WiNGS-Planning Assurance Report

May 23, 2023

Bringing Ingenuity to Life.
paconsulting.com

Denver Office

PA Consulting Group Inc.
Suite 3550
1700 Lincoln Street
Denver
CO 80203
USA
+1 720 566 9920

paconsulting.com

Prepared by: PA Consulting, Inc.

Version: FINAL

Figures

Tables

Executive Summary

PA Consulting (PA) was engaged by San Diego Gas & Electric's (SDG&E) Wildfire Mitigation team to conduct an independent review of the Wildfire Next Generation (WiNGS) models. In this report, PA covers the findings and recommendations for the WiNGS-Planning model. WiNGS-Planning is utilized to assess SDG&E wildfire risk, and to identify potential mitigation solutions to reduce the wildfire risk. WiNGS-Planning develops recommendations for either undergrounding or covered conductor mitigation options to help inform SDG&E Capital Planning process to meet its wildfire risk reduction targets. This model has involved utilizing industry and domain-specific assumptions to generate inputs and derive calculations to drive an optimized output. This model also uses a wide array of disparate data sources to ensure a thorough and encompassing view of the network is included. PA Consulting finds that the WiNGS-Planning model has become more matured, better documented, and presents an effective tool for use in Capital Planning for Wildfire Mitigation, and meets the regulatory requirements outlined in the California Office of Energy Infrastructure Safety 2023-2025 Wildfire Mitigation Plan Technical Guidelines. SDG&E's Wildfire Mitigation Strategy team is well aligned and have built and maintain the model with a level of competence in keeping with the quality of the end product. Prior independent assessment recommendations were followed through (or in process of following through), and improvements are being developed and deployed on an iterative basis.

PA has applied its proprietary Artificial Intelligence Assurance Framework (AI Assurance Framework) in this independent review to assess the end-to-end process utilized for model initiation, development and operation. This review is focused on establishing if industry best practices for the deployment of Artificial Intelligence (AI) and Machine Learning (ML) have been adhered to and looks to provide recommendations for improvements to be made to the WiNGS-Planning model. The output of the review is captured in detail across the following sections which are structured in the same manner as the AI Assurance Framework. The AI Assurance Framework is results focused, and as such, we associated severity levels on the recommendations, from the perspective of potential of impact to output should recommendation not be implemented.

The WiNGS-Planning model is a robust model which meets user needs and performs the function for which it was designed. There are two broader recommendations from the review that would require a larger planning and implementation effort. These are for development of an enterprise-wide data governance function and an overall WiNGS-Planning model refresh. An enterprise-wide data governance function can ensure that all data inputs and calculations are documented, understood and kept up to date, thus ensuring greater trust and understanding in the WiNGS-Planning model and its outputs. Some of WiNGS-Planning model inputs were found to have not been refreshed recently, and a number of assumptions were less than fully documented or explained. A model refresh might be necessary to ensure that WiNGS-Planning output and calculations are based on most accurate and up to date inputs and assumptions.

PA found no High severity issues that could change the output of the model (e.g. change mitigation option recommendations), and have made a number of recommendations for future enhancement. The majority of findings have been assessed as severity level "Low" and are focused on best practice model development practices.

The "Medium" severity items were mainly in the data input and assumptions area where legacy assumptions were used and there is less certainty if the assumptions are still valid for the period the WiNGS-Planning is being used calculate risk and recommend mitigations for. There were several recommendations based on lack of documented assumptions, a missing clarity on the input's purpose, lack of validation of the data inputs and calculations which could lead to erroneous results, and lack of up-to-date data inputs which mean outputs could be based on an inaccurate representation of the current situation. Finally, the lack of sensitivity analysis (making recommendations particularly sensitive to certain underlying drivers) and testing (unit testing to confirm modules of model functioning exactly as intended) are also classified as "Medium" severity.

With full understanding and consideration of the recommendations contained in this document, the SDG&E Wildfire Mitigation Team's WiNGS-Planning model is well-placed to calculate the utility's wildfire risks, and meet the needs of the utility's Capital Planning effort for Wildfire Mitigation.

1 Introduction

San Diego Gas & Electric's (SDG&E) Wildfire Mitigation teams have been utilizing Data Science techniques and technologies to create advanced models for risk and investment planning purposes. These models are data assets in use for Capital Planning and Operational purposes. Each of these models have involved utilizing industry and domain-specific assumptions to generate inputs and derive calculations to drive an optimized output. These models also use a wide array of disparate data sources to ensure a thorough and encompassing view of the network is included. These models are both referred to as the Wildfire Next Generation System (WiNGS) models. SDG&E engaged PA Consulting to perform the independent third-party review on two models. The two main models discussed for initial review are mentioned below with this report forming the output of the review of the WiNGS-Planning model:

- WiNGS-Planning: This model, hosted in AWS, is utilized for investment planning purposes. One of the main sources of data involved is a historic Ignition Model, based on mileage of overhead conductors. Other variables are included based on wind probability assumptions. A Decision Matrix is utilized for final output of model for use by investment teams.
- WiNGS-Ops: This is a risk-based model for more real-time determination of the risk posed to the network in wildfire season. This model has a strong Machine Learning component and is time-series based. The model has been released and is operating in AWS Sagemaker.

With the exponential increase in data, organizations are leveraging Artificial Intelligence (AI) and Machine Learning (ML) to identify insights and help make data driven decisions. These data science projects can be a catalyst for organizational strategy and objectives. However, it is also vital that these projects prove to be reliable and trustworthy. PA's AI Assurance Framework follows industry best practices for the deployment of AI and ML by reviewing and providing evidence on how they are governed and managed. PA's general assurance framework is designed to provide assurance that the models are well documented, has the trust of its business owners, inputs and limitations are well understood, algorithms are secure (against unapproved or un-intentional changes), and they work as intended. The PA Consulting team applied this framework to the independent review of SDG&E's WiNGS models.

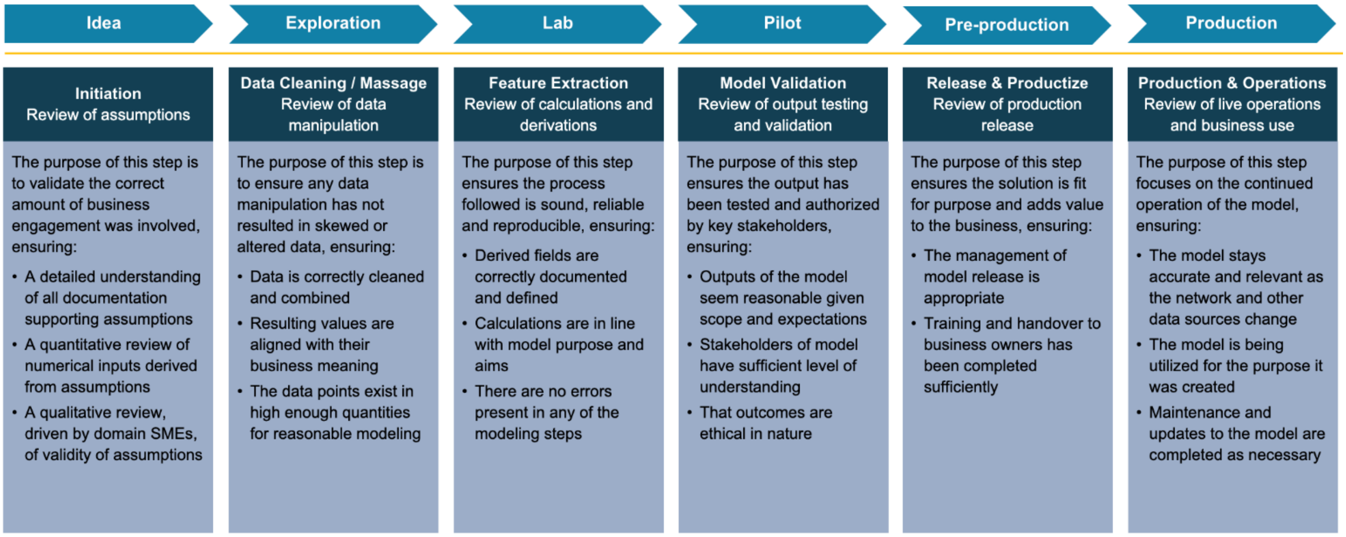
1.1 AI Assurance Framework and Approach

The PA AI Assurance Framework is designed to review an organization's AI system for best practices and risks, ensuring trust in the end solution. The results of the evaluation are aimed to help foster the responsible design, development, deployment, and use of those AI systems over time.

The framework steps through each stage of the algorithm lifecycle to investigate common underlying risks, identify controls to mitigate these risks, and detect evidence required to prove these controls are in place. At each stage, discussions with the relevant stakeholders are performed to understand the approach and methods in place, with the stakeholder answer questions and providing proof while walking through pertinent documentation, datasets, code, repositories, final deliverables, and IT environments.

Figure 1 below shows the stages of PA's AI Assurance framework which were followed during the review of the WiNGS-Planning model. These modular areas of focus look to cover the full model development lifecycle from Initiation and problem formulation through to release, production runs and use by the end business users.

Figure 1: PA's AI Assurance Framework



Each of these stages aims to focus on a specific part of the modelling process. Table 1 found on the next page describes each stage's process objectives and the overall risk that can be introduced when not following best practice:

Table 1: AI Assurance Framework stages and objectives

Stage	Potential Risk	Overall Process Objective
Initiation	Lack of business engagement	Ensure the business takes full sponsorship of the project: provide necessary resources during the project and after go-life
Data collection	Inaccurate data collection	Ensure that complete and adequate data is selected and used as input for the data model and corrections are properly made based on (plausibility) checks and appropriate approval
Data cleaning	Inaccurate data cleaning	Ensure that data is correctly cleaned and combined, such that the relevant data is appropriately formatted, has values that are aligned with their business meaning, and exists in high enough quantities for the prospective model
Feature extraction	Inadequate feature extraction	Ensure that features are extracted in a sound (reliable, accurate and reproducible) way and operates within the boundaries of applicable rules and regulations
Model selection/ training	Inadequate selection/training	Ensure that the model is selected and trained in an adequate way so that it makes correct, justified and predictable decisions
Model testing	Inadequate testing	Ensure that testing is adequately performed and documented so that errors and mistakes are identified and solved before the solution is set to production
Model validation	Model not validated	Ensure that the model is validated and authorized by key decision makers
Release & productize	Not fit for purpose	Ensure that the solution fits its purpose and continuously adds value to the business
Production & operations	Model becomes inaccurate (drift)	Ensure that the solution stays accurate, predictable, without drift
Feedback & Learning	No feedback & learning to improve the model	Ensure that feedback and continuous learning loops are in place so that the model improves continuously
Retire	Inadequate ‘close down’ of solution	Ensure that the solution can be maintained by the right people, is properly handed-over to the business and is documented in an easy and complete way

Throughout the independent review, findings are captured, and recommendations are made. The criticality of the potential impact which a recommendation aims to remediate is defined in

Table 2 below:

Table 2: Impact criticality definitions

Potential Criticality	Definition
H	Likely to change recommended mitigation for given segment.
M	Over/under state risk for segment, may change ranking or overall recommended portfolio (displacement of other segments)
L	Unlikely to change recommendation by segment or portfolio

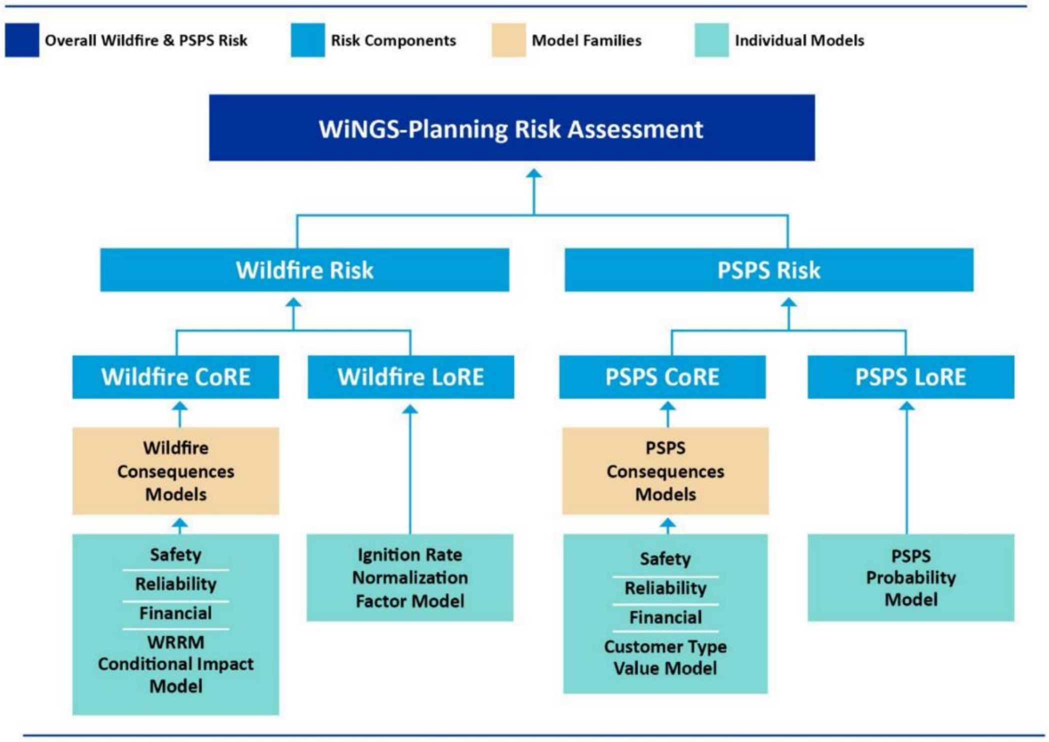
1.2 Regulatory requirements

This independent review of WiNGS-Planning is conducted to meet requirements outlined in Section 6.6 Quality Assurance and Control and Appendix B – Model Substantiation, of the Office of Energy Infrastructure Safety’s (OEIS) 2023-2025 Wildfire Mitigation Plan Technical Guidelines (WMP Technical Guidelines) Documentation. This review of model substantiation is aimed to ensure that a model is correct and suitable for its purposes, understood by the users, and validated. We conclude the model is used and useful, and follows the requirements of the WMP Technical Guidelines.

1.2.1 Risk assessment framework and calculation schematic

The WiNGS-Planning model follows the WMP Technical Guideline’s method to determine the risks that SDG&E faces.

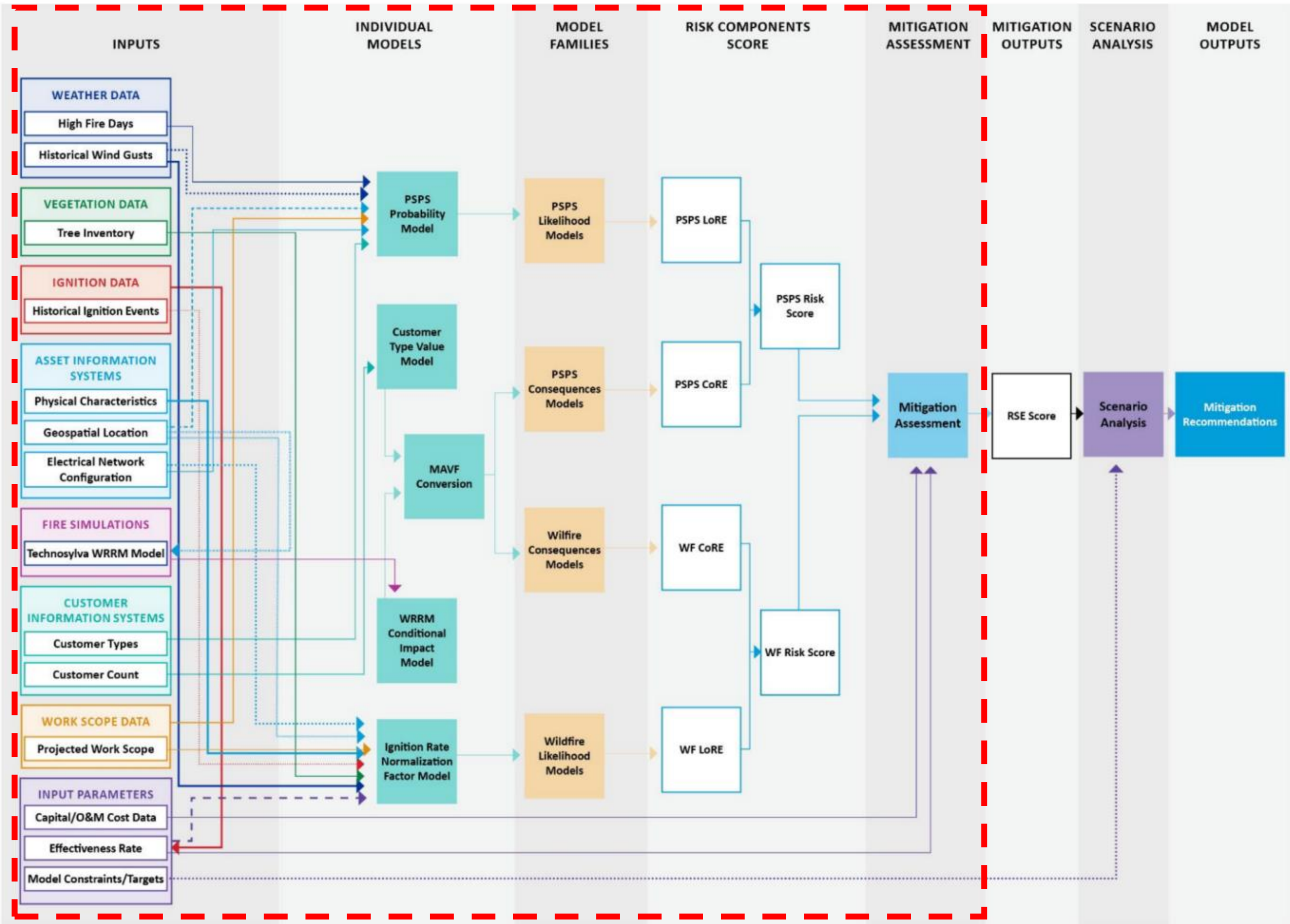
Figure 2: SDG&E WiNGS-Planning Risk Assessment Framework



For SDG&E, the Ignition Risk is defined as the Wildfire Risk, which is calculated as the product of the Wildfire Consequence of Risk Events (CoRE) and the Wildfire Likelihood of Risk Events (LoRE). Similarly, the Public Safety Power Shutoff (PSPS) risks is decomposed into a PSPS CoRE and PSPS LoRE. The calculation schemes are presented in Figure 3. The Wildfire LoRE is computed as the normalization adjusted likelihoods that result from separate wildfire driving causes (e.g. asset/equipment, vegetation). The Wildfire CoRE is computed to address the various impact factors such as safety, reliability, financial consequences resulting from wildfires (consequences are weighted to address their relative importance). Similarly, the PSPS LoRE addresses the risks that particular circuit segments are likely to be impacted by PSPS, and the PSPS CoRE addresses the consequences of the PSPS activation events.

WiNGS-Planning is meant to be a more deterministic model to assess SDG&E's risk as defined by the risk assessment framework (Figure 2) and follows the calculation schematic in Figure 3. The portion of the calculation schematic outlined in red represents SDG&E's approach to meeting the risk category component requirements as outlined in Section 6 of the WMP Technical Guidelines.

Figure 3: SDG&E WiNGS-Planning Calculation Schematic



PA's review of the WiNGS-Planning model is conducted in accordance with our AI Assurance Framework (described in more detail in Section 2), which has been adapted since WiNGS-Planning does not currently leverage machine learning or artificial intelligence models. WiNGS-Planning is meant to calculate the overall risk levels for the High Fire Threat District (HFTD) circuits on a circuit segment level. This model is also used to help develop recommended mitigation scopes to reduce wildfire risks based on effectiveness of mitigation options (i.e., undergrounding and covered conductors) from both timing and Risk Spend Efficiency (RSE) perspectives. The recommendations from WiNGS-Planning are used by Electrical System Hardening (ESH) to guide the development of actual mitigation scopes.

1.2.2 Prior independent assessments

SDG&E has made significant progress on recommendations and findings from prior independent assessments of the WiNGS-Planning model. Logic20/20 conducted WiNGS-Planning independent model review in August 2022 and most of the recommendations have been successfully addressed. The prior major focus during the time of the assessment was to transition from legacy Microsoft Excel based spreadsheets to python models, which has been successfully transitioned. As of the writing of this report, six recommendations for future action are still underway (documenting SME processes and supplied data, data governance, metrics on key data elements, validation and code optimization). There was also a December 2022 report where nine future enhancements were recommended, and SDG&E is in the process of implementing those recommendations.

Since the completion of Python model as well as cloud infrastructure migration, the WiNGS-Planning team have started to address the list of improvements and enhancements to make the model more efficient and better documented. For example, there's a current effort underway to make the queries for the ingestion of data more streamlined. There are also efforts to seek out commonalities (e.g., data sources, feature engineering and extractions) with WiNGS-Ops to consolidate data sources and model components. Ultimately, both WiNGS-Planning (segment) and WiNGS-Ops (pole and span) plan to shift to a span model and there are common components that can and should be shared across both. We did not review the full development pipeline for WiNGS-Planning but have reviewed what is considered included for short / medium / long term development targets.

2 WiNGS-Planning Assessment

To be compliant with the Office of Energy Infrastructure Safety Wildfire Management Program guidelines, SDG&E initiated an independent third-party review on the WiNGS-Planning model. This model evaluates both wildfire and PSPS impacts at the sub-circuit and segment level to inform investment decision by determining which initiatives provide the greatest benefit per dollar spent in reducing both wildfire risk and PSPS impact. The key decisions driven from this model are how to most efficiently and effectively apply wildfire and PSPS mitigation in the HFTD.

2.1 Limitations

This section details any limitations of the independent review, while considering their impacts on the findings. This review was not intended to verify the veracity of the assumptions, or the correctness of the calculations carried out, but is more meant to validate the approaches and methodologies used. In our assessment of the WiNGS-Planning model, we documented a number of assumptions that were used by the model that we could not independently verify via documentation. This is not meant to indicate that the assumptions are inaccurate but meant to document that the model outputs have certain limitations in the sense that initial assumptions / inputs are used that have unknown sources or have impacts that are not documented / identified.

2.1.1 Inputs-related Limitations

There are a number of input-related limitations used by the model that should be more thoroughly documented[1]. Some of these less than fully documented assumptions were carried out through the current version of WiNGS-Planning to maintain certain consistency purposes. These are needed to ensure various iterations of analyzing the same circuit risks do not arrive at conflicting conclusions. As pieces of WiNGS-Planning model gets updated and legacy pieces of calculations are replaced by newer approaches and assumptions, some of these less than fully documented assumptions may be deprecated in future iterations of the risk calculations.

One additional concern that was raised in our interviews with primary business user / stakeholder of WiNGS-Planning was timing of runs and reproducibility of results. Due to the long lead times needed to scope, engineer and design mitigation solutions, there were concerns that subsequent WiNGS-Planning model outputs could be using different and updated inputs as well as run with enhancements that would alter the results and recommendations for scoping projects that were already well underway. Work is in progress, but not yet fully deployed in production and adopted within the business, that would use version-controlled data and models to increase the reproducibility of results to address the concern of timing and versioning of model outputs.

2.1.2 Usage-related Limitations

The WiNGS-Planning model is used to calculate the baseline risk levels for SDG&E, and to identify recommendations to mitigate risky circuit segments and to reduce overall risk. The recommendations are reviewed by ESH to develop into mitigation plans. ESH does use additional factors to develop the final risk reduction mitigation scope such as design and constructability factors, exact routing of mitigation solutions, as well as if a circuit segmented recommended for mitigations have recently been mitigated (either with traditional hardening or covered conductors already). These additional considerations do not fall into the scope of measuring risks and are not captured in WiNGS-Planning.

However, the majority of mitigation recommendations are accepted by ESH for scoping and design to mitigate risks. The reasons for deviations away from the recommended solutions are reflective of individual project challenges, usually in one of the areas covered in this section that are not in the

[1] Either due to model developer or SME turn over and the original creators of these assumptions and inputs did not provide full documentation as to how the input was generated / determined.

WiNGS-Planning scope. In cases where the solution differs from the WiNGS-Planning recommended solution, there are processes to understand the reason for the deviation, as well as for executive approval. This indicates that the output for the WiNGS-Planning model is indeed useful to help reduce SDG&E's risk.

2.2 Assessment Outcomes

Based on PA's assessment, the WiNGS-Planning model has matured from where it used to be at the time of the prior independent review. Significant improvements have been made in terms of implementing recommendations, deploying additional controls and enhancements. The primary focus of the development team has been the successful migration from Excel to Python and cloud-based development and infrastructure in the recent months. The team is regularly maintaining and working to address items on the development roadmap to carry out further enhancements.

3 WiNGS-Planning Model Assurance Details

3.1 Process Introduction and High-level Recommendations

The independent review which has been conducted on the WiNGS-Planning model, captured a number of recommendations, with severity ranging from Low to Medium. These have been documented in the sections below, split for each pillar of PA's AI Assurance methodology. Each of these recommendations aim to individually address a part or process component, suggesting an improvement in line with Data Science and modelling best practice. This section also touches on some larger recommendations which span multiple pillars of review and would have a greater positive impact if implemented. These more impactful recommendations also would require greater levels of planning and effort in their implementation to reap the full value.

3.1.1 Enterprise-wide Data Governance

Strong enterprise-wide Data Governance is critical for any successful data-driven organization. Without proper Data Governance procedures in place for managing the data assets in SDG&E, the value of the enterprise's data may not be fully realized. Proper ownership and management of the data ensures that the data is always clearly defined with definitions that are agreed and understood across the business. There must also be robust management of the information generated. This includes ownership and governance of the calculation methodologies, and definitions for the models, metrics and KPIs used across the business. Technology may be utilized to aid in a more robust management of data, allowing the mechanisms and processes to be digitally formalized in a solution such as Collibra or Informatica.

There exists a Data Governance function for WMP and separate Enterprise Data Governance which covers the range of inputs used in WiNGS-Planning, however these functions are not well integrated which may pose a risk. This means that any changes in business definitions, standards for use or overall changes in the underlying data may occur without the WMP being made aware. This could lead to an unexpected change in the data, and an unexpected change in the output. There is no clear owner of the derived data and calculations involved in the model to determine their definition, principles of use or to make decisions on adjustments or changes that would be required. Without proper governance, there may not be a clear path for making decisions for changes of the model. The recommendation would be for a governance function, integrated with the enterprise-wide function which would cover the data inputs, information use, modeling and the overall decision-making process for changes to WiNGS-Planning. This would enable correct management of the data and information assets across SDG&E, utilized by the Wildfire Mitigation team, ensuring:

R1.1 Enhance communication with data owners: Ensure that there is an integrated function, such that communication from specific business owners for each data input into the models is cohesive and timely. This would ensure definitions (e.g., span length refers to the distance between two poles excluding insulator), use (e.g., this data point must always be viewed in conjunction with the other values in the segment), bounds for validity and decisions on changes that would be needed are communicated. They would also be responsible for ensuring that the data is up to date and accessible to all who may need it.

Severity Level: Medium – lack of communication from data owners may result in unexpected changes and diminished data integrity. The data owner is accountable for the use, quality and protection of a dataset.

R1.2 Calculation ownership: Owners of the specific constants (e.g., PSPS risks) and calculation methodologies sometimes called "information" such that their definitions and approaches are agreed, documented and uniform across the business. This is to ensure that any colloquial terms used for aggregated data assets are consistent such that an output like "miles of span in HFTD in one group's calculation is the same as another's.

Severity Level: Low – a calculation owner will be accountable for ensuring calculation methodologies are clearly defined and are used appropriately and consistently.

R1.3 Broader model ownership in the form of a board / group with regular meeting cadence to agree higher-level changes and adjustments, reviewing output of sensitivity analysis and changes prior to implementation. This would ensure that the responsibility for driving the direction of overall model enhancements and improvements is agreed amongst the Developers, Wildfire Mitigation team and the Business users.

Severity Level: Low – without regular communication between all stakeholders, the direction and prioritization of model development and improvements can be missed.

3.1.2 WiNGS-Planning Model Update

The WiNGS-Planning model was created utilizing a large number of disparate data sources which contained the best available data for the purpose the model was designed. Some of these data sources are static and have not been updated, specifically Circuit Health Index (CHI) of 2020. There may also be some double counting amongst inputs. For example, in the Ignition Rate Normalization Factor Model, the Asset Health Adjustment combines conductor age with the CHI, which also uses conductor age (as well as size and material) to derive the Conductor Failure Rate component of the CHI.

The recommendation would be to conduct a full update of the input sources to ensure the latest and most effective data inputs are utilized in the model. This might include:

R1.4 Development of a new Vegetation Risk Model, replacing the GIS Surveyors, Inc. (GSi) Tree Strike input which is based on 2018 data (finding F3.9).

Severity Level: Medium – development of a new vegetation risk model has the potential to change the ignition rate vegetation adjustment step which will change the risk scores, and may alter the mitigation rankings. A sensitivity analysis should be performed to capture any changes.

R1.5 Replace / refresh the CHI input to incorporate updated data and ensure data components are not utilized more than once in the same calculations (finding F3.6).

Severity Level: Medium – updating the CHI values will likely result in minor changes to the ignition rate asset health adjustment step which will change the risk scores slightly and may impact the mitigation rankings. A sensitivity analysis should be performed to capture any changes.

R1.6 Review the models and components utilized in WiNGS-Ops to validate whether an updated data input is available. This must be done while ensuring that the purpose and definition of the data is fully understood so any data assets or model inputs from WiNGS-Ops are complimentary to the existing WiNGS-Planning model.

Severity Level: Medium – updating constants will alter the final risk score results; however, the mitigation rankings may not change, or only change slightly.

3.2 Model Initiation

In the initiation step of the AI assurance framework, the purpose is to validate the correct amount of business engagement was involved in the early stage of model planning and development. This ensures that the problem has been appropriately defined and understood, and that the modeling exercise was commenced with the correct goals in mind.

The process involves understanding the initial problem formulation and workshopping process to devise the task and focus for the models. Additionally, a vision of an end-product model is clear and an accepted view as to what the value the model will be to the business with metric driven KPIs. It is also important to ensure the relevant business areas have taken full sponsorship of the project. This pillar will aim to establish whether proper engagement has been made and maintained with the business owners, ensure that the boundaries of the model are well-defined and understood by stakeholders and review the documented assumptions and requirements involved in the model.

3.2.1 Findings

F2.1 The WiNGS-Planning Model is entering into its 3rd version (V3), with the first version created in 2020. V3 is fundamentally similar to version 1 and 2 with the focus on migrating the model from Excel to Python, improving source control with Git, implement version model releases, applying coding standards, automate manual steps with code scripts, create unit and end to end testing, and convert optimization to Python (SDG&E 2023 – 2025 Wildfire Mitigation Plan, page 87).

F2.2 The purpose and problem are well documented in the SDG&E 2023 – 2025 Wildfire Mitigation Plan: 2023-2025 WiNGS-Planning Model (Appendix B, page 1). These are detailed in F2.3 and F2.4.

F2.3 Purpose: The WiNGS-Planning model, building upon the RSE methodology in the Risk Assessment and Mitigation Phase (RAMP) report, evaluate both wildfires and PSPS impacts at the sub-circuit/segment level to inform investment decisions by determining which initiative provide the greatest benefit per dollar spent in reducing both wildfire risk and PSPS impact.

F2.4 Problem: The WiNGS-Planning model was developed to aid with the allocation of grid hardening initiatives across the HFTD segments based on an assessment of both wildfire risk and PSPS impacts (SDG&E 2023 – 2025 Wildfire Mitigation Plan, page 61).

F2.5 Wings-Planning calculates the overall system risks and risk reductions resulting from mitigation actions. While the overall risk reduction is calculated by the model, the recommendations are not always followed (see 2.1.2), therefore there is value in capturing how the model's recommendations are followed. In terms of measuring the adoption rate of recommended solutions, there currently is no measurable metric that is formalized.

F2.6 Most of the stakeholders in the original model development are no longer with the company and some of the assumptions were not well documented but are still used in the current model version.

F2.7 The WiNGS-Planning team directly corresponds with the ESH team, who are the end users of the model outputs. Their meetings were weekly after previous model releases, and ad hoc when there were questions or when new scenarios need to be tested. The Wildfire Mitigation Program (WMP) and ESH team are not currently meeting on a regular basis.

3.2.2 Recommendations

R2.1 In order to quantify the value the model brings to the business, define a measurable metric that clearly shows what benefit the model is providing in order to evaluate if the value offsets the costs. A potential metric could be tracking the percent ESH deviates from the model recommendations, per finding F2.5.

Severity Level: Low – while not directly affecting the model output, it is best practice to regularly evaluate the value a model brings to your business to determine future growth and investment.

R2.2 Per finding F2.6, we recommend documenting the initiation stage in order to capture critical elements of the initial planning stage. This includes defining what problem this model will solve, what is the feasibility of this model, who are the end users and how do they want to ingest the model outputs, who are the subject matter experts and what is their ability to participate in the model development, who will be the business owner of the model, what are the initial assumptions and how were they determined, and confirmation that all relevant business areas have taken full sponsorship of the project. Additional details on why certain decisions were made with respect to the model generation are also critical to document in the initiation process. Going forward, with the initiation of new model versions, we recommend documenting these critical elements so they can be referenced by future developers and users of the model.

Severity Level: Medium – as demonstrated with the lack of documentation from the initiation of the WiNGS-Planning model, there are several assumptions and decisions that were made that cannot be explained now that the original stakeholders are no longer with the company. A better understanding of why these assumptions were made could flag areas to improve or where to focus sensitivity analyses. This in turn may modify certain components or constants used and change the model output results.

3.3 Data Cleaning

In the Data Cleaning stage, the purpose is to validate the data cleaning process of fixing or removing data is thorough and has not resulted in skewed or altered data. This ensures the data inputs are as reliable and accurate as possible. The process involves assessing the methods used to validate the input data. Additionally, to confirm the steps taken on detecting, correcting and documenting duplications, missing values, misspellings, lexical errors, irregularities, and mis-fielded entries are in line with expectation.

3.3.1 Findings

F3.1 Internal and external data used for the WiNGS-Planning model is collected and centralized in an Amazon Web Services based cloud environment.

F3.2 Data external to SDG&E includes Technosylva WRRM model, GSi Tree Location data, and GSi projected work timeline.

F3.3 Data documentation, dictionaries and schema for all data input providers varies:

- Technosylva has provided documentation on the WRRM model that includes details of the calculations, references to studies that support the calculations, list of assumptions made, list of limitations, independent review of results, examples, data dictionary of data inputs used to generate the WRRM values, and a data dictionary of the output fields that are sent to SDG&E that includes the description of the fields. Technosylva's documentation addresses model sensitivity.
- Meteorology team has provided documentation on the PSPS calculations and how they substantiate the quality of their data through weather station calibrations, automated python scripts that check for anomalous data, and the parsing logic to include only Santa Ana wind event data. They do not have a data dictionary of the fields that are sent to the WiNGS-Planning team in the documentation.

F3.4 Only one validation step is performed on the input data. That step exists to check the Technosylva WRRM data and was initiated due to an error in the data where the lower probabilities had a higher value of affect (buildings destroyed, acres burned). No other validation by the WiNGS-Planning team on data inputs is performed. Per the data quality verification section in the technical documentation (Section 2.6.1.1), five data sources (GIS electric system data, outage data, ignition data, weather data, and vegetation data) have quality control steps in place by the data source provider, so the data is accepted as is.

F3.5 Model constants are hard coded into the starting_constants.py file and have been updated with each version. Because the starting_constants.py file is saved in the repository, the file will be version controlled.

F3.6 The CHI data has not been refreshed for several years and is now out of date and not representative of current conditions.

F3.7 GSi's tree strike pilot update report indicated that there's value in updating tree location and height using the 2018 LiDAR survey to correct for position of trees as well as tree heights. This pilot study has not been incorporated by the WiNGS-Planning Model, nor were the tree position and height corrections by LiDAR.

F3.8 GSI's tree strike pilot update indicates the height of the conductor is not accounted for, i.e., all conductors are considered lying on the ground for the estimation of tree strike potential. This can potentially over-estimate the risks from trees that are not physically tall enough to strike the actual conductors.

F3.9 The Wildfire Risk Data Analytics team believes that GSi's process and model produces good results, they do not update their model regularly and responsive communication is inconsistent.

3.3.2 Recommendations

R3.1 Per finding F3.2, require documentation for all input data. Documentation should include the data owner, the context of the data, data collection methodology, structure and organization of the data, data validation and quality assurance steps, data manipulations from raw data, and data confidentiality, access and use conditions. If applicable, it should also include any calculations used to derive any of the fields, data dictionary of input data into those calculations, assumptions, references to methodologies or assumptions, and any limitations of the data. This will ensure a detailed understanding of the data that can be referenced as needed.

Additionally, data dictionaries should also be required for all input data. Data dictionaries should list all the data fields and for each one includes a description, data type, acceptable numerical ranges or classification values if applicable, units, if mandatory, null or missing value definition, effective date, update information (including date of update, by who, what was updated and why). This will ensure a thorough understanding of each data field, as well as a reference for data validation steps.

Severity Level: Low – not having documentation or data dictionaries do not prevent the model from running, however, there is a risk of misunderstanding the data, or if there is turnover on the data science team, new team members will have a more challenging time referencing and understand the data inputs. Therefore, documentation and data dictionaries are critical for ensuring an understanding of the data ingested into the models.

R3.2 Per finding F3.4, every data input should pass through some degree of automated data validation check to look for outliers, errors, text control, contradictions, etc. Each of these validation checks should have associated documentation that includes what to do when data is missing or anomalous. Provide examples of how it is detected and how corrections are performed in a demonstratable way if necessary.

Severity Level: Medium – there is currently a lot of reliance on source data owners to validate their data, however, as found out with the Technosylva data, errors still happen and can be overlooked. If erroneous data makes its way into the model, inaccurate outcomes will result. Poor data quality can therefore lead to poor model outcomes, which will result in a loss of trust in the model by the end users.

R3.3 Per finding F3.5, the constants used in the model calculations should be stored somewhere other than code itself. This will allow for better documentation of the assumptions that go into the constants decisions, and ease of readability for review.

Severity Level: Low – this won’t change any of the model outputs, however it is inefficient and more challenging to view the values, include all the proper documentation (see recommendation R2.1) and track changes (When it was changed, from what value, by who, and full reasoning for the change).

R3.4 Per finding F3.6, update the tree locations based on available LiDAR data to present a more accurate count of strikes per mile input for the circuit segments.

Severity Level: Medium – changing location of trees will likely change the tree strike potentials for circuit segments.

R3.5 Per finding F3.8, consider updating the tree strike model to address short trees that cannot hit the conductors based on the actual conductor height.

Severity Level: Medium – accounting for shorter trees will unlikely fall into conductors are likely over-represented in the risks currently captured.

R3.6 As the CHI input data was last refreshed in 2020, per finding F3.6, the recommendation would be to refresh or update this input, so it contains the most relevant data to provide the latest contribution to the modelling output.

Severity Level: Medium – by updating the CHI values, this will likely result in minor changes to the ignition rate asset health adjustment step and will probably have minimal impact on mitigation rankings.

3.4 Feature Extraction

In the Feature Extraction stage, the purpose is to validate the feature extraction process is sound, reliable, and reproducible. This ensures any derived values are informative, non-redundant, and appropriately reduces the number of resources required for evaluation. This process involves understanding the feature selection process to create a feature dataset, understand the feature extraction steps that were utilized to make the modelling more effective and responsive, and ensure the derived fields are correctly documented and defined.

3.4.1 Findings

F4.1 Due to the simple nature of the WiNGS-Planning calculations, advanced feature extraction processes, such as dimensionality reduction, are not used.

F4.2 Many derived fields are generated during the aggregation process in the aggregation.py script. These include averaging (for example: pole age and conductor age), aggregating asset data to the segment level, calculating rate data (tree strikes per segment), and summation (number of customers downstream of segment).

F4.3 Data dictionaries for derived fields are actively being developed which is good. Currently, it includes descriptions of the derived field and is located on an active branch, and not the main branch in the repository.

F4.4 Only one validation step is in place, which is to check that after each ignition rate adjustment step, the rate is normalized back to the annual ignition rate prior to moving on to the next step.

F4.5 The vegetation adjustment step in the ignition rate model might have an unnecessary extra step. After the tree strike rate per overhead HFTD mile is calculated, 0.001 is added to each value to remove any zero values (segments where there is no tree strike potential). Because the next step in the calculation process creates a weight adder that is added back into the tree strike rate per overhead HFTD mile, there will be no segments where the value will be zero. Through testing and demonstration, as long as a multiplier delta is used in creating the wt. adder, the initial step of adding 0.001 (or any value) performs no function and is cancelled out in the subsequent step.

3.4.2 Recommendations

R4.1 Data dictionaries are currently in development per finding F4.3, however more detailed documentation needs to be added for each derived field that includes the calculation, data validation and quality assurance steps, data manipulations, null or missing value definition and/or handling, acceptable numerical ranges if applicable, effective date, update information (including date of update, by who, what was updated, and why).

Severity Level: Low – similar to recommendation R3.1, not having documentation or data dictionaries do not prevent the model from running, however, there is a risk of misunderstanding the data or how to validate the results, particularly if there is turnover on the data science team. Having detailed documentation and data dictionaries are critical for ensuring an understanding of the generated data.

R4.2 In line with recommendation R3.2 and finding F4.4, incorporate data validation steps when new fields are derived to ensure the generated data is explainable, and include documentation that explains the validation steps taken and what to do when data is missing or anomalous. Provide examples of how any flagged data is detected and how corrections are performed in a demonstratable way if necessary. For example, when discussing the tree strike per overhead HFTD mile derived value, a potential outlier was found with the max value where there are 255 tree strikes in 0.05 miles of overhead HFTD for that segment. It is possible that segment is partially undergrounded or only partially in an HFTD zone, but the tree strike value includes all the tree strikes along that segment, including portions of that segment that are underground or not in a HFTD zone.

Severity Level: Medium – validating derived data is an important step for ensuring the most accurate model outputs. Some values are valid on their own which allows them to make it through the initial data ingest validation step, but when put in context with another value, it may indicate the data is an outlier. Poor data quality can lead to poor model outcomes, which will result in a loss of trust in the model by the end users.

R4.3 Per finding F4.5, perform a detailed analysis of this step to confirm it is an unnecessary step to reduce the technical debt, as well as reduce the amount of unnecessary documentation, especially when there is no explanation for this step.

Severity Level: Low – this step performs no function and therefore will not have any effect on the model results.

R4.4 Per finding F4.2, we recommend conducting a detailed assessment of the instances where mean values are utilized in the calculations. This would look to determine if the approach would correctly account for outliers, potentially presenting a less risky situation than is accurate.

Severity Level: Medium – if the assessment determined that using mean values didn't correctly account for outliers and a decision to change to, for example, median or max, then the data will change, which will result in a change to the risk score.

3.5 Model Validation

In the model validation stage, the purpose is to assess how the models are challenged, validated and approved. This will ensure the models have been reviewed by all pertinent stakeholders and the outputs are correctly interpreted. This process involves reviewing the validation process and ensuring it accounts for a suitably wide number of scenarios, the outcomes are ethical in nature, and the model achieves its intended purpose. Also, to ensure the outputs of the model seem reasonable given the scope and expectation. Additionally, to confirm that the model is validated and authorized by key decision makers, and they have a sufficient level of understanding which is in line with the documented purpose of the model.

3.5.1 Findings

F5.1 The ESH team will deviate from the model due to engineering sense checks and choosing to complete a circuit as a whole when only partial segments are recommended. The ESH team, along with the WiNGS-Planning team, must present their reason to leadership and get approval.

F5.2 Overall, the ESH team finds the model useful. There was a request from the ESH team for a more detailed sensitivity analysis.

F5.3 In the technical documentation, there is mention of a sensitivity analysis to validate RSE and mitigation sections of the WiNGS-Planning model. In the sensitivity analysis, the cost per mile estimates and RSE thresholds are adjusted to analyze the sensitivity around mitigation recommendations.

F5.4 ESH team believes the model documentation can be strengthened, specifically providing more details on model assumptions and data inputs and outputs.

F5.5 No sensitivity analysis has been performed on the potential bias with the customer type weighted multipliers to evaluate unintended bias.

F5.6 The WMP Advanced Analytics model owner performs final ad hoc sense checks of the final output data, mainly reviewing the highest risk ranked segments. This includes checking the highest wildfire risk segments with vegetation and wind data. There is no documented formalized validation process.

F5.7 Four Pytests are used to check for changes in the number of rows and columns, changes to datatypes, and checking for missing indexes between model versions.

F5.8 There currently isn't a documented formal process through which users may provide feedback or make requests for model updates / adjustments. This could mean in future, that requests for changes are difficult to cater for, track and implement.

F5.9 While it hasn't happened, if a data output issue is found during the validation process, they would complete the fix and rerun the model. If the output data has already been passed on to the end users, they notify them right away. Most issues are caught during the development process, or during the model run.

3.5.2 Recommendations

R5.1 Per finding F5.2, the model would benefit from a more robust sensitivity analysis (as outlined in ASTM E 1355 Section 10), performed at a regular cadence. It is recommended that business stakeholders are aware of this sensitivity analysis and should be invited to participate in choosing the variables and their value ranges for completion of this analysis. The business users should then be involved in all output reviews and have the suggested changes / remediation actions presented to them, such that the impacts may be fully understood and agreed with.

Severity Level: Medium – a sensitivity analysis will provide the end users a better understanding of how different values affect the model as well as help identify which values are influencing the model the most. This will allow the end users to make more informed decisions when determining if they need to deviate from the model results.

R5.2 Per finding F5.5, we recommend that a sensitivity analysis should be performed on the results of the customer type weight multipliers to evaluate if any unintended bias has resulted by adding weights to certain types of customers. This could include understanding the distribution of medical baseline and urgent customers relative to certain areas that may result in lower priority of hardening.

Severity Level: Medium – if the results of the study indicate that the different customer type multipliers have potential to adversely impact certain communities / demographics, and the multiplier values are adjusted, that will result in changes to the CoRE model outputs and may change the mitigation rank for certain segments.

R5.3 Devise and document formal process for validating the overall model outputs, per finding F5.6. This can be completed by comparing the run's results with previous iterations' outputs as well as identifying outputs that appear erroneous. It is also recommended to engage the end users to incorporate any additional thoughts or checks they have into the validation process.

Severity Level: Low – a formalized model validation process will instill greater trust by end users by knowing how the model results are validated prior to receiving the outputs, and can reference any generated validation reports.

R5.4 Create formalized demand management process for external parties to provide feedback and request adjustments to the models as per finding F5.8. This will ensure that as the team, model and user base continue to grow, there is a robust mechanism through which updates may be requested, tracked and implemented in the Cloud environment.

Severity Level: Low – this will not directly affect the model outputs; however, this is an important validation step between model developers and end users to continue to facilitate model development, accuracy, and value to the business.

3.6 Model Release and Productization

In the Model Release and Productization stage, the purpose is to validate if a formal release management process is in place, the quality of code is tested in a demonstratable and correct way, and a proper hand-over plan to the business stakeholders is in place. This process involves reviewing the code quality checks, checking the version control procedures, ensuring the solution fits its purpose and adds value to the business, and evaluating how data is consumed by the end users.

3.6.1 Findings

F6.1 Version control is based on Semantic Versioning and Python PEP 400, a version identification and dependency specification standard.

F6.2 Major, minor and patch changes are well defined and documented on Azure DevOps wiki. The definitions for what constitute a major, minor or patch change are robust and uniform, which ensures they are followed by all. A patch change indicates a change has been made to the model which has had no impact on the outputs. A minor change indicates a change to the model which has had an impact, albeit an expected one, on the outputs. A major change indicates that the model change has had a large impact on the outputs, which warrants a further, more detailed review with the business stakeholders. These change types were also discussed with the ESH team, who were aware and in agreement of each change type.

F6.3 Tracking and monitoring are self-governed using the standard options from the in-built AWS services.

F6.4 There is currently no set standard approach for model update notifications, other than patch level changes which do not affect results and therefore no notifications are sent.

F6.5 All files in Azure DevOps repository are backed up and can be viewed and compared to the latest version.

F6.6 Input data and output data are all in AWS and daily snapshots are captured for historical data pulls. This includes flat files which are pulled into their own database and tables with AWS Glue and capture dates are embedded.

F6.7 Everyone on the WMP team has access to the repository, however, only the three members of the Wildfire Risk Data Analytics Team have read and write privileges. They are also the admins and oversee maintaining the access list.

F6.8 All changes to any file in the repository must be approved by the admin team before it gets incorporated.

F6.9 Constants are hardcoded in the starting_constants.py file. Because the file is on Azure DevOps, there is a way to pull up previous versions and therefore previous values.

F6.10 Flake8 is used for linting, based on PEP8 code standards with slight configuration options. Auto formatting is completed by Black, and Pyright is used as the static code checker.

F6.11 A profiler tool has not been used extensively.

F6.12 Currently not performing any unit testing on the model scripts. No operational unit testing will allow bugs or defects to remain in the model, unidentified until impacting the output data.

F6.13 Only one validation script is run during the model run (ignition rate adjustment factor calculation to check if the renormalization step normalized the sum of values to the original annual ignition rate total). Lack of validation steps in the process could allow erroneous outputs to flow through, being identified at the output step, rather than earlier in the model.

F6.14 Not every function or constant has docstring, or is lacking some vital details. For example, in the starting_constants.py file, the unit cost for traditional hardening, covered conductor and undergrounding are lacking details on units (dollars per mile) as well as the fact that the value is reported in 1000's.

3.6.2 Recommendations

R6.1 Create a standardized approach for how model update notifications are delivered per finding F6.4, and work with end users to capture the correct granularity and details that they would need to understand the changes.

Severity Level: Low – this recommendation will not have any effect on the model output, but ensures that the appropriate level of communication is delivered between the development team and the end users.

R6.2 Ensure all python functions have docstrings – per finding F6.14. there is good coverage of docstrings with the newer functions, but older functions have not been updated. This will ensure that all functions are correctly documented, and definitions, descriptions and decision point reasoning are captured. Docstring best practice for a function include a brief description of what the function is and what it's used for, any arguments that are passed, labeling which are required and which are optional, any restrictions on when the function can be called, or any exceptions that are raised.

Severity Level: Low – this recommendation will not affect the model outputs, but is a best practice to follow when writing code.

R6.3 Run a profiler to identify any unused code that is taking up unnecessary technical debt, per finding F6.11.

Severity Level: Low – this recommendation does not affect the model output, but may improve the runtime performance of the model.

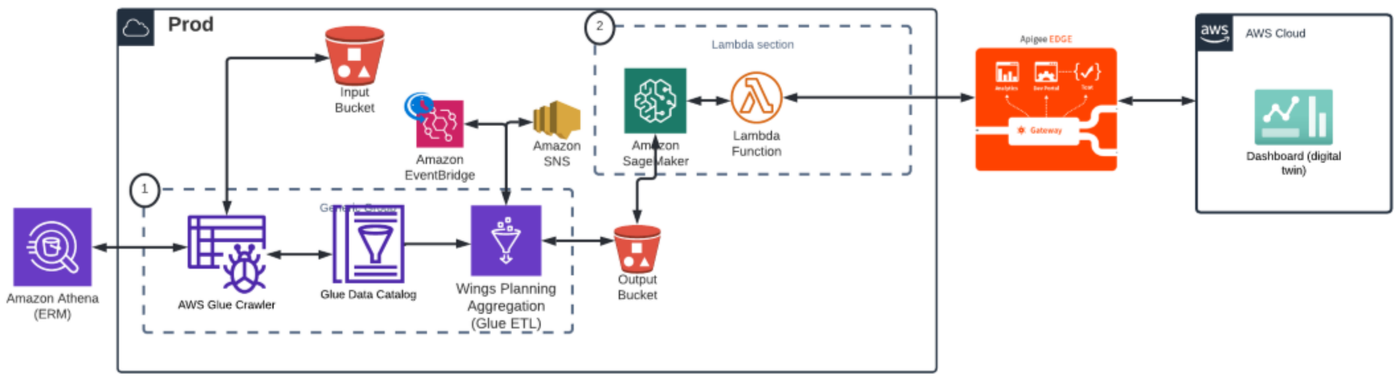
R6.4 Incorporate unit testing to ensure all functions are performing as expected, per finding F6.12.

Severity Level: Low – this recommendation will only affect the model if any functions are not performing as they should.

3.7 Production and Operations

In the production and operations stage, the purpose is to review the model's use in production by operational groups. This ensures that the model is utilized for the purpose that was intended such that maximum benefit is being realized. This process involves ensuring that the technical measures are in place, the solution stays accurate, predictable, and without drift. Also, maintenance and updates to the model are completed as necessary. Additionally, to confirm the model is being utilized for the purpose it was created.

The below figure shows the architecture diagram for the Production instance of the WiNGS-Planning model in Amazon Web Services (AWS). The section highlighted in #1 completes the aggregation of the data using AWS Glue to draw inputs from AWS Athena and S3 buckets. Section #2 indicates the inference side of the model where Lambda functions trigger the run of the model in AWS Sagemaker. Eventbridge and SNS alert to potential run failures while the Apigee service exposes the output data for visualization purposes.



3.7.1 Findings

F7.1 Historically, an excel file with the output values were emailed to the ESH team. There is currently no process in place for transferring results to ESH team.

F7.2 There are currently no budget spending limits on any of the environments, processes or accounts. This may pose a risk for unintentional spending in instances of an error or bug.

F7.3 WMP Advanced Analytics Team product owner provides access to AWS and APIs, managed through Azure DevOps. Access is removed when the product owner is notified that someone has left. There is currently no row or column-level security.

F7.4 Cloud services are utilized from each of the three main cloud vendors. Azure DevOps is utilized for its file repository, version control, and project tracking. AWS provides the infrastructure for the solution itself. And the Google product Apigee is used for the API management services.

F7.5 There is identical infrastructure and services in the User Acceptance (UA) and Production environments which ensures that thorough testing of any release in UA will work to specification when released to Production.

F7.6 There were plans mentioned to incorporate snapshots to ensure a copy of each data point, model run, and output is captured for future review

F7.7 There are three AWS Athena databases in use by WiNGS-Planning. There is a Data Mesh database which connects data siloes, ensuring greater data access for all. This contains Asset Management data. There is a geospatial database and also a separate Athena database for flat file upload.

F7.8 The process for a new version release currently involves approval of the update from WMP team and IT team. There is no business involvement in the approval for release of a new model or data version.

F7.9 WiNGS-Planning and WiNGS-Ops teams use the same account on AWS, so teams have access to the same cloud spaces. This may create a risk where different teams can access different models or datasets without the required understanding or onboarding for use.

3.7.2 Recommendations

R7.1 Per finding F7.1, work with end user to see how they would like to consume the data, then develop and implement a standard way to delivering data.

Severity Level: Low – this recommendation has no effect on the model output results, but it is important to establish the most efficient way to deliver the output results to the end users.

R7.2 As per finding F7.2, it may be advisable to introduce billing limits for certain sandbox / development activities such that there is not a risk of an unintended spike in cloud costs for a development error.

Severity Level: Low – this recommendation is to ensure the model costs are monitored and meet the set budget.

R7.3 As per finding F7.3, recommendation to review access control principles, focused on two areas:

- Review the default access periods, so access is revoked if someone doesn't access for a given period of time.
- Consider enabling row or column-level security to ensure users only access certain subsets of data most relevant and appropriate to them. This will become more needed in the WiNGS visualization tool.

Severity Level: Low – following the security pillar from the 6 pillars of the AWS Well-Architected Framework will ensure the confidentiality and integrity of the data, and prevent unauthorized access and changes to the model and systems.

R7.4 In future, it may be preferential to consolidate services under one cloud provider for ease of use, integration, and billing, per finding F7.4. This can ensure that future updates to any of the cloud services are always made in a way to keep compatibility and seamless integration with the other developed components.

Severity Level: Low – this recommendation has no impact on the output of the WiNGS-Planning model, but would allow for greater efficiency in use of cloud services.

R7.5 With improved Governance of the data, it would be preferable to have only one instance of AWS Athena, with the GIS and Flat File data combined into the Data Mesh layer, as per finding F7.7. This introduces a complexity which must be understood and addressed appropriately. With the data available in the Data Mesh, appropriate ownership and controls must be established such that any shared data is used within the bounds of its intended purpose.

Severity Level: Low – reducing from multiple instances of AWS Athena down to one would ensure efficiency of use and a lower overhead to manage, monitor and maintain.

R7.6 As per finding F7.8, engage with business user for a release of a new model version in the form of a Go / No-Go meeting such that the end users are engaged in the decision to approve a release as well as being aware of any projected impact or change.

Severity Level: Medium – by performing a Go / No-Go meeting, there is assurance that the end-users understand and approve the newest model version. Without this assurance, the end users may not fully understand the latest model outputs which could result in a misinterpretation of the model outputs.

R7.7 As per finding F7.9, would recommend creating separation in the access to Cloud workspaces as the products mature.

Severity Level: Low – this would allow more control over access control, budget planning and spend tracking for the separate groups.

Appendix A: Table of Recommendations

ID	Recommendation Name	Description	Severity Level
R1.1	Data Ownership	Enhance communication with data owners: Ensure that there is an integrated function, such that communication from specific business owners for each data input into the models is cohesive and timely. This would ensure definitions (e.g., span length refers to the distance between two poles excluding insulator), use (e.g., this data point must always be viewed in conjunction with the other values in the segment), bounds for validity and decisions on changes that would be needed are communicated. They would also be responsible for ensuring that the data is up to date and accessible to all who may need it.	*Severity Level: Medium* – lack of communication from data owners may result in unexpected changes and diminished data integrity. The data owner is accountable for the use, quality and protection of a dataset.
R1.2	Calculation Ownership	Calculation ownership: Owners of the specific constants (e.g., PSPS risks) and calculation methodologies sometimes called “information" such that their definitions and approaches are agreed, documented and uniform across the business. This is to ensure that any colloquial terms used for aggregated data assets are consistent such that an output like “miles of span in HFTD in one group’s calculation is the same as another’s.	*Severity Level: Low* – a calculation owner will be accountable for ensuring calculation methodologies are clearly defined and are used appropriately and consistently.
R1.3	Model Ownership	Broader model ownership in the form of a board / group with regular meeting cadence to agree higher-level changes and adjustments, reviewing output of sensitivity analysis and changes prior to implementation. This would ensure that the responsibility for driving the direction of overall model enhancements and improvements is agreed amongst the Developers, Wildfire Mitigation team and the Business users.	*Severity Level: Low* – without regular communication between all stakeholders, the direction and prioritization of model development and improvements can be missed.
R1.4	Develop New Vegetation Risk Model	Development of a new Vegetation Risk Model, replacing the GIS Surveyors, Inc. (GSi) Tree Strike input which is based on 2018 data (finding F3.9).	*Severity Level: Medium* – development of a new vegetation risk model has the potential to change the ignition rate vegetation adjustment step which will change the risk scores, and may alter the mitigation rankings. A sensitivity analysis should be performed to capture any changes.
R1.5	Refresh CHI	Replace / refresh the CHI input to incorporate updated data and ensure data components are not utilized more than once in the same calculations (finding F3.6).	*Severity Level: Medium* – updating the CHI values will likely result in minor changes to the ignition rate asset health adjustment step which will change the risk scores slightly and may impact the mitigation rankings. A sensitivity analysis should be performed to capture any changes.

ID	Recommendation Name	Description	Severity Level
R1.6	Update Data Input Check	Review the models and components utilized in WiNGS-Ops to validate whether an updated data input is available. This must be done while ensuring that the purpose and definition of the data is fully understood so any data assets or model inputs from WiNGS-Ops are complimentary to the existing WiNGS-Planning model.	*Severity Level: Medium* – updating constants will alter the final risk score results; however, the mitigation rankings may not change, or only change slightly.
R2.1	Model Value	In order to quantify the value the model brings to the business, define a measurable metric that clearly shows what benefit the model is providing in order to evaluate if the value offsets the costs. A potential metric could be tracking the percent ESH deviates from the model recommendations, per finding F2.5.	*Severity Level: Low* – while not directly affecting the model output, it is best practice to regularly evaluate the value a model brings to your business to determine future growth and investment.
R2.2	Initiation Stage Documentation	Per finding F2.6, we recommend documenting the initiation stage in order to capture critical elements of the initial planning stage. This includes defining what problem this model will solve, what is the feasibility of this model, who are the end users and how do they want to ingest the model outputs, who are the subject matter experts and what is their ability to participate in the model development, who will be the business owner of the model, what are the initial assumptions and how were they determined, and confirmation that all relevant business areas have taken full sponsorship of the project. Additional details on why certain decisions were made with respect to the model generation are also critical to document in the initiation process. Going forward, with the initiation of new model versions, we recommend documenting these critical elements so they can be referenced by future developers and users of the model.	*Severity Level: Medium* – as demonstrated with the lack of documentation from the initiation of the WiNGS-Planning model, there are several assumptions and decisions that were made that cannot be explained now that the original stakeholders are no longer with the company. A better understanding of why these assumptions were made could flag areas to improve or where to focus sensitivity analyses. This in turn may modify certain components or constants used and change the model output results.

ID	Recommendation Name	Description	Severity Level
R3.1	Data Documentation and Dictionaries	Per finding F3.2, require documentation for all input data. Documentation should include the data owner, the context of the data, data collection methodology, structure and organization of the data, data validation and quality assurance steps, data manipulations from raw data, and data confidentiality, access and use conditions. If applicable, it should also include any calculations used to derive any of the fields, data dictionary of input data into those calculations, assumptions, references to methodologies or assumptions, and any limitations of the data. This will ensure a detailed understanding of the data that can be referenced as needed. Additionally, data dictionaries should also be required for all input data. Data dictionaries should list all the data fields and for each one includes a description, data type, acceptable numerical ranges or classification values if applicable, units, if mandatory, null or missing value definition, effective date, update information (including date of update, by who, what was updated and why). This will ensure a thorough understanding of each data field, as well as a reference for data validation steps.	*Severity Level: Low* – not having documentation or data dictionaries do not prevent the model from running, however, there is a risk of misunderstanding the data, or if there is turnover on the data science team, new team members will have a more challenging time referencing and understand the data inputs. Therefore, documentation and data dictionaries are critical for ensuring an understanding of the data ingested into the models.
R3.2	Data Input Validation	Per finding F3.4, every data input should pass through some degree of automated data validation check to look for outliers, errors, text control, contradictions, etc. Each of these validation checks should have associated documentation that includes what to do when data is missing or anomalous. Provide examples of how it is detected and how corrections are performed in a demonstratable way if necessary.	*Severity Level: Medium* – there is currently a lot of reliance on source data owners to validate their data, however, as found out with the Technosylva data, errors still happen and can be overlooked. If erroneous data makes its way into the model, inaccurate outcomes will result. Poor data quality can therefore lead to poor model outcomes, which will result in a loss of trust in the model by the end users.
R3.3	Constants	Per finding F3.5, the constants used in the model calculations should be stored somewhere other than code itself. This will allow for better documentation of the assumptions that go into the constants decisions, and ease of readability for review.	*Severity Level: Low* – this won't change any of the model outputs, however it is inefficient and more challenging to view the values, include all the proper documentation (see recommendation R2.1) and track changes (When it was changed, from what value, by who, and full reasoning for the change).
R3.4	LiDAR Tree Data	Per finding F3.6, update the tree locations based on available LiDAR data to present a more accurate count of strikes per mile input for the circuit segments.	*Severity Level: Medium* – changing location of trees will likely change the tree strike potentials for circuit segments.

ID	Recommendation Name	Description	Severity Level
R3.5	Shorter Than Conductor Height Trees Strike Buffer	Per finding F3.8, consider updating the tree strike model to address short trees that cannot hit the conductors based on the actual conductor height.	*Severity Level: Medium* – accounting for shorter trees will unlikely fall into conductors are likely over-represented in the risks currently captured.
R3.6	CHI Update	As the CHI input data was last refreshed in 2020, per finding F3.6, the recommendation would be to refresh or update this input, so it contains the most relevant data to provide the latest contribution to the modelling output.	*Severity Level: Medium – by* updating the CHI values, this will likely result in minor changes to the ignition rate asset health adjustment step and will probably have minimal impact on mitigation rankings.
R4.1	Derived Field Data Dictionaries	Data dictionaries are currently in development per finding F4.3, however more detailed documentation needs to be added for each derived field that includes the calculation, data validation and quality assurance steps, data manipulations, null or missing value definition and/or handling, acceptable numerical ranges if applicable, effective date, update information (including date of update, by who, what was updated, and why).	*Severity Level: Low* – similar to recommendation R3.1, not having documentation or data dictionaries do not prevent the model from running, however, there is a risk of misunderstanding the data or how to validate the results, particularly if there is turnover on the data science team. Having detailed documentation and data dictionaries are critical for ensuring an understanding of the generated data.
R4.2	Derived Data Validation	In line with recommendation R3.2 and finding F4.4, incorporate data validation steps when new fields are derived to ensure the generated data is explainable, and include documentation that explains the validation steps taken and what to do when data is missing or anomalous. Provide examples of how any flagged data is detected and how corrections are performed in a demonstratable way if necessary. For example, when discussing the tree strike per overhead HFTD mile derived value, a potential outlier was found with the max value where there are 255 tree strikes in 0.05 miles of overhead HFTD for that segment. It is possible that segment is partially undergrounded or only partially in an HFTD zone, but the tree strike value includes all the tree strikes along that segment, including portions of that segment that are underground or not in a HFTD zone.	*Severity Level: Medium* – validating derived data is an important step for ensuring the most accurate model outputs. Some values are valid on their own which allows them to make it through the initial data ingest validation step, but when put in context with another value, it may indicate the data is an outlier. Poor data quality can lead to poor model outcomes, which will result in a loss of trust in the model by the end users.
R4.3	Ignition Rate Veg Adjustment 0.001 Adder	Per finding F4.5, perform a detailed analysis of this step to confirm it is an unnecessary step to reduce the technical debt, as well as reduce the amount of unnecessary documentation, especially when there is no explanation for this step.	*Severity Level: Low* – this step performs no function and therefore will not have any effect on the model results.

ID	Recommendation Name	Description	Severity Level
R4.4	Mean Value Assessment	Per finding F4.2, we recommend conducting a detailed assessment of the instances where mean values are utilized in the calculations. This would look to determine if the approach would correctly account for outliers, potentially presenting a less risky situation than is accurate.	*Severity Level: Medium* – if the assessment determined that using mean values didn't correctly account for outliers and a decision to change to, for example, median or max, then the data will change, which will result in a change to the risk score.
R5.1	Stakeholder Involved Sensitivity Analysis	Per finding F5.2, the model would benefit from a more robust sensitivity analysis (as outlined in ASTM E 1355 Section 10), performed at a regular cadence. It is recommended that business stakeholders are aware of this sensitivity analysis and should be invited to participate in choosing the variables and their value ranges for completion of this analysis. The business users should then be involved in all output reviews and have the suggested changes / remediation actions presented to them, such that the impacts may be fully understood and agreed with.	*Severity Level: Medium* – a sensitivity analysis will provide the end users a better understanding of how different values affect the model as well as help identify which values are influencing the model the most. This will allow the end users to make more informed decisions when determining if they need to deviate from the model results.
R5.2	Customer Type Multiplier Sensitivity Analysis	Per finding F5.5, we recommend that a sensitivity analysis should be performed on the results of the customer type weight multipliers to evaluate if any unintended bias has resulted by adding weights to certain types of customers. This could include understanding the distribution of medical baseline and urgent customers relative to certain areas that may result in lower priority of hardening.	*Severity Level: Medium* – if the results of the study indicate that the different customer type multipliers have potential to adversely impact certain communities / demographics, and the multiplier values are adjusted, that will result in changes to the CoRE model outputs and may change the mitigation rank for certain segments.
R5.3	Formalize Model Validation Process	Devise and document formal process for validating the overall model outputs, per finding F5.6. This can be completed by comparing the run's results with previous iterations' outputs as well as identifying outputs that appear erroneous. It is also recommended to engage the end users to incorporate any additional thoughts or checks they have into the validation process.	*Severity Level: Low* – a formalized model validation process will instill greater trust by end users by knowing how the model results are validated prior to receiving the outputs, and can reference any generated validation reports.
R5.4	Formalize External Feedback Management Process	Create formalized demand management process for external parties to provide feedback and request adjustments to the models as per finding F5.8. This will ensure that as the team, model and user base continue to grow, there is a robust mechanism through which updates may be requested, tracked and implemented in the Cloud environment.	*Severity Level: Low* – this will not directly affect the model outputs; however, this is an important validation step between model developers and end users to continue to facilitate model development, accuracy, and value to the business.

ID	Recommendation Name	Description	Severity Level
R6.1	Standardize Model Notifications	Create a standardized approach for how model update notifications are delivered per finding F6.4, and work with end users to capture the correct granularity and details that they would need to understand the changes.	*Severity Level: Low* – this recommendation will not have any effect on the model output, but ensures that the appropriate level of communication is delivered between the development team and the end users.
R6.2	Docstring Best Practice	Ensure all python functions have docstrings – per finding F6.14. there is good coverage of docstrings with the newer functions, but older functions have not been updated. This will ensure that all functions are correctly documented, and definitions, descriptions and decision point reasoning are captured. Docstring best practice for a function include a brief description of what the function is and what it's used for, any arguments that are passed, labeling which are required and which are optional, any restrictions on when the function can be called, or any exceptions that are raised.	*Severity Level: Low* – this recommendation will not affect the model outputs, but is a best practice to follow when writing code.
R6.3	Profiler	Run a profiler to identify any unused code that is taking up unnecessary technical debt, per finding F6.11.	*Severity Level: Low* – this recommendation does not affect the model output, but may improve the runtime performance of the model.
R6.4	Unit Testing	Incorporate unit testing to ensure all functions are performing as expected, per finding F6.12.	*Severity Level: Low* – this recommendation will only affect the model if any functions are not performing as they should.
R7.1	End User Data Consumption	Per finding F7.1, work with end user to see how they would like to consume the data, then develop and implement a standard way to delivering data.	*Severity Level: Low* – this recommendation has no effect on the model output results, but it is important to establish the most efficient way to deliver the output results to the end users.
R7.2	Aws Billing Limits	As per finding F7.2, it may be advisable to introduce billing limits for certain sandbox / development activities such that there is not a risk of an unintended spike in cloud costs for a development error.	*Severity Level: Low* – this recommendation is to ensure the model costs are monitored and meet the set budget.
R7.3	Aws Access Control	As per finding F7.3, recommendation to review access control principles, focused on two areas: · Review the default access periods, so access is revoked if someone doesn't access for a given period of time. · Consider enabling row or column-level security to ensure users only access certain subsets of data most relevant and appropriate to them. This will become more needed in the WiNGS visualization tool.	*Severity Level: Low* – following the security pillar from the 6 pillars of the AWS Well-Architected Framework will ensure the confidentiality and integrity of the data, and prevent unauthorized access and changes to the model and systems.

ID	Recommendation Name	Description	Severity Level
R7.4	Single Cloud Vendor Consolidation	In future, it may be preferential to consolidate services under one cloud provider for ease of use, integration, and billing, per finding F7.4. This can ensure that future updates to any of the cloud services are always made in a way to keep compatibility and seamless integration with the other developed components.	*Severity Level: Low* – this recommendation has no impact on the output of the WiNGS-Planning model, but would allow for greater efficiency in use of cloud services.
R7.5	AWS Athena Consolidation	With improved Governance of the data, it would be preferable to have only one instance of AWS Athena, with the GIS and Flat File data combined into the Data Mesh layer, as per finding F7.7. This introduces a complexity which must be understood and addressed appropriately. With the data available in the Data Mesh, appropriate ownership and controls must be established such that any shared data is used within the bounds of its intended purpose.	*Severity Level: Low* – reducing from multiple instances of AWS Athena down to one would ensure efficiency of use and a lower overhead to manage, monitor and maintain.
R7.6	Go / No-Go	As per finding F7.8, engage with business user for a release of a new model version in the form of a Go / No-Go meeting such that the end users are engaged in the decision to approve a release as well as being aware of any projected impact or change.	*Severity Level: Medium* – by performing a Go / No-Go meeting, there is assurance that the end-users understand and approve the newest model version. Without this assurance, the end users may not fully understand the latest model outputs which could result in a misinterpretation of the model outputs.
R7.7	Separate Access On AWS	As per finding F7.9, would recommend creating separation in the access to Cloud workspaces as the products mature.	*Severity Level: Low* – this would allow more control over access control, budget planning and spend tracking for the separate groups.

About PA.

We believe in the power of ingenuity to build a positive human future.
As strategies, technologies, and innovation collide, we create opportunity from complexity.
Our diverse teams of experts combine innovative thinking and breakthrough technologies to progress further, faster. Our clients adapt and transform, and together we achieve enduring results.
We are over 4,000 strategists, innovators, designers, consultants, digital experts, scientists, engineers, and technologists. And we have deep expertise in consumer and manufacturing, defense and security, energy and utilities, financial services, government and public services, health and life sciences, and transport.
Our teams operate globally from offices across the UK, Ireland, US, Nordics, and Netherlands.

PA. Bringing Ingenuity to Life.

Discover more at paconsulting.com and connect with PA on LinkedIn and Twitter.

Denver Office
PA Consulting Group Inc.
Suite 3550
1700 Lincoln Street
Denver
CO 80203
USA
+1 720 566 9920

paconsulting.com