during and following floods using telephone helplines etc.
d) ensuring that blockages in its sewer system are cleared prior to and following a flood.

Electricity Distribution Company

a) maintaining the safety of the electricity supply system; including emergency shutdown of installations that may provide risk to the public if damaged by a dam break
b) liaising with the Fire and Rescue Service and others regarding pumping operations at substations;
c) obtaining pumps to maintain its continuity of electricity supply as long as possible and where it is safe to do so;
d) informing the Police and local authority as soon as practicable in the event that the substations need to be shut down;
e) seeking to provide alternative means of supply during the interruption and restoring power as soon as possible.

Gas Network Provider

a) maintaining the safety of the gas supply system; including emergency shutdown of vulnerable mains across the flow path
b) obtaining pumps to maintain the continuity of supplies at key locations;
c) informing the Police and local authority as soon as practicable in the event that the key supply points need to be shut down;
d) seeking to provide alternative means of supply during the interruption and restoring power as soon as possible.

D.2.8 The private sector -Other private sector organisations (3.55-3.57)

These may play a direct role in the response to emergencies, especially if their organisation is the cause of an emergency (e.g. industrial incident at their premises), is affected by an emergency or can provide resources required to mitigate the effects

The Reservoir Undertaker

a) ongoing surveillance and situation assessment
b) implementing a range of measures to avert failure, including those in their on-site plan;
c) notifying the Police (and local authority, as appropriate) of as accurate information as possible as soon as possible following any identification of any significantly increased risk of dam failure or actual occurrence of a dam breach together with any relevant details (e.g. status of warning; anticipated failure mode; actions being taken to avert failure; estimated probability of failure and likely timescales) in line with arrangements set out in the flood plan, to facilitate an informed decision on evacuation.
d) providing a knowledgeable person to multi-Agency meetings to assist with deliberations and decision-making
e) participating in control arrangements for the off-site response and providing timely updates on the progress of the incident.

D.3 Coordination and control arrangements

D.3.1 Activation and Incident level

Where the undertaker (dam owner) considers there is a significantly increased risk of dam failure, they should notify this to the Police (and local authority emergency planning officer, as appropriate) in order to consider activation of this off-site plan. A system of specific trigger levels has been developed for use in this plan (see Table A.2) which provide for a proportionate response dependent on the circumstances pertaining (e.g. whether dam failure is possible, imminent or has already happened). The organisation receiving the alert makes arrangements for the activation of the plan as appropriate in conjunction with the relevant partners.

D.3.2 Multi-agency Gold, Silver and Bronze Controls

(1) If a dam breach is occurring or deemed imminent, it is expected that the initial alert or notification would be provided by the undertaker to the Police for activation of the off-site plan. The Police would then activate the plan and instigate the co-ordination of the multi-agency response of the emergency services, local authority and other key partners under the control of the Police's Silver Commander at ….

(2) The Police may set-up a Strategic Control (i.e. Gold or Strategic Co-ordinating Centre) at its Headquarters to provide appropriate leadership at the most senior level.

(3) Key players are also likely to have an Operational (Bronze) Control in place close to the scene in areas affected by flooding. The Bronze Commanders will liaise with staff from other agencies at the scene to ensure a co-ordinated response. Details of the control points to be used are located in Appendix 5.

D.3.3 Other Agencies' Control Arrangements

Each organisation represented in this plan operates a control centre from which it co-ordinates its response to the major flood incident. The control centres normally transmit their requests for assistance or information on their actions to the Multi-agency Gold or Silver Control.

D.3.4 Public Warning and Information

Following the implementation of a multi-agency control centre, co-ordination of public information is undertaken by the Police PR function in accordance with local emergency media protocols and specific contingency arrangements set out in Appendix D.5.F. The Police PR function should liaise with the press officers from its partner agencies to ensure a consistent message is communicated to the public. Each organisation mobilises its emergency communications or public information arrangements to complement the activities of the Police.

Information to the public could be provided through:

a) systems in place in the relevant area which may be used to provide warnings of an imminent dam breach: *(list e.g. specific sirens, EA Multi-media messaging system etc)*
b) specific internet sites used for emergencies *(list)*
c) public information lines invoked for the event;
d) local multi-media alert systems.

The dissemination of these warnings may be backed-up by the use of the loudhailer vehicles, the Police undertaking door-to-door knocking or using a Police helicopter's 'Skyshout' system.

D.4 Action

This section should summaries the actions taken by each organisation at each level of incident, with details set out in each agencies plan.

Standby	This section details the actions taken by each organisation following notification that a dam breach is possible (in line with advisory or alarm stages of on-site plan).
Implementation (Imminent or Actual Dam Breach and Flooding)	This section details the actions taken by each organisation following the failure of the dam(s) or where such an event is deemed imminent.
Stand-Down And Recovery	This section details the actions taken by each organisation as floodwaters subside, following the dissemination of an 'All Clear' communication or a return to properties being permitted by authorised agencies. This section should be cross-referenced to any generic recovery plans co-ordinated by the local authority.

Table D.1 : Trigger Levels for Implementing the Off-Site Plan to Respond to Potential and Actual Dam Breaches

Level	Trigger	Actions Taken and By Whom ?
Standby[1]	A dam breach is possible (in line with advisory or alarm stages of the on-site plan, as shown in Table 4.4).	Undertaker alerts Police (and LA EPO, as appropriate) with situation report. Police contacts all relevant partners to place on standby and to undertake any preparatory measures appropriate to the situation, including the implementation of preliminary control and co-ordination arrangements.
Implementation	Dam failure is deemed inevitable or imminent or actually fails (in line with the imminent failure or Failed stages of the on-site plan)	Police implement plan in conjunction with partners undertaking all necessary actions in line with roles and responsibilities outlined. Police implement all relevant control and co-ordination arrangements.
Stand-Down and Recovery	Decision taken by partner agencies that initial response phase of emergency has been completed and steps should be taken towards the restoration of normality.	Partners issue an 'All Clear' communication and advise whether a return to properties might be permitted where appropriate. Multi-agency Gold considers the transfer of the responsibility for leading the recovery to the appropriate agency and what next steps need to be taken.

Notes

1. This may be relatively frequent, for example at a major London NHS hospital in the last ten years standby has been declared several times a year, but only three of these have escalated to the status of a major incident.

D.5 Appendices to possible off-site plan

D.5.A Contact numbers for key players

To be completed

D.5.B Useful Background Information

a) Description and OS map of the location of the reservoir(s);
b) Description of local communities and census data on composition of local population (size, age, ethnicity, language etc);
c) List of information available in Undertaker's flood plan (or reproduce sections)

D.5.C Schedule of the Vulnerable

a) Description, details and maps of vulnerable establishments located in inundation area (e.g. schools, hospitals, residential homes, sheltered housing) together with estimated times for floodwaters to reach these locations;
b) Procedure for accessing details of vulnerable individuals from the data-owners.

D.5.D Schedule of Critical Local Infrastructure

Details of infrastructure in areas likely to be affected, including maps and schedule of key elements with both isolation points to minimise consequential damage (e.g. allow closing of major gas mains to reduce risk of explosions and fire) and for priority reinstatement:

a) road network with maps identifying arterial roads and bridges;
b) rail infrastructure and utility services with maps identifying lines
c) power and gas supplies with maps identifying power and gas lines/electricity substations
d) telecommunications links
e) clean and waste water assets

D.5.E Schedule of culturally and environmentally sensitive areas

Details of any sites with statutory designation e.g. Ramsar, SSSI.

D.5.F Specific Contingency Arrangements

Description and map of location of

a) control points and rendez-vous points (RVPs);
b) road blocks/closures and diversions;
c) evacuation priorities, escape routes, evacuee assembly points and premises requiring special consideration;
d) specific rest or reception centre arrangements for this scenario
e) Contingency arrangements for utility loss (heating and light; emergency communications; potable water)

D.5.G Detailed risk assessment

D.5.H Details of plan validation and training arrangements

D.5.J Public information arrangements

These should cover both proactive public information and reactive alert or warning messages in the event of an actual incident.

D.5.K Log of plan validation (exercise) and training