GENERAL INSURANCE PRACTICE COMMITTEE

Technical Paper: The Use of Catastrophe Model Results by Actuaries

July 2015

Contents

A. Purpose and status of Technical Paper

1. This Technical Paper has been prepared by the General Insurance Practice Committee (GIPC) to assist Members who are required to provide commentary under either:

   (a) Prudential Standards issued by the Australian Prudential Regulation Authority (APRA); or

   (b) Professional Standards issued by the Actuaries Institute,

   on estimates of liabilities or prescribed capital that rely to a material degree on the output of catastrophe models.

2. No previous Technical Paper has been prepared on this topic. It does not represent a Professional Standard or Practice Guideline of the Institute.

3. Feedback on this Technical Paper from Institute Members is encouraged and should be forwarded to Susan Ley by email at sley@munichre.com

B. Background

4. The GIPC requested that a working party draft an Technical Paper to assist actuaries who need to:

   (a) use or comment on the output of complex catastrophe models when estimating catastrophe costs; and

   (b) otherwise consider catastrophe models as part of professional and regulatory requirements.

5. "Catastrophe models are developed by groups of scientists, engineers, mathematicians and actuaries working together to simulate catastrophic events. While most actuaries conceptually agree that catastrophe models may provide more realistic measures of catastrophic risk than those provided by analysing the latest twenty to fifty years of catastrophe losses, most actuaries are not experts in many of the underpinnings of these models."[1]

6. Most actuaries are not experts in the field of catastrophe modelling. In most cases, they will need to rely on the work of others. The purpose of this Technical Paper is to provide some tools that an actuary could use to assist him or her in gaining comfort in this reliance.

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[1] Actuarial Standards Board (2011): ASOP 38.

7. This Technical Paper is not intended to provide information on how to build catastrophe models; rather, simply to provide actuaries with guidance on areas that they should consider in determining whether the model or models are used appropriately.

8. This Technical Paper is structured in three sections. The first deals with the appropriateness of the catastrophe model, data and assumptions used. It looks at some questions the actuary could ask, given the purpose for which the modelled results are needed, to gain comfort that the model is a reasonable one to use. The second part considers whether the specific outputs are reasonable to use for a given purpose and the third part looks at the uncertainty surrounding the results and considers some approaches to getting a better understanding of what that uncertainty may mean.

9. Given the subject matter of this Technical Paper, the working party consisted of both actuaries and catastrophe modellers.

C. Applicable standards and other materials

C.1 Regulatory and professional requirements

10. There are several aspects of legislative requirements and professional standards where Members are asked to comment on results that are likely to have been produced using catastrophe models. Where Members need to comment on reinsurance programs or insurance concentration risk charges, they should be familiar with the requirements of the relevant standards.

11. As at the date of this Technical Paper, the following standards may require actuaries working in Australia to assess that catastrophe models are being used appropriately and that they may rely on the work of others in this area:

   (a) **Professional Standard 305** (Financial Condition Reports and Review of Run-off Plans for General Insurance) – March 2013 – Actuaries Institute (PS 305);

   (b) **GPS 320** (Actuarial and Related Matters) – January 2013 – APRA (GPS 320);

   (c) **GPS 116** (Capital Adequacy: Insurance Concentration Risk Charge) – January 2013 – APRA (GPS 116); and

   (d) **Professional Standard 300** (Valuations of General Insurance Claims) – March 2013 – Actuaries Institute (PS 300).

12. The purpose of this Technical Paper is to give actuaries some tools and approaches which provide ways of gaining comfort around relying on the use of complex models developed by others. While the focus is on specific actuarial requirements, the

approach suggested is equally applicable for non-regulatory requirements or regulatory requirements that may be addressed by a wide variety of parties.

C.2 APRA publications

13. While neither a professional nor prudential standard, APRA has provided some guidance on better practice in Financial Condition Reports (FCRs).[2] APRA has commented that better practice in FCRs includes:

    (a) separate discussion of the Probable Maximum Loss (PML) and the reinsurance arrangements, including discussion of the uncertainty in the PML;

    (b) discussion on risks and limitations regarding catastrophe modelling, as well as commentary on ranges of model outcomes based on different input assumptions and reasonableness checks against historical events;

    (c) clear statement of reinsurance arrangements, including retention, upper limit, defined coverage, reinsurers involved, reinstatements and downgrade clauses;

    (d) discussion of the process for selecting the structure of a reinsurance program and resulting catastrophe cover; and

    (e) providing an actuarial opinion, as well as stating facts on the suitability and adequacy of the reinsurance arrangements and identifying gaps in process or areas for improvement.

14. The tools and approach discussed in this Technical Paper may be of assistance to the actuary in addressing these requirements.

C.3 Other materials

15. There are many useful references covering catastrophe models. The following two, in particular, are very useful and actuaries who are not familiar with catastrophe models and their functionality and limitations would benefit from reviewing them:

    (a) ASOP 38 "Using models outside the Actuary's Area of Expertise (Property and Casualty)" prepared by the Actuarial Standards Board (US). This considers similar topics and provides a useful approach to the topic; and

    (b) "Industry Good Practice for Catastrophe Modelling" published by the Association

[2] "An assessment of the suitability and adequacy of reinsurance arrangements, including the documentation of reinsurance arrangements and the existence and impact of any limited risk transfer arrangements, and whether the reinsurance arrangements are sufficient to cover the Probable Maximum Loss defined in GPS 116": APRA (2013): Letter to Industry: Catastrophe Risk Governance.

of British Insurers (ABI).

16. Other background materials and publications of interest in this area are listed in the bibliography with links to the documents online. This list is not a complete or comprehensive list and was prepared in August 2014. Other publications, standards or guidance may become available after that date.

D. Catastrophe modelling terms

17. Specific terms used in this Technical Paper:

(a) "Aggregate Exceedance Probability" (AEP)

A measure of the probability that one or more occurrences will combine in a year to exceed the threshold. AEP is the annual losses from all events in a year. This is useful if there is an annual aggregate cover (stop-loss) or in analysing reinstatement requirements. It is also useful for pricing insurance business as it gives the distribution of annualised catastrophe losses, given that more than one event can occur in the same year. This can be used in determining appropriate catastrophe loads for insurance premiums.

(b) "Annual Average Loss" (AAL)

Annualised expected loss value.

(c) "Attenuation functions"

Attenuation is the gradual loss in intensity of any kind of flux through a medium. In this context, the movement transmitted through the ground following an earthquake is meant. Scientific opinion differs here on the best form and shape of these equations at specific locations and, for earthquake sparse data, does not help make the equations definitive.

(d) "Catastrophe model"

Catastrophe modelling is the process of using computer-assisted calculations to estimate the losses that could be sustained by a portfolio of risks due to a catastrophic event that has not necessarily occurred, but which is scientifically credible. It draws upon a number of disciplines including actuarial science, engineering, meteorology and seismology.

A catastrophe model typically comprises three modules:

- ► Hazard Module: The Hazard Module simulates the frequency and severity of natural phenomenon (events) that could possibly take place using scientific equations and variables to estimate the destructive force at a given location. For example:

– for cyclone, the wind speed at any location is a function of central pressure, distance and direction to the eye and forward speed of the storm system; over land, the geographical and topographical features are also considered; and

– for earthquake, the amount of ground shaking at any location is a function of magnitude, distance to the epicentre location and local soil conditions.

► Vulnerability Module: The Vulnerability Module combines the event characteristics from the Hazard Module with information relating to the risks exposed to estimate the potential damage caused by the simulated events. Vulnerability functions translate parameters from the Hazard Module into the expected amount of damage, often expressed as a percentage of insured value. The vulnerability function may depend on the risk's characteristics such as its construction, height, roof type, etc.

► Financial Module: The Financial Module translates the estimate of damage from the Vulnerability Module into an insured loss, taking into account the insurance policy's financial terms and conditions such as limits and deductibles.

(e) "Demand Surge"

A basic definition of demand surge is the definition of the Actuarial Standards Board (US): "A sudden and usually temporary increase in the cost of materials, services, and labour due to the increased demand for them following a catastrophe." This reflects the definition used in this Technical Paper.

(f) "Event set" or "event loss table"

Complete list of all modelled scenarios usually containing a unique event ID, loss and frequency.

(g) "Horizontal requirements"

The natural perils horizontal requirement (NP HR) for an insurer that has exposures to natural perils is calculated as:

► the greater of H3 requirement (the net retention post three 1 in 10 year events) and H4 (the net retention post four 1 in 6 year events) requirement (as defined in paragraphs 29 and 36 of GPS 116 respectively); ***less***

- Premium Liability (PL) offset (the expected future allowance for natural catastrophe perils allowed for in premium liabilities (if any)) (as defined in paragraph 43 of GPS 116).

An insurer does not need to calculate both the H3 requirement and the H4 requirement if it is able to demonstrate that one of these amounts is expected to be materially lower than the amount determined for the other.

(h) "Non-modelled perils"

In Australia, the main six perils of relevance for reinsurance are cyclone, earthquake, bushfire, flood, storm and hail. The various catastrophe model vendors provide widely used systems for modelling tropical cyclones and earthquakes. The perils of bushfire, flood, storm and hail are collectively known as "non-modelled perils", as vendor modellers do not traditionally provide models for these. Some vendors now have models for some of these remaining perils, but these have not been universally accepted.

More literally and specifically, where certain perils are material to an insurer but not included in its computer-based modelling techniques (that is, literally not modelled), an allowance for losses in respect of these perils would need to be added to the Natural Perils (NP) PML.

(i) "Occurrence Exceedance Probability" (OEP)

This is a measure of the probability that a single occurrence will exceed a certain threshold. OEP is the single largest occurrence in a year. This is useful in determining how likely a loss will be ceded to a per occurrence reinsurance layer. This distribution is used in pricing of catastrophe risk reinsurance.

The AEP is always larger than or equal to the OEP at a given return period (as more than one event can occur per year).

(j) "Probable Maximum Loss" (PML)

This represents the maximum loss that is likely with a given level of probability over a defined time frame (usually annual), such as the one in two hundred PML over the next year (for example, the 0.5% (1/200) loss estimate from the OEP curve). This figure may need to be adjusted to allow for a variety of factors (for example, exposure growth, demand surge, etc).

(k) "Secondary uncertainty"

This relates to the uncertainty in loss given that an event has occurred. Typically, this relates to the precise local intensity of the hazard, and the vulnerability of a property to this hazard.

(l) "Underinsurance"

Where the declared replacement value is not sufficient to fully reinstate the building and/or contents. Overinsurance is a similar concept where the declared replacement value is too high. When this Technical Paper refers to underinsurance, the possibility of overinsurance should also be considered.

(m) "Vertical Requirement" (VR)

The Natural Perils (NP) vertical requirement is the maximum of:

- the net whole of portfolio loss; and
- the net PML less NP reinsurance recoverables,

both at a stated return period of at least 1 in 200.[3]

E. Context of reviewing output of a catastrophe model

18. It is important to clarify the context in which the model is being considered. Members may be requested or required to assess the catastrophe modelling carried out for a variety of reasons, including but not limited to:

(a) regulatory requirements and professional standards;

(b) providing advice on the insurer's reinsurance or reinsurer's retrocession programs; and

(c) pricing.

19. This Technical Paper is intended to provide some possible approaches an actuary could take in fulfilling the regulatory requirements, as well as those of the professional standards. While not the primary function of this Technical Paper, many of the considerations are applicable to other circumstances where an actuary may need to comment directly or indirectly on the use of catastrophe modelling.

20. Materiality is a key consideration when reviewing the appropriate use of models and model results. The extent to which the details of a model need to be understood should

3 APRA (2013): GPS 116, paragraph 21.

be consistent with its intended use and the materiality of its outputs to the results. For example:

(a) when considering the vertical component of the Insurance Concentration Risk Charge, a greater focus on the appropriateness of the models and model results may be warranted where, all else being equal, an insurer chooses to purchase reinsurance to a 1 in 200 year return period rather than a 1 in 500 year return period;

(b) a greater focus on the appropriateness of the earthquake model, rather than the cyclone model, may be warranted where an insurer writes business primarily in the southern states of Australia; and

(c) when considering the horizontal component of the Insurance Concentration Risk Charge, a greater focus on the model results in comparison to historical loss experience, and the adequate blending between the model results and experience, may be appropriate if relevant experience is available.

F. Assessing the appropriateness of catastrophe models and results

F.1 Data availability and quality

21. As with any modelling exercise, having data that is fit for purpose is vital.

22. The exposure data used in a catastrophe model is of key importance. It should be as complete and accurate as possible. Gaps in the data can impact on the results and understanding such impacts is part of assessing the model's suitability. To understand any gaps, the actuary may need to have discussions with catastrophe modellers, underwriting and systems/IT.

23. It is important to consider the aspects of the data in the context of what the model and the insurer require. For example, it does not matter if the data is not available at a more granular level if the model requires data by CRESTA zones.

24. Potential data questions to ask include:

(a) What classes are included in the data? Is the data detailed with individual locations or is it aggregated? What does the insured value represent? Is it the replacement value or other (such as a policy limit or average rebuild cost per m^2)? Are values split by coverage (for example, buildings, contents, business interruption)?

(b) How detailed is the address data? What is the geocoding resolution? What action is taken for locations which have no address or cannot be geocoded? What countries are included in the data? Are all country perils covered by the models available?

(c) Are all the relevant financial conditions for each policy recorded? These include limits, deductibles, attachments, coinsurance share, sub limits, peril or site specific restrictions, other aspects of coverage and reinsurance. Have the financial conditions been applied correctly in the model?

(d) What risk characteristics have been captured? These include construction, occupancy, year property built, number of storeys and number of structures.

(e) Is the data suitable for the models and perils being considered? Have any assumptions been applied to the data? Are these documented with explanations given for the chosen values? Are there any relevant exposures missing from the data? Have all potential adjustments to the data been considered (for example, treatment of GST/ITC, growth projections, underinsurance and policy benefits)?

(f) What changes have there been in the data compared to previous analyses (for example, sum insured, risk count, average sum insured, regional exposures, financial conditions and risk characteristics)? Are these as expected? Has the data been reconciled against systems and other reporting?

(g) Where data is missing, incomplete or may be inaccurate, how has it been dealt with and what are the implications of this? Is the data a true representation of the portfolio of risks?

25. The use and management of data for catastrophe modelling is also covered in detail in other documents. See, for example, Annexure A documents:

- (b) GPG 116, paragraphs 97-104;
- (f) ICRC Natural Perils, Chapter 2;
- (g) Industry Good Practice for Catastrophe Modelling, Chapter 4; and
- (e) ASOP 38.

F.2 Data governance

26. Good practice suggests a governance framework is in place to ensure that the data used is subjected to the required level of review, complete, accurate and consistent and any limitations are understood. This should involve the following:

(a) documentation of the process of transferring data from the insurer's systems to the catastrophe models, and details of any assumptions or estimates used;

(b) comparisons over time of the data with the catastrophe model output;

(c) processes and controls to ensure data is complete and reconciled against other summaries of exposure data from different sources;

(d) summaries of data quality, including risk characteristics and geocoding resolution;

(e) understanding of the impact of limitations in the data used, and the possibility of errors in the data; and

(f) periodic review by qualified staff who are independent of the data process.

F.3 Assessing the appropriateness of the use of the model

27. Catastrophe models are complex and what is an important consideration for one model may be less important for another. Some of the key points an actuary may wish to consider when looking at the choice of model used are given below. Not all of these areas are relevant in all circumstances and the relative importance of each will also vary.

28. It is not suggested that an actuary either asks all these questions or carries out all the investigations. However, asking the relevant questions, or ensuring that they have been asked, may assist the actuary in confirming that a reasonable model choice has been made.

29. The primary question to be considered is whether the model is 'fit for purpose'. Whilst what is regarded as 'fit for purpose' may vary depending on the context, consideration may need to be given to the following areas.

(a) Does the model adequately represent the hazard risk? For example, the actuary could confirm that the items listed make sense relative to the limit purchased and the capital levels of the company.

(i) Do the AAL and the OEP curve make sense in comparison to historical losses or loss expectations? It is noted that, for some perils, this will be difficult to assess. This check is high level and may be useful only for some perils.

(ii) What elements of the hazard are included (for example, does the earthquake model include liquefaction, landslide and fire following or is the model limited to ground shaking)? Where allowances have been made, how much of an allowance has been included?

(b) Does the model accurately represent the hazard risk for the specific portfolio being considered?

(i) Are all the relevant perils covered by the model(s)? For example in Australia, do the models cover cyclone, earthquake, flood, bushfire, storm and hail?

(ii) Are all relevant lines of business covered by the model? For example, marine or agricultural business is not well covered by any of the current Australian models.

(iii) Are all geographic regions where the insurer writes business represented by the model?

(iv) Does the model allow for all relevant financial terms and conditions (for example, per site / per policy / per event limits and deductibles, inuring reinsurance etc)?

(v) Is the model granular enough to reflect changes in underwriting policy? For example, a postcode-based cyclone model may not reflect an insurer's focus on reducing exposure in coastal areas.

(c) Is the model calibrated to the local conditions?

(i) Consider that vulnerability functions may have been adopted from other countries and whether this could be a material issue.

(ii) Where specific information is unknown (for example, construction type), how is 'unknown' data treated within the model and is it material?

(iii) Does the model take into consideration historical changes in building codes?

(d) Model governance.

(i) Was the model built by experts in the relevant fields? Consider the extent to which the model has been reviewed by suitably qualified experts.

(ii) Is the model documentation and the level of technical support available appropriate?

(iii) Are model upgrades appropriately delivered (for example, with appropriate explanations for any changes)?

30. There are a number of approaches available to test whether a model is 'fit for purpose' and to assist in illustrating the uncertainty and variability within and between different catastrophe models.

(a) Comparison to other vendor model results, high level sense checks, and the major drivers of model differences.

(i) Consideration should be given both to the differences in the AAL and to any variation in losses along the OEP curve of the return period(s) of focus.

(ii) Comparisons should be undertaken for the relevant geographic regions and exposure types (classes of business) and the relativities in the model results for different regions and exposure types.

(iii) Attempts should be made to understand any significant differences in model results, especially if the differences are materially impacting the financial decisions to be made as a result of the PML figure.

(b) Sensitivity analyses.

The sensitivity of the modelled losses to changes in key parameters (for example, occupancy type, construction class, year built, building height etc) should be tested, documented and, if possible, compared to other vendor model results and historical event data where available.

(c) Reference to other independent sources can assist in forming a view as to the appropriateness of a model. For example:

(i) relevant scientific research;

(ii) opinions from suitably qualified experts; and

(iii) relevant industry organisations.

(d) Comparison to historical events.

(i) Has the model been calibrated to historical events? How have historical losses been adjusted to account for inflation, changes in sums insured and population density? What is the current industry loss estimate for historical events and do they look reasonable? What return period is implied for the historical events based on the model results?

(ii) Does the frequency of events with certain characteristics (for example, magnitude for earthquake events) look reasonable when compared to historical events, both nationally and by region?

(iii) Caution should be used when using return periods as a means of comparing the frequency of historical events and the definition of return period should be consistent. There are a number of different uses of the term "Return Period" so the form of the phrase should be made clear in any analysis. For example, the phrase may be used in the following instances:

- the return period of the loss amount, in relation to the PML curve from the individual company's catastrophe analysis, when considering all perils across the entire portfolio of insured risks;
- the return period of the loss amount, in relation to the PML curve from the individual company's catastrophe analysis, but only considering a specific peril, a selection of classes of insured risks or a specific geographic region; or
- the return period of the event, in terms of the scientific and engineering measure of hazard intensity at a specific location or region. For example, a 1 in 100 flood in the Hunter Catchment Area.

F.4 Considerations when using the model results for a particular purpose

31. Once the model results are obtained, there is a need to consider whether the results appear sensible. The factors listed below may be useful when considering the appropriateness of specific modelling results for a given portfolio.

(a) Are the results plausible from a high level, macro perspective? What would the 1 in 200 year loss imply for the industry-wide 1 in 200 year loss after allowing for the company's market share?

(b) Are the results consistent through time? Are the year-on-year changes in model results adequately explained by movements in exposure, model or assumption changes?

(c) How do the results compare with historical experience? This needs to be undertaken with due caution, as models will rarely replicate a real event. Models are designed to accurately represent the hazard risk over a long time horizon.

(d) A comparison of model output with 'industry wisdom/knowledge' (for example, old PML factors (if known)) may be undertaken.

(e) Reverse stress testing can be undertaken; that is, select a specific large modelled event and consider the event in terms of the number of claims, geographic spread of claims etc in order to assess whether the loss is reasonable given the geophysical characteristics of the event.

(f) How do the modelled loss results compare to realistic disaster scenarios that have been developed either internally or by external industry bodies or agencies?

(g) If more than one model has been used, has the potential for 'overlap' been considered and dealt with appropriately? This is particularly relevant when considering weather-related perils, such as hail and storm, which may include elements of both wind- and water-related damage.

32. As noted earlier, not every model includes all possible loss components. The following components may not have been allowed for (at all or adequately) in the modelled results. There may be loss components for which too little allowance has been made. Additional adjustment factors may need to be applied to the model outputs. The factors listed below, while not exhaustive, should be considered in this context and allowance made, or the results adjusted to reflect their impact.

(a) Demand surge or post loss inflation; that is, the increase in the price per unit of materials, plant or labour as a result of the increase in demand from the event exceeding the available supply.

(b) Underinsurance; that is, where the declared replacement value is not sufficient to fully reinstate the building and/or contents. Betterment and the requirement to comply with current building codes are also relevant considerations.

(c) Loss adjustment expenses; that is, the direct and indirect costs associated with assessing and settling claims.

(d) Additional living expenses / business interruption. Is this cover offered and, if so, has it been appropriately dealt with in the model?

(e) Additional benefits over and above the sum insured (for example, removal of debris and professional fees).

(f) Input tax credits (if not already allowed for in the input data).

(g) Secondary perils, such as storm surge, liquefaction, fire following etc.

(h) Adequate growth factors (between the exposure in-force date(s) to the period under consideration) have been applied to exposures or modelling results and the appropriateness of implied assumptions embedded in the way these growth factors are applied.

(i) Classes of business which, whilst not generally captured within the models, still expose the insurer’s balance sheet (for example, marine and agriculture).

G. Uncertainty

33. Uncertainty cannot be eliminated. A good understanding of the key sources of uncertainty, and clear communication of resulting limitations of the model results, should help reduce the adverse impact of uncertainty on decisions.

34. Prudential and professional standards require uncertainty to be highlighted and, where possible, quantified or illustrated. APRA has indicated the need for insurers to

understand the uncertainty in their catastrophe modelling and its subsequent use. Documentation of any analyses carried out to understand uncertainty can help to inform the insurer and give all parties a common understanding.

35. In assessing that the process for identifying and managing uncertainty is adequate, it is not necessarily required that an actuary undertakes any or all of the analysis himself or herself; rather, the actuary may wish to consider that appropriate analysis has been undertaken.

G.1 Sources of uncertainty

36. Uncertainty is part of every aspect of catastrophe modelling. It starts with the development of a hazard module and ends with the unknowns that need to be considered, but are well outside the scope of a model (for example, non-modelled perils or classes of business or demand surge).

37. Theoretically, the underlying cause of the uncertainty is from two fundamental forms:

    (a) first, Aleatory uncertainty – uncertainty due to natural unpredictable processes (for example, weather is chaotic). Aleatoric uncertainty cannot be eliminated. If it is known that a natural process can be described by a Poisson distribution, and its mean is known, it cannot be known how many events will occur next year; and

    (b) secondly, epistemic uncertainty – uncertainty in our knowledge about the world. Epistemic uncertainty is due to a lack of understanding and potentially limited observations (for example, unknown fault lines).

38. Natural catastrophe models typically do a good job of capturing the aleatoric uncertainty (based on certain assumptions), but do not address the epistemic uncertainty.

39. The secondary uncertainty in catastrophe models is aleatoric. For the given assumptions about hazard and vulnerability calculations, models capture a range of possible losses for a single location in a single event. For example, in an earthquake model, secondary uncertainty includes variation about a particular mean ground motion attenuation function, but does not include different ground motion equations. Which form of ground motion equations would be epistemic uncertainty and indeed, in Australia, where there is a justified scientific difference of opinion on the correct form of these equations, this is made harder by the limited data.

40. Additional, external, uncertainties come in to play when a model is used. These principally arise from the quality of the data being fed into the model, but also include the use of "switches" (model option settings) that might not be set appropriately for the analysis at hand.

41. From a practical high level perspective, there are two main categories of uncertainty in catastrophe modelling:

    (a) the uncertainty in the frequency and severity of events (due to both aleatory and epistemic uncertainty); and

    (b) the uncertainty in the loss quantity.

    The following paragraphs predominantly address the latter category (that is, the uncertainty in the loss quantity). The event frequency and severity distributions used by the models are at the core of the scientific parameterisation of the peril in question. Assessing and potentially adjusting for any uncertainty in these metrics is likely to be beyond the expertise of the majority of model users. Alternative approaches, such as those described later in this Technical Paper, are ways in which insurers can gain an understanding of the uncertainty.

42. It is important to note that various uncertainty sources could increase or sometimes decrease the loss quantity. For example, consider the impact of 'unknown' construction types. If all risks modelled with 'unknown' construction types were actually made from unreinforced masonry, the loss quantity for an earthquake event should likely be higher. Conversely, if the risks were made from reinforced concrete, the loss quantity for an earthquake event is likely to be lower. However, various sources might only add to the modelled loss, such as non-modelled perils or classes of business. For the most part, users of model output will be concerned with establishing reasonable upper bounds for the loss quantity.

43. Some models attempt to quantify the uncertainty around the loss quantity. This method is sometimes referred to as 'secondary uncertainty'. Approaches to this vary by model vendor, with some generating a distribution around a mean loss, and others having different loss values for the same event occurring. These approaches recognise that, for a given event, the actual loss can vary depending on a number of factors including:

    - the hazard (for example, a similar earthquake may generate different levels of ground shaking);
    - the vulnerability of buildings (for example, similar types of buildings may have been constructed to varying levels of quality); and
    - the quality and detail of the risk data used in the model.

    These methods should be noted when selecting models for analysis and interpreting results. For a description of secondary uncertainty, see Boss, C *et al* (2011) Chapter 9.4.

44. There are two sources of uncertainty that need to be considered and possibly adjusted for, if material (assuming that the actuary has already determined the appropriateness of the model for its intended use): 'Model Input' and 'Model Scope':

(a) 'Model Input' is all about the exposure data that is fed into the model and the associated assumptions that need to be made; and

(b) 'Model Scope' captures items such as non-modelled perils or classes of business, or other claims costs (including demand surge or issues with policy wordings or legislation that lead to higher loss costs).

45. For completeness, it is noted that there will be uncertainty in any model design due to the fact that scientific understanding of the underlying phenomena may be incomplete and the amount of available data is limited. Even if a model accurately reflects current understanding of the phenomena, it may not accurately reflect the phenomena.

46. There are many models for each natural phenomenon, each with their own perspective. Having results from a number of models may help to understand the uncertainty surrounding the models for a particular peril. However, it is not necessary to obtain results from every model, or even several models, to have an informed view of the catastrophe risk or the uncertainty surrounding a given model.

47. In some cases, there are no models available for specific catastrophe risk in certain regions which will be material to the company. The actuary may wish to identify these cases and understand the company's approach to modelling and managing these risks and the associated uncertainties.

G.2 An approach to documenting uncertainty

48. In this section, some possible practical approaches for assessing catastrophe model uncertainty are presented. These approaches do not represent an exhaustive, all-inclusive methodology.

49. Although internal and external specialists are best placed to provide advice on these, any assumptions underlying these approaches are owned by the Board.

50. Without the ability to quantify every parameter within the hazard and damage modules within the internal workings of the catastrophe model, it is not possible to obtain an all-inclusive, mathematically-derived confidence interval around an OEP curve; instead, a way to consider a practical approach for assessing model uncertainty is suggested. Quantification of uncertainty in this approach is largely based on expert judgment. Occasionally, it might be possible to find useful scientific studies and publications. The impact of various exposure data uncertainties can be assessed with sensitivity studies. In some instances, an alternative catastrophe model or historical

experience can be used to quantify the impact of certain secondary perils (such as fire following earthquake, or storm surge following cyclone).

51. Different uncertainty sources may have different relevance for small or large loss events. For example, an uncertainty loading for capturing demand surge will be larger for large loss events and it might be nil for small losses. It is therefore critical to determine which point on the OEP curve is to be assessed. The overall approach remains the same, but the potential adjustments will vary accordingly.

52. One approach considers each aspect of the modelling. The steps are:

(a) Create a list of uncertainty items that should be considered. This can initially include a large number of items which will be reduced over the process. It can be useful to sort or divide the list into 'model input' or 'data' items and 'model scope' items. For example, 'model input' items may include underinsurance or construction information; 'model scope' items could include things like non-modelled perils or demand surge.

(b) Assess each item in the raw list in regards to their potential materiality and the ability to quantify a possible adjustment. If practical, this should be done consulting various experts. This step will help identify the material items.

(c) Claims experience, especially for major events, can help highlight key items of uncertainty relevant for the portfolio. Analysis of claims and implementation of lessons learnt will improve management and understanding of uncertainty over time.

(d) Items on the reduced list then need to be assessed to determine the best adjustment method and a suitable value or range of values. This should be done consulting experts and various other sources of information. For example, there could be a simple post-modelling PML loading to allow for demand surge, or some total sum insured increase prior to modelling to account for underinsurance. As some data adjustments need to occur before modelling, the uncertainty discussions need to be addressed early on in the process.

53. Many of the uncertainty adjustments will be subjective.

54. Annexure B includes a sample list and commentary to help illustrate this approach.

55. Other methods of illustrating uncertainty have already been highlighted in paragraph 30. These and others include:

(a) comparison of different vendor models;

(b) sensitivity analyses;

(c) reference to other independent sources, such as scientific research; and

(d) comparison to historical events – how well did the model predict the actual losses?

Scenario testing can also assist in identifying and prioritising sources of uncertainty in model results. One approach to scenario testing is considered in the next section.

H. Realistic Disaster Scenarios (RDS)

56. RDS can provide a company with an alternative practical method of stress testing in a way that is more easily understood by Boards and others within a company.

57. RDS are one way to quantify catastrophic loss potential and manage catastrophic exposure. They have been used in other markets for many years (Lloyds introduced pre-defined event scenarios for managing agents in 1995).

58. A Realistic Disaster Scenario can be based on an actual past event, or an event similar to an actual past event, or a completely theoretical event based on potential knowledge of the hazard (for example, any event from a catastrophe model event set, or a potential event not within the event set). The value from an RDS exercise can be the thought process around what can happen, and not depending on a model to quantify this. A thorough RDS exercise is pragmatic and judgmental and may lead to changes in exposure (that is, the insurer/reinsurer actively changing their risk profile, or wordings.)

59. A specific RDS event typically has the following details:

(a) a definition of the physical event, with a map showing the footprint or storm-track;

(b) the assumed industry insured loss (this could be split by line of business (for example, property–domestic, commercial industrial) or include other classes of business if material (for example, marine));

(c) an estimated return period of the event, defined either in terms of industry loss or in terms of the physical characteristics of the event; and

(d) average loss defined as a proportion of exposure with differing ratios by class of business and by geographical location (postcode, CRESTA or otherwise).

Other details could be provided (for example, where applicable, a catalogue of major infrastructure (for example, ports) that may be affected by the event).

60. The events should be selected to represent material catastrophic risk to the insured. For example, in Australia, each of bushfire, flood, storm and hail perils should be

considered, as well as earthquake and cyclone. RDS events do not need to be limited to these perils and could consider other relevant perils (for example, tsunami) if material.

61. RDS scenarios could also consider multiple events within a short timeframe (for example, two earthquakes within 30 days within a similar geographic area or multiple storms in a short period).

62. APRA's horizontal requirement within the prescribed capital for the insurance concentration risk is intended to address the risk of multiple events within a year. Some vendor catastrophe models use a Poisson distribution for event frequency. A Poisson distribution assumes that events have a small probability, are independent and proportional to time. For more frequent events that can occur multiple times in year, this may well not be the case. For example, if the conditions are right for bushfires (for example, a hot and dry summer driven by El Nino), this may well mean that several happen in one year. This can be tested using past data, and could be used to form the basis of an RDS.

63. The event scenarios should be regularly reviewed and updated to ensure they represent material catastrophe risks.

64. RDS scenarios can be stress tested in that they contain damage assumptions which can be varied in realistic ranges. This is a practical deterministic way to consider secondary uncertainty.

65. The RDS approach has the following advantages:

(a) less complex – easily understood by non-technical management, Board members and other interested parties and does not require detailed explanations from engineers and scientists of the parameters making up the model;

(b) allows the introduction of thought and judgment and synthesises these into the risk assessment;

(c) good practice – multi-model does not simply mean running multiple stochastic catastrophe models, but alternative approaches;

(d) the output can provide significant insight into the effectiveness of a company's catastrophe risk strategy without unnecessary management time investment;

(e) it delivers a common sense approach to testing reinsurance arrangements and developing an expectation of the potential benefits of protections being considered or in place;

(f) it gives a quick answer;

(g) the assumptions are explicit and able to be altered at an event level (that is, damage ratios);

(h) the resultant loss is based on a realistic actual event, not a reading of an OEP curve at a particular return period (which is contributed to in a probabilistic manner by many events); and

(i) helps a company assess an event from an operational as well as other perspectives such as reputational and financial.

66. However, the RDS approach has the following disadvantages:

(a) the RDS scenarios chosen are a subjective method of quantification and they may miss the company's key risks and give a false view of a company's exposure to a risk; and

(b) a slightly different RDS may show a very different picture (however, this disadvantage may be mitigated through careful selection of scenarios and sensitivity testing of the outputs).

67. There are a range of approaches to selecting the events. One method that would generate specific events at market return periods (not company return periods) is described in Gardner (2012) (reference (i) in the bibliography in Annexure A).

68. Alternative derivations of RDS events are:

(a) pre-prepared representative events (for example, Lloyds and some reinsurance brokers);

(b) carefully selected from stochastic models;

(c) characteristic (floating) events (for example, a $13.5bn industry loss from a Sydney earthquake, using geographic information systems software to float the footprint);

(d) rerun of past events; and

(e) past events with a geographic shift.

69. Elements of more detail that could be derived from RDS events are shown below. Note that these factors may be qualitative and be enhanced by a team discussion with appropriate experts:

(a) claims:

- estimation of numbers of claims (and the resultant impact on the claims handling department);
- potential claims handling issues (that is, delays in settlement);
- demand surge post-event (often simplified in catastrophe model runs); and
- consideration of accumulations, due to anti-selection (desired or otherwise);

(b) estimation of timing of recoveries considering industry impact:

- reinsurer insolvency potential, consideration of the mix of reinsurers, and the potential domino impacts. The thoughts, judgment and process around the diversity of the panel could be pertinent here;
- diversity of panel, potential systemic issues; and
- business interruption of large commercial risks (for example, a disaster in a non-local region that represents a core supplier could lead to business interruption losses further down the value chain); and

(c) effect on net company capital and statutory solvency position:

- economic capital impacts allowing for cash flow analysis; and
- statutory capital impacts, including ways to improve solvency post-event.

I. Other matters

I.1 Considerations outside the model

70. If the actuary is asked to provide an opinion on the calculation of reinsurance recoverables in relation to any component of the Insurance Concentration Risk Charge, unless the natural perils component is immaterial, it is essential for the reinsurance contract wording to be seen. The following key points, not an exhaustive list, highlight items beyond the model that may be of relevance:

(a) Are events with secondary perils impacting the PML possible (for example, the 1974 Cyclone Wanda which caused cyclonic wind damage, as well as significant flood losses)?

In addition, consideration may be given to the impact of climate cycles, such as El Nino Southern Oscillation (ENSO). Many models do not allow for the differing risk characteristics of a particular year, which can be heavily impacted by ENSO. For example:[4]

- on average, there are fewer tropical cyclones in the Australian region during El Niño years; and
- as a result of decreased rainfall and increased maximum temperatures, the frequency of high fire danger ratings and risk of a significant fire danger season in southeast Australia are significantly higher following an El Niño year.

(b) Does the reinsurance contract apply equally to all perils at all levels? Are there any restrictions on cover or growth in regions? Stipulations could limit exposure growth above the 26th parallel for instance.

(c) Are there any per risk or per location limits in the reinsurance contract that could materially impact the horizontal cover?

(d) Does the PML allow for the possibility of aggregation of flood and cyclonic wind damage under the hours clause (for example, often cyclones cause later flooding and could be a single proximate cause under the hours clause). Consideration should be given to the flood and cyclone model output – are they independent or do they overlap or are they connected at an event level? It is likely that correlation is not even along the OEP curve (that is, the big cyclones cause big floods).

(e) Does the Natural Perils Vertical Requirement allow for sufficient growth and planned portfolio changes (for example, a strategic move to write more risks in a high catastrophe risk zone)? The detail of the rolling forward method of exposure would be relevant here.

(f) Has the aggregate risk been based purely on model output, and does this cover all perils? If based on experience, has an allowance been made for perils where there were low or minimal losses over the experience time horizon? If based on exposure, does it allow sufficiently for multiple events in a year (for example, not just a Poisson frequency assumption)?

(g) Does the Horizontal Requirement calculation consider a planned change in mix (for example, lines of business or geographical locations) and could this have a material impact?

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[4] Source: BOM.

I.2 What is not modelled?

71. One key question when considering catastrophe model output is whether all relevant catastrophe perils have been represented in the results. In some cases, there may not be a model available, but the peril is known to exist (for example, Thailand flood).

72. The hours clause in reinsurance coverage is a key factor. It can have a large practical implication on the stated PML, as two events could occur in quick succession (for example, the New Zealand earthquakes).

73. For other risks – including motor (large hail risk), aviation and some marine risks (large cyclone risk) – there are additional challenges related to the issues of time-variable value, location, as well as specific risk themes relevant to those types of risks and their vulnerability. In many of these lines of business, there are specific issues that need consideration. In many cases, workarounds are used within the model. For example, modelling pleasure craft risk as mobile homes. For these lines of business dependent on the materiality, simpler approximations may be appropriate, such as using:

    - "percentage captured" based on premium income, and load catastrophe data accordingly, per peril; or
    - more sophisticated techniques, depending on the level of confidence in the existing data and its level of overall completeness.

    Any such approximations have limitations which will impact on any modelling results.

74. It is unlikely to be possible to develop a single methodology for capturing non-modelled perils. If this is a potentially material exposure, then understanding the method and parameters that were used is important.

I.3 Further considerations

75. In addition to each of the issues outlined above, there are a number of further complications in regards to the use of catastrophe models that should be taken into consideration.

    (a) Paragraphs 21 to 26 above discuss a number of general processes that should be followed when collating data for use in catastrophe models. In addition, it is prudent to occasionally interrogate the data prior to the modelling process in terms of spot checks on the data as it appears within the catastrophe model. This is particularly the case in relation to the treatment of complex policy and reinsurance terms on large commercial risks.

    (b) Additional simulation error may appear when catastrophe modelling results are used within dynamic financial analysis software to simulate potential losses in the optimisation of reinsurance and capital. Since the extreme events of focus in catastrophe modelling recur with low probability (in relative terms), the variability around estimates due purely to simulation error needs to be assessed and managed when using such results.

(c) When comparing results from modelling undertaken at different times, it is prudent to compare differences in the figures and identify the cause of changes. In addition, it is also beneficial to compare the results between different classes of business and by different geographical regions in relative terms. That is, a comparison may be made of the PML by return period as a proportion of total modelled sum insured for each grouping, as a reasonableness check to ensure the results make sense in relative terms from one grouping to another.

(d) It is beneficial to identify peak drivers of the PMLs in terms of classes of business, individual perils and geographical region. The sensitivity of the 'all perils' whole of portfolio PML to results from key peak groupings should be considered.

(e) Although the return period of interest for the Vertical Requirement and for reviewing reinsurance is often 200 years, it is prudent to review the model results above this return period. For example, does the PML "flatten out" after 200 years or does it rise sharply beyond that point? The results of such review may indicate a need for further analysis and/or review of reinsurance and capital adequacy.

(f) This Technical Paper focuses mostly on the modelling of natural perils, but consideration should also be given to the frequency and potential severity of man-made disasters (such as large commercial fires, accidental explosions and contaminations, and terrorism-related events).

J. Conclusions

76. As this Technical Paper highlights, catastrophe modelling is not an exact science and requires actuaries to use best judgment when preparing data for modelling, undertaking analysis using models and interpreting model outputs.

77. The methods of best practice outlined in this Technical Paper are not exhaustive, but should provide actuaries who need to use or comment on the output of catastrophe models with guidance in areas for particular focus.

Annexure A: Bibliography

The list below was compiled during the preparation of this Technical Paper and was applicable at the time of issuance. Standards will change over time and the actuary needs to ensure they are viewing the latest version and that the standards referred to are still applicable.

(a) APRA "Prudential Standard GPS 116 Capital Adequacy: Insurance Concentration Risk Charge", January 2013

http://www.apra.gov.au/GI/PrudentialFramework/Documents/GPS-116-Capital-Adequacy-Insurance-Concentration-Risk-Charge-January-2013.pdf

(b) APRA "Prudential Practice Guide GPG 116 – Insurance Concentration Risk", March 2013

http://www.apra.gov.au/GI/PrudentialFramework/Documents/GPG-116-Insurance-Concentration-Risk-March-2013.pdf

(c) Laughlin, I "Challenges for Board and Management: Adequate Catastrophe Cover and Meeting Capital Requirements" Speech, Aon Benfield Hazards Conference, Gold Coast, 24 September 2013

http://www.apra.gov.au/Speeches/Documents/Ian-Laughlin-AON-Benfield-Hazards-Conference-24-September-2013-published.pdf

(d) APRA "Letter to industry: Catastrophe Risk Governance", 19 December 2013

http://www.apra.gov.au/GI/PrudentialFramework/Pages/Letter-to-GIs-on-catastrophe-risk-governance.aspx

(e) Actuarial Standards Board "Using Models Outside the Actuary's Area of Expertise (Property and Casualty)", May 2011

http://www.actuarialstandardsboard.org/pdf/asops/asop038_155.pdf

(f) Waite, JGT, Gardner, W, Lin, A "Insurance Concentration Risk Charge Natural Perils" Actuaries Institute General Insurance Seminar, 12–13 November 2012

http://www.actuaries.asn.au/library/events/gis/2012/gis2012paperwaitegardnerlim.pdf

(g) Boss, C *et al* "Industry Good Practice for Catastrophe Modelling" ABI, December 2011

https://www.abi.org.uk/~/media/Files/Documents/Publications/Public/Migrated/Solvency%20II/Industry%20good%20practice%20for%20catastrophe%20modelling.ashx

(h) Simic, M *et al* "Non-Modelled Risks – A guide to more complete catastrophe risk assessment for (re)insurers" ABI, April 2014

https://www.abi.org.uk/~/media/Files/Documents/Publications/Public/2014/prudential%20regulation/Nonmodelled%20risks%20a%20guide%20to%20more%20complete%20catastrophe%20risk%20assessment%20for%20reinsurers.ashx

(i) Gardner, W "Practical Stress Testing Using Realistic Disaster Scenarios" presentation (and audio) from the Actuaries Institute General Insurance Seminar 2012

http://www.actuaries.asn.au/Library/Events/GIS/2012/4b_Gardner.pdf (presentation)

http://www.actuaries.asn.au/Library/Events/GIS/2012/01%20Concurrent%204%20Room%20B.mp3 (audio)

(j) Santoso et al "Recent Developments in Predicting El Nino and the Implications for Insurers" Actuaries Institute General Insurance Seminar, 17-18 November 2014

http://www.actuaries.asn.au/Library/Events/GIS/2014/7CAndrewsEtAlClimateChangePres.pdf

Annexure B: Simple sample uncertainty table

The table below is a fictitious example of how uncertainty may be allowed for in deriving a 1 in 200 year PML. This is a simplification and does not necessarily cover all factors that need to be considered (for example, claims handling expenses). The actual adjustments applied will vary depending on an insurer's exposure and circumstances, the models used and various other factors. The adjustments applied may also be different for other severity levels, especially at the lower end of the curve.

It is important to note that the adjustments applied need to be owned by the Board.

The key benefit of this approach is the thought process of considering the different areas of uncertainty and how these may impact the insurer and documenting the outcome.

When combining all individual adjustments, possible correlations should be considered as all sources of uncertainty are unlikely to apply to the fullest possible extent for all events. Practitioners should be wary of introducing unintended conservatism if adopting similar approaches.

In the example below, a number of adjustments are made:

(a) the sums insured have been increased to allow for suspected underinsurance; and

(b) the modelled loss has been adjusted to allow for:

- (i) a large proportion of risks with an unknown construction type;
- (ii) demand surge; and
- (iii) flood following cyclone.

In the example below, a total adjustment of 27.5% is made to the modelled loss.

Uncertainty source	Category	Material?	Comment	Proposed adjustment method	Adjustment	
					Data	Modelled loss
Policy Sums Insured	Input	Yes	Suspected underinsurance	Increase building TSI before model run	12%	n/a
Buildings not constructed as stated	Input	Yes	25% of policies have 'unknown' construction	Conduct sensitivity study, adjust modelled loss	n/a	7%
Clean up costs (covered by policies)	Scope	No	Considered immaterial, as government often steps in to clean up after big disaster	n/a	n/a	n/a
Demand surge	Scope	Yes	Quantity based on XYZ study, signed-off by Board	Adjust modelled loss	n/a	15%
Landslides	Scope	No	No significant risk for portfolio		n/a	n/a
Liquefaction	Scope	No	No significant risk for portfolio		n/a	n/a
Looting	Scope	No	No significant risk for portfolio		n/a	n/a
Paying for claims not covered due to reputation risk	Scope	No	No significant risk for portfolio		n/a	n/a
Flood following cyclone	Scope	No		Adjust modelled loss based on relative impact of this sub-peril as per alternative model XYZ	n/a	0.50%
Loss adjusting costs	Scope	Yes	Conducted historical claims analysis and identified range of 1%-5%	Adjust modelled loss	n/a	5%
Tsunami	Scope	No	Underwriting strategy is to avoid coastal areas		n/a	n/a
Meteorite impact	Scope	Yes	Can be material, but believed to be extreme low probability; no allowance applied		n/a	n/a
				Total adjustment	**12.0%**	**27.5%**

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