**Statistical StandarDS**

**S-1 Modeled Results and Goodness-of-Fit**

1. ***The use of historical data in developing the hurricane model shall be supported by rigorous methods published in current scientific and technical literature.***
2. ***Modeled and historical results shall reflect statistical agreement using current scientific and statistical methods for the academic disciplines appropriate for the various hurricane model components or characteristics.***

 Purpose: Many aspects of hurricane model development and implementation involve fitting a probability distribution to historical data for use in generating stochastic storms. Such fitted models must be checked to ensure that the distributions are reasonable. The chi-square goodness-of-fit test may not be sufficiently rigorous for demonstrating the reasonableness of models of historical data.

 Relevant Forms: G-3, Statistical Standards Expert Certification

 M-1, Annual Occurrence Rates

 S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year

 S-2A, Examples of Hurricane Loss Exceedance Estimates (2012 FHCF Exposure Data)

 S-2B, Examples of Hurricane Loss Exceedance Estimates (2017 FHCF Exposure Data)

 S-3, Distributions of Stochastic Hurricane Parameters

 S-4, Validation Comparisons

 S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled

**Disclosures**

1. Provide a completed Form S-3, Distributions of Stochastic Hurricane Parameters. Identify the form of the probability distributions used for each function or variable, if applicable. Identify statistical techniques used for estimation and the specific goodness-of-fit tests applied along with the corresponding *p*-values. Describe whether the fitted distributions provide a reasonable agreement with the historical data. Provide a link to the location of the form [insert hyperlink here].

1. Describe the nature and results of the tests performed to validate the windspeeds generated.
2. Provide the dates of hurricane loss of the insurance claims data used for validation and verification of the hurricane model.
3. Provide an assessment of uncertainty in hurricane probable maximum loss levels and hurricane loss costs for hurricane output ranges using confidence intervals or other scientific characterizations of uncertainty.
4. Justify any differences between the historical and modeled results using current scientific and statistical methods in the appropriate disciplines.
5. Provide graphical comparisons of modeled and historical data and goodness-of-fit tests. Examples to include are hurricane frequencies, tracks, intensities, and physical damage.
6. Provide a completed Form S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year. Provide a link to the location of the form [insert hyperlink here].
7. Provide a completed Form S-2A, Examples of Hurricane Loss Exceedance Estimates (2012 FHCF Exposure Data). Provide a link to the location of the form [insert hyperlink here].
8. Provide a completed Form S-2B, Examples of Hurricane Loss Exceedance Estimates (2017 FHCF Exposure Data). Provide a link to the location of the form [insert hyperlink here].

 **Audit**

1. Forms S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year, S-2A, Examples of Hurricane Loss Exceedance Estimates (2012 FHCF Exposure Data), S-2B, Examples of Hurricane Loss Exceedance Estimates (2017 FHCF Exposure Data), and S-3, Distributions of Stochastic Hurricane Parameters, will be reviewed. Justification for the distributions selected, including for example, citations to published literature or analyses of specific historical data, will be reviewed.
2. The modeling organization’s characterization of uncertainty for windspeed, damage estimates, annual hurricane loss, hurricane probable maximum loss levels, and hurricane loss costs will be reviewed.

**S-2 Sensitivity Analysis for Hurricane Model Output**

***The modeling organization shall have assessed the sensitivity of temporal and spatial outputs with respect to the simultaneous variation of input variables using current scientific and statistical methods in the appropriate disciplines and shall have taken appropriate action.***

Purpose: Sensitivity analysis involves the quantification of the magnitude of the output (e.g., windspeed, hurricane loss cost) by identifying and quantifying the input variables that impact the magnitude of the output when the input variables are varied simultaneously. The simultaneous variation of all input variables enables the modeling organization to detect interactions and to properly account for correlations among the input variables. Neither of these goals can be achieved by using one-factor-at-a-time variation; hence, such an approach to sensitivity analysis does not lead to an understanding of how the input variables jointly affect the hurricane model output. The simultaneous variation of the input variables is an important diagnostic tool and provides needed assurance of the robustness and viability of the hurricane model output.

Relevant Forms: G-3, Statistical Standards Expert Certification

 S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis

**Disclosures**

1. Identify the most sensitive aspect of the hurricane model and the basis for making this determination.
2. Identify other input variables that impact the magnitude of the output when the input variables are varied simultaneously. Describe the degree to which these sensitivities affect output results and illustrate with an example.
3. Describe how other aspects of the hurricane model may have a significant impact on the sensitivities in output results and the basis for making this determination.
4. Describe and justify action or inaction as a result of the sensitivity analyses performed.
5. Provide a completed Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis. (Requirement for hurricane models submitted by modeling organizations which have not previously provided the Commission with this analysis. For hurricane models previously found acceptable, the Commission will determine, at the meeting to review modeling organization submissions, if an existing modeling organization will be required to provide Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, prior to the Professional Team on-site review). If applicable, provide a link to the location of the form [insert hyperlink here].

**Audit**

1. The modeling organization’s sensitivity analysis will be reviewed in detail. Statistical techniques used to perform sensitivity analysis will be reviewed. The results of the sensitivity analysis displayed in graphical format (e.g., color-coded contour plots with temporal animation) will be reviewed.
2. Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, will be reviewed, if applicable.

**S-3 Uncertainty Analysis for Hurricane Model Output**

***The modeling organization shall have performed an uncertainty analysis on the temporal and spatial outputs of the hurricane model using current scientific and statistical methods in the appropriate disciplines and shall have taken appropriate action. The analysis shall identify and quantify the extent that input variables impact the uncertainty in hurricane model output as the input variables are simultaneously varied.***

Purpose: Uncertainty analysis involves the quantification of the output (e.g., windspeed, hurricane loss cost) through a variance calculation or by use of confidence intervals. While these statistics provide useful information, uncertainty analysis goes beyond a mere quantification of these statistics by quantifying the expected percentage reduction in the variance of the output that is attributable to each of the input variables. Identification of those variables that contribute to the uncertainty is the first step that can lead to a reduction in the uncertainty in the output. It is important to note that the key input variables identified in an uncertainty analysis are not necessarily the same as those in a sensitivity analysis nor are they necessarily in the same relative order. As with sensitivity analysis, uncertainty analysis is an important diagnostic tool and provides needed assurance of the robustness and viability of the hurricane model output.

Relevant Forms: G-3, Statistical Standards Expert Certification

 S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis

**Disclosures**

1. Identify the major contributors to the uncertainty in hurricane model outputs and the basis for making this determination. Provide a full discussion of the degree to which these uncertainties affect output results and illustrate with an example.
2. Describe how other aspects of the hurricane model may have a significant impact on the uncertainties in output results and the basis for making this determination.
3. Describe and justify action or inaction as a result of the uncertainty analyses performed.
4. Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, if disclosed under Standard S-2, Sensitivity Analysis for Hurricane Model Output, will be used in the verification of Standard S-3, Uncertainty Analysis for Hurricane Model Output.

**Audit**

1. The modeling organization’s uncertainty analysis will be reviewed in detail. Statistical techniques used to perform uncertainty analysis will be reviewed. The results of the uncertainty analysis displayed in graphical format (e.g., color-coded contour plots with temporal animation) will be reviewed.
2. Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, will be reviewed, if applicable.

**S-4 County Level Aggregation**

***At the county level of aggregation, the contribution to the error in hurricane loss cost estimates attributable to the sampling process shall be negligible.***

Purpose: The intent of this standard is to ensure that sufficient runs of the simulation have been made or a suitable sampling design invoked so that the contribution to the error of the hurricane loss cost estimates due to its probabilistic nature is negligible. To be negligible, the standard error of each output range must be less than 2.5% of the hurricane loss cost estimate.

Relevant Form: G-3, Statistical Standards Expert Certification

**Disclosure**

1. Describe the sampling plan used to obtain the average annual hurricane loss costs and output ranges. For a direct Monte Carlo simulation, indicate steps taken to determine sample size. For an importance sampling design or other sampling scheme, describe the underpinnings of the design and how it achieves the required performance.

**Audit**

1. A graph assessing the accuracy associated with a low impact area such as Nassau County will be reviewed. If the contribution error in an area such as Nassau County is small, the expectation is that the error in other areas would be small as well. The contribution of simulation uncertainty via confidence intervals will be reviewed.

**S-5 Replication of Known Hurricane Losses**

***The hurricane model shall estimate incurred hurricane losses in an unbiased manner on a sufficient body of past hurricane events from more than one company, including the most current data available to the modeling organization. This standard applies separately to personal residential and, to the extent data are available, to commercial residential. Personal residential hurricane loss experience may be used to replicate structure-only and contents-only hurricane losses. The replications shall be produced on an objective body of hurricane loss data by county or an appropriate level of geographic detail and shall include hurricane loss data from both 2004 and 2005.***

Purpose: The hurricane model is to reasonably reproduce known hurricane losses for past events.

 Relevant Forms: G-3, Statistical Standards Expert Certification

 S-4, Validation Comparisons

**Disclosures**

1. Describe the nature and results of the analyses performed to validate the hurricane loss projections generated for personal and commercial residential hurricane losses separately. Include analyses for the 2004 and 2005 hurricane seasons.
2. Provide a completed Form S-4, Validation Comparisons. Provide a link to the location of the form [insert hyperlink here].

**Audit**

1. The following information for each insurer and hurricane will be reviewed:
2. The validity of the hurricane model assessed by comparing projected hurricane losses produced by the hurricane model to actual observed hurricane losses incurred by insurers at both the state and county level,
3. The version of the hurricane model used to calculate modeled hurricane losses for each hurricane provided,
4. A general description of the data and its source,
5. A disclosure of any material mismatch of exposure and hurricane loss data problems, or other material consideration,
6. The date of the exposures used for modeling and the date of the hurricane,
7. An explanation of differences in the actual and modeled hurricane parameters,
8. A listing of the departures, if any, in the windfield applied to a particular hurricane for the purpose of validation and the windfield used in the hurricane model under consideration,
9. The type of coverage applied in each hurricane to address:
	* 1. Personal versus commercial
		2. Residential structures
		3. Manufactured homes
		4. Commercial residential
		5. Condominiums
		6. Structures only
		7. Contents only
		8. Time element,
10. The treatment of demand surge or loss adjustment expenses in the actual hurricane losses or the modeled hurricane losses, and
11. The treatment of flood losses, including storm surge losses, in the actual hurricane losses or the modeled hurricane losses.
	1. The following documentation will be reviewed:
12. Publicly available documentation referenced in the submission in hard copy or electronic form,
13. The data sources excluded from validation and the reasons for excluding the data from review by the Commission (if any),
14. An analysis that identifies and explains anomalies observed in the validation data, and
15. User input data for each insurer and hurricane detailing specific assumptions made with regard to exposed property.
16. The confidence intervals used to gauge the comparison between historical and modeled hurricane losses will be reviewed.
17. Form S-4, Validation Comparisons, will be reviewed.
18. The results of one hurricane event for more than one insurance company and the results from one insurance company for more than one hurricane event will be reviewed to the extent data are available.

**S-6 Comparison of Projected Hurricane Loss Costs**

***The difference, due to uncertainty, between historical and modeled annual average statewide hurricane loss costs shall be reasonable, given the body of data, by established statistical expectations and norms.***

Purpose: The differences between historical and modeled annual average statewide hurricane loss costs are to be plausible from a statistical perspective.

Relevant Forms: G-3, Statistical Standards Expert Certification

 S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled

**Disclosures**

1. Describe the nature and results of the tests performed to validate the expected hurricane loss projections generated. If a set of simulated hurricanes or simulation trials was used to determine these hurricane loss projections, specify the convergence tests that were used and the results. Specify the number of hurricanes or trials that were used.
2. Identify and justify differences, if any, in how the hurricane model produces hurricane loss costs for specific historical events versus hurricane loss costs for events in the stochastic hurricane set.
3. Provide a completed Form S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled. Provide a link to the location of the form [insert hyperlink here].

**Audit**

1. Form S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled, will be reviewed for consistency with Standard G-1, Scope of the Hurricane Model and Its Implementation, Disclosure 5.
2. Justification for the following will be reviewed:
3. Meteorological parameters,
4. The effect of by-passing hurricanes,
5. The effect of actual hurricanes that had two landfalls impacting Florida,
6. The departures, if any, from the windfield, vulnerability functions, or insurance functions applied to the actual hurricanes for the purposes of this test and those used in the hurricane model under consideration, and
7. Exposure assumptions.

**Form S-1: Probability and Frequency of Florida Landfalling**

**Hurricanes per Year**

Purpose: This form illustrates the differences between historical and modeled frequencies of landfalling Florida hurricanes per year. The historical events are derived from the Base Hurricane Storm Set with possible adjustments by the modeling organization as specified in Standard M-1, Base Hurricane Storm Set.

Complete the table below showing the probability and modeled frequency of landfalling Florida hurricanes per year. Modeled probability shall be rounded to four decimal places in the printed form. The historical probabilities and frequencies below have been derived from the Base Hurricane Storm Set for the 117 year period 1900-2016 (as given in Form A-2B, Base Hurricane Storm Set Statewide Hurricane Losses (2017 FHCF Exposure Data)). Exclusion of hurricanes that caused zero modeled Florida damage or additional Florida landfalls included in the modeling organization Base Hurricane Storm Set as identified in their response to Standard M-1, Base Hurricane Storm Set, should be used to adjust the historical probabilities and frequencies provided.

If the data are partitioned or modified, provide the historical probabilities and frequencies for the applicable partition (and its complement) or modification as well as the modeled probabilities and frequencies in additional copies of Form S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year.

Include Form S-1, Probability and Frequency of Florida Landfalling Hurricanes per Year, in a submission appendix.

|  |
| --- |
| **Hurricane Model Results** |
| **Probability and Frequency of Florida Landfalling Hurricanes per Year** |
|  |  |  |  |  |
| **Number****Of Hurricanes****Per Year** | **Historical****Probability** | **Modeled****Probability** | **Historical****Frequency** | **Modeled****Frequency** |
| 0 | 0.6068 |  | 71 |  |
| 1 | 0.2393 |  | 28 |  |
| 2 | 0.1282 |  | 15 |  |
| 3 | 0.0256 |  | 3 |  |
| 4 | 0.0000 |  | 0 |  |
| 5 | 0.0000 |  | 0 |  |
| 6 | 0.0000 |  | 0 |  |
| 7 | 0.0000 |  | 0 |  |
| 8 | 0.0000 |  | 0 |  |
| 9 | 0.0000 |  | 0 |  |
| 10 or more | 0.0000 |  | 0 |  |

**Form S-2A: Examples of Hurricane Loss Exceedance Estimates**

**(2012 FHCF Exposure Data)**

Purpose: This form provides the modeling organization’s hurricane loss exceedance estimates for a notional risk dataset (Form A-1, Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code) and for the 2012 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data.

* 1. Provide estimates of the annual aggregate combined personal and commercial insured hurricane losses for various probability levels using the notional risk dataset specified in Form A-1, Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code, and using the 2012 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data provided in the file named *“hlpm2012c.exe.”* Provide the total average annual hurricane loss for the hurricane loss exceedance distribution. If the modeling methodology does not allow the hurricane model to produce a viable answer for certain return periods, state so and why.

B. Include Form S-2A, Examples of Hurricane Loss Exceedance Estimates, in a submission appendix.

**Part A**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Return****Period (years)** | **Annual****Probability of Exceedance** | **Estimated** **Hurricane Loss****Notional Risk Dataset** |  | **Estimated Personal and Commercial Residential** **Hurricane Loss** **2012 FHCF Dataset** |
| Top Event |  NA  |   |  |   |
| 10,000 | 0.01% |   |  |   |
| 5,000 | 0.02% |   |  |   |
| 2,000 | 0.05% |   |  |   |
| 1,000 | 0.10% |   |  |   |
| 500 | 0.20% |   |  |   |
| 250 | 0.40% |   |  |   |
| 100 | 1.00% |   |  |   |
| 50 | 2.00% |   |  |   |
| 20 | 5.00% |   |  |   |
| 10 | 10.00% |   |  |   |
| 5 | 20.00% |   |  |   |

**Part B**

|  |  |  |  |
| --- | --- | --- | --- |
| Mean (Total Average Annual Hurricane Loss) |   |  |  |
| Median |   |  |   |
| Standard Deviation |   |  |   |
| Interquartile Range |   |  |   |
| Sample Size |   |  |   |

**Form S-2B: Examples of Hurricane Loss Exceedance Estimates**

**(2017 FHCF Exposure Data)**

Purpose: This form provides the modeling organization’s hurricane loss exceedance estimates for a notional risk dataset (Form A-1, Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code) and for the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data.

* 1. Provide estimates of the annual aggregate combined personal and commercial insured hurricane losses for various probability levels using the notional risk dataset specified in Form A-1, Zero Deductible Personal Residential Hurricane Loss Costs by ZIP Code, and using the 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data provided in the file named *“hlpm2017c.exe.”* Provide the total average annual hurricane loss for the hurricane loss exceedance distribution. If the modeling methodology does not allow the hurricane model to produce a viable answer for certain return periods, state so and why.

B. Include Form S-2B, Examples of Hurricane Loss Exceedance Estimates, in a submission appendix.

**Part A**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Return****Period (years)** | **Annual****Probability of Exceedance** | **Estimated** **Hurricane Loss****Notional Risk Dataset** |  | **Estimated Personal and Commercial Residential** **Hurricane Loss** **2017 FHCF Dataset** |
| Top Event |  NA  |   |  |   |
| 10,000 | 0.01% |   |  |   |
| 5,000 | 0.02% |   |  |   |
| 2,000 | 0.05% |   |  |   |
| 1,000 | 0.10% |   |  |   |
| 500 | 0.20% |   |  |   |
| 250 | 0.40% |   |  |   |
| 100 | 1.00% |   |  |   |
| 50 | 2.00% |   |  |   |
| 20 | 5.00% |   |  |   |
| 10 | 10.00% |   |  |   |
| 5 | 20.00% |   |  |   |

**Part B**

|  |  |  |  |
| --- | --- | --- | --- |
| Mean (Total Average Annual Hurricane Loss) |   |  |  |
| Median |   |  |   |
| Standard Deviation |   |  |   |
| Interquartile Range |   |  |   |
| Sample Size |   |  |   |

**Form S-3: Distributions of Stochastic Hurricane Parameters**

Purpose: This form identifies the probability distributions used in the stochastic hurricane model and provides their justification.

* + - 1. Provide the probability distribution functional form used for each stochastic hurricane parameter in the hurricane model. Provide a summary of the justification for each functional form selected for each general classification.
			2. Include Form S-3, Distributions of Stochastic Hurricane Parameters, in a submission appendix.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Stochastic Hurricane Parameter****(Function or Variable)** | **Functional Form of Distribution** | **Data Source** | **Year Range Used** | **Justification for Functional Form** |
|  |  |  |  |  |
|  |  |  |  |  |
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**Form S-4: Validation Comparisons**

Purpose: This form illustrates the differences between actual and modeled hurricane loss for a variety of specified conditions.

A. Provide five validation comparisons of actual personal residential exposures and hurricane loss to modeled exposures and hurricane loss. Provide these comparisons by line of insurance, construction type, policy coverage, county or other level of similar detail in addition to total hurricane losses. Include hurricane loss as a percentage of total exposure. Total exposure represents the total amount of insured values (all coverages combined) in the area affected by the hurricane. This would include exposures for policies that did not have a hurricane loss. If this is not available, use exposures for only those policies that had a hurricane loss. Specify which was used. Also, specify the name of the hurricane event compared.

B. Provide a validation comparison of actual commercial residential exposures and hurricane loss to modeled exposures and hurricane loss. Use and provide a definition of the hurricane model’s relevant commercial residential classifications.

C. Provide scatter plot(s) of modeled versus historical hurricane losses for each of the required validation comparisons. (Plot the historical hurricane losses on the *x*-axis and the modeled hurricane losses on the *y*-axis.)

D. Include Form S-4, Validation Comparisons, in a submission appendix.

Rather than using a specific published hurricane windfield directly, the winds underlying the modeled hurricane loss cost calculations must be produced by the hurricane model being evaluated and should be the same hurricane parameters as used in completing Form A-2A, Base Hurricane Storm Set Statewide Hurricane Losses (2012 FHCF Exposure Data) and Form A-2B, Base Hurricane Storm Set Statewide Hurricane Losses (2017 FHCF Exposure Data).

***Example Formats for Personal Residential:***

Hurricane =

Exposure = Total exposure or hurricane loss only (please specify)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Company Actual** | **Modeled** |  |
| **Construction** | **Hurricane Loss / Exposure** | **Hurricane Loss / Exposure** | **Difference** |
| Wood Frame |  |  |  |
| Masonry |  |  |  |
| Other (specify) |  |  |  |
| **Total** |  |  |  |

Hurricane =

Exposure = Total exposure or hurricane loss only (please specify)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Company Actual** | **Modeled** |  |
| **Coverage** | **Hurricane Loss / Exposure** | **Hurricane Loss / Exposure** | **Difference** |
| A |  |  |  |
| B |  |  |  |
| C |  |  |  |
| D |  |  |  |
| **Total** |  |  |  |

***Example Format for Commercial Residential:***

Hurricane =

Exposure = Total exposure or hurricane loss only (please specify)

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Company Actual** | **Modeled** |  |
| **Construction** | **Hurricane Loss / Exposure** | **Hurricane Loss / Exposure** | **Difference** |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| **Total** |  |  |  |

**Form S-5: Average Annual Zero Deductible Statewide**

**Hurricane Loss Costs – Historical versus Modeled**

Purpose: This form provides an illustration of the differences in actual and modeled average annual zero deductible statewide personal and commercial residential hurricane loss costs corresponding to the 2012 and 2017 Florida Hurricane Catastrophe Fund personal and commercial residential zero deductible exposure data.

A. Provide the average annual zero deductible statewide personal and commercial residential hurricane loss costs produced using the list of hurricanes in the Base Hurricane Storm Set as defined in Standard M-1, Base Hurricane Storm Set, based on the 2012 Florida Hurricane Catastrophe Fund’s personal and commercial residential zero deductible exposure data found in the file named *“hlpm2012c.exe*.*”*

**Average Annual Zero Deductible Statewide Personal and**

**Commercial Residential Hurricane Loss Costs**

|  |  |  |
| --- | --- | --- |
| **Time Period** | **Historical Hurricanes** | **Produced by Hurricane Model** |
| Current Submission |  |  |
| Previously-Accepted Hurricane Model\* (2015 Standards) |  |  |
| Percent Change Current Submission/Previously-Accepted Hurricane Model\* |  |  |
| Second Previously-Accepted Hurricane Model\* (2013 Standards) |  |  |
| Percent Change Current Submission/Second Previously-AcceptedHurricane Model\*  |  |  |

*\*NA if no previously-accepted hurricane model.*

B. Provide a comparison with the statewide personal and commercial residential hurricane loss costs produced by the hurricane model on an average industry basis.

C. Provide the 95% confidence interval on the differences between the means of the historical and modeled personal and commercial residential hurricane loss costs.

D. Provide the average annual zero deductible statewide personal and commercial residential hurricane loss costs produced using the list of hurricanes in the Base Hurricane Storm Set as defined in Standard M-1, Base Hurricane Storm Set, based on the 2017 Florida Hurricane Catastrophe Fund’s personal and commercial residential zero deductible exposure data found in the file named *“hlpm2017c.exe*.*”*

**Average Annual Zero Deductible Statewide Personal and**

**Commercial Residential Hurricane Loss Costs**

|  |  |  |
| --- | --- | --- |
| **Time Period** | **Historical Hurricanes** | **Produced by Hurricane Model** |
| Current Submission |  |  |

E. Provide a comparison with the statewide personal and commercial residential hurricane loss costs produced by the hurricane model on an average industry basis.

F. Provide the 95% confidence interval on the differences between the means of the historical and modeled personal and commercial residential hurricane loss costs.

G. If the data are partitioned or modified, provide the average annual zero deductible statewide personal and commercial residential hurricane loss costs for the applicable partition (and its complement) or modification, as well as the modeled average annual zero deductible statewide personal and commercial residential hurricane loss costs in additional copies of Form S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled.

H. Include Form S-5, Average Annual Zero Deductible Statewide Hurricane Loss Costs – Historical versus Modeled, in a submission appendix.

**Form S-6: Hypothetical Events for Sensitivity and Uncertainty Analysis**

Purpose: This form requires the hurricane model to be run under a variety of specified parameter settings in order to perform detailed sensitivity and uncertainty analyses.

**Specifications**

The Excel file *“FormS6Input17.xlsx”* contains nine worksheets which are to be used by the modeling organization in performing sensitivity and uncertainty analyses for their hurricane model. The first eight worksheets are classified, as follows:

|  |  |
| --- | --- |
| **Sensitivity Analysis** | **Uncertainty Analysis** |
| 1. Sen Anal all Variables | 2. Unc Anal for CP3. Unc Anal for Rmax4. Unc Anal for VT5. Unc Anal for Shape Parameter6. Unc Anal for CF7. Unc Anal for FFP8. Unc Anal for Quantile |

The first worksheet (“Sen Anal all Variables”) contains three sets of 100 random combinations of the following seven hurricane model input variables for each of three categories of hurricanes (1, 3, and 5):

* CP = central pressure (in millibars)
* Rmax = radius of maximum winds (in statute miles)
* VT = translational velocity (forward speed in miles per hour)
* Hurricane model shape parameter such as the Holland B parameter
* CF = conversion factor for converting the modeled gradient winds to surface winds
* FFP = far field pressure (in millibars)
* Quantiles for possible additional input variable (use is optional)

These hurricane model input variables are based on the probability distributions given in *Figure 4*.

These hurricane model input variables may or may not exactly match those used by the modeling organization. A second input file *“FormS6Input17Quantiles.xlsx”* has been provided that contains the corresponding quantiles for the seven hurricane model input variables above, hence there is a one-to-one correspondence between these two files. Modeling organizations may use the quantiles in *“FormS6Input17Quantiles.xlsx”* in lieu of the specific values in *“FormS6Input17.xlsx.”* Note that the values of CP and Rmax, and the corresponding quantiles, have been produced with a rank correlation of 0.3 in the case of the Category 5 hurricane. No other variables or quantiles are correlated.

Disclose how quantiles were used.

If any hurricane model input variables are modified, provide the modified input files corresponding to those in the worksheet “Sen Anal all Variables.”

The values of CP and FFP in the Excel file can either be used as the basis for calculating pressure difference, which would then be used as a single hurricane model input, or both CP and FFP can be used as hurricane model inputs. Disclose whether CP and FFP were used as the basis for calculating pressure difference or as direct hurricane model inputs.

Rmax, VT, and CF (as appropriate to the hurricane model) are to be used as direct hurricane model inputs where applicable. An example of CF implementation is presented below.

***Figure 4* Probability Distributions for Hurricane Model Input Variables**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Category** |  **Distribution** | **Parameters** |
| **CP** | Cat 1 |  Triangular | a=975, b=982.5, c=990 |
|  | Cat 3 |  Triangular | a=945, b=952.5, c=960 |
|  | Cat 5 |  Triangular | a=900, b=910, c=920 |
| **Rmax** | Cat 1 |  Triangular | a=12, b=22, c=40 |
|  | Cat 3 |  Triangular | a=8, b=20, c=40 |
|  | Cat 5 |  Triangular | a=5, b=12, c=25 |
| VT | Cat 1 |  Triangular | a=10, b=15, c=20 |
|  | Cat 3 |  Triangular | a=10, b=15, c=20 |
|  | Cat 5 |  Triangular | a=10, b=15, c=20 |
| **Holland B** | Cat 1 |  Quantile provided |
|  | Cat 3 |  Quantile provided |
|  | Cat 5 |  Quantile provided |
| **CF** | Cat 1 |  Uniform | (0.8, 0.95) |
|  | Cat 3 |  Uniform | (0.8, 0.95) |
|  | Cat 5 |  Uniform | (0.8, 0.95) |
| **FFP** | Cat 1 |  Uniform | (1006, 1020) |
|  | Cat 3 |  Uniform | (1006, 1020) |
|  | Cat 5 |  Uniform | (1006, 1020) |
| **No. 7** | Cat 1 |  Quantile provided |
|  | Cat 3 |  Quantile provided |
|  | Cat 5 |  Quantile provided |

The fourth hurricane model input variable in the above list specifies quantiles (0 ≤ p ≤ 1) to be used with the modeling organization’s distribution for the shape of the wind profile parameter, for example the Holland B profile parameter (or suitable alternative). Quantiles from 0 to 1 have been provided in the Excel input file *“FormS6Input17Quantiles.xlsx”* rather than specific values since modeling organizations may use different ranges and distributions for the Holland B profile parameter.

As an illustration, if the quantile has been specified as 0.345 in the Excel input file, input the specific value of x into the hurricane model such that P(X ≤ x) = 0.345 where X is a random variable representing the modeling organization’s distribution for the Holland B profile parameter or other shape parameter used by the modeling organization.

If the last quantile input variable is used, describe how it was used and provide the specific values that correspond to the quantiles in Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis. That is, this quantile variable would be treated in the same manner as the Holland B profile parameter.

Note that the fourth and seventh input variables appear as quantiles in both *“FormS6Input17.xlsx”* and *“FormS6Input17Quantiles.xlsx.”*

The CF variable is used to implement uncertainty in the conversion of modeled gradient winds to surface winds CF as a function of the radius (r) from the center of the hurricane to a given point in the hurricane windfield. The following example is provided to illustrate how CF could be implemented based on the following three intervals:

**CASE 1:** r < Rmax

The value of the random variable CF from the Excel input file *“FormS6Input17.xlsx”* is multiplied by r/Rmax. This ratio varies from 0 at the center of the eye to 1 at r = Rmax so CF increases linearly from the center of the eye to its maximum at Rmax. As an example, suppose the value of CF in a particular input vector in the Excel file is 0.84, then the value of CF is zero at the center of the hurricane and 0.84(1) = 0.84 at Rmax. In between these two positions, the value of CF is based on linear interpolation using multiplication by r/Rmax.

**CASE 2:** Rmax < r < 3\*Rmax

Within this interval, the value of the random variable CF is decreased from its maximum at r = Rmax by the following amount:

[(r - Rmax)/(3\*Rmax - Rmax)]\*(0.1)

Thus, at r = Rmax, CF is not decreased. At r = 3\*Rmax, CF is decreased by 0.1. This calculation is simple linear interpolation between Rmax and 3\*Rmax.

**CASE 3:** r > 3\*Rmax

The value of the random variable CF at 3\*Rmax is used for the remainder of the outer region, i.e., beyond r = 3\*Rmax.

In summary, CF ramps up from its minimum value of 0 at the center of the hurricane to its maximum at Rmax and then ramps down in a linear fashion to 3\*Rmax, where it achieves its maximum decrease of 0.1 from its value at Rmax. CF then remains at this value beyond 3\*Rmax. As an example, the previous value of CF = 0.84 would occur at Rmax and then decrease in a linear fashion to 0.84 – 0.1 = 0.74 at 3\*Rmax and remain at this value beyond 3\*Rmax.

*Figure 5* shows an “Uncertainty Envelope” for CF using the methodology in this example. The horizontal axis in this graph is in units of Rmax. Thus, r = 0\*Rmax represents the center of the hurricane, r = 1\*Rmax represents Rmax and r = 3\*Rmax represents the start of the outer region. Two red lines have been added in *Figure 5* to show the minimum and maximum possible values of CF from the input vectors in the Excel file *“FormS6Input17.xlsx”*over the region of the hurricane. The blue line represents the expected value of CF when the distribution is uniform between 0.80 and 0.95. Thus, the minimum value of CF at r = Rmax is 0.8 and the maximum is 0.95. At r = 3\*Rmax, these minimum and maximum values are decreased by 0.1 to 0.7 and 0.85, respectively. This description of CF is meant to be illustrative and serve as a guide for the modeling organization to adapt CF to their hurricane model.

***Figure 5***

**Uncertainty Envelope for the Conversion Factor**

The 100 combinations of these seven hurricane model input variables represent different initial conditions for each of three categories of hurricanes (1, 3, and 5) given in the Excel input file. These hurricanes follow a straight due west track passing through the point (24.8611N, 80.1196W).

The 21×40 grid illustrated in *Figure 6* for southern Florida uses an approximate 3 statute mile spacing. For purposes of hurricane decay, use existing terrain consistent with the grid in *Figure 6* or *Figure 7* (map version with grid identified as a rectangular region).

The point (0, 0) is the location of the center of the hurricane at time 0, and is 9 miles east of the landfall location (25.8611N, 80.1196W), identified by the red rectangle in *Figure 6*. The hurricane is to be modeled for 12 hours starting at time 0. The approximate latitudes and longitudes for the 840 vertices in the 21x40 grid are given in the ninth worksheet of the Excel input file.

***Figure 6* Grid for Calculating Hourly Wind Velocities**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **42N** |
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| **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **•** | **-6S** |
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| **117W** | 114W | 111W | 108W | **105W** | **102W** | **99W** | **96W** | **93W** | **90W** | **87W** | **84W** | **81W** | **78W** | **75W** | **72W** | **69W** | 66W | 63W | 60W | **57W** | **54W** | **51W** | **48W** | **45W** | **42W** | **39W** | 36W | **33W** | **30W** | **27W** | **24W** | **21W** | **18W** | **15W** | **12W** | **9W** | **6W** | **3W** | **0** |  |

# Hurricane Path from (0, 0) to (117W, 0)

***Figure 7* Map Version of Grid for Calculating Hourly Wind Velocities**



**Hurricane Loss Costs**

Successful completion of Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, demonstrates that the modeling organization is capable of running an insurance portfolio at a latitude/longitude level directly and at a street address level indirectly with appropriate conversion to latitude/longitude.

Hurricane loss costs are to be determined using a $100,000 insured structure with a zero deductible policy, not to include contents, time element, or appurtenant structure coverages, at each of the 682 land-based vertices in *Figure 6*. The Excel input file contains a ninth worksheet (Land-Water ID) that lists the 840 grid coordinates with an indicator variable defined, as follows:

 0 = coordinate is over-water

 1 = coordinate is over-land

The following house is assumed at each of the land-based grid points designated by the indicator variable.

* Single family
* Single story
* Masonry walls
* Truss anchors
* Gable end roof
* No shutters
* Shingles with one layer 15# felt
* 1/2" plywood roof deck with 8d nails at 6" edge and 12" field
* House constructed in 1980

Produce hurricane loss costs for each hurricane category in two forms:

 1. Aggregated hurricane loss costs over the 682 land-based vertices in the grid in *Figure 6* for each input vector and each hurricane category (100 x 3 = 300 values).

 2. The mean hurricane loss cost at each of the 682 land-based vertices in the grid in *Figure 6* over all 100 input vectors for each hurricane category (682 x 3 = 2,046 means).

1. Calculate the total hurricane loss cost over the 682 land-based vertices in the grid for each of the 100 input vectors and then divide this sum by $68,200,000 to get the expected hurricane loss cost as a percent of total exposure. The results for each input vector should be reported on a single row with the following information:

* Hurricane category (1, 3, or 5)
* Input vector number
* Total hurricane loss cost over the 682 land-based vertices in the grid
* The expected hurricane loss cost as a percent of total exposure to two decimal places (i.e., 15.42 for 15.42%)

Thus, the entries in this file for input vectors 35-37 for the Category 5 hurricane will appear as in the following format:

 5 35 4767326. 6.99

 5 36 4365003. 6.40

 5 37 2531948. 3.71

Provide the results in an ASCII file and a PDF file named *“XXX17Expected Hurricane Loss Cost”* where XXX denotes the abbreviated name of the modeling organization. The ASCII file will have 300 rows.

Display these results as cumulative empirical distribution functions as shown in *Figure 8* or its equivalent.

***Figure 8***



**Comparison of CDFs of Hurricane Lost Costs for all Hurricane Categories**

2. Report the mean hurricane loss cost at each of the 682 land-based vertices in the grid over all 100 input vectors for each hurricane category. The results should be reported with the following information:

* Hurricane category (1, 3, or 5)
* E-W grid coordinate (0, 3, 9, 12, …, 120)
* N-S grid coordinate (-15, -12, -9, -6, …, 45)
* Hurricane loss cost as a percent of the exposure ($100,000) at each land-based coordinate to four decimal places (i.e., 0.1207 for 12.07%)

Thus, the entries in this file for the land-based vertices (12,18), (15,18), and (18,18) for the Category 5 hurricane will appear as in the following format:

 5 12 18 0.5142

 5 15 18 0.4533

 5 18 18 0.3872

Provide the results in an ASCII file and a PDF file named *“XXX17Hurricane Loss Cost Contour”* where XXX denotes the abbreviated name of the modeling organization. The ASCII file will have 3 x 682 = 2,046 rows.

Display the mean of the 100 input vectors as contour plots for each hurricane category as shown in *Figures 9* to *11* (use the suggested contour levels in these figures).

Note for contour plotting. The grid coordinates are written from east to west, but most contour plot software will have the origin in the lower left-hand corner (i.e., west to east). Thus, the X coordinates 18, 15, and 12 in the above example will need to be plotted as 120-18=102, 120-15=105, and 120-12=108 to avoid having a mirror image plot. Labels on the east-west axis will then have to be added to reflect the east to west grid as in *Figures 9* to *11.*

***Figure 9***



**Contour Plot of Hurricane Loss Cost for a Category 1 Hurricane**

***Figure 10***



**Contour Plot of Hurricane Loss Cost for a Category 3 Hurricane**

***Figure 11***



**Contour Plot of Hurricane Loss Cost for a Category 5 Hurricane**

**Uncertainty and Sensitivity Analysis for Hurricane Loss Costs**

The modeling organization shall perform uncertainty and sensitivity analyses for expected hurricane loss costs as outlined below. The Professional Team will perform uncertainty and sensitivity analyses based on the modeling organization’s expected hurricane loss cost calculations as part of its preparation prior to reviewing the modeling organization’s internal uncertainty and sensitivity analyses (using the hurricane model’s actual hurricane vulnerability functions) during the on-site reviews. The modeling organization shall present to the Professional Team during the on-site review their uncertainty and sensitivity analyses using the hurricane model’s hurricane vulnerability functions.

Sensitivity analyses will be based on standardized regression coefficients (SRC) for each hurricane model input variable in the Excel input file. The calculation of the SRCs is explained on page 22 of the *Professional Team Demonstration Uncertainty/Sensitivity Analysis* by R.L. Iman, M.E. Johnson, and T.A. Schroeder, September 2001, available at [*www.sbafla.com/method/portals/methodology/CommissionInquiries/UA-SA%20Demo.pdf*](http://www.sbafla.com/method/portals/methodology/CommissionInquiries/UA-SA%20Demo.pdf)*.*

Hurricane loss costs used in these sensitivity analyses were based on the Professional Team’s surrogate hurricane vulnerability function. If the SRC is positive for a given hurricane model input variable, then hurricane loss costs increase as the variable increases while negative SRC values indicate that hurricane loss costs decrease as the variable increases. The SRCs in these sensitivity analyses are summarized, as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Category | CP | Rmax | VT | Holland B | CF | FFP |
| 1 | -0.3924 | 0.4350 | 0.0692 | 0.5995 | 0.3633 | 0.0944 |
| 3 | -0.2342 | 0.6996 | -0.0488 | 0.3755 | 0.4265 | 0.1181 |
| 5 | -0.1328 | 0.9397 | -0.0373 | 0.1129 | 0.3372 | 0.0599 |

*Figure 12* presents graphs of these SRCs for all six input variables for each category of hurricane. This figure shows that the Holland B profile parameter has the most influence on the magnitude of hurricane loss costs for a Category 1 hurricane and this relationship is positive. Rmax has the second most influence on the magnitude of hurricane loss costs (positive) followed closely by CP (negative relationship) and CF (positive). FFP and VT had slight influence.

The Category 3 results in *Figure 12* show that Rmax now has the most influence on the magnitude of hurricane loss costs followed by CF and then Holland B and CP. FFP and VT again had the least influence.

The SRCs for Category 5 in *Figure 12* have the same ordering as for a Category 3 with the exception that Holland B and CP interchanged in the middle two positions.

Over all hurricane categories, Rmax, CF, and Holland B have the most influence on the magnitude of hurricane loss costs followed in fourth place by CP and then FFP and VT.

Note: Individual modeling organization results may differ significantly from the demonstration results shown here.

***Figure 12***



**Hurricane Category**

**Standardized Regression Coefficients**

**SRC by Hurricane Category**

**SRCs for Expected Hurricane Loss Costs for all Input Variables for all Hurricane Categories**

Uncertainty analyses will be based on expected percentage reduction (EPR) for each hurricane model input variable in the Excel input file. The calculation of the EPRs is explained on page 22 of the *Professional Team Demonstration Uncertainty/Sensitivity Analysis* by R. L. Iman, M. E. Johnson, and T. A. Schroeder, September 2001, available at [*www.sbafla.com/method/portals/methodology/CommissionInquiries/UA-SA%20Demo.pdf*](http://www.sbafla.com/method/portals/methodology/CommissionInquiries/UA-SA%20Demo.pdf)*.*

If the EPR is large for a given input variable, that variable makes a large contribution to the uncertainty in hurricane loss costs while a small EPR indicates that the variable contributes much less to the uncertainty in hurricane loss costs. The EPRs in these uncertainty analyses are summarized, as follows:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Category | CP | Rmax | VT | Holland B | CF | FFP |
| 1 | 14.2% | 16.9% | 0.6% | 37.6% | 15.0% | 1.4% |
| 3 | 5.3% | 43.7% | 0.1% | 12.1% | 15.7% | 0.8% |
| 5 | 2.8% | 88.7% | 0.0% | 1.7% | 12.8% | 0.7% |

*Figure 13* presents graphs of these EPRs for all six input variables for each category of hurricane. This figure shows that the Holland B profile parameter makes the largest contribution to the uncertainty (37.6%) in hurricane loss costs for a Category 1 hurricane. Rmax makes the next largest contribution (16.9%) followed closely by CF (15.0%) and then CP (14.2%). FFP (1.4%) and VT (0.6%) made very little contribution to the uncertainty in hurricane loss costs.

The Category 3 results in *Figure 13* show that Rmax makes the largest contribution to the uncertainty (43.7%) in hurricane loss costs followed by CF (15.7%) and Holland B (12.1%) while CP drops (5.3%). FFP (0.8%) and VT (0.1%) again make very little contribution to the uncertainty in hurricane loss costs.

The EPRs for Category 5 in *Figure 13* have the same ordering as for a Category 3 with the exception that Holland B and CP are interchanged in the middle two positions. It is important to note that Holland B dominates the uncertainty in hurricane loss costs for smaller hurricanes and then decreases in influence for larger hurricanes while just the opposite is true for Rmax. CF is in second place for Category 3 and 5 and in third place for Category 1.

Over all hurricane categories, Rmax, CF, and Holland B make the largest contributions to the uncertainty in hurricane loss costs followed in fourth place by CP and then FFP and VT.

The EPRs in the above summary do not necessarily sum to 100% unless the underlying hurricane model is linear. In this case, the sums for Category 1, 3, and 5 are 86%, 78%, and 107%.

Note: Individual modeling organization results may differ significantly from the demonstration results shown here.

***Figure 13***



**Expected Percentage Reduction**

**EPR by Hurricane Category**

**Hurricane Category**

**EPRs for Expected Hurricane Loss Costs for all Input Variables for all Hurricane Categories**

**Clarification of Input and Output Files for Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis**

The Professional Team will need all actual input and output files to verify the modeling organization’s sensitivity and uncertainty analyses results for hurricane loss costs as specified in Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis. The following explanation is provided to clarify which files the modeling organization must submit. Compliance in submitting these files will eliminate the need for the Professional Team to request these files during the on-site review and to allow verification of the results prior to the on-site review.

**Sensitivity Analysis.** The first worksheet in the Excel file “*FormS6Input17.xlsx*” is entitled “Sen Anal all Variables.” This worksheet contains Latin hypercube samples (LHS) consisting of 100 random combinations of the following seven hurricane model input variables for each of three categories of hurricanes (1, 3, and 5):

* CP = central pressure (in millibars)
* Rmax = radius of maximum winds (in statute miles)
* VT = translational velocity (forward speed in miles per hour)
* Hurricane model shape parameter such as the Holland B parameter
* CF = conversion factor for converting the modeled gradient winds to surface winds (or an optional additional input variable if conversion factor is not used)
* FFP = far field pressure (in millibars)
* Quantiles for possible additional input variable (use is optional)

Modeling organizations might choose to use some variation of these input variables. For example, the modeling organization might choose not to use the “hurricane model shape parameter,” but choose to include the “quantile” variable. The actual LHS files used by the modeling organization shall be submitted including the identification of the input parameters that were used. The modeling organization shall also submit the hurricane loss cost output files for the sensitivity analysis portion of Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis.

**Uncertainty Analysis.** Worksheets 2-8 in the Excel file “*FormS6Input17.xlsx*” are used for the uncertainty analysis portion of Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, and are labeled, as follows:

2. Unc Analysis for CP

3. Unc Analysis for Rmax

4. Unc Analysis for VT

5. Unc Analysis for Shape Parameter

6. Unc Analysis for CF

7. Unc Analysis for FFP

8. Unc Analysis for Quantile

The modeling organization shall submit the hurricane loss cost output files for the uncertainty analysis portion of Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, corresponding to worksheets 2-8.

Include the disclosures and displays as noted in the Form S-6, Hypothetical Events for Sensitivity and Uncertainty Analysis, instructions in a submission appendix.