National Flood Insurance Program

Risk Rating 2.0 Methodology and Data Sources

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TABLE OF CONTENTS

PURPOSE AND ORGANIZATION OF REPORT 1

DATA AND DATA VALIDATION 2

GIS DATA 2

MARKET BASKETS 2

Single Family Home Locations 2

HISTORICAL AND INFORCE EXPOSURES 4

CATASTROPHE MODELING 4

Inland Flood and Storm Surge Models 4
Great Lakes Flooding 5
Tsunami 5
Leveed Areas 7
Catastrophe Model Review 7

METHODOLOGY 8

TARGET RATE LEVEL 8

Introduction 8
Mainland Inland Flood and Storm Surge Losses 8
Non Mainland Inland Flood and Storm Surge Losses 9
Tsunami Losses 9
Great Lakes Losses 9
Coastal Erosion Losses 9
Expenses 9

CONCENTRATION RISK 10

RATING FACTORS 11

Geographic Rating Factors 12
Property Characteristics Rating Factors 13
Rating Territories 14
Leveed Area Analysis 16
Non Single-Family Home Analysis 17
Insurance To Value/Deductible Analysis 17

COMPARISON TO HISTORICAL RESULTS 19

RATE ORDER CALCULATION AND SELECTIONS 20

Community Rating System Discount 20
Elevated Machinery and Equipment 20
First Floor Height 20
Foundation Type 20
Maximum Rate 20
Prior Claims 21
Rating Factor Capping 21

BASE RATES 21

FINAL RATING FACTORS AND RATING EXAMPLES 21

ACTUARIAL STANDARDS OF PRACTICE 24

CAS STATEMENT OF PRINCIPLES REGARDING PROPERTY & CASUALTY INSURANCE RATEMAKING 24

ASOP 12: RISK CLASSIFICATION (FOR ALL PRACTICE AREAS) 25

ASOP 23: DATA QUALITY 26

ASOP 25: CREDIBILITY PROCEDURES 26

ASOP 29: EXPENSE PROVISIONS IN PROPERTY/CASUALTY INSURANCE RATEMAKING 26
ASOP 30: TREATMENT OF PROFIT AND CONTINGENCY PROVISIONS AND THE COST OF CAPITAL IN PROPERTY/CASUALTY INSURANCERATEMAKING 27
ASOP 38: USING MODELS OUTSIDE THE ACTUARY'S AREA OF EXPERTISE (PROPERTY AND CASUALTY) 27
ASOP 39: TREATMENT OF CATASTROPHE LOSSES IN PROPERTY/CASUALTY INSURANCE RATEMAKING 28
ASOP 41: ACTUARIAL COMMUNICATIONS 29
ASOP 53: ESTIMATING FUTURE COSTS FOR PROSPECTIVE PROPERTY/CASUALTY RISK TRANSFER AND RISK RETENTION 29
ASOP 56: MODELING 30
LIMITATIONS 32
GLOSSARY OF TERMS 34
APPENDIX A - GIS Technical Appendix 35
APPENDIX B - Market Basket Variable Imputation 55
APPENDIX C - Uniform Book Assumptions 63
APPENDIX D - Rating Factors
APPENDIX E - Rating Examples

PURPOSE AND ORGANIZATION OF REPORT

The Federal Emergency Management Agency ("FEMA") requested Milliman, Inc. ("Milliman") assist it with its Risk Rating 2.0 initiative, which consists in developing a new rating plan for the National Flood Insurance Program ("NFIP"). Milliman's work under Risk Rating 2.0 has been fully documented in over 40 separate actuarial communications to FEMA provided over the course of the engagement, including both actuarial reports and other formats such as spreadsheets and electronic data files. The purpose of this report ("the Milliman report") is to provide a consolidated description of the methodology and data sources used to develop the Risk Rating 2.0 plan and information about how our work complied with relevant actuarial standards of practice. The report also shows the Risk Rating 2.0 algorithm, rates, and rating factors, and provides examples to illustrate how premiums are calculated under the new plan. Milliman provided FEMA with a draft report on September 28, 2020, a revised draft report on March 11, 2021, and this final report on March 25, 2021.

This report is divided into several sections. The first main section describes the data sources used and the methods of validation employed. Data sources include GIS data, Market Basket data, NFIP inforce exposures, NFIP historical loss and exposure data, and catastrophe model output.

The next section, comprising the bulk of this report, discusses the methodology employed in the analysis. This includes a discussion of how Milliman calculated the target rate level, the net cost of reinsurance and retained risk, the rating factors, the concentration risk loads, and how Milliman used FEMA's historical loss data.

The next section consists of a discussion of the rating algorithm and selections made by FEMA.

The final sections of the report provide information about how Milliman complied with relevant actuarial standards of practice, describe the limitations of this report, and provide a glossary of terms.

The report also includes the following appendices, which are referenced in relevant sections of the report text:

- Appendix A: GIS Technical Appendix
- Appendix B: Market Basket Variable Imputation
- Appendix C: Uniform Book Assumptions
- Appendix D: Rating Factors
- Appendix E: Rating Examples

DATA AND DATA VALIDATION

GIS DATA

Documentation of the GIS data and analyses used in Risk Rating 2.0 can be found in the attached Appendix A. This appendix describes how geospatial datasets used in Risk Rating 2.0 were acquired and/or created, how these datasets were queried to append rating variables to policy locations, and additional GIS analysis that was incorporated into the rating plan design.

MARKET BASKETS

Single Family Home Locations

Due to the concentrated nature of FEMA's inforce policies, Milliman created Market Baskets for all states and territories to use in this analysis. The Market Baskets were created to be a representative sample of all single-family homes ("SFHs"). These Market Baskets were primarily designed to assist in the creation of rating factors.

Three separate books (portfolios of policies) were created from the Market Basket data:

1. Uniform Book. The Uniform Book is a representative sample of locations of SFHs. Each location was assigned identical property and coverage characteristics, which are shown in Appendix C.
2. Uncorrelated Market Basket. Approximately half of all locations were designated as the Uncorrelated Market Basket. These locations were assigned generally uncorrelated property and policy characteristics that are not necessarily representative of the state or territory's true distributions, as described in more detail in Appendix B. This book was utilized to understand non-geographic (i.e. property and coverage) risk differences. An exception to the lack of correlation was the relationship between foundation type and first floor height, since certain combinations are inherently not possible. For example, it is not possible to have a slab foundation with a 10-foot first floor height.
3. Correlated Market Basket. The remaining locations not designated as part of the Uncorrelated Market Basket make up the Correlated Market Basket. In the Correlated Market Basket, property and policy characteristics are representative of the distributions by state or territory, as described in more detail in Appendix B.

In creating these books, the first major step was to create the location of all SFHs within each state or territory. The uniform book was made directly from these locations. The next major step was to impute unknown property and coverage characteristics. Details on the imputations are included in Appendix B. The final step was to separate the Uncorrelated and Correlated Market Basket locations, and to re-impute the Uncorrelated Market Basket property and coverage characteristics.

Market Basket locations were derived primarily from CoreLogic ParcelPoint data ("parcel data") provided to Milliman by FEMA. This parcel data contained point and polygon features for the majority of counties in the United States. Additional datasets used to create Market Basket locations include 2010 Decennial Census Data ("2010 Census"), American Community Survey 2016 5-year estimates ("ACS"), and Census TIGER files ("Census geographies") from the U.S. Census Bureau as well as water areas from the National Hydrography Dataset ("NHD"). Census geographies used include state, county, census block group ("block-group"), and census block ("block") boundaries in addition to road centerlines.

For counties with parcel data, parcel points were initially selected based on their assigned land-use and property indicator types. The initial count of selected parcels was then compared to the expected count based on ACS estimates of SFHs by county. In many cases, the initial selections varied significantly from the expected counts. Counties were reviewed manually using satellite imagery to diagnose material discrepancies between actual and expected counts. For example, many counties contained parcel points where the property type was agricultural or the land-use type was forest. These parcels were added to the single-family home dataset where property characteristics existed that distinguished them as SFH locations, such as year built, number of bedrooms, or assessed value of improvements. In other cases where the initial parcel counts were high relative to the expected ACS counts, parcel points that were incorrectly assumed to be SFHs were identified either as empty using property characteristics or as duplicates using Assessor's Parcel Number. The final selected parcel points were then overlaid with NHD water areas to ensure no location was over water; where necessary, parcel polygons were clipped using water areas so that a new parcel centroid outside of the water area could be generated.

For the small number of counties with missing or limited parcel data, a stratified, constrained, random point generation method was used to create representative locations of SFHs. Estimated counts of SFHs from the ACS by block-group were allocated to the block level using counts of housing units by block from the 2010 Census. Randomly generated points were placed in each block based on these allocations subject to the following constraints:

1) Points cannot be within water areas
2) Points cannot be within 200 m of a highway or highway ramp centerline
3) Points cannot within 25 m of a main road centerline
4) Point must be between 8 and 100 m of a local road centerline
5) Points cannot be within 15 m of another point.

All constraints were based on a study of known SFH locations and their respective distances to road centerlines and neighboring locations.

Details on the development of the Uncorrelated Market Basket and Correlated Market Basket are in Appendix B.

HISTORICAL AND INFORCE EXPOSURES

Milliman utilized the FEMA inforce exposures from May 31, 2018 for the catastrophe modeling and dislocation analysis. The following fields were appended:

- Leveed Area Indicator
- Levee System ID
- Levee Quality
- Distance to River
- Elevation Relative to River
- Flood Depth Difference (the difference between the 10 year and 100 year flood depth)
- Drainage Area
- Hydrologic Unit Codes (“HUCs”)
- Building Replacement Cost Value (provided to FEMA by CoreLogic)
- Contents Actual Cash Value (estimated from Building Replacement Cost Value)
- Ground Up Modeled Average Annual Loss (“AAL”) by catastrophe model and peril
- Gross Modeled AAL by catastrophe model and peril (after limits and deductibles applied)
- Type of Use and Floors of Interest (Non Single Family Homes only)

Milliman utilized NFIP historical losses and exposures from January 1, 1992 to June 30, 2018. For these historical exposures the Building Replacement Cost Value (“RCV”) from FEMA’s database was used. Although Milliman compared these values to the values supplied to CoreLogic for the inforce exposures to assess the reasonableness of the recorded RCVs in the NFIP database, we were not able to validate the recorded RCVs.

CATASTROPHE MODELING

Inland Flood and Storm Surge Models

Milliman prepared the Uniform Book, Uncorrelated Market Basket, Correlated Market Basket, and FEMA inforce exposures for catastrophe modeling. The catastrophe models used in the analysis were KatRisk SpatialKat and SoloKat (“KatRisk model”), AIR Touchstone version 5 (“AIR model”), CoreLogic RQE v. 17.0 US Flood Model (“CoreLogic model”), Mapping Data Integration (“MDI model”), and PFRA (“PFRA model”). The MDI and PFRA models were based on FEMA flood maps and other data sources and were developed by FEMA contractors including Atkins, STARR II and Compass. When different settings for the models existed, Milliman requested that they be run using the long-term event sets and with demand surge. Milliman reviewed the models to assess their suitability for the purpose of making rates for the NFIP.

AIR and KatRisk input files were provided to FEMA, CoreLogic input files were provided to CoreLogic, and MDI input files were provided to Atkins for modeling. PFRA input files were provided to STARR II and Compass for modeling.

The catastrophe model vendors and Atkins provided written documentation regarding their models. The documentation of the MDI model is in the draft document "Mapping Data Integration ("MDI") Model Documentation Version 2.0" dated February 13, 2020. KatRisk provided "KatRisk Data and Model Technical Documentation" dated February 2018. AIR provided "AIR Inland Flood Model for the United States" (June 2016), "AIR Hurricane Model for the United States" (June 2017), and "AIR Earthquake Model for the United States" (December 2019). The earthquake documentation contains AIR's documentation regarding its Tsunami model. CoreLogic provided "RQE v. 18.0 US Flood Model Principles and Methodology" (July 2018). Milliman referred to the documentation of all of these models during the course of the analysis. No written documentation was provided for the PFRA model, however there were numerous conference calls between the PFRA contractors, FEMA, and Milliman to discuss the methodology and assumptions used in the model.

The MDI model was not run on the FEMA inforce exposures because it could not be run inside the FEMA firewall and the exposure data included Personally Identifiable Information ("PII") that could not be brought outside the firewall. MDI was the only model available for Great Lakes Flooding and Tsunami outside the contiguous United States. Inforce AALs for these cases were estimated using the Market Basket AALs and an adjustment for the different exposure distribution.

The PFRA model was run on the inforce exposures but was not used to set territory factors due to the small number of locations available.

The AIR Inland Flood Model utilized did not include precipitation from tropical cyclones. This was accounted for in the analysis by adding a provision for these losses based on KatRisk.

Great Lakes Flooding

The Great Lakes can experience seiche flooding, which occurs when winds produce a standing wave. It is Milliman's understanding that the commercially available catastrophe models do not include explicit modeling of this phenomenon. FEMA wished to explicitly address this source of flooding and requested that it be incorporated into the MDI model by Atkins. Atkins supplied Milliman with AALs for Market Basket locations for this peril.

Tsunami

MDI results for the Uniform Book, Uncorrelated Market Basket, and Correlated Market Basket were provided for the states of California, Oregon, Washington, Alaska, and Hawaii and for the territories of Guam, American Samoa, and the Northern Mariana Islands. AIR results were provided only for the states covered by the AIR Tsunami model: California, Oregon, and Washington. Atkins stated that the methods they employed were not suitable for evaluating Tsunami risk in the Atlantic basin and therefore did not provide Milliman with AALs for states or territories in the Atlantic basin. Since no Tsunami models were available for the Atlantic coastal states, Milliman's analysis does not include a provision for Tsunami for this region.

Milliman's review of the AIR model results found a significant number of locations with extremely high AALs. Examples of these locations were provided to FEMA and AIR. FEMA and Milliman discussed this issue with AIR, who agreed that AALs near the ocean (or other water sources) could be unreasonably high due to the resolution of the model, which was based on a sub-grid of approximately 132 meters. Thus, Milliman developed a method to identify and exclude locations defined as "outliers" from the analysis.

Key indicators of outliers included:

- Locations with a Distance to Ocean ("DTO") greater than 20 miles were almost always outliers. These were primarily found in Puget Sound, Lake Washington, and the San Juan Islands in Washington.
- Outliers tended to have high AALs. Locations with AALs greater than $5,000 were almost always outliers. Locations with AALs less than $1,000 were rarely identified as outliers.
- Locations within 150 meters of the ocean tended to be outliers, as expected based on the size of the AIR sub-grid.

The conditions for exclusion were as follows:

1) Locations greater than 20 miles from the ocean were removed. 15% of locations with non-zero ground up AALs were removed in this step. A small number of locations that were likely not outliers in the San Juan Islands were dropped in this step. This did not materially impact results, as these locations had relatively low modeled AALs.
2) Ground up AALs greater than $5,000 were removed. 3% of locations with non-zero ground up AALs were removed in this step.
3) A Generalized Linear Model ("GLM") was fit at this point on the subset that included locations with DTO greater than 150 meters and with AAL less than $1,000, in Oregon and Washington only. The GLM was used to estimate the Tsunami burn rate[1] using elevation and distance to ocean, and the Pearson Residual (a measure of the difference between the actual burn rate and the estimated burn rate) was calculated for each location. Locations with ground up AAL greater than $1,000 and a Pearson Residual greater than 2 were dropped. 3% of locations with non-zero ground up AALs were removed in this step.
4) Locations in California zip codes 92647, 92648, and 92649 were also removed if they had ground up AAL greater than $1,500 and DTO greater than 1,000 meters. 2% of locations with non-zero AIR ground up AALs were removed in this step.

The removal of many outliers through the above process significantly reduced the bias in the rating factors developed based on the AIR model but may not eliminate all bias.

[1] Burn rate is AAL per thousand dollars of value.

Leveed Areas

FEMA consulted with the United States Army Corps of Engineers to develop assumptions regarding the definition of leveed areas, the probability of overtopping, and the probability of failure prior to overtopping that could inform the catastrophe modeling. FEMA reran the KatRisk model based upon these assumptions and requested that Atkins rerun the model and provide the updated AALs to Milliman. FEMA advised that it was not possible to rerun the other catastrophe models using these assumptions, and therefore instructed Milliman to exclude them from the leveed analysis.

Catastrophe Model Review

Milliman reviewed AALs from the catastrophe models for reasonableness and anomalies using the following procedures:

- AALs were mapped and reviewed to ensure losses varied as expected.
- Univariate summaries were run on all GIS variables and reviewed for expected patterns. For example, AALs by elevation group were reviewed to ensure a monotonically decreasing trend since Storm Surge AALs should decrease as elevation increases, all else being equal.

METHODOLOGY

TARGET RATE LEVEL

Introduction

Milliman developed target premiums based on NFIP inforce exposures as of May 31, 2018 supplied by FEMA. This date was chosen because the RCV for these exposures had already been obtained and the catastrophe modeling data prep performed as part of the NFIP's reinsurance placement. The target premiums were developed separately across several dimensions:

- Coverage type: Building, Contents
- Occupancy type: SFHs, Non Single-family Homes (NSFHs)
- Levee status: Non-leveed, Leveed
- Peril: Inland Flood, Storm Surge, Tsunami, Great Lakes, Coastal Erosion
- State/Territory

The target premiums were developed using catastrophe model output and loss selections from FEMA, as well as provisions for underwriting expense, loss adjustment expense ("LAE"), and the net cost of reinsurance.

Mainland Inland Flood and Storm Surge Losses

AALs for inforce policies in mainland states[2] were modeled using the AIR, CoreLogic, and KatRisk models for the perils of Inland Flood and Storm Surge. Guy Carpenter compared the AIR and KatRisk results to the NFIP's historical experience. For Inland Flood this was performed at the sub-peril level: non-tropical cyclone flooding, hurricane precipitation, and tropical storm precipitation. Based on this analysis, Guy Carpenter selected adjustment factors and FEMA directed Milliman to use these factors to rescale the AALs from the AIR and KatRisk models.

Milliman calculated the target loss by backing out the LAE and Increased Cost of Compliance ("ICC") loads from FEMA's selection and allocated this target loss by occupancy type, levee status, and state. Milliman then adjusted the Inland Flood and Storm Surge rescaled AALs for each catastrophe model to match the targets by occupancy type and leveed status. The Inland Flood and Storm Surge AALs were adjusted uniformly for each combination of model, occupancy type, and levee status.

As a result, the mainland states Inland Flood and Storm Surge adjusted AALs for AIR, Corelogic, and KatRisk each totaled the target losses by occupancy type and leveed status. AALs still varied by peril, coverage (building and contents), and state.

2 These are all states except Alaska and Hawaii.

Milliman selected AALs by state using both adjusted AALs from the three catastrophe models and the current NFIP premium. Milliman then allocated these selected AALs to peril and coverage.

Non Mainland Inland Flood and Storm Surge Losses

The AIR and CoreLogic models were not available for non-mainland locations. KatRisk Storm Surge was not available for non-mainland locations. Consequently, for Storm Surge the non-mainland analysis relied solely on the MDI model. For Inland Flood, both KatRisk and MDI were used for SFHs but only KatRisk was used for NSFHs.

When the MDI model was used to select a target loss provision, Milliman used a Market Basket burn rate approach since inforce AALs were unavailable. Milliman calculated burn rates (AAL per coverage value) for the Correlated Market Basket using MDI AALs. These burn rates were calculated by elevation relative to river for Inland Flood and by elevation for Storm Surge. Burn rates were then multiplied by inforce coverage value to develop estimates for MDI inforce AAL.

Tsunami Losses

For California, Oregon, and Washington, Milliman used the AIR and MDI models to estimate Tsunami inforce AAL. For other states and territories, Milliman used the MDI model to select target Tsunami AAL since the AIR model was not available. In the case of MDI, Milliman used a burn rate by elevation approach, similar to that described above, to estimate inforce AAL.

Great Lakes Losses

Milliman used the MDI model to select target Great Lakes AAL, using a burn rate by elevation relative to lake approach, similar to that described above, to estimate inforce AAL.

Coastal Erosion Losses

Coastal Erosion inforce AAL was selected in a different manner from other perils, as Coastal Erosion was not available as a peril in any of the available catastrophe models. FEMA provided premium rates based on the current Risk Rating 1.0 methodology with and without Coastal Erosion by state, occupancy group, and leveed status. By applying these rates to inforce coverage, Milliman determined the amount of Coastal Erosion premium implied by the current rates. Estimated current expenses were removed from these premiums to determine the implied Coastal Erosion AALs.

Expenses

Loss Cost Multiplier and Expense Constant

FEMA provided all current expense data. Based on current expenses and premiums, Milliman calculated a current loss cost multiplier (“LCM”) that includes both variable and fixed expenses, as there is no expense constant in the current rates.

The Risk Rating 2.0 algorithm includes loss and expense constants applied to every policy. The Loss Constant is described further below. The Expense Constant reflects the NFIP's fixed expenses. Milliman developed a proposed LCM to load the NFIP's variable expenses in proportion to expected loss. In order to keep total expenses equivalent, the proposed LCM is lower than the current LCM because it excludes the fixed expenses which are now included as a flat load per contract.

Net Cost of Reinsurance and Retained Risk

Milliman developed net risk loads which were applied as a load on the AALs to reflect the Net Cost of Reinsurance ("NCOR") and the retained risk of non-attritional losses. These net risk loads increase each state's overall target premium based on the expected NCOR and retained risk for that state. The loads were developed by first calculating reinsurance premium multiples, which reflect the ratio of cost of reinsurance to the ceded expected loss and LAE per layer estimated from the KatRisk model. FEMA provided Milliman with reinsurance premium data and Guy Carpenter provided Milliman with expected ceded losses used to develop these multiples. Multiples for retained layers were estimated based on a curve fit to the reinsurance multiples. The Guy Carpenter modeled losses by peril, state, and layer were used to derive the combined net risk load by peril and state using the reinsurance and retained layer multiples discussed above.

CONCENTRATION RISK

The risk of large loss events is greater in areas with a higher concentration of policies. In order to reflect these differences in risk due to differences in policy concentration, Milliman developed concentration risk loads that vary by geographic area. The territories selected for the application of these loads were based on Metropolitan Statistical Areas ("MSAs"), Micropolitan Statistical Areas ("µSAs"), Combined Statistical Areas ("CSAs"), and Hydrological Unit Codes ("HUCs"). MSAs and µSAs are composed of counties and are delineated by the United States Office of Management and Budget ("OMB") based on Census Bureau data. The OMB further defines CSAs as combinations of adjacent MSAs and µSAs.

Milliman ranked CSAs, MSAs unincorporated into a CSA, and µSAs unincorporated into a CSA by policies in force. The top 50 areas by policy count were chosen to be distinct territories for the application of the concentration risk load. Each statistical area outside of the top 50 had 0.2% of the total policies in force or less.

The remainder of the country outside of the top 50 statistical areas was generally organized by HUC at the regional level (HUC 02). The mainland states, Alaska, Hawaii, and territories are organized into 21 HUC 02 areas, each representing the drainage area of a major river or the combined drainage of a series of rivers. Two HUC 02 regions were split by HUC 04 (sub-region) to limit the policies in force in each selected territory. Additionally, several HUC 02 regions were combined due to small policy counts. The mapping of HUC 02 to selected territory is shown below in Table 1.

Table 1: Selection of HUC-Based Concentration Risk Territories

Selected Territory	Name	HUC 02	HUC 04
H1	HUC South Atlantic	03 (partial)	0301 through 0309
H2	HUC Lakes	04	All
H3	HUC Mid Atlantic	02	All
H4	HUC Gulf	03 (partial)	0310 through 0318
H5	HUC CA	18	All
H6	HUC Lower MS	08	All
H7	HUC OH East	05 (partial)	0501 through 0507, 0509
H8	HUC Rio-CO-Great Basin	13, 14, 15, 16	All
H9	HUC AR	11	All
H10	HUC MO	10	All
H11	HUC Upper MS	07, 09	All
H12	HUC OH West	05 (partial)	0508, 0510 through 0514
H13	HUC TX Gulf	12	All
H14	HUC Pacific Northwest	17	All
H15	HUC New England	01	All
H16	HUC KY	06	All
H17	HUC PR-VI	21	All
H18	HUC HI-Pacific Territories	20	All
H19	HUC AK	19	All

Each HUC-based selected territory had less than 1.5% of total policies in force.

The 69 selected territories (50 based on statistical area, 19 based on HUC) were appended to the inforce data by FEMA. Guy Carpenter ran this data through the KatRisk model and summarized the resulting expected ceded losses for each layer and concentration territory using the reinsurance structure provided for Inland Flood and Storm Surge separately.

For each territory and peril (Inland Flood and Storm Surge), the net risk load calculated from the expected loss and LAE by layer was compared to the unlimited expected AAL and LAE. The ratios for each territory and peril were compared to the overall ratio to determine concentration risk factors.

RATING FACTORS

Rating factors were developed using several different approaches. Initial indicated rating factors for geographic rating variables, such as distance to coast ("DTC"), were developed using GLMs built on the Uniform Book. Initial indicated rating factors for non-geographic property characteristic rating variables, such as number of stories, were developed through GLMs built on Uncorrelated Market Baskets. Rating factors for coverage terms, such as deductible and limit, were developed using a loss elimination ratio method. Each of these analyses is described in detail in a separate section below.

Geographic Rating Factors

Geographic rating factors were developed by fitting GLMs on the Uniform Book for each peril except Coastal Erosion. Separate GLMs were fit for each catastrophe model, region of the country ("segments")[3], and for leveed areas versus non-leveed areas. Burn rate (defined as AAL per thousand dollars of value) was the target variable. The models were fit using a Tweedie distribution and log link function. The Tweedie p parameter was selected separately for each modeler and peril by maximizing log-likelihood. Two-thirds of the data was randomly assigned to a training dataset and the remaining third was used as a holdout to evaluate the models.

For Storm Surge, Tsunami, and Great Lakes, areas with essentially no risk (far from the coast, at high elevation, or far from a lake shore) were removed from the model training data. For Storm Surge, Milliman also removed locations in any HUC where the maximum AAL was zero. These represent areas with little to no risk. When rating policies in these locations the Storm Surge, Tsunami, and/or Great Lakes premium is set to zero. Table 2, below, shows which locations were included in the analyses.

Table 2: Storm Surge and Tsunami filters

Peril	Filter
Inland Flood	Segment 4 – MDI: Distance to River of less than $e^{6.5}$ meters All Other: No Filter
Storm Surge	Segment 1: DTC < 50 miles and Elevation < 40 ft. Segment 2: DTC < 50 miles and Elevation < 20 ft. Segment 5 - HI,GU,AS, MP: DTC < 50 miles and Elevation < 10 ft. Segment 5 - AK, PR, VI: DTC < 50 miles and Elevation < 20 ft.
Great Lake	Distance to Lake < 10km and Elevation above Lake < 15 ft.
Tsunami	Segment 4: Distance to Ocean < 10 miles and Elevation < 100 ft. Segment 5 - AK: Distance to Coast < 3 miles and Elevation < 60 ft. Segment 5 - AS: Distance to Coast < 1 miles and Elevation < 40 ft. Segment 5 GU/MP: Distance to Coast < 2 miles and Elevation < 60 ft. Segment 5 HI: Distance to Coast < 3 miles and Elevation < 75 ft.

Locations with missing GIS values were also removed. In the initial analysis, Milliman found the model did not fit well for barrier islands. To address this issue, Milliman constructed polygons to define barrier islands and fit storm surge GLMs separately for barrier islands and the mainland.

Preliminary models were fit with binned predictor variables that were selected based on an intuitive relationship with loss. For example, the Storm Surge model included elevation and distance to

[3] Segment 1 consists of Texas, Louisiana, Mississippi, Alabama, Florida, Georgia, South Carolina, and North Carolina. Segment 2 consists of Virginia, Maryland, Washington D.C., Delaware, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine. Segment 3 consists of Arkansas, Iowa, Illinois, Indiana, Kansas, Kentucky, Michigan, Minnesota, Missouri, North Dakota, Nebraska, Ohio, Oklahoma, South Dakota, Tennessee, Vermont, West Virginia, and Wisconsin. Segment 4 consists of Arizona, California, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming. Segment 5 consists of Hawaii, Alaska, and the US territories.

coast. The Inland Flood model included variables such as elevation relative to river and relative elevation, which is the elevation of the policy minus the average elevation within approximately 500 meters. In each case, Milliman made a preliminary determination as to whether the variables should be included in the model based on the fitted coefficients. For example, in cases where the variable seem to have no connection to loss, it was excluded. To select between closely related variables, such as the elevation minus the average elevation over different radii, double lift charts were used to compare models using different variables.

Milliman selected transformations for some predictor variables, such as logarithm transformations or minimum/maximum caps, by analyzing the factors produced by the binned models.

The GLMs were reviewed using residual plots by state comparing the average actual and predicted burn rate as a function of all predictor variables and also variables not included in the model. This was used to validate that the estimated burn rates were tracking the actual burn rates as expected for each variable consistently across states. The purpose of this step was to evaluate the quality of the fit and check if any important variables were omitted from the models. Residual plots on the training and holdout data were compared to check for evidence of overfitting.

Other methods of validation included lift charts and residual maps. To create lift charts, the holdout dataset was split into deciles by predicted burn rate. A well-performing model should have significant differentiation in the average actual burn rate by decile on data not used to train the model, which was found to be the case for all of the models. Residual maps were examined to assess the presence of spatial autocorrelation in residuals, which would indicate possible omitted variables.

Once all selections were finalized, the Correlated Market Baskets were rerated using the selected factors to create estimated AALs. Milliman examined expected loss ratios ("ELRs"), the ratio of the actual AAL to estimated AAL, by each catastrophe model, peril, and rating variable as a final check on the soundness of the GLMs.

For Coastal Erosion there were no available catastrophe models. Since Coastal Erosion can only occur in locations very near the coast, the selected Coastal Erosion rating factor decreases linearly within 100 meters of the coast. No other geographic rating factors apply to Coastal Erosion.

Property Characteristics Rating Factors

Property characteristics rating factors include those rating variables that are based on characteristics of the insured property other than its location or policy terms. Examples include number of stories and first floor height. Similar to the approach for geographic rating factors, the indicated rating factors were developed by using a GLM with burn rate as the target variable. The models for property characteristics were fit on the Uncorrelated Market Basket. The Uniform Book, which was used for the geographic rating factor analysis, has property characteristics that are all the same and so could not be used to set the property characteristics rating factors. The

Correlated Market Basket has property characteristics that vary, but some levels are very sparsely populated and some property characteristics are highly correlated with geographic risk. Because of these data issues, the Correlated Market Basket would produce high standard errors for the sparsely populated levels and the models would be unstable. The Uncorrelated Market Basket corrects for these issues.

The burn rate from the Uniform Book was used as an offset since it captures the risk explained by the geographic location. These burn rates were then adjusted to account for the varying coverage amounts in the Uncorrelated Market Basket and the different vulnerability in Coverage A versus Coverage C. For the Tsunami peril, locations flagged as outliers for the uniform book were dropped from the modeling dataset.

Like the geographic factor models, Milliman used a Tweedie distribution and log link, as well as binned models to identify variable transformations. Unlike the geographic rating factor models, which were fit separately by segment and by leveed/non-leveed, the property characteristic GLMs were fit on countrywide data and leveed/non-leveed combined. Milliman reviewed residual plots, lift charts, and ELRs on the Correlated Market Basket to assess the GLMs for each catastrophe model and peril.

No rating factors based on property characteristics are applied for Coastal Erosion.

Rating Territories

Rating territories were based on HUC12 and barrier island indicators for non-leveed areas and HUC12 and Levee ID for leveed areas. For each territory and peril, a preliminary territory factor was developed based on the residuals on the Correlated Market Basket. These factors were then adjusted based on the inforce book to reflect differences in exposure distribution within the territory for the inforce versus the Market Basket.

Territory was not included in the GLMs because of the high number of levels, most of which are sparsely populated. Since territory was not included in the GLMs, the territory factors were created after the GLMs were finalized. For each catastrophe model and peril, an estimated AAL for each location in the Correlated Market Basket was calculated as the estimated burn rate from the combined GLM rating factors multiplied by the coverage value. The estimated AALs and actual AALs from the catastrophe models were aggregated by HUC 12, HUC10, HUC8, HUC6, HUC4, and HUC2. An implied territory factor, the ratio of the actual AAL to estimated AAL, was calculated at each level of aggregation.

The credibility of each aggregation level was also calculated and used to weight the implied territory factors. For example, the complement of the credibility at the HUC12 level was assigned to the HUC10 factor, the complement of credibility at the HUC10 level was assigned to the HUC8 factor, and so on. The credibility for each geographic level was set as the difference between the credibility of that geographic level and the next smaller geographic level according to the square root rule and variable full credibility standards. The full credibility standard varied by territory due to the observation that different rating territories had varying levels of heterogeneity. Some territories had very low variation in implied territory adjustments, while some territories displayed large variation. Milliman believes the territories with low variation are more homogeneous and therefore should have a lower full credibility standard than those with high variation in the territory adjustment. Rating territories were grouped into deciles by the level of variation for each peril, with higher full credibility standards for territories with higher levels of variability.

To separate territories in this manner, Milliman sorted them into deciles by peril as follows. For each location, the ratio of actual to estimated AAL was calculated. KatRisk uniform AAL was used for the calculation for Inland Flood and mainland Storm Surge. MDI uniform AAL was used for the calculation for Tsunami, Great Lakes, and non-mainland Storm Surge. The ratio was normalized by dividing by the mean of the ratio of the corresponding HUC12 for non-leveed areas and HUC12/Levee ID for leveed areas. The location level transformed territory adjustment was calculated as the natural logarithm of the normalized ratio. The logarithm transformation was used to create a symmetry between the expected value and actual value and reduce the impact of outliers. At each HUC level, the weighted standard deviation was calculated as the square root of the variance of the transformed territory adjustments, weighted by actual AAL. The weighted standard deviations were ordered at each HUC level into deciles.

To determine the full credibility standard for each decile, Milliman performed a sampling analysis as follows. This sampling process occurred separately for each peril. Milliman took all Market Basket locations, subject to geographic filters by peril, bucketed them into the deciles based on the HUC12, and calculated the natural logarithm of the normalized ratio of the actual to estimated AAL at the location level as detailed above. For each decile, the population mean of this ratio was calculated. A sample of locations within each decile was taken and the number of locations with a ratio within 5% of the population mean of the ratio was determined. This sampling process was repeated many times, allowing Milliman to determine the minimum number of locations needed to have 95% of sample mean ratios within 5% of the population mean ratio. This minimum number of locations was designated the full credibility standard. In cases where the full credibility standard implied by the sampling process for a peril decreased as the variable decile increased, deciles were judgmentally grouped to result in increasing credibility standards. For the Great Lakes and non-mainland Storm Surge perils, the full credibility standards implied by the sampling process were volatile by decile, so the sampling process was performed for all deciles combined.

Credibilities were assigned to each HUC level for each rating territory based on the assigned decile and the policy count. Incremental credibilities were calculated from the smallest (HUC12 or HUC12/Levee ID) to the largest (HUC2) HUC region for each rating territory. The implied territory factors were weighted with the incremental credibilities to arrive at the final territory factor for each rating territory.

For HUC12s or HUC12/Levee ID combinations without Market Basket locations, the factor was filled using the average factor of the nearest hydrologic neighbors (for Inland Flood) or nearest neighbors (for Storm Surge, Tsunami, and Great Lakes), weighted by the number of Market Basket locations in each neighboring HUC12 or HUC12/Levee ID. Hydrologic neighbors were defined using the USGS NHD HUC12 relationship table. If up to the third order neighbors of a given HUC12 had no assigned factor, the HUC12 was given a territory factor of 1.0.

There were often significant exposure distributional differences between the Market Basket and inforce book for individual rating territories. For example, a rating territory may contain many X Zone policies in the Market Basket, but may be dominated by Special Flood Hazard Area ("SFHA") policies in the inforce book. To adjust for these distributional differences, Milliman adjusted the territory factors to account for the inforce book distribution. This procedure was done separately for both Inland Flood and Storm Surge.

For each rating territory, the inforce credibility was determined using the inforce policy counts and the same decile assignment and full credibility standards from the original territory factor derivation. The inforce target premium was determined by rating territory using the average AAL from the AIR, CoreLogic, and KatRisk models. The estimated premium was calculated as the proposed premium using the original territory factors. The ratio of target premium to estimated premium provided an implied adjustment. This was credibility weighted with the original territory factor and off-balanced to give a final selected territory factor.

Leveed Area Analysis

In general, the analysis approach for leveed areas was similar to that for non-leveed areas, however the leveed area analysis relied solely on KatRisk and MDI because it was not possible to adjust the AIR and CoreLogic models based on the levee data inputs described above.

As in the non-leveed analysis, GLMs were used to develop geographic rating factors for leveed areas. For the non-leveed analysis, separate models were fit by segments that consisted of groups of states. For the leveed analysis, there was a smaller volume of data that was more highly geographically concentrated. Using the same segments as the non-leveed analysis would have produced policy counts that were too low within a segment. Instead, the GLMs were fit on the countrywide data. Upon reviewing the residuals, Milliman created an interaction term in the Inland Flood model to allow for elevation as a rating variable in Louisiana. Without this rating variable, AALs were underpredicted in low elevation areas, especially areas with negative elevation in New Orleans. Milliman also found it necessary to create separate GLMs for Louisiana Storm Surge.

Additionally, Levee Quality was included as a predictor variable in the KatRisk GLM. This variable was derived from levee data including the probability of overtopping and probability of failure prior to overtopping. Levee Quality was not a significant predictor in the MDI GLM.

Non Single-Family Home Analysis

The NSFH analysis was done by primarily leveraging the information from the SFH analysis. Rating factors for the GIS and most property characteristic factors were selected to be the final SFH values. Adjustments were then made to the rating factors and rates to reflect the unique elements of NSFH.

In addition to the rating factors used for SFH, NSFH includes rating factors for Type of Use and Floor of Interest. The Type of Use rating factor analysis was done in two steps. An initial set of rating factors were selected based on available catastrophe model output. However, the catastrophe models do not include all the types of use that are available in the FEMA data and on which FEMA wishes to rate. Factors for these additional types of use were developed by performing an analysis of historical loss ratios ("HLRs"), rerating the historical experience using the initial type of use factors based on the catastrophe models. These factors were then adjusted based on the HLR results. This final set of factors allows varies by all desired types of use and aligns the rates with the NFIP's historical experience.

The Floor of Interest factors vary for Residential Unit (condominium unit owners, or other insureds in a multi-unit residential building) versus all other NSFH types of use. This split was made to reflect the fact that Residential Unit insured only have an insurable interest in their own floor. For these factors, FEMA selected the assumption of a 12 foot height for each floor of a building. The factors were then based on the selected height for each floor and the corresponding SFH first floor height factor for open, no obstruction locations.

The NSFH Floor of Interest factors for other types of use were based on a separate analysis. Buildings between one and three stories received the same factors as a SFH structure with the same number of stories. The indicated rating factors for buildings with four or more stories were calculated by weighting the factor for the first three floors with the maximum rate discount from the Residential Unit analysis. Final factors were then tempered to only apply half of this indicated discount. This tempering was applied because of data limitations, specifically the catastrophe models do not currently have separate vulnerability functions for buildings with more than three stories and FEMA's current data does not capture the exact number of stories.

Insurance To Value/Deductible Analysis

Milliman developed geographic and property characteristic rating factors based on data gross of deductible and limit. This allowed Milliman to analyze both geographic and property characteristics and their effect on flood risk independent from effects of deductible and insurance to value ("ITV"). Milliman performed a separate deductible and ITV analysis to develop these rating factors.

Milliman defined ITV as the ratio of coverage limit to coverage replacement cost. Policies identical in all respects other than deductible and limit will have identical expected ground up pure premiums. They may have different expected gross pure premiums due to the loss elimination effects of different limits and deductibles.

All policies in the Uncorrelated Market Basket were grouped based on two ratios:

- (Coverage deductible + coverage limit) / coverage replacement cost, ("deductible and limit percentage")
- Coverage deductible / coverage replacement cost, ("deductible percentage")

The policies were grouped as such for building and contents coverage separately. Within each group, the ratio of total gross AAL / ground up AAL was calculated. This was performed for the following catastrophe model-peril combinations:

- AIR: Inland Flood, Storm Surge, Tsunami
- CoreLogic: Inland Flood, Storm Surge
- KatRisk: Inland Flood, Storm Surge
- MDI: Tsunami, Great Lakes

The deductible effect on gross pure premium was accounted for first. Curves were fit to each cumulative loss elimination ratio, resulting in Deductible to Coverage Value Ratio factors for each model, peril, and coverage type combination.

The combined ITV and deductible effect on gross pure premium was accounted for second. The ratios on these pages account for the Deductible to Coverage Value Ratio factors selected previously, thereby isolating the effects due to increased deductible and limit percentage. Curves were fit to these ratios, producing Deductible & Limit to Coverage Value Ratio factors for each model, peril, and coverage type combination.

Selections were made for each combination of peril and coverage type. Inland Flood and Storm Surge selections were based on the average of the indicated factors from three models (AIR, CoreLogic, and KatRisk). Tsunami and Great Lakes factor selections were based on the Storm Surge factors because of anomalous results for the Tsunami and Great Lakes analyses.

Within the rate order of calculation, the Deductible to Coverage Value Ratio and Deductible & Limit to Coverage Value Ratio factors are combined to produce the Initial Deductible & ITV factor as follows:

Initial Deductible & ITV factor = Deductible & Limit to Coverage Value Ratio factor
– Deductible to Coverage Value Ratio factor

The Final Deductible & ITV factor is set to zero when the corresponding coverage limit is zero and is otherwise floored at 0.001.

COMPARISON TO HISTORICAL RESULTS

Milliman compared the rates derived from the catastrophe models to the NFIP's historical losses from January 1, 1992 to June 30, 2018 by looking at univariate historical loss ratios ("HLRs") using the indicated and selected rates. The indicated HLRs were calculated by rerating the historical exposures at proposed rates using preliminary rating factors derived from the catastrophe models. Based on review of the indicated HLRs, Milliman made adjustments to some rating factors and rerated the historical exposures a second time. Selected rating factors were validated by comparing the resulting selected HLRs with the indicated HLRs.

Milliman made the following changes based on the indicated HLRs:

- Flattened the Coverage Value factors. The catastrophe models all assume that AAL is proportional to value, all else being equal, because they are built to predict damage ratios (i.e. loss divided by replacement cost value). The HLRs indicated that losses have historically increased less than proportionately. Milliman tempered the flattening relative to what was indicated because of limitations in the quality of the RCV data on the historical exposures.

- Tempered Number of Stories factors. The reduction in historical losses from more than one story was less than that indicated from the catastrophe models.

- Addition of Loss Constant. Historical pure premiums did not approach zero as the rerated premium approached zero. This is possibly a result of loss exposure not captured by catastrophe models. Milliman estimated a non-modeled loss provision by performing a linear regression on pure premium versus rerated premium for small values of rerated premium. A loss constant (i.e. a constant loading for loss per contract) was selected based on the intercept term of this regression.

- Flattened Distance to River factors. The indicated HLRs suggested the Distance to River ("DTR") factors should be flatter than indicated, so Milliman tempered this rating factor.

- Flattened Elevation Relative to River and River Class factors. The impact of elevation relative to river and River Class on historical losses was more muted than indicated so Milliman tempered these factors.

- Distance to Coast and Elevation. Based on the HLRs, Milliman steepened the DTC factors near the coast and flattened the elevation factors.

It is important when reviewing HLRs to keep in mind that a large portion of the NFIP's losses resulted from a small number of events and rates should not be overfit to those historical events. In order to address this, Milliman considered HLRs filtered on state groups selected based on historical events.

It is also important to consider the credibility of the historical experience. Although the NFIP has over 800,000 claims that are considered in the analysis, the number of claims can become small when the data is subdivided. For example, In New York/New Jersey there are only 23 claims with an elevation relative to river greater than 75 feet by an H class river in a non-leveed area.

Milliman did not perform an HLR analysis for leveed areas. In order for an HLR analysis to be appropriate, it is important that it not be unduly influenced by the inclusion or exclusion of a small number of historical events. Nearly half of policies in leveed areas are in Louisiana and therefore were affected by the inclusion of Katrina in the historical data. However, if these policies were excluded, the remaining number of policies in leveed areas was too small to have a sufficient number of claims to be credible.

RATE ORDER CALCULATION AND SELECTIONS

Community Rating System Discount

Currently the NFIP has separate Community Rating System ("CRS") discounts for the SFHA and non-SFHA. Consistent with FEMA's plan to remove flood zone from rating, under Risk Rating 2.0 the SFHA CRS discounts will be applied to all policies. These discounts are described in the NFIP CRS discount documentation.

Elevated Machinery and Equipment

FEMA selected a factor of 0.95 for Machinery and Equipment that is elevated above the first floor.

First Floor Height

FEMA selected First Floor Height ("FFH") factors that vary by foundation type and foundation design.

Foundation Type

The following factors were selected:

- 1.30 for Basements
- 1.25 for Elevated with Enclosure, not post, pile, or pier
- 1.20 for Crawlspaces
- 1.00 for all other foundation types

Maximum Rate

A maximum building rate of $15 per thousand dollars of Building Value times the ITV factor and a maximum contents rate of $15 per thousand dollars of Contents Value times the ITV factor were selected.

Prior Claims

A prior claim is defined as a paid flood loss occurring within 20 years prior to the policy period. The subsequent experience of policies with a prior claim is much worse than claims-free policies, justifying a prior claims surcharge. A prior claims surcharge was selected of $2 per thousand dollars of value times the weighted ITV Coverage A factor for each claim after the first claim. However, FEMA informed us that this surcharge will not be applied on any existing policy until they file a new claim after the implementation of Risk Rating 2.0 and therefore we did not apply it when rerating policies at proposed rates.

Rating Factor Capping

A ceiling on rating factors corresponding to the factor closest to the 95th percentile of the exposure distribution and a floor at the factor closest to the 5th percentile of the exposure distribution. This was done separately by each unique portion of the rating plan (e.g. peril and segment).

BASE RATES

The base rates were determined by state/territory, coverage, and peril separately for Single-Family Non-Leveed, Single-Family Leveed, and NSFHs. Base rates were calculated such that the rerated premium was within 0.1% or $1,000 of the target premium, whichever was greater. In a few cases, states or territories were grouped because they had a very small number of inforce locations and premium. In a few small states, there was no base rate where the rerated premium would equal the target premium because of the selected maximum rate. In these cases, Milliman capped the maximum base rate. Since this only occurred in states or territories with small target premiums, the impact of this capping on the overall rerated premium was minimal.

FINAL RATING FACTORS AND RATING EXAMPLES

The selected rating factors are shown in Appendix D. There are 115,862 territories for non-leveed areas and 14,866 territories for leveed areas. Because of the large number of territories, factors are not listed for every individual territory, but are shown in ranges.

To illustrate the calculation of premiums under Risk Rating 2.0, four rating examples are shown in Appendix E, as follows:

- South Carolina non-Leveed Area SFH risk (Pages 1-2)
- Michigan non-Leveed Area SFH risk (Pages 3-4)
- California Leveed Area SFH risk (Pages 5-6)
- South Carolina non-Leveed Area Residential Unit risk (Pages 7-8)

In the first rating example, Page 1 shows all the inputs needed to rate a non-Leveed SFH risk when a policy is being quoted, as follows:

- The geographic inputs (e.g. state, HUC12, Distance to River, Relative Elevation, CRS discount, etc.) are based on the location (latitude and longitude) of the risk. The first example risk is located in South Carolina, 111 meters from a river and 231 meters from the coast.
- The property characteristic inputs (Single Family Home indicator, First Floor Height, Coverage A value, etc.) are based on the characteristics of the insured property. The example risk is a SFH with Coverage A RCV of $250,000 and First Floor Height of 5.5 feet.
- The policy characteristic inputs (Coverage A limit, Coverage A deductible, etc.) are based on the policy coverage being purchased. The example risk is purchasing $250,000 in Coverage A limit, with a deductible of $1,250.

Page 2 shows the calculation of the policy premium for the risk, as follows:

- Row A shows the SFH base rate for the state, by flood sub-peril and policy coverage (building vs. contents); the base rates are shown in Appendix D.
- Rows B through K show rating factors associated with the policy's geographic characteristics. The rating factors are shown in Appendix D, although actual values will be interpolated (e.g. the Distance to Coast factor at 231 meters is between the Distance to Coast factors at 200 and 250 meters).
- Row L shows the geographic rates by peril and coverage, calculated as the product of Rows A through K.
- Rows M through S4 show the rating factors associated with the property and policy characteristics; the rating factors are shown in Appendix D.
- Row T shows the rating factors associated with concentration risk; the rating factors are shown in Appendix D.
- Rows U1 and U2 show the application of the CRS Discount.
- Rows V through X show the rates by peril and coverage, reflecting all the prior factors.
- Rows Y through AA show the calculation of a weighted Deductible and ITV factor by coverage.
- Rows AB through AG apply a minimum and maximum rate per $1,000 of building and contents to determine a final rate.
- Rows AH through AL show the calculation of initial premium without fees based on the final rates multiplied by the value of building and contents coverage in $1,000s.

- Rows AM and AN modify the premium to include a prior claims surcharge.
- Rows AO through AQ modify the premium to include an expense constant and loss constant per contract.
- Rows AR through AV modify the premium to include the cost of ICC and the Reserve Fund.
- Rows AW through AZ modify the premium to include fees.

The calculations for the other two premium examples are similarly depicted.

ACTUARIAL STANDARDS OF PRACTICE

Throughout this project Milliman has been guided by relevant Actuarial Standards of Practice (ASOPs), Statement of Principles (SOPs) and other guidance promulgated by the Actuarial Standards Board (ASB), the American Academy of Actuaries (AAA) and the Casualty Actuarial Society (CAS).

This section of the report illustrates how we complied with the most relevant guidance, including the following:

- CAS *Statement of Principles Regarding Property & Casualty Insurance Ratemaking*
- ASOP 12: *Risk Classification (for All Practice Areas)*
- ASOP 23: *Data Quality*
- ASOP *25: Credibility Procedures*
- ASOP *29: Expense Provisions in Property/Casualty Insurance Ratemaking*
- ASOP 30: *Treatment of Profit and Contingency Provisions and the Cost of Capital in Property/Casualty Insurance Ratemaking*
- ASOP 38: *Using Models Outside The Actuary's Area of Expertise (Property and Casualty)*
- ASOP 39: *Treatment of Catastrophe Losses in Property/Casualty Insurance Ratemaking*
- ASOP 41: *Actuarial Communications*
- ASOP 53*: Estimating Future Costs for Prospective Property/Casualty Risk Transfer and Risk Retention*
- ASOP 56: *Modeling*

Full text of the CAS SOPs can be found on the CAS website here:
https://www.casact.org/professionalism/standards/princip/sppcrate.pdf

Full text of the ASOPs can be found on the ASB website here:
http://www.actuarialstandardsboard.org/standards-of-practice/

Please note that the discussion in this section is intended to be illustrative rather than exhaustive; only the SOPs and ASOPs of primary relevance to this particular type of actuarial work are referenced below, but our work was conducted in adherence to additional professional guidance, as generally applicable to all actuarial work.

CAS STATEMENT OF PRINCIPLES REGARDING PROPERTY & CASUALTY INSURANCE RATEMAKING

The CAS SOPs contains four principles applicable to property and casualty insurance ratemaking. These principles are as follows:

- *Principle 1: A rate is an estimate of the expected value of future costs.*
- *Principle 2: A rate provides for all costs associated with the transfer of risk.*
- *Principle 3: A rate provides for the costs associated with an individual risk transfer.*
- *Principle 4: A rate is reasonable and not excessive, inadequate, or unfairly discriminatory if it is an actuarially sound estimate of the expected value of all future costs associated with an individual risk transfer.*

Examples of how our analysis adhered to these principles are as follows:

- We attempted to capture the costs associated with all sources of flood risk, both modeled and non-modeled, in our estimate of losses.
- We included provisions for all prospective expenses associated with the management of the NFIP, including the net cost of reinsurance and a risk load that reflects the NFIP's retained risk.
- We considered the historical loss experience of similar risks and assessed the credibility of such experience using data grouped in many different ways.
- We considered the impact of catastrophes on the experience and developed procedures to include an allowance for the catastrophe exposure in the rate.
- The resulting Risk Rating 2.0 structure produces an estimated rate for the cost associated with the transfer of risk at the policy level, using the classification structure, risk factors and rating algorithm shown in Appendix D and E.

The CAS SOPs are frequently referenced in the ASOPs, so additional detail of how we complied with those provisions is discussed in the remainder of this section.

ASOP 12: RISK CLASSIFICATION (FOR ALL PRACTICE AREAS)

In accordance with ASOP 12, as part of the design of our classification system we:

- Selected risk characteristics that are related to expected outcomes;
- Selected risk characteristics that are capable of being objectively determined;
- Reflected practical considerations underlying the data capture needed to determine risk characteristics;
- Showed that the variation in actual experience correlates to the risk characteristic;
- Considered the interdependence of risk characteristics and made appropriate adjustments; and
- Considered the reasonableness of results, including the consistency of patterns of rates, values and factors among risk classes.

ASOP 23: DATA QUALITY

In accordance with ASOP 23, in considering the data to use for this analysis we:

- Used available data that, in our professional judgment, allowed us to perform the desired analysis;
- Considered whether the available data was internally consistent, with a reasonable effort to identify data values that were questionable or produced significantly inconsistent relationships;
- Considered whether the available data was reasonable as compared to external information available to us;
- Considered known significant limitations of the data and the implications of such limitations on our analysis;
- Considered the availability of alternate data, and the practicality versus benefit of collecting it;
- Made enhancements and/or judgmental adjustments to available data as appropriate; and
- Disclosed our data sources, reliance on data provided by others, limitations of the data and how we enhanced or adjusted it in our reports to FEMA.

ASOP 25: CREDIBILITY PROCEDURES

In accordance with ASOP 25, the procedures we developed in order to evaluate the credibility of subject experience considered:

- Whether the procedures were expected to produce reasonable results;
- Whether the procedures were appropriate for the intended use; and
- Whether the procedures were practical to implement.

Where we determined that the subject loss experience was not fully credible, we supplemented it with relevant experience that, in our judgment, would be predictive of future losses. We also considered whether there were segments that were not representative of the experience set as a whole, and considered treating them separately in order to enhance the predictive value of the experience set as a whole.

ASOP 29: EXPENSE PROVISIONS IN PROPERTY/CASUALTY INSURANCE RATEMAKING

In accordance with ASOP 29, in determining our estimated expense provisions:

- We determined the provisions for loss adjustment expenses; commission and brokerage fees; other acquisition expenses; general administrative expenses; and taxes, licenses, and fees that are appropriate for the policies to be written or coverages provided during the time the rates are expected to be in effect.

- For expenses other than premium-related expenses, we estimated these expenses on a per contract basis.
- We included a provision for the net cost of reinsurance that considers the amount to be paid to the reinsurer; ceding commissions or allowances; expected reinsurance recoveries; and other relevant information specifically relating to cost.
- We reflected the conditions expected during the time these policies or coverages are expected to be in effect and included all expenses expected to be incurred in connection with the transfer of risk.

ASOP 30: TREATMENT OF PROFIT AND CONTINGENCY PROVISIONS AND THE COST OF CAPITAL IN PROPERTY/CASUALTY INSURANCE RATEMAKING

Unlike most providers of property/casualty insurance, the NFIP is a government program and does not hold capital to support its operations. Therefore, some of the provisions in ASOP 30 such as calculating the cost of capital do not apply to the NFIP's rates.

However, ASOP 30 does apply to all property/casualty insurance coverages and risk financing systems that provide similar coverages, and states that references in the standard to risk transfer should be interpreted to include risk financing systems that provide for risk retention in lieu of risk transfer.

In adhering to the ASOP 30 guidance regarding underwriting profit provisions, we incorporated net risk loads that reflected the NCOR and retained risk of non-attritional losses.

ASOP 38: USING MODELS OUTSIDE THE ACTUARY'S AREA OF EXPERTISE (PROPERTY AND CASUALTY)

As discussed in the "Catastrophe Modeling" section of this report, we used models that incorporate specialized knowledge outside our own area of expertise when developing the Risk Rating 2.0 structure. Examples of ways that our use of these models adhered to ASOP 38 are as follows:

- We determined appropriate reliance on experts, considering the expertise of the experts who produced the models and whether the models had previously been tested or validated.
- We obtained a basic understanding of the model components, user input and output.
- We evaluated whether the models were appropriate for the intended application, including limitations of the models, modifications to the models, and the assumptions needed in order to apply the model output.
- We considered the quality of data availability for user input and examined the model output for reasonableness, considering:

- The results derived from alternate models or methods, where available and appropriate;
- How historical observations compared to results produced by the model;
- The consistency and reasonableness of relationships among various output results; and
- The sensitivity of the model output to variations in the user input and model assumptions.

- We used professional judgment to determine whether it was appropriate to use the model results, subject to any appropriate adjustments.
- We disclosed such adjustments in our reports to FEMA.

ASOP 39: TREATMENT OF CATASTROPHE LOSSES IN PROPERTY/CASUALTY INSURANCE RATEMAKING

The flood peril subject to the NFIP's rates is generally considered to be a catastrophic peril as defined in ASOP 39, in that flooding is caused by relatively infrequent events or phenomenon that produce unusually large aggregate losses. Therefore, the entire NFIP rating plan would be considered an allowance for catastrophe exposure.

Examples of our adherence to ASOP 39 are as follows:

- We considered the applicability of historical insurance data for the insured coverage, including whether catastrophe losses are likely to differ significantly among elements of the rate structure; whether such differences should be reflected in the ratemaking procedures; how to reflect such differences; and whether there is a sufficient number of years of comparable, compatible historical insurance data.
- We made adjustments to the historical insurance data to reflect conditions likely to prevail during the period in which the rate will be in effect. Such adjustments take into account the impact of changes in the exposure to loss, including coverage differences, the underlying portfolio of insured risks, building codes and practices; population shifts; and costs.
- We considered the extent to which the rates would change if the catastrophe ratemaking procedure were to be carried out using different historical experience periods, and modified the procedure to reduce the sensitivity.
- Because in our judgment the available historical insurance data do not sufficiently represent the exposure to catastrophe losses, we used noninsurance data such as GIS data (including models based thereon) as input to ratemaking procedures; and we also used models based on a combination of historical insurance data and noninsurance data.

The resulting ratemaking procedures were designed to appropriately reflect the expected frequency and severity distribution of catastrophes, as well as anticipated class, coverage, geographic, and other relevant exposure distributions.

ASOP 41: ACTUARIAL COMMUNICATIONS

Milliman's work under Risk Rating 2.0 has been fully documented in over 40 separate actuarial communications to FEMA provided over the course of the engagement, including both actuarial reports and other formats such as spreadsheets and electronic data files. Some general examples of ways in which our actuarial communications adhered to ASOP 41 are as follows:

- We designed the form, content and language of each actuarial communication to be appropriate to the particular circumstances, taking into account the intended users.
- In deciding on the timing of the communications, we considered the needs of the intended users.
- We identified the actuaries responsible for the communications.
- With respect to actuarial reports:
    - We stated the actuarial findings, and identified the methods, procedures, assumptions, and data used by the actuary.
    - With respect to each report we considered specific circumstances such as its intended timing, use and distribution, and whether that report built upon previous reports, in deciding how much detail to include.
    - We disclosed sources for data and other information, including reliance on other parties.
    - We identified the party or parties responsible for each material assumption and method.

ASOP 53: ESTIMATING FUTURE COSTS FOR PROSPECTIVE PROPERTY/CASUALTY RISK TRANSFER AND RISK RETENTION

ASOP 53 incorporates all of the considerations contained in the CAS SOP and addresses issues related to the estimation of future costs for risk transfer and risk retention not addressed in previously existing ASOPs. It references many of the other ASOPs previously discussed in this section. Examples of ways we adhered to ASOP 53 beyond the previous discussion are as follows:

- We determined the elements that are appropriate to include in the future cost estimate. Such elements related to the NFIP's coverage and include loss and LAE, operational and administrative expenses, the cost of reinsurance and a risk load.
- We determined the intended measure of the future cost estimate based on the purpose and use of the estimate, considering the desires or needs of the principal, legal requirements, and the regulatory environments in which the future cost estimate will be used.

- We determined what data were available and appropriate for estimating future costs, how to organize the data to develop the elements of the future cost estimate, and how to segment the data to improve the cost estimation analysis.
- We selected appropriate methods and models consistent with the intended measure for each element of the future cost, and reasonable assumptions (including parameters) appropriate to each method and model that, in our professional judgment, have no known significant bias in the aggregate relative to the intended measure.
- We selected exposure bases that bear a strong relationship to the cost of risk transfer and are practical, in that they are objectively measurable and easily verifiable.

ASOP 56: MODELING

ASOP 56 becomes effective for work performed on or after October 1, 2020 and thus was not in effect during the period in which we conducted our Risk Rating 2.0 analysis. However, it has been adopted in final form and provides useful guidance on modeling that would otherwise have applied to our work, so we have chosen to include it in our discussion of adherence to ASOPs. We have already discussed our use of catastrophe models in the ASOP 38 section above, so in this section we will focus on additional comments relevant to our use of GLMs and Loss Elimination Ratios in the analysis.

In designing and developing each of the models used in our analysis:

- We confirmed that, in our professional judgment, the capability of the model was consistent with the intended purpose.
- We assessed whether the structure of the model (including judgments) was appropriate for the intended purpose, considering:
  - Which provisions and risks specific to a business segment, were material and appropriate to reflect in the model;
  - Whether the form of the model is appropriate;
  - Whether the use of the model dictates a particular level of detail; and
  - Whether there is a material risk of the model overfitting the data.
- We used data appropriate for the model's intended purpose.
- Where applicable, we used assumptions as input that are appropriate given the model's intended purpose. In this step we often used ranges of assumptions, evaluated assumptions within the model for consistency, and considered the reasonability of the model output when determining whether the assumptions are reasonable in the aggregate.
- We evaluated model risk and, if appropriate, took reasonable steps to mitigate model risk, through steps such as:

- Testing to ensure that the model reasonably represents that which is intended to be modeled;
- Validating that the model output reasonably represents that which is being modeled; and
- Implementing internal procedures regarding model review and checking to reduce the risk that the model output is not reliably calculated or not utilized as intended.

LIMITATIONS

Qualifications. The above-referenced professional is currently a member in good standing of the American Academy of Actuaries (AAA) and the Casualty Actuarial Society (CAS) and has satisfied the current continuing education requirements of the AAA.

Geospatial Uncertainty. All geospatial datasets are simplified representations of reality and contain varying levels of abstraction and uncertainty. It is certain that actual, real-world values will not conform exactly to estimates provided by our geospatial data products. The degree of uncertainty will depend heavily on the quality of the input property location and as well as the original data used to develop the final products.

Data Reliance. In performing the services, we relied on data and other information provided to us by FEMA and other sources. We did not audit, verify or review the data and other information for reasonableness and consistency. Such a review is beyond the scope of our assignment. If the underlying data or information is inaccurate or incomplete, the results of our analysis may likewise be inaccurate or incomplete. In that event, the results of our analysis may not be suitable for the intended purpose.

We performed a limited review of the data used directly in our analysis for reasonableness and consistency. We did not find material defects in the data. If there are material defects in the data, it is possible that they would be uncovered by a detailed, systematic review and comparison of the data to search for data values that are questionable or relationships that are materially inconsistent. Such a detailed review was beyond the scope of our assignment.

Variability of Results. Any projection of future loss ratios or loss relativities involves estimates of future contingencies. While our analysis is based on sound actuarial principles, it is important to note that variation from the projected result is not only possible, but, in fact, probable. While the degree of such variation cannot be quantified, it could be in either direction from the projections. Such uncertainty is inherent in any set of actuarial projections.

Responsibility for Program. It is not possible to guarantee the financial success of FEMA's programs based upon sound rates alone. Responsibility for the program's success or failure ultimately rests with FEMA.

Actuarial Uncertainty. Differences between our projections and actual amounts depend on the extent to which future experience conforms to the assumptions made for the analyses. It is certain that actual experience will not conform exactly to the assumptions to be used in these analyses. Actual amounts will differ from projected amounts to the extent that actual experience is better or worse than expected.

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GLOSSARY OF TERMS

µSA	Micropolitan Statistical Area
AAL	Average Annual Loss
ACS	American Community Survey
BFE	Base Flood Elevation
CSA	Combined Statistical Area
CRS	Community Rating System
DHS	Department of Homeland Security
DTC	Distance to Coast
DTO	Distance to Ocean
ELR	Expected Loss Ratio
FEMA	Federal Emergency Management Agency
FFH	First Floor Height
FIMA	Federal Insurance and Mitigation Administration
GIS	Geographic Information Systems
GLM	Generalized Linear Model
HUC	Hydrological Unit Code
ICC	Increased Cost of Compliance
ITV	Insurance to Value
LAE	Loss Adjustment Expense
LCM	Loss Cost Multiplier
MDI	Mapping Data Integration
MSA	Metropolitan Statistical Area
NCOR	Net Cost of Reinsurance
NHD	National Hydrography Dataset
NFIP	National Flood Insurance Program
NSFH	Non-Single Family Home
OMB	Office of Management and Budget
PII	Personally Identifiable Information
RCV	Replacement Cost Value
SFH	Single Family Home
SFHA	Special Flood Hazard Area
USACE	United States Army Corps of Engineers

APPENDIX A - GIS Technical Appendix

Table of Contents

Glossary of Terms 1

Scope 2

Software Requirements 2

GIS Data Sources 2

GIS Layers 5

Query Process 11

Additional GIS Analysis Used in Rating Plan Development: HUC12 Territory Factor Filling 14

GLOSSARY OF TERMS

3DEP	USGS 3D Elevation Program
5m AK DEM	5 meter Alaska Digital Elevation Model
CONUS	Conterminous United States
DEM	Digital Elevation Model
ESRI	Supplier of GIS software
Feature Class	Vector dataset within an ESRI geodatabase
Geodatabase	ESRI proprietary database for storing spatial data
GIS	Geographic Information Systems
HUC12	12-digit hydrologic unit code
HUC4	4-digit hydrologic unit code
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NCCOS	NOAA National Centers for Coastal Ocean Science
NFHL	FEMA National Flood Hazard Layer
NHD	National Hydrography Dataset
NHDPlus HR Beta	National Hydrography Dataset High Resolution Plus Beta
NHDPlus V2	National Hydrography Dataset Plus Version 2
NLD	National Levee Database
NOAA	National Oceanic and Atmospheric Administration
Raster	Spatial dataset that defines space as an array of equally sized cells, arranged in rows and columns where each cell represents a particular value such as elevation or land-use.
Shapefile	Spatial data format for storing vector data
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
Vector	Spatial dataset comprised of vertices and paths, usually representing points, boundaries, or networks.
WBD	USGS Watershed Boundary Dataset

SCOPE

Geographic Information Systems ("GIS") is a framework for gathering, managing, manipulating, and analyzing spatial datasets. GIS has been a major component of both the risk rating redesign process and finalized rating plan. GIS variables are necessary for the development of rating factors and determination of final territory factors. Milliman has provided GIS support for Risk Rating 2.0 ("RR2.0") for the duration of the project with the assistance of other FEMA contractors and Milliman subcontractors.

This appendix describes how the geospatial datasets used in RR2.0 were acquired and/or created, how these datasets were queried to append rating variables to policy locations, and explains additional GIS analysis that was incorporated into the rating plan design.

SOFTWARE REQUIREMENTS

Milliman used ESRI ArcGIS Pro Version 2 with the Spatial Analyst extension and Python 3 for the vast majority of RR2.0 GIS dataset development and analysis. The GIS datasets require approximately 1.75 terabytes of storage space.

GIS DATA SOURCES

This section provides an overview of all data sources used in the development of the RR2.0 geospatial datasets. Links to access and download the source data as of September 2020 (if available online) are embedded below.

1/3 ARC-SECOND DIGITAL ELEVATION MODEL

The 1/3 arc-second Digital Elevation Model ("DEM") is a raster dataset from the United States Geological Survey ("USGS") 3D Elevation Program ("3DEP"). The 1/3 arc-second dataset has an approximately 10-meter resolution, is seamless for all states and territories, and is published as 1-degree raster tiles with elevation in meters relative to the North American Vertical Datum of 1988 ("NAVD88") for all areas within the Conterminous United States ("CONUS"). 1-degree tiles are available via bulk download from The National Map. Milliman requested a hard drive with all available 1/3 arc second DEM rasters for the states and territories from the USGS on August 23, 2018.

1 ARC-SECOND DIGITAL ELEVATION MODEL

The 1 arc-second DEM is a raster dataset from the USGS 3DEP. The 1 arc-second dataset has an approximately 30-meter resolution, is seamless for all states and territories, and is published as 1-degree raster tiles with elevation in meters relative to NAVD88 for all CONUS areas. 1-degree tiles are available via bulk download from The National Map. Milliman downloaded these rasters from The National Map in July 2019.

5 METER ALASKA DIGITAL ELEVATION MODEL

The 5-meter Alaska DEM ("5m AK DEM") is a raster dataset from the Alaska Division of Geological and Geophysical Surveys which represents ground elevation and is published as 1-degree raster tiles. This data was obtained and processed by another contractor, Atkins Global ("Atkins"), at the request of FEMA in 2019.

NATIONAL HYDROGRAPHY DATASET

The National Hydrography Dataset ("NHD") represents the nation's drainage networks and related geographic features such as rivers, streams, lakes, and coastlines. The national dataset is available for download from The National Map. Over the course of this project, Milliman obtained and used two additional versions of the NHD, described in the sections below.

NATIONAL HYDROGRAPHY DATASET PLUS HIGH RESOLUTION BETA

The National Hydrography Dataset Plus High Resolution Beta ("NHDPlus HR Beta") is a geospatial model of the flow of water across the landscape and through a stream network. The NHDPlus HR Beta is built using the NHD High Resolution data at a 1:24,000 scale or better, the 1/3 arc-second 3DEP data, and the National Watershed Boundary Dataset ("WBD"). This product is currently in beta version and not available for all states and territories, although new datasets are frequently becoming available. It can be downloaded by 4-digit Hydrologic Unit Code ("HUC4") from The National Map. Milliman downloaded the NHDPlus HR Beta on April 23, 2020.

NATIONAL HYDROGRAPHY DATASET PLUS VERSION 2

The National Hydrography Dataset Plus Version 2 ("NHDPlus V2") is a geospatial model of the flow of water across the landscape and through a stream network. The NHDPlus V2 is built using the NHD Medium Resolution data at 1:100,000 scale or better, the 1 arc-second 3DEP data, and the WBD. It is available to download from the Environmental Protection Agency Link. Milliman downloaded the NHDPlus V2 on April 23, 2020.

NATIONAL WATERSHED BOUNDARY DATASET

The National Watershed Boundary Dataset ("WBD") is a seamless hydrologic unit dataset and contains eight levels of hierarchical hydrologic units identified by unique 2- to 16-digit codes. The dataset is complete for the United States to the 12-digit hydrologic unit. The national dataset is available for download from The National Map. Over the course of this project, Milliman obtained and used two different versions of the WBD, one for Alaska and one for all other areas. These versions are described detail in the GIS Layers section below.

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION NATIONAL SHORELINE

The National Oceanic and Atmospheric Administration ("NOAA") national shoreline represents the land/water interface for coastal areas throughout CONUS, with Washington, Maine, and the Great Lakes only partially represented; Hawaii and portions of Alaska, Puerto Rico, and the U.S. Virgin Islands are also included. This is available for download from NOAA Link. Milliman downloaded the shoreline in June 2019.

NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE SHORELINE SHAPEFILES

The NOAA National Centers for Coastal Ocean Science ("NCCOS") Shoreline Shapefiles are geospatial datasets which represent the land/water interface for select coastal areas, including many island territories. This is available for download from NOAA Link. Milliman accessed the shapefiles in April 2019.

KATRISK FLOOD DEPTH DATA

The catastrophe modeling company, KatRisk LLC ("KatRisk"), created raster datasets representing modeled 10- and 100-year return period flooding depths for CONUS, Hawaii, and Alaska. This data is not publicly available. Milliman obtained this dataset directly from KatRisk on behalf of FEMA on June 6, 2019. This was used to construct River Classes by subdividing the difference between the 10 year and 100 year return period flooding depths in one foot increments. River Class A corresponds to a flood depth difference between zero and one foot, River Class B corresponds to a flood depth difference between one foot and two feet, etc.

US CENSUS TIGER/LINE FILES

U.S. Census TIGER/Line files include, but are not limited to, polygon boundaries for Census statistical areas such as Census Block. TIGER/Line files are available for download from the U.S. Census Link. Milliman accessed the TIGER/Line files in Q1 of 2018.

FEMA NATIONAL FLOOD HAZARD LAYER

The FEMA National Flood Hazard Layer ("NFHL") includes effective, pending, and preliminary flood hazard data. Milliman additionally obtained preliminary unpublished flood hazard data for the following Louisiana parishes from Dewberry Engineers, Inc.: Lafourche, Plaquemines, St. Charles, and Terrebonne. The NFHL is available for download from the FEMA Flood Map Service Center Link. Milliman used the NFHL as of January 2018.

UNITED STATES ARMY CORPS OF ENGINEERS NATIONAL LEVEE DATABASE

The United States Army Corps of Engineers ("USACE") National Levee Database ("NLD") is a congressionally authorized database that contains information on locations, general condition, and risks associated with the levees throughout the United States. Milliman obtained the NLD directly from USACE on May 29, 2020.

UNITED STATES ARMY CORPS OF ENGINEERS GREAT LAKES WATER LEVEL DATA

The USACE publishes short-term and long-term average, maximum, and minimum water levels for the Great Lakes, updated on a monthly basis. This data is available from the USACE Detroit District's website Link. Milliman accessed this data in December 2019.

GIS LAYERS

This section provides a list and an explanation of how each GIS dataset used in RR2.0 was developed. Table 1 lists the GIS datasets along with their names or naming conventions, and their original source datasets.

Table 1: GIS Datasets Used in RR2.0

GIS Dataset	Database Name(s)	Source Data
Elevation Rasters	*Named by 1-degree tile*	1/3 arc-second DEM 1 arc-second DEM
Focal 50 Rasters	*Named by 1-degree tile or by state*	1/3 arc-second DEM 1 arc-second DEM
Barrier Island	BarrierIsland	NHD
Coast	Coast	NHD NFHL NOAA National Shoreline NCCOS Shoreline Shapefiles
Ocean	Ocean	NHD
Great Lakes	GreatLakes	NHD USACE Great Lake Water Level Data
HUC12	WBDHU12	WBD
Flowlines	*Named by HUC4* e.g. Flowlines_<*HUC4*>	NHDPlus HR Beta NHDPlus V2 WBD KatRisk
River Polygons	*Named by HUC4* e.g. RiverPolys_<*HUC4*>	NHD WBD KatRisk
Alaska HUC12	WBDHU12_AK	WBD
Alaska Riverlines	Riverlines_AK	5m AK DEM WBD KatRisk
Alaska River Polygons	RiverPolys_AK	NHD WBD KatRisk
Leveed Areas	LeveedAreas	USACE NLD
Census Blocks	tl_2017_a_us_block	Census TIGER/Line Files

ELEVATION RASTERS

Data type: Raster
Description: Elevation in meters
Coverage extent: All states and territories. The lower resolution 1 arc-second tiles are only used along the U.S.-Canada and U.S.-Mexico borders as well as Alaska to provide additional coverage where the 1/3 arc-second data is not available.
Processing steps: No pre-processing was needed.

FOCAL 50 RASTERS

Data type: Raster
Description: Average elevation within an approximately 500 meter radius
Coverage extent: All states and territories
Processing steps: For CONUS, focal 50 rasters were created on a statewide basis by mosaicking all the necessary 1-degree raster tiles; for Alaska, Hawaii, and the Island Territories, focal 50 rasters were created on a 1-degree raster tile basis. Focal 50 rasters were calculated as the average ground elevation of all raster cells with a centroid within an approximately 500 meter radius of each input raster cell. If there was NoData coverage in any portion of the radius, the output for that cell was NoData. For NoData water areas, we assumed that the input elevation was 0 to allow for calculations along shorelines.

BARRIER ISLAND

Data type: Vector
Description: Outlines the extent of all coastal barrier islands, barrier spits, and additional coastal areas surrounded by mainland waterways
Coverage extent: TX, MS, AL, FL, GA, SC, NC, VA, MD, DE, NJ, and NY
Processing steps: Barrier islands were manually delineated by drawing polygons around selected land features based on NHD water areas. All island areas completely detached from the mainland and land areas that extend into open water and attached to the mainland at only one end were included, as well as additional similar landforms.

COAST

Data type: Vector
Description: Coast
Coverage extent: All states and territories
Processing steps: The coastal features for all states and territories excluding CA, OR, WA, and AK were based on a selection of coastal features and near-coastal waterways from the NHD. This dataset was modified to include or exclude water features based on their spatial contiguity to all NFHL VE Special Flood Hazard Area Zones and selected AE Special Flood Hazard Zones where Static Base Flood Elevation is less than or equal to 30 feet. In areas where there was no effective

NFHL, preliminary, or pending data, available digitized zones were used instead. Note that some coastal areas did not have NFHL coverage and, as such, feature contiguity with NFHL zones could not be considered in these areas.

The coastal features for CA, OR, WA, and AK were based on only a selection of coastal features from the NHD (SeaOcean, BayInlet, and Estuary) and do not include near-coastal waterways based on contiguity to NFHL zones.

Since the NHD does not have coverage for the Islands of Rota and Tinian in the Northern Mariana Islands (MP) and portions of the Pribilof Islands in AK, we supplemented the NHD with NCCOS Shoreline Shapefiles for MP and the NOAA National Shoreline for AK.

Coastal features for CONUS were based on a version of the NHD downloaded in Q1 2018; Coast features for AK, HI, and the island territories are based on a version of the NHD downloaded on August 9, 2018. Extensive manual evaluation and editing of raw source data were necessary when creating coastline features.

OCEAN

Data type: Vector
Description: Ocean
Coverage extent: Gulf and Atlantic States, CA, OR, and WA
Processing steps: The Ocean dataset was derived from NHDArea SeaOcean features as a starting point and then modified to include only the outer seaward edge of barrier islands or major land areas if no barrier island system was present. Ocean features were based on a version of the NHD downloaded on August 9, 2018.

GREAT LAKES

Data type: Vector
Description: Great Lakes
Coverage extent: MN, WI, IL, IN, MI, OH, PA, and NY
Processing steps: The Great Lakes dataset was derived by selecting and merging all NHD Waterbody polygons identified as “Lake Erie”, “Lake Huron”, “Lake Michigan’, “Lake Ontario”, or “Lake Superior” within the Great Lakes region. The average water surface elevation for each lake was assigned as the 2018 long-term water level as published by the USACE. The USACE water surface elevation values were projected from International Great Lakes Datum of 1985 to North American Vertical Datum of 1988 (“NAVD88”) to ensure appropriate comparison to ground elevation data. Great Lake features were based a version of the NHD downloaded on August 9, 2018.

HUC12

Data type: Vector
Description: Boundaries of 12-digit Hydrologic Units Codes ("HUC12") sub-watersheds
Coverage extent: All states and territories excluding AK
Processing steps: None – the WBDHU12 was extracted directly from the WBD published on April 18, 2020.

FLOWLINES

Data type: Vector
Description: Routes that make up the linear surface water drainage network
Coverage extent: All states and territories excluding AK
Processing steps: There are currently 223 separate flowline feature classes, one for each HUC4 within the "coverage extent" where features matching selection criteria were present. To prepare a flowline dataset for a given HUC4 we:

- Downloaded the most recently available NHDPlus geodatabase for the HUC4. If no NHDPlus HR Beta data was available, we downloaded the NHDPlus V2 data for that region.
- Joined the NHDPlus Flowline Value-Added Attribute table (NHDPlusFlowlineVAA) table to the NHDFlowline feature class by NHDPlusID. The NHDPlusFlowlineVAA table provides a number of pre-calculated flow network statistics for the NHD flowline network.
- Selected all NHDFlowline features where divergence-routed drainage area (DivDAsqKm) was greater than or equal to 1 sq. km and the feature type (FType) was a StreamRiver or ArtificialPath (query: DivDAsqKm ≥ 1 AND FType in (460, 558)). These represent drainage channels that have a minimum upstream area of 1 square kilometer.
- Removed artificial path flowlines within the extent of the Great Lakes polygons to ensure the Great Lakes did not get selected as a River Polygon (see "River Polygons" below). Intersected flowlines with the WBDHU12 dataset.
- Calculated the KatRisk flood depth difference for each feature. Depth difference was defined as the average 100-year return period flood depth minus the average 10-year return period flood depth along the extent of the feature.

RIVER POLYGONS

Data type: Vector
Description: All NHDArea StreamRiver polygons and select NHDArea LakePond features
Coverage extent: All states and territories excluding AK
Processing steps: There are currently 223 separate river polygon feature classes, one for each HUC4 within the coverage extent where features matching selecting criteria were present. To prepare a river polygon dataset for a given HUC4 we:

- Selected all NHDArea StreamRiver features that intersected the given HUC4.
- Selected all NHDArea LakePond features that intersected a filtered flowline within the HUC4.
- Merged the selected StreamRiver and LakePond features into a single RiverPolys feature class.
- Intersected the river polygons with the WBDHU12 dataset.
- Converted the river polygons to single part features and added a new unique identifier field.
- Calculated the KatRisk flood depth difference for each feature. Depth difference was defined as the average 100-year return period flood depth minus the average 10-year return period flood depth along the extent of the feature.

River Polygons were based a version of the NHD and WBD that was downloaded on April 23, 2020.

ALASKA DISTANCE TO RIVER FEATURES

NHDPlus HR Beta was in development for Alaska and therefore the datasets for Distance to River queries in Alaska were based on a raster-derived flow model instead of the NHDPlus HR Beta filtered flowlines. The three datasets listed below are only for use in Alaska.

ALASKA HUC12

Data type: Vector
Description: Boundaries of HUC12 sub-watersheds in Alaska
Coverage extent: AK
Processing steps: We extracted the WBDHU12 directly from the WBD downloaded on July 26, 2018 and selected only HUC12s within the state of Alaska.

ALASKA RIVERLINES

Data type: Vector
Description: Flow model derived riverlines
Coverage extent: AK
Processing steps: The riverlines in Alaska were developed by Atkins at the request of FEMA and supplied to Milliman on October 4, 2019. The process to create these riverlines was as follows:

- Mosaicked together the highest-resolution available DEM rasters.
- Created flow accumulation and flow direction rasters from the mosaicked DEMs.
- Utilized the flow accumulation and flow direction rasters to create stream features with a minimum flow accumulation of 1 sq. km.

- Calculated the KatRisk flood depth difference for each feature. Depth difference was defined as the average 100-year return period flood depth minus the average 10-year return period flood depth along the extent of the feature.

ALASKA RIVER POLYGONS

Data type: Vector
Description: All NHDArea StreamRiver polygons and NHDArea Lake/Pond features intersected by a riverline
Coverage extent: AK
Processing steps: To prepare the River Polygons for Alaska we:

- Selected all NHDArea StreamRiver features that intersected the state of Alaska.
- Selected all NHDArea Lake/Pond features that intersected an AK riverline.
- Merged the selected StreamRiver and LakePond features into a single RiverPolys feature class.
- Intersected the RiverPolys with the WBDHU12_AK dataset.
- Converted the RiverPolys to single part features and added new a unique identifier field.
- Calculated flood depth difference for each feature. Depth difference was defined as the average 100-year return period flood depth minus the average 10-year return period flood depth along the extent of the feature.
- Alaska River Polygons are based a version of the NHD that was downloaded on April 23, 2020.

LEVEED AREAS

Data type: Vector
Description: Polygons representing areas protected by levees
Coverage extent: All U.S. states and territories
Processing steps: None – data was received directly from USACE.

CENSUS BLOCKS

Data type: Vector
Description: Polygons representing Census Block boundaries as of 2017
Coverage extent: All U.S. states and territories
Processing steps: None – data was downloaded directly from the U.S. Census.

QUERY PROCESS

This section provides an overview of how each GIS dataset is queried to obtain a rating variable for a given policy location. Table 2 lists each GIS rating variable and its corresponding GIS source dataset(s).

For all queries, it is assumed that input the latitude and longitude references the North American Datum of 1983 ("NAD83") coordinate system.

Table 2: GIS Rating Variables

Rating Variable	Variable Name	Source Dataset(s)
Ground Elevation	Elevation	Elevation rasters
Focal 50	Focal50	Focal 50 rasters
Barrier Island	BarrierIsland	Barrier Island
Distance to Coast	DTC	Coast
Distance to Ocean	DTO	Ocean
Distance to Great Lake	DTL	Great Lakes
Elevation Above Lake	ElevAboveLake	Elevation rasters
Hydrologic Unit 12	HUC12	Hydrologic Unit 12
Distance to River	DTR	Flowlines Riverlines River Polygons
Drainage Area	DrainageArea	Flowlines
Flood Depth Difference	DepthDiff	Flowlines River Polygons
Elevation Above River	ElevAboveRiver	Elevation rasters
Leveed Area System ID	SystemID	Leveed Areas
Census Block ID	CensusBlock	Census Blocks

GROUND ELEVATION

Query the appropriate raster tile. If no 1/3 arc-second data is available for a given latitude/longitude, use the 1 arc-second data instead.

FOCAL 50

Query the appropriate focal 50 raster. If there is no focal 50 raster based on 1/3 arc-second data available for a given latitude/longitude, use the focal 50 raster based on the 1 arc-second data.

BARRIER ISLAND

Query the Barrier Island polygons using a spatial join. If the input location is within a Barrier Island polygon, assign BarrierIsland as Yes; otherwise assign as No.

DISTANCE TO COAST

If the input state is a coastal state (AK, AL, AS, CA, CT, DC, DE, FL, GA, GU, HI, LA, MA, MD, ME, MP, MS, NC, NH, NJ, NY, OR, PA, PR, RI, SC, TX, VA, VI, WA), calculate the geodesic distance to the nearest Coast polygon within 50 miles. If the input state is not a coastal state or the geodesic distance to the nearest Coast polygon is greater than 50 miles, then Distance to Coast is null.

DISTANCE TO OCEAN

If the input state is CA, OR, or WA and Distance to Coast is not null, calculate the geodesic distance to the nearest Ocean polygon. If the input state is AL, DE, FL, GA, MD, MS, NC, NJ, NY, SC, TX, or VA and BarrierIsland indicator is “Yes”, then calculate the geodesic distance to the nearest Ocean polygon. If none of these are conditions are met, then Distance to Ocean is null.

DISTANCE TO GREAT LAKE

If input state is MN, WI, IL, IN, MI, OH, PA, or NY, calculate the geodesic distance to the nearest Great Lakes polygon within 10 kilometers. If the input state is not MN, WI, IL, IN, MI, OH, PA, or NY, or the geodesic distance to the nearest Great Lakes polygon is greater than 10 kilometers, then Distance to Great Lake is null.

ELEVATION ABOVE LAKE

If Distance to Great Lake is not null, select the water surface elevation of the nearest Great Lakes polygon within 10 kilometers. Subtract the water surface elevation value from the location’s ground elevation value to obtain the elevation of the risk above the lake. If Distance to Great Lake is null, then Elevation Above Lake is null.

HYDROLOGIC UNIT 12

Query the appropriate HUC12 polygons using a spatial join.

DISTANCE TO RIVER

Calculate the geodesic distance to the nearest river feature (line or polygon) within a location's corresponding HUC12.

DRAINAGE AREA

This is the Drainage Area of the nearest flowline within a location's corresponding HUC12. Drainage Area is not available for Alaska or the island territories.

FLOOD DEPTH DIFFERENCE

This is the Flood Depth Difference of the nearest river feature (line or polygon) within the location's corresponding HUC12.

ELEVATION ABOVE RIVER

Determine the latitude and longitude coordinate of the nearest point on the nearest river feature (nearest river point). Query the appropriate raster tile to determine the ground elevation of the near river point. Subtract the elevation of the nearest river point from the ground elevation of the risk to determine the risk's Elevation AboveRiver.

LEVEED AREA SYSTEM ID

Query the Leveed Area polygons using a spatial join. If the location is within a Leveed Area polygon, assign it the System ID of the associated Leveed Area polygon.

CENSUS BLOCK

Query the Census Block polygons using a spatial join. Assign Census Block as the 15-digit GEOID of the associated polygon.

ADDITIONAL GIS ANALYSIS USED IN RATING PLAN DEVELOPMENT: HUC12 TERRITORY FACTOR FILLING

Rating territories were based on HUC12 and Barrier Island indicators (i.e., Yes or No) for non-leveed areas and on HUC12 and Levee Area System ID for leveed areas. A territory factor was developed for each combination of HUC12 and Barrier Island indicator (HUC12/BarrierIsland) and each HUC12 and Leveed Area (HUC12/LeveedArea) combination, based on the Correlated Market Basket.

The Correlated Market Basket is a representative sample of single-family homes with property and coverage characteristics that generally reflect the distributions of those characteristics in each state/territory. Since there were not Market Basket locations in every HUC12/BarrierIsland and HUC12/Leveed Area combination, a process called "HUC12 factor filling" was used to assign factors to combinations where no territory factors could be directly developed due to a lack of market basket locations. Table 3 describes the filling process for each peril in cases where a territory factor was missing. In these cases, the best available value was assigned using the territory factor fill options listed in Table 3 by order of preference. The remainder of this section describes the feature and neighborhood relationship table creation process.

Table 3: Process to Fill Missing Territory Factors by Area and Peril

Area	Peril	Features to Fill	Neighborhood Definition	Territory Factor Fill Value
Non-Leveed	Inland Flood	All HUC12	Hydrologic	1) Policy count weighted average factor of 1st order neighbors 2) Policy count weighted average factor of 2nd order neighbors 3) Policy count weighted average factor of 3rd order neighbors 4) Default value: 1
Non-Leveed	Non-Mainland Storm Surge	HUC12 on barrier islands	Polygon	1) Policy count weighted average factor of 1st order neighbors 2) Policy count weighted average factor of 2nd order neighbors 3) Policy count weighted average factor of 3rd order neighbors 4) Factor of same HUC12 for non-BarrierIsland 5) Default value: 1
Non-Leveed	Mainland Storm Surge	HUC12 within 50 miles of coast	Polygon	1) Policy count weighted average factor of 1st order neighbors 2) Policy count weighted average factor of 2nd order neighbors 3) Policy count weighted average factor of 3rd order neighbors 4) Factor of same HUC12 for BarrierIsland 5) Default value: 1
Non-Leveed and Leveed	Tsunami	CA/OR/WA: HUC12 within 10 miles of ocean AS: HUC12 within 1 mile of coast GU/MP: HUC12 within 2 miles of coast HI: HUC12 within 3 miles of coast AK: HUC12 within 3 miles of coast	Polygon	1) Policy count weighted average factor of 1st order neighbors 2) Policy count weighted average factor of 2nd order neighbors 3) Policy count weighted average factor of 3rd order neighbors 4) Default value: 1
Non-Leveed and Leveed	Great Lakes	HUC12 within 10 kilometers of Great Lakes	Polygon	1) Policy count weighted average factor of 1st order neighbors 2) Policy count weighted average factor of 2nd order neighbors 3) Policy count weighted average factor of 3rd order neighbors 4) Default value: 1
Leveed	Inland Flood	All HUC12	Hydrologic	1) Policy count weighted average factor of 1st order neighbors 2) Policy count weighted average factor of 2nd order neighbors 3) Policy count weighted average factor of 3rd order neighbors 4) Default value: 1
Leveed	Inland Flood	All LeveedAreas split by HUC12 (HUC12/LeveedArea)	n/a	1) Policy count weighted average factor for LeveeArea System ID 2) Factor for same HUC12 2) Filled factor for same HUC12
Leveed	Mainland Storm Surge	HUC12 within 50 miles of coast	Polygon	1) Policy count weighted average factor of 1st order neighbors 2) Policy count weighted average factor of 2nd order neighbors 3) Policy count weighted average factor of 3rd order neighbors 4) Default value: 1
Leveed	Mainland Storm Surge	All LeveedAreas split by HUC12 (HUC12/LeveedArea) within 50 miles of coast	n/a	1) Policy count weighted average factor for LeveeArea System ID 2) Factor for same HUC12 3) Filled factor for same HUC12

SELECTING FEATURES TO FILL

Table 3 lists the appropriate spatial filters by area (leveed or non-leveed) and peril used when determining which HUC12/BarrierIslands and HUC12/LeveedAreas feature combinations require filled factors. To determine the HUC12/BarrierIsland features, we spatially intersected the HUC12 polygons with Barrier Island polygons; to determine the HUC12/LeveedArea features, we spatially intersected the HUC12 polygons with the Leveed Areas polygons (see Figure 1 for example). Note that for filling features in Alaska, we used the WBDHUC12_AK dataset; for filling features everywhere else, we used the WBDHU12 dataset.

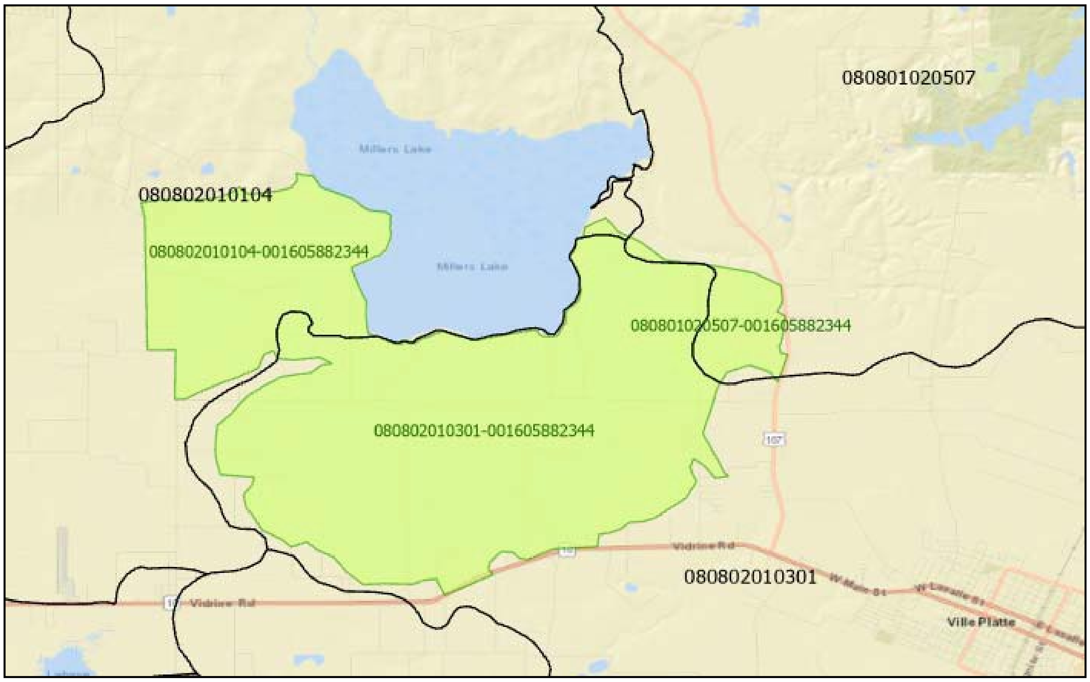

Figure 1 Example of HUC12/Leveed area combinations. LeveedArea 001605882344 (in green) is split by 3 HUC12s (black outlines), and therefore becomes 3 separate features to fill.

NEIGHBORHOOD RELATIONSHIP TABLES

Hydrologic Neighbors: A HUC12's hydrologic neighbors include the HUC12s to which a given HUC12's water flows to and from (see Figure 2 for example). To determine the 1st order hydrologic neighbors for all HUC12s, we exported the "HUC12" and "ToHUC" fields from the WBDHU12 attribute table in the WBD. Then we assigned each HUC12 its ToHUC(s) and determined which HUC12(s) its flow comes from (defined as "FromHUC"). 1st order hydrologic neighbors for a given HUC12 include all of its ToHUCs and FromHUCs; 2nd order neighbors are its neighbors' neighbors; 3rd order neighbors are its neighbors' neighbors' neighbors. Note that some HUC12s may not have any hydrologic neighbors as they have no inflow or outflow. Additionally, some HUC12s flow to Mexico, Canada, and the ocean. Any ToHUC listed as "Mexico", "Canada", "Ocean", or "Closed Basin" was excluded when building the neighborhood tables.

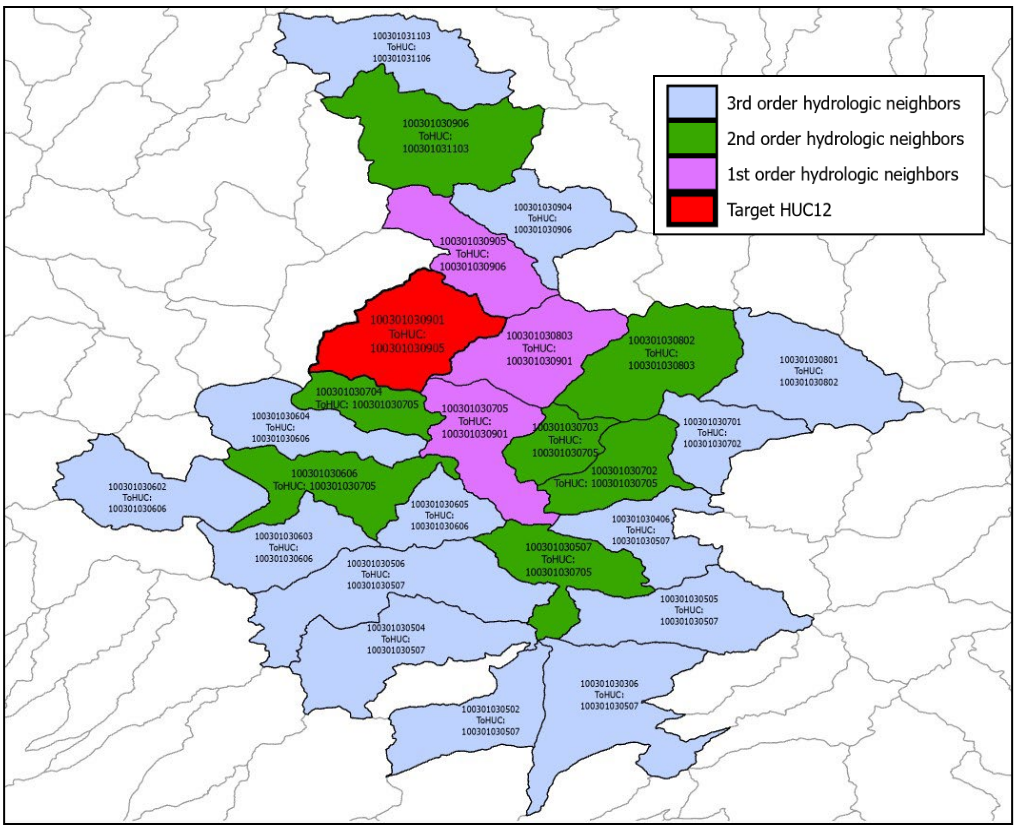

Figure 2 Representation of hydrologic neighbors for HUC12 100301030901.

Polygon neighbors: HUC12 polygon neighbors are those HUC12s that are contiguous to the selected HUC12 (see Figure 3 for example). Note that some HUC12s may have no polygon neighbors. 1st order polygon neighbors for a given HUC12 include all HUC12s with which it shares a boundary; 2nd order neighbors are its neighbors' neighbors; 3rd order neighbors are its neighbors' neighbors' neighbors.

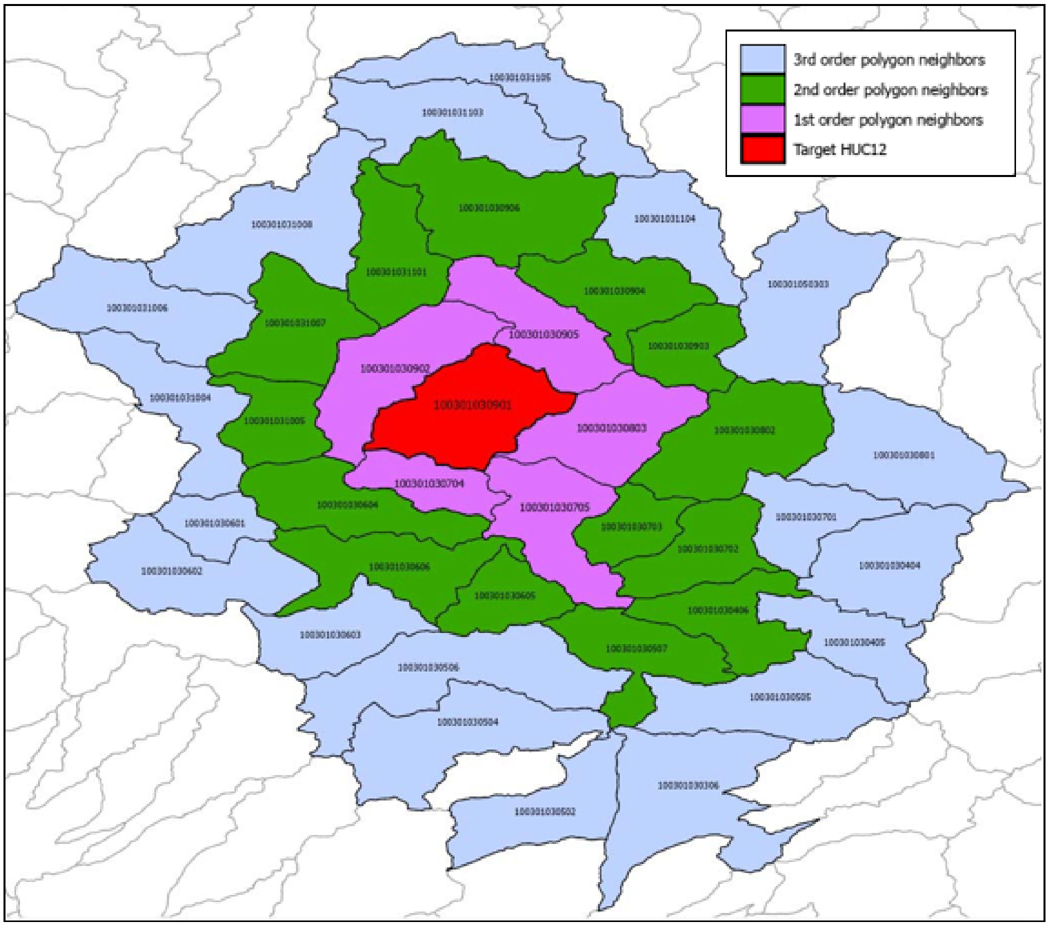

Figure 3 Representation of polygon neighbors for HUC12 100301030901.

APPENDIX B - Market Basket Variable Imputation

Table of Contents

Table A. Correlated Market Basket Fields 1
Table B. Uncorrelated Market Basket Fields 3

TABLE A. CORRELATED MARKET BASKET FIELDS

Characteristic	Data Source	Filling Method
Year Built	Parcel data[1]	Missing values simulated using distribution by county. For counties with insufficient data, missing values simulated using distribution by state.
Number of Stories	Parcel data	Missing values simulated by distribution by state and year built.
Construction	Parcel data	Missing values simulated by distribution by state and year built. For states with insufficient data, missing values simulated from neighboring state's distribution by year built.
Foundation Type	Hazus[2], 2009 Residential Energy Consumption Survey[3]	Missing values simulated from distribution by state, Census Block type (coastal, riverine, or lake, as defined by Hazus), flood zone, year built, elevation, and base flood elevation.
First Floor Height	Hazus	Imputed based on elevation, base flood elevation, foundation type, and year built.
Dwelling Value	FEMA NAIC report[4]	Modeled based on ZIP Code, year built, number of stories, and flood zone, and adjusted based on distributions of amount of insurance by state from NAIC report. Dwelling Value was further restricted to be greater than Dwelling Limit.
Dwelling Limit	FEMA	Modeled using state and Dwelling Value. Randomly set 5% of policies to $0 Dwelling Limit to represent Contents-only policies, based on FEMA data. Dwelling Limit was capped at $250,000 and restricted to be at least $1,000 greater than Dwelling Deductible.
Contents Value	Calculated	Contents Value based on Dwelling Insurance to Value ("ITV") ratio and Contents Limit.
Contents Limit	FEMA	Contents Limit as a percentage of Dwelling Limit (Contents Limit %) was simulated using distribution by state in 5% increments. Randomly set 20% of policies to $0 Contents Limit, based on FEMA data, to represent Dwelling-only policies. Contents Limit set as Dwelling Limit times

		Contents Limit %, capped at a maximum of $100,000. Contents Limit was further restricted to be at least $1,000 greater than Contents Deductible, and no policies were allowed both $0 Dwelling Limit and $0 Contents Limit.
Dwelling Deductible	FEMA	Randomly assigned 25% of the policies a $1,250 Dwelling Deductible and $1,250 Contents deductible. All other combinations of Dwelling/Contents Deductibles were assigned randomly with equal weight. Finally, the Deductibles were capped according to NFIP's minimum deductible rule.
Contents Deductible	FEMA	Randomly assigned 25% of the policies a $1,250 Dwelling Deductible and $1,250 Contents deductible. All other combinations of Dwelling/Contents Deductibles were assigned randomly with equal weight. Finally, the Deductibles were capped according to NFIP's minimum deductible rule.
Equipment in Basement	None	Set to No.
Finished Basement	None	Set to No. All basements simulated in the market basket are considered unfinished.
Detached Structures Limit	None	Set to 0.
Loss of Use Limit	None	Set to 0.

Notes

1. Parcel data refers to CoreLogic ParcelPoint data provided to Milliman by FEMA.
2. Hazus refers to "Hazus – MH, Multi-hazard Loss Estimation Methodology, Flood Model Technical Manual", developed by FEMA.
3. "2009 Residential Energy Consumption Survey" from U.S. Energy Information Administration.
4. NAIC report refers to "Dwelling Fire, Homeowners Owner-Occupied, and Homeowners Tenant and Condominium/Cooperative Unit Owner's Insurance Report: Data for 2015" issued by National Association of Insurance Commissioners.

TABLE B. UNCORRELATED MARKET BASKET FIELDS

Characteristic	Filling Method
Year Built	Simulated from uniform distribution from 1900 to 2017.
Number of Stories	Simulated from uniform distribution of 1, 2, and 3.
Construction	Simulated from uniform distribution of Frame and Masonry.
Foundation Type	Simulated from uniform distribution of Pile, Wall, Pier, Basement, Crawlspace, Fill, and Slab.
First Floor Height	Based on Foundation Type. Foundation type and first floor height have a necessary relationship and are therefore not decoupled in the uncorrelated book.
Dwelling Value	Simulated on uniform distribution from min to max Correlated Market Basket Dwelling Value by state.
Dwelling Limit	Simulated on uniform distribution from $0 to $250,000, with 5% set to $0. Dwelling Limit was further restricted to be at least $1,000 greater than Dwelling Deductible.
Contents Value	Simulated on uniform distribution from min to max Correlated Market Basket Contents Value by state.
Contents Limit	Simulated on uniform distribution from $0 to $100,000, with 20% set to 0. Contents Limit was further restricted to be at least $1,000 greater than Contents Deductible. No policies were allowed $0 Dwelling and Contents Limits.
Dwelling Deductible	Simulated on uniform distribution of all combinations of Dwelling/Contents Deductibles. Deductibles are capped according to NFIP's minimum deductible rule.
Contents Deductible	Simulated on uniform distribution of all combinations of Dwelling/Contents Deductibles. Deductibles are capped according to NFIP's minimum deductible rule.
Equipment in Basement	Set to No.
Finished Basement	Set to No. All basements simulated in the uncorrelated book are considered unfinished.
Detached Structures Limit	Set to 0.
Loss of Use Limit	Set to 0.

APPENDIX C - Uniform Book Assumptions

TABLE 1. UNIFORM BOOK ASSUMPTIONS

Characteristic	Value
Dwelling Value	$200,000
Dwelling Limit	$200,000
Dwelling Deductible	$1,500
Contents Value	$50,000
Contents Limit	$50,000
Contents Deductible	$1,500
Construction Type	Frame
Basement	No
Year Built	1990
Number of Stories	1
First Floor Height	1 foot