The Management of Losses Arising from Extreme Events

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D E A Sanders (Chair)

Anders Brix

Paul Duffy

Will Forster

Tony Hartington

Gavin Jones

Charles Levi

Paddy Paddam

Dimitris Papachristou

Geoff Perry

Stephen Rix

Fiona Ross

Andy J Smith

Anup Seth

David Westcott

Mark Wilkinson

Contents

1. Introduction

1.1 This paper explores extreme events and their impact on the insurance market.

There are 5 basic sections

The first of these relates to a description of the types of events that we need to consider. The appendices give fuller details and data relating to the risks. These form an historic perceptive of the issues.

This is followed by an explanation of Extreme Value Theory. Accompanying this paper is an Excel spreadsheet with worked examples.

The next section deals with the various cat models that are used in the market. At the end of this section we consider the differences between the bottom up approach from cat modeling and compare with EVT as a top down approach.

Finally we deal with the management of extreme events and look at realistic disaster scenarios and consider risk measures.

1.2 We conclude with a section that brings all these issues together. If the world's to globalise then the final conclusion is that the growth of mega cities and mega risks combined with a limited number of ultimate risk takers will mean that there is insufficient world wide insurance capacity to deal with many of the realistic loss scenarios, and that matters will not improve as the process continues. The main alternative is to rely on the wealth of the financial sector to absorb these losses which are minimal compared with daily fluctuations in asset values.

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2 Extreme Events

2.1 Weather Related Events

Is it as bad as it can get?

2.1.1 We all complain about the weather and the fact that it is getting wetter, warmer, colder and so on. Summers in our youth were always better than those of today. We have great difficulty in predicting weather – in fact a good predictor for tomorrows weather is that it is the same as today's!

2.1.2 We appreciate that the Earth's weather is a hugely complex system, with multiple interacting elements. Because they defy simple expression, meteorologists rely on a "bottom up" approach to modeling the climate. They divide the world into boxes, model the forces on the atmosphere and oceans in each box, and then guess the overall effect. This is the approach used in Cat modeling. However to make the approach work you often need to include a number of "fudge factors" to make the models fit with known events.

2.1.3 Alternatively we have the top down approach. The entity that drives the complex system is the Sun. Solar energy warms the Earth, and it does so disproportionately, heating the tropics much more than the poles. This creates a temperature gradient with the effect that heat goes from low to high latitudes and drives the climate.

2.1.4 This heat flow from the tropics to the poles reflects the second law of thermodynamics, which states that heat flows from warm to cold regions and never the other way round. This heat flow produces mechanical work in the atmosphere and oceans. The dynamical system is lifting water to drop as rain or snow, whipping up waves and blowing sand into dunes. One critical element is that the second law of thermodynamics gives no indication of the speed that the process takes place.

2.1.5 We know that if the process is fast then temperature throughout the world would be the same, and if it were slow then Northern Europe would be in an ice age. The reality is somewhere in between.

2.1.6 Garth Paltridge, an Australian climatologist now at the University of Tasmania, experimented with a model of the Earth divided into latitude zones with different amounts of sunlight and cloud cover. One of the free parameters of his model was the heat flow between the zones. Paltridge found that if he set this factor so it maximised the production of the thermodynamic quantity called entropy, the results modeled Earth's climate well. Entropy production is a measure of the generation of disorder, and it is closely related to a system's capacity for mechanical work. Both quantities peak at about the same heat flow. The same theory has been tested and appears to work on the moons of Jupiter.

2.1.7 Most orthodox meteorologists dismiss the result as an uninteresting fluke. There's no reason why the climate should maximize entropy, or the work done. However, if it is not a fluke then we can see that the earth's dynamical weather system has limits on the extreme events. This top down approach is equivalent to an Extreme Value approach to weather events, whereas the bottom up approach is equivalent to Cat Modeling. The theory is being tested on other bodies in the solar system with positive conclusions.

2.1.8 In the appendices we set out a number of weather events that give rise to large insurance claims. These include Hurricanes, Tornadoes and Floods. If the historic hurricanes were repeated today, then the largest one would potentially give rise to a loss of $90 billion. In the 1980's the industry was concerned with two $6billion hurricanes hitting in one year.

2.1.10 Europe has been hit by storms – the recent European storms in France have been estimated from Cat models as being “as bad as it can get”. However we often fail to recognise that the losses may arise from other sources. It has been estimated that the Floods following the 1947 winter, if repeated, would give losses twice as high as Storm 90A at about $4bn.

2.1.11 Finally we need to consider the impact of climate change, and the two key weather driver, the Southern Ocean Oscillation (and EL Nino) and the North Atlantic Oscillation.

2.1.12 All of these events are all summarised in the various appendices.

2.2 Geological events

Uncertainty v Predictability

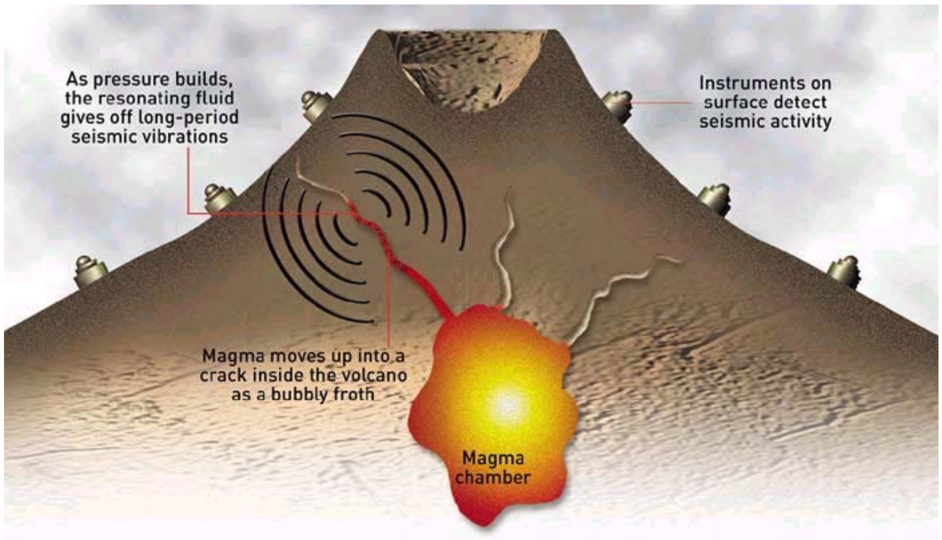
2.2.1 Geological events differ from weather events. We know that earthquakes occur at tectonic boundaries, we know where volcanoes are and earthquake Tsunami tend to impact on coasts. However meteorite or comet collisions can occur anywhere.

2.2.2 What has proven to be more difficult is to determine when an event is likely to occur with sufficient time to minimise loss.

2.2.3 Prediction in respect of volcanoes has improved considerably in recent years. The factor appears to be long period events or resonance in magna discovered by seismologist Bernard Chouet from the US Geological Survey in Menlo Park. Using these techniques, on 16 December 2000, a warning was issued that the Popocatepetl volcano in Mexico would explode in exactly two days’ time. On 18 December, Popocatepetl unleashed its largest eruption for a thousand years.

2.2.4 The approach, however, gives no indication of the size of the eruption.

With Earthquakes, there is no predictive formula. The predictive Parkfield quake, which is supposed to occur regularly every 20 years, is now well overdue.



Chouets Volcano Predictions – (New Scientist 12 January 2002)

2.2.5 Most theories regarding earthquake predictability are controversial, found wanting and untested. A recent method has come from geophysicist Didier Sornette, who claims that there is a subtle underlying signal, common to many catastrophes, that can sound the alarm before it's too late. Sornette, in analyzing the rupture of materials such as concrete, has modelled the breakdown as a network of growing and interacting microcracks that finally result in rupture. Sornette found that the rate at which these growing cracks released energy was correlated with the time left before the material suffered catastrophic failure. In other words, the cracks-even the seemingly insignificant ones-give you a countdown to disaster. The pattern is a little trill appearing at intervals in the recording, a bit like the chorus in a song that grows higher and higher, with ever smaller gaps between repeats, until suddenly the material breaks.

This is similar to the volcanic analysis, and should be in the seismic data, 2.2.6 The most dangerous geological event is the meteorite/comet collision. It has been shown that, on average, 3,900 people die each year as a result of meteorite collision (See Appendix 13). This compares with about 700 deaths per annum from civil aircraft. The uncertainty of the event and the inability to predict makes analysis virtually worthless. However, the Tunguska event destroyed an area similar to that of London with the M25 as the edge. The loss of life would be in the millions and the loss of value immeasurable.

2.3 Man made Events

We have used the term Man made events as a generic term for the residual classes. These exclude losses arising out of financial extreme events (e.g. Enron) which will be the subject of another (later) paper.

2.3.1 Explosions/Fires

Explosions and Fires are regular occurrences. However, there have been some very major explosions. The three largest ones covered in Appendix 13 are Halifax Explosion 1917, the Texas City Explosion (1947), Piper Alpha (1987) and Toulouse (2001). The most devestating explosions tend to be either chemical fertiliser or petroleum based. These events are expensive but tend to be local. Other UK specific losses are Flixborough and more recently Corus (2001) explosion.

2.3.2 Motor

Major motor losses are of two types. Either one vehicle causes considerable damage (for example Selby), or there are other events which have severe consequence- for example Alpine tunnel fires, motor claims associated with WTC, or Hail storms (Munich). These have tended not to cause significant cataatrophe losses. Private Eye has estimated the total cost of Selby as £1.4bn, although this is not all insured!

2.3.3 Aviation Disaster

Set out in Appendix 13 are summaries of the largest aviation disasters. These are all well documented. On average 700 lives are lost in commercial aviation losses each year.

2.3.4 Marine Disasters

Excluding ferry losses in Philippines and World War 2 losses in the Baltic, the major marine disasters involving loss of life are Titanic and Estonia. There are in excess of 380 vessels sinking (or being total losses) every year.
Claims excluding loss of life include pollution spills. The most expensive loss was Exxon Valdez (36,000 tons). However this ranks only 35th in terms of largest spill. Other spills are Atlantic Express (300,000 tons off Tobago 1974), Castillo de Belver (272,000 tons off Cape Town, 1979) and ABT Summer (268,000 tons off Angola, 1991). UK includes Torrey Canyon (117,000 tons, 1967) and Amoco Cadiz (223,000 tons, 1978). A marine explosion could be very devastating (Piper Alpha).

3 Extreme Value Theory

3.1 Overview

3.1.1 This summary briefly introduces the key results for application of Extreme Value Theory (EVT). The key idea is that there are certain families of distributions (the Generalised Pareto and the Generalised Extreme Value) which describe the behaviour of the tails of many distributions. Therefore to understand the behaviour of extreme events whose behaviour is controlled by an underlying distribution we should apply EVT in order to extrapolate the tail of the distribution from the underlying data.

3.1.2 There are applications to many typical insurance problems including

Pricing of insurance products
Exposure to Catastrophic risks
Choice of reinsurance strategy
Cost of reinsurance
Asset risk
Investment risks and hedging
Risk management & Solvency exposure

3.1.3 The aim is to outline the basic results with which an actuary can begin to apply EVT. Therefore a brief introduction discusses the key results and potential impact of an EVT analysis, the underlying mathematics is summarised and the results are then illustrated with a particular example calculated using an accompanying spreadsheet. At the end a survey of current literature is given. It is the intention that a reader will be able to apply simply key results of EVT, by use of the accompanying spreadsheet model (web address). The application is illustrated in the example section

3.1.4 EVT is underpinned by work describing the extreme behaviour of random processes. This work is not reviewed here, there are many excellent references described later which give a thorough description of the theory.

3.2 Introduction

3.2.1 Suppose we wish to price an insurance contract and we have loss data $x_1, x_{2,\ldots,} x_n$ from previous years available. Typically one would fit a distribution to the historical data and derive from this the expected cost and risk. Implicitly one is assuming that the historical data is *independent* and *identically distributed*. In practice these assumptions never hold exactly but we can assess the goodness of fit by comparing with the historical data. However it is difficult to validate the fit in the tails of the distribution due to the limited data, furthermore it may be that the extreme observations may follow an unusual distribution due for example to a different process underlying the extreme observations.

3.2.2 In any event if a contract price is dependent on the tail of a distribution it may make sense to fit a separate distribution to the extreme observations. This is the context in which EVT operates. Instead of selecting an arbitrary distribution based on a choice dependent on the main portion of the data (e.g. lognormal), or external information (PML) one should seek to understand the tail of the distribution and then use this insight. EVT provides a mathematical foundation for using a specific family of distributions to describe extreme observations.

3.2.3 Two main results of Extreme Value Theory may very roughly be stated as

1. The distribution of the maxima $M_n = \text{Max}\{x_1, x_{2,\ldots,} x_n\}$ is approximately described by the Generalised Extreme Value (GEV) family of distributions for n sufficiently large

This helps answer questions such as, “what is the maximum loss I can expect in one year?” and has lead to the use of EVT in assessing the impact of natural events, being used in the determination of appropriate coastal defences.

2. The tail of the distribution above a threshold, Pr(Y>y+u|Y>u), can be approximated by the Generalised Pareto Distribution (GPD), for large u.

This can answer questions such as “what is the expected loss to this layer?” and is useful for Excess of Loss pricing and risk management purposes.

3.2.4 These results are particularly useful when considering events that might give rise to observations larger than those previously observed – for example potential catastrophe costs. In this case the empirical distribution gives no direct information on the tail of the distribution and EVT provides a rigorous framework within which to make judgements on the possible tail.

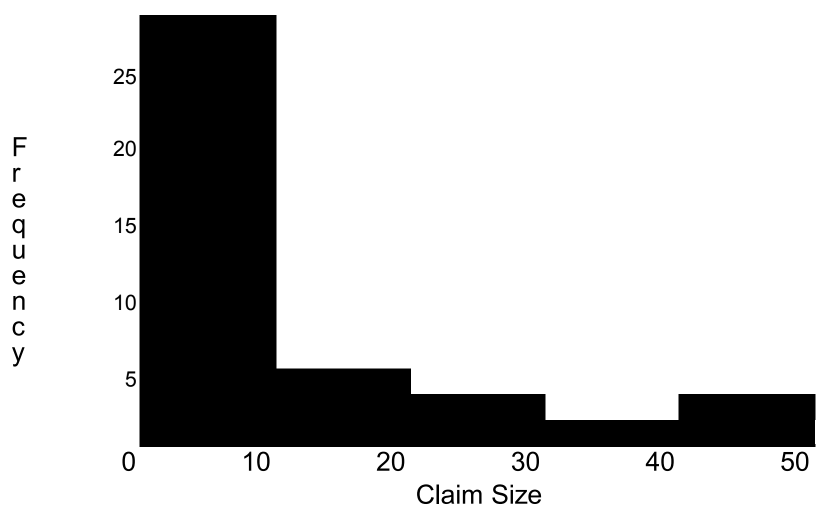
3.2.5 The precise circumstances under which the results on the GEV and GPD apply have been left vague. Where all the data is i.i.d. the results hold, and often in much weaker circumstances. The weakest hypotheses under which results may hold are still the subject of active work and the reader is referred to the various reference works for full statements.

3.2.6 Of course there is still very limited data to fit to the EVT distributions so significant elements of uncertainty remain due to the large bias that must exist in any estimate. However the existence of a rigorous framework offers a theoretically sound context in which to assess extreme risks.

3.2.7 An example of the use of EVT is as follows (this example by Mark Dixon of City University). Data for windstorm claims in Sweden is shown for the purpose of insurance pricing. The following graph illustrates the claims, to an excess layer, in Sweden over a 10 year period. The graph shows claims size on the horizontal axis as against claim frequency on the vertical axis. In order to estimate the risk premium for insurance cover of this risk one needs to understand the distribution which for example will allow one to estimate the mean claim size. In particular this requires an understanding of the likely impact of large claims, and hence the ability to extrapolate a distribution underlying the data.

Graph 1

Swedish Windstorm Claims



Typical estimates for the mean claim size, either directly from the data or fitting a distribution (such as the lognormal) give a mean claim size between 7 and 10.

3.2.8 Applying Extreme Value Theory allows one to choose a tail distribution with some theoretical justification. Applying EVT (fitting a Generalised Pareto Distribution to the tail) one obtains a mean claim size close to 14 – in other words fitting an extreme value distribution suggests a very different tail underlies the risk than might be assumed from the data. This implies that the likely risk premium charged under a conventional analysis would be incorrect. As it happens the next year saw wind storm with a claim size of over 100.

3.2.9 This both illustrates the difficulties of trying to take account of extreme events and the potential benefit that Extreme Value Theory can bring. Any analysis which failed to bring to bear the techniques of EVT is likely to fail to extract the most information available from the data about the tail of the distribution.

3.3 The Extreme Value Distributions

This section outlines the details of two key extreme value distributions, the Generalised Extreme Value distribution (GEV) and the Generalised Pareto distribution (GPD).

3.3.1 The Generalised Extreme Value distribution

The GEV family describes the distribution of the maxima of sets of observations. A typical application would be to consider the largest annual claim Y under a given insurance contract (assuming the underlying risks and exposure are independent and uniform). The behaviour of the annual maximum Y (suitably scaled and translated) is then approximately described by one of the GEV family of distributions, given by the cumulative distribution function:

$$P(Y < y) = GEV(y; \xi, \mu, \sigma) = \exp\left(-[1+\xi(y-\mu)/\sigma]_+^{-1/\xi}\right)$$

For $\mu,\sigma>0$ and $\{y: 1+\xi(y-\mu)/\sigma > 0\}$, the notation $[y]_+$ denotes max(y,0).

As ξ tends to 0 the GEV converges to the Gumbel distribution

$$P(Y,y)=F(y)=\exp(-\exp(-(Y-\mu)/\sigma))$$

Here the key parameter is ξ, the shape parameter and μ,σ are location and scale parameters respectively. If $\xi < 0$ the distribution ('Weibull') has a finite upper bound indicating an absolute maximum, so one might expect to fit such a distribution to the ages of a human population indicating an upper bound to possible age.

For $\xi>0$ the tails of the distributions becomes heavier with infinite variance and this is typically the subset of distributions ('Frechet' distributions) with which one would be concerned for extreme insurance events.

This result due in various parts to Fisher, Tippett, von Mises and Gnedenko is known as the 'Extremal Types Theorem', classifying the extremal behaviour into one of three families of distributions.

3.3.2 Application of GEV

In order to apply the GEV to a data set one would first collate the data into an appropriate grouping. For example considering maximum annual losses for a particular contract. This might require adjustment for exposure, decision as to whether certain events were single or separate, and a check that the behaviour of the observations was reasonably independent. Then using a maximum likelihood estimator or method of moments one would parameterize the GEV.

Though the GEV is very helpful it only offers partial information on the probable tail distribution. There are also issues with deciding on an appropriate block of data (annual, monthly, when are two events distinct) and possible non-stationarity of any underlying time series.

In order to properly understand the underlying distribution one would fit a standard distribution to the bulk of the data and then truncate the standard model and apply EVT to analyse the possible tail behaviour.

3.3.3 The Generalised Pareto Distribution

Over some threshold the Generalised Pareto Distribution (GPD) approximates most distributions. Therefore to fit the tail of a distribution (to price a high XL layer for example) one needs to select a threshold and then fit the GPD to the tail . For many insurance pricing purposes this is more convenient than the GEV. This approach is sometimes known as 'Peaks over Threshold'.

Suppose Y is a random variable (e.g. claim size) then the following result, due to Pickands and Balkema-De Haan, describes the tail.

(†) $\Pr(Y>y+u|Y>u) \approx G(y; u, \xi, \sigma) = [1+ \xi y/\sigma]_+^{-1/\xi}$, for $y>0$.

Here the distribution function 1-G is the GPD, and the scale parameter σ depends on the threshold u. The shape parameter ξ is the same parameter which appears in the GEV and therefore controls the weight of the tail. The symbol $\approx$ indicates an approximation, which improves with u. As u increases and the approximation improves then for y>u, large u we get

(‡) $\Pr(Y\leq y) \approx 1- \lambda_u [1+ \xi (y-u)/ \sigma]_+^{-1/\xi}$

Where $\lambda_u = \Pr(Y>u)$.

3.3.4 Application

Here, rather than deciding on the periods over which we are taking maxima which is the key decision on the underlying data for the GEV, we are required to decide on the threshold u after which we will approximate the underlying distribution by the GPD. The trade-off is between the quality of the approximation to the GPD (good for high u) as against the level of bias in the fit we achieve (good for low u as there is more data to fit the GPD). Typically one may choose u around the 90%-95% quantile.

In order to fit the GPD to a dataset we need then to select a threshold u so that the asymptotic result (†) holds.

Then we need to estimate the probability λ_u of exceeding this threshold, and the parameters σ and ξ .

In order to select the threshold the key result (‡) is that for a GPD the mean exceedance of a threshold is linear in u – i.e. if you graph the excess of the GPD random variable Y over the threshold u as u varies the plot will be linear.

(*) $E(Y-u|Y>u)$ is linear in u for Y a GPD.

Therefore to fit a GPD to a random variable (say a claim amount) first of all plot the mean exceedance of the random variable, $E(Y-u|Y>u)$ against u. After some threshold point, u say, the fit will approach linearity. Above this point fit a GPD to the data by calculating λ_u and then using standard techniques (MLE,MoM) to calculate ξ and σ.

For the distribution below the threshold u one can fit the data using a standard distribution (e.g. normal, or bootstrap the empirical results) truncate it at the threshold u and above it apply the GPD.

Significant judgement may be required in choosing a threshold u to fit the GPD. As well as the trade-off between asymptotic accuracy and bias there may be difficulty in deciding at which point the mean exceedance has passed into a linear regime. The use of the mean exceedance plot is therefore a key diagnostic test in fitting a GPD and requires a certain amount of judgement to choose the threshold. But just because some level of judgement is involved does not mean that the results are invalid – all actuarial techniques require judgment to be exercised and the use of extreme value theory highlights the role of that judgement.

3.4 Example and Application

In this section we review two examples using an accompanying spreadsheet. They are designed to illustrate the application of EVT and some of the features that distinguish it from other analyses.

3.4.1 Introduction

The GPD spreadsheet is a simple tool to help decide whether a particular set of data is suitable for extreme value analysis, and, if so, to provide parameters for a generalised pareto distribution (GPD). This relates to the second of the two main results of EVT as stated above; i.e. that the tail of a distribution above a threshold can be approximated by a GPD. It is thus possibly suitable for deriving a severity distribution for large loss data.

The dataset used in this example is listed in Appendix 16. The data comprises large losses above a certain threshold, which have been adjusted for inflation.

3.4.2 Remarks regarding the spreadsheet

The spreadsheet uses Excel's Solver add-in. For this to work, you need to have it installed and to have a reference to it for VBA (Visual Basic for Applications). Instructions for how to do this are included on the "Read Me" worksheet of the spreadsheet.

3.4.3 How to use the spreadsheet

To start with, do the following:

1) Paste the data into the worksheet "GPD"
2) Set the threshold to the value of the lowest data point (in this case approximately 406,000)
3) Press the "Estimation" button
4) Press the "Validation plots" button
5) Press the "Envelopes" button

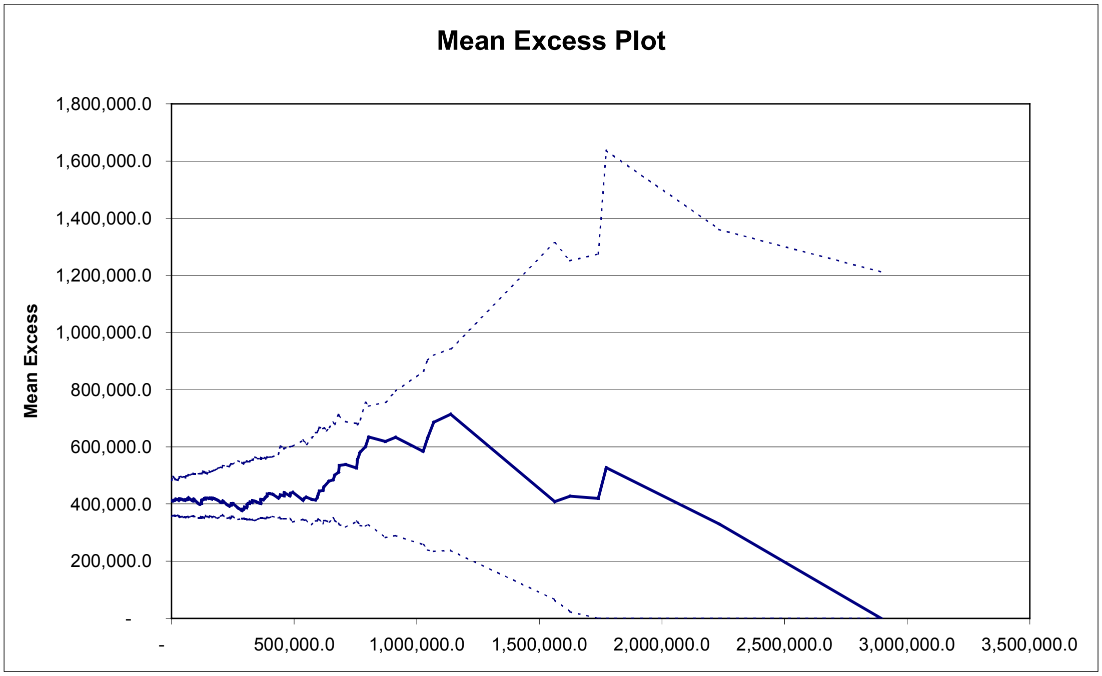
Now look at the various plots in the spreadsheet in order to assess the fit of the model. Each plot displays envelopes (the dotted lines), which represent 90% confidence intervals for each point on the plot. There are four plots, which are briefly described below. Note that the data values these plots use are the original data values minus the selected threshold.

3.4.4 Mean Excess Plot

This plots each data value against the average amount by which the larger values exceed it. For example, in the sample dataset, the value 306,119 (which is in column I on worksheet "GPD", and corresponds to an original loss amount of 712,119 minus the threshold of 406,000) has a mean excess value of 387,397. This is calculated as the average of all the values from 306,119 and higher, minus 306,119.

For a GPD, the mean excess function is linear. If the plot becomes approximately linear in the tail, it is an indication that the GPD might be a good fit to the tail of the data. If no part of the plot is linear the GPD is not an appropriate fit to the data. However because of the universal features of the GPD it will fit a distribution at a sufficiently high threshold.

For the example dataset the following plot is obtained:



Here one might decide that the graph is approximately linear from the chosen threshold (of 406,000) or at a higher threshold (of around 1,000,000 say). Both choices would fit the GPD, however they would fit the GPD with different parameters. At the chosen threshold of 406,000 there are 123 datapoints included. At a threshold of 1,000,000 this reduces to 28. The trade-off between approximation to the underlying distribution (good for high threshold) and bias (good for low threshold) is particularly brutal in the world of extreme values. As a rough observation significantly fewer than 40 observations can make the GPD fit quite variable. At a threshold of 1,500,000 there would be just 7 observations used to fit the GPD. Clearly each one of these observations can have a significant impact on the fitted distribution.

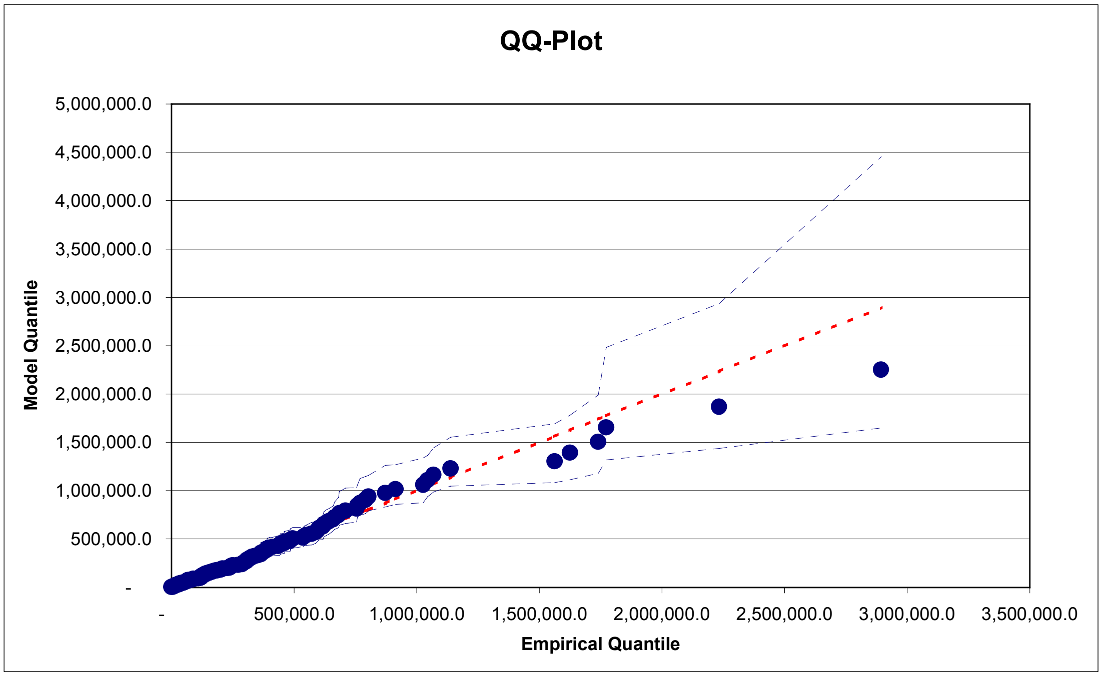
One significant observation is that at the chosen threshold the mean excess plot is broadly speaking flat. At a higher threshold the mean excess plot decisively slopes downward, this change would point to a significant difference in the parametrization of the fitted distribution at the different thresholds.

3.4.5 QQ plot

This plots the data values against the equivalent quantiles for the parameterised GPD.

For example, in the sample dataset there are 123 data values (when the threshold is set to 406,000). The value of 306,119 is the 62nd highest value, which is equivalent to the median (50th quantile) in the empirical distribution. This value is plotted against the 50th quantile of the GPD, which is 269,184. A “perfect” fit would result in a line y = x. How close the QQ plot is to this line is a measure of goodness of fit. Drift away from this line in one direction indicates that the underlying distribution may have a heavier (or lighter tail) than the fitted distribution. For the sample dataset the fitted distribution appears to have a heavier tail than the empirical distribution as the higher empirical quantiles lie beneath the line y=x. This corresponds to the drift downward in the mean excess plot, which indicates that a higher threshold chosen would lead to a less heavy tail in the fitted distribution.

For the example dataset the following plot is obtained:



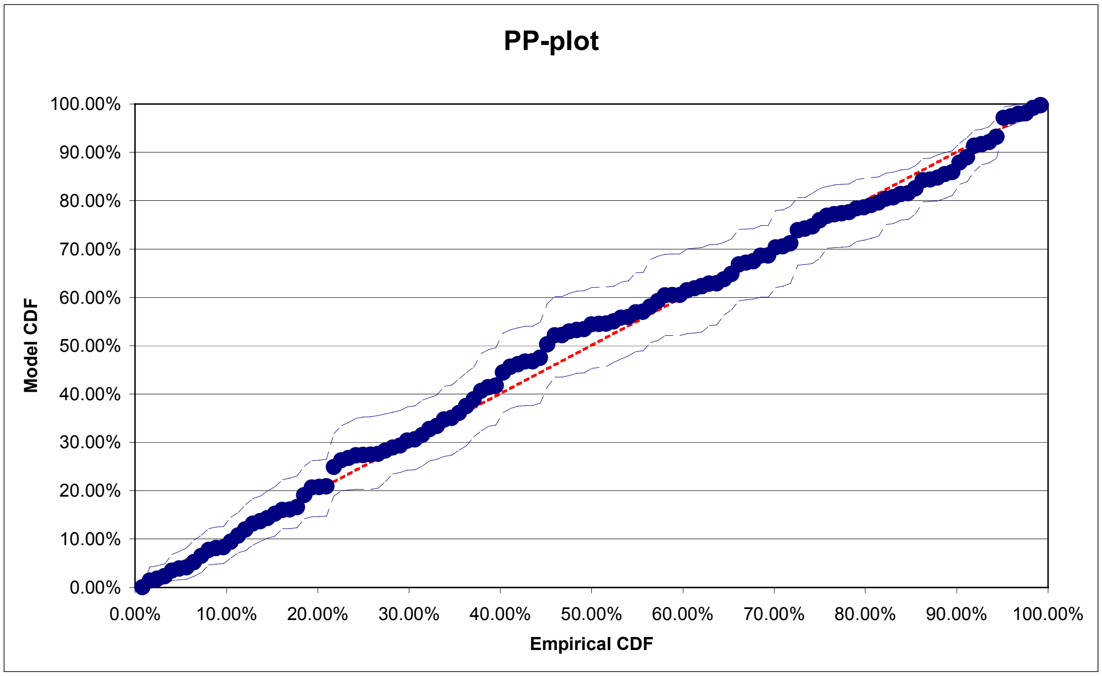
3.4.7 PP plot

This plots the percentile of the empirical distribution for each data value, against the implied percentile of the GPD for the same value.

For example, the value 306,119 is the 50th quantile of the empirical distribution and t he 54th quantile (approximately) of the GPD. As with the QQ plot, a "perfect" fit would result in a line y = x.

The QQ plot is better than the PP plot when assessing the goodness of fit in the tail of the distribution: the values of the PP plot will tend towards 100%, so a bad fit in the tail is not always apparent.

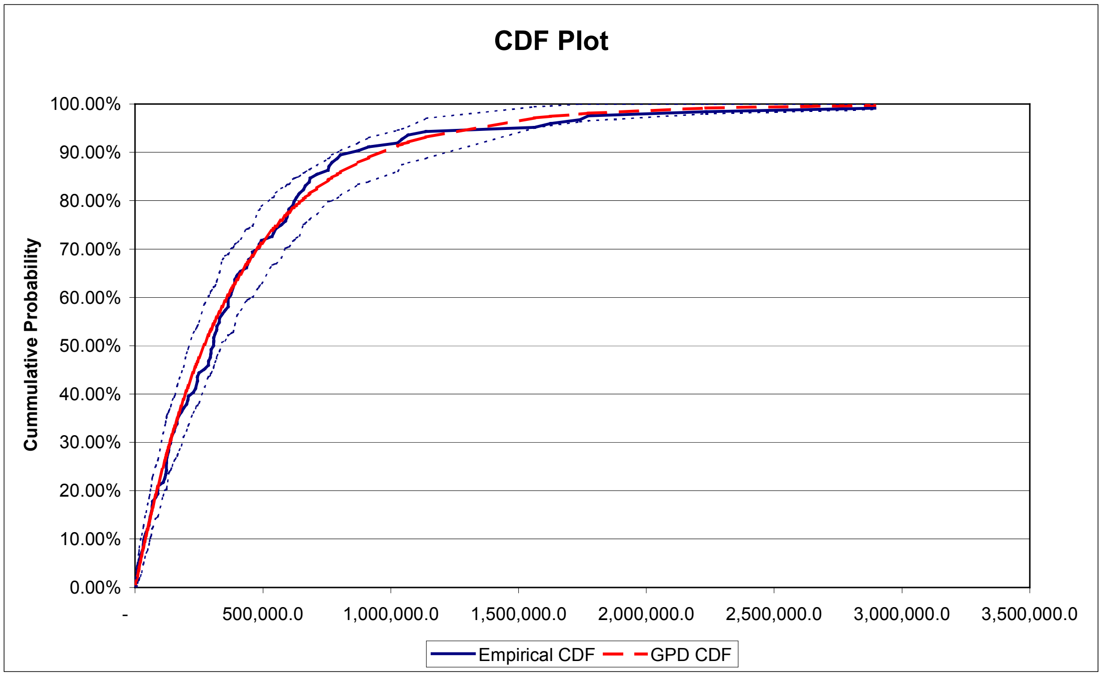
For the example dataset the following plot is obtained:



3.4.8 CDF plot

This plots the empirical CDF against the GPD. The same comments as for the PP – plot apply in that both the empirical and the fitted distribution must both converge to 100% and so a poor fit in the tail may be obscured.

For the example dataset the following plot is obtained:



All these plots remain within the envelopes, therefore we can reasonably conclude that the GPD is a good model for this data.

In this particular case it is not surprising that the whole dataset is a good fit, as it comprises only losses over a threshold; i.e. the dataset already represents the tail of an underlying distribution, however it has been argued that all insurance losses are over some (low) threshold.

If the plots suggest that a good fit has not been obtained, increase the threshold and repeat steps 3 through 5 above, until either an acceptable plot is obtained or it becomes clear that a GPD is not a good fit. As often occurs, there might be a trade-off between goodness of fit and quantity of data, in which case there is no definitive answer and judgement must be applied. In situations with smaller datasets the application of judgement becomes key and a variety of possible distributions are justifiable in the same way that significant variation may emerge through different Cat models.

4 Catastrophe Models

4.1 Structure Of Cat Models

Cat models consist of a number of modules;

1. The **Stochastic Module** which is used to randomly generate the catastrophic events.
2 The **Hazard Module** which is used to determine the geographical effect of a catastrophic event brought about by variations in Topography. E.g. regional flood depths, lower wind speeds in sheltered areas etc.
3 The **Vulnerability Module** which is used to calculate damage to buildings, contents and business turnover based on a number of factors including, for example
Building Type: Residential, Commercial or Agricultural,
Building Design and Construction Quality,
Building Height/number of floors,
Occupancy Type, and so on

4. The **Financial Module** which quantifies the financial loss to the insurer.

4.2 Overview of existing models

This overview is not exhaustive. Indeed, from the data in the appendix it is possible to create a simplified US Hurricane model. Certain models included detailed explanations of what they do; others restrict the information to users alone. We have tried to include the main ones of the first category and excluded those from the second.

4.2.1 Europe Storm Cat Models

4.2.1.1 RMS Europe Windstorm

This model covers windstorms in Belgium, Denmark, France, Germany, Luxembourg, Netherlands and the UK. Windstorm losses can also be linked with the corresponding losses from RMS East-Coast UK Storm Surge Flood model using a package called "RiskLink.

The Model is based on the following components

Stochastic Component:

In Europe, no single agency or publication has created a consistent catalogue of significant windstorms over the past century. Accordingly RMS created its own catalogue of windstorms by analysing:

- (a) more than 2,000 of the most significant storms in the Atlantic-European margin dating back to 1869;
- (b) highly damaging storms back to the 14^{th} century;
- (c) data from over 150,000 weather maps.

The RMS catalogue was used to generate 17,230 unique stochastic storm events. The storm probability is based on 13 key parameters (e.g. size, location, severity).

Hazard Component:

This is based on topographic features. Surface roughness factors are derived from high-resolution (1km grid) data.

Vulnerability Component:

Separate damage curves were derived for 12 regions within the 7 core countries reflecting the distinctive build environments. There were 23 occupancy classes, including greenhouses, aquaculture, and small marine, 5 roof construction modifiers and 4 building height ranges. The building inventory databases reflect building stock mix by CRESTA zone (plus postcode sector-level in the UK), line of business, height, and occupancy.

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Financial Component:

The financial losseswere calibrated using recent insurance loss data and loss a adjusters' claims databases.

Data Requirements

(he model can take data at two levels of detail, in what are called the ALM (aggregate loss model) and DLM (detailed loss model). Described below are the different levels of data required for the two models.

1. MINIMUM LEVEL OF INFORMATION (ALMl)

DATA FIELD	**EXAMPLE DATA**
Total Sum Insured	564,124,000
CRESTA	4
Occupancy type	Commercial
Deductible	10%
Number of risks	12

RMS and the client would agree on the assumptions regarding the coverage split (by occupancy type). Information such as construction type, year built, number of stories etc. will be inferred from the RMS inventory databases.

2. DETAILED LEVEL OF INFORMATION

Three separate files; Policy, Location and Reinsurance file

POLICY FILE:

DATA FIELD	EXAMPLE DATA
Policy Number	POL123
Attachment Point	5,000,000
Blanket Limit	35,000,000
Total Layer Amount	40,000,000
Policy Deductible	4%
Maximum Deductible	500,000

LOCATION FILE:

DATA FIELD	EXAMPLE DATA
Policy Number	POL123
Location Number	LOC1
Postcode	52118
Building Limit	25,000,000
Building Deductible	4%
Building Value	30,000,000
Content Limit	10,000,000
Content Deductible	4%
Content Value	15,000,000
BI Limit	6,000,000
BI Deductible	4%
BI Value	8,000,000
Occupancy Type	General Commercial
Construction type	Masonry
Year Built	1972
Number of buildings	3

REINSURANCE FILE:

DATA FIELD	**EXAMPLE DATA**
Treaty Number	SUR123
Policy Number	POL123
Percent Ceded	35%
Layer Amount	20,000,000
Attachment Point	0
Priority	1
Reinsurance Type	Surplus treaty

Outputs

Two forms of modelling can be undertaken: "Deterministic" or "Stochastic".

Under **deterministic** modelling, the damage function and the loss ratios that it predicts can be applied to a customer's current portfolio to give them an estimated as-if loss for any actual or hypothetical storm.

Under **Stochastic** modelling, for a given household portfolio, event losses for different return periods can be calculated. This information can then be used to approximate the aggregate annual loss distribution.

4.2.1.2 EQECAT EUROWIND

The Peril covered is European Windstorm in UK, Ireland, France, Germany, Belgium, the Netherlands, Luxembourg, Denmark and Southern Sweden.

The data upon which some of the constituent modules are based are described below:

Stochastic Component:

The Probabilistic calculations are based on approximately 6,000 possible storms with differing return periods. Storms were generated through a painstaking reconstruction of the wind speed and duration of 125 historic storms dating back to 1897.

Hazard Component:

Because the model was designed to address aggregate data (not individual sites) the effects of surface roughness, topography etc. were smeared into an urban/ rural/ city_centre classification. EQECAT are currently revising the model to handle more detailed exposure data and so now need to address these issues more fully.

Vulnerability Component:

The initial damage functions were based on extensive loss information collected from storms dating back to 1983. The damage function derived has the following parameters:

Country

Risk type: residential, industrial, commercial or agricultural

Insured coverage: building, contents or mixed

Quality of design (i.e. level of windspeed the building is designed against)

Exposure (i.e. is a building protected by other buildings)

Level of maintenance and condition of building

Maximum gust wind speed

Storm duration

Country, risk type and insured coverage comes from the input dataset. The quality of design, exposure and level of maintenance are summarised by geographic region and held within the software package. Maximum gust speed and storm duration are generated by the model.

Financial Component:

For a 'Scenario' analysis, the damage functions are applied to the insurer's data to get a total loss.

For a 'probabilistic' analysis, the loss distribution for each event in the stochastic set is calculated using the damage functions above. The system then determines the loss exceedance curve using the distribution of each event. The latest version of the software uses simulation to get the per occurrence and annual aggregate loss exceedance curves for more complex insurance conditions such as multi-peril annual limits

Data Requirements

The minimum data that the model needs is the location and aggregate insured value. During import the user can then set the other parameters. The fields available are as follows:

Exposure information

Locator: country and zone (e.g. FRA-075) can take aggregate data at country, Cresta zone or postcode level

Value: aggregate value for the locator

Currency:

Risktype: Residential, Commercial, Industrial, etc.

Coverage: Buildings, Contents, BI

Occupancy: Chemical, High Tech, unknown, etc.

Structure Type: Steel, Concrete, timber, unknown, etc.

Structural Modifier: Average, Good, Poor, etc.

Insurance Information

Deductible

Limit

Coinsurance

Multi-site policy deductibles

Treaty type (CatXL, Quota Share)

Layer attachment points, limits and shares

In the absence of specific information generic or average values are assumed.

Outputs

For a given portfolio of insured properties, the financial consequence of windstorms can be investigated for specific 'scenario' events. Alternatively, a probabilistic analysis can be carried out which allows for a full range of possible events, each assessed for its likelihood of occurrence.

For both a ‘scenario’ and ‘probabilistic’ analysis, predicted portfolio losses can be split by postcode sector and property type. For a ‘probabilistic’ analysis, different losses can be given for events of different return periods together with a standard deviation of losses. NB. The distribution of losses is assumed to be Normal.

4.2.1.3 Comparison Between RMS Europe Windstorm, EQECAT UKWIND & EQECAT EUROWIND

Based on experience and on industry sources, the RMS Europe Windstorm output can be viewed as being reasonably conservative (cautious). The EQECAT EUROWIND is more conservative than RMS Europe Windstorm by about 40-60% for the UK. In some extreme cases, the results for EQECAT EUROWIND are over 100% higher than those for EQECAT UKWIND.However, we understand EUROWIND loss estimates are likely to decrease following the release of the next version of the software.

4.2.1.4 Benfield Greig Europe GAPWind

The Peril covered is European Windstorm in UK, Belgium, Denmark, France, Germany, Ireland, Luxembourg, Netherlands, Norway and Sweden.

Note that although the Europe GAPWind model covers the UK – it is not currently used for UK windstorm modelling. Instead, the UK GAPWind 3.0 is the favoured Benfield Greig model for UK windstorm

The Europe GAPWind model is based on the following componets

Stochastic Component:

European wind recording methodologies have varied throughout Europe in the past and therefore readings from earlier years have not been used in calibrating the Stochastic component of the model.

Benfield Greig created a dataset of 77 storms covering the period 1976 to 1998 with the aid of a prominent meteorological institute. The company employed leading climatic scientists to make sure that this period was representative of likely future windstorm activity in north-west Europe (especially when considering possible effects such as global warming).

Each storm in the dataset was allocated a return period. The return periods were determined by fitting frequency and severity distributions to the old storm data. The frequency distribution was assumed to be Poisson and the severity distribution was assumed to be one-parameter Pareto. These distributions were combined to get the probability that a storm creating a loss bigger than a certain amount would occur in a year.

Hazard Component:

The hazard component allows for geograpical elevation, surface roughness and household density.

The geographical elevation is determined using Benfield Greig global height data which apparently isn't very detailed. However, whilst more detailed height datasets are available, it is argued that any additional resolution would be spurious.

The surface roughness of a particular area is determined by the size and distribution of the roughness elements it contains. For example, land surfaces are typically made up of vegetation, built-up areas and the soil surface. Surface roughness data from the European Wind Atlas and Swedish Meteorological Office (SMHI) has been used.in the model. The SMHI data is for a 55x55km grid.

Data from the Statistical Office of the European Union (EUROSTAT) has been used in determining household density. The geographical resolution of the data is that of "Nomenclature of Territorial Units for Statistics (NUTS)". NUTS splits the European Union into about 1,000 areas at its lowest overall resolution although a more detailed split is available for Finland, Greece, Ireland, Luxembourg, Portugal and the UK. Where household density is not available, population density has been used as a proxy.

Vulnerability Component:

The vulnerability component of the model has been calibrated using customer data for the storm of 24th-27th January 1990 ('Daria', 90A LUNCO code) which had an impact on a large part of western Europe. For Sweden, the storm of 21st-23rd January 1993 has been used instead.

The variables that have been considered in the model for the purpose of predicting damage are: maximum gust speed, coastal proximity, wind direction, elevation, household density and basic wind speed. Maximum gust speed is the primary variable in the model and it is assumed that the relationship between maximum gust speed and the proportion of damage caused is one of an exponential nature.

Financial Component:

The vulnerability component of the model provides a set of predicted damage ratios for any given storm for each grid square. Multiplying these by the customer's exposures gives a set of predicted loss values for the storm.

Data Requirements

If the customer can provide Benfield Greig with sums insured and loss amounts for the storm of 24th-27th January 1990 then it is possible to check the accuracy of Europe GAPWind against the actual losses experienced by the customer for that particular storm.

The provision of "current" sums insured will allow Benfield Greig to predict as-if loss amounts based upon the repetition of the January 1990 storm and/or the storm supplied by the customer.

Sum insured data should be ideally at the following resolution:

Country	Resolution
Belgium	1 digit postcode (e.g. 1-9)
Denmark	2 digit postcode (e.g. 10-99)
France	department (e.g. 1-95)
Germany	2 digit postcode (e.g. 1-99)
Ireland	county level (e.g. 1-26)
Luxembourg	country (e.g. 1)
Netherlands	2 digit postcode (e.g. 10-99)
Norway	cresta (e.g. 1-9)
Sweden	kommun (e.g. 1-3000)
UK	postal town (e.g. AB-ZE)

Outputs

Two forms of modelling can be undertaken: "Deterministic" or "Stochastic".

Under Deterministic modelling, the damage function and the loss ratios that it predicts can be applied to a customer's current portfolio to give them an estimated as-if loss for any actual or hypothetical storm.

Under Stochastic modelling, for a given household portfolio, event losses for different return periods can be calculated. This information can then be used to approximate the aggregate annual loss distribution.

The software also has the ability to compare particular portfolio exposure with that of the market as a whole, thus identifying potential levels of concentration of risk.

4.2.2 Other Models

4.2.2.1 RMS river flood

RMS's UK River Flood catastrophe model (released in October 2001) was developed in response to the serious river flooding experienced in the UK in 1998 and 2000. All existing UK flood models cover coastal flooding only, and it has long been recognised that a stochastic model for river flood would be extremely useful. This is in fact the first high resolution river flood catastrophe model in the world

Previous river flood models simply specified flood zones for a range of return periods. The RMS model allows account to be taken of:

- Flood defences
- Building characteristics
- Insurance policy details

The model is based on a stochastic event set; each event is a single or multiple rainfall system, which is combined with antecedent groundwater conditions and snowmelt. This allows loss dependency to be taken into account, such as several locations on the same river being affected. An event is restricted to a 168 hour period, to reflect common catastrophe reinsurance coverage.

4.2.2.2 Earthquake

These include models from Risk engineering (US and Canada), HAZUS (US) and Benfield Blanch (US), EQE and AIR

4.2.2.3 Hurricane

Models include Risk engineering (US) Benfield Blanch (US) EQE and AIR

4.2.3 UK Coastal Flood Cat Models

4.2.3.1 RMS East-Coast UK Storm-Surge Flood Model

The Peril covered is UK East-Coast Flood,Coastal Flood losses can be linked with associated losses from RMS Europe Windstorm model using a package called “RiskLink”. The location covered is only the East-Coast of the UK.. This region was also covered by a Halcro report for ABI

Stochastic Component:

The Proudman Oceanographic Laboratory provided tide-gauge data for 46 gauges (15 of which have been operating since 1953), for 176 events since 1953. A total of 620 windstorm events have been assigned different combinations of tidal amplitude and sea-defence performance scenarios to give 2880 storm-surge events. Postal unit (for 26925 units at risk) or postcode sector (for 387 sectors at risk) analyses are supported.

Hazard Component:

The Model incorporates sea-defences and probability of breach/over-topping. The Environment Agency Sea-Defence Survey (1990-1996) provided information on the condition of 909 sea-defences. 50m Ordnance Survey Digital Elevation Model was used to describe topography.

Vulnerability Component:

The Model discriminates between 210 combinations of building type, occupancy and construction class. Losses are based on a combination of published methodologies, US Army Corps data and a survey of losses from the 1998 Easter river floods in England. Some of the published methodologies are: Flair Report 1990, Stauble et al 1991, FEMA 1986, Co ck & Wolff 1991 and Mackay 1994.

Financial Component:

The model was calibrated using recent insurance loss data and loss adjusters' claims databases

Data Requirements

See the RMS Europe Windstorm model for the data requirements.

Outputs

See the RMS Europe Windstorm model for the outputs

4.2.3.2 EQECAT UKFLOOD

The Peril covered is UK Storm-Surge Flood damage on the East-Coast. The area of coverage extends from the northern coast of Kent (as far as Margate), through the Thames Estuary around the coast of East Anglia up to the Humber Estuary and the Tees Estuary. Later Releases will include the whole of the low-lying populated coastline of the UK.

A new feature is the ability to calculate the losses to automobiles (excluding commercial vehicles) due to storm surge events.

Stochastic Component:

The population of storm surges are represented by more than 60 combinations of peak water elevation at different locations. The tide gauge at Sheerness (part of the present Class A DATARING national tide gauge network) has been taken as the fundamental sea-level reference point for this study. Annual maximum water-levels were first collected at Sheerness in 1819 and records are complete for the past 133 years. Based on these extremes a Gumbel maxima analysis of the annual exceedance probabilities for sea-level has been performed to derive extremes down to an annual probability of 1 in 10,000.

The extreme water levels at Sheerness have been extrapolated around the east coast allowing for differences in direction of tides and surges.

Hazard Component:

All those areas that have the potential to be flooded in the most extreme storm-surges have been subdivided into ‘cells’. A cell is a contiguous area that shares common characteristics with respect to its flood potential. i.e. similar elevation, as well as being protected by the same sea (or inland) defences. Information on the location of insured properties is provided to the software model at the post code sector level (e.g. RH13 6). Therefore, cells are also defined so that they fit within the sectors. Cells can also reflect differences in land usage within the sector, as between agricultural, residential and industrial.

Information on the sea-defences has come from the NRA database (The Sea Defence Survey) supplemented by site visits to assess sections of defences. This database reflects the current best knowledge of the sea-defences, and is the same as that employed in the recent Halcrow Survey for the ABI.

When a sea defence is breached or fails, inland flooding has been modelled using the "Bathtub" approach. The elevation of land within the floodplains has been based first on the contours that define the 5m and 10m land elevations, on Ordnance Survey 1:10,000 maps and then refined through the use of all available spot-height elevations. This process has been undertaken with care; in some areas spot-heights are for causeways not typical of the surrounding land. Visits have been made to a number of the most critical floodplain areas to assist in the definition of elevations.

Detailed maps of the 1953 and 1978 storm-surge floods, produced by the National Rivers Authority, have been employed for demonstrating (for the affected areas) that the cell subdivisions provide a realistic depiction of flooding.

Vulnerability Component:

The damage functions that have been developed for UKFLOOD are largely based on detailed loss data collected over many years by the Flood Hazard Research Centre at Middlesex University (formerly Middlesex Polytechnic).

The model includes separate damage functions for the following property types:

- Residential urban detached house
- Residential urban semi-detached house
- Residential urban terraced house
- Residential urban bungalow
- Residential rural detached house
- Residential rural semi-detached house

Residential rural terraced house

Residential rural bungalow

General commercial

Retail commercial

Office commercial

The damage function has three parameters: depth of water, duration of the flood event and the velocity of the floodwater.

The depth of water is the primary parameter and is obtained by subtracting the height of the flood from the elevation of each cell that is flooded.

The duration of the flood event is expected to be higher for low-lying areas where the floodwater is likely to “pond”, prevented from escaping by sea-defences. Significant increase in loss is found where a building is immersed in floodwater for several days, rather than experiences a flood lasting only two or three hours.

For storm-surge, the highest flood water velocities are found closest to where the sea-defence breaches or is overtopped. As it is not possible to predict the exact point where defences are overtopped or fail, flood velocity has been included by raising the susceptability to damage for cells in which buildings are located immediately adjacent to sea-defences.

In addition, for the latest release of UKFLOOD a generic motor vehicle damage function has been established.

Data Requirements

Data must be provided at postcode sector level (e.g. RH13 6).

Outputs

For a given portfolio of insured properties, the financial consequence of storm surges can be investigated for specific 'scenario' events. Two 'scenario' storm-surge floods are available to be run in the model: the 1953 storm-surge and a 1953 storm-surge occuring at the time of a spring tide. Alternatively, a probabilistic analysis can be carried out which allows for a full range of possible events, each assessed for its likelihood of occurrence.

For both a 'scenario' and 'probabilistic' analysis, predicted portfolio losses can be split by postcode sector and property type. For a 'probabilistic' analysis, different losses can be given for events of different return periods together with a standard deviation of losses.

4.2.3.3 UKFLOOD

According to industry sources the EQECAT PMLs can be upto 8 times higher than the RMS PMLs. This result may arise because RMS's assumptions regarding the probability of sea-defence failure are much more optimistic than the equivalent EQECAT assumptions.

4.2.3.4 Benfield Greig UK GAPFlood 2.1

The Peril covered is UK Storm-Surge Flood damage on the coast of England & Wales.

Stochastic Component:

The model is deterministic and only generates losses based on one coastal flood event. This event is the 1953 east coast flood which is estimated to have a return period of 1 in 250 years.

Hazard Component:

In determining surge height and direction, an allowance is made for sea bed topography. i.e. Bathymetry. The sea bed topography is described by a Continental Shelf Model which has a resolution down to 35km grids.

The adequacy of sea defences is modelled using data obtained from the Sea Defence Survey produced for the environment agency in 1995. It covers ALL tidal coastline and estuary defences in England and Wales. Data for each segment includes structure/material of sea defence, maintenance condition, height to which the defence can protect and probability of failure.

A model has been developed in conjunction with Delft Hydraulics which computes water flow across the land surface. This model is called the "Hydrodynamic Flood Propagation Model" and is based on a digital terrain model, extreme water level time series and landuse parameters.

The digital terrain model has a 100 metre cell resolution. The data has been obtained from the Ordnance Survey and there is a 5 metre interval between contour lines.

The extreme water levels are based on a database of 40 year's readings.

Additional topographic data giving landuse is used in the physical wave model. There are 25 classifications of landuse type (e.g. urban, marsh, agricultural etc) and the data is stored in 25m grids, aggregated to 1km.

Vulnerability Component:

The "Domestic Property Function" has been derived from limited, local flood events by the ABI. It assumes that a flood is of at least 6 hours' duration and it does not allow for moving or salt water. The function provides a nominal loss figure per depth band per risk count.

The “Commercial Property Function” estimates the loss as a percentage of sum insured. It uses a sliding scale per depth of flooding.

Financial Component:

The insurer’s domestic property losses are calculated at unit postcode level by multiplying the nominal loss figure from the damage function by a policy count.

The insurer’s commercial property losses are calculated at unit postcode level by multiplying the sum insured % loss from the damage function by the total sum insured. For this purpose, content’s and building’s insurances are treated separately.

Data Requirements

The insurer should ideally provide Benfield Greig with the following data at unit postcode level:

- total sum insured split by cover section (e.g. buildings, contents)
- policy count split by cover section

Outputs

Single event catastrophe loss estimates based onhistoric storm surges
synthetic storm surges derived from historical parameters
Flood height at postcode unit level for two assumptions:

- with sea defence failure test
- assuming all sea defences fail (with the exception of the Thames Barrier)

4.2.4 Cat Models – Hurricane Modelling

4.2.4.1 Introduction

Hurricanes are a class of tropical cyclone specific to the Atlantic-Caribbean basin. The structure of a Hurricane is distinguished by the eye, which is surrounded by high walls of high clouds and rotating winds. In addition to wind and rain related damage, hurricanes also produce effects known as storm surge. Storm surge refers to the rising ocean water levels along hurricane coastlines that can cause widespread flooding.

The Saffir-Simpson scale is widely used to measure hurricane intensity, represented by values from 1 to 5, where 1 represents the least intense and 5 being the most intense (see Appendix X)

4.2.4.2 Overview of Existing Models

There are a number of vendor companies that supply hurricane models to the insurance industry, with the prime ones being RMS, AIR and EQECAT.

4.2.4.3 RMS Hurricane Model

The Perils covered are Hurricanes and associated Storm surge

Stochastic Component

This is based on historical storm data collected by RMS, the probabilities of hurricane landfall (the point at which a hurricane first touches land) are simulated across the Atlantic coastline of the United States. Probability density functions are developed for the key hurricane parameters, such as central pressure, forward velocity and angle of landfall.Stochastic storms are generated from the probability density functions of storm characteristics using a stratified sampling technique.Once the landfall parameters are simulated, the sampled storm is modelled along its lifecycle. A realistic track path is associated with the sampled storm, together with a decay rate

Hazard Component

Once the parameters of each hurricane in the stochastic set are defined, the wind speed is calculated for each storm at each location in an analysed portfolio.The wind speed is calculated at a site identified by its latitude and longitude, street address or Zip Code.The wind speed is then transformed into a peak gust wind at a specific location that also takes into account local terrain conditions. Surface friction effects are modelled as a function of distance to coast, and are represented by a roughness coefficient.

Vulnerability Component

The vulnerability of a portfolio of buildings to hurricanes is expressed through vulnerability curves or damage curves.These curves represent the relationship between wind speed and the mean damage ratio of a coverage.The building vulnerability module includes six main elements: Construction classes, Occupancy classes, Year built, Number of stories, Secondary characteristics and Building inventory data.

Financial Component

Calculates the losses to different financial perspectives, considering the insurance and reinsurance conditions.

Output

An exceedance probability curve for a given portfolio together with the mean and standard deviation of losses for a given portfolio.

4.2.4.4 Comparison with EQECAT and AIR model

All three models have very similar structures and methodologies, i.e. a Stochastic, Hazard, Vulnerability and Financial component. The methodologies adopted by each of the three companies are approved by the Florida Commission on Hurricane Loss Projection Methodology This has led to a convergence in the loss results produced by each model. The models vary slightly on how the stochastic hurricanes are generated – the RMS model uses a stratified Latin Hyper-Cube sampling technique whereas the AIR model uses Monte Carlo sampling. All three models allow hurricane losses to be modelled with or without associated storm surge. All three models allow for property damage including or excluding business interruption cover;

4.3 Use Of Catastrophe Models In Direct Pricing

4.3.1 Introduction

In direct pricing it is nornal to model individual perils separately. Catastrophic events will only be relevant for some of the perils e.g. for domestic household insurance, cat models will only be relevant for the windstorm, flood and earthquake perils.

4.3.2 Data Required

Unlike reinsurance pricing, the actual modelling package is not used for direct pricing. For direct pricing, a postcode data-set containing the average annual catastrophe loss as a % of sum insured would suffice. Typically, the following fields would be required in the data-set are:

- Postcode
- Building Type
- Building Occupancy
- Building Basements
- Property Age
- Average annual cat loss as a % of sum insured
- Best case annual cat loss as a % of sum insured
- Worst case annual cat loss as a % of sum insured
- Cat loss as a % of sum insured for a recent event

The "best" case annual cat loss could be defined as the 50^{th} lowest simulated loss out of 1,000 runs. Similarly, the "worst" case annual cat loss could be defined as the 50^{th} worst simulated loss out of 1,000 runs. Normally, the cat rate used would be somewhere between the "average" and "worst" case rates to introduce some degree of prudence.

You might want more data for comparison with data-sets provided by other external companies. For example, for river flood, you might want the following additional information for each postcode:

- Flood defence band
- For 1 in 100 year events, a flag indicating the marginally wet postcodes
- Maximum flood depth for different return periods
- Depth to loss curves for each property type

4.3.3 Background Vs Catastrophic Losses

The Cat model definition of what is counted as a Catastrophic event and what isn't needs to be clear. The overall risk rate for a peril equals: risk rate for "background" losses + risk rate for "catastrophic" losses. The risk rate for *"background"* losses should be modelled from your own data. Rating factors and their associated multipliers can be determined using Generalised Linear Modelling techniques. The risk rate for *"catastrophic"* losses should be determined from the Cat data-set. Claims from events which would have been classed as catastrophes in the Cat model should be removed from the data to avoid *overlapping* of risk rates.

4.3.4 Expenses

It is important to check what allowance has been made in the Cat model results for claim handling expenses and loss adjuster fees. Is this consistent with the rest of your pricing methodology? I.e. Are expenses being double counted.

4.3.5 Marketability

One check the should be made is to see whether the overall premium rates will be acceptable in the market. For example, properties close to rivers which have a past history of flooding might be charged ridiculous premiums. If premiums are too high, you might get complaints from the ABI. Also, corporate partners may require that you reduce your rates to more acceptable levels. In risky postcodes, you can afford to reduce risk premiums below their theoretically correct levels as long as you are charging more than the market.

4.4 Advantages/disadvantages of cat models

4.4.1 The **advantages** of the Cat models are:

- they use the maximum available information;
- they are based on scientifically-derived models of relevant perils
- they take account of changes such as
  - insurer's exposure,
  - underlying policy details,

building codes,
physical environment, flood
defences

4.4.2 Against this the disadvantages are

They tend to be black box models
They are extremely complex, and hence difficult to understand
The user getssdifferent results from different models
The quantity of data required is enormous and may be difficult and costly to obtain
The modelling time is long and the cost expensive
There are often approximations/compromises in the model
Thes is invariable calibration error, particularly in the more extreme catatrophes
There is invariably a lack availability of data to underwriters
time/cost of modelling

4.5 Use of cat models in practice

Cat modelling has been used for a number of reasons in practive, other than for extreme events. The major management uses are as follows;

Managing to 100/250 return period (e.g. deciding upon cat XL capacity)
Establishing a measure of 'fair price'
Assessing capital requirement, which is often driven largely by cat exposure; e.g. 1% risk of ruin
Establishing an optimal cost of capital and comparison of reinsurance coists vs. free assets
The cat model results can be used as input to stochastic DFA model
The model can help measuring diversification across territories , and then allocate reinsurance costs across territories/divisions
The model can help establish reinsurance condition and definition of terms (limit/retention/price) in the reinsurance slip

Quantifying risk in securitizations

5. Management and Control of Extreme Events

5.1 Before the event

5.1.1 The Role of Management

The function of management is, in itself, the subject of many papers and books. In the context of the management of extreme events there are a number of issues that need to be addressed. These include the extent to which the issues are understood, the extent that these responsibilities are delegated to others, including underwriters, the controls to ensure that the delegated responsibilities are being managed within a controlled framework, that the degree of risk assumed does not exceed the shareholder's appetite, and that the reward is matched to the degree of risk undertaken.

5.1.2 Responsibilities

Amongst many other responsibilities the management are responsible to the shareholder to ensure that:

(i) the business plan submitted is realistic

(ii) that the execution of the business plan does not expose the shareholder to a level of risk greater than the shareholder is willing to accept.

(iii) That the business plan is achieved

(iv) That the results of the business are accurate (i.e. they adequately allow for the costs incurred by running the business).

(v) That a materially better risk/reward combination could not be achieved by an alternative plan.

To meet such generic responsibilities each manager will need to understand what specific responsibilities there are, how these are shared or divided between the members of the management team and satisfy themselves that no activities fall between the gaps.

It is interesting to contrast in the responsibilities of a typical Property/Casualty Actuary with those prescribed for a Life Appointed Actuary (see extract from Section 2 of The Discussion paper on Actuarial Governance in Appendix 18)

5.1.3 Typical components of an Underwriting Operation

Within underwriting operations the management is typically made up of a representative(s) from the following key functions within the operation.

(a) Underwriting
(b) Reinsurance
(c) Claims
(d) Financial Reporting
(e) Actuarial
(f) Compliance / Regulation
(g) Internal Audit
(h) General Accounting
(i) IT
(j) Personnel

However, the responsibilities, scope of involvement and knowledge of the individuals may vary significantly from one operation to the next.

5.1.4 Operation of the business – understanding the business dynamics

Within the many functions within any underwriting operation the management should identify to what extent should those who are directly, and who are indirectly responsible for the achievement of the plan result, understand the operation of the business.

Specifically how much does each member of the management need to appreciate:

- business underwritten
- business scope
- Policy deductibles
- terms and conditions (and how these are changing over the course of recent renewals)
- The extent of any boundaries in which underwriters operate, and how they are prescribed in terms of:

  limitation of risk undertaken
    - type / class of risk
    - geographical or other homogeneous set.
    - size of risk undertaken (usually measured in terms of normal maximum line size per risk or programme)

  At the time risks are underwritten:
    - qualitative considerations
    - quantitative considerations (methodology)
    - quantitative considerations (assumptions)

  documentation
- The relationships through which the underwriters obtain business
- Measurement of risk

  the amount of risk undertaken and how this varies over time,

  the method(s) by which risk is being assessed and the strengths and weaknesses of these methods.

the value (or absence of it) of the conditions attaching to the risks written

- How business is reinsured and the dynamics of the reinsurance programme
- The measure by which an underwriter's relative success is gauged.

5.2 Extreme Events – Commonly used measures and controls of exposure

5.2.1 Underwriting Authorities

Underwriting Authorities define the business a given underwriter is empowered to undertake. An example for an underwriter writing London Market business is provided in Appendix 15.

Typically, the Underwriting Authority is limited to specifying the nature of the business and the quantitative limits on risk to be bound by the underwriter. Requirements regarding rating methodology are not usually covered.

5.3 Realistic Disaster Scenarios

5.3.1 Current Situation

In all of the below, we are considering multiple classes of business. Whilst for a natural catastrophe the main affected class may be property business, even here other classes may contribute significantly. For more man-made disasters, other classes may contribute the largest amount. Classes under consideration could be summarised into the following categories:

- Property – Direct, Treaty, Facultative
- Marine – Hull, Cargo, Liability
- Aviation - Hull, Cargo, Liability
- Casualty – WCA, EL, Auto
- PI – D&O, E&O
- Political Risk

We first examine firstly the UK regulatory system, and then briefly look at non-UK systems. Following this, an analysis of the positives and negatives of the various systems is given and suggestions for improvements.

5.3.2 UK – Lloyds (as of March 2002 (see Appendix 16 for full description))

1. US Florida / Gulf WS 50 Bn
2. Marine Event (largest of four scenarios)
3. North Sea Complex
4. Aviation Collision
5. Major Risk Loss
6. Space Storm
7. Liability (largest of five scenarios)
8. Political Risk
9. Second Event
10. Alternative A
11. Alternative B
12. Specific Florida WS
13. Specific Los Angeles EQ
14. Specific New Madrid EQ
15. Specific European EQ
16. Specific Japanese EQ

5.3.3 UK – Company Market

1. Largest net loss from a single individual contract by FSA Class
2. Largest net loss for class by FSA Class

There are 8 FSA Classes

a. Accident & Health
b. Motor Vehicle
c. Aircraft
d. Ships
e. Goods in Transit
f. Property Damage
g. General Liability
h. Pecuniary Loss

5.3.4 Investigation of Current Systems

The most detailed system currently in use in the UK is within the Lloyds' market. The company market are not required to provide any specific scenarios, and are never required to show cross-class loss estimates. The shortfalls of the company market regulations are clear, and can be covered within a discussion of the advantages and disadvantages of the Lloyds system as shown below.

5.3.5 Advantages of System

5.3.5.1 Before any such systems were in place some organisations relied on reinsurance to protect their exposures, but without any requirement to demonstrate its effectiveness against a number of scenarios. It is difficult to gauge the consequence of this, but experience would suggest that there are a number of situations in which reinsurance has become exhausted that might have been prevented. The list of twelve described events gives an idea of how to start considering the exposures to extreme events.

5.3.5.2 Another advantage is that the system attempts to look at some clash between classes – e.g. EQ loss estimates are supposed to have exposures from not only property classes, but also marine, WCA etc.

5.3.5.3 The Lloyds Realistic Disaster Scenarios are updated each year. The most recent year considered the addition of a further two scenarios (the Second Event scenario, number 9, and the Liability scenarios, number 7). These two scenarios addressed two of the concerns associated with the 2001 Realistic Disaster Scenarios, namely that there was no specific liability consideration at all, and also the lack of investigation into exhaustion of reinsurance protection (or failure of reinsurance entities following a major loss).

5.3.5.4 Another change in the 2002 RDS listing was that two more natural peril events became more prescribed – the European WS and Japanese EQ. This should enable a more consistent comparison between syndicates.

5.3.6 Disadvantages of System

5.3.6.1 The scenarios by definition are 'realistic' disaster scenarios. Before the events of September 11th, a scenario of two planes crashing into the tallest most populated office towers in the largest business centre in the world would have probably been considered unrealistic. As the results of these events are used by a large number of people and considered by them to be the worst event losses that a syndicate could experience, it would seem wise to expand the list to include 'unrealistic' disaster scenarios taking into account more extreme events. See below for suggestions of such possible scenarios.

5.3.6.2 The advantage described above has in some cases led to an over reliance in these scenarios. The danger is that reinsurance is only purchased up to the amount shown in the scenario, without considering the possibility of a more extreme event happening, an event happening affecting several classes (of which WTC is a prime example), or a completely different altogether (see below for a discussion of these).

5.3.6.3 The approach only looks at one point of the distribution. As mentioned above, there could be a more extreme event (the US WS is approximately a 1 in 170 yr event – some companies may feel they should protect up to say a 1 in 250 yr event) which would be more costly. Alternatively, it could be that what actually hurts a company more is not 1 50Bn event but 3 10Bn events in the same year, as property catastrophe protection is often bought with just one reinstatement. These scenarios make no reference to this.

5.3.6.4 There is no consideration to not only clash of classes in a single event, but the accumulation of more than one separate extreme event happening in the same year. Again this could have an impact on reinsurance recoveries if some classes are protected by whole account type covers.

5.3.6.5 Difficulties in estimating the loss amounts.

Natural peril property catastrophe exposures are relatively 'easy' to evaluate due to the presence of several large modelling companies devoting much time and resource to investigating the issues (although as discussed elsewhere there are often widely varying views between the software companies). However, there is nothing available for the other classes of business. These are often very hard exposures to become comfortable with, and would require much detailed analysis by the individual companies which they often do not have time to do. As a result a simplistic method of assuming PML percentages is often used, but insufficient effort is made at validating the numbers used.

5.3.6.6 As a result of this subjective method, there is often a great deal of Inconsistency between companies, so that figures from different companies should be compared with much caution. This causes a problem when for example a rating agency might use the published figures in order to review a rating but not have the level of detail needed to be able to properly compare two similar companies' figures.

5.3.6.7 The dollar amounts in the Lloyds scenarios are not dynamic – they have been static for at least three years. They should be trended in line with increasing exposures if they are to remain consistent benchmarks for comparison between years. By keeping them fixed, entities are being asked to consider lower return period type events year on year.

5.3.6.8 There is a tendency in certain of the classes to only consider scenarios based on what has already happened. For example, before this year, there were no specific liability scenarios, and then following on from the Enron collapse, a scenario considering the failure / collapse of a major consideration is introduced.

5.3.6.9 There is a great deal of freedom to interpret what some of the RDS scenarios would comprise. For example, take the aviation collision, the loss may be better standardised by breaking down the additional components into:

Structural damage / number of buildings in flight path
Fire loss
Subway collapse
Workers Compensation
D&O suits against airlines/manufacturers/sub-contractors
Business Interruption

Or in the case of the failure of a large multinational company, to look at:

D&O of primary company
D&O of auditors, lawyers and other advisors

5.3.6.10 Man made events are considered in relative brief – this is possibly the area which could cause the biggest concerns going forward, as demonstrated by the WTC loss. Several more man-made events are considered below.

5.3.6.11 All the events consider only the liability side of the losses. Asset deterioration could cause as much of a problem.

5.3.6.12 A second event is now considered, but what may actually cause significantly more financial damage to a syndicate / company is a third event in the same reinsurance year, as often catastrophe reinsurance protection is purchased with one reinstatement of cover.

5.3.6.13 Figures are provided both net and gross of reinsurance. Net figures could be very difficult to assess as reinsurance programs may be complex, and several classes may be involved. Also, potential reinsurance exhaustion is not explicitly contemplated, particularly where several classes share common catastrophe protections.

5.3.6.14 The net data is also to include a provision for bad debt. This is again difficult to do and introduces more subjectivity into the equation.

5.3.6.15 No requirement to have any actuarial, or other professional, input.

5.3.6.16 In the case of Lloyd's, the Managing Agency Board may delegate the completion of the RDS. It is questionable to what degree the Board are aware of the results contained, the methodologies employed, assumptions made and key sensitivities to the business.

5.3.6.7 When applying the reinsurance programme particular consideration should be given to:

- The number of risks losses will be advised on (and their distribution by size)
- Event limits applicable in the outward risk reinsurance programme

5.3.7 Enhancements to existing framework

The existing framework mentioned above and discussed at length is merely the regulatory one currently imposed. Although some enhancements could be made to the current system, the rest may be more appropriate for internal consideration. The danger particularly within Lloyds at the moment as it has the more extensive list is to consider these scenarios only and to delve no further. What may be more beneficial is to give recommendations for a more thorough internal investigation to be performed so management is clear as to the implications of more extreme events for the business.

5.3.8 Consideration of a more extensive list of scenarios and other considerations

5.3.8.1 Additional Guidance is often necessary, particularly on calculation for different lines of business, and the Usage of different available cat models

5.3.8.2 A more prescribed basis may also be considered. Examples are PML percentages by class of business and Bad debt provisions – with the requirement to use S&P percentages

5.3.8.3 Other matters that may wish to be considered are the need for the calculations to be signed off by professional person – e.g. actuary. In addition the management should consider scenarios that are thought to be larger than "Realistic". We set out below a realistic suggested list for a London Market business. We believe that analysis of this nature is more in line with the Turnbull recommendations

Largest Earthquake Perils (including possible Marine Hull, cargo and aircraft aggregations)
Largest Windstorm Perils (including possible Marine Hull, cargo and aircraft aggregations)
Aircraft colliding over a large US city
Collision of tankers or cruise ships
Economic crisis - in USA or a number of countries where we have high exposures (i.e. Argentina, Turkey, Israel, Malaysia)
Political crisis - in USA or a number of countries where we have high exposures (i.e. Argentina, Turkey, Israel, Malaysia)
Widespread malpractice (such as Dot com IPO's, High Tech Bio/Tech, Conveyancing/ etc.)
Collapse of large multinational company
Collapse of major currency (Dollar, Yen, Euro……)
Fire/Explosion
Oil rig or petrochemical factory

Gas carrier
High value property
Terrorism
Strategic bombing of property (with catastrophic potential)
Aircraft attack
Chemical / Biological / Nuclear attack

Such analyses should include the impact of economic ramifications

5.3.8.4 Availability of information

Extent of Standardized Information / New requirements following Cat 48?

5.3.9 What comprises a good measure of exposure?

5.3.9.1 Total aggregate exposure and PML estimates tend to be the only realistic measure of exposures used in practice. PML estimates are of use in determining a benchmark for how much reinsurance to buy. Understating the PMLs may mean that company is exposed to extreme events that it erroneously believes it has protection against.

5.3.9.2 PML's are used for reinsurance pricing. Overstating PMLs could result in the reinsured being overcharged the 'fair' price for reinsurance relative to other companies that do not overstate their PMLs. Understating PMLs may mean that the company gets a cheaper price than if the correct PMLs were disclosed. Reinsurers may allow for the perceived understatement of PMLS, though may not give full credit for perceived overstated PMLs

5.3.9.3 PMLs are used for capital allocation

Capital is largely needed to pay for extreme events. The amount of capital needed to maintain a given probability of ruin (or other measure) would depend to some extent on the PML amounts estimated. This will also affect the pricing or target returns

5.3.9.4 Estimating expected reinsurance recoveries

The cedant may not know how their reinsurer has determined the price required for a program, but for management and reporting purposes he will wish to estimate the expected recoveries on the program.

5.3.9.5 Allocation of reinsurance costs across classes/territories etc.

A reinsurance program may protect several lines of business, geographical zones, etc.. In order to allocate the costs and expected recoveries PMLs may be one of the most useful statistics available. For example, a Cat XL program may protect several companies in a group, each of which will be judged, and may have bonuses dependent on, its 'bottom line'. Therefore it will be desirable at the company level to have a fair allocation of costs between them. (The Group may prefer a different allocation due to tax efficiency, for example).

5.3.9.6 Limiting how much business to write

Underwriting authorities may limit the amount of business that can be written quantified in terms of PML. Caps may be voluntary on the part of the insurer or may be imposed by their reinsurers.

5.3.9.7 DFA modelling

One test of a DFA model will be how it models the tail of the loss distribution. PML losses are a good reality check on the output of such a model.

5.3.9.8 PML Quantification

One way that companies manage their exposure to the potential losses from extreme events is to limit the amount of exposure to such events that underwriters are authorised to expose the company to. Such limits are usually outlined in the underwriting authorities issued to each underwriter. The way that these limits are quantified can vary by class of business and method of placement.

5.3.9.10 Common methods of limiting the exposure include applying caps to Premium income, PML aggregate, Total aggregate etc. Such limits will generally be specified as being applicable to the amounts in respect of individual perils/losses rather than for the whole account. However, limits may also be applied to the whole account. For example, here is an example extract of the underwriting authorities that may be given to a Property Catastrophe underwriter:

$15M any one event/programme.

EPI for whole account not to exceed $100m

PML aggregate in Peak zones not to exceed:

Caribbean Windstorm	$100m
European Windstorm	$100m
Japanese Windstorm	$150m
Japanese Earthquake	$150m
California Earthquake	$125m
SE US Windstorm	$100m

5.3.11 We set out below a list of difficulties/issues in quantification of PML exposures This list is not exhaustive :

Reinsurer gets same individual loss from different cedants who have co-insured large underlying insureds (e.g. PI for large accountancy/law firms, large industrial installations, Surety bonds, etc.);

PML on inwards Risk XL business;

AADs on inwards business;

Multi-territory inwards business (e.g. Worldwide Risk XL);

Event limits on inwards;

Unlimited horizontal cover;

Unlimited vertical cover;

Marine business Catastrophe (locations not fixed);

Benchmarking against historical losses (e.g. 90A, Andrew, Northridge) – issues with as-iffing;

Benchmarking against specified future losses (e.g. RM8.5 epicentral to SF);

LMX Risk XL (i.e. Risk XL on business which is itself Fac/Direct Excess business);

Personal Accident accumulations (WTC, plane/train crashes, credit card business);

Correlation between classes of business;

PML reporting of large zones (e.g. Japan –would a 250-year return period event be the 250-year event for Tokyo, or should it be the 250-year from anywhere in Japan, which may well be the 400-year event for Tokyo);

Possible double-counting of events – e.g. SE US windstorm may be one that goes through FL - GA - SC, or could be FL -AL -MS - LA – TX, yet PML event may be Miami Category 5 in both cases, its just two paths for where it goes next;

Reinsurance exhaustion;

Uncertainties in calibration;

Uncertainties in output of Cat models;

If gross PML to an event is $200M and have reinsurance program of $175M xs $25M is the net PML the $25M retention? If PML defined as the expected max loss on 250 years then (not the value at the 99.6th percentile) then get higher net PML;

Definition of PML – percentiles, extreme value theory'

If using Cat models and collect the 250-year loss (99.6%ile) for each cedant, then adding these amounts together will give a portfolio amount which has a higher return period than 250 years.

5.4 **Methods of calculating PML aggregates (peril means zone and type of event)**:

5.4.1 Apply a fixed % to the FGU limits exposed to business exposed in various territories for E.g. for Cat XL, Property Treaty Prorata, Property Fac, and Political Risk business.

Peril PML for programme= FGU TSI aggregate * Peril PML % applied to programme limits, where for example, the PML factors may be:

UK	2.5%	
Greece	5%	
Turkey	10%	
Mexico	20%	Mexico City
	5%	Rest of country

Example 1: FGU and Cat XL

TSI Aggregate	10,000M
FGU PML%	5.0%
FGU PML Loss	500M gross

RI Program	150M xs 50M
	200M xs 200m
	300M xs 400M
	300M xs 1,000M

Cat XL PML = 450M

FGU Net PML = 50M

The Issues with this are:

Unused exposure above 500M in top layer so if the program stopped at 200Mxs300M the PML would be the same.

There is no allowance for the lower layers in particular being exhausted by other events, and also no allowance for horizontal exhaustion, so if this approach is adopted for several perils

Example 2: Single-risk Fac XL

TSI Aggregate	10,000K FGU PML
FGU PML%	5.0%
FGU PML Loss	500K gross

RI Program	800K xs 200K
	9,000M xs 1,000M

Fac XL PML = 300K on first layer, nil on second layer

The Issues with this are that this approach would normally be applied to each risk in the Fac XL portfolio separately and the resulting PML amounts summed. As can be seen in the example, any Fac XL layer that attaches excess of the PML% will have a nil PML calculated.

In practice, if the PML event occurs and the damage as a % of TSI is the PML% not all properties will suffer the same amount of damage. This method ignores this. This mean that this method could systematically understate or overstate the PML loss to a Fac XL underwriter If understated, then it means that the credit that the insured would take for Fac recoveries in the event of a PML loss (assuming it is done on the same basis) is also understated, so the cedants PML estimate is overstated.

5.4.2 An alternative to this is to

Apply PML% to reinsurer's total exposed aggregate in various territories

Peril PML for programme = Signed share*Min(Event limit, Limit *(Num reinst +1))*Peril PML %

PML% here may be different to previous method

Example: Risk XL PML

PML factor 30%

Max line 10,000K

Amounts in $000's

Risk XL Program Layer	Reinstatements	Event Limit	Share
1,500K xs 500	3 @ 100%	3,000	10%
3,000 xs 2,000	2 @ 100%	6,000	10%
5,000 xs 5,000	1 @ 100%	5,000	10%

PML= 10% * 30% * (3,000 + 6,000 + 5,000) = 420K

The problems with this approach are the same PML factor applied to all layers, yet there must be a greater probability of loss to the lower layers.

The same PML is derived irrespective of the size of the insured portfolio and irrespective of the risk profile of the insured portfolio.

No allowance is made for the reinstatements already being used for non-Cat losses, and no allowance for the reinstatements already being used up by other Cat losses.

Although FGU PML factors may have some credibility due to there being some historical industry statistics, the Risk XL PML factor is less reliable. Other issues are the PML for Multi-zone (e.g. Worldwide excl USA) contracts – how would you calculate the PML for each territory, or even each state with

USA? The data available for Risk XL typically is not at the required detail for typical Cat PML reporting

5.4.3 In this case we use PML factors vary by level of attachment as well as peril

For example,

Attachment as % of Max line	**PML%**
< 10%	100%
10% - 20%	80%
20% - 30%	60%
30% - 50%	30%
50% - 75%	15%
75% - 100%	5%

The good point for this approach is that it makes some allowance for difference between low and high level layers. On the other hand the approach doesn't allow for the size of the portfolio, and doesn't allow for the shape of the risk profile. This may be adjusted by making the PML factors vary by Rate on line as well as peril

Rate on line	PML%
> 100%	100%
75%-100%	80%
50% - 75%	60%
30% - 50%	30%
20% - 30%	15%
< 10%	5%

This approach makes some allowance for difference between low and high level layer, the size of portfolio will be implicitly included in the ROL and the pricing will have made allowance for the shape of the Risk Profile. The problem is that Pricing will be based on Fire as well as Cat expected losses – this model assumes they're correlated.

5.4.4 An alternative is to put portfolio through a CAT model (e.g. RMS, Catmap, etc..) and take the N-year return period event. The good points for this are

- Makes allowance for actual current exposures;
- Scientific methodology;
- State of the Art.

Against this we have issues such as

- Cat model may not exist;
- Cat models expensive;
- Cat model may not cover the class interested in. (Risk XL);
- Cat model may not allow for actual underlying policy coverages/terms and conditions;
- Uncertainty over how Cat model treats some policy features (e.g. deductibles);
- Data intensive

5.4.5 **Market share methods**

These methods are easy to apply, and easy to compare different companies. The main problems are that the insurer may not have market share of losses even of if have market share by premium/TSI, the market share may not have fine enough geographical resolution, and uncertainty of which measure of market share to use.

Capture details of clashing underlying exposures (e.g. for PA Cat XL business obtain details of exposures to firms in large shared buildings such as Canary Wharf, Sears Tower, etc. For Surety/Credit business obtain exposures to firms insured by several cedants. For Marine obtain details of each Oil Platform insured). This approach is data intensive, and you may miss some key named perils/exposures. You also need to model how the measured exposures apply to the inwards

This topic is also addressed in detail in the paper Accumulations of Exposure in the London Market by C. J. W. Czapiewski, D.H. Craighead and D. M. Hart

5.5 After the Event

5.5.1 Approaches to assessing extent of loss

Top down / bottom up

Following the occurrence of an extreme event, the question on everybody's lips is; what will be the cost? The media and general public might talk about the total damage bill, insurance industry regulators and Lloyd's would have an interest in the overall cost to the insurance industry and company management will be itching to know the company's exposure to the event.

This section of the paper focuses on how one might determine the extent of the loss that a company might face and the issues associated with determining such a loss.

Following the events on the 11th September 2001, Lloyd's and company management was primarily focused on determining the cost to companies and the industry as a whole. Such an extreme event, an event that many people thought was just not possible, was on top of everyone's agendas. So how did different players in the insurance industry attempt to solve such a difficult question? Given the urgency for estimates of the extent of loss the only reasonable approach was for companies to conduct an exposure based analyses. There are a number of issues that need to be considered in conducting an exposure based analysis and different players in the insurance market will have different issues. The issues discussed relate to any extreme event, however the WTC terrorist attacks are occasionally used for illustrative purposes.

5.5.2 Availability of detail

All underwriters of insurance business will in some way need to establish which contracts will result in a claim. This involves examining the data available, reading the wording of insurance contracts and determining the extent of vertical and horizontal exhaustion on reinsurance programs. The extent of data available to determine the impact will depend on the role of the player in the insurance market. Each of the players is briefly discussed below.

5.5.3 Direct insurers

Direct insurers will no doubt have a large volume of data with which to estimate expected costs, most of which should have been recorded into computer systems at the time of underwriting. Using the WTC as an example, management of an insurance company would know whether or not they wrote the employers liability cover for the New York Police Department or the New York Fire Department. A computer program could be quickly run to determine property exposure within the vicinity of the twin towers. Aviation insurers would know whether or not they insured particular carriers. Similarly for other classes of business, information would be available to allow the direct insurer to estimate exposures or at least to estimate a reasonable range of exposures. Consultation with the reinsurance department would allow a reasonable estimate of recoveries under outwards reinsurance protections.

5.5.4 Primary Reinsurers

Primary reinsurers are those that reinsure the direct insurers. The ability of a primary reinsurer to determine exposures through the use of computer programming and data mining is greatly reduced. Instead the reinsurer will need to examine contract wordings and rely on knowledge of their business established through relationships with the direct writers. Similarly to direct writers, reinsurers need to establish the extent of outwards protection into the retrocession market to determine the extent of vertical and horizontal exhaustion of their reinsurance protections.

5.5.5 Retrocessionaires

The ability of the retrocessionaire, insurer of the reinsurers, to quickly determine exposure to an extreme event is greatly reduced compared to that of the direct insurer and even the primary reinsurer. The retrocessionaire will need to evaluate contracts that potentially have exposure and hold discussions with the cedant. Retrocessionaires will also have outwards protection and will need to evaluate potential recoveries. One particular danger faced in this market is the risk of spiral and hence the potential for exposures to particular events to be much larger than first anticipated.

5.5.6 Reinsurance Bad Debt

Some companies, depending on their exposure to the event, may be put under some financial strain. Catastrophic events also result in insolvencies in the market. In producing estimates of loss, the actuary and management need to carefully consider the impact that an extreme event will have on reinsurance bad debt. Following the WTC disaster, the Institute of Actuaries published a WTC working party paper that provided a suggested revision to bad debt calculations. In short, it involved allowing for the downgrading of reinsurers by one grade in the bad debt calculations.

5.5.7 Number of Events

Given the sheer size of catastrophic events, there will inevitably be some ongoing dispute as to the number of events or occurrences arising from the catastrophe. Again using WTC as an example, disputes have arisen regarding whether or not the collapse of each of the twin towers are separate events or the same event. This has ramifications for the amount of protection to the insured, the amount of reinsurance coverage to the insurer and a knock on effect into the outwards protections of reinsurers.

Dealing with disputes in reserving for extreme events is a difficult issue for both the actuary and management. Drawn out legal arguments will ultimately conclude the dispute but in the meantime an actuary must use scenario testing and estimated likelihood of scenarios to assist management in determining the exposure to loss and hence setting a reserve for the event in the company's accounts.

5.5.8 Range of reasonable outcomes

The level of uncertainty associated with trying to determine exposure to extreme events in the immediate aftermath is extremely high. Uncertainties surrounding the number of events, reinsurance disputes, changes in reinsurance bad debt volumes and so forth will usually result in actuaries producing a range of outcomes via scenario testing.

6 Coherent risk measures

6.1 In order for a company to manage its exposure to extreme events it is necessary to quantify the potential exposure. As discussed in other sections of the paper the way this is currently done is usually by means of RDS and PML.

6.2 These two measures are both point estimates. They may usually be thought of as being the expected losses from events with certain return periods, whether or not the return period itself is specified. For example, Lloyds RDS1 ($50Bn =Windstorm) is estimated to have a return period of approximately 170 years.

Such measures are known as Value at Risk (VaR) measures as they represent the value at a given percentile of the loss severity distribution.

VaR measures are also commonly used in other areas of the Finance industry, For example, it may be used in banking to (i) measure aggregate risk (ii) set position limits (iii) assess capital requirements [http://www.gsm.uci.edu/~jorion/var.html]. In particular, they are used to measure and manage the daily exposures of banks' trading desks (such as FX or derivatives). The immediacy and importance of measuring the risk of such business has spurred a great deal of academic research into the subject of risk measurement.

6.3 A key paper on the subject, "Coherent measures of Risk" by Artzner et al. was published in (1999). This proposed that a sensible measure of risk, R, should satisfy the following four axioms (taken from Wang's "A risk measure that goes beyond coherence"):

Subadditivity: For all random losses X and Y, R(X+Y) <= R(X) + R(Y)

Montonicity : if X<Y for each outcome, then R(X) <= R(Y)

Positive Homogeneity: for constant b>0, R(bX) = bR(X)

Translational Invariance: for constant c, R(X+c) = R(X) + c

Such a risk measure is said to be **coherent**.

These can be paraphrased as:

diversification does not increase risk;

if for two portfolios the loss from a given event is always greater to one portfolio than the loss to the other, then the risk measure of the first portfolio should be more than that of the second;

it doesn't matter what units you work in (e.g. currency)

.

A trivial risk measure that satisfies these requirements is the nil measure, R(X)=0, but we can ignore that.

6.4 VaR does not necessarily satisfy axiom (i).

For example, consider the case where the probability space of outcomes of two independent events X and Y are specified as:

P(X=0) = P(Y=0) = 98%

P(X = 100) = P(Y=0) = 2%

For example X and Y may be credit defaults on bonds with the same credit rating, or may represent the losses due on a CatXL layer or CatBond with an ILW.

Denote the VaR at the nth percentile as VaR_n

Then,

$VaR_{97.5}(X) = VaR_{97.5}(Y) = 0$

$VaR_{97.5}(X+Y) = 100$

Atzner at al give an example where X and Y are digital (ie "all-or-nothing") put and call options on the same underlying stock at the same exercise price.

For more examples of this see "Pitfalls in the Probability of Ruin Type Risk management" {Evans 2001].

Note that this means that PML measures therefore are not coherent, and are therefore not ideal.

6.5 A number of coherent risk measures have been proposed as alternatives to VaR. Actuaries will already be familiar with many of these.

One of the simpler ones, and is the "Tail Value at Risk", Tail-VaR. This also seems to have a number of other names in commonly use, such as Tail Conditional Expectation (TCE), Conditional Tail Expectation (CTE), Worst Conditional Expectation(WCE), Expected Shortfall (ES), which appear to be identical for all practical purposes. These are effectively the Expected PolicyHolder Deficit (EPD).

Seehttp://www-m4.mathematik.tu-muenchen.de/m4/Papers/Tasche/shortfall_talk.pdf and the associated paper for a discussion of the differences.

6.6 Sean Wang has proposed using "Distortion Risk measures" which is a family of risk measures of which VaR and TailVar are special cases. This approach is similar to the Proportional-Hazard transform also proposed by Wang.
(See http://www.stats.uwaterloo.ca/Stats_Dept/IIPR/2001-reports/IIPR-01-18.pdf)

6.7 In practice, although such measures may well be more theoretically robust, there are a number of practicalities that mean that VaR measures such as PML may not be superseded in the short term.

These include:

Simplicity : as it only involves estimating one point on the severity distribution it is computationally simpler than TailVar

Ease of comparison : If one company uses a 10% PML factor, say, for Earthquake business in a certain territory, and another uses 15% then it is simple to see that the second is more conservative than the first. It would not be so easy to compare approaches if you only know what distribution assumptions the two companies used. This is similar to the way that it is easy to compare the thickness of the tails of 1-parameter Pareto (1PP) distributions knowing just the Alpha parameter value, whereas it is not so easy to compare the tails of the 2PP or GPD distributions given the parameters.

Universality: VaR measures are the "industry standard", virtually all companies use them.

Management and underwriter buy-in : company managers and underwriters can usually understand VaR and the relativities between risks. It may not be so easy to persuade them of the benefits of the more obscure methods which they may understand less, and over which they have less control in the calibration of.

Regulation: Regulators may generally be interested in ensuring capital adequacy. If VaR methods have a bias in overstating the risk (due to non-subadditivity) then the regulator may not mind. Indeed, such bias may partially compensate for some of the estimation errors.

Parsimony: there are fewer parameters to estimate in using a simple VaR method (e.g. PML factors) compared to a TailVar method (e.g. use of GPD).

Parameter error: it is hard enough to derive PML factors that are likely to be reliable; trying to estimate additional parameters needed for TailVar will be subject to a greater degree of uncertainty. For example, although it may be hard to estimate the size of a 100-year return period event, to calculate a TailVar measure will require the estimation of the 200-, 500-, 1,000, 5,000-year etc. event loss amounts. The issue is whether the reduction in model error (due to using TailVar rather than VaR) offsets the additional parameter error (due to extra parameterisation)

FGU vs loss to company: the modelling process is made more complicated for reinsurance companies compared to insurance companies. This is because the amount of loss to them is not often proportional to the size of the market/cedant loss due to the impact of factors such as program deductibles, uneven shares written on different layers of programs. It is even harder to evaluate the expected losses to Excess Fac or Risk XL business. This means that sophisticated methods may not be appropriate. However, TailVar will make allowance for the vertical exhaustion of reinsurance coverage.

CatXL bought to PML: in some territories cedants may only purchase up to the "industry" PML factor for that territory. In some countries the PML factor is specified by statute. Therefore the VaR and TailVar of a CatXL program will be the same if the reinsurer evaluates the PML using the same industry PML factor.

Extrapolation: having a point estimate of a loss amount together with the associated return period allows you to estimate the loss amounts at other return periods. This can be very useful.

Ruin: for shareholders once a company is bankrupt, they do not really need to care quite how bankrupt the company is, as they'll get nothing back in either case. VaR tells them all they need to know.

Priority: there are other issues that are more pressing on company management's time and attention than the minutiae of risk measures. There will probably also be more important issues to resolve in the quantification of extreme events than coherence. For example, the extent to which sub-zonation should be used in the risk quantification of large zones (e.g. use of CRESTA zones), and the way that the risk measures of sub-zones should be treated to obtain the risk measure of the whole zone (e.g. European Windstorm aggregation from CatXL business written in UK, France, Netherlands, Belgium, Germany, etc.).

Relativity: VaR measures will in the majority of cases produce a similar ranking of risks in terms of the measure of risk as TailVar measures. For many aspects of risk management it is more important to get the relativities of risk ranking correct than to get the absolute values of the risks. Therefore VaR measure may suffice.

However, TailVar still has uses. Its main use will be as one of the most rational bases for capital allocation.

7 Conclusions

7.1 The analysis and management of large events is becoming a fundamental part of managing any insurance entity. The exposures are getting larger, and the impact of similar historic events will produce a strain on insurance resources. It must be noted that it is not the first event that causes the problems – but often the second and third event as witnessed by the catastrophic events of 1989-1990.

7.2 The insurance industry tends to learn and unlearn in cycles. Following the catastrophes of 1989-1990, and with the introduction of more sophisticated cat models, insurers were keeping accurate records of exposures and limiting their risk, Thus Andrew in 1992 was a well managed loss and did not create material strain on the insurance industry. Since then it is our belief that analysis of real exposures has become less important – primarily through the absence of any major event.

7.3 WTC has possibly changed this outlook; but there are still a significant number of insurers who are running risks without being fully aware of the consequences of a significant loss, or number of losses, on their portfolio.

7.4 CAT modelling is a good approach to managing, in that it makes insurers aware of their exposures. The downside of cat modelling is that the calibration is often incomplete, and initial estimates of losses are often (significantly) lower than the final outcome. This was the case in Northridge and Andrew. This is not the fault of the model, but the need to get a number of known yet rare events, to enable calibration of the tail. This is a ground up approach.

7.5 Against this we have extreme value theory which is a top down approach. This produces many insights, and helps produce results for alternative values of risk such as VAR and TailVar (CVAR). In an ideal world the Cat models and the EVT models should produce the same amounts – but the world is not ideal!

7.6 Insurance managers are exploring both before the event and after the event controls. The various scenarios used are realistic – but not excessive. This gives rise for concern. In the paper we have indicated historic hurricanes producing losses of $90 billion. We have not considered some of the loss potential of economic loss, but would point out that a major Tokyo earthquake would impact both the asset and liability side of a balance sheet, as Japanese holdings around the world are sold and realised to finance the reconstruction after the loss.

7.7 The other area of concern is the increasing reliance on reinsurance through a decreasing number of larger providers. One of the criteria for insurance is the ability to diversify risk. We have indicated that the risks themselves are getting larger through increasing urbanisation. Furthermore this increase is being made in locations which are vulnerable to natural disasters. The concentration of capital in a limited number of providers may itself not be helpful. When there were a number of providers the fact that one or two became insolvent did not materially impact on the insurance market. However, the demise of one of these megareinsurers will have significant impact.

7.8 Furthermore, in this paper we have not considered the pricing of reinsurance, nor have we considered claims arising out of correlated economic events. Experience has indicated that insurers get their prices wrong in catastrophic events. As an example, the World Trade Center was written in a number of layers, where the top layers were underwritten at a significant discount to the lower and middle layers. This may have appeared to be mathematically correct. However, if, say, 25% of the building was destroyed then, to a large extent it would probably have been a constructive write off. Thus the pricing of the higher layers should have been the same as the middle or lower layers. Applying practical logic to many reinsurance treaties would indicate that the higher layers may be too cheap, and also explain some of the difficulties in calibration of the cat models, which may not have a continuous as opposed to a step approach to loss values. This possibly encourages more use of EVT.

7.9 This paper is meant as an initial introduction to extreme insurance losses. It is the intention to continue this work with a detailed paper on the impact of large economic and financial losses.

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Appendix 1

Recent United States Extreme Weather Events

Extracted from

National Climatic Data Center Technical Report No. 2000-02

A CLIMATOLOGY OF RECENT EXTREME WEATHER AND CLIMATE EVENTS

Thomas F. Ross and J. Neal Lott

National Climatic Data Center

Asheville, North Carolina

Introduction

An "Extreme Weather and Climate Events" suite of web pages highlights these events and provides access to images,descriptions, statistics, and other detailed information for each event via the worldwide web (http://www.ncdc.noaa.gov/extremes.html).

One of the more popular web pages in the "Extreme Weather and Climate Events" suite is the"Billion Dollar U.S. Weather Disaster" page (http://www.ncdc.noaa.gov/ol/reports/billionz.html), which focuses on extreme events that caused more than $1 billion in monetary losses in the United States,and provides links to detailed reports on many of these events. During the past twenty years (1980-1999), 46 'billion-dollar' weather disasters occurred in the U.S. This appendix provides an overview of these disasters and the damage and loss of life they caused.

U.S. Events, 1980-1999

There were 46 weather-related disasters during the 1980-1999 period in which overall losses reached or exceeded $1 billion at the time of the event. Thirty-nine of these disasters occurred since 1988 with total losses exceeding $170 billion. Seven events occurred in 1998 alone.

Below is a list of these disasters in chronological order, beginning with the most recent. Two damagef igures are given for events prior to 1996. The first figure represents actual dollar costs at the timeof the event and is not adjusted for inflation. The value in parenthesis (if given) is the dollar cost normalized to 1998 dollars using a Gross National Product (GNP) inflation/wealth index. The total normalized losses from the 46 events are over $275 billion..

The 'billion-dollar' disasters

• **Hurricane Floyd** September 1999.
Large, category 2 hurricane makes landfall in eastern
North Carolina, causing 10-25 inch rains in 2 days, with severe flooding in North Carolina
and some flooding in South Carolina, Virginia, Maryland, Pennsylvania, New York, New Jersey, Delaware, Rhode Island, Connecticut, Massachusetts, New Hampshire, and Vermont;
estimate of at least $6.0 billion damage/costs; 77 deaths.

• **Eastern Drought/Heat Wave** Summer 1999.
Very dry summer and high temperatures,
mainly in eastern U.S., with extensive agricultural losses; over $1.0 billion damage/costs; estimated 502 deaths.

• **Oklahoma-Kansas Tornadoes** May 1999.
Outbreak of F4-F5 tornadoes hit the states of
Oklahoma and Kansas, along with Texas and Tennessee, Oklahoma City area hardest hit; over $1.1 billion damage/costs; 55 deaths.

• **Arkansas-Tennessee Tornadoes** January 1999.
Two outbreaks of tornadoes in 6-day
period strike Arkansas and Tennessee; approximately $1.3 billion damage/costs; 17 deaths.

• **Texas Flooding** October-November 1998.
Severe flooding in southeast Texas from 2 heavy rain events, with 10-20 inch rainfall totals; approximately $1.0 billion damage/costs; 31 deaths.

• **Hurricane Georges** September 1998.
Category 2 hurricane strikes Puerto Rico, Florida
Keys, and Gulf coasts of Louisiana, Mississippi, Alabama, and Florida panhandle, 15-30 inch
2-day rain totals in parts of Alabama/Florida; estimated $5.9 billion damage/costs; 16 deaths.

• **Hurricane Bonnie** August 1998.

Category 3 hurricane strikes eastern North Carolina and
Virginia, extensive agricultural damage due to winds and flooding, with 10-inch rains in 2
days in some locations; approximately $1.0 billion damage/costs; 3 deaths.

• **Southern Drought/Heat Wave** Summer 1998.

Severe drought and heat wave from
Texas/Oklahoma eastward to the Carolinas; $6.0-$9.0 billion damage/costs to agriculture and ranching; at least 200 deaths.

• **Minnesota Severe Storms/Hail** May 1998.

Very damaging severe thunderstorms with large hail over wide areas of Minnesota; over $1.5 billion damage/costs; 1 death.

• **Southeast Severe Weather** Winter-Spring 1998.

Tornadoes and flooding related to El Nino in southeastern states; over $1.0 billion damage/costs; at least 132 deaths.

• **Northeast Ice Storm** January 1998.

Intense ice storm hits Maine, New Hampshire,
Vermont, and New York, with extensive forestry losses; over $1.4 billion damage/costs; 16
deaths.

• **Northern Plains Flooding** April-May 1997.

Severe flooding in Dakotas and Minnesota due to heavy spring snow melt; approximately $3.7 billion damage/costs; 11 deaths.

• **Mississippi and Ohio Valleys Flooding & Tornadoes** March 1997.

Tornadoes and severe flooding hit the states of Arkansas, Missouri, Mississippi, Tennessee, Illinois, Indiana,Kentucky, Ohio, and West Virginia, with over 10 inches of rain in 24 hours in Louisville;estimated $1.0 billion damage/costs; 67 deaths.

• **West Coast Flooding** December 1996-January 1997.

Torrential rains (10-40 inches in 2weeks) and snow melt produce severe flooding over portions of California, Washington,Oregon, Idaho, Nevada, and Montana; approximately $3.0 billion damage/costs; 36 deaths.

• **Hurricane Fran** September 1996. Category 3 hurricane strikes North Carolina and Virginia, over 10-inch 24-hour rains in some locations, extensive agricultural and other losses; over $5.0 billion damage/costs; 37 deaths.

• **Pacific Northwest Severe Flooding** February 1996. Very heavy, persistent rains (10-30 inches) and melting snow over Oregon, Washington, Idaho, and western Montana; approximately $1.0 billion damage/costs; 9 deaths.

• **Blizzard of '96 Followed by Flooding** January 1996. Very heavy snowstorm (1-4 feet) over Appalachians, Mid-Atlantic, and Northeast; followed by severe flooding in parts of same area due to rain & snow melt; approximately $3.0 billion damage/costs; 187 deaths.

• **Southern Plains Severe Drought** Fall 1995 through Summer 1996. Severe drought in agricultural regions of southern plains--Texas and Oklahoma most severely affected; approximately $5.0 billion damage/costs; no deaths.

• **Hurricane Opal** October 1995. Category 3 hurricane strikes Florida panhandle, Alabama,
western Georgia, eastern Tennessee, and the western Carolinas, causing storm surge, wind,
and flooding damage; over $3.0 (3.3) billion damage/costs; 27 deaths.

• **Hurricane Marilyn** September 1995. Category 2 hurricane devastates U.S. Virgin Islands;
estimated $2.1 (2.3) billion damage/costs; 13 deaths.

• **Texas/Oklahoma/Louisiana/Mississippi Severe Weather and Flooding** May 1995. Torrential rains, hail, and tornadoes across Texas - Oklahoma and southeast Louisiana - southern Mississippi, with Dallas and New Orleans area (10-25 inch rains in 5 days) hardest
hit; $5.0-$6.0 (5.5-6.6) billion damage/costs; 32 deaths.

• **California Flooding** January-March 1995. Frequent winter storms cause 20-70 inch rainfall and periodic flooding across much of California; over $3.0 (3.3) billion damage/costs; 27 deaths.

• **Texas Flooding** October 1994. Torrential rain (10-25 inches in 5 days) and thunderstorms
cause flooding across much of southeast Texas; approximately $1.0 (1.1) billion

damage/costs; 19 deaths.

• **Tropical Storm Alberto** July 1994. Remnants of slow-moving Alberto bring torrential 10-
25 inch rains in 3 days, widespread flooding and agricultural damage in parts of Georgia, Alabama, and panhandle of Florida; approximately $1.0 (1.1) billion damage/costs; 32 deaths.

• **Western Fire Season** Summer-Fall 1994. Severe fire season in western states due to dry
weather; approximately $1.0 (1.1) billion damage/costs; death toll undetermined.

• **Southeast Ice Storm** February 1994. Intense ice storm with extensive damage in portions
of Texas, Oklahoma, Arkansas, Louisiana, Mississippi, Alabama, Tennessee, Georgia, South
Carolina, North Carolina, and Virginia; approximately $3.0 (3.3) billion damage/costs; 9 deaths.

• **California Wildfires** Fall 1993. Dry weather, high winds and wildfires in Southern California; approximately $1.0 (1.1) billion damage/costs; 4 deaths.

• **Midwest Flooding** Summer 1993. Severe, widespread flooding in central U.S. due to persistent heavy rains and thunderstorms; approximately $21.0 (23.1) billion damage/costs;
48 deaths.

• **Drought/Heat Wave** Summer 1993. Southeastern U.S.; about $1.0 (1.1) billion damage/costs to agriculture; at least 16 deaths.

• **Storm/Blizzard** March 1993.
"Storm of the Century" hits entire eastern seaboard with tornadoes (Florida), high winds, and heavy snows (2-4 feet); $3.0-$6.0 (3.3-6.6) billion damage/costs; approximately 270 deaths.

• **Nor'easter of 1992** December 1992.
Slow-moving storm batters northeast U.S. coast, NewEngland hardest hit; $1.0-$2.0 (1.2-2.4) billion damage/costs; 19 deaths.

• **Hurricane Iniki** September 1992.

Category 4 hurricane hits Hawaiian island of Kauai; about $1.8 (2.2) billion damage/costs; 7 deaths.

• **Hurricane Andrew** August 1992.

Category 4 hurricane hits Florida and Louisiana, high winds damage or destroy over 125,000 homes; approximately $27.0 (32.4) billion damage/costs; 61 deaths.

• **Oakland Firestorm** October 1991.

Oakland, California firestorm due to low humidities and high winds; approximately $2.5 (3.3) billion damage/costs; 25 deaths.

• **Hurricane Bob** August 1991.

Category 2 hurricane–mainly coastal North Carolina, Long Island, and New England; $1.5 (2.0) billion damage/costs; 18 deaths.

• **Texas/Oklahoma/Louisiana/Arkansas Flooding** May 1990.

Torrential rains cause flooding along the Trinity, Red, and Arkansas Rivers in Texas, Oklahoma, Louisiana, and Arkansas; over $1.0 (1.3) billion damage/costs; 13 deaths.

• **Hurricane Hugo** September 1989.

Category 4 hurricane devastates South and North Carolina with ~ 20 foot storm surge and severe wind damage after hitting Puerto Rico andthe U.S. Virgin Islands; over $9.0 (12.6) billion damage/costs (about $7.1 (9.9) billion in Carolinas); 86 deaths (57--U.S. mainland, 29--U.S. Islands).

• **Northern Plains Drought** Summer 1989.

Severe summer drought over much of the northern plains with significant losses to agriculture; at least $1.0 (1.4) billion indamage/costs; no deaths reported.

• **Drought/Heat Wave** Summer 1988.

1988 drought in central and eastern U.S. with very severe losses to agriculture and related industries; estimated $40.0 (56.0) billiondamage/costs; estimated 5,000 to 10,000 deaths (includes heat stress-related).

• **Southeast Drought and Heat Wave** Summer 1986.

Severe summer drought in parts of the southeastern U.S. with severe losses to agriculture; $1.0-$1.5 (1.6-2.4) billion in damage/costs; estimated 100 deaths.

• **Hurricane Juan** October-November 1985.

Category 1 hurricane--Louisiana and Southeast U.S.–severe flooding; $1.5 (2.6) billion damage/costs; 63 deaths.

• **Hurricane Elena** August-September 1985.

Category 3 hurricane--Florida to Louisiana; $1.3 (2.2) billion damage/costs; 4 deaths.

• **Florida Freeze** January 1985.

Severe freeze central/northern Florida; about $1.2 (2.0) billion damage to citrus industry; no deaths.

• **Florida Freeze** December 1983.

Severe freeze central/northern Florida; about $2.0 (3.6)billion damage to citrus industry; no deaths.

• **Hurricane Alicia** August 1983.

Category 3 hurricane--Texas; $3.0 (5.4) billion damage/costs; 21 deaths.

• **Drought/Heat Wave** June-September 1980.

Central and eastern U.S.; estimated $20.0(44.0) billion damage/costs to agriculture and related industries; estimated 10,000 deaths(includes heat stress-related).

As new events occur and updated statistics become available, NCDC will continue to update its worldwide web system (as shown in Figure 1, accessible via http://www.ncdc.noaa.gov/extremes.html).

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Appendix 2

British Weather Extremes

Disasters:
Avalanche: 8 killed when a cornice of frozen snow broke away in sunshine & fell about 60 m (about 200 ft) onto houses in Lewes (East Sussex), 27 December 1836.
Flood: 2,000 died around the Severn Estuary, 20 January 1606.
Lightning, annual total: 31 deaths in 1914.
Smog: 3,500-4,000 died, mostly children & the elderly, from acute bronchitis caused by smog in London, 4 to 9 December 1952.
Storm: approx. 8,000 killed by "The Channel Storm" of 26 November 1703.
Sunshine: approx. 40,000 new cases of skin cancer & approx. 2,000 deaths from skin cancer occur annually, with totals rising year-on-year.
Whirlwind: 74 killed when train plunged into sea from Tay Bridge (Tayside), after bridge collapsed under impact of 2 or 3 waterspouts, 28 December, 1879.
Fog:
Longest duration at low altitude: 4 days 18 hours in London, from 26 November to 1 December 1948 and again from 5 to 9 December 1952.
Precipitation:
Lowest mean: 513 mm (20.2 in), 1964-1982, at Lee Wick Farm, St. Osyth (Essex)
Highest mean: 4,391 mm (173 in) at Styhead Tarn (Cumbria).
Lowest in any year: 236 mm (9.3 in) at one station in Margate (Kent) in 1921.
Highest in any 24 hours: 279 mm (11 in) at Martinstown (Dorset) on 18 & 19 July 1955.
Highest in any month: 1,436 mm (56.5 in) at Llyn Llydau (Gwynedd) in October 1909.
Highest in any year: 6,527 mm (257 in) at Sprinkling Tarn (Cumbria) in 1954.
Pressure:
Highest: 1054.7 hPa (31.15 in) at Aberdeen (Grampian) on 31 January 1902.
Lowest: 925.5 hPa (27.33 in) at Ochtertyre, near Crieff (Tayside) on 26 January 1884.

Sunshine:

Least in any month: nil, at Westminster, London, in December 1890.

Temperature:

Greatest diurnal range: 29 C (52.2 F), from -7 C (19.4 F) to 22 C (71.6 F) at Tummel Bridge (Tayside) on 9 May 1978.

Highest: 37.1 C (98.8 F) at Cheltenham (Gloucestershire) on 3 August 1990.

Lowest: -27.2 C (-17 F) at Braemar (Grampian) on 11 February 1895 & 10 January 1982; and at Altnaharra (Highland) on 30 December 1995.

Warmest annual mean: 11.5 C (52.7 F) at Penzance (Cornwall) and on the Isles of Scilly, averaged from 1931 to 1960.

Wind:

Highest hourly mean: 159 km/h (99 mi/h) at Great Dun Fell (Cumbria) on 15 January and Lowther Hill, Scotland on 20 January 1963.

Highest annual mean at low altitude: 33.1 km/h (20.6 mi/h) at Fair Isle (Shetland), from 1974 to 1978.

Highest non-tornadic gust: 278 km/h (172 mi/h) on Cairn Gorm Summit on 20 March 1986.

Highest non-tornadic gust at low altitude: 228 km/h (142 mi/h) at Fraserburgh (Grampian) on 13 February 1989.

Highest wind in upper atmosphere: 656 km/h (408 mi/h) at 47,000 m (47 km) or 154,200 ft (29.2 mi) recorded by rocket above South Uist (Outer Hebrides) on 13 December 1967.

Strongest tornado: T8 (343-386 km/h, 213-240 mi/h) at St. Mary le Bow, central London on 23 October 1091 and Old Portsmouth to Southsea Common (Hampshire) on 22 September 1810

Storm 1987 J (From New Scientist Big Weather)

The GREAT storm that hit southern England on the night of 15-16 October 1987 wasn't a **hurricane**, as by the time it struck it wasn't a tropical storm, and its steady wind speed did not reach 118 kilometres an hour. But it had started life as **Hurricane** Floyd, which crossed Florida on 12 October, faded in intensity as it swung northward, and then gained energy from the ocean as it crossed the North Atlantic at fairly low latitudes, where the water was still warm. The storm then tracked northeast along the coast of Brittany and past the Channel Islands, before swinging across the English Channel. In England, the highest wind speed recorded that night was a gust of 185 kilometres an hour, at Shoreham in Sussex, while the strongest overall gust measured, which occurred on the Brittany coast, was 220 kilometres an hour. The lowest pressure recorded in the centre of the storm was 960 millibars.

To put the storm in perspective, it was probably the strongest such example of big weather to hit England since the great storm of November 1703, in which, according to Daniel Defoe, "No pen could describe it, nor tongue express it, nor thought conceive it unless by one in the extremity of it," and more than 8000 people lost their lives. In 1987, there was very little loss of life, largely because the storm was strongest after midnight, when few people were out of doors. Scots may have wondered what the fuss was about, since severe depressions are relatively common in northern Britain-in February 1989, for example, a gust measuring 225 kilometres an hour was recorded at Fraserburgh.

Appendix 3

Hurricanes

Saffir/Simpson Scale

Hurricanes can be fickle beasts with the observed or potential damage ranging from relatively minimal to catastrophic. The damage is dependent upon several factors. Not only is the intensity of the storm important, but geophysical factors such as the size of the storm and it's associated windfield, surrounding synoptic weather situation, coastal geological features, and the astronomical tide situation play an important part. The second major portion of the "equation for disaster" is the extent of economic, industrial, and residential development of the area affected.

Following numerous on-site investigations of hurricane damage, especially that from Hurricane Camille, Herbert Saffir devised a five-category damage scale in the early 1970's. The scale had the advantage of relating ranges of sustained winds to effects on vegetation and structures. Robert Simpson, a former director of the National Hurricane Center, added additional reference to expected storm surge (the rise of a body of water above astronomical tide due to a tropical cyclone).

In 1972, the Tropical Prediction Center (then known as the National Hurricane Center) adopted the Saffir/Simpson Hurricane Scale to relate hurricane intensity and damage potential. This scale uses the storm surge, central pressure, and/or the maximum sustained winds to classify Atlantic hurricanes into one of five categories.

The Saffir / Simpson Hurricane Intensity Categories

Wind Speed -------- Storm Surge	Equivalent Fujita Scale -------- Central Pressure	Typical Effects
Category One Hurricane -- Weak		
74-95 mph (64-82kt)	F1.0 - F1.4	Minimal Damage: Damage is primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real damage occurs in building structures. Some damage is done to poorly constructed signs.
4-5 ft (1.2-1.5m)	Greater than 980 mb (28.94 in)	Low-lying coastal roads are inundated, minor pier damage occurs, some small craft in exposed anchorages torn from moorings.
Category Two Hurricane -- Moderate		
96-110 mph (83-95kt)	F1.5 - F1.9	Moderate Damage: Considerable damage is done to shrubbery and tree foliage, some trees are blown down. Major structural damage occurs to exposed mobile homes. Extensive damage occurs to poorly constructed signs. Some damage is done to roofing materials, windows, and doors; no major damage occurs to the building integrity of structures.
6-8 ft (1.8-2.4m)	965-979 mb (28.50-28.91 in)	Coastal roads and low-lying escape routes inland may be cut by rising water 2-4 hours BEFORE the hurricane center arrives. Considerable pier damage occurs, marinas are flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying island areas is required.
Category Three Hurricane -- Strong		
111-130 mph (96-113kt)	F2.0 - F2.4	Extensive damage: Foliage torn from trees and shrubbery; large trees blown down. Practically all poorly constructed signs are blown down. Some damage to roofing materials of buildings occurs, with some window and door damage. Some structural damage occurs to small buildings, residences and utility buildings. Mobile homes are destroyed. There is a minor amount of failure of curtain walls (in framed buildings).
9-12 ft (2.7-3.7m)	945-964mb (27.91-28.47in)	Serious flooding occurs at the coast with many smaller structures near the coast destroyed. Larger structures near the coast are damaged by battering waves and floating debris. Low-lying escape routes inland may be cut by rising water 3-5 hours BEFORE the hurricane center arrives. Flat terrain 5 feet (1.5 m) or less above sea level flooded inland 8 miles or more. Evacuation of low-lying residences within several blocks of shoreline may be required.
Category Four Hurricane -- Very Strong		
131-155 mph (114-135kt)	F2.5 - F2.9	Extreme Damage: Shrubs and trees are blown down; all signs are down. Extensive roofing material and window and door damage occurs. Complete failure of roofs on many small residences occurs, and there is complete destruction of mobile homes. Some curtain walls experience failure.
13-18 ft (3.9-5.5m)	920-944mb (27.17-27.88in)	Flat terrain 10 feet (3 m) or less above sea level flooded inland as far as 6 miles (9.7 km). Major damage to lower floors of structures near the shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland may be cut by rising water 3-5 hours BEFORE the hurricane center arrives. Major erosion of beaches occurs. Massive evacuation of ALL residences within 500 yards (457 m) of the shoreline may be required, and of single-story residences on low ground within 2 miles (3.2 km) of the shoreline.
Category Five Hurricane-- Devastating		
Greater than 155 mph (135kt)	Greater than F3.0	Catastrophic Damage: Shrubs and trees are blown down; all signs are down. Considerable damage to roofs of buildings. Very severe and extensive window and door damage occurs. Complete failure of roof structures occurs on many residences and industrial buildings, and extensive shattering of glass in windows and doors occurs. Some complete buildings fail. Small buildings are overturned or blown away. Complete destruction of mobile homes occurs.
Greater than 18 ft (5.5m)	Less than 920mb<27.17IN)	Major damage occurs to lower floors of all structures located less than 15 ft (4.6 m) above sea level and within 500 yards (457 m) of the shoreline. Low-lying escape routes inland are cut by rising water 3-5 hours BEFORE the hurricane center arrives. Major erosion of beaches occurs. Massive evacuation of residential areas on low ground within 5 to 10 MILES (8-16 km) of the shoreline may be required!

In a 1998 study, Roger Pielke Jr. of the National Center for Atmospheric Research, and Chris Landsea of the NOAA Hurricane Research Division calculated what past hurricanes would cost if these same storms hit the same places today. They took into account inflation, increases in population, and increases in personal property in areas the storms hit. Below are the ten hurricanes that would cost in 2000.

The Normalized Damage =

Original Damage * GNP Inflation Index * FRTW Index * Coastal County Population Change

Table A3.1

Normalized Damage

	Hurricane	Year	Category	Cost (2000)
1	Southeastern Fla., Ala.	1926	4	$87,170
2	Andrew (southeast Fla., La.)	1992	4	$39,900
3	Galveston, Tex.	1900	4	$32,090
4	Galveston, Tex.	1915	4	$27,190
5	southwestern Fla.	1944	3	$20,330
6	New England	1938	3	$20,050
7	southeastern Fla.	1928	4	$16,630
8	Betsy (southeastern Fla., La.)	1965	3	$14,990
9	Donna (Fla., East Coast)	1960	4	$14,530
10	Camille (Miss., La., Va.)	1969	5	$13,220

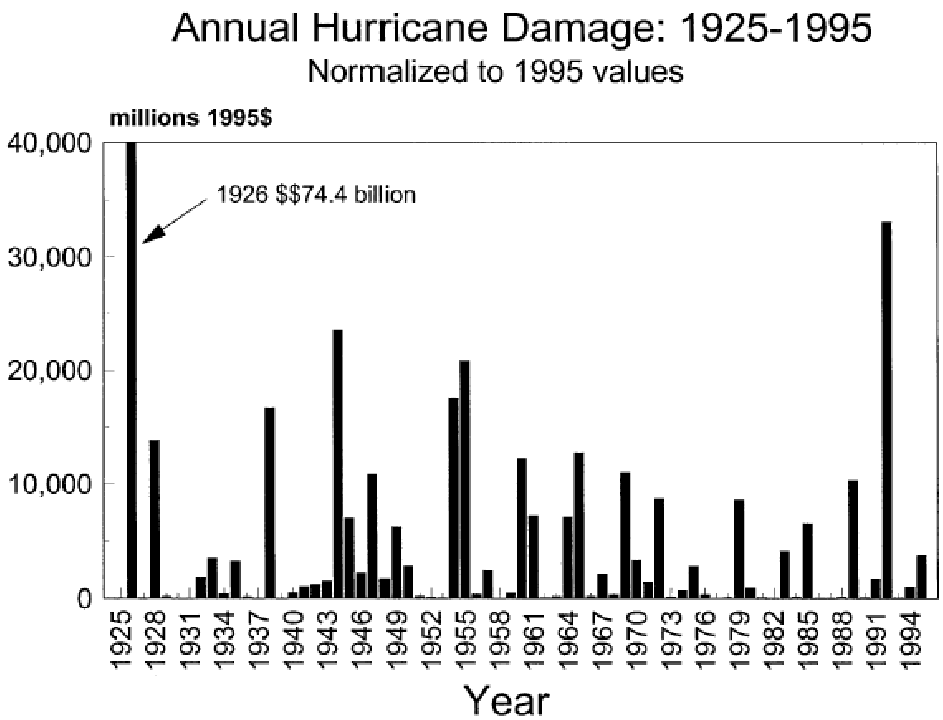


FIG. 4. Time series of United States hurricane-related losses (direct damages in millions of 1995 U.S. dollars) from 1925 to 1995 in normalized 1995 damage amounts (utilizing inflation, coastal county population changes, and changes in wealth).

Hurricane Data

The following data is taken from

Normalized Hurricane Damages in the United States: 1925–95

ROGER A. PIELKE JR.

Environmental and Societal Impacts Group, National Center for Atmospheric Research, Boulder, Colorado

CHRISTOPHER W. LANDSEA

Hurricane Research Division, NOAA/AOML, Miami, Florida

And Hurricane Watch – Forecasting the Deadliest Storms on Earth (See References)

Table A3.2

Costliest Hurricanes

Rank	Hurricane	Year	Category	Cost (in year 2000 dollars)
1	Andrew	1992	4	$34.3 billion
2	Hugo	1989	4	$10.9 billion
3	Agnes	1965	1	$8.4 billion
4	Betsy	1965	3	$8.4 billion
5	Camille	1969	5	$6.8 billion
6	Dianne	1955	1	$5.4billion
7	Frederic	1979	3	$4.9 billion
8	New England	1938	3	$4.7 billion
9	Floyd	1999	3	$4.6 billion
10	Fran	1996	3	$3.6 billion
11	Opal	1995	3	$3.5 billion
12	Alicia	1983	3	$3.4 billion
13	Carol	1954	3	$3.1 billion
14	Carla	1961	4	$2.5 billion
15	Juan	1985	1	$2.4 billion
16	Donna	1960	4	$2.4 billion
17	Iniki	1992	Unknown	$2.3 billion
18	Celia	1970	3	$2.1 billion
19	Elena	1985	3	$2.0 billion
20	Bob	1991	2	$2.0 billion
21	Hazel	1954	4	$1.9 billion
22	Miami, Fla.	1926	4	$1.7 billion
13	Marilyn (t)	1995	2	$1.7 billion
24	Galveston, Tex.	1915	4	$1.5 billion
25	Dora	1964	2	$1.5 billion
26	Eloise	1975	3	$1.5 billion
27	Gloria	1985	3	$1.5 billion
28	Puerto Rico	1928	4	$1.3 billion
29	Northeast U.S.	1944	3	$1.2 billion
30	Beulah	1967	3	$1.1 billion

Table A3.3

Number of US Hurricanes

Decade	Category					**ALL**	**Major**
						1,2,3,4,5	**3,4,5**
	1	**2**	**3**	**4**	**5**		
1900-1909	5	5	4	2	0	16	6
1910-1919	8	3	5	3	0	19	8
1920-1929	6	4	3	2	0	15	5
1930-1939	4	5	6	1	1	17	8
1940-1949	7	8	7	1	0	23	8
1950-1959	8	1	7	2	0	18	9
1960-1969	4	5	3	2	1	15	6
1970-1979	6	2	4	0	0	12	4
1980-1989	9	1	5	1	0	16	6
1990-1996	0	3	3	1	0	7	4
1900-1996	57	37	47	15	2	158	64

AREA	Category Number					ALL	MAJOR
	1	2	3	4	5	1,2,3,4,5	3,4,5
U.S. (Texas to Maine)	58	36	47	15	2	158	64
Texas	12	9	9	6	0	36	15
(North)	7	3	3	4	0	17	7
(Central)	2	2	1	1	0	6	2
(South)	3	4	5	1	0	13	6
Louisiana	8	5	8	3	1	25	12
Mississippi	1	1	5	0	1	8	6
Alabama	4	1	5	0	0	10	5
Florida	17	16	17	6	1	57	24
(Northwest)	9	8	7	0	0	24	7
(Northeast)	2	7	0	0	0	9	0
(Southwest)	6	3	6	2	1	18	9
(Southeast)	5	10	7	4	0	26	11
Georgia	1	4	0	0	0	5	0
South Carolina	6	4	2	2	0	14	4
North Carolina	10	4	10	1 *	0	25	11
Virginia	2	1	1 *	0	0	4	1 *
Maryland	0	1 *	0	0	0	1 *	0
Delaware	0	0	0	0	0	0	0
New Jersey	1 *	0	0	0	0	1 *	0
New York	3	1 *	5 *	0	0	9	5 *
Connecticut	2	3 *	3 *	0	0	8	3 *
Rhode Island	0	2 *	3 *	0	0	5 *	3 *
Massachusetts	2	2 *	2 *	0	0	6	2 *
New Hampshire	1 *	1 *	0	0	0	2 *	0
Maine	5 *	0	0	0	0	5 *	0

Hurricane Probabilities

Set out below are probabilities of any hurricane and of a major hurricane with winds of 111 mph or faster passing within 75 miles of various locations in any year. The numbers are a measure of the relative danger.The numbers can also be read as the number of storms to be expected in an average 100-year period. For example, Biloxi has a 10 percent chance of any hurricane passing within 75 miles and a 3 percent chance of a major hurricane coming within 75 miles each year. During an average century Biloxi can expect 10 hurricanes and 3 major hurricanes

Table A3.4

Hurricane Probabilities

Location	Any	Major	Location	Any	Major
Brownsville, Tex.	7.1	2.2	Virginia Beach, Va.	6.7	1.3
Corpus Christi, Tex.	6.7	2.3	Norfolk, Va.	4.8	0.8
Port O'Connor, Tex.	11.1	3.1	Ocean City, Md.	4.2	0.9
Galveston, Tex.	14.3	4.2	Cape May, N.J.	7.1	1.9
Port Arthur, Tex.	11.1	3.1	Atlantic City, N.J.	4.8	1.2
New Iberia, La.	8.3	1.9	New York City, N.Y.	6.3	1.6
New Orleans, La.	12.5	3.2	Montauk Point, N.Y.	6.3	1.5
Biloxi, Miss.	10	3	Providence, R.I.	10	2.9
Pascagoula, Miss.	11.1	3.3	Newport, R.I.	6.3	1.4
Mobile, Ala.	10	3	Nantucket, Mass.	12.5	3.2
Gulf Shores, Ala.	12.5	3.7	Hyannis, Mass.	10	3.2
Pensacola, Fla.	12.5	3.7	Boston, Mass.	5.9	1.3
Panama City, Fla.	14.3	3.7	Portland, Me.	2.9	0.3
Appalachicola, Fla.	14.3	3.3	Bar Harbor, Me.	12.5	2.9
St. Marks, Fla.	6.7	1.4	Antigua	20	6.7
Cedar Key, Fla.	11.1	2.4	Barbados	8.3	2.3
Tampa, Fla.	17.5	4.8	Belize City	10	2.9
Venice, Fla.	17.2	4.8	Bermuda	25	9.1
Port Charlotte, Fla.	17	4.6	Bonaire	2.2	0.6
Fort Myers, Fla.	17.5	5.6	Guantanamo, Cuba	6.3	1.9
Naples, Fla.	18.9	6.3	Havana, Cuba	16.7	6.3
Key West, Fla.	19.6	7.7	Kingston, Jamaica	14.3	5.9
Marathon, Fla.	22.2	9.1	Merida, Mexico	9.1	3
Miami, Fla.	26.3	11.1	Nassau, Bahamas	22.2	9.1
Ft. Lauderdale, Fla.	27	10	San Juan, Puerto Rico	12.5	4.2
West Palm Beach,	18.2	7.1	Santo Domingo,	11.1	3.9
Lake Okeechobee,	14.3	5.3	U.S. Virgin Islands	16.7	5.9
Ft. Pierce, Fla.	16.7	5.6	Charleston, S.C.	10	2.2
Cocoa Beach, Fla.	14.3	4.2	Myrtle Beach, S.C.	10	2.6
Cape Canaveral, Fla.	14.3	3.9	Wilmington, N.C.	10	2.1
Daytona Beach, Fla.	11.1	2.6	Morehead City, N.C.	12.5	2.7
Jacksonville, Fla.	9.1	1.9	Cape Hatteras, N.C.	21.3	5.3
Savannah, Ga.	7.1	1.3			

Hurricane Strength

Strengths are measured at the time each storm hit the United States; many were stronger at other times. Central pressure readings, not wind speeds, are used because pressure is a more accurate representation of a storm's power. Locations that the storm affected most are given before 1950. After 1950, when naming began, storm names are given.

Table A3.5

Hurrican Strength

	Hurricane	Year	Category	Pressure
1	Florida Keys	1935	5	26.35
2	Camille	1969	5	26.84
3	Andrew	1992	4	27.23
4	Florida Keys, Texas	1919	4	27.37
5	Lake Okeechobee, Fla.	1928	4	27.43
6	Donna	1960	4	27.46
7	Galveston, Tex.	1900	4	27.49
7	Grand Isle, La.	1909	4	27.49
7	New Orleans	1915	4	27.49
7	Carla	1961	4	27.49
11	Hugo	1989	4	27.58
12	Miami, Fla.	1926	4	27.61
13	Hazel	1954	4	27.7
14	southeastern Florida	1947	4	27.76
15	northern Texas	1932	4	27.79
16	Gloria	1985	3	27.92
16	Opal	1995	3	27.82
18	Audrey	1957	4	27.91
18	Galveston, Tex.	1915	4	27.91
18	Celia	1970	3	27.91
18	Allen	1980	3	27.91
22	New England	1938	3	27.94
22	Frederic	1979	3	27.94
24	Northeast U.$.	1944	3	27.97
24	Carolinas	1906	3	27.97
26	Betsy	1965	3	27.99
26	southeastern Florida	1929	3	27.99
26	southeastern Florida	1933	3	27.99
26	southern Texas	1916	3	27.99

Table A3.6

Cost by decade US

Deaths	Years	2000 dollars)	Dollars per death
8,734	1900-1909	$1.447 billion	$165,674
1,036	1910-1919	$3.504 billion	$3.382 million
2,124	1920-1929	$2.223 billion	$1.047 million
1,146	1930-1939	$6.059 billion	$5.287 million
216	1940-1949	$5.521 billion	$25.679 million
880	1950-1959	$13.362 billion	$15.184 million
585	1960-1969	$25.221 billion	$43.113 million
235	1970-1979	$20.610 billion	$87.702 million
129	1980-1989	$21.426 billion	$166.093 million
249	1990-1999	$56.659 billion	$227.546 million

APPENDIX 4

TORNADOES

(extracted from http://www.ncdc.noaa.gov/extremes.html)

According to the Glossary of Meteorology (AMS 2000), a tornado is "a violently rotating column of air, pendant from a cumuliform cloud or underneath a cumuliform cloud, and often (but not always) visible as a funnel cloud." In order for a vortex to be classified as a tornado, it must be in contact with the ground and the cloud base. Weather scientists haven't found it so simple in practice, however, to classify and define tornadoes. For example, the difference is unclear between an strong mesocyclone (parent thunderstorm circulation) on the ground, and a large, weak tornado. It is well-known that a tornado may not have a visible funnel..

The classic answer of how tornadoes form -- "warm moist Gulf air meets cold Canadian air and dry air from the Rockies" -- is a gross oversimplification. Many thunderstorms form under those conditions (near warm fronts, cold fronts and drylines respectively), which never even come close to producing tornadoes. Even when the large-scale environment is extremely favorable for tornadic thunderstorms, as in an SPC "High Risk" outlook, not every thunderstorm spawns a tornado. The truth is that we don't fully understand. The most destructive and deadly tornadoes occur from supercells -- which are rotating thunderstorms with a well-defined radar circulation called a mesocyclone. [Supercells can also produce damaging hail, severe non-tornadic winds, unusually frequent lightning, and flash floods.] Tornado formation is believed to be dictated mainly by things which happen on the storm scale, in and around the mesocyclone. Recent theories and results from the VORTEX program suggest that once a mesocyclone is underway, tornado development is related to the temperature differences across the edge of downdraft air wrapping around the mesocyclone (the occlusion downdraft). Mathematical modelling studies of tornado formation also indicate that it can happen without such temperature patterns; and in fact, very little temperature variation was observed near some of the most destructive tornadoes in history on 3 May 1999.

Tornadoes can appear from any direction. Most move from southwest to northeast, or west to east. Some tornadoes have changed direction amid path, or even backtracked. [A tornado can double back suddenly, for example, when its bottom is hit by outflow winds from a thunderstorm's core.] Some areas of the US tend to have more paths from a specific direction, such as northwest in Minnesota or southeast in coastal south Texas. This is because of an increased frequency of certain tornado-producing weather patterns (say, hurricanes in south Texas, or northwest-flow weather systems in the upper Midwest).

Some landfalling hurricanes in the U.S. fail to produce any known tornadoes, while others cause major outbreaks. Though fewer tornadoes tend to occur with tropical depressions and tropical storms than hurricanes, there are notable exceptions like TS Beryl of 1994 in the Carolinas. Relatively weak hurricanes like Danny (1985) have spawned significant supercell tornadoes well inland, as have larger, more intense storms like Allen (1980) and Beulah (1967). Hurricane Beulah, in fact, caused the second biggest tornado outbreak on record in numbers, with 115. Hurricane-spawned tornadoes tend to occur in small, low-topped supercells within the outer bands, NNW through ESE of the center -- mainly the northeast quadrant. There, the orientation and speed of the winds create vertical shear profiles somewhat resembling those around classic Great Plains supercells -- but weaker and shallower. Because tornado-producing circulations in hurricane supercells tend to be smaller and shorter-lived than their Midwest counterparts, they are harder to detect on Doppler radar, and more difficult to warn for. But hurricane-spawned tornadoes can still be quite deadly and destructive, as shown by the F3 tornado from Hurricane Andrew at La Place LA (1992, 2 killed) and an F4 tornado at Galveston TX from Hurricane Carla (1961, 8 killed). We don't know how many tornadoes hurricanes produce over the water. But the similarity in Doppler radar velocity signatures over water to tornado-producing cells in landfalling hurricanes suggest that it does happen -- and that they can be yet another good reason for ships to steer well clear of tropical cyclones. For more details, there is a set of articles on tropical cyclone tornadoes listed in the Scientific References section.

About one thousand tornadoes hit the US yearly. The actual average is unknown, because tornado spotting and reporting methods have changed so much in the last several decades that the officially recorded tornado climatologies are believed to be incomplete. Also, in the course of recording thousands of tornadoes, errors are bound to occur. Events can be missed or mis-classified; and some non-damaging tornadoes in remote areas could still be unreported.

Tornado season usually means the peak period for historical tornado reports in an area, when averaged over the history of reports. There is a general northward shift in "tornado season" in the U.S. from late winter through mid summer. The peak period for tornadoes in the southern plains, for example, is during May into early June. On the Gulf coast, it is earlier during the spring; in the northern plains and upper Midwest, it is June or July. Remember: tornadoes can happen any time of year if the conditions are right! If you want to know the tornado peak periods for your area, Harold Brooks of NSSL has prepared numerous tornado probability graphics, which include distribution during the year.

Tornado Alley is a nickname in the popular media for a broad swath of relatively high tornado occurrence in the central U.S. Various Tornado Alley maps which you may see can look different because tornado occurrence can be measured many ways -- by all tornadoes, tornado county-segments, strong and violent tornadoes only, and databaes with different time periods. Most recently, Concannon, et al., have prepared a "Tornado Alley" map using significant tornado data. Remember, this is only a map of greatest incidence. Violent or killer tornadoes do happen outside this Tornado Alley every year. Tornadoes can occur almost anywhere in the U.S., and even overseas.

Wind speeds in tornadoes range from values below that of hurricane speeds to more than 300 miles per hour! Unlike hurricanes, which produce wind speeds of similar values over relatively widespread areas (when compared to tornadoes), the maximum winds in tornadoes are often confined to extremely small areas, and vary tremendously over very short distances, even within the funnel itself. The tales of complete destruction of one house next to one that is totally undamaged are true and well documented.

In 1971, Dr. T. Theodore Fujita of the University of Chicago devised a six-category scale to classify U.S. tornadoes into six intensity categories, named F0-F5. These categories are based upon the estimated maximum winds occurring within the funnel. The Fujita Tornado Scale (or the "F Scale") has subsequently become the definitive scale for estimating wind speeds within tornadoes based upon the damage done to buildings and structures. It is used extensively by the National Weather Service in investigating tornadoes (all tornadoes are now assigned an F scale), and by engineers in correlating damage to building structures and techniques with different wind speeds caused by tornadoes.

The Fujita scale bridges the gap between the Beaufort Wind Speed Scale and Mach numbers (ratio of the speed of an object to the speed of sound) by connecting Beaufort Force 12 with Mach 1 in twelve steps. The equation relating the wind velocities (V in mph) with the F scale (F) is V = 14.1 * ((F+2) to the 1.5 power).
F1 on the Fujita scale is equal to B12 (73 mph) on the Beaufort scale, which is the minimum windspeed required to upgrade a tropical storm to a hurricane. F12 on the Fujita scale is equal to M1 (738 mph) on the Mach numbers. Though the Fujita scale itself ranges up to F12, the strongest tornadoes max out in the F5 range (261 to 318 mph).

The Fujita Tornado Scale

Maximum Wind Speeds	Equivalent Saffir-Simpson Scale*	Typical Effects
F0 Category Tornado		
40-72 mph (35-62 kt)	NA	Gale Tornado. Light Damage: Some damage to chimneys; breaks twigs and branches off tress; pushes over shallow-rooted trees; damages signboards; some windows broken; hurricane wind speed begins at 73 mph.
F1 Category Tornado		
73-112 mph (63-97 kt)	Cat 1/2/3	Moderate Tornado. Moderate damage: Peels surfaces off roofs; mobile homes pushed off foundations or overturned; outbuildings demolished; moving autos pushed off the roads; trees snapped or broken.
F2 Category Tornado		
113-157 mph (98-136 kt)	Cat 3/4/5	Significant Tornado. Considerable damage: Roofs torn off frame houses; mobile homes demolished; frame houses with weak foundations lifted and moved; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
F3 Category Tornado		
158-206 mph (137-179 kt)	Cat 5	Severe Tornado. Severe damage: Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forests uprooted; heavy cars lifted off the ground and thrown; weak pavement blown off roads.
F4 Category Tornado		
207-260 mph (180-226 kt)	Cat 5?	Devastating Tornado. Devastating damage: Well constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and disintegrated; large missiles generated; trees in forest uprooted and carried some distance away.
F5 Category Tornado		
261-318 mph (227-276 kt)	NA	Incredible Tornado. Incredible damage: Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 300 ft (100 m); trees debarked; incredible phenomena will occur.
F6-F12 Category Tornadoes		
Gtr than 319 mph (277 kt)	NA	The maximum wind speeds of tornadoes are not expected to reach the F6 wind speeds.

The largest outbreak occurred on April 3-4 1974. The storm spawned 148 tornadoes, with 315 fatalities, 6142 injuries and estimated loss of $600m (1974 money)

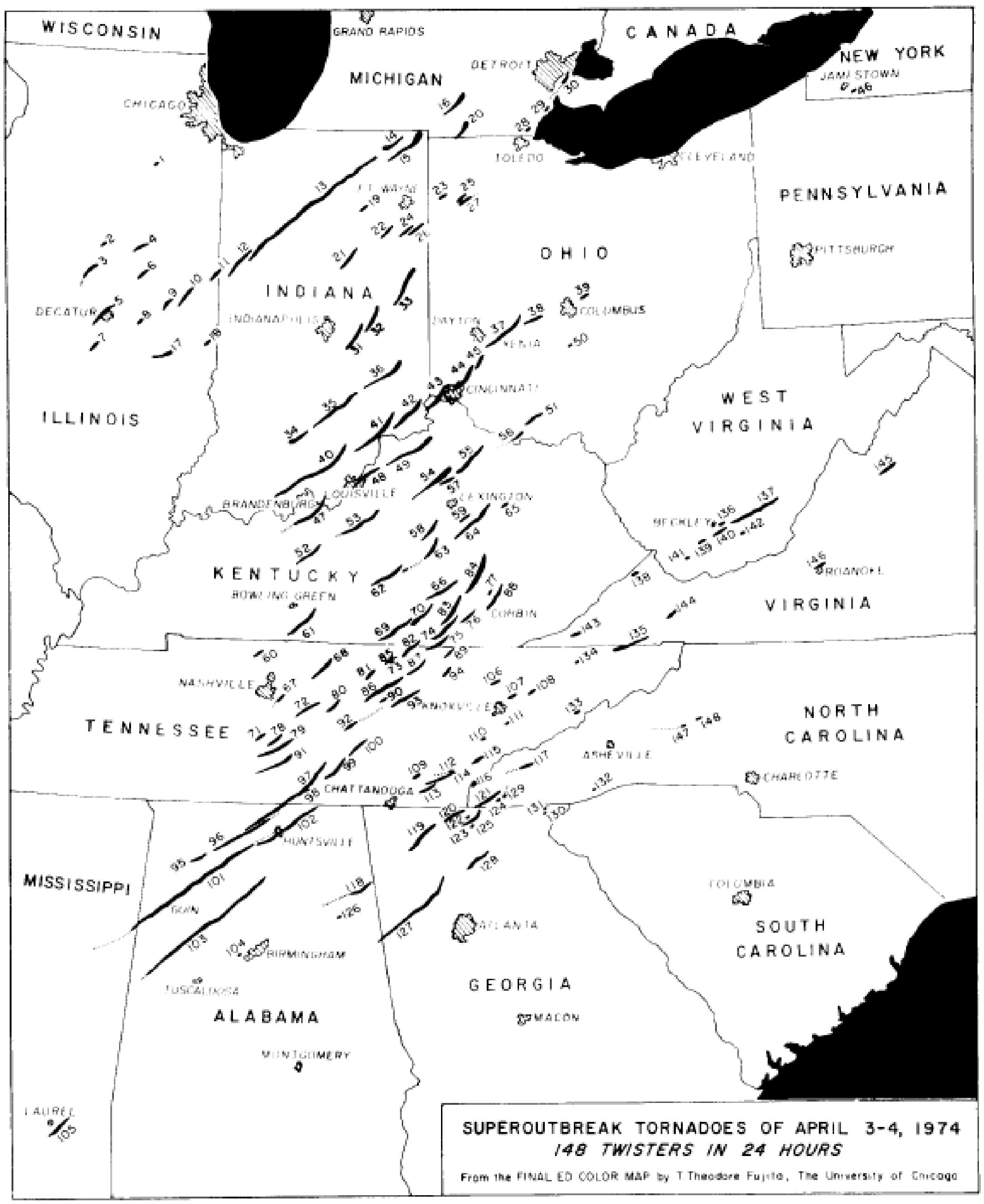


Figure 1 Tornado tracks for the period 1200 CST, April 3 to 1200 CST, April 4, 1974 [Fujita (1975)].

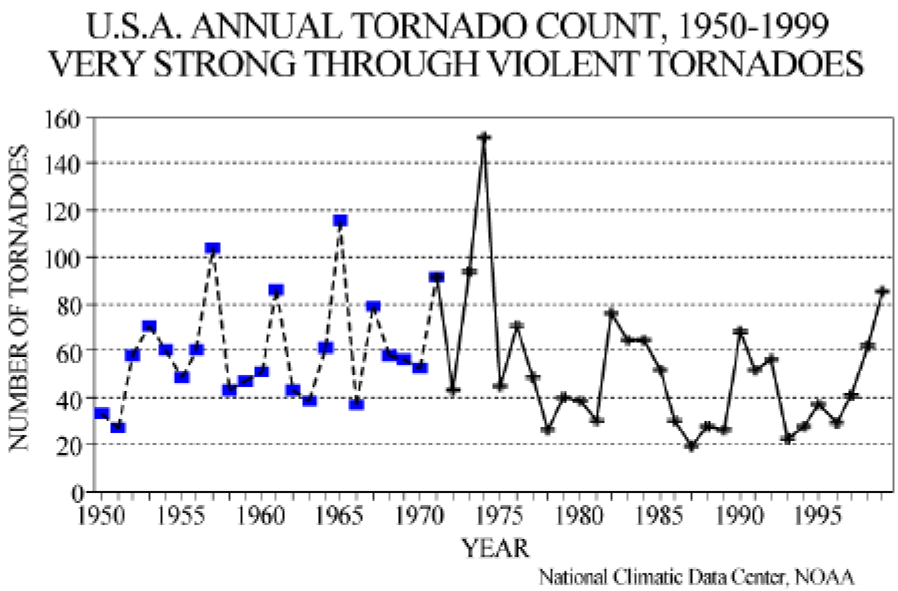
Tornado Statistics

Source NOAA National Climatic data Center

Table A4.1

Monthly Tornado Statistics, 1996-1999, Storm Prediction Center

	Number of Tornados						Number of Deaths			
	1999 Prelim	1999 Final	1998 Prelim	1998 Final	1997 Final	1996 Final	1999	1998	1997	1996
Jan	169	212	20	47	50	35	18	0	2	1
Feb	18	22	56	72	23	14	0	42	1	1
Mar	28	56	66	72	102	71	1	16	28	6
Apr	152	176	196	182	114	177	15	55	1	12
May	325	311	309	312	225	235	54	10	29	1
June	275	289	372	376	193	128	4	3	0	0
July	82	100	59	80	188	202	0	0	4	1
August	86	79	32	61	84	72	1	0	1	0
Sept	42	56	61	104	32	101	0	2	1	0
Oct	5	18	64	86	100	68	0	2	0	0
Nov	10	9	18	26	25	55	0	0	0	2
Dec	13	15	1	6	12	15	2	0	0	1
Total	1,205	1,343	1,254	1,424	1,148	1,173	95	130	67	25



Annual total number of very strong through violent (F3-F5) tornadoes, which are defined as having estimated wind speeds from 158 to 318 mph. The Fujita tornado classification scale was implemented in 1971. Prior to 1971, these data are based on storm damage reports.

Appendix 5

European Windstorm

A selection of historical windstorm events in Europe

Country	Date	Event, area	Fatalities	Overall loss in €m
Austria	1990, January-March	Winter storms	3	200
Belgium	1990, January-March	Winter storms	15	870
Denmark	1981, 24th/25th November	Gale	9	280
	1990, January-March	Winter storms		160
	1999, 3rd/4th December	Winter storm Anatol	7	2,600
France	1967, 25th June	Tornados, north		40
	1982, 6th-9th November	Gale	14	430
	1987, 15th/16th October	Gale "87J", northwest	4	1,400
	1990, January-March	Winter storms	66	1,650
	1998, 1st-5th January	Winter storms		140
	1999, December	Winter storms	92	12,000
Germany	1164, February	Storm surge: Julianenflut	20,000	
	1219, January	Storm surge, North sea	36,000	
	1287, December	Storm surge, North sea	50,000	
	1362, January	Storm surge, Große Manndränke	100,000	
	1532, November	Storm surge, Nordstrand/Eiderstedt	5,000	
	1570, November	Storm surge, North Sea	9,000	
	1625, February	Storm surge, Baltic Sea	9,100	
	1634, October	Storm surge, North Sea	8,400	
	1717, December	Storm surge, North Sea	11,500	
	1825, February	Storm surge, North Sea	800	20
	1962, February	Storm surge, North Sea	347	1,200
	1967, February	Gale, North Sea	40	600
	1968, 10th July	Tornado, Pforzheim	2	60
	1972, 12th/13th November	Lower Saxony gale	54	700
	1976, 2nd–4th January	Capella gale	27	450
	1990, January–March	Winter storms	64	3,800
	1994, 27th January	Winter storm Lore	6	360
	1998, 27th–29th October	Winter storm Xylia	5	130
	1999, December	Winter storms	18	1,800
	2001, 3rd August	Severe storm	1	850
Great Britain	1588, 21st September	Gale (Sinking of the Spanish Armada)	20,000	
	1703, 6th/7th December	Gale, south	8,125	
	1976, 2nd–4th January	Capella gale	24	200
	1987, 15th/16th October	Gale 87J, south	13	1,600
	1990, January–March	Winter storms	85	4,100
	1991, 5th/6th January	Winter storm Undine	30	700
	1997, 23rd–25th December	Winter storm Yuma	7	230
	1998, 1st–5th January	Winter storms	15	470
	1998, 24th October	Winter storm Winnie	3	250
	1998, 26th/27th December	Winter storm Silke	5	170
Italy	1973, 26th October	Gale, Palermo		170
	2001, 17th/18th July	Severe storm, tornado		200
Luxembourg	1990, January–March	Winter storms		300
Netherlands	1281, January	Storm surge, Zuidersee	80,000	
	1421, November	Storm surge	100,000	
	1953, January/February	Storm surge	1,932	6,450
	1990, January–March	Winter storms	21	1,500
Poland	1928, 6th July	Tornado, Warsaw	82	
Switzerland	1990, January-March	Winter storms	4	160
	1999, 26th December	Winter storm Lothar	12	1,500
Europe	1976, 2nd–4th January	Capella gale	82	1,600
	1987, 15th/16th October	Gale 87J	17	3,000
	1990, January–March	Winter storms	272	12,800
	1999, December	Winter storms	>150	18,500

As at November 2001. Hail events are not included. Loss figures in original values, converted into €.
Source: Munich Re NatCat*SERVICE*.

Munich Re

APPENDIX 6

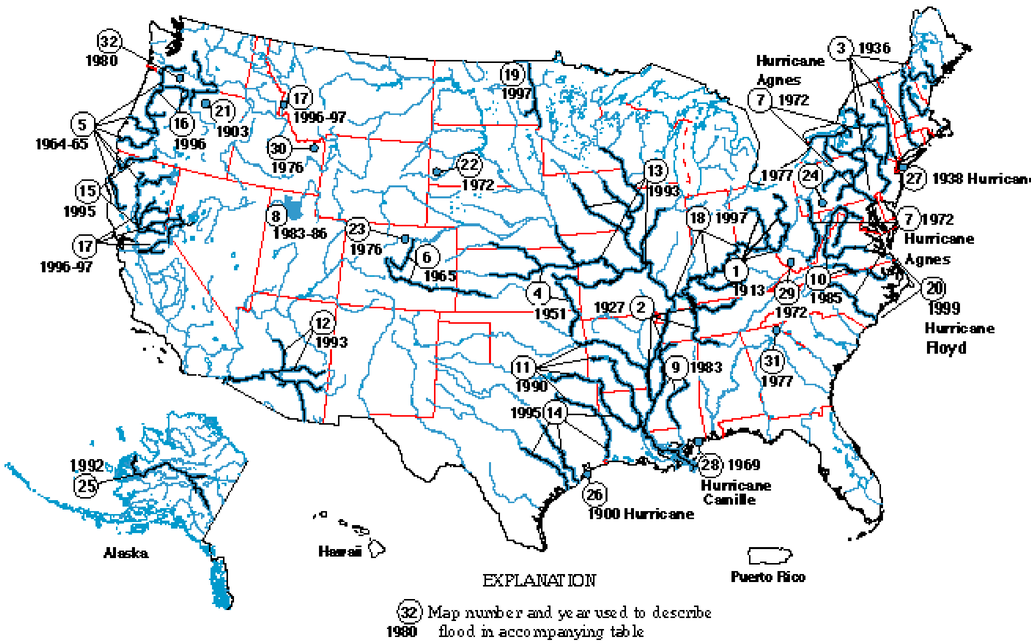
US Floods

Source USGS fact Sheets

Significant Floods of the 20th Century

[M, million; B, billion]

Flood type	Map no.	Date	Area or stream with flooding	Reported deaths	Approximate cost (uninflated)	Comments
Regional flood	1	Mar.–Apr. 1913	Ohio, statewide	467	$143M	Excessive regional rain.
	2	Apr.–May 1927	Mississippi River from Missouri to Louisiana	unknown	$230M	Record discharge downstream from Cairo, Illinois.
	3	Mar. 1936	New England	150+	$300M	Excessive rainfall on snow.
	4	July 1951	Kansas and Neosho River Basins in Kansas	15	$800M	Excessive regional rain.
	5	Dec. 1964–Jan. 1965	Pacific Northwest	47	$430M	Excessive rainfall on snow.
	6	June 1965	South Platte and Arkansas Rivers in Colorado	24	$570M	14 inches of rain in a few hours in eastern Colorado.
	7	June 1972	Northeastern United States	117	$3.2B	Extratropical remnants of Hurricane Agnes.
	8	Apr.–June 1983 June 1983–1986	Shoreline of Great Salt Lake, Utah	unknown	$621M	In June 1986, the Great Salt Lake reached its highest elevation and caused $268M more in property damage.
	9	May 1983	Central and northeast Mississippi	1	$500M	Excessive regional rain.
	10	Nov. 1985	Shenandoah, James, and Roanoke Rivers in Virginia and West Virginia	69	$1.25B	Excessive regional rain.
	11	Apr. 1990	Trinity, Arkansas, and Red Rivers in Texas, Arkansas, and Oklahoma	17	$1B	Recurring intense thunderstorms.
	12	Jan. 1993	Gila, Salt, and Santa Cruz Rivers in Arizona	unknown	$400M	Persistent winter precipitation.
	13	May–Sept. 1993	Mississippi River Basin in central United States	48	$20B	Long period of excessive rainfall.
	14	May 1995	South-central United States	32	$5-6B	Rain from recurring thunderstorms.
	15	Jan.–Mar. 1995	California	27	$3B	Frequent winter storms.
	16	Feb. 1996	Pacific Northwest and western Montana	9	$1B	Torrential rains and snowmelt.
	17	Dec. 1996–Jan. 1997	Pacific Northwest and Montana	36	$2-3B	Torrential rains and snowmelt.
	18	Mar. 1997	Ohio River and tributaries	50+	$500M	Slow-moving frontal system.
	19	Apr.–May 1997	Red River of the North in North Dakota and Minnesota	8	$2B	Very rapid snowmelt.
	20	Sept. 1999	Eastern North Carolina	42	$6B	Slow-moving Hurricane Floyd.
Flash flood	21	June 14, 1903	Willow Creek in Oregon	225	unknown	City of Heppner, Oregon, destroyed.
	22	June 9–10, 1972	Rapid City, South Dakota	237	$160M	15 inches of rain in 5 hours.
	23	July 31, 1976	Big Thompson and Cache la Poudre Rivers in Colorado	144	$39M	Flash flood in canyon after excessive rainfall.
	24	July 19–20, 1977	Conemaugh River in Pennsylvania	78	$300M	12 inches of rain in 6-8 hours.
Ice-jam flood	25	May 1992	Yukon River in Alaska	0	unknown	100-year flood on Yukon River.
Storm-surge flood	26	Sept. 1900	Galveston, Texas	6,000+	unknown	Hurricane.
	27	Sept. 1938	Northeast United States	494	$306M	Hurricane.
	28	Aug. 1969	Gulf Coast, Mississippi and Louisiana	259	$1.4B	Hurricane Camille.
Dam-failure flood	29	Feb. 2, 1972	Buffalo Creek in West Virginia	125	$60M	Dam failure after excessive rainfall.
	30	June 5, 1976	Teton River in Idaho	11	$400M	Earthen dam breached.
	31	Nov. 8, 1977	Toccoa Creek in Georgia	39	$2.8M	Dam failure after excessive rainfall.
Mudflow flood	32	May 18, 1980	Toutle and lower Cowlitz Rivers in Washington	60	unknown	Result of eruption of Mt. St. Helens.



Confluence of Mississippi and Missouri Rivers, August 1993. Extensive floods in the Mississippi River Basin during the spring and summer of 1993 caused $20 billion in damages. (Photograph, Srenco Photography, St. Louis, Mo.)

Appendix 7
U K Floods

1947 – a synopsis
Source (Met Office)

Serious snowfall

From 22 January to 17 March in 1947, snow fell every day somewhere in the UK, with the weather so cold that the snow accumulated. The temperature seldom rose more than a degree or two above freezing. This was not the coldest winter in recent years – that was 1963.

There were several snowfalls of 60 cm or more, and depths of level snow reached 150 cm in upper Teesdale and the Denbighshire Hills. Across Britain, drifts more than five metres deep blocked roads and railways. People were cut off for days. The armed services dropped supplies by helicopter to isolated farmsteads and villages, and helped to clear roads and railways.

During the night of 15-16 January, the temperature at Leeming in North Yorkshire didn't fall below 11.7 °C. The following day, maximum temperatures close to 14 °C were recorded in Norfolk, Herefordshire and Flintshire. All this was soon to change.

An area of high pressure moved northwards from France on 18 January. Two days later, the anticyclone was centred off north-west Norway. It then drifted south-east to southern Scandinavia, and dominated weather over the British Isles for the rest of the month. The first night frost came on the 20th and the winter began in earnest on the 23rd, when snow fell heavily over the south and south-west of England. Even in the Isles of Scilly, a few centimetres of snow fell. The blizzard in south-west England was the worst since 1891; many villages in Devon were isolated.

Unrelenting harsh weather

The cold, snowy weather continued through February and into March. Any breaks in the cold weather were short-lived. On no day in February 1947 did the temperature at Kew Observatory top 4.4 °C, and only twice in the month was the night minimum temperature above 0 °C . Mean minimum temperatures were more than 4 °C below average everywhere in the south and south-west of England, and almost 6 °C below average in some places February 1947 was the coldest February on record in many places and, for its combination of low temperatures with heavy snow, bore comparison with January 1814.

Another unusual feature of February 1947 was the lack of sunshine in the Midlands and south of England - a complete contrast to the north-west of Scotland, where the weather was unusually sunny. When skies did clear, night-time temperatures plunged. A minimum of -21 °C was recorded at Woburn in Bedfordshire early on 25 February. Without the cloud, the month would almost certainly have been even colder than it was, certainly at night.

More snow, flooding and then gales

In some parts of the British Isles, snow fell on as many as 26 days in February 1947. Much of the snow was powdery and was soon whipped into deep drifts by strong winds. If February hadn't been enough, March was even worse. In the first half of the month, there were more gales and heavy snowstorms.

On 4 and 5 March, heavy snow fell over most of England and Wales, with severe drifting. On 6 March, drifts were five metres deep in the Pennines and three metres in the Chilterns. In some places, glazed frost occurred. On 10 and 11 March, southern Scotland had its heaviest snowfall of the winter, and the snowstorm reached the Scottish

Highlands, where, on 12 March, drifts more than seven metres deep were reported. Meanwhile, mild air with a temperature of 7-10 °C edged into the extreme south-west of the British Isles on 10 March, bringing rain. The ensuing thaw was rapid. By the evening of 11 March, vast areas of southern England were under water. After weeks of frost, the ground was frozen hard. The rain and melt-water couldn't soak into the ground. Surface run-off was the only option.

The warm air spread northwards and eastwards. Melt-water from the Welsh mountains poured into the valleys of the Severn and Wye, flooding Herefordshire and Gloucestershire. The rivers of the English Midlands burst their banks. By 13 March, Fenland rivers were close to overspilling.

On 15 March, a deepening depression from the Atlantic approached the British Isles, bringing rain and severe gales. During the afternoon of 16 March, mean winds over southern England reached 50 knots, with gusts of 80-90 knots.

Buildings were damaged and waves were whipped up on floodwaters. In East Anglia, where the major rivers flow north-eastwards, the south-westerly wind drove water before it and waves pounded the dykes. Water levels rose and the dykes gave way. Most of Fenland was inundated. Troops were called in, but they could do little to stop water pouring through the breached dykes.

River levels rose relentlessly. For example, the banks of the Trent burst at Nottingham on 18 March and hundreds of homes were flooded, many to first floor level. When floodwater reached the tidal part of the Trent, it was impeded by a spring tide, and the whole of the lower Trent valley was flooded.

The floods in the West Country subsided after 20 March, but rivers continued to rise in eastern England. The Wharfe, Derwent, Aire and Ouse all burst their banks and flooded a huge area of southern Yorkshire. The town of Selby was almost completely under water.

Only the ancient abbey and a few streets around the market place escaped inundation. 70 percent of all houses in the town were flooded.

The return period of this event has been estimated at 150 years

It has been estimated that if these events occurred today the cost could be as high as £4 bn

2000 Floods

The floods in Autumn 2000 were the most serious floods for many years and indeed may well have been unprecedented in duration and extent. The last floods on this scale were in 1947 but direct comparisons are difficult as many flood defences have been built since then, but so too have many more premises. The flooding was the result of what has proved to be the wettest Autumn since records began in the 1700s; river catchments were saturated and did not hold water which therefore ran straight into rivers. Of the 1.8 million premises at risk of flooding in this country, about 9000 premises were flooded, some on several occasions. Fortunately there was no loss of life directly attributable to the flooding.

The Environment Agency has produced a full assessment of the floods; their causes and their effects; the effectiveness of flood forecasting, warning and response and the lessons to be learned. This report (*Lessons Learned Autumn 2000*) is available from their website.

The estimated costs and return periods fro recent floods has been esrimated as follows by RMS

Easter 1998	£137m	6 year return period
October 2000	£50m	1-2 year return period
Winter 2000	£700m	30 year return period

Appendix 8

El Niño

Early sailors fishing off the coast of South America noticed a phenomenon where during certain years the coastal waters near Peru were abnormally warm, causing unfavorable fishing conditions. This would usually occur during the Christmas period, so the occurrence became known as El Niño meaning "The Little Boy" or "the Christ Child". Today the term is often used in reference to unusually warm ocean surface temperatures in the Equatorial region of the Pacific.

La Niña

La Niña is Spanish for "The Little Girl" and refers to abnormal cold ocean surface temperatures in the Equatorial Pacific. Other terms used, although less often, are El (Old Man) and anti-El Niño.

El Niño is a disruption of the ocean-atmosphere system in the tropical Pacific having important consequences for weather around the globe.

Among these consequences are increased rainfall across the southern tier of the US and in Peru, which has caused destructive flooding, and drought in the West Pacific, sometimes associated with devastating brush fires in Australia. Observations of conditions in the tropical Pacific are considered essential for the prediction of short term (a few months to 1 year) climate variations. To provide necessary data, NOAA operates a network of buoys which measure temperature, currents and winds in the equatorial band. These buoys daily transmit data which are available to researchers and forecasters around the world in real time.

In normal, non-El Niño conditions the trade winds blow towards the west across the tropical Pacific. These winds pile up warm surface water in the west Pacific, so that the sea surface is about 1/2 meter higher at Indonesia than at Ecuador.

The sea surface temperature is about 8 degrees C higher in the west, with cool temperatures off South America, due to an upwelling of cold water from deeper levels. This cold water is nutrient-rich, supporting high levels of primary productivity, diverse marine ecosystems, and major fisheries. Rainfall is found in rising air over the warmest water, and the east Pacific is relatively dry. The observations at 110 W) show that the cool water (below about 17 degrees C,) is within 50m of the surface.

During El Niño, the trade winds relax in the central and western Pacific leading to a depression of the thermocline in the eastern Pacific, and an elevation of the thermocline in the west. The observations at 110W show, for example, that during 1982-1983, the 17-degree isotherm dropped to about 150m depth. This reduced the efficiency of upwelling to cool the suface and cut off the supply of nutrient rich thermocline water to the euphotic zone. The result was a rise in sea surface temperature and a drastic decline in primary productivity, the latter of which adversely affected higher trophic levels of the food chain, including commercial fisheries in this region. The weakening of easterly tradewinds during El Niño is evident in this figure as well. Rainfall follows the warm water eastward, with associated flooding in Peru and drought in Indonesia and Australia. The eastward displacement of the atmospheric heat source overlaying the warmest water results in large changes in the global atmospheric circulation, which in turn force changes in weather in regions far removed from the tropical Pacific.

The Southern Oscillation

The Walker circulation (Walker, 1924) is an east-west atmospheric circulation pattern characterised by rising air above Indonesia and the western Pacific and sinking air above the eastern Pacific, as shown in Figure 1. Associated with the rise in air above Indonesia are heavy convective rains. The term "Southern Oscillation" refers to the variability of the strength of the Walker Circulation system and is quantified through the Southern Oscillation Index. During El Niño events there is a weakening of the Walker circulation, generally bringing drier conditions to the western Pacific region. During La Niña events the Walker circulation is especially strong, and rainfall may be unusually high over Indonesia. El Niño and the Southern Oscillation are two characteristics of the one large ocean-atmosphere event which we now refer to as ENSO.

Calculating the Southern Oscillation Index (SOI)

The SOI is an index used to quantify the strength of an ENSO event. It is calculated from the difference between the sea level pressure (SLP) at Tahiti and Darwin. Although there are several methods of determining this relationship, a method often used, was presented by Troup (1965):

$$SOI = 10.0 \times \frac{[\, SLPdiff - avSLPdiff \,]}{StdDev(SLPdiff)}$$

where
SLPdiff = (mean Tahiti SLP for the month) - (mean Darwin SLP for the month),
avSLPdiff = long term mean of SLPdiff for the month in question, and
StdDev(SLPdiff) = standard deviation of SLPdiff for the month in question.

Physical characteristics

While the SOI is a measure based on atmospheric pressure, an ENSO event is also portrayed by sea surface temperature (SST) maps. The "normal" conditions are for warmer SSTs to the west of the equatorial Pacific basin and cooler SSTs to the east,. This, combined with the normal Walker atmospheric circulation, produces higher precipitation on the islands bordering the west Pacific and little rainfall over the eastern Pacific. It also influences the ocean surface salinity values in these regions.
During typical El Niño conditions, warmer SSTs spread further east, producing the warmer ocean surface temperatures . This coincides with a weakening of the Walker circulation and may cause a lower rainfall over the western Pacific and excessive rain on parts of Peru and Ecuador. Other notable anomalies during these events are changes in

sea surface heights, with higher than average heights experienced to the east of the Pacific. Convective cloud, usually situated over the western Pacific shifts to the east and centres itself in the middle of the equatorial region of the Pacific. It should be noted that while ENSO conditions provide the basis for such impacts other factors can also cause equally opposite reactions.

La Niña events are associated with cooler SSTs extending further west and warmer temperatures contracting to the west . Strengthening of the Walker circulation causes an increase in precipitation, particularly over Indonesia, and abnormally high sea surface heights over the western Pacific. Generally drier conditions are experienced over Peru and Ecuador. A strengthening of the Trade winds is also observed.

Further areas of influence

While the effects of an ENSO period are directly linked to areas within the Pacific Basin, its signal is noticeable as far away as India, Africa, Antarctica (Bromwich et al, 2000) and North America. Impacts are usually expressed in the form of a change in the precipitation regime.

Causes

We know that ENSO events are a mix of changes in atmospheric and oceanic conditions, and that SST warming and a low SOI are signals of an El Niño event. But what causes the onset of these conditions? Several causes have been put forward. These include:
climate cycles or ocean-atmosphere oscillations
underwater earthquakes on the East Pacific Rise
solar activity

Of these the last two are generally regarded as being less likely causes of ENSO events. It is more probable that the onset of an ENSO event is caused by complex oscillations in a dynamic ocean-atmospheric system. Is there a link between ENSO events and climate change/global warming? At this stage there is no consensus on this matter. There is, however, evidence that the characteristics of ENSO are changing. Although El Niño's are is normally cited as being a relatively rare event, it has become apparent that in the 1980s and 1990s El Niño events occurred more frequently, and lasted longer. The longest El Niño of the 20th Century persisted from 1991 to 1995, and was rapidly succeeded by the most intense El Niño of the 20th century, which occurred in the period 1997-98 (WMO, 1999). In the three decades since 1970, the WMO lists five El Niño events, in 1972-73, 1982-83, 1986-88, 1991-95 and 1997-98. In the preceding seven decades the same number of events are listed, in 1899-1900, 1904-5, 1913-15, 1925-26 and 1940-41 (WMO, 1999).

North Atlantic Oscillation

The North Atlantic Oscillation (NAO) is a large-scale mode (i.e., pattern) of natural climate variability that has important impacts on the weather and climate of the North Atlantic region and surrounding continents, especially Europe. Although the NAO occurs in all seasons, it is during winter that it is particularly dominant, and therefore the focus of this information sheet is on the December to March period. The NAO is a north-south shift (or vice versa) in the track of storms and depressions across the North Atlantic Ocean and into Europe. The storm track exhibits variations from winter to winter in its strength (i.e., number of depressions) and position (i.e., the median route taken by that winter's storms), but a particularly recurrent variation is for the storm track to be either strong with a north-eastward orientation taking depressions into NW or weaker with an east-west orientation taking depressions into Mediterranean Europe). Since the Atlantic storms that travel into Europe control our rainfall, there is a strong influence on European precipitation patterns (with a wet northern Europe and a dry Mediterranean Europe during a high NAO winter, and the opposite during a low NAO winter).

The year-to-year variability in storm tracks is associated with a change in the mean atmospheric circulation averaged over the winter season. This is evident in the anomalous sea level pressure (SLP) patterns associated with high or low NAO winters. When the Iceland Low pressure centre is deeper than usual, the Azores High is stronger than usual, and vice versa. The change in the mean atmospheric circulation drives patterns of warming and cooling over much of the northern hemisphere (For example, when the NAO is high, the SLP gradient between Iceland and the Azores/Iberia is enhanced , driving stronger westerly and southwesterly flow that carries warm maritime air over the cold winter Eurasian land mass, bringing anomalously warm winter temperatures.

The sea level pressure averaged over the winter is easier to between the mean winter SLP at Gibraltar and the mean winter SLP over Iceland. Some people use Lisbon or the Azores instead of Gibraltar, but it makes little difference. The figure, and the underlying data, are regularly updated on the CRU website. Note there is high year-to-year variability in the NAO, combined with an upward trend from the 1960s to the early 1990s whose possible cause has not yet been identified.

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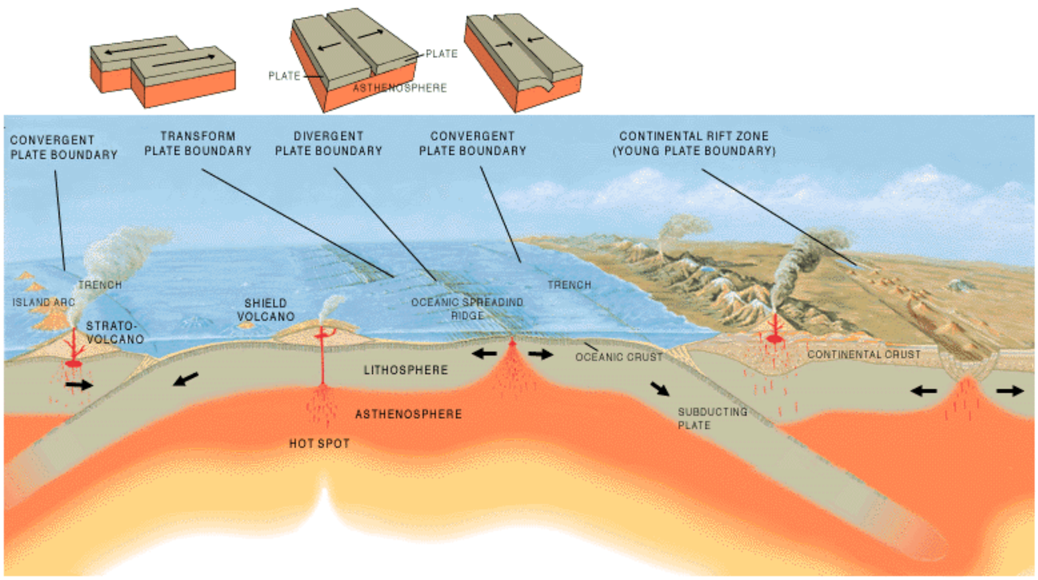
Because the influence of the NAO is so strong on the winter climate of Europe, if the state of the NAO (i.e., the value of the NAO index) could be forecast in advance (say 6 months ahead) then extremely valuable seasonal climate forecasts could be made for Europe. Unfortunately, the NAO is a noisy mid-latitude phenomenon and even the best predictions to date have not be able to capture more than 10% of its year-to-year variance. David Stephenson outlines the potential for forecasting the NAO on his website (http://www.met.rdg.ac.uk/cag/NAO/Forecasts.html).

Appendix 9

Earthquake



Intensity

Intensity is a subjective measure of cultural damage done by an earthquake. Intensity values are heavily dependent on type of structures, construction methods, population density, type of ground, and distance from earthquake. In the United States, the Modified Mercalli scale, ranging from I to XII, is generally used. Other commonly used scales are the Rossi-Forel (I to X) scale in Europe and the Japan Meteorological Agency scale (0 to 7) in Japan.

Caution: Intensities of events prior to the early 20th century tend to be overrated. There are strong biases depending on population density, type of construction, time of day of the event, etc. Uncertainties in maximum intensity can easily reach two or three intensity levels

Magnitudes are, in principle, an objective measure of the amount of ground movement (and by implication, energy) in an earthquake. They are generally calculated as the $\log_{10}$ (Amplitude) + correction for distance and focal depth. M_o is calculated by quantitative analysis of the waveform taking frequency and focal mechanism into account. M_w is defined from M_o by $[(2/3) \log M_o] - 6.03$; M_o in newton-meters. The original Richter magnitude scale is a local magnitude (M_L) defined for small events recorded at relatively short distances from the earthquake.

m_b: body-wave magnitude, generally based on the 1 second P-wave.

M_S: surface-wave magnitude, generally based on the 20 sec Love or Rayleigh wave.

M_w: Moment magnitude as defined by Kanamori (1977)

M_o: Seismic moment in newton-meters. Best estimate of energy release in an earthquake.

M_t: Tsunami magnitude as defined by Abe (1979)

M_L: Local (Richter) magnitude.

In general, the press will report the highest magnitude obtained from a variety of sources. Currently used magnitude scales are defined by the U.S. Geological Survey

Alternatively one might consider the modified Mercalli Intensity Scale

Modified Mercalli Intensity Scale of 1931

I. Not felt except by a very few under especially favorable circumstances.

II. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.

III. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration like passing truck. Duration estimated.

IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, and doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing motorcars rock noticeably.

V. Felt by nearly everyone; many awakened. Some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbance of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.

VI. Felt by all; many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.

VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motor cars.

VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motor cars disturbed.

IX. Damage considerable in specially designed structures; well- designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.

X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed over banks.

XI. Few, if any (masonry), structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.

XII. Damage total. Waves seen on ground surfaces. Lines of sight and level distorted. Objects thrown upward into the air.

Historic Earthquakes

The scientific study of earthquakes is comparatively new. Until the 18th century, few factual descriptions of earthquakes were recorded, and the natural cause of earthquakes was little understood. Those who did look for natural causes often reached conclusions that seem fanciful today; one popular theory was that earthquakes were caused by air rushing out of caverns deep in the Earth's interior.

The earliest earthquake for which we have descriptive information occurred in China in 1177 B.C. The Chinese earthquake catalog describes several dozen large earthquakes in China during the next few thousand years. Earthquakes in Europe are mentioned as early as 580 B.C., but the earliest for which we have some descriptive information occurred in the mid-16th century. The earliest known earthquakes in the Americas were in Mexico in the late 14th century and in Peru in 1471, but descriptions of the effects were not well documented. By the 17th century, descriptions of the effects of earthquakes were being published around the world - although these accounts were often exaggerated or distorted.

The most widely felt earthquakes in the recorded history of North America were a series that occurred in 1811-1812 near New Madrid, Missouri. A great earthquake, whose magnitude is estimated to be about 8, occurred on the morning of December 16, 1811. Another great earthquake occurred on January 23, 1812, and a third, the strongest yet, on February 7, 1812. Aftershocks were nearly continuous between these great earthquakes and continued for months afterwards. These earthquakes were felt by people as far away as Boston and Denver. Because the most intense effects were in a sparsely populated region, the destruction of human life and property was slight. If just one of these enormous earthquakes occurred in the same area today, millions of people and buildings and other structures worth billions of dollars would be affected.

The San Francisco earthquakes of 1906 was one of the most destructive in the recorded history of North America - the earthquake and the fire that followed killed nearly 700 people and left the city in ruins.

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The Alaska earthquake of March 27, 1964, was of greater magnitude than the San Francisco earthquake; it released perhaps twice as much energy and was felt over an area of almost 500,000 square miles.

The ground motion near the epicenter was so violent that the tops of some trees were snapped off. One hundred and fourteen people (some as far away as California) died as a result of this earthquake, but loss of life and property would have been far greated had Alaska been more densely populated.

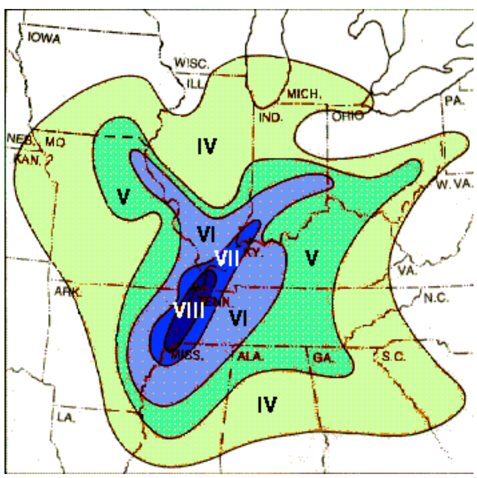
The recent earthquake which struck Kobe, Japan, resulted in the loss of over 5000 lives and millions of dollars in property. However, large parts of the United States are also subject to large magnitude quakes - quakes which could be far more powerful than the Kobe quake! Although we tend to think of California and Alaska as the places where most of our earthquakes occur, the fact is that the central U.S. has been the site of some very powerful earthquakes.

New Madrid Earthquakes

In the past three centuries, major earthquakes outside of California and Alaska generally occurred in sparsely-settled areas, and damage and fatalities were largely minimal. But some took place in areas that have since been heavily built up. Among them are three earthquakes that occurred in 1811 and 1812 near New Madrid, MO. They are among the Great earthquakes of known history, affecting the topography more than any other earthquake on the North American continent. Judging from their effects, they were of a magnitude of 8.0 or higher on the Richter Scale. They were felt over the entire United States outside of the Pacific coast. Large areas sank into the earth, new lakes were formed, the course of the Mississippi River was changed, and forests were destroyed over an area of 150,000 acres. Many houses at New Madrid were thrown down. "Houses, gardens, and fields were swallowed up" one source notes. But fatalities and damage were low, because the area was sparsely settled then.

The probability for an earthquake of magnitude 6.0 or greater is significant in the near future, with a 50% chance by the year 2000 and a 90% chance by the year 2040. A quake with a magnitude equal to that of the 1811- 1812 quakes could result in great loss of life and property damage in the billions of dollars. Scientists believe we could be overdue for a large earthquake and through research and public awareness may be able to prevent such losses.

Los Angeles can expect to be mightily damaged by movement on the San Andreas Fault, or the Newport-Inglewood or other neighboring faults, most probably within the next 25 years. But the Eastern and Midwestern states also face ground shaking of colossal proportions, repetitions of such known upheavals as the 1886 Charleston, S.C., quake, the 1755 Boston quake, and the Jamaica Bay quake hundreds of years ago on New York's Long Island. The granddaddy of them all was the 1811-1812 series of three great quakes on the New Madrid Fault (halfway between St. Louis and Memphis beneath the Mississippi), which shook the entire United States. The next time the New Madrid Fault produces such a quake, it is estimated 60 percent of Memphis will be devastated, leaving $50 Billion in damage and thousands of dead in its wake. Memphis, you see - like



Armenia - has looked down the barrel of a loaded seismic gun for decades, but has done virtually nothing to move out of the crosshairs.

Table A9.1

MAGNITUDES OF THE LARGEST EVENTS OF THE 20th CENTURY

Rank	Date	Location	m_b	M_S	M_w	M_o (Nm)
1a	1960.05.22	Chile Mainshock	7.9	8.3-8.5	9.6	3.2×10^{23}
1b	1960.05.22	Chile "Precursor"			9.5	1.9×10^{23}
2	1964.03.28	Prince William Sound Alasks	7.9	8.4	9.2	8.2×10^{22}
1c	1960.05.22	Chile "Afterslip"		9	4×10^{22}	
3	1952.11.04	Kamchatka	7.9	8.2	9	3.5×10^{22}
4	1965.02.04	Aleutian Islands	7.7	7.75-8.2	8.7	1.4×10^{22}
5	1950.08.15	Assam, India	8	8.6	8.7	1.4×10^{22}
6	1933.03.02	Sanriku, Japan	8.2-8.3	8.3-8.5	8.6	9.5×10^{21}
7	1957.03.09	Aleutian Islands	7.7	8.1-8.25	8.6	8.8×10^{21}
8	1906.01.31	Ecuador-Colombia	8.2	8.2	8.6	8×10^{21}
9	1963.10.13	Etorofu, Kurile Islands	7.7	8.1	8.5	7.5×10^{21}
10	1938.02.01	Banda Sea	8	8.2	8.5	7.5×10^{21}
11	1906.08.17	Valparaiso, Chile	8.1-8.4	8.5	6.6×10^{21}	
12	1923.02.03	Kamchatka	7.7	8.3	8.5	5.5×10^{21}
13	1958.11.06	Etorofu, Kurile Islands	8	8.1	8.4	4.4×10^{21}
14	1922.11.11	Atacama, Chile		8.3	8.4	4.2×10^{21}
15	1952.03.04	Tokachi-oki, Japan	8	8.3	8.4	3.8×10^{21}
16	1977.08.19	Sumbawa, Indonesia	6.8-7.0	7.9-8.1	8.3	3.59×10^{21}
17	1924.06.26	Macquarie Ridge	7.9	7.7	8.3	3.02×10^{21}
18	1920.12.16	Kansu, China	7.9	8.5-8.6	8.3	3×10^{21}
19	1994.10.04	Etorofu, Kuriles	7.3-7.4	8.1	8.3	3×10^{21}
20	1905.07.09	Mongolia	7.7	7.6	8.3	3×10^{21}
21	1905.07.23	Mongolia	8.2	7.7	8.3	3×10^{21}
22	1946.04.01	Aleutian Islands	7.3	7.4	8.3	3×10^{21}
23	1979.12.12	Colombia-Ecuador	6.2-6.4	7.6-7.7	8.3	2.9×10^{21}
24	1923.09.01	Kanto (Tokyo), Japan	7.7	7.9-8.2	8.3	2.9×10^{21}
25	1968.05.16	Tokachi-oki, Japan	7.6	8.1	8.3	2.8×10^{21}
26	1938.11.10	Alaska	8.2	8.3	8.3	2.8×10^{21}
27	1919.04.30	Tonga	7.7	8.2-8.3	8.3	2.71×10^{21}
28	1994.06.09	Bolivia	6.9	6.8	8.3	2.63×10^{21}
29	1950.12.09	Argentina	7.5	7.9	8.3	2.6×10^{21}
30	1959.05.04	Kamchatka	7.9	7.9-8.0	8.2	2.5×10^{21}
31	1940.05.24	Peru	7.8	7.7-8.25	8.2	2.5×10^{21}
32	1918.08.15	Mindanao, Philippines	7.6	8.0-8.25	8.2	2.5×10^{21}
33	1996.02.18	West Irian, Indonesia	6.5	8.1	8.2	2.41×10^{21}
34	1989.05.23	Macquarie Ridge	6.4	8.1-8.2	8.2	2.4×10^{21}
35	1949.08.22	Queen Charlotte Island	7.5	8.1	8.2	2.3×10^{21}
36	1928.06.17	Oaxaca, Mexico	7.6	7.8	8.2	2.3×10^{21}
37	1918.09.07	Urup, Kurile Islands	7.6	8.0-8.2	8.2	2.2×10^{21}
38	1969.08.11	Shikotan, Kurile Islands	7.9	7.8	8.2	2.2×10^{21}
39	1960.05.21	Chile Foreshock	7.5	7.9-8.1	8.2	2×10^{21}
40	1966.10.17	Northern Peru	6.3	7.8	8.2	2×10^{21}
41	1970.07.31	Columbia			8.2	2×10^{21}
42	1924.04.14	Philippines	7.7	8.3	8.2	1.95×10^{21}

Table A9.2
MAGNITUDES OF THE LARGEST EVENTS

Pre 20th Centuary

Date	Location	m_b	M_S
684.11.29	Nankaido, Japan		8.4
869.08.03	Sanriku, Japan		8.6
887.08.26	Mino, Japan		8.6
1096.12.17	Tokaido, Japan		8.4
1361.08.03	Kinai, Japan		8.4
1498.09.20	Tokaido, Japan		8.6
1570.02.08	Chile		8.0-8.3
1575.12.16	Valdivia, Chile		8.5
1604.11.23	Peru-Chile		8.4-8.5 ?
1647.05.13	Santiago, Chile		7.9-8.5 ?
1668.07.25	Shantung, China	8.3	8.5 ?
1700.01.26	Cascadia, Washington		
1703.12.31	Kanto, Japan		8.2
1707.10.28	Tosa, Japan		8.4
1725.02.01	Eastern Siberia, Russia		8.2
1730.07.08	Valparaiso, Chile		8.5-8.7
1737.10.17	Kamchatka		8.3
1751.05.25	Concepcion, Chile		8.5 ?
1755.11.01	Lisbon, Portugal		8.6-9.0
1792.08.22	Kamchatka		8.4
1797.02.04	Ecuador		8.3
1819.06.16	Rann of Kutch, India		8.3
1841.05.17	Kamchatka		8.4
1843.02.08	Guadalupe, Caribbean		8.3
1843.04.25	Etorofu, Kuriles		8.2-8.4
1854.12.23	Tokaido, Japan		8.4
1854.12.24	Nankaido, Japan		8.4
1868.08.13	Chile-Peru-Bolivia		8.5
1877.05.10	Iquique, Chile		7.9-8.5
1889.07.11	Chilik, Kazakhstan		8.3
1891.10.28	Mino-Owari, Japan		8.0-8.4
1896.06.15	Sanriku, Japan		6.8-7.2
1897.06.12	Assam, India	8	8
1897.09.21	Philippines		7.5-8.2

Table A9.3

MAGNITUDES OF THE LARGEST EVENTS

Other Significant Events

Date	Location	m_b	M_S	M_w	M_o (Nm)
115	Antioch, Turkey				
1556.01.23	Shensi, China		8		
1737.10.11	Calcutta, India				
1811.12.16	New Madrid, MO	7.2-7.3	8.5-8.6	7.2-7.3*;8.1	1.8×10^{21}
1812.01.23	New Madrid, MO	7.1	8.4	7.0*; 7.8	
1812.02.07	New Madrid, MO	7.3-7.4	8.7-8.8	7.4-7.5*; 8	
1857.01.19	Fort Tejon, CA		8.3	7.9	9×10^{20}
1872.03.26	Owens Valley, CA		8.0-8.5	7.8	5×10^{20}
1886.08.31	Charleston, SC	6.6	7.5-7.6	7.3	1.0×10^{20}
1899.09.10	Yakutat Bay, AK	7.9	8		
1906.04.18	San Francisco, CA	7.4	7.8	8	1.0×10^{21}
1908.12.28	Messina,Italy		7.2		
1959.08.18	Madison Canyon, MT		6.5	7.3	9.5×10^{19}
1960.02.29	Agadir, Morocco		5.9		
1971.02.09	San Fernando, CA	6.2	6.5-6.6	6.6	1.2×10^{19}
1975.02.04	Haicheng, China	6.1-6.4	7.4	7	3.1×10^{19}
1976.02.04	Guatemala		7.5	7.7	3.7×10^{20}
1976.07.27	Tangshan, China	6.3	7.9-8.0	7.5	2.77×10^{20}
1985.09.19	Michoacan, Mexico	6.4-7.0	7.9-8.1	8	1.1×10^{21}
1989.10.17	Loma Prieta, CA	6.2-6.6	7.1	6.9	2.69×10^{19}
1992.06.28	Landers, CA	6.1-6.2	7.5-7.6	7.3	1.06×10^{20}
1994.01.17	Northridge, CA	6.4	6.8-6.9	6.7	1.18×10^{19}
1995.01.16	Kobe, Japan	6.1-6.4	6.8-6.9	6.9	2.43×10^{19}
1999.08.17	Kocaeli, Turkey	6.3	7.8	7.6	2.88×10^{20}
2001.01.26	Western India	6.9	8	7.7	3.8×10^{20}

Table A9.4

High Casualty 20th Centuary

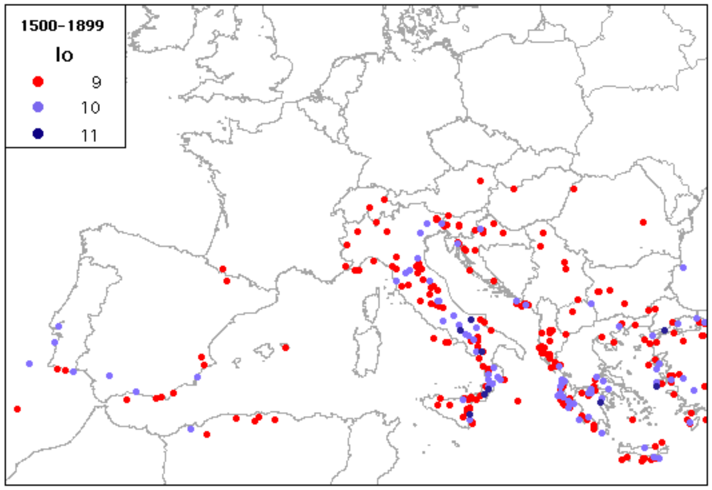
Date	Location	Fatalities	Intensity	M_S	M_w
1976.07.27	Tangshan, China	242,700	X	7.9-8.0	7.5
1920.12.16	Kansu, China	180,000		8.5-8.6	8.3
1923.09.01	Kanto (Tokyo), Japan	142,807	X	7.9-8.2	8.3
1908.12.28	Messina, Italy	82,000	XI-XII	7.2	
1970.05.31	Yungay, Peru	66,794	VIII-X	7.6	8
1990.06.20	Iran	40-50,000	VII	7.7	7.4
1927.05.22	Nanshan, China	40,912		7.9	7.7
1939.12.26	Erzinca, Turkey	23,000-32,700	XI-XII	7.8	7.7
1915.01.13	Avezzano, Italy	29,980-32610	XI	6.8**	
1935.05.30	Quetta, Pakistan	25-30,000	X	7.6	8.1
2001.01.26	Western India	est. 30,000		8	7.7
1939.01.25	Concepcion, Chile	28,000	X	7.8	7.7
1988.12.07	Leninakan, Armenia	25,000	X	6.8	6.8
1978.09.16	Tabas, Iran	15-25,000		7.2	7.4
1976.02.04	Guatemala	22,836	IX	7.5	7.7
1974.05.10	Szechwan, China	20,000		6.8	
1905.04.04	Kangra, India	19-20,000		8	7.8
1968.08.31	Mashad, Iran	12-20,000		7.1	7.3
1985.09.19	Michoacan, Mexico	9,500-20,000	IX	7.9-8.1	8
1948.10.05	Ashkabad, Turkmenistan	19,800	X	7.3	7.2

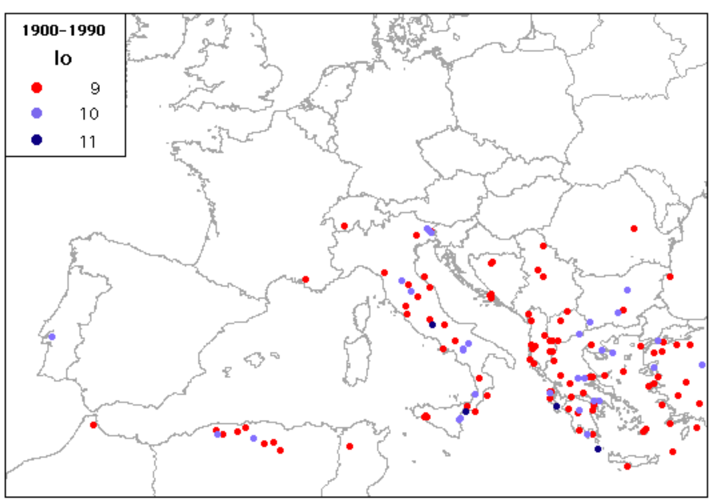
Table A9.5

High Casualty – Others

Date	Location	Fatalities	Intensity	M_S	M_w
1556.01.23	Shensi, China	300-830,000	IX-XI	8.0*	
1737.10.11	Calcutta, India	300,000			
115	Antioch, Turkey	260,000	XI		
1139	Gyandzha, Caucasus	200-300,000	IX	6.8	
1876	Andaman Islands	215,000			
856.12.22	Qumis, Iran	200,000	VIII	6.5	
1138.09.08	Egypt-Syria	100-230,000	XI		
1779	Tabriz, Iran	100-200,000	IX	7	
533.11.29	Syria-Turkey	130,000	X?		
893.03.27	Armenia-Iran	82-180,000	IX	5.3	
1201	Aegean Sea	100,000			
1290.09.27	Jehol, China	100,000	IX	6.75	
1693.01.11	Sicily, Italy	60-93,000	XI		
1868.08.16	Chile-Peru	40-100,000	X-XI	8.5	

European Earthquakes





Appendix 10

Tsunami

A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position. In the case of earthquake-generated tsunamis, the water column is disturbed by the uplift or subsidence of the sea floor. Submarine landslides, which often accompany large earthquakes, as well as collapses of volcanic edifices, can also disturb the overlying water column as sediment and rock slump downslope and are redistributed across the sea floor. Similarly, a violent submarine volcanic eruption can create an impulsive force that uplifts the water column and generates a tsunami. Conversely, supermarine landslides and cosmic-body impacts disturb the water from above, as momentum from falling debris is transferred to the water into which the debris falls. Generally speaking, tsunamis generated from these mechanisms, unlike the Pacific-wide tsunamis caused by some earthquakes, dissipate quickly and rarely affect coastlines distant from the source area.

In Lituya Bay, Alaska, a huge, landslide-generated tsunami occurred on July 9, 1958. The earthquake-induced rockslide, shown in upper right-hand corner of this image, generated a 525 m splash-up immediately across the bay, and razed trees along the bay and across LaChausse Spit before leaving the bay and dissipating in the open waters of the Gulf of Alaska.

Historic Tsunami

TSUNAMI RISK IN THE NORTHEAST ATLANTIC

The Storegga Slides

The most extensive and complex area of submarine slides in the North Atlantic region occurs in the Storegga area located off the west coast of Norway. In marked contrast, there are no fossil submarine slides in the North Sea region since the area is characterised by an extensive area of shallow and relatively flat continental shelf. Thus, whereas tsunamis can theoretically be generated in the North Sea region as a result of offshore earthquakes, it is impossible to generate tsunamis in this area as a result of submarine slides. The last major earthquake that took place in the central North Sea region took place in 1931 and did not generate a tsunami.

The Storegga submarine landslide complex in the Norwegian Sea is one of the largest areas of slope failure in the world. In this area, three very large underwater landslides are known to have taken place during the last 100,000 years Offshore surveys in the area have also shown that several (presently undated) older slides also occur beneath the main Storegga Slide complex. The most detailed information for palaeotsunamis associated with these fossil slides is for the Second Storegga Slide that took place circa 7,100 years ago. The tsunami generated by this landslide is believed to have been the most widespread coastal flood known to have struck coastlines bordering the eastern North Atlantic and North Sea. Several sites showing possible former tsunami inundation associated with the Second Storegga Slide have been reported from western Norway and have been associated with flood runup values as high as 20m

Canary Islands

In 1994, Juan Carlos Carracedo from the Volcanological Station of the Canary Islands in Tenerife described dramatic evidence for a landslide collapse on El Hierro in the Canary Islands. Around 120,000 years ago, a volcano rising at least 1500 metres above sea level tore itself apart. A huge chunk of the north-west side of the island plunged onto the sea floor, breaking up as it fell. What remains behind is a bay 15 kilometres across, whose gently sloping floor is backed by a breathtaking semicircular escarpment more than a kilometre high. It is as if some gigantic sea monster had taken a bite out of the island. When 500 billion tonnes of rock plunge into the sea off the west coast of Africa, people in the US had better head for the hills. Tristan Marshall scans the horizon.

However, a gargantuan wave could sweep westwards across the Atlantic towards the coast of North America. A mighty wall of water 50 metres high would hit the Caribbean islands, Florida and the rest of the eastern seaboard, surging up to 20 kilometres inland and engulfing everything in its path. If you thought the tsunamis that periodically terrorise the Pacific Ocean were big, consider this: the Atlantic wave will be five times bigger. It will start its journey 6000 kilometres away, when half an island crashes into the sea.

Jim Moore of US geological surveyalso suggested that the Hawaiian landslides generated giant waves. He attributed marine deposits in the Hawaiian islands that lie up to 375 metres above sea level to the action of tsunamis, though this is still highly controversial .But most scientists now agree that island collapses around the world would inevitably have caused gigantic tsunamis. For instance, giant wave deposits found in the Bahamas coincide with a past collapse in the Canaries

Simon Day of the Benfield Greig Hazard Research Centre at University College London has discovered that a huge chunk of La Palma, the most volcanically active island in the Canaries, is now unstable. "If the flank of the volcano slides into the ocean, the mass of moving rock will push the water in front of it, creating a tsunami wave far larger than any seen in history," says Day. "The wave would then spread out across the Atlantic at the speed of a jet airliner until it strikes coastal areas all around the North Atlantic."

.In a recent published paper, Day and his colleagues suggested that this structure could lead to a mighty landslide. Day believes that the western flank of the volcano is becoming gradually detached from the eastern half. What's more, he thinks the western flank is subtly altering in shape, making it easier for magma to break through to the surface. During the three most recent summit eruptions in 1585, 1712 and 1949, vents opened up on the western flank of the volcano, while none appeared on the eastern flank.

Hermann Fritz, a PhD student at the Swiss Federal Institute of Technology in Zurich, has spent several years modelling how landslides generate waves when they fall into water. Hehas constructed a lab model of the western flank of the Cumbre Vieja in a wave tank.

Fritz found that the sliding block generated a long, shallow, fast-moving wave--the classic profile of a tsunami. The model predicts that in real life the crest of the wave generated by the collapse of the western flank of the Cumbre Vieja would initially be a staggering 650 metres above normal sea level, more than enough to submerge the tallest building in the world... If the La Palma collapse produced a single tsunami, it would be 40 to 50 metres high when it reached the American coast. "That mass of water moving at that speed would remove buildings, trees, roads, everything," says Day.

Appendix 11

Volcanoes

Scale Index

Some scientists recently proposed the Volcanic Explosivity Index (VEI) to attempt to standardize the assignment of the size of an explosive eruption, using ejecta volume as well as the other criteria mentioned earlier. The VEI scale ranges from 0 to 8. A VEI of 0 denotes a nonexplosive eruption, regardless of volume of erupted products. Eruptions designated a VEI of 5 or higher are considered "very large" explosive events, which occur worldwide only on an average of about once every 2 decades. The May 1980 eruption of Mount St. Helens rated a VEI of 5, but just barely; its lateral blast was powerful, but its output of magma was rather small. The VEI has been determined for more than 5,000 eruptions in the last 10,000 years. None of these eruptions rates the maximum VEI of 8. For example, the eruption of Vesuvius Volcano in A.D. 79, which destroyed Pompeii and Herculaneum, only rates a VEI of 5. Since A.D. 1500, only 21 eruptions with VEI 5 or greater have occurred: one VEI 7 (the 1815 Tambora eruption), four of VEI 6 (including Krakatau in 1883), and sixteen of VEI 5 (counting Mount St. Helens in 1989 and El Chichon, Mexico in 1982). Considered barely "very large," the eruption of Mount St. Helens in May 1980 was smaller than most other "very large" eruptions within the past 10,000 years and much smaller than the enormous caldera-forming eruptions--which would rate VEl's of 8--that took place earlier than 10,000 years ago.

Major Eruptions

Volcano	Year	Cubic Miles	Cubic Kilometers
Large" Eruptions			
Kilauea, Hawaii	1983	0.02	0.1
Mauna Loa, Hawaii	1976	0.09	0.375
Mauna Loa, Hawaii	1984	0.05	0.22
Mt. Pelee, Martinique	1902	0.1	0.5
Mount St. Helens	1980	0.2	0.7
Askja, Iceland	1875	0.5	2
Vesuvius, Italy	79	0.7	3
Major" Eruptions			
Pinatubo, Philippines	1991	2.4	10
Krakatoa, Indonesia	1883	4.3	18
Ilopango, El Salvador	300	10	40
Santorini, Greece	1450BC	14	60
Mazama, Oregon	4000BC	18	75
Tambora, Indonesia	1815	36	150
"Great" Eruptions			
Valles, New Mexico	1.4 Million BC	72	300
Long Valley, Calif.	740,000BC	120	500
Lava Creek Ash	600,000BC	240	1000
Mesa Falls	1.2 Million BC	67	280
Huckleberry	2.0 Million BC	600	2500
Columbia, Washington	15 Million BC	24,000	100,000

The preceeding table was complied using data from the following sources: R. L. Smith (1979) GSA Special Paper 180, pp. 5-27; R. B. Smith and L. W. Braile (1994) J. Volc. Geotherm. Res. 61:121-187; J. J. Dvorak, C. Johnson and R. I. Tilling (1992) Sci. Am., August, pp. 46-53; J. M. Rhodes (1988) J. Geophys. Res. 93:4453-4466; F. Press and R. Siever (1974) Earth, W. H. Freeman & Co.

US Eruptions

Mount St. Helens, Washington

1980-1986: Large explosive eruption on May 18, 1980, followed by 21 smaller eruptive episodes. The last 17 episodes built a lava dome in the volcano's crater. See USGS fact sheet of activity between 1986 and 2000.

1800-1857: Large explosive eruption in 1800 was followed by extrusions of lava that formed a lava flow on the volcano's northwest flank (Floating Island lava flow) and a lava dome on the north flank (Goat Rocks lava dome).

Late 1700's: Layers of volcanic rocks record a variety of activity related to the growth of a lava dome at the volcano's summit, including pyroclastic flows, lahars, and tephra fall.

Lassen Peak, California

1914-1917: A series of small explosions that began on May 30, 1914, was followed 12 months later by extrusion of lava from the summit and a destructive pyroclastic flow and lahars on May 21, 1915. Minor activity continued through middle of 1917. See USGS fact sheet about the eruption.

Mount Rainier, Washington

1894 & early 1800's: Several eyewitness accounts describe minor releases of steam and ash-laden steam during November and December 1894. The most recent eruption that formed a thin and discontinuous tephra layer, however, occurred during the first half of the 19th century.

Mount Hood, Oregon

1856-1865 & late 1700's: According to eyewitnesses, small explosive eruptions occurred from the summit area between 1856 and 1865. In the latter half of the 18th century, however, a lava dome was erupted, which was accompanied by pyroclastic flows, lahars, and tephra fall.

Mount Shasta, California

1786: An eruption cloud was observed above the volcano from a ship passing by north coast California, and the activity included pyroclastic flows.

Glacier Peak, Washington

17th - 18th centuries: Between about 200 and 300 years ago, small eruptions deposited pumice and ash east of the volcano, and may have been observed by Native Americans.

Mount Baker, Washington

1840-1870: Historical literature refers to several episodes of small tephra-producing events in the mid 1800's, and increased fumarolic activity began in Sherman Crater near the summit in 1975 and remains elevated today.

Table A11.1

Major Losses from the May 18, 1980 Eruption of Mount St. Helens.

Sector	Federal	Private	State	Local	Total	%Total
Forestry	$168.0	$218.1	$63.7	---	$449.8	46.6
Clean-up	307.9	9.7	5.0	$41.3	363.0	37.4
Property	43.6	44.8	2.5	16.0	106.9	11.0
Agriculture	--	39.1	--	--	39.1	4.0
Income	--	8.9	--	--	8.9	0.9
Transport	--	--	--	2.1	2.1	0.2
Total	$518.6	$320.6	$71.2	$59.4	$969.8	--
Percent of total	53.0	33.1	7.3	6.1	--	--

In millions of dollars.

From Washington State Department of Commerce and Economic development Research Division.

Note: Smart's Insurance Bulletin, May 18, 1981 reported over 40,000 insurance claims were filed, 166 recovery loans were applied for and $215 million was spent on dredging rivers as of fall, 1981.

Appendix 12

Meteorite Collision

Table A12.1

Torino Scale

White Zone: Events Having No Likely Consequences

0

The likelihood of a collision is zero, or well below the chance that a random object of the same size will strike the Earth within the next few decades. This designation also applies to any small object that, in the event of a collision, is unlikely to reach the Earth's surface intact.

Green Zone: Events Meriting Careful Monitoring

1

The chance of collision is extremely unlikely, about the same as a random object of the same size striking the Earth within the next few decades.

Yellow Zone: Events Meriting Concern

2

A somewhat close, but not unusual encounter. Collision is very unlikely.

3

A close encounter, with 1% or greater chance of a collision capable of causing localized dstruction.

4

A close encounter, with 1% or greater chance of a collision capable of causing regional devastation.

Orange Zone: Threatening Events

5

A close encounter, with a significant threat of a collision capable of causing regional devastation.

6

A close encounter, with a significant threat of a collision capable of causing a global catastrophe.

7

A close encounter, with an extremely significant threat of a collision capable of causing a global catastrophe.

Red Zone: Certain Collisions

8

A collision capable of causing localized destruction. Such events occur somewhere on Earth between once per 50 years and once per 1000 years.

9

A collision capable of causing regional devastation. Such events occur between once per 1000 years and once per 100,000 years.

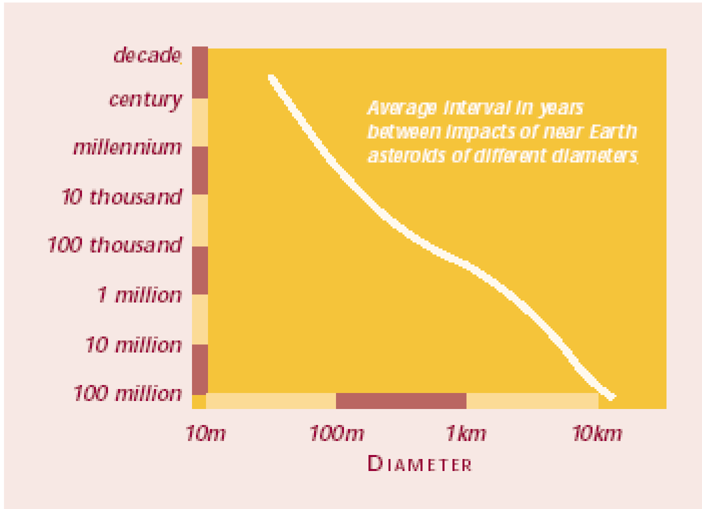
10

A collision capable of causing a global climatic catastrophe. Such events occur once per 100,000 years, or less often.

NEO diameter	Yield megatonnes (MT*)	Crater diameter (km)	Average interval between impact (years)	Consequences
	<10			Upper atmosphere detonation of "stones" (stony asteroids) and comets; only "irons" (iron asteroids) <3%, penetrate to surface.
75m	10 to 100	1.5	1,000	Irons make craters (Barringer Crater); Stones produce air-bursts (Tunguska). Land impacts could destroy area the size of a city (Washington, London, Moscow).
160m	100 to 1,000	3	4,000	Irons and stones produce ground-bursts; comets produce air-bursts. Ocean impacts produce significant tsunamis. Land impacts destroy area the size of large urban area (New York, Tokyo).
350m	1,000 to 10,000	6	16,000	Impacts on land produce craters; ocean-wide tsunamis are produced by ocean impacts. Land impacts destroy area the size of a small state (Delaware, Estonia).
700m	10,000 to 100,000	12	63,000	Tsunamis reach hemispheric scales, exceed damage from land impacts. Land impacts destroy area the size of a moderate state (Virginia, Taiwan).
1.7km	100,000 to 1 million	30	250,000	Both land and ocean impacts raise enough dust to affect climate, freeze crops. Ocean impacts generate global scale tsunamis. Global destruction of ozone. Land impacts destroy area the size of a large state (California, France, Japan). A 30 kilometre crater penetrates through all but the deepest ocean depths.
3km	1 million to 10 million	60	1 million	Both land and ocean impacts raise dust, change climate. Impact ejecta are global, triggering wide-spread fires. Land impacts destroy area size of a large nation (Mexico, India).
7km	10 million to 100 million	125	10 million	Prolonged climate effects, global conflagration, probable mass extinction. Direct destruction approaches continental scale (Australia, Europe, USA).
16km	100 million to 1 billion	250	100 million	Large mass extinction (for example K/T or Cretaceous-Tertiary geological boundary).
	>1 billion			Threatens survival of all advanced life forms.

IMPACT EFFECTS BY SIZE *of Near Earth Object*

Source Report by the Task Force on Potentially Hazardous Near Earth Objects

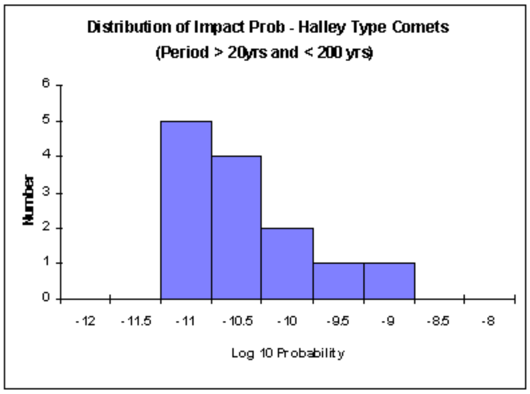


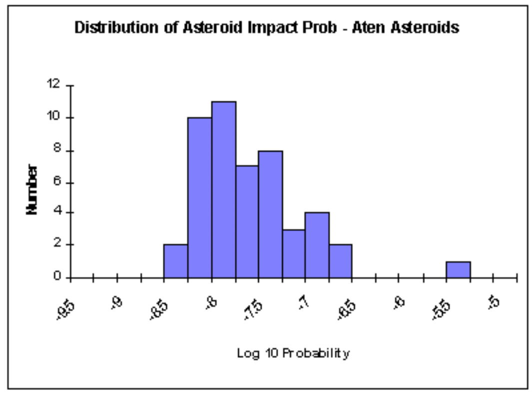
AVERAGE INTERVAL IN YEARS BETWEEN IMPACTS on the Earth of near Earth asteroids of different diameters. The underlying data are as for the graph on page 13, and have the same wide range of uncertainties. If comets were included, impacts of a given destructive level would be more frequent by between 10 and 30 per cent. For a 1 kilometre asteroid the interval is about 200 thousand years; and for a 100 metre one, about 3 thousand years. Based on an unpublished diagram from Alan Harris of NASA/JPL including data from Rabinowitz et al (2000).

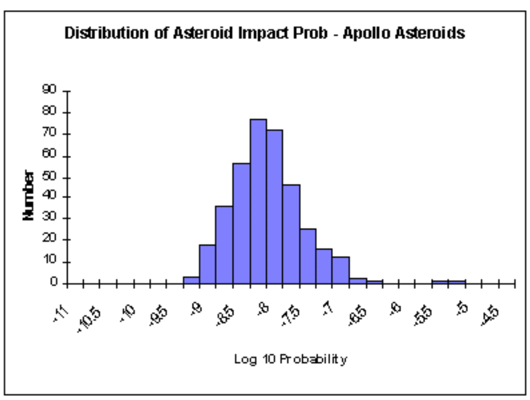
Probability Distributions

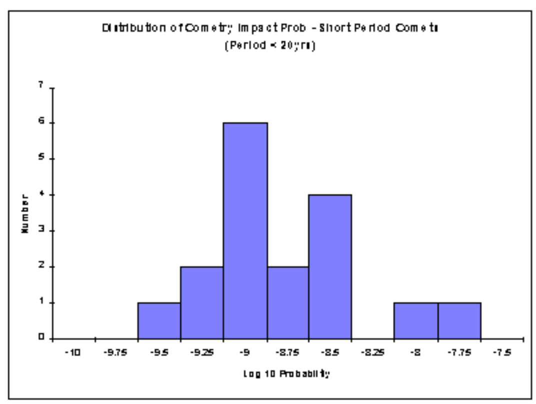
Source: Task Force

Probability Distributions









Source Armargh Observatory

Table A12.2

Here are educated guesses about the consequences of impacts of various sizes:

from 'The Impact Hazard', by Morrison, Chapman and Slovic, published in

Hazards due to Comets and Asteroids

Impactor Diameter (meters)	Yield (megatons)	Interval (years)	Consequences
< 50	< 10	< 1	meteors in upper atmosphere most don't reach surface
75	10 - 100	1000	irons make craters like Meteor Crater; stones produce airbursts like Tunguska; land impacts destroy area size of city
160	100 - 1000	5000	irons,stones hit ground; comets produce airbursts; land impacts destroy area size of large urban area (New York, Tokyo)
350	1000 - 10,000	15,000	land impacts destroy area size of small state; ocean impact produces mild tsunamis
700	10,000 - 100,000	63,000	land impacts destroy area size of moderate state (Virginia); ocean impact makes big tsunamis
1700	100,000 - 1,000,000	250,000	land impact raises dust with global implication; destroys area size of large state (California, France)

Recent Events

Type of event	Diameter of impactor	Average fatalities per impact	Typical interval (years)
High atmospheric break-up	<50m	close to zero	frequent
Tunguska-like events	50m to 300m	5,000	250
Large sub-global event	300m to 1.5km	500,000	25,000
Low global effect threshold	>600m	1.5 billion	70,000
Nominal global effect threshold	>1.5km	1.5 billion	500,000
High global effect threshold	>5km	1.5 billion	6 million
Rare K/T scale events (of type associated with extinction of dinosaurs)	>10km	6 billion	100 million

***ESTIMATED FATALITIES** for a wide variety of different impact scenarios (after Chapman & Morrison, 1994, Nature **367**, 33)*

B-1: *Some major impacts of asteroids and comets*

Age (years) or date	Place	Notes *references in square brackets below given in Bibliography*
2,000 million	South Africa	Vredefort, oldest known crater on Earth, estimates of crater diameter vary from 140 kilometres to 300 kilometres [1]
290 million	Canada	Clearwater Lakes, two craters of diameters 32 kilometres and 22 kilometres [2]
250 million	Australia	Woodleigh, 130 kilometre crater, discovered April 2000. Explosion thought to be source of the massive Permian-Triassic extinction of almost all life on Earth [3]
215 million	Quebec, Canada	Manicouagan, 150 kilometre crater [4]
200 million	Chad, Africa	Aorounga, chain of several large craters from multiple impact, each >10 kilometres [5]
143 million	Australia	Gosses Bluff, 22 kilometre crater [6]
100 million	Canada	Deep Bay, 13 kilometre crater [7]
65 million	Yucatan peninsula	Chicxulub, 170 kilometre scar, mass extinction (dinosaurs) [8]
38 million	Canada	Mistastin Lake, 28 kilometre crater [9]
35 million	USA	Chesapeake Bay 85 kilometre crater [10]
5 million	Namibia, Africa	Roter Kamm, ~3 kilometre crater [11]
3 million	Tajikistan	Kara-Kul, ~50 kilometre crater [12]
2.15 million	SE Pacific Ocean	Eltanin asteroid impact causing tsunami, Asteroid size > 1 kilometre [22]
1 million	Ghana, Africa	Bosumtwi, 10.5 kilometre crater [13]
300 thousand	Australia	Wolfe Creek, 0.9 kilometre crater [14]
49 thousand	Arizona, USA	Barringer or "Meteor" Crater, 1.2 kilometre crater [15]
120 to 600	Saudi Arabia	Wabar Craters in Empty Quarter of Saudi Arabia [17]
1490 *not confirmed*	China	About 10,000 people reported killed [16]
1908	Siberia, Russia	Tunguska, stony object, diameter ~60 metres, exploded at altitude of ~ 8 kilometres, flattening over 2000 square kilometres of trees and starting fires. 10–20 MT [18]
1930	Brazil	Tunguska-like airburst of 10–50 metre object, significant ground damage; no crater identified [19]
1947, Feb	Russia	Sikhote-Alin, one hundred craters, above 0.5 metre (longest about 14 metres) resulting from an iron object breaking up at ~ 5 kilometres [20]
1994, Jul	Comet Shoemaker-Levy 9 collision with Jupiter	Fragmented comet collided with Jupiter creating Earth-sized impact zones [21]

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Table A12.3

"Danger radius": Estimated radius from impact for a tsunami 10m or higher at the shore

Stony Asteroid	**Tsunami Run-up Factor**			
Diameter	**5**	**10**	**20**	**40**
(m)	Distance from impact (km)			
50	10	20	40	60
100	40	70	130	230
200	140	250	460	820
500	800	1400	2500	4400
1000	2800	5000	9000	16 000

Table A12.4

Estimated interval between major tsunami events (tsunami height 10m or more)

Stony Asteroid	**Tsunami Run-up Factor**			
Diameter	**5**	**10**	**20**	**40**
(m)	Average interval between tsunami events (years) for a single location ("city") on the shore of a deep ocean.			
50	-	81 million	20 million	9 million
100	-	66 million	19 million	6 million
200	83 million	26 million	8 million	2 million
500	20 million	7 million	2 million	670 000
1,000	4 million	1.3 million	400 000	330 000
All*	3 million	1 million	300 000	190 000

*All = $1/ (1/T_{50} + 1/T_{100} + 1/T_{200} + 1/T_{500} + 1/T_{1000})$

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Poisson Distribution - events randomly distributed in time

In a Poisson process "events" occur at random points in time. It is possible to work out the probability of a certain number events occurring over a given interval of time. This can be useful for understanding the "uncertainty" about the time between impact events, and why the *apparent* lack of significant impacts over the past few hundred years (other than Tunguska) does not mean the estimates of impacts, from the known NEO population, are incorrect. This table sets out the probability for a process where the *long term* average interval between events is 100 years, as is estimated to be the case with the impact of 50m asteroids.

Table A12.5

Probability of given number of events in an interval

Number of events

Interval (yrs)	Nil	1	2	3	4
50	61%	30%	8%	1%	0.2%
100 (mean)	37%	37%	18%	6%	2%
200	14%	27%	27%	18%	9%
500	1%	3%	8%	14%	17%

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Table A12.6

Estimate of death toll from various types of impact

Asteroid Diameter (m)	Area devastated (sq km)	"Typical" Direct Fatalities	Ratio of indirect/direct fatalities	Total fatalities	Annual chance for inhabited regions 1 in ...	Equivalent annual death toll
50	1900	200 000	4	1 million	900	1100
100	7200	650 000	4	3 million	8000	400
200	29 000	2 000 000	6	14 million	30 000	500
500	70 000	4 000 000	8	35 million	180 000	200
1 km	200 000	7 000 000	8	63 million	290 000	200
2 km	-	-	-	1.5 billion	1 million	1500
All					800	3900

For comparison, the average annual death toll from earthquakes is about 10,000 per year. That of commercial airliner crashes is about 700 per year

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Appendix 13

Man Made Events

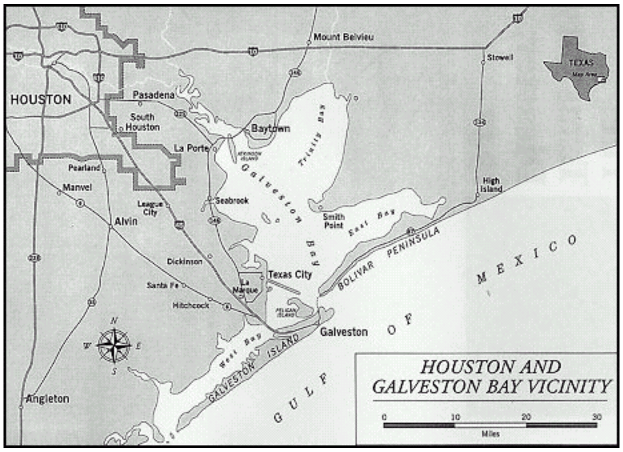
Explosion

THE HALIFAX EXPLOSION: 6TH DECEMBER 1917.

At 9:05 on the 6th December 1917, a munition ship exploded in Halifax harbour, (Nova Scotia, Canada). This explosion was so vast that it killed over 2,000 people and completely flattened two square kilometres of northern Halifax. This was the greatest explosion of the Great war, and the largest man-made explosion until the dropping of the bomb at Hiroshima in 1945.

Texas City Explosion 16 April 1947

A ship in the Texas City harbor, the ***Grand Camp***, bearing a cargo of ammonium nitrate fertilizer destined for war torn Europe, caught fire. The fire department was on the scene trying to put out the fire, and a crowd of people (many children) had gathered to watch the firefighters. The bright orange color that came out of the black smoke seemed to catch everyone's attention. The crowd must not have known that ammonium nitrate is highly explosive or they didn't know what was in the cargo hold of the ship. The standard plan for towing a dangerously burning ship from the harbor was not implemented until it was too late, and the tug boat didn't arrive in time to prevent what happened next. A little after 9:00 a.m. the Texas City Disaster, as it is often referred to, happened as the ***Grand Camp*** exploded. A great column of smoke shot up an estimated two thousand feet, followed in about ten seconds by another, and even more violent shockwave. Within moments of the second blast, the Monsanto Chemical Plant was in flames that resulted from broken lines and shattered containers. As entire buildings collapsed, trapping people inside, fires quickly spread to the refineries that made up the Texas City industrial complex.



Another catastrophic event happened when a miniature tidal wave resulted when the water from the bay, which had been driven out by the explosion, rushed in over the docks and continued as far inland as one hundred and fifty feet, sweeping everything in its path with it. All day long the work of caring for the injured and fighting the fires was underway. By nightfall, the town was filled with rescue workers, and ambulances had been making repeated trips to area hospitals. Darkness did not stop the efforts to find those who were still trapped in the wreckage. Throughout the night, fear mounted because another freighter, the *High Flyer*, which was also loaded with ammonium nitrate as well as sulfur, had also been burning all day. Tugs had tried in vain to tow her out of the ruined harbor. At 1:00 a.m. on April 17, everyone was ordered away from the area. At 1:10 a.m. the *High Flyer* exploded in the most violent of all the blasts, taking with her another ship, the *Wilson B. Keene*. It also destroyed a concrete warehouse and a grain elevator and triggered even more fires. Almost the entire fire department had been lost in the first explosion, along with plant workers, dock workers, school children, and other bystanders. Windows rattled in Baytown and a fine mist of black oil rained in Galveston.

The Grandcamp's explosion triggered the worst industrial disaster, resulting in the largest number of casualties, in American history. Such was the intensity of the blasts and the ensuing confusion that no one was able to establish precisely the number of dead and injured. Ultimately, the Red Cross and the Texas Department of Public Safety counted 405 identified and 63 unidentified dead. Another 100 persons were classified as "believed missing" because no trace of their remains was ever found. Estimates of the injured are even less precise but appear to have been on the order of 3,500 persons. Although not all casualties were residents of Texas City, the total was equivalent to a staggering 25 percent of the town's estimated population of 16,000. Aggregate property loss amounted to almost $100 million, or more than $700 million in today's monetary value. Even so, this figure maybe too low, because this estimate does not include 1.5 million barrels of petroleum products consumed in flames, valued at approximately $500 million in 1947 terms. Refinery infrastructure and pipelines, including about fifty oil storage tanks, incurred extensive damage or total destruction. The devastated Monsanto plant alone represented about $20 million of the total. Even though the port's break-bulk cargo-handling operations never resumed, Monsanto was rebuilt in little more than a year, and the petrochemical industry recovered quickly. One-third of the town's 1,519 houses were condemned, leaving 2,000 persons homeless and exacerbating an already-serious postwar housing shortage.

Toulouse

On Friday, September 21,2001 at 10:18 a.m. the French town of Toulouse was rocked by a devastating chemical explosion. Two production halls of the AZF fertiliser factory, a subsidiary of AtoFina and part of the oil giant TotalFinaElf, literally flew into the air. Initial reports spoke of 29 dead and 34 with severe injuries. A total of 2,400 were injured, most of them with cuts arising from splintered, flying glass. On Sunday evening five chemical workers remained unaccounted for. One of the dead was a 15-year-old boy.

Four hundred sixty workers are employed in the factory, working in several shifts. The workers present were caught off-guard by the huge explosion and had no chance to escape. Two chimneys collapsed and all that remained from the two halls at the centre of the explosion was a crater 10 metres deep and 50 metres wide. The pressure from the explosion was sufficient to send automobiles flying into the air, causing a nearby shopping centre to collapse and severely damaging all buildings in the surrounding area.

Windows were shattered over a radius of 5 kilometres and many students at a secondary school in the neighbourhood suffered injuries. The city motorway towards the south was transformed into a field of rubble by a rain of dust and bricks, which damaged numerous cars and injured their drivers.

The detonation resulted in a panic in the city centre some 3 kilometres from the blast. The telephone network collapsed as a huge orange coloured cloud of gas, smelling of ammonia, moved towards the city centre. Gas masks were distributed in the town centre and the metro system in Toulouse was evacuated because of the spread of gas. The city council issued a warning that people should stay indoors and close their windows—a problem for those whose windows had already been shattered.

The airport at Toulouse-Blagnac and the main railway station were closed and 90 schools in the area evacuated. Over radio, inhabitants were called upon to refrain from drinking tap water and use as little water as possible. As many citizens attempted to leave in their cars, they suddenly encountered police blockades at the main roads to the south and at the central city ring road.

Damage caused by the explosion and the subsequent pressure wave is expected to run into several billion francs. The detonation could be felt 80 kilometres away and the Institute for Geophysics at Strasbourg, which measures all seismic changes, registered the blast at 3.4 on the Richter scale. This makes the explosion at Toulouse one of the biggest in modern industrial history, ranking together with such accidents as the 1921 explosion at the Oppau nitrogen works in Germany, with over 500 dead, and the chemical leak at Union Carbide in Bhopal, India in 1984, in which thousands died.

(source – wsws.org)

A13.1.4 Piper Alpha

Piper Alpha was an oil platform in the North Sea that caught fire and burned down on July 6, 1988. It was the worst ever offshore petroleum accident, during which 167 people died and a billion dollar platform was almost totally destroyed.

The platform consisted of a drilling derrick at one end, a processing/refinery area in the center, and living accommodations for its crew on the far end. Since Piper Alpha was close to shore than some other platforms in the area, it had two gas risers (large pipes) from those platforms leading into the processing area. It processed the gas from the risers plus the oil products it drilled itself and then piped the final products to shore.

The disaster began with a routine maintenance procedure. A certain backup propane condensate pump in the processing area needed to have its pressure safety valve checked every18 months, and the time had come. The valve was removed, leaving a hole in the pump where it had been. Because the workers could not get all the equipment they needed by 6:00 PM, they asked for and received permission to leave the rest of the work until the next day.

Later in the evening during the next work shift, a little before 10:00 PM, the primary condensate pump failed. The people in the control room, who were in charge of operating the platform, decided to start the backup pump, not knowing that it was under maintenance. Gas products escaped from the hole left by the valve with such force that workers described it as being like the scream of a banshee. At about 10:00, it ignited and exploded.

The force of the explosion blew down the firewall separating different parts of the processing facility, and soon large quantities of stored oil were burning out of control. The automatic deluge system, which was designed to spray water on such a fire in order to contain it or put it out, was never activated because it had been turned off.

About twenty minutes after the initial explosion, at 10:20, the fire had spread and become hot enough to weaken and then burst the gas risers from the other platforms. These were steel pipes of a diameter from twenty-four to thirty-six inches, containing flammable gas products at two thousand pounds per square inch of pressure. When these risers burst, the resulting jet of fuel dramatically increased the size of the fire from a billowing fireball to a towering inferno. At the fire's peak, the flames reached three hundred to four hundred feet in the air and could be felt from over a mile away and seen from eighty-five.

The crew began to congregate in the living accommodations area, the part of the platform that was the farthest from the blaze and seemed the least dangerous, awaiting helicopters to take them to safety. Unfortunately, the accommodations were not smoke-proofed, and the lack of training that caused people to repeatedly open and shut doors only worsened the problem.

Conditions got so bad in the accommodations area that some people realized that the only way to survive would be to escape the station immediately. They found that all routes to lifeboats were blocked by smoke and flames, and in the lack of any other instructions, they made the jump into the sea hoping to be rescued by boat. Sixty-two men were saved in this fashion; most of the other 167 who died suffocated on carbon monoxide and fumes in the accommodations area.

The gas risers that were fueling the fire were finally shut off about an hour after they had burst, but the fire continued as the oil on the platform and the gas that was already in the pipes burned. Three hours later the majority of the platform, including the accommodations, had melted off and sunk below the water. The ships in the area continued picking up survivors until morning, but the platform and most of its crew had been destroyed.

Source Rice University

A 13.1.5 Recent Explosions (source BBC world service)

2001

21 September, France Thirty people are killed and 2,000 injured in an explosion at a petrochemical factory in the south-western city of Toulouse.

16 August, India: At least 25 people are killed in an explosion at a government-owned dynamite factory in the southern Indian state of Tamil Nadu. Officials say the blast was caused by an "accidental ignition".

10 August, Portugal: Five people are killed and another is injured in an explosion at a fireworks factory in Caldelas, Portugal.

11 July, Afghanistan: Three people are injured in an explosion at an ammunition depot at Darulaman on the southern outskirts of the Afghan capital, Kabul.

21 July, Russia: Three people are killed and four others are injured in a blaze at an army ammunition depot in the Buryat region of eastern Siberia. The accident was reportedly caused by lightning.

8 June, Vietnam: At least four people are injured and 100 homes are damaged in an explosion at an army base in central Vietnam. Reports say 3.5 tons of explosives and ammunition blew up at an army warehouse in Hoa They, south of the Vietnamese capital, Hanoi.

1 June, Pakistan: At least nine people are killed and four others are injured in an explosion at an illegal fireworks factory in Lahore.

7 March, China: At least 37 pupils and four teachers are killed in a blast at a primary school which was being used for manufacturing fireworks in Jiangxi province, eastern China. A doctor at the scene said pupils had been putting fuses into firecrackers at the time of the explosion.

3 March, Guinea: At least 10 people are killed after a fire starts a series of explosions at an ammunitions dump at army base in the Guinean capital, Conakry.

2000

5 August, China: At least 21 people are killed and 25 others are injured in an explosion at an illegal fireworks factory in China's Jiangxi province. Officials say the blast, which destroyed a five-storey building, was probably caused by a dropped cigarette.

15 May, Spain: Five people are killed and 18 others are injured in a fire and explosion at a fireworks factory in Rafelcofer in Spain. Reports say the blast could be felt 3.5 km (2 miles) away.

13 May, Netherlands: Twenty people are killed in an explosion at a fireworks factory in the Dutch town of Enschede. Another 950 people are injured in the blast, which destroyed about 400 homes.

14 March, Mexico: Three people are killed and 17 others are injured in an explosion after sparks ignite hundreds of fireworks at a religious festival in Santa Ana Jilotzingo.

13 January, China: Up to 22 people, including 11 children, are killed in a blast at an unregistered fireworks factory in Anhui province, eastern China.

1999

9 October, Afghanistan: At least seven Taleban soldiers are killed in a series of explosions at an arms dump in northern Afghanistan.

1998

28 December, Peru: Seven people are killed and eight others are injured after an explosion at an illegal fireworks factory sets of a huge fire in the capital, Lima.

12 December, Brazil: Twenty-four people are killed and 50 others are injured in a blast at an illegal fireworks factory in San Antonio de Jesus. Nine of the dead are reported to be children working illegally in the plant.

12 December, US: Seven workers are killed in an explosion at a fireworks factory in Osseo, Michigan. The blast is heard up to 32 km (20 miles) away.

13 October, Mexico: At least 10 people are killed and more than 30 are injured in an explosion at an unauthorised fireworks factory in Tultepec.

18 June, Russia: At least 14 servicemen are killed after lightning strikes an army munitions depot in the Ural mountains.

13 February, China: Forty-seven people are reported killed in a series of explosions at a fireworks factory near Beijing. Chinese media says fireworks sellers demonstrating their

wares are thought to have set off sparks which ignited fireworks stored in vehicles nearby.

Other Fires

Other Historic Fires/Explosions include

Great Fire of London

On Sunday, 2 September 1666, the destruction of medieval London began. Within five days the city was ravaged by fire. An area one and a half miles by half a mile lay in ashes: 373 acres inside the city wall, 63 acres outside, 87 churches and 13,200 houses. Amazingly, only six people were definitely known to have died, but it would seem probable that many more perished.

1871 Great Chicago Fire

The summer of 1871 was very dry, leaving the ground parched and the wooden city vulnerable. On Sunday evening, October 8, 1871, just after nine o'clock, a fire broke out in the barn behind the home of Patrick and Catherine O'Leary at 13 DeKoven Street. How the fire started is still unknown today, but O'Leary's cow often gets the credit.

Firefighters, exhausted from fighting a large fire the day before, were first sent to the wrong neighborhood. When they finally arrived at the O'Leary's, they found the fire raging out of control. The blaze quickly spread east and north. Wooden houses, commercial and industrial buildings, and private mansions were all consumed in the blaze.

After two days, rain began to fall. On the morning of October 10, 1871, the fire died out, leaving complete devastation in the heart of the city. At least 300 people were dead, 100,000 people were homeless, and $200 million worth of property was destroyed. The entire central business district of Chicago was leveled. The fire was one of the most spectacular events of the nineteenth century.

Aviation

Table A13.1

100 worst Airdisaters.

	Fatal	Date	Location	Carrier	Type
1	5607*	09/11/2001	New York City, New York	American /United Airlines	B767 / B767
2	583	03/27/1977	Tenerife, Canary Islands	Pan Am / KLM	B747 / B747
3	520	08/12/1985	Mt. Osutaka, Japan	Japan Air Lines	B747
4	349	11/12/1996	New Delhi, India	Saudi / Kazastan	B747 / Il76
5	346	03/03/1974	Bois d' Ermenonville, France	Turkish Airlines	DC10
6	329	06/23/1985	Atlantic Ocean West of Ireland	Air India	B747
7	301	08/19/1980	Riyadh, Saudi Arabia	Saudi Arabian Airlines	L1011
8	290	07/03/1988	Persian Gulf	Iran Air	A300
9	273	05/25/1979	Chicago, Illinois	American Airlines	DC10
10	270	12/21/1988	Lockerbie, Scotland	Pan American World Airways	B747
11	269	09/01/1983	Sakhalin Island, Russia	Korean Airlines	B747
12	264	04/26/1994	Komaki, Japan	China Airlines	A300
13	261	07/11/1991	Jeddah, Saudi Arabia	Nigeria Airways	DC8
14	257	11/28/1979	Mt. Erebus, Antarctica	Air New Zealand	DC10
15	256	12/12/1985	Gander, Newfoundland, Canada	Arrow Airways	DC8
16	234	09/26/1997	Buah Nabar, Indonesia	Garuda Indonesia Airlines	A300
17	230	07/17/1996	Off East Moriches, New York	Trans World Airlines	B747
18	229	09/02/1998	Off Nova Scotia, Canada	Swissair	MD11
-	229	08/06/1997	Agana, Guam	Korean Airlines	B747
20	227	01/08/1996	Kinshasa, Zaire	African Air	AN32
21	223	05/26/1991	Ban Nong Rong, Thailand	Lauda Air	B767
22	217	10/31/1999	Off Nantucket, Massachusetts	EgyptAir	B767
23	213	01/01/1978	Off Bandra, Maharashtra, India	Air India	B747
24	203	02/16/1998	Taipei, Taiwan	China Airlines	A300
25	200	07/10/1985	Uchuduk, Uzbekistan, USSR	Aeroflot	TU154
26	191	12/04/1974	Maskeliya, Sri Lanka	Martinair Holland	DC8
27	189	09/11/2001	Arlington, Virginia	American Airlines	B757
-	189	02/06/1996	Puerto Plata, Dominican Republic	Alas Nacionales (Birgenair)	B757
29	188	08/03/1975	Immouzer, Morocco	Aila Royal Jordanian Airlines	B707
30	183	05/09/1987	Warsaw, Poland	Polskie Linie Lotnicze	IL62
-	183	11/15/1978	Katunavake, Sir Lanka	Loftleidir	DC8

	Fatal	Date	Location	Carrier	Type
32	181	11/27/1983	Madrid, Spain	Avanca	B747
33	180	12/01/1981	Mt. San Pietro, Corsica, France	Index Adria Avioproment	MD80
34	178	10/11/1994	Omsk, Russia	Aeroflot	TU154
-	178	08/11/1979	Dneprodzerzhinsk, USSR	Aeroflot / Aeroflot	TU134/TU134
36	176	06/07/1989	Paramaribo, Surinam	Surinam Airways	DC8
-	176	09/10/1976	Gaj, Hrvatska, Yugoslavia	Index Adria Avio / BA	DC9 /Trident
-	176	01/22/1973	Kano, Nigeria	Aila Royal Jordanian Airlines	B707
39	174	10/13/1972	Krasnaya Polyana, USSR	Aeroflot	IL62
40	171	09/19/1989	Bilma, Niger	Union des Trans. Aeriens	DC10
-	171	09/04/1989	Havana, Cuba	Cubana	IL62M
42	169	01/30/2000	Off Abidjan, Ivory Coast	Kenya Airways	A310-304
43	167	09/28/1992	Bhadagon, Katmandu, Nepal	Pakistan Inter. Airlines	A300
-	167	03/31/1986	Maravatio, Mexico	Mexicana	B727
45	166	07/07/1980	Nar Alma-Ata, Kasakastan, USSR	Aeroflot	TU154B
46	163	07/30/1971	Morioko, Japan	All Nippon / Japanese AF	B727 / F86F
47	160	12/20/1995	Buga, Columbia	American Airlines	B757
-	160	06/06/1994	Xi'an, China	China Northwest Airlines	TU154M
49	159	11/28/1987	Mauritius, Indian Ocean	South African Airways	B747
50	157	12/22/1992	Tripoli, Libya	Libya Arab Airlines / Lib AF	B727
51	156	08/16/1987	Romulus, Michigan	Northwest Airlines	MD82
-	156	08/14/1972	Konigs Wusterausen, East Germany	Interflug	IL62
-	156	11/26/1979	Jeddah, Saudi Arabia	Pakistan Inter. Airlines	B707
54	155	12/03/1972	Tenerife, Canary Islands	Spantax	Convair 990
-	155	04/04/1975	Siagon, Vietnam	U.S. Air Force	C-5 Gallaxy
56	154	03/16/1969	Maracaibo, Venezuela	Venezolana Inter. de Av.	DC9
-	154	09/19/1976	Karatepe Mountains, Turkey	Turkish Airlines	B727
58	153	07/09/1982	Kenner, Louisiana	Pan American World Airways	B727
59	148	02/19/1985	Mt. Oiz, Spain	Iberia Airlines	B727
60	146	04/25/1980	Tenerife, Canary Islands	Dan Air	B727
61	145	07/04/2001	Irkutsk, Russia	Vladivostokavia	TU154
62	144	02/08/1989	Santa Maria, Azores	Independent Air Inc	B707
-	144	09/25/1978	San Diego, California	Pacific Southwest/Private	B727 /C172
64	143	11/07/1996	Lagos, Nigeria	Aviation Devel. Corp.	B727
-	143	03/17/1988	Cucuta, Colombia	Avianca	B727
-	143	08/23/2000	Off Manama, Behrain	Gulf Air	A320

	Fatal	Date	Location	Carrier	Type
67	141	08/29/1996	Spitsbergen, Norway	Vnokovo Airlines	TU154
-	141	12/18/1995	Kahengula, Angola	Trans Service Airlift	L188C
-	141	11/24/1992	Liutang, Guangxi, China	China Southern Airlines	B737
70	137	06/08/1982	Sierra de Pacatuba, Brazil	VASP	B727
71	135	08/02/1985	Ft. Worth-Dallas, Texas	Delta Air Lines	L1011
72	134	12/16/1960	Staten Island/Brooklyn, New York	United Air Lines / TWA	DC8 / L1049
73	133	02/04/1966	Tokyo Bay, Japan	All Nippon Airways	B727
-	133	02/08/1993	Tehran, Iran	Iran Air / Air Force	TU154M
75	132	09/08/1994	Aliquippa, Pennsylvania	USAir	B737
-	132	05/19/1993	Medellin, Colombia	SAM	B727
-	132	06/28/1982	Southern Belarus, USSR	Aeroflot	YAK42
78	131	11/19/1977	Funchal Island, Portugal	TAP	B727
-	131	04/19/2000	Samal Island, Philippines	Air Philippines	B737
80	130	10/02/1990	Kuwait City, Kuwait	Iraqi Airways	IL76
-	130	11/08/1983	Lubango, Huila, Angola	TAAG Angola Airlines	B737
-	130	11/16/1967	Near Sverdlovsk, Russia	Aeroflot	IL62
-	130	06/03/1962	Villeneuve-le-Roi, France	Air France	B707
84	128	10/02/1990	Guangzhou, China	Xiamen / China SW	B737 / B757
-	128	01/21/1980	Elburz Mountains, Iran	Iran National Airlines	B727
-	128	06/30/1956	Grand Canyon, Arizona	United Airlines / TWA	DC7 / L1049
87	127	10/21/1989	Tegucigalpa, Honduras	TAN Airlines	B727
-	127	03/05/1976	Voronezh, Russia	Aeroflot	IL18D
-	127	11/23/1996	Moroni, Comoros Islands	Ethiopian Airlines	B767
90	126	08/20/1975	Damascus, Syria	Ceskoslovenske Aerolinie	IL62
-	126	04/20/1967	Nicosia, Cypress	Chartered Britannia	Bris. Brit 175
92	125	01/03/1994	Irrupts, Siberia, Russia	Baikal Air	TU154M
93	124	10/19/1988	Ahmedabad, India	Indian Airlines	B737
-	124	03/05/1966	Mt. Fuji, Japan	British Overseas Airways	B707
95	123	02/29/1996	Arequipa, Peru	Compania de Aviacion Fau.	B737
-	123	07/11/1973	Paris, France	VARIG	B707
-	123	04/20/1968	Windhoek, South Africa	South African Airways	B707
98	122	06/18/1972	Kharkov, Ukraine, USSR	Aeroflot	AN10A
99	119	10/13/1973	Domodedovo, Russia	Aeroflot	TU104B
-	119	05/20/1965	Cairo, Egypt	Pakistan Inter. Airlines	B720

Marine Energy

Source - Large Property Damage Losses in the,Hydrocarbon-Chemicallndustries-

A Thirty-Year Review,Trends and Analysis by Marsh Risk Consulting

Largest Property Damage Losses—1970 to 1999

(Excess of $150,000,000 property damage)

Onshore

Date	Location	Plant Type	Event Type	PD Loss ($MM)
10-23-89	Texas	Petrochemical	VCE	839
5-4-88	Nevada	Chemical	Explosion	383
5-5-88	Louisiana	Refinery	VCE	368
11-14-87	Texas	Petrochemical	VCE	285
12-25-97	Malaysia	Gas Plant	Explosion	282
7-23-84	Illinois	Refinery	VCE	268
11-9-92	France	Refinery	VCE	262
12-13-94	Iowa	Chemical	Explosion	224
9-18-89	Virgin Islands	Refinery	Hurricane	207
8-17-99	Turkey	Refinery	Earthquake	200
9-27-98	Mississippi	Refinery	Hurricane	200
5-27-94	Ohio	Chemical	Explosion	200
9-25-98	Australia	Gas Plant	Explosion	187
10-16-92	Japan	Refinery	Explosion	187
3-4-77	Qatar	Gas Plant	VCE	174
6-1-74	England	Petrochemical	VCE	164

The loss amounts were adjusted for inflation.

VCE - Vapor Cloud Explosion

This listing does not include the onshore losses to the Kuwait oil fields during the Gulf War. Total losses are estimated at over $2,500,000,000 (US).

These amounts exclude business interruption which is often as much (or more than the property value).

Largest Property Damage Losses—1970 to 1999

(Excess of $150,000,000 property damage)

Offshore

Date	Location	Facility Type	Event Type	PD Loss ($MM)
7-7-88	North Sea	Platform	Explosion	1,085
8-26-92	Gulf of Mexico	Platform	Hurricane	931
8-23-91	North Sea	Concrete Jacket	MD	474
4-24-88	Brazil	Platform	Blowout	421
11-1-92	Australia	Jacket	MD	314
1-20-89	North Sea	Drilling	Blowout	273
11-2-99	Angola	Process Deck	MD	210
7-1-74	Dubai	Platform	Blowout	204
10-1-74	North Sea	Platform	MD	196

The loss amounts were adjusted for inflation.

MD - Mechanical Damage

Titanic

The *Titanic* was a White Star Line steamship carrying the British flag. She was built by Harland and Wolff of Belfast, Ireland, at a reported cost of $7.5 million. Her specifications were:

Length overall: 882.5 feet

Gross tonnage: 46,329 tons

Beam: 92.5 feet

Net tonnage: 24,900 tons

Depth 59.5 feet

Triple screw propulsion

On 10 April 1912, the *Titanic* commenced her maiden voyage from Southampton, England, to New York, with 2,227 passengers and crew aboard. At 11:40 p.m. on the night of 14 April, traveling at a speed of 20.5 knots, she struck an iceberg on her starboard bow. At 2:20 a.m. she sank, approximately 13.5 miles east-southeast of the position from which her distress call was transmitted. Lost at sea were 1,522 people, including passengers and crew. The 705 survivors, afloat in the ship's twenty lifeboats, were rescued within hours by the Cunard Liner, *Carpathia.*

Exxon Valdez

SPILL: The wreck of the Exxon Valdez

Final Report, Alaska Oil Spill Commission

Published February 1990 by the State of Alaska

The following is a reprint of the text from pages 5-14. Graphics are not included.

No one anticipated any unusual problems as the Exxon Valdez left the Alyeska Pipeline Terminal at 9:12 p.m., Alaska Standard Time, on March 23,1989. The 987foot ship, second newest in Exxon Shipping Company's 20-tanker fleet, was loaded with 53,094,5 10 gallons (1,264,155 barrels) of North Slope crude oil bound for Long Beach, California. Tankers carrying North Slope crude oil had safely transited Prince William Sound more than 8,700 times in the 12 years since oil began flowing through the trans-Alaska pipeline, with no major disasters and few serious incidents. This experience gave little reason to suspect impending disaster. Yet less than three hours later, the Exxon Valdez grounded at Bligh Reef, rupturing eight of its 11 cargo tanks and spewing some 10.8 million gallons of crude oil into Prince William Sound.

Until the Exxon Valdez piled onto Bligh Reef, the system designed to carry 2 million barrels of North Slope oil to West Coast and Gulf Coast markets daily had worked perhaps too well. At least partly because of the success of the Valdez tanker trade, a general complacency had come to permeate the operation and oversight of the entire system. That complacency and success were shattered when the Exxon Valdez ran hard aground shortly after midnight on March 24.

No human lives were lost as a direct result of the disaster, though four deaths were associated with the cleanup effort. Indirectly, however, the human and natural losses were immense-to fisheries, subsistence livelihoods, tourism, wildlife. The most important loss for many who will never visit Prince William Sound was the aesthetic sense that something sacred in the relatively unspoiled land and waters of Alaska had been defiled.

Industry's insistence on regulating the Valdez tanker trade its own way, and government's incremental accession to industry pressure, had produced a disastrous failure of the system. The people of Alaska's Southcentral coast-not to mention Exxon and the Alyeska Pipeline Service Company-would come to pay a heavy price. The American people, increasingly anxious over environmental degradation and devoted to their image of Alaska's wilderness, reacted with anger. A spill that ranked 34th on a list of the world's largest oil spills in the past 25 years came to be seen as the nation's biggest environmental disaster since Three Mile Island.

The Exxon Valdez had reached the Alyeska Marine Terminal at 11:30 p.m. on March 22 to take on cargo. It carried a crew of 19 plus the captain. Third Mate Gregory Cousins, who became a central figure in the grounding, was relieved of watch duty at 11:50 p.m. Ship and terminal crews began loading crude oil onto the tanker at 5:05 a.m. on March 23 and increased loading to its full rate of 100,000 barrels an hour by 5:30 a.m. Chief Mate James R. Kunkel supervised the loading.

March 23, 1989 was a rest day of sorts for some members of the Exxon Valdez crew. Capt. Joseph Hazelwood, chief engineer Jerry Glowacki and radio officer Joel Roberson left the Exxon Valdez about 11:00 a.m., driven from the Alyeska terminal into the town of Valdez by marine pilot William Murphy, who had piloted the Exxon Valdez into port the previous night and would take it back out through Valdez Narrows on its fateful trip to Bligh Reef. When the three ship's officers left the terminal that day, they expected the Exxon Valdez's sailing time to be 10 p.m. that evening. The posted sailing time was changed, however, during the day, and when the party arrived back at the ship at 8:24 p.m., they learned the sailing time had been fixed at 9 p.m.

Hazelwood spent most of the day conducting ship's business, shopping and, according to testimony before the National Transportation Safety Board (NTSB), drinking alcoholic beverages with the other ship's officers in at least two Valdez bars. Testimony indicated Hazelwood drank nonalcoholic beverages that day at lunch, a number of alcoholic drinks late that afternoon while relaxing in a Valdez bar, and at least one more drink at a bar while the party waited for pizza to take with them back to the ship.

Loading of the Exxon Valdez had been completed for an hour by the time the group returned to the ship. They left Valdez by taxi cab at about 7:30 p.m., got through Alyeska terminal gate security at 8:24 p.m. and boarded ship. Radio officer Roberson, who commenced prevoyage tests and checks in the radio room soon after arriving at the ship, later said no one in the group going ashore had expected the ship to be ready to leave as soon as they returned.

Both the cab driver and the gate security guard later testified that no one in the party appeared to be intoxicated. A ship's agent who met with Hazelwood after he got back on the ship said it appeared the captain may have been drinking because his eyes were watery, but she did not smell alcohol on his breath. Ship's pilot Murphy, however, later indicated that he did detect the odor of alcohol on Hazelwood's breath.

Hazelwood's activities in town that day and on the ship that night would become a key focus of accident inquiries, the cause of a state criminal prosecution, and the basis of widespread media sensation. Without intending to minimize the impact of Hazelwood's actions, however, one basic conclusion of this report is that the grounding at Bligh Reef represents much more than the error of a possibly drunken skipper: It was the result of the gradual degradation of oversight and safety practices that had been intended, 12 years before, to safeguard and backstop the inevitable mistakes of human beings.

Third Mate Cousins performed required tests of navigational, mechanical and safety gear at 7:48 p.m., and all systems were found to be in working order. The Exxon Valdez slipped its last mooring line at 9:12 p.m. and, with the assistance of two tugboats, began maneuvering away from the berth. The tanker's deck log shows it was clear of the dock at 9:21 p.m.

Dock to grounding

The ship was under the direction of pilot Murphy and accompanied by a single tug for the passage through Valdez Narrows, the constricted harbor entrance about 7 miles from the berth. According to Murphy, Hazelwood left the bridge at 9:35 p.m. and did not return until about 11:10 p.m., even though Exxon company policy requires two ship's officers on the bridge during transit of Valdez Narrows.

The passage through Valdez Narrows proceeded uneventfully. At 10:49 p.m. the ship reported to the Valdez Vessel Traffic Center that it had passed out of the narrows and was increasing speed. At 11:05 p.m. Murphy asked that Hazelwood be called to the bridge in anticipation of his disembarking from the ship, and at 11: 10 p.m. Hazelwood returned. Murphy disembarked at 11:24 p.m., with assistance from Third Mate Cousins. While Cousins was helping Murphy and then helping stow the pilot ladder, Hazelwood was the only officer on the bridge and there was no lookout even though one was required, according to an NTSB report.

At 11:25 p.m. Hazelwood informed the Vessel Traffic Center that the pilot had departed and that he was increasing speed to sea speed. He also reported that "judging, ah, by our radar, we'll probably divert from the TSS [traffic separation scheme] and end up in the inbound lane if there is no conflicting traffic." The traffic center indicated concurrence, stating there was no reported traffic in the inbound lane.

The traffic separation scheme is designed to do just that-separate incoming and outgoing tankers in Prince William Sound and keep them in clear, deep waters during their transit. It consists of inbound and outbound lanes, with a half-mile-wide separation zone between them. Small icebergs from nearby Columbia Glacier occasionally enter the traffic lanes. Captains had the choice of slowing down to push through them safely or deviating from their lanes if traffic permitted. Hazelwood's report, and the Valdez traffic center's concurrence, meant the ship would change course to leave the western, outbound lane, cross the separation zone and, if necessary, enter the eastern, inbound lane to avoid floating ice. At no time did the Exxon Valdez report or seek permission to depart farther east from the inbound traffic lane; but that is exactly what it did.

At 11:30 p.m. Hazelwood informed the Valdez traffic center that he was turning the ship toward the east on a heading of 200 degrees and reducing speed to "wind my way through the ice" (engine logs, however, show the vessel's speed continued to increase). At 11: 39 Cousins plotted a fix that showed the ship in the middle of the traffic separation scheme. Hazelwood ordered a further course change to a heading of 180 degrees (due south) and, according to the helmsman, directed that the ship be placed on autopilot. The second course change was not reported to the Valdez traffic center. For a total of 19 or 20 minutes the ship sailed south-through the inbound traffic lane, then across its easterly boundary and on toward its peril at Bligh Reef. Traveling at approximately 12 knots, the Exxon Valdez crossed the traffic lanes' easterly boundary at 11:47 p.m.

At 11:52 p.m. the command was given to place the ship's engine on "load program up"-a computer program that, over a span of 43 minutes, would increase engine speed from 55 RPM to sea speed full ahead at 78.7 RPM. After conferring with Cousins about where and how to return the ship to its designated traffic lane, Hazelwood left the bridge. The time, according to NTSB testimony, was approximately 11:53 p.m.

By this time Third Mate Cousins had been on duty for six hours and was scheduled to be relieved by Second Mate Lloyd LeCain. But Cousins, knowing LeCain had worked long hours during loading operations during the day, had told the second mate he could take his time in relieving him. Cousins did not call LeCain to awaken him for the midnight-to-4-a.m. watch, instead remaining on duty himself

Cousins was the only officer on the bridge-a situation that violated company policy and perhaps contributed to the accident. A second officer on the bridge might have been more alert to the danger in the ship's position, the failure of its efforts to turn, the autopilot steering status, and the threat of ice in the tanker lane.

Cousins' duty hours and rest periods became an issue in subsequent investigations. Exxon Shipping Company has said the third mate slept between I a.m. and 7:20 a.m. the morning of March 23 and again between 1: 30 p.m. and 5 p.m., for a total of nearly 10 hours sleep in the 24 hours preceding the accident. But testimony before the NTSB suggests that Cousins "pounded the deck" that afternoon, that he did paperwork in his cabin, and that he ate dinner starting at 4:30 p.m. before relieving the chief mate at 5 p.m. An NTSB report shows that Cousins' customary in-port watches were scheduled from 5:50 a.m. to 11:50 a.m. and again from 5:50 p.m. to 11:50 p.m. Testimony before the NTSB suggests that Cousins may have been awake and generally at work for up to 18 hours preceding the accident.

Appendix F of this report documents a direct link between fatigue and human performance error generally and notes that 80 percent or more of marine accidents are attributable to human error. Appendix F also discusses the impact of environmental factors such as long work hours, poor work conditions (such as toxic fumes), monotony and sleep deprivation. "This can create a scenario where a pilot and/or crew members may become the 'accident waiting to happen.' ... It is conceivable," the report continues, "that excessive work hours (sleep deprivation) contributed to an overall impact of fatigue, which in turn contributed to the Exxon Valdez grounding."

Manning policies also may have affected crew fatigue. Whereas tankers in the 1950s carried a crew of 40 to 42 to manage about 6.3 million gallons of oil, according to Arthur

McKenzie of the Tanker Advisory Center in New York, the Exxon Valdez carried a crew of 19 to transport 53 million gallons of oil.

Minimum vessel manning limits are set by the U.S. Coast Guard, but without any agencywide standard for policy. The Coast Guard has certified Exxon tankers for a minimum of 15 persons (14 if the radio officer is not required). Frank Iarossi, president of Exxon Shipping Company, has stated that his company's policy is to reduce its standard crew complement to 16 on fully automated, diesel-powered vessels by 1990. "While Exxon has defended their actions as an economic decision," the manning report says, "criticism has been leveled against them for manipulating overtime records to better justify reduced manning levels."

Iarossi and Exxon maintain that modem automated vessel technology permits reduced manning without compromise of safety or function. "Yet the literature on the subject suggests that automation does not replace humans in systems, rather, it places the human in a different, more demanding role. Automation typically reduces manual workload but increases mental workload." (Appendix F)

Whatever the NTSB or the courts may finally determine concerning Cousins' work hours that day, manning limits and crew fatigue have received considerable attention as contributing factors to the accident. The Alaska Oil Spill Commission recommends that crew levels be set high enough not only to permit safe operations during ordinary conditions-which, in the Gulf of Alaska, can be highly demanding-but also to provide enough crew backups and rest periods that crisis situations can be confronted by a fresh, well-supported crew.

Accounts and interpretations differ as to events on the bridge from the time Hazelwood left his post to the moment the Exxon Valdez struck Bligh Reef. NTSB testimony by crew members and interpretations of evidence by the State of Alaska conflict in key areas, leaving the precise timing of events still a mystery. But the rough outlines are discernible:

Some time during the critical period before the grounding during the first few minutes of Good Friday, March 24, Cousins plotted a fix indicating it was time to turn the vessel back toward the traffic lanes. About the same time, lookout Maureen Jones reported that Bligh Reef light appeared broad off the starboard bow-i.e., off the bow at an angle of about 45 degrees. The light should have been seen off the port side (the left side of a ship, facing forward); its position off the starboard side indicated great peril for a supertanker that was out of its lanes and accelerating through close waters. Cousins gave right rudder commands to cause the desired course change and took the ship off autopilot. He also phoned Hazelwood in his cabin to inform him the ship was turning back toward the traffic lanes and that, in the process, it would be getting into ice. When the vessel did not turn swiftly enough, Cousins ordered further right rudder with increasing urgency. Finally, realizing the ship was in serious trouble, Cousins phoned Hazelwood again to report the danger-and at the end of the conversation, felt an initial shock to the vessel. The grounding, described by helmsman Robert Kagan as "a bumpy ride" and by Cousins as six "very sharp jolts," occurred at 12:04 a.m.

On the rocks

The vessel came to rest facing roughly southwest, perched across its middle on a pinnacle of Bligh Reef Eight of 11 cargo tanks were punctured. Computations aboard the Exxon Valdez showed that 5.8 million gallons had gushed out of the tanker in the first three and a quarter hours. Weather conditions at the site were, reported to be 33 degrees F, slight drizzle rain/snow mixed, north winds at 10 knots and visibility 10 miles at the time of the grounding.

The Exxon Valdez nightmare had begun. Hazelwood-perhaps drunk, certainly facing a position of great difficulty and confusion-would struggle vainly to power the ship off its perch on Bligh Reef. The response capabilities of Alyeska Pipeline Service Company to deal with the spreading sea of oil would be tested and found to be both unexpectedly slow and woefully inadequate. The worldwide capabilities of Exxon Corp. would mobilize huge quantities of equipment and personnel to respond to the spill-but not in the crucial first few hours and days when containment and cleanup efforts are at a premium. The U.S. Coast Guard would demonstrate its prowess at ship salvage, protecting crews and lightering operations, but prove utterly incapable of oil spill containment and response. State and federal agencies would show differing levels of preparedness and command capability. And the waters of Prince William Sound-and eventually more than 1,000 miles of beach in Southcentral Alaska-would be fouled by 10.8 million gallons of crude oil.

After feeling the grounding Hazelwood rushed to the bridge, arriving as the ship came to rest. He immediately gave a series of rudder orders in an attempt to free the vessel, and power to the ship's engine remained in the "load program up" condition for about 15 minutes after impact. Chief Mate Kunkel went to the engine control room and determined that eight cargo tanks and two ballast tanks had been ruptured; he concluded the cargo tanks had lost an average of 10 feet of cargo, with approximately 67 feet of cargo remaining in each. He informed Hazelwood of his initial damage assessment and was instructed to perform stability and stress analysis. At 12:19 a.m. Hazelwood ordered that the vessel's engine be reduced to idle speed.

At 12:26 a.m., Hazelwood radioed the Valdez traffic center and reported his predicament to Bruce Blandford, a civilian employee of the Coast Guard who was on duty. "We've fetched up, ah, hard aground, north of Goose Island, off Bligh Reef and, ah, evidently leaking some oil and we're gonna be here for a while and, ah, if you want, ah, so you're notified." That report triggered a nightlong cascade of phone calls reaching from Valdez to Anchorage to Houston and eventually around the world as the magnitude of the spill became known and Alyeska and Exxon searched for cleanup machinery and materials.

Hazelwood, meanwhile, was not finished with efforts to power the Exxon Valdez off the reef. At approximately 12:30 a.m., Chief Mate Kunkel used a computer program to determine that though stress on the vessel exceeded acceptable limits, the ship still had required stability. He went to the bridge to advise Hazelwood that the vessel should not go to sea or leave the area. The skipper directed him to return to the control room to continue assessing the damage and to determine available options. At 12:35 p.m., Hazelwood ordered the engine back on-and eventually to "full ahead"-- and began another series of rudder commands in an effort to free the vessel. After running his computer program again another way, Kunkel concluded that the ship did not have acceptable stability without being supported by the reef. The chief mate relayed his new analysis to the captain at I a.m. and again recommended that the ship not leave the area. Nonetheless, Hazelwood kept the engine running until 1:41 a.m., when he finally abandoned efforts to get the vessel off the reef.

Estonia

Source Estonia Ministry of Transport and Communications

THREE COUNTRY COMMISSION COMPLETES INVESTIGATION OF ESTONIA SINKING

A Finnish-Swedish-Estonian commission issued an official report in early December attributing the sinking of the passenger ferry, *ESTONIA*, in which 852 people died, to technical factors. The ship, a roll-on roll-off car and passenger ferry was sailing in rough seas at midnight, on September 28, 1994, when it started taking on water, capsized and sank in minutes trapping most passengers inside. Most of the passengers were Swedes and Estonians sailing between Tallinn and Stockholm.

The investigation found that the bow visor locking devices failed due to wave induced loads creating opening moments about the deck hinges. The report explained that the *ESTONIA* had experienced sea conditions of equivalent severity to those on the night of the accident only once before and the probability of the vessel encountering heavy bow seas in her earlier service had been very small. Thus, the failure occurred in what were most likely the worst wave load conditions she ever encountered.

The investigation revealed that the design of the bow visor on the *ESTONIA* was inadequate, due to limited information on the effects of hydrodynamic loads on large ships when she was built. And, although other incidents involving inadequate bow visors were identified during the investigation, it was found that there was no systematic collection or analysis of that information available to the shipping industry. Therefore, the previous incidents led to no systemic inspection or requirement for enforcement of bow visor standards. New, stronger design requirements were developed after the *ESTONIA* was built, but existing ships were not required to comply.

Crew issues were also addressed in the report. Because the visor could not be seen from the conning position, the bridge officers did not reduce their speed. The commission concluded that this contributed significantly to the speed with which the ship capsized. Further, the commission concluded that the crew did not use all means to seek or exchange information regarding the occurrence at a stage when it would have been possible to influence the development of the accident. The bridge crew apparently did not look at the available television monitor which would have shown them that water was entering the car deck; nor did they ask those in the control room from where the water intake was observed, or get information from them.

Finally, the commission concluded that more could have been done by the crew and rescuers to save lives. The lifeboat alarm was not given until about 5 minutes after the list developed, and no information was given to the passengers over the public address system. The alarm to the rescue helicopters was not timely, and they were dispatched with inadequate personnel for the situation.

The sinking of the *ESTONIA* was Europe's worst maritime accident since World War II.: Estonia Ministry of Transport and Communications Tel: 372 6 397613 or Fax: 372 6 397606.

Appendix 14

Review of EVT Literature

#	Reference	Level	Comments
	Embrechts P Extremes and Insurance 28 ASTIN Colloquium 1997	Introduction	**More examples**
	Embrechts P, Kluppelberg C, and Mikosh T Modelling Extremal Events Springer Verlag, Berlin 1997	Comprehensive text book including theory and applications. More theoretical than Coles.	**The major textbook on the subject.**
	Beirlant J, Matthys G, Dierckx G Heavy Tailed Distributions and Rating ASTIN Bulletin, Vol 31, No 1, pp 37-58, May 2001	Advanced. Some parts of the paper are very mathematical, but a good next step for the actuary who has mastered the basic theory.	**Includes a comprehensive list of references, and the current research topics.**
	McNeil AJ Estimating the Tails of Loss Severity Distributions using Extreme Value Theory ASTIN Bulletini, Vol 27 no 1 pp 117-137 http://www.casact.org/library/astion/vol27no1/117.pdf	A very readable and practical introduction	**Worked example on Danish Fire Data**
	McNeil AJ and Saladin T The Peaks over Thresholds Method for Estimating High Quantiles of Loss Distributions 28 ASTIN Colloquium 1997	Introduction	**Application of peaks over threshold method in pricing reinsurance**
	Patrik P and Guiahi F, An Extrememly Important Application of Extreme Value Theory to Reinsurance Pricing 1998 CAS Spring Meeting Florida	Introduction	**A presentation of the basic theory and an analysis of ISO claims severity**
	Reiss R, and Thomas M Statistical Analysis of Extreme Values Birkhauser, Basel, Boston, 1997	Introductory textbook	**Includes XTREMES software**
	Coles S An Introduction to Statistical Modeling of Extreme Values Springer, New York. 2001	Introductory textbook	**Well written introduction, likely to become the standard text on the subject**
	Leadbetter MR, Lindgren G and Rootzén H Extremes and related properties of random sequences and processes Springer, New York 1983	Advanced textbook Very mathematical	**Slightly out of date and out of print, but well written**
	Lauridsen S Estimation of value at risk by extreme value methods Extremes, 3, 107-144 2000	Technical	**Overview of Value-At-Risk using EVT** **Includes comprehensive list of**

	McNeil A Calculating quantile risk measures for financial return series using extreme value theory 1998. Preprint available from http://www.math.ethz.ch/~mcneil/pub_list.html	Can be technical at certain points.	**references and a back testing study** **Application of EVT to financial return series**

Appendix 15

Example Underwriting Authorities

1.1 GENERIC UNDERWRITING PRINCIPLES / OBJECTIVES

1. The overriding objective within the account is to underwrite a profitable account gross and net.

2. All accounts must be underwritten in accordance with the business plan targets and the reinsurance programme in force.

3. Aggregations of risk must be monitored and controlled in accordance with agreed parameters on a country basis, further sub-divided by Cresta zones, economic scenario or political action (as appropriate).

4. Specific loss scenarios to be monitored and controlled e.g. specific hurricane tracks and earthquakes.

5. To be able to influence terms and conditions wherever possible, including as a leader.

6. Individual risk details to be entered into the business recording system within 1 working day of risk acceptance.

7. To liaise and communicate with all other business departments as required, particularly in respect of exposures emanating from all other accounts which will aggregate.

8. To maintain knowledge of local market terms and conditions and an understanding of locally operating insurance or reinsurance operations, so as not to deviate adversely from them.

9. Any areas of business interest in breach of the specific underwriting managers' / class underwriters' authorities must be referred to the Managing Director prior to acceptance.

10. Underwriting limits can only be increased if facultative reinsurance with approved security is obtained and agreed, in advance, by the Managing Director.

11. Any acceptance of business in currencies other than £ or US$ to be calculated at the rate of exchange to £ in accordance with the individual underwriting authority limits at date of acceptance.

12. All account managers / class underwriters must refer any contracts with an estimated premium income in excess of £Y for the anticipated signed line to the Managing Director prior to acceptance.

13. Individual underwriting teams to review all business accepted within the team on a daily basis before commencement of underwriting the following working day.

14. To participate in the weekly underwriting reviews.

15. Monthly reports to be provided to the Managing Director for each main line of business.

16. No new Binding Authorities, other than renewals, will be accepted by the Company.

17. London market Brokers Binding Authorities will not be accepted where the binding entity does not retain any risk exposure for their own account.

18. Cover facilities / lineslips are only acceptable to the Company where the binding underwriter accepts a proportion of the risk exposure for their own account. Wherever possible, the Underwriter should be a leader / binding underwriter on any business falling within this category.

1.2.1 SPECIFIC UNDERWRITING AUTHORITY (Accident / Liability Classes)

UNDERWRITING AUTHORITY

Class: Direct and Indirect Facultative Non-Proportional and Pro-Rata Accident and Liability

Name:

Title:

Reports to:

Underwriting Responsibility for: Underwriter 1 Name / Underwriting scope
Underwriter 2 Name / Underwriting scope Underwriter 3 Name / Underwriting scope

---

Objectives

To manage and underwrite an account in line with general underwriting principles and objectives.

To ensure that the reinsurance programme is adhered to by monitoring both vertical capacity and horizontal coverage available.

	Gross			Reinsurance	
	Signed Premium	Acquisition Cost Ratio	Claims Ratio	Premium	Recovery Ratio
Excess of Loss Facultative & Direct Pro-Rata					

For underwriting year 2002 the targets by broad class of business

{Reinstatement premiums in may be specified separately/indicated as being included}

{Outward reinsurance premiums should include any expected adjustment premiums}

{Outward reinsurance premiums should include reinstatement premium on anticipated recovery}

{Outward details may be subdivided by Type (i.e. Faculatitive / Quota Share / Surplus / XL }

{Absolute Limits to which target premium may vary may be specified here. Variations in gross premium may also have contingent variations in outward reinsurance cost}

To control and monitor on a daily basis that underwriting staff reporting to authority holder comply fully with underwriting principles and authorities delegated to them.

Authority

Full authority for new and renewal direct and indirect facultative non-proportional and pro-rata accident and liability business up to stated maximum lines.

Policy endorsements of any nature within this underwriting authority.

Scope

Territorially worldwide for licensed countries and / or states.

{Quantum limits may be specified here and may be specified in terms of geographic zone, industry type, type of business, duration of risk etc… and are typically measured in terms of PML or Total Sum Insured or premium income…}

Principal Classes Accepted

Direct and indirect facultative, proportional portfolio of:-

Banks and Financial Institutions
Surety
Jewellers
Personal Accident
Bonds
Credit and Political Risks
Professional Indemnity on a claims made basis
Directors and Officers on a claims made basis

Non-proportional portfolio as above plus:-

Public Liability
Motor Liability
Products Liability

To be underwritten with limited reinstatements or with loss ratio limitation.

Normal Maximum Lines

£ m / US$ m in respect of proportional treaty business.

£ m / US$ m in respect of any non-proportional treaty programme.

£ m / US$ m in respect of any non-proportional treaty programme involving public, motor or products classes.

£ m / US$ m in respect of any one insurance and facultative reinsurance risk.

Absolute maximum lines may also be stated here.

Exclusions

Any contract involving fronting arrangements for inwards or outwards business.

Life assurance.

Mortgage business.

Insurance and facultative reinsurance of credit.

Insurance and facultative reinsurance of pure financial guarantee where no collateral is provided.

Non-proportional excess of loss portfolios with direct USA exposure where underlying policies are not underwritten on a “claims made” basis.
Contingency business.

Motor business on an unlimited liability basis.

Contracts where the claims reporting tail may exceed five years.

Insurance and facultative reinsurance of general liability business.

Specific USA lineslips protecting Directors and Officers liability.

Major five accountancy firms for operations in USA, Canada and UK.

Contracts where any Employers' Liability content exceeds A% of the overall exposure measured by premium income.

Medical Malpractice insurance and facultative reinsurance.

Contracts where any Recall policy content exceeds B% of the overall exposure measured by premium income.

Contracts where any Environment Impairment Liability (EIL) content exceeds C% of the overall exposure measured by premium income.

Policies involving retroactive coverage on a known or unknown loss basis.

Referrals Prior to Acceptance

To the Managing Director where it may be damaging to the commercial interests of the Company not to consider a participation on a specific risk.

As an acknowledgement that you have noted and understood these authorities, please countersign this agreement below and return to me, keeping a copy for your own record.

Signed…………………………………………………………………………………….

Date.…………………………………

Acknowledged and understood by………………………………………………………

Date………………………………….

UNDERWRITING AUTHORITIES

Class: Non-Proportional Treaty Property

Name:

Title:

Reports to:

Underwriting Responsibility for: Underwriter 1 Name / Underwriting scope
Underwriter 2 Name / Underwriting scope
Underwriter 3 Name / Underwriting scope

Objectives

To manage and underwrite an account in line with general underwriting principles and objectives.

To ensure that the reinsurance programme is adhered to by monitoring both vertical capacity and horizontal coverage available.

For underwriting year 2002 the targets by broad class of business

	Gross			Reinsurance	
	Signed Premium	Acquisition Cost Ratio	Claims Ratio	Premium	Recovery Ratio
Excess of Loss					

{Reinstatement premiums in may be specified separately/indicated as being included}

{Outward reinsurance premiums should include any expected adjustment premiums}

{Outward reinsurance premiums should include reinstatement premium on anticipated recovery}

{Outward details may be subdivided by Type (i.e. Faculatitive / Quota Share / Surplus / XL }

{Absolute Limits to which target premium may vary may be specified here. Variations in gross premium may also have contingent variations in outward reinsurance cost}

To control and monitor on a daily basis that underwriting staff reporting to authority holder comply fully with underwriting principles and authorities delegated to them.

Authority

Full authority for new and renewal non-proportional treaty property business up to the stated normal maximum lines.

Policy endorsements of any nature within this underwriting authority.

Scope

Territorially worldwide for licensed countries and / or states.

{Quantum limits may be specified here and would usually be expressed in terms of geographic zone}

Classes Accepted

New and renewal non-proportional treaty property risks.

Normal Maximum Lines

Any one acceptance to be limited to:

£ m / US$ m per programme in respect of business protecting risk exposures, on sum insured basis.

£ m / US$ m per programme in respect of business protecting catastrophe exposures, on sum insured basis.

Class aggregate limitation in respect of any modelled loss to remain within S$Xm vertical protection available within outwards reinsurance programme. (Specification of aggregation limits may be more complex in practice)

Absolute maximum lines may also be stated here.

Exclusions

Any contract involving fronting arrangements for inwards or outwards business.

War and Civil War.

Nuclear Energy.

Marine, aviation and satellites.

Reinstatement premium protection policies.

Stop-loss covers.

Brokers Binding Authorities.

Appointment of any Underwriting Agencies.

Policies involving retroactive coverage on a known or unknown loss basis.

Policies involving loss portfolio transfers.

Acceptances Beyond the Scope of this Underwriting Authority

These should be referred to the Head of Underwriting.

As an acknowledgement that you have noted and understood these authorities, please countersign this agreement below and return to me, keeping a copy for your own record.

Signed……………………………………………………………………………….

Date..…………………………………

Appendix 16

Realistic Disaster Scenarios

Regulatory Bulletin

LLOYD'S

One Lime Street London EC3M 7HA

FROM:	Head of Market Supervision
LOCATION:	86/5
EXTENSION:	5355
DATE:	26 March 2002
REFERENCE:	011/2002
SUBJECT:	**REALISTIC DISASTER SCENARIOS 2002**
ATTACHMENTS:	Appendices I and II
ACTION POINTS:	**Managing Agents to complete and return required RDS data**
DEADLINE:	**31 May 2002**

At its meeting on 7 December 2001, the Prudential Supervision Committee ("PSC") prescribed the 2002 Realistic Disaster Scenarios ("RDS") which are attached at Appendix I.

A number of developments have been agreed and the resultant changes are discussed in this bulletin and Appendix II, 'Guidance to the completion of the RDS Return'.

New Requirements

A Second Event scenario has been added in order to test the effectiveness of syndicate reinsurance programmes that have already suffered one substantial event. Details of this event are outlined in Appendix I and guidance on the preparation of this scenario can be found in Appendix II. For the first year of this scenario, this data will primarily be used for market-level analysis.

Liability exposures will be captured under a new separate scenario, rather than under the Alternative scenarios. This will involve syndicates selecting one scenario from a list of five. Syndicates should select the scenario that would result in the highest net loss to the syndicate. This new format will facilitate analysis and allow Lloyd's to understand in greater depth the potential for liability losses.

REALISTIC DISASTER SCENARIOS

1 USA Windstorm

Assume a US $50 billion insured loss arising from a windstorm hitting Florida / Gulf of Mexico.

2 Marine Event

Syndicates should return a marine loss scenario based on one of the following four incidents, selecting whichever scenario provides the highest net loss to the syndicate. In all scenarios, excess layers of liability, hull and cargo should be added based on maximum aggregate exposures.

i) A fully laden tanker calling at Prince William Sound is involved in a collision with a cruise vessel carrying 500 passengers. The incident involves the tanker spilling its cargo and loss of lives aboard both vessels. Assume 70% tanker owner / 30% cruise vessel apportionment of negligence and that the collision occurs in US waters.

ii) A ULCC tanker spills in US waters with subsequent pollution reaching land. The charterer is also held liable. In addition, OPA exposures, particularly in California, should be factored in.

iii) A LNG tanker explodes in harbour. Attention should be paid to resultant property damage onshore, business interruption etc. coupled with the possibility of the liability claim for bodily injury exceeding/exhausting the P&I limit.

iv) A U.S. owned passenger vessel, carrying a minimum of 3000 paying customers, is sunk or severely damaged with attendant loss of life, bodily injury, trauma, loss of possessions. Claims to be heard in an American court.

3 North Sea – Loss of major complex

Include property damage, removal of wreckage, liabilities, loss of production income, capping of well.

4 Aviation Collision

Assume a collision between 2 aircraft over a major US city, using the syndicate's two highest airline exposures. The names of the airlines must be disclosed. Assume a liability loss of US $1.5 billion per airline and an involvement from a products liability policy. Consideration should be given to other exposures on the ground.

5 Major Risk loss

Assume a loss to the syndicate's largest single risk that results in the total exhaustion of policy limits, including a PML failure, together with any other potential interests which may arise from additional perils (business interruption or liabilities) or other methods of acquisition (e.g. risk excess).

6 Space Storm

Assume storm destroys six in-orbit satellites.

7 Liability

Syndicates should return a liability loss scenario based on one of the following, selecting whichever scenario provides the highest net loss to the syndicate.

i) US 'laddering' scenario involving improper conduct by firms in connection with initial public offerings. This results in a combined SEC class action, with the litigation involving 5 of the syndicate's assureds to the full slip limits.

ii) UK pensions mis-selling, involving 5 of the syndicate's assureds to the full slip limits.

iii) A failure/collapse of a major corporation, involving 5 of the syndicate's assureds to the full slip limits.

iv) A failure of a merger, involving 5 of the syndicate's assureds to the full slip limits.

v) A failure of a construction project, involving 5 of the syndicate's assureds (for example, architects, surveyors, and engineers) to the full slip limits.

8 Political Risks

This exercise is designed to capture the effects of a series of attritional losses arising from unrelated causes. The aim of this exercise is to test the cumulative potential loss effect of a series of losses against the available horizontal reinsurance protection.

Where syndicates have already designed internal disaster scenarios on this basis, they should enter the data in the relevant screen. For syndicates that have not designed a tailor made scenario, the following methodology should be adopted when completing the return.

For your largest exposed country assume a deteriorating political and economic environment in the country in question causing losses to the top 10 individual risks as at 1 April 2002 from differing non-aggregating causes. The following classes of business should be specifically included: political risks, contract frustration, aircraft repossession/CEND, credit risks and financial guarantee exempted classes. Relevant exposures within the property and cargo classes should be included. All political risk specific reinsurances should be added, together with other specifics as may be applicable, being war and/or cargo. Whole account reinsurances should be included as applicable.

9 Second Event

Syndicates should model a US windstorm comparable to Hurricane Andrew occurring shortly after an earthquake comparable to the Northridge earthquake. Syndicates should assume that these events fall in the same reinsurance year and that there has not been sufficient time between events to purchase additional reinsurance.

10 Alternative RDS: A

The syndicate should state two further realistic events not listed above for scenarios numbered 10 and 11. For example, syndicates with substantial exposures to a San Francisco earthquake event or to a UK flood could use the Alternative scenarios to model these events.

11 Alternative RDS: B

Further alternative scenario, as above.

12 Specific Event Based Scenarios – Florida Windstorm

Landfall: Florida (East coast)
Saffir Simpson[1] on landfall: Category 5

State	County	Direction	Saffir Simpson	Mean wind speed (mph)	Major towns
Florida	Dade	West	Category 4	147	Miami, Kendall
Florida	Monroe	West	Category 3	119	-
Florida	Broward	West	Category 3	111	Coral Springs, Fort Lauderdale
Florida	Collier	West	Category 2	100	East Naples
Florida	Palm Beach	West	Category 1	91	West Palm Beach, Belle Glade
Florida	All others		< Category 1	< 73	-

13 Specific Event Based Scenarios – Los Angeles Earthquake

Fault name: Santa Monica
Richter Magnitude[1]: 7.5

State	County	Modified Mercalli Intensity[1] (MMI)	Major towns
California	Los Angeles	8 - 9	Los Angeles, Long Beach, Pasadena, Burbank, Lancaster
California	Ventura	8 - 9	Ventura
California	Orange	6 - 7	Orange, Anaheim, Santa Ana, Costa Mesa
California	San Bernardino	6 - 7	San Bernardino, Barstow
California	Riverside	5 - 6	Riverside, Palm Springs, Hemet, Indio
California	San Diego	5 - 6	San Diego, Oceanside
California	Kern	5 - 6	Bakersfield
California	San Luis Obispo	5 - 6	San Luis Obispo
California	Santa Barbara	5 - 6	Santa Barbara, Santa Maria
California	All others	1 - 5	-

[1] Additional information on the specific events, along with an explanation of the Saffir Simpson, Richter, Moment Magnitude, and MMI scale, is available from the MRRU x6496.

14 Specific Event Based Scenarios – New Madrid Earthquake

Seismic Zone: New Madrid
Moment Magnitude[2]: 7.4

State	Counties	Modified Mercalli Intensity (MMI)[2]
Arkansas	Craighead, Cross, Jackson, Mississippi, Poinsett	9 - 10
Arkansas	Clay, Crittenden, Greene, Lawrence, Lee, Monroe, St. Francis, Woodruff	8 - 9
Arkansas	Arkansas County, Independence, Lonoke, Phillips, Prairie, Randolph, White	7 - 8
Arkansas	Cleburne, Desha, Jefferson, Lincoln, Sharp	6 - 7
Arkansas	Baxter, Chicot, Cleveland, Conway, Drew, Faulkner, Fulton, Grant, Izard, Pulaski, Saline, Stone, Van Buren	5 - 6
Illinois	Alexander	6 - 7
Illinois	Massac, Pulaski	5 - 6
Kentucky	Carlisle, Fulton, Hickman	6 - 7
Kentucky	Ballard, Calloway, Graves, McCracken	5 - 6
Missouri	Dunklin, New Madrid, Pemiscot	8 - 9
Missouri	Butler, Mississippi, Ripley, Stoddard	7 - 8
Missouri	Scott	6 - 7
Missouri	Bollinger, Cape Girardeau, Carter, Howell, Oregon, Shannon, Wayne	5 - 6
Mississippi	Coahoma, De Soto, Quitman, Tate, Tunica	7 - 8
Mississippi	Benton, Bolivar, Marshall, Panola, Tallahatchie	6 - 7
Mississippi	Alcorn, Calhoun, Grenada, Humphreys, Lafayette, Leflore, Pontotoc, Sunflower, Tippah, Union, Washington, Yalobusha	5 - 6
Tennessee	Dyer, Lake, Lauderdale, Tipton	8 - 9
Tennessee	Crockett, Fayette, Gibson, Haywood, Obion, Shelby	7 - 8
Tennessee	Hardeman, Madison, Weakley	6 - 7
Tennessee	Carroll, Chester, Henderson, Henry, McNairy	5 - 6

The MMIs in this scenario are average values for the counties and have been grouped in steps of 1. The information is sorted by State, then by MMI group, followed by County.

[2] Additional information on the specific events, along with an explanation of the Saffir Simpson, Richter, Moment Magnitude, and MMI scale, is available from the MRRU x6496.

15 Specific Event Based Scenarios – European Windstorm

Region: Northern Europe
Peak Wind speed [3]: 54 metres per second

Country	Area	Max Windspeed (m/s)
Belgium	All except Brussels	40-50
Belgium	Brussels	30-40
Denmark	All	30-40
France	Nord, Pas-de-Calais	40-50
France	Brittany, Loire, Ile-de-France, Central France	30-40
France	Rest of France	<30
Germany	Mecklenburg-Vorpommern, Niedersachsen, Schleswig-Holstein	40-50
Germany	Baden-Wurttemberg, Brandenburg, Bremen, Hamburg, Hessen, Nordheim-Westfalen, Rheinland-Pfalz, Saarland	30-40
Germany	Bayern, Berlin, Sachsen, Sachsen-Anhalt, Thuringen	20-30
Ireland	All	30-40
Luxembourg	All	30-40
Netherlands	Delta, Northern Netherlands	40-50
Netherlands	Central & Southern Netherlands	30-40
Norway	Atlantic & Southern Norway	20-30
Sweden	Southern Sweden	30-40
Sweden	Rest of Sweden	<30
UK	SW England	>50
UK	Rest of England, and Wales	40-50
UK	Scotland	30-40
UK	Northern Ireland	20-30

16 Specific Event Based Scenarios – Japanese Earthquake

Description: Based on Great Kanto event of 1923
Moment Magnitude[3]: 7.9

Prefecture	Modified Mercalli Intensity[3] (MMI)
Chiba, Kanagawa, Shizuoka	9 - 10
Saitama, Tokyo, Yamanashi	8 - 9
Gumma, Ibaraki, Nagano, Tochigi	7 - 8
Aichi, Gifu, Niigata	6 - 7
Fukui, Fukushima, Ishikawa, Mie, Shiga, Toyama	5 - 6

[3] Additional information on the specific events, along with an explanation of the Saffir Simpson, Richter, Moment Magnitude, and MMI scale, is available from the MRRU x6496.

Guidance to completion of the RDS return

a) A Second Event Scenario has been added. Syndicates should assume that an earthquake similar to Northridge has already occurred when a hurricane similar to Hurricane Andrew occurs. Syndicates should assume that there had not been sufficient time between events to purchase additional reinsurance.

b) A Liability Scenario has been added. Syndicates should select one scenario from the list of five that would result in the highest net loss to the syndicate.

c) The Marine Scenario has been amended. Syndicates should select one scenario from the list of four that would result in the highest net loss to the syndicate.

d) For the five specific events it is expected that syndicates will utilise the specific event information (e.g. location, path, intensity) when producing their estimates. The results should be on a 'best-estimate' basis to allow the meaningful aggregation of the results at market-level. For some syndicates or types of business (e.g. direct and retrocessional) this may be difficult and broad assumptions may be necessary.

   For each peril, the location and magnitude of the event are given in Appendix I. Maps showing the path/location and the intensity of the specific catastrophes are available from the MRRU on extension 6496. Syndicates using catastrophe models should contact the respective modelling agency in the first instance. Letters were sent to all modelling agencies on 25 March 2002, providing the parameters necessary to model these events.

   Syndicates should note the six aggregate types (numbered 7 to 12) which should be used for the specific events. These will enable the MRRU to gain an understanding of whether the losses have been calculated using modelling techniques, or by using a market share approach. If a syndicate's approach does not fall into either of these categories, then one of the Regulatory aggregate types (numbered 1 to 6) should be used.

e) Other than for the required minimum eight scenarios, syndicates are entitled to apply a materiality test to the returns. Where a prescribed scenario results in both a gross loss that is less than 10% and a net loss of less than 3% of stamp, then no return is required. A syndicate must satisfy both criteria so that in instances where a loss is less than 10% gross but more than 3% net, a return must still be made. The minimum eight scenarios should include the five specific scenarios and Second Event scenario - a 'nil return' facility is included within the software for the mandatory scenarios to simplify this process for those syndicates with no exposure.

f) Syndicates should use the notes feature to discuss any material changes in methodology used to complete the RDS return. The software allows for notes at both scenario and a general level.

g) Syndicates should continue to record stop loss recoveries on the RDS data screen and also use the general notes page of the return to explain the extent of any stop loss cover relied upon in scenarios, including details such as limits and the excess points. Syndicates should also indicate, using the reinsurer screen of the software, which reinsurers and related recoveries are stop loss recoveries. This may result in multiple entries for some reinsurers.

h) Syndicates should also complete the new cash flow and funding screens, which can be accessed via each scenario screen. The cash flow screen should be completed for each scenario and syndicates should assume that year and quarter dates commence on the date of the loss. The funding screen should be completed for the specific scenarios and also for the scenario producing the largest cash deficit to the syndicate (if this is not one of the specific scenarios). When completing the funding details, percentages should be based on the largest cash deficit in a particular quarter.

i) The current list of classes of business used to provide detail within each scenario has been rationalised, to remove duplication and improve the quality of the returns. As a consequence, when importing last year's return into the new software, the class of business field will not be populated and a new class of business will need to be selected. Please refer to the software manual for more clarification on this and also for a list of the new classes.

j) For the political risks scenario, syndicates should select the exposed country from a drop-down list. Alternatively, if syndicates are returning a scenario involving exposures in more than one country, then the 'other e.g. cross-border' option should be selected and details of the scenario should be provided in the notes section.

k) Reinsurance recoveries should be broken down by reinsurer across each scenario submitted. To avoid reconciling recoveries to the last cent, syndicates are required to break down recoveries to at least 90% of the total reinsurance for each scenario.

l) The latest set of LORS codes will be incorporated in the software prior to distribution. Should any security not appear on the listing, syndicates should first check the validity of their code with the LORS team or the broker, and then contact Catherine Davidson on extension 6553.

m) Syndicates are now required to complete the 'Date of Board Approval' field on the main form. This should be the date on which either the Board, or a sub-committee with delegated authority, approves the RDS return.

n) In order to facilitate monitoring of the Related Parties regime set out under Regulatory Bulletin 081/99 dated 20 September 1999, syndicates are required to detail the business assumed from and ceded to related companies (as defined by the Lloyd's Act 1982). In previous versions of the software, syndicates were required to show related company business assumed as additional entries to any non-related class of business entries. This secondary entry is no longer required, as a 'related party %' field has been included on the class of business line of data. A related company indicator is still included on the reinsurance outwards detail section.

o) A number of validation procedures are included within the software and will automatically run when syndicates begin to extract the data. Details of these checks can found in the RDS software manual.

Lloyds Realistic Disaster Scenarios (2001)

REALISTIC DISASTER SCENARIOS

2001

Prescribed Scenarios

USA Windstorm

Assume a US $50 billion insured loss arising from a windstorm hitting Florida / Gulf of Mexico.

European Storm / Flood

Assume a £10 billion insured loss.

Japanese Earthquake

Assume an earthquake with an epicentre in zone 5 of magnitude MMI IX or greater, resulting in a US $15 billion insured loss, with damage occurring in adjacent zones.

Marine Collision

Assume a collision between a ULCC and a cruise liner in US coastal waters. Assume that the courts find for contributory negligence on a 70/30 basis. Both vessels are reinsured through the International P&I clubs and the resultant insured loss to the programme, including the excess layers, is $4 billion. Syndicates must also include additional liability coverages such as Charterers' Liability, Umbrella policies and

Mortgagees Additional Perils, representing a further $500 million of losses. In addition, syndicates must add hull and cargo values. Hull exposures should represent the largest lines on a ULCC and a cruise liner.

Syndicates writing fixed premium contracts should base their exposures on a collision between insured vessels, whether these be covered by a fixed premium contract or insured by a P&I club.

North Sea – Loss of major complex

Include property damage, removal of wreckage, liabilities, loss of production income, capping of well.

Aviation Collision

Assume a collision between 2 aircraft over a major US city, using the syndicate's two highest airline exposures. The names of the airlines must be disclosed. Assume a liability loss of US $1.5 billion per airline and an involvement from a products liability policy.

Major Risk loss

Assume a loss to the syndicate's largest single risk that results in the total exhaustion of policy limits, including a PML failure, together with any other potential interests which may arise from additional perils (business interruption or liabilities) or other methods of acquisition (e.g. risk excess).

Space Storm

Assume storm destroys six in-orbit satellites.

Alternative RDS: A

The syndicate should state two further realistic events not listed above for scenarios numbered 9 and 10. If the 2001 long tail income to the syndicate is projected to be over 25% of the total gross premium income, at least one liability scenario is to be returned. Liability scenarios should be chosen for their appropriateness to the account; causing either a horizontal problem (e.g. pension mis-selling) or vertical event involving multiple interests (e.g. failure of a publicly quoted company). Long tail income is defined as premiums classified under the risk codes designated 'Non-Marine All Other' for solvency reserve purposes.

Alternative RDS: B

Further alternative scenario, as above.

Political Risks

This exercise is designed to capture the effects of a series of attritional losses arising from unrelated causes. The aim of this exercise is to test the cumulative potential loss effect of a series of losses against the available horizontal reinsurance protection**.**

Where syndicates have already designed internal disaster scenarios on this basis, they should enter the data in the relevant screen.

For syndicates that have not designed a tailor made scenario, the following methodology should be adopted when completing the return.

For your largest exposed country assume a deteriorating political and economic environment in the country in question causing losses to the top 10 individual risks as at 1 April 2001 from differing non-aggregating causes. The following classes of business should be specifically included: political risks, contract frustration, aircraft repossession, credit risks and financial guarantee. Relevant exposures within the property and cargo classes should be included. All political risk specific reinsurances should be added, together with other specifics as may be applicable, being war and/or cargo. Whole account reinsurances should be included as applicable.

Specific Event Based Scenarios – Windstorm

RMS Event Number: 4808
First landfall: Florida (East coast)
Saffir Simpson[1]: Category 5
(on first landfall)

State	**County**	Direction	**Saffir Simpson**	**Mean wind speed (mph)**	**Major towns**
Florida	Dade	West	Category 4	147	Miami, Kendall
Florida	Monroe	West	Category 3	119	-
Florida	Broward	West	Category 3	111	Coral Springs, Fort Lauderdale
Florida	Collier	West	Category 2	100	East Naples
Florida	Palm Beach	West	Category 1	91	West Palm Beach, Belle Glade
Florida	All other counties		< Category 1	< 73	-

Specific Event Based Scenarios – Los Angeles Earthquake

RMS Event number: 33
Fault name: Santa Monica

[1] An explanation of the Saffir Simpson, Richter, Moment Magnitude and MMI scale is available from the MRU x5985.

Richter[1]: 7.5

State	County	Modified Mercalli Intensity[1] (MMI)	Major towns
California	Los Angeles	8 - 9	Los Angeles, Long Beach, Pasadena, Burbank, Lancaster
California	Ventura	8 - 9	Ventura
California	Orange	6 - 7	Orange, Anaheim, Santa Ana, Costa Mesa
California	San Bernardino	6 - 7	San Bernardino, Barstow
California	Riverside	5 - 6	Riverside, Palm Springs, Hemet, Indio
California	San Diego	5 - 6	San Diego, Oceanside
California	Kern	5 - 6	Bakersfield
California	San Luis Obispo	5 - 6	San Luis Obispo
California	Santa Barbara	5 - 6	Santa Barbara, Santa Maria
California	All other counties	1 - 5	-

Specific Event Based Scenarios – New Madrid Earthquake

AIR Event number: RDS_NM01

Fault name: New Madrid

Moment Magnitude[2]: 7.4

State	Counties	Modified Mercalli Intensity (MMI)[2]

[2] An explanation of the Saffir Simpson, Richter, Moment Magnitude and MMI scale is available from the MRU x5985.

Arkansas	Craighead, Cross, Jackson, Mississippi, Poinsett	9 - 10
Arkansas	Clay, Crittenden, Greene, Lawrence, Lee, Monroe, St. Francis, Woodruff	8 - 9
Arkansas	Arkansas County, Independence, Lonoke, Phillips, Prairie, Randolph, White	7 - 8
Arkansas	Cleburne, Desha, Jefferson, Lincoln, Sharp	6 - 7
Arkansas	Baxter, Chicot, Cleveland, Conway, Drew, Faulkner, Fulton, Grant, Izard, Pulaski, Saline, Stone, Van Buren	5 - 6

Illinois	Alexander	6 - 7
Illinois	Massac, Pulaski	5 - 6

Kentucky	Carlisle, Fulton, Hickman	6 - 7
Kentucky	Ballard, Calloway, Graves, McCracken	5 - 6

Missouri	Dunklin, New Madrid, Pemiscot	8 - 9
Missouri	Butler, Mississippi, Ripley, Stoddard	7 - 8
Missouri	Scott	6 - 7
Missouri	Bollinger, Cape Girardeau, Carter, Howell, Oregon, Shannon, Wayne	5 - 6

Mississippi	Coahoma, De Soto, Quitman, Tate, Tunica	7 - 8
Mississippi	Benton, Bolivar, Marshall, Panola, Tallahatchie	6 - 7
Mississippi	Alcorn, Calhoun, Grenada, Humphreys, Lafayette, Leflore, Pontotoc, Sunflower, Tippah, Union, Washington, Yalobusha	5 - 6

Tennessee	Dyer, Lake, Lauderdale, Tipton	8 - 9
Tennessee	Crockett, Fayette, Gibson, Haywood, Obion, Shelby	7 - 8
Tennessee	Hardeman, Madison, Weakley	6 - 7
Tennessee	Carroll, Chester, Henderson, Henry, McNairy	5 - 6

The MMIs in this scenario are average values for the counties and have been grouped in steps of 1. The information is sorted by State, then by MMI group, followed by County.

Maps showing the path/location and the intensity of the specific catastrophes are available from the MRU on extension 5985.

Appendix 17

Data used in example spreadsheet

1516.76	104670.65	233727.76	451070.90	676128.43
1789.61	106253.07	233840.70	463665.62	757588.85
4238.02	107572.98	234306.26	465247.03	800683.85
6477.59	109995.24	245097.33	474179.46	814098.67
10683.98	110784.27	252353.47	481574.17	823908.55
11099.17	114752.78	255344.58	492533.89	839914.95
12478.10	127613.38	260918.07	503709.54	878476.27
12547.87	128263.97	267886.39	505789.56	878502.47
16080.10	135174.69	274966.53	506065.09	926600.96
22452.26	137103.06	278196.20	509110.55	954021.61
28052.34	139928.05	280510.84	516710.23	1034210.97
43216.37	144048.93	302967.58	529278.56	1036047.45
49838.36	153419.64	310216.98	533059.63	1202432.40
55599.25	153899.04	324277.61	565087.55	1213690.24
57166.01	157293.33	325989.37	566417.65	1265554.15
57860.30	158358.07	343296.43	571043.53	1556938.43
61985.17	164646.94	358334.44	574329.44	1681821.52
65679.44	165730.42	361107.49	582128.21	1692381.01
67613.30	170329.20	363738.69	599796.47	1802363.41
70692.86	185309.80	366450.38	613681.34	1834689.69
71169.46	186622.92	367583.25	632684.60	2309075.24
78576.22	208299.43	387365.45	639596.56	2837556.73
82495.35	211280.85	397467.04	648147.16	3094794.25
93053.63	226151.10	414193.79	657840.77	
95712.73	227403.65	428915.90	657931.06	

Appendix 18

Actuarial Governance

Actuarial Governance

A Discussion Paper

February 2002

This discussion paper has been prepared by the Actuarial Governance Working Party of the Life Board, and is being issued by that Board to promote debate.

Anyone wishing to offer written comments on this paper should send them by the end of March 2002 to:

Paul Bristow

Secretary, Life Board

Staple Inn Hall

High Holborn

London WC1V 7QJ

tel.: 020 7632 2118

fax.: 020 7632 2131

e-mail: paulb@actuaries.org.uk

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1. INTRODUCTION

1.1 Background

At the current time, the whole basis of regulation of the financial services industry is undergoing considerable change and the regulation of the insurance industry, in particular, is under intense scrutiny as a result of recent high profile cases such as the Equitable and Independent Insurance.

As well as a number of investigations relating to the specific circumstances and events surrounding the closure of the Equitable to new business, the FSA are currently undertaking a review of various aspects of the operation and regulation of with-profits business, including the issue of Governance and Discretion.

Although the Appointed Actuary system is perceived to have worked well in the past, the perception is also that the influence of Appointed Actuaries has been gradually reduced over the last few years with the role narrowing towards an increasingly detailed set of formal requirements. This has led to some concern that changes may be required if Appointed Actuaries are to carry out their responsibilities effectively.

Post N2, the framework within which the Appointed Actuary operates has been strengthened with the introduction of the FSA Supervision Manual which formalises the existing obligations in professional guidance and places corresponding obligations on the company and its directors. The current FSA review of with-profit business may lead to changes in the governance framework for this business.

Further, more significant changes are expected to be introduced in January 2004, as proposed in the draft Integrated Prudential Sourcebook (FSA CP97), leading towards a risk-based capital approach to supervision.

1.2 Terms of Reference

The terms of reference of the Actuarial Governance Working Party ("AGWP") are as follows:

Taking account of other relevant policy developments and, in particular, proposals being formulated by the Life Board for compliance review of Appointed Actuaries, the

group's remit is

_ To consider governance issues relating to the role of the Appointed Actuary in life assurance in the UK and

_ To make recommendations to the Life Board on changes that may be needed to such governance.

Following the Life Board's consideration of its recommendations, the group's remit is

also:

_ To reflect the outcome of the Board's consideration in a discussion paper to be exposed to the membership during the 2001/02 Session and

_ To support the Life Board in considering feedback to the discussion paper and in deciding whether to promote changes to actuarial governance in the light of such feedback.

1.3 Composition of Working Party

The working party is made up as follows:

P. Needleman - (consultant) Chairman

A. Chamberlain - (consultant)

A. Eastwood - (employed Appointed Actuary)

W. Hewitson - (FSA)

A. Saunders - (employed Appointed Actuary)

M. Shelley - (consultant) Chairman, Life Compliance Review Working Party

1.4 Scope of Work

The working party has undertaken the following work programme in compiling the discussion paper:

_ Review of current investigations and reports (report by the Corley Committee of Inquiry; FSA report on review of ELAS regulation 1999/2000 – the 'Baird Report'; HM Treasury consultation on draft whistle-blowing regulations)

_ Interviews and responses from a range of interested parties including

3

_ Board members

_ Current and future Presidents of the Institute/Faculty

_ FSA

_ A limited sample of directors, management, and Appointed Actuaries of life offices

_ Consumers associations

_ Other Appointed Actuaries

_ Review of Turnbull recommendations on Corporate governance

_ Discussion with major audit consultancy re auditor independence

_ Review of current recommendations for Compliance Review

_ Review of governance aspects of Schedule 2C Schemes of Transfers

_ Review of current roles and functions of Appointed Actuary (GN1/GN8 and FSA Supervision manual)

It is recognised that the overall framework for governance of life companies will have a significant impact on the ability of Appointed Actuaries to fulfil their responsibilities,

and may influence the appropriate model for actuarial governance. The AGWP have not taken into account any changes which may arise as a result of the FSA's review of governance of With-Profits funds in framing this discussion paper.

2. ACTUARIAL WORK IN LIFE OFFICES

Before considering the specific scope of the responsibilities of the Appointed Actuary it is helpful to review the full range of actuarial work required within a life office. Many of these areas will not be the direct responsibility of the Appointed Actuary, but

aspects of the work may directly or indirectly overlap with the work of the Appointed Actuary. Later sections of this paper will discuss the extent to which this work is currently required by statute or professional guidance.

2.1 Solvency and Capital Management

2.1.1 Statutory Valuations

Carry out statutory valuations and prepare reports to the relevant regulatory authority. In particular:

_ Ensure data is complete and accurate

_ Determine appropriate valuation methods and procedures

_ Maintain appropriate valuation calculation models

_ Analyse historic experience

_ Determine valuation basis, including appropriate margins making due allowance for risk

_ Include appropriate provision for all options and guarantees

_ Report in writing to the directors and to the regulatory authority

_ Take steps to ensure that the company can meet its liabilities at all times between successive annual investigations.

2.1.2 Solvency Projections and Solvency Management

Carry out projections of the future progress of statutory solvency, including:

_ Expected new business plans

_ A number of scenarios chosen to illustrate the range of potential outcomes or to highlight a particular risk exposure of the company

_ Stochastic modelling taking account of expectations of how management might react to each simulation (e.g. in respect of bonus or investment policy).

_ Monitor the company's ability to meet liabilities to policyholders both now and in reasonably foreseeable future circumstances

Advise the company on potential sources of capital and ways to use existing resources most efficiently.

2.1.3 Reassurance management

_ Consider whether reinsurance arrangements are adequate and appropriate

_ Monitor arrangements having regard to situations where contracts may be unenforceable

2.2 Profit Reporting & Shareholder Issues

Enhance shareholder value through:

_ Business portfolio management

Involvement in business planning

Calculate reported profits, potentially including:

_ Modified Statutory

_ Achieved Profits

_ Embedded Value

_ US GAAP

2.3 Terms of Business

Advise on all aspects of the terms on which new business is sold by the company, including:

2.3.1 Premium Rates

_ Prepare a realistic profit assessment in order to demonstrate that the proposed product can meet the required return targets.

_ Ensure that premium rates are adequate taking into account the resources of the company.

2.3.2 Manage Insurance Risk

_ Advise company on appropriate underwriting standards and ensure that premium rates, valuation assumptions and underwriting standards are aligned.

_ Advise company on appropriate risk reassurance arrangements

2.3.3 Encashment terms

_ Maintain calculation bases for policy surrenders that are fair, both relative to underlying asset values and to other policy classes

_ Manage the application of MVAs on unitised with-profits policies similarly

2.3.4 Disclosure

Ensure that incoming policyholders are not misled:

_ Prepare appropriate analyses of expenses for use in point of sale and post sale disclosure of commission equivalent rates and the effect of charges

_ Prepare RIY, surrender and investment return disclosures for With-Profits Guide

_ Prepare statements of bonus policy and MVA policy for use in With-Profits Guides and elsewhere

_ Review all policyholder literature to ensure misleading claims are not made

_ Increasingly, prepare disclosure for inclusion in annual mailings to (in particular) with-profits policyholders

2.4 PRE/Customers Interests

2.4.1 Advise on PRE

_ Monitor literature to ensure that nothing is being said that may cause unreasonable expectations to become established.

_ Advise the Board on PRE and any action that should be taken to manage PRE, including any examples where PRE may have become established to the extent that additional reserves are required.

2.4.2 Determine discretionary charges on policies

_ Where required by policy conditions, determine appropriate charge deductions in respect of mortality, morbidity or expenses, having regard to PRE and the experience of the company

2.5 Investment policy/ALM

_ Advise the board on appropriate investment policy taking account of the liability mix and PRE (e.g. bonus policy, statements made about asset mix)

_ Advise on investment constraints that may be necessary to protect policyholders

_ Advise on the use of derivatives

_ Carry out regular asset – liability modelling to ensure that asset portfolios remain adequately matched to liabilities

2.6 Bonus Policy for With-Profits Business

_ Advise on the extent to which surplus may be distributed to with-profits policyholders and shareholders

_ Make recommendations on the allocation of profits, having regard to equity between different classes of policy and between reversionary and terminal bonuses

_ Maintain appropriate models of policy asset shares to support the above

_ Analyse achieved investment returns (allowing for tax effects) and allocate to appropriate policy classes

2.7 Unit Pricing

2.7.1 Monitor Equity in Unit Pricing

_ Ensure that all aspects of unit pricing are carried out with regard to PRE and Unfair Contract Terms legislation

2.7.2 Box Management

_ Manage the unit "box" maintained by the company to ensure adequate matching of unit sales and purchases.

2.8 (Long Term) Risk Management

Actuaries will often be involved in risk analysis to support the company's risk management processes.

2.9 "One Off" Transactions

2.9.1 Advise Company on Restructuring, capital raising and M&A Transactions

_ Provide advice on valuations of life portfolios for purchase, sale or corporate restructuring

_ Advise on possible structures

_ Evaluate alternative options

_ Advise on alternative forms of capital raising

2.9.2 Responsibilities Arising from Corporate restructuring

It is common for the Appointed Actuary to be given specific additional responsibilities

under Section 2C Schemes of Arrangement such as those arising from demutualisations. Often these will relate to protections for groups of transferring policyholders and may cast the Appointed Actuary in the position of being the sole protector of these policies interests. Such requirements can sit uneasily alongside the Appointed Actuary's need to operate as an impartial adviser in the ongoing running of the business.

2.10 Services to Other Customers

There may be some actuarial services provided to clients other than the life office, for example carrying out periodic scheme valuations for final salary pension schemes insured or managed by the company, or providing services of a Pension Scheme Actuary to the trustees of such schemes.

2.11 Duties to Regulator - "Whistle-blowing" responsibilities

The Appointed Actuary has always had a statutory obligation to inform the regulator if

he or she believes that the company may be acting in an inappropriate way.

Historically, the Appointed Actuary was required to inform the board first and make efforts to persuade the company to change its ways. Under proposed new regulations, it will no longer be necessary (or in some cases appropriate) for the Appointed Actuary to discuss with the board before approaching the FSA, although we would expect that in most circumstances the issues would be raised firstly with senior management and/or the Board before approaching the FSA. The intention is to speed up the process and to keep the regulator more informed, creating a more open dialogue.

2.12 Exercise of Discretion

In order to carry out many of the above activities, a degree of discretion is often required. Advising on the application of discretion in a manner that maintains fairness is an integral part of the actuary's work.

An actuary has an obligation to influence the manner in which discretion is exercised by advising the Board of his or her interpretation of fair treatment, both for particular classes of policyholder, between different classes and potentially between policyholders and shareholders (for example in respect of the management of the free estate). The application of discretion by the Board also needs to be monitored.

Historically, some actuaries may have tended to recommend that the Board approve the results of their judgement without a detailed explanation of possible alternative views on the factors taken into account. In the future it may be necessary for actuaries to bring out the different interests of groups of policyholders (and the shareholder) to enable an open debate at the board so that the balancing of interests is better understood by the board and discretion is more clearly exercised by the directors.

The recent Equitable Life judgements have resulted in the need for companies to consider the legal dimension, where the legal interpretation of fairness may not be in line with a normal actuarial approach.

2.13 Formal Requirements of Actuaries

Broadly, the work required of the Appointed Actuary under statute is covered by sections 2.1 (Solvency and Capital Management), 2.6 (Bonus Policy) and 2.11 (Duties to regulator). FSA rules also impose some duties under 2.3.

Professional Guidance in GN1 and GN8 extends this to include 2.3 (Terms of

Business), 2.4 (PRE), 2.5 (Investment Policy) and 2.7 (Unit Pricing). GN22 covers commission equivalent and charge disclosure.

The next section gives more detail on the current regulatory framework for the role of the Appointed Actuary.

3. REGULATORY FRAMEWORK

3.1 Pre-N2 Role of Actuary

The statutory role of an 'Appointed Actuary' was first recognised in the 1egislation introduced in 1973 and continued in the Insurance Companies Act 1982 and associated regulations. These required the appointment of an actuary to all life insurance companies, who had to be a Fellow of the Faculty or the Institute and at least 30 years old. The statutory duty of the actuary was to carry out the annual valuation of the long-term liabilities in accordance with the liability regulations (which

would also establish whether there was any available surplus that could be distributed from the long-term fund) and to provide an appropriate certificate in the returns each year.

There were a number of gradual developments in both the regulations and the associated professional guidance over that period. For example, the Appointed Actuary was required from around 1983 to disclose in the annual returns all relevant financial interests in the insurer, including both share options and with-profit policies. In addition, the Appointed Actuary has been required since 1992 to obtain a practising certificate from the profession before appointment and this has to be renewed each year. The criteria for obtaining such a certificate are that the actuary has the relevant skills and knowledge, has not been the subject of professional disciplinary action or been convicted of criminal offences involving dishonesty, and has maintained appropriate CPD over the year.

The annual actuary's certificate in the FSA returns, in the form that applied from around 1996, confirmed that a proper provision had been established for the longterm liabilities, that adequate records had been maintained for that purpose, that appropriate premiums had been charged for new business, and that professional guidance notes GN1 and GN8 had been complied with.

While GN8 was concerned primarily with professional guidance to supplement the regulations on the valuation of the liabilities, GN1 established a number of additional professional responsibilities for the actuary. These included the continuous monitoring of the financial condition of the insurer and production of a report to the directors prior to the transfer of any surplus to shareholders or any declaration of bonus to policyholders by the insurer. For with-profit companies this report also involves advising on the appropriateness of that bonus declaration after taking account of the need to balance the ongoing financial soundness of the insurer with the need to take account of the reasonable expectations of policyholders.

In addition, GN1 required the actuary to advise the company more generally about his or her interpretation of the reasonable expectations of policyholders. This included advice on areas where the company had discretion to vary charges under the terms of its contracts with policyholders. The phrase 'reasonable expectations' was not defined in the legislation, but the inability to meet these expectations was a ground on which the regulator could intervene in the affairs of the company.

The actuary was required to inform the company whenever a material risk had been identified that the company might not be able to meet its obligations. If the company did not take appropriate remedial measures, then the actuary was required by professional guidance to inform the regulator.

In addition, GN1 required appointed actuaries to undertake the range of specific responsibilities described in Section 2.13 above.

A separate best practice guidance note GN2 recommended that the actuary should produce a financial condition report each year for the board of directors which would include some analysis of the effect on statutory solvency of different possible future scenarios in relation to both economic and business risks. This was expected to include dynamic solvency testing which looked at the sensitivity of the financial projections to different assumptions. The report was also expected to explain how the insurer could deal with adverse developments and thereby mitigate the potential risks to the insurer, where possible.

In addition, each life insurer was expected to consult its Appointed Actuary over the determination of the amount of remuneration to agents that was required to be disclosed to policyholders. GN22 provided guidance to actuaries on giving this advice about remuneration, along with guidance to actuaries giving advice to insurers on disclosure of the amount of appropriate charges under with-profit products, and also on disclosure of the cost of risk benefits to policyholders under these products. Therefore, while the formal responsibility for the sound and prudent management of the company in accordance with all the relevant statutory criteria, including the need to have due regard to the interests of policyholders, rested with the directors, the actuary was expected to provide appropriate advice to the directors about how these criteria should be met. This broad responsibility of the directors, as advised by the Appointed Actuary, has now been carried forward in similar form into the post-N2 regime, although with greater emphasis on the responsibilities of Directors to look after the interests of policyholders, as well as shareholders.

3.2 Post-N2 Role of Actuary

Under Section 340 of the Financial Services & Markets Act 2000 ("FSMA"), the FSA
is able to make rules requiring the appointment of an actuary to all firms carrying on life insurance business. Rules may also then be made requiring these firms to have a periodic financial report that is reported on by an actuary (or an auditor), and imposing other duties on actuaries as may be specified. At the same time, rules may also be made giving the actuary appropriate powers in order to carry out his responsibilities.

An offence is committed if a firm knowingly or recklessly provides information to an Appointed Actuary that is false or misleading in a material particular. Similarly, an individual director or manager who deliberately attempted to mislead an Appointed Actuary, whether by act or omission, would not be complying with the FSA statement
of principles for approved persons, and could therefore be subject to the relevant FSA disciplinary sanctions.

The Act also enables HMT to make 'whistle-blowing' regulations that would require appointed actuaries to communicate certain matters direct to FSA. A consultation paper has been issued in October 2001 concerning these regulations, and these are expected to be introduced early in 2002.

Under the FSA rules, the insurer must take reasonable steps to ensure that the actuary has the required skills and experience to fulfil the regulatory role at the insurer, and is a Fellow of the Faculty or the Institute. The profession has continued its practising certificate requirement for the Appointed Actuary, and the insurer is expected to verify that this certificate is indeed held.

The role of the Appointed Actuary is then defined more closely in the FSA rules contained in the Supervision Manual. These set out a prime responsibility that the actuary should identify and monitor the risks that may have a material impact on the firm's ability to meet its liabilities to policyholders as they fall due. These liabilities would of course include any constructive obligations in respect of future annual or final bonuses to with-profit policyholders.

Secondly, the actuary is expected to inform the management (and directors) of any material concerns about the current and ongoing ability of the firm to meet these liabilities, in both the present and reasonably foreseeable future circumstances, including the adequacy of the financial resources available for this purpose, and taking account also of the adequacy of the premium rates for new business.

Thirdly, the actuary is expected to carry out the actuarial investigation of the firm each year and produce the appropriate abstract to be included in the FSA returns. This investigation has to value the long-term liabilities in accordance with detailed FSA rules which include an overall requirement that the valuation should be made on actuarial principles that make proper provision for all liabilities.

Accordingly, the present requirement is for the Appointed Actuary to provide this report directly, rather than to report on a financial return produced by another individual, as might be construed from the wording of Section 340 of FSMA (see above).

For the purpose of carrying out all these responsibilities, the actuary may request from the firm such information and explanations as may be considered reasonably necessary, and is expected to advise the firm of data and systems that are reasonably needed for this purpose. The firm must then establish those systems and provide the necessary resources for the actuary.

In addition, the firm must keep the actuary informed about its business plans and request advice from the actuary about the effect of material changes to those plans or other circumstances that may affect the rights or the reasonable expectations of policyholders. The firm must then pay due regard to this advice, and indeed all other advice from the Appointed Actuary, and allow him or her direct access to the board of directors.

The actuary is also required to take reasonable steps to maintain freedom from any perceived conflict of interest, and to be objective in the performance of all duties. This should also follow from application of the profession's Professional Conduct Standards.

The substance of professional guidance notes GN1, GN2, GN8 and GN 22 have been largely maintained, but GN1 does now reflect the greater statutory role that has been given to the Appointed Actuary.

3.3 Current Regulatory Reviews

Following the various reports that have been produced concerning the recent problems at Equitable Life, the FSA has initiated a broad review of the Future of Insurance Regulation. This will include a review of the role of the Appointed Actuary.

This review may include issues such as the allocation of actuarial responsibilities within the firm, the production of annual financial condition reports (including a risk analysis and stress and scenario testing), the separation of the role of the actuary from other executive responsibilities and the extent to which some of these actuarial responsibilities should either be carried out or reviewed by an external actuary. There is also a review taking place of the contents of the FSA returns, and the extent to which this information should be reviewed and published.

Separately, the FSA is undertaking a review of with-profits business, and this will include corporate governance issues. This is likely to centre around each firm having a clear set of principles for financial management which include an interpretation of the reasonable expectations of policyholders such as the need to treat customers fairly and regular monitoring within the firm of adherence to these principles. This could involve the setting up of a regulatory committee for this purpose, of which the Appointed Actuary would be one member. A regular report could then be produced by this committee setting out these principles, how the firm has attempted to meet them and some measure of its success in this respect.

4. COMPLIANCE REVIEW

The terms of reference of the AGWP included the assumption that there would be external compliance review of internal Appointed Actuaries, as part of the governance framework applying to Appointed Actuaries.

In March 2001 FIMC accepted the recommendations of the Professional Affairs Board that Compliance Review would be introduced for all areas of actuarial work covered by mandatory Professional Guidance. The Life Board was asked to prepare recommendations in respect of Appointed Actuaries and a working party was set up chaired by Mike Shelley. Following the initial report of the working party the Life Board agreed seven principles for Compliance Review. The Compliance Review working party has now been asked to suggest options for the scope (and associated cost) of compliance review.

The Compliance Review working party have kept in close touch with FSA and are aware that FSA intend to require:

_ certification of the actuarial sections of FSA returns to an audit standard

_ a more detailed compliance review of aspects of the Appointed Actuary role.

Whilst these aspects are as yet not determined, their thinking is understood to be similar to that of the Life Board; i.e. that compliance review would provide appropriate professional challenge which would cover the following areas:

_ Solvency

_ Financial condition reports

_ Bonus declaration and financial management of with-profit funds, and other areas of PRE

_ Disclosure requirements covered by GN22

FSA rules in this area would be supported by actuarial guidance so that between them they defined who might act as a reviewer and the nature of the review.

The requirement for compliance review arises in part from the concern that, without independent review, the work of the Appointed Actuary does not benefit from professional challenge or from the experience of another professional coming from a different background. In particular, independent review of actuarial advice should ensure that alternative views are not dismissed without professional challenge.

Thus the primary objectives of Compliance Review are:

_ the peer review of the work of the Appointed Actuary by another senior and appropriately qualified actuary to ensure it complies with professional standards,

_ the sharing of best practice and experience from a wider range of sources than might otherwise be available to an employed Appointed Actuary,

_ to provide an external and independent review, which should give comfort that the internal actuary has given appropriate weight to his or her responsibilities to regulators and in relation to policyholder interests, and has not been overly influenced by the inevitable pressures which are faced in balancing these interests with those of his or her employer and its owners.

The final point should ensure that the use of internal Appointed Actuaries can continue, combined with the further benefits of external review.

The AGWP believe that it is important to consider the form and depth of review, which would achieve the objectives, at a minimum of additional cost. This will depend on the governance structure ultimately agreed for the Appointed Actuary and the extent of conflicts that remain in the role. The more conflicts remain in the Appointed Actuary role, the wider the role of the reviewer will need to be to maintain public confidence in the system of governance.

We have some concerns that if the level of review and form of "sign-off" is not suitably limited, then the costs of the review will escalate. Also, with a heavier level of review, it is likely that the reviewer will become more involved in some of the decisions and recommendations. There is then a risk that the effective responsibility shifts to the reviewer and away from the Appointed Actuary.

In Section 6 we have considered a number of alternative models for actuarial governance, which may require either a 'lighter' level of review, or a 'heavier' and more intrusive level of review. We refer to the reviewer as the "Independent Review Actuary".

5. KEY ISSUES

5.1 Context of Actuarial Governance

The AGWP's terms of reference are set out in section 1.2. The AGWP have taken "issues relating to the role of the Appointed Actuary" to include all issues relating to activities in a life assurance business that may frequently involve the Appointed Actuary – including those which are not necessarily the formal responsibilities of the Appointed Actuary. "Governance" has been interpreted as the process of ensuring and proving that these activities are appropriately governed.

The introduction of external compliance review of the discharge of the formal responsibilities of appointed actuaries is seen as a key element of strengthening actuarial governance. The AGWP believe that actuarial governance might be further strengthened by providing further detail on the duties of directors in safeguarding policyholder interests, as well as those of shareholders.

Potential conflicts of interest arise primarily where the company has discretion over certain policy terms that can influence the benefits paid to policyholders, and for the Appointed Actuary, when he is advising the company how such discretion might be exercised. Such conflicts can potentially arise both between the interests of policyholders and shareholders, and amongst the interests of different groups of policyholders. There is scope for such conflicts to be exacerbated where key individuals in an organisation have specific objectives and/or a remuneration package that could encourage actions in conflict with their responsibilities either

(a) to have due regard to policyholder interests in exercising or advising on exercising discretion or

(b) to manage the business in a sound and prudent manner.

The degree of external compliance review required should depend on the extent to which the scope for these conflicts has been eliminated. We discuss this further in section 6.

5.2 The Role of Directors

The first legal duty of the directors is to the company concerned. Ultimately directors are accountable to the shareholders of a proprietary company or the current members of a mutual company, and the shareholders or members may dismiss the directors for poor performance. However, the directors of a life insurance company must operate in accordance with the demands of the regulatory framework. If the regulatory framework imposes formal responsibilities on the directors, they should be able to justify their actions to shareholders or members accordingly. Nevertheless one of the actuaries providing input believes that it is unrealistic to expect the directors of a proprietary company to have to balance the interests of shareholders and policyholders.

At the time of writing, the FSA is still to publish its issues paper on governance of with-profits business. The AGWP would wish to study and discuss this document before drawing definitive conclusions. However, in common with most interviewees, the AGWP believe it is appropriate that all directors should have formal responsibilities to have due regard for policyholders' interests and reasonable expectations. There is a risk that the Appointed Actuary is seen by the board of directors as the one who has to consider policyholder interests, and that the board can regard themselves as having adequately fulfilled their responsibilities in this regard if the Appointed Actuary signs the relevant certificate.

Whilst it is the Appointed Actuary's duty to advise (and whistle-blow if inappropriate actions are taken), it is the directors' responsibility to have due regard for policyholder interests, and we believe this should continue. It would be inappropriate to place the burden of ensuring that policyholder interests are adequately considered on any single individual.

If the board of directors has insufficient time to consider some of the issues in adequate depth, a committee of the board of directors could be formed to consider issues in greater depth. The AGWP believe it would be preferable for such a committee to have a majority of non-executive members. One contributor argued strongly that independence is necessary. An independent committee may be appropriate for certain companies – particularly under certain Schedule 2C schemes. However, the AGWP believe that the primary responsibility for safeguarding policyholder interests should lie with the ultimate decision-maker in an organisation – i.e. the board of directors. The board would therefore remain responsible for the Committee's recommendations, just as it remains responsible for matters typically considered in more depth by the Audit Committee.

5.3 Exercise of discretion disclosure

None of the above eliminates the potential conflicts of interest – although we believe that greater clarity of the priority of policyholders' reasonable expectations over shareholder or member interests would help. Thus it is essential that there is adequate disclosure of how discretion has been exercised. Elements of such disclosure are currently made through the abstract of the Appointed Actuary's valuation report included in the FSA Returns. Enhancements to disclosure are suggested in the Issues Paper on Regulatory Reporting prepared by the FSA under its With-Profits Review. Further disclosure might typically be made directly to policyholders in annual statements for with-profits policies or in other statements when charges under other policy types are reviewed. More detailed disclosure may be necessary from time to time.

We believe that disclosure should wherever practicable be made in public documents. However, we recognise that, particularly in the case of with-profits business, detailed and timely disclosure of certain information would create problems of anti-selection that could ultimately destroy the proposition for all policyholders. In such circumstances, disclosures might reasonably be made to the reviewer or the regulator on a confidential basis.

5.4 Key Questions relating to the Role of the Appointed Actuary

The AGWP identified a range of inter-related key governance issues relating to the role of the Appointed Actuary in life assurance in the UK.

5.4.1 Should the Appointed Actuary be an employee of the company (or an external consultant)?

Whilst many smaller companies employ external appointed actuaries, this is quite unusual for larger companies.

Some of those interviewed suggested that the Appointed Actuary would be in a better position to resist pressure if part of an organisation external to the life company itself. Such an arrangement should ensure that the Appointed Actuary has access to others who have faced similar issues. It would also help to avoid the unintentional acceptance of certain risks ‘by tradition’.

On the other hand, the advantages to the Appointed Actuary of being ‘naturally’ involved in management decisions on a day-to-day basis are clear and are far more likely to be achieved through being an on-site member of the management team.

In practice, ‘softer’ factors will be critical to the successful execution of the Appointed Actuary’s role, whether internal or external. The actuarial function in a life office, and ideally the Appointed Actuary, need to be perceived as business-enabling rather than solely acting as a constraint on the business.

The ideal arrangement will also depend on the level of business and actuarial understanding amongst management making day-to-day decisions. The adequacy of the Appointed Actuary’s day-to-day involvement will be heavily influenced by the personalities involved and the backgrounds of the executive directors. Some appointed actuaries may be happy to rely on others to ensure that actuarial perspectives are adequately represented where there is no formal requirement to involve the Appointed Actuary.

The AGWP recognise that an external consultant can become sufficiently closely involved in the running of the affairs of the company to overcome the disadvantages of being external. However, if this occurred, then one of the advantages of being external – namely being independent - could be diluted, as the advantages of being close to management and seen as 'part of the team' are gained. Commercial confidentiality may mean that an external actuary acting as Appointed Actuary and having a close involvement with one client would not be able to perform a similar role as Appointed Actuary for another client.

One of the models considered in section 6 attempts to combine the benefits of both an external appointed actuary, with an internal actuary closely involved in management decisions.

5.4.2 Should an internal Appointed Actuary also be a director?

As a board director, the Appointed Actuary might have greater influence. However the Appointed Actuary's obligations to advise the Board on his or her interpretation of policyholders' reasonable expectations heighten the potential conflicts of interest. With external compliance review and improved clarity over the priority of policyholders' reasonable expectations, these conflicts should generally be manageable. However the Appointed Actuary (or prospective Appointed Actuary) concerned should carefully consider the demands of both roles before accepting the joint appointment. In a mutual, the conflicts are more likely to be manageable, whereas certain Schedule 2C Schemes may place specific demands on the Appointed Actuary which make the conflicts more difficult, if he/she is also a Director.

5.4.3 How should the relationship between the Appointed Actuary and the board of directors operate?

The Appointed Actuary should have the automatic right to attend and speak at all meetings of the board of directors. He should also receive all board and board committee papers and minutes unless explicitly advised that this is not the case (as may be appropriate for the deliberations of any Remuneration

Committee).

Some contributors suggested that the Appointed Actuary should attend all board meetings as a matter of course. This would ensure that the actuary has the opportunity to be involved in all deliberations, but may not represent the best use of the Appointed Actuary's time if he or she has been provided with the agenda and advance papers and previously involved in discussions of any pertinent matters with any Executive Committee.

In groups, the right to attend and speak at board meetings would apply to the decision-making board or committee, as well as the insurance company board, which may only meet once or twice a year.

5.4.4 What restrictions should be placed on the wider management responsibilities that an internal Appointed Actuary should take on?

The range of demands on the Appointed Actuary and the potential conflicts of interest between different groups of policyholders and shareholders or members are such that it is difficult to see how the role of Appointed Actuary can be combined with certain other key roles. Further the achievement of specific objectives (such as profit or sales targets) may from time to time conflict with the obligation to manage the business in a sound and prudent manner.

It is nevertheless essential that the Appointed Actuary is sufficiently involved in product development and business, capital and profit planning. There will typically be an Executive Committee responsible for these aspects and many of the day-to-day operations of the business. The Appointed Actuary might be a member of the Committee. If not, there needs to be a formal documented mechanism for ensuring that the Appointed Actuary attends the meetings of such a Committee when appropriate.

5.4.5 Should the Appointed Actuary's role be one of "Policyholder Champion"?

The general view of those interviewed was that the Appointed Actuary needs to take a balanced view. The Appointed Actuary's role is currently seen more as one of adviser rather than negotiator. If the Appointed Actuary were to act as negotiator on behalf of the policyholders, it would clearly be difficult also to be a director or advise the directors on the fairness of any particular course of action. The normal continuing operation of a life insurance business should not generally require anyone to negotiate on behalf of the policyholders. Significant changes, particularly reconstructions, will however from time to time give rise to the need for such a role.

5.4.6 Should there be restrictions on the number of Appointed Actuary roles an individual actuary might take on?

In deciding whether or not to accept an appointment, an actuary will typically take into account the implications of both workload and potential conflicts of interest. The introduction of external compliance reviews will introduce new potential conflicts. The number of roles it is appropriate for an actuary to take on will inevitably depend on the demands and complexity of each of them.

5.4.7 Should the Appointed Actuary's responsibilities and powers be extended in any areas?

With the new Interim Prudential Sourcebook environment and the latest revision of GN1, the AGWP have not identified any material areas for further change at this stage.

Paragraph 3.6 of the latest version of GN1 requires the Appointed Actuary to satisfy himself that adequate systems of control are in place to ensure that the insurer's policyholders are not misled as to their expectations. Paragraph 6.6 requires the Appointed Actuary to advise on the appropriateness both of disclosed charges and expenses and of the with-profits guide.

It was suggested to us that the Appointed Actuary should be required to publish an annual report on how a life office has met policyholders' reasonable expectations. The Appointed Actuary is already effectively required to report on how the company has exercised discretion in the abstract of the report included in the FSA Returns. There may be a place for a more consumer-focused report produced by the company on how it believes PRE have been met.

5.4.8 What restrictions, if any, should be placed on the financial incentives of Appointed Actuaries?

As a senior permanent employee of a proprietary life insurance company, the

Appointed Actuary would probably be entitled to share options that are generally seen as a tax-efficient part of standard remuneration package for senior employees. It will be difficult to attract quality personnel to the role of Appointed Actuary without something equivalent. Further there is a risk that if the Appointed Actuary has a radically different remuneration package, he or she will not be seen as part of the team. However share options in particular may damage the perception of the actuary's ability to act independently of the shareholders' interests. In principle, there are similar considerations for directors (who must act in the shareholders' interests subject to any regulatory constraints).

A number of those interviewed did not see a difficulty with a remuneration package including incentives at a level consistent with those of employees of equivalent seniority in the life office. However, opposite views were expressed by others who thought share options should not be permitted.

5.4.9 What should be the role of the actuarial profession in supporting Appointed Actuaries and the actuarial governance of life insurance companies?

The principal areas requiring – or potentially requiring – input from the profession are:

_ Ensuring fitness of the Appointed Actuary and external reviewer

_ Encouraging compliance reviewers and appointed actuaries to share best practice on a non-attributable basis

_ Identifying potential problem areas in advance

_ Potentially to support the development and operation of an Actuarial Standards Board. This is seen as more likely to influence insurance company accounting in the short term, but its remit could be extended. We would not see this as being a prescriptive body, laying down detailed standards in a wide range of areas, but rather as focusing on a few areas where additional and more specific guidance would be most valuable.

6. ACTUARIAL GOVERNANCE MODELS AND RECOMMENDATIONS

6.1 Introduction

Compliance review is a key element of actuarial governance. The overall approach to actuarial governance needs to take into account the level and form of compliance review, and function within the context of the general governance framework for life companies.

We have concentrated on the framework appropriate to the formal responsibilities of the Appointed Actuary including those required by guidance notes GN1, GN8 and GN22. Actuarial profit-reporting calculations will normally be audited and the work of the Independent Actuary in a transfer of business typically provides an effective control on the advice that the Appointed Actuary is likely to provide in such a situation. However, there will be other aspects of actuarial advice offered by the actuarial function in a life office which may be key, but not naturally subject to independent actuarial scrutiny. As directors become used to receiving external review reports on the advice of the Appointed Actuary, they may well seek similar reviews of advice on decisions that are critical for the business, but not part of mandatory guidance (and hence not otherwise automatically subject to external actuarial review).

We have assumed that, whilst some changes may be made to strengthen governance of with-profit offices and to ensure the appropriate use of discretion, nevertheless the current form of governance remains essentially unchanged. In particular we have presumed that directors will have responsibility for ensuring that policyholders are treated fairly and their interests are properly taken into account, in parallel with the directors’ primary responsibility to the company and its members.

6.2 Alternative Models

In order to facilitate discussion and clarify the trade-offs between various alternative approaches to actuarial governance, we have considered the merits of a number of alternative models.

The four options we have given further consideration to are as follows:

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A an internal Appointed Actuary, remaining an integral part of the senior management team, often as a director, supported by a level of compliance review necessary to demonstrate that conflicts are not biasing his advice.

B an internal Appointed Actuary who is not a director, and whose management responsibilities are primarily confined to the actuarial functions (including the broad roles outlined in section 2), so as to remove conflicts, allowing a more limited level of compliance review.

C the actuarial responsibilities are shared between an external Appointed Actuary, who has certain formal statutory and whistle-blowing responsibilities, and an internal Chief Actuary who also has certain formal responsibilities and obligations, but may be a director and/or member of the senior management team.

D an external Appointed Actuary, subject to peer review only at a level commensurate with or lighter than that in B above, reflecting the fact that the external Appointed Actuary is independent of the company and not subject to conflicts between shareholder and policyholders' interests.

As some form of compliance review of internal Appointed Actuaries is widely considered as necessary, we have not considered the status quo any further.

Our comments apply to proprietary companies where conflicts between policyholder and shareholder interests can be significant. We comment later on the position in mutuals.

6.3 Option A

Many existing Appointed Actuaries believe that they would be much less effective and would have less influence if they were not a director and/or part of the senior management team. They do not believe, in practice, that their position as a Director or senior manager, and any potential conflict this creates, are incompatible with their statutory responsibilities as the Appointed Actuary and their role in protecting policyholders' interests, recognising that all the Directors must consider the interests of policyholders as well as shareholders.

In this situation we would envisage a relatively heavy level of compliance review, which would be pitched at a level that would give comfort and avoid any public perception that the conflicts for the internal Appointed Actuary were inappropriate. The level of review and involvement of the reviewer, in key aspects such as the interpretation of PRE and matters affecting the solvency of the office, would be significant and commensurate with the level envisaged under option C below (although under this option, formal responsibility remains with the internal Appointed

Actuary). We would envisage that most Appointed Actuaries would want to have discussions with the Independent Review Actuary on a continuous basis and would wish to refer key reports and recommendations to the reviewer prior to finalising and presenting them to the Board.

With the counter-balance of an effective and significant level of compliance review the AGWP believe that this option would be a viable, albeit quite costly alternative. It would be consistent with a strengthening of the governance framework to constrain the level of discretion (or at least create a better defined framework within which such discretion was exercised) and where more emphasis was placed on the directors' responsibilities to policyholders. It would also give the highest chance that the role of the Appointed Actuary did not become isolated or confrontational, which is a risk with some of the other options.

The role of the internal Appointed Actuary should remain influential and attract high calibre candidates.

Apart from the potentially heavy costs, the main risk is that the effective responsibility for decisions might shift to the Independent Review Actuary – who would become a 'shadow' Appointed Actuary. In the event that differences in opinion became apparent to the Board, then the Board might look directly to the Independent Review Actuary for advice and this might weaken the position of the Appointed Actuary or lead to the reviewer being appointed formally as the Appointed Actuary (i.e. a move to Option C or D).

6.4 Option B

If the main sources of conflicts were to be removed, we believe that the Appointed Actuary would not be able to hold any senior management positions such as CEO, CFO or Sales & Marketing Director. Similarly the Appointed Actuary would not be a Director – although this would depend on the extent of changes to the overall governance approach. The Appointed Actuary would nevertheless, be entitled to attend all Board meetings. The Appointed Actuary would not be able to participate (to any material extent) in share option schemes or other value based incentive plans, or otherwise own a material interest in the shareholder profit stream. The level of materiality would have to be defined by the Profession. This would depend on the group structure and significance of the life operations to the group, but we would envisage a maximum level for the value of options granted around 25% of salary.

In this situation, we would suggest that a much lighter level of review would be appropriate, with the primary objective of ensuring the Appointed Actuary's work was consistent with professional guidelines, and to share best practice and experience from outside the Appointed Actuary's own firm. There would not be a need to provide an 'independent review' by someone not subject to the conflicts of the Appointed Actuary as in Option A, hence this lighter level of review might also be appropriate for Appointed Actuaries of mutuals.

The main advantages of this approach are that it retains responsibility with the inhouse Appointed Actuary who is close to the business and keeps costs to a minimum. However, the status and influence of the Appointed Actuary is likely to be diminished quite substantially, as is the attractiveness of the job, and there is clearly a risk of losing the best internal actuaries to external firms. It may also make the Appointed Actuary job more confrontational, as there will be a clear separation of the role from that of the management team and directors.

We believe that this approach carries a risk of weakening the actuarial governance of life offices.

6.5 Option C

This option is based upon Option A, but by moving the formal responsibility onto the external Appointed Actuary, it would avoid isolating the internal Chief Actuary and permit him or her to function within the senior management team on an equivalent basis to others. The costs could be similar to those of Option A. The loss of internal "on the spot" involvement might reduce the effectiveness of the Appointed Actuary compared with Option A, but this should be counter-balanced by the involvement of the Chief Actuary.

This model is dependent upon there being a senior actuary in place within the insurer as Chief Actuary and is, therefore, only likely to be viable for an office of reasonable size.

The internal Chief Actuary would be responsible for all actuarial work, including the production of FSA returns, and the Appointed Actuary would discharge a formal reporting role, as envisaged under section 340 of the Financial Services and Markets Act 2000, and have the duty to inform FSA under section 342. This would require the FSA rules to be amended to allow the Appointed Actuary to report to the Board upon the firm's investigation, rather than be responsible for conducting it.

The division between the Appointed Actuary and the Chief Actuary could, of course, be adapted slightly according to circumstances. However, for a large office, the Chief Actuary would be responsible, on behalf of the insurer, to see that the actuarial work was carried out. In most areas the Chief Actuary would draft a report and cover within that report all issues that are relevant. However, the Appointed Actuary would review this, and would give his or her view on aspects impacting upon either the solvency of the Long Term Business Fund or upon policyholders' reasonable expectations.

The Appointed Actuary would be allowed professionally to place reliance upon the work of the Chief Actuary, subject to conducting reviews on a similar basis to a compliance reviewer on matters other than those where opinions are expressed, such as interpretation of PRE. In those areas he or she would take full responsibility. Matters of actuarial judgement would be reported upon and an opinion expressed. In particular the Appointed Actuary would have to give special attention to issues relating to the solvency of the Long Term Business Fund.

Although a significant part of the responsibilities of the Chief Actuary would, without doubt, be to ensure that the Appointed Actuary was aware of, and in agreement with, the approach being recommended by the Chief Actuary on all key issues, nonetheless, the Chief Actuary would be able to have considerable influence, and would be able to express proper professional views. Although not directly responsible for advising the Board on issues such as policyholders' reasonable expectations, in meeting FSA Principle 6, the Chief Actuary would be able to influence the Board and management decisions, not least because of the importance of avoiding the Appointed Actuary having to report the firm to the FSA. The Chief Actuary would also, however, be free to give weight to commercial considerations in framing his recommendations. The Appointed Actuary would review and report on these recommendations having regard to their reasonableness from a regulatory/policyholder point of view.

6.6 Option D

The external Appointed Actuary would be responsible for producing all the reports and recommendations to the Board and may, in some cases, carry out much of the underlying work.

Whilst companies may choose to use an external appointed actuary, and this may often be the most effective option for small life offices and friendly societies, we do not see any reason to make this alternative mandatory. If a life company wishes to employ an internal Appointed Actuary, and is prepared to meet the cost of external compliance review, then it should remain available as an option.

Where an external actuary is appointed, we believe that a lighter level of compliance review would be appropriate.

The main professional firms have internal compliance review procedures. Provided it can be established that this Appointed Actuary role forms a small part of the firm's income (in the same way that auditors show independence from their client) it is possible that an external practice review will be sufficient. However, we recognise that, whilst this satisfies two of the objectives of compliance review mentioned in Section 4, namely 'peer review' by another Actuary, and independence, it does not necessarily meet the third objective of sharing best practice and experience from a wider range of sources.

As with internal Appointed Actuaries, there are circumstances where an external Appointed Actuary, or his or her employer, are not seen to be sufficiently independent of the life company to which he or she is appointed. In such

circumstances, a heavier level of review, from someone outside of the external Appointed Actuary's firm, would be appropriate or in certain cases it may be desirable that a different actuary is appointed, from a firm without such a conflict.

The level of costs under this option will depend on the extent of work carried out by the external Appointed Actuary. Although costs may often be greater than, say, Options A and C, there would be a saving where there are no significant internal actuarial resources or senior actuary.

6.7 Summary and Recommendations

6.7.1 Internal or external

We believe that for many life companies there can be significant advantages in having an internal Appointed Actuary who is both close to the business and can influence the senior management team and directors. We therefore believe that Option A should continue to be available. Nevertheless we recognise that, in some cases, the role of the Appointed Actuary and the influence accorded to the Appointed Actuary within firms have been diminishing in recent years. There is also the risk that changes to the governance structure designed to strengthen the position of the Appointed Actuary may in fact have the opposite effect. If this occurs, then we believe that the option of an external Appointed Actuary, combined with some formalisation of the role and responsibilities of the senior in-house actuary, (Option C) would be preferable. Given the potentially substantial costs of compliance review, this alternative is unlikely to be significantly more costly than the alternative of an internal Appointed Actuary (Option A).

Overall, we believe Option A or C provide the best alternatives from a governance perspective – combining the benefits of both an influential internal actuary and in the case of A, a strong compliance review, or in the case of C the shifting of the formal Appointed Actuary responsibility to an external independent actuary. We recognise that these options may be the most costly, but favour them over B which we believe is likely to be a less effective model in the longer term. We also recognise that alternative D is an acceptable alternative, especially for small offices.

6.7.2 Management positions and directorships

Where either Option A or C is adopted, we believe that few, if any, changes are required to the current position of Appointed Actuaries/Chief Actuaries as directors or

senior managers. As at present, it would not usually be considered appropriate for the Appointed Actuary to be the CEO or Marketing and Sales Director.

We believe it is also preferable, under Option A that the Appointed Actuary of a proprietary life office does not hold the position of Finance Director, where the primary responsibility of this position is the enhancing of shareholder value. However, we recognise that in some companies this responsibility rests primarily with

the CEO, and the FD role is primarily one of 'financial controller'. In such cases the roles of finance director and appointed actuary could still be combined. Nevertheless, we would not see this as 'best practice' other than in mutual companies where there may well be advantages in combining these roles.

If a company wished to combine the roles of their senior actuary with that of Finance Director, we would see Option C as being more appropriate.

If Option B is adopted, we would recommend that the Appointed Actuary did not hold

any other major management roles which might lead to potential conflicts with the duties of the Appointed Actuary. Under this option, and assuming no radical changes to the overall Governance framework, we would also recommend that the Appointed Actuary in a proprietary office was not a director.

6.7.3 Financial Incentives and Independence

In relation to share options or other incentives, we believe that any internal Appointed Actuary should consider, as required by existing professional guidance, whether the level of such financial incentives may be such as to create undue influence in their decisions. However under Option A, we would not recommend an outright ban on Appointed Actuaries being entitled to participate in such share option or incentive schemes. Similarly, under Option C, we would envisage that the Chief Actuary would be entitled to participate in share option or incentive schemes. Under Option B, we would suggest a more restrictive approach.

We also recommend that disclosure of remuneration, in particular the basis used to disclose share options, be improved.

For external Appointed Actuaries and those carrying out compliance review, the profession should consider setting guidelines relating to fee income and other factors which might prejudice the independence of those carrying out these roles.

6.7.4 Policyholder Champion

We do not consider it appropriate to require the Appointed Actuary to act as a 'policyholder champion'. In the normal course of business a balanced approach is required and in exceptional circumstances, such as a reconstruction, a separate person might be appointed as a 'negotiator' on behalf of the policyholders.

6.7.5 Wider responsibilities?

We do not believe that the breadth of responsibilities of the Appointed Actuary needs to be extended further, although we recognise the need for greater involvement in all elements of disclosure – which will become increasingly important in establishing PRE and limiting the extent of discretion which can be exercised by the Directors.

A number of issues arise for the Appointed Actuary out of whistle-blowing requirements of the FSMA 2000, which have been set out in the profession's response (January 2002) to HM Treasury's consultative document (October 2001) on the draft "Communications by Actuaries" regulations.

The increasing demands on the Appointed Actuary in a complex business can – even without the additional responsibilities that are likely to come with additional influence – be such that in practice the Appointed Actuary needs to rely on the work of professional colleagues, including that of other actuaries. The Professional Conduct Standards and guidance notes make it clear that actuaries giving advice remain responsible for it. There is currently no explicit recognition that actuaries may rely on reports from other actuaries, in giving advice and remaining responsible for it, and we recommend that this is addressed.

6.7.6 Role of the Profession

Finally, we have considered how the role of the profession may be extended to support Appointed Actuaries (and reviewers). We believe that further consideration should be given to practical ways of providing additional technical 'guidance' as to best practice and appropriate methods and assumptions in relation to key areas of actuarial practice.

This might involve the formation of some form of actuarial standards board (separate from or as part of any similar requirement in relation to financial reporting); developing the profession's equivalent of 'Dear Appointed Actuary letters', or providing some more technical papers or more detailed 'position statements' in respect of key topics.

The AGWP also felt that the Profession should review the approach to issuing practising certificates. In particular, it might be appropriate to monitor the knowledge and experience of the actuary in relation to the business for which he/she is appointed.

Practising certificates should also be required in some form for reviewing actuaries, thus the current approach to issuing certificates will need to be reviewed.