SOUTHERN CALIFORNIA
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(U 338-E)

2021 General Rate Case
A.19-08-_____

Workpapers

Risk Informed Strategy & Business Plan
SCE-01 Volume 02

August 2019

I.
INTRODUCTION

A. Content and Organization of Volume

In this portion of Exhibit SCE-01, Southern California Edison (SCE) discusses its Enterprise Risk Management (ERM) program. To protect our customers, our workers, and the communities we serve, and to continue to reliably deliver service, SCE has developed a company-wide program that systematically identifies, evaluates, mitigates, and monitors risks. In doing so, we are able to deliberately review, discuss, and prioritize enterprise risks. Our ERM approach also fosters SCE incorporating risk-informed planning in the many decisions we make while serving our customers and conducting our business.

The testimony is broken down into five chapters. The content is structured as follows:

- Chapter 1 provides an overall introduction.
- Chapter 2 explains SCE's ERM program.
- Chapter 3 provides an overview of SCE's 2018 RAMP report, discusses feedback SCE received on the RAMP report (with particular focus on SED's recommendations), gives SCE's responsive comments to those recommendations, and provides a roadmap for the RAMP-to-GRC integration.
- Chapter 4 outlines SCE's wildfire risk analysis and approach. This chapter also discusses a risk analysis that SCE performed to evaluate the public safety impacts of shifting resources from traditional infrastructure replacement programs to wildfire mitigation programs and activities. That analysis showed that the safety reduction gained through the enhanced portfolio of wildfire mitigations exceeds the safety reduction lost in other risk initiatives when the resources are shifted.
- Chapter 5 summarizes certain other operational risk frameworks being utilized at SCE for Transmission & Distribution, Generation, and Cybersecurity.

II.

OVERVIEW OF ENTERPRISE RISK AT SCE

A. Introduction to SCE Enterprise Risk Management

Through ERM, we centralize oversight and guidance on key risks across the Company. Specifically, ERM's role is to identify the highest and most critical risks facing the entire enterprise, validate that appropriate mitigation measures have been initiated, monitor the status of the risks and the mitigation measures, and communicate ERM's findings concerning enterprise- and operational-level risks to SCE's senior management and Board of Directors.

ERM works closely with each operating unit (OU) through a "hub-and-spoke" structure to manage risk across the Company. Through this "hub-and-spoke" structure, risk-informed decisions are centralized at the "hub," with these decisions informed mainly by actions occurring at the "spokes." ERM, the "hub," establishes SCE's common risk management framework and facilitates cross-OU collaboration in developing and maintaining consistent and coherent risk management tools and systems. The OUs, who serve as the "spokes" in this context, provide data, analysis, and guidance on the risks as found within each OU.[1] This helps ERM prioritize and manage the key risks across the Company.

SCE is working to further integrate risk into the Company's major planning and decision-making processes. ERM is driving this effort, working closely with corporate and OU partners to integrate risk into these planning and decision-making efforts.

B. Governance

Company senior leadership is deeply engaged with managing the enterprise risks at SCE. Enhancements and changes to the risk-informed decision-making framework are regularly communicated to senior leadership, and in turn our senior leadership actively provides guidance and feedback.

Throughout the year, the ERM group meets with senior leaders to review and discuss enterprise- and operational-level risks and mitigation plans. SCE senior leadership plays a critical role in establishing a strong risk assessment culture across the Company. Our senior leaders actively engage with ERM efforts, encourage leaders and subject matter experts (SMEs) throughout the Company to

1 Certain specific risk-informed decisions (such as project-level decisions) are made at the "spokes," because such decisions do not rise to the level of enterprise risk management.

participate in the risk assessment process, and make such risk-related efforts one of the Company-wide continuous improvement priorities. This support has enabled the ERM group to develop, establish, and implement a more consistent and structured risk-informed decision-making framework.

SCE has a Finance and Risk Management (FRM) Committee. This committee is chaired by the SCE Chief Financial Officer (CFO) and consists of the SCE General Counsel and the Senior Vice President (SVP) of Regulatory Affairs as voting members. The SCE Chief Executive Officer (CEO) and President actively participate in FRM Committee meetings. (Approval from the CEO is mandated when matters exceed certain cost or impact thresholds.) The purpose of this committee is to: (1) oversee and approve the allocation of SCE's financial resources, energy procurement activities, and enterprise-wide risk management; and (2) provide a forum and a process to identify, understand, manage and mitigate critical risks related to these areas, in accordance with regulatory directives and Company policies.

The leadership team at SCE's parent company, Edison International (EIX), has established a Risk Management Committee (EIX RMC) that oversees SCE's risk management program and enterprise risks. The EIX RMC is chaired by the EIX CFO, and its membership includes the EIX CEO, EIX General Counsel, EIX SVP of Strategy and Corporate Development, and the EIX Vice President of Enterprise Risk Management & Insurance and General Auditor ("EIX VP of Risk Management") as a participant. The SCE CEO, CFO, and General Counsel also participate in matters involving SCE risks.

The EIX RMC is responsible for reviewing and understanding critical risks facing SCE. The EIX RMC reviews and approves the annual enterprise risk assessment and mitigation plans. EIX leadership is also responsible for fostering a corporate-wide culture that makes identifying, analyzing, managing, mitigating, and reporting risks an integral part of corporate strategy and operations.

Through these various executive committees and forums, oversight of SCE's enterprise risk management program is provided at all levels of the Company. The ERM oversight includes:

- EIX and SCE Board of Directors, Audit Committees of the Boards of Directors, and EIX RMC;
- SCE senior management including the SCE CEO, President, CFO, the General Counsel, and FRM Committee;
- EIX VP of Risk Management, who reports to the EIX CFO;
- SCE senior leaders who manage OU risks across the Company;
- SCE's Director of Risk Management, who reports to the EIX VP of Risk Management;
- SCE's Principal Manager of ERM, who reports to SCE's Director of Risk Management; and

- Risk Advisors and Senior Advisors, who report to SCE's Principal Manager of ERM.

C. **Regulatory Background**

On November 14, 2013, the Commission issued an Order Instituting Rulemaking to Develop a Risk Based Decision Making Framework to Evaluate Safety and Reliability Improvements and Revise the Rate Case Plan for Energy Utilities (R.13-11-006, or Risk OIR). The Risk OIR sought to incorporate a risk-based framework into the Rate Case Plan that each energy utility must follow. In the Risk OIR, the Commission instituted two new processes designed to feed into the portions of General Rate Case applications where utilities request funding for safety-related activities. These two processes are the Safety Model Assessment Proceeding (SMAP) and the Risk Assessment and Mitigation Phase (RAMP).

SCE's RAMP report originates from, and is guided by, two key Commission decisions. First, in the Risk OIR, the Commission issued D.14-12-025, which modified the Rate Case Plan to include a risk-based framework and "provide a transparent process to ensure that the energy utilities are placing the safety of the public, and of their employees, as a top priority in their respective GRC proceedings."[2] The decision indicated that each utility's RAMP report should show:

- The utility's prioritization of the risks it believes it is facing and a description of the methodology used to determine these risks.
- A description of the controls currently in place, and the "baseline" costs associated with the current controls.
- The utility's prioritization of risk mitigation alternatives, in light of estimated mitigation costs in relation to risk mitigation benefits (a Ratio of Risk Mitigated to Cost).
- The utility's risk mitigation plan, including an explanation of how the plan considers: utility financial constraints; execution feasibility; affordability impacts; and any other constraints identified by the utility.
- For comparison purposes, at least two other alternative mitigation plans the utility considered and an explanation of why the utility views these plans as inferior to the proposed plan.[3]

Second, the Commission issued an interim decision in its SMAP. That interim decision, D.16-08-018, provided certain guidelines regarding what should be included in the utilities' RAMP reports,

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[2] D.14-12-025, p. 35.

[3] D.14-12-025, pp. 31-32.

including adopting the Cycla Corporation 10-step framework.[4] The decision also gave guidance to SED on the criteria it should apply when evaluating the utilities' RAMP submissions.

In accordance with the Commission's guidance in D.14-12-025,[5] on August 29, 2018, SCE duly requested an Order Instituting Investigation (OII) to provide a docket for filing of SCE's RAMP showing, as well as comments and feedback on that RAMP. On November 9, 2018 the Commission opened I.18-11-006.

D. <u>Overview of Risk-Informed Decision Making Framework</u>

The process of developing the RAMP report enhanced SCE's risk-informed decision making (RIDM) framework. This framework enables the company to identify, evaluate, mitigate, and monitor risks and to report on the risks to the company's senior leadership. This framework also lets us concretely embed risk considerations into SCE's decision-making process. Senior leadership employs the framework to review, discuss, prioritize, monitor, and address enterprise risks. This represents an important tool as our senior leaders make decisions to better prioritize and allocate resources to achieve greater risk reductions, where feasible.

SCE's risk-informed decision making framework is built on the foundation we described in SCE's SMAP Application.[6] Since filing that Application, SCE has taken measured steps to enhance our internal risk management capabilities. SCE has benefitted from actively participating in the SMAP process and collaborating closely with the Commission's Safety Enforcement Division (SED), intervenors, and other California utilities. While SCE's RAMP report represented a prudent step forward in implementing a quantitative risk management framework, we are committed to continuously improving by incorporating best practices and lessons learned, and continuing the collaboration and knowledge-sharing with the Commission and external stakeholders.

The development of SCE's RAMP report followed Cycla's 10-step framework, which is shown in Figure II-1 below.[7] SCE briefly describes our approach to each step in the sections that follow.

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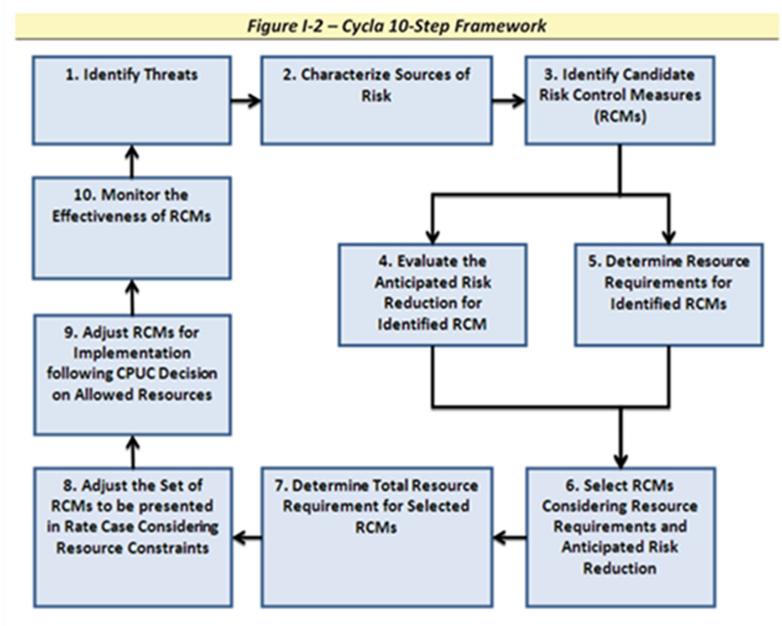
[4] D.16-08-018, Ordering Paragraph (OP) 4. See also Figure II-1 of this testimony (Cycla 10-Step Framework).

[5] See D.14-12-025, p. 41, Table 3.

[6] A.15-05-002, SCE's Safety Model Assessment Proceeding application, submitted May 2015.

[7] In D.16-08-018, the Commission adopted the Cycla Corporation 10-Step Evaluation Method as a common yardstick for evaluating the maturity, robustness, and thoroughness of utility risk assessment and mitigation models and risk management frameworks. See D.16-08-018, at p. 2.

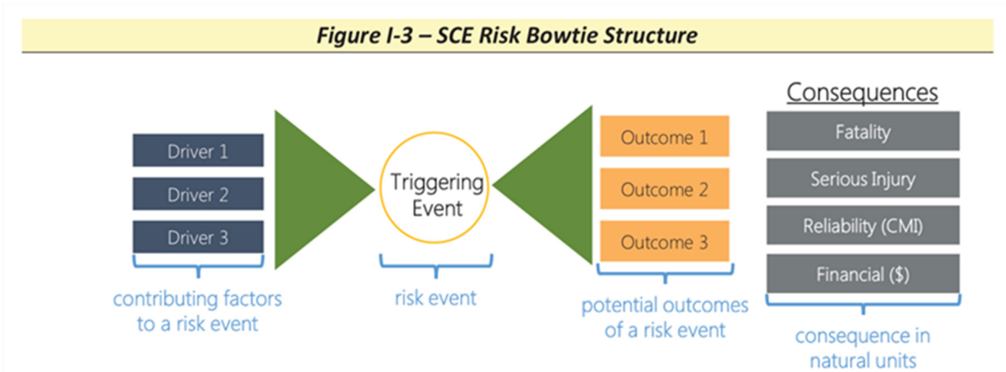
Figure II-1
Cycla 10-Step Framework



Step 1: Identify Threats & Step 2: Characterize Sources of Risk

SCE began by developing an understanding of a risk event, the fundamental elements contributing to the risk event (risk drivers), and the potential negative outcomes and consequences if the risk event materializes. SCE applied the risk bowtie structure to enable us to consistently and systematically identify threats and characterize sources of risk. The risk bowtie is shown in Figure II-2.

Figure II-2
SCE Risk Bowtie Structure



Step 3: Identify Candidate RCMs (Risk Control Measures)

SCE developed a multi-attribute risk scoring (MARS) approach for probabilistically quantifying risk in its RAMP report, based on available data and input from subject matter experts. SCE's MARS approach aligns with Multi-Attribute Value Function (MAVF) principals of the SMAP Settlement.

For each risk, SCE then assessed existing controls, and identified potential new mitigation measures that can reduce either the likelihood or the negative consequences of the risk.

Step 4: Evaluate the Anticipated Risk Reduction for Identified RCMs

To estimate the anticipated risk reduction for control and mitigation measures, SCE then estimated the effectiveness of each measure on reducing the likelihood and/or consequences of the risk. The same MARS calculation is then conducted to estimate the post-mitigated risk score associated with each measure and the resulting risk reduction (benefits).

Step 5: Determine Resource Requirements for Identified RCMs

Besides estimating effectiveness of each mitigation measure, SCE considers multiple factors including timing of deploying the mitigation, resource allocation, technology maturity, alternative mitigations, and other potential considerations to develop a comprehensive complementary suite of solutions to reduce risks. At this stage, SCE estimates what resources are needed for each mitigation.

Step 6: Select RCMs Considering Resource Requirements and Anticipated Risk Reduction & Step 7: Determine Total Resource Requirements for Selected RCMs

Once we have estimated the cost and risk reduction associated with each mitigation, we then calculate the risk spend efficiency (RSE). This is a measure of risk reduction per dollar spent. It is calculated for each mitigation. RSE helps us estimate the effectiveness of each mitigation and is also used to compare the effectiveness of different mitigations. RSE is an important consideration for selecting and developing a mitigation plan for each risk.

We determine the total resource requirements to manage and mitigate a risk by aggregating the resource needs across the various individual mitigation measures contemplated for the mitigation plan.

These two steps help us consider all resource requirements to mitigate a risk and to prepare for developing a practical and feasible mitigation plan.

Step 8: Adjust the Set of RCMs to be Presented in the GRC Considering Resource Requirements

For each risk, the mitigation plan is then finalized, taking into account factors such as the feasibility of executing the overall portfolio and applicable resource constraints. In SCE's RAMP report, the finalized mitigation portfolio for each risk is referred to as the Proposed Plan. At the time SCE prepared its RAMP report, the Proposed Plan represented our best estimate of what we planned to request in the 2021 GRC. As new information became available, SCE further adjusted these RCMs in SCE's 2021 GRC; SCE considered broader funding constraints, emergent risks, changes in available technologies, new data or information, or the emergence of alternative methods to mitigate the risk.

In addition, for each risk, SCE's RAMP report presented two alternatives to the Proposed Plan.

Step 9: Adjust RCMs for Implementation following CPUC Decision on Allowed Resources & Step 10: Monitor the Effectiveness of RCMs

The final two steps were not directly applicable to the SCE's 2018 RAMP report. However, SCE plans to complete Step 9 following a decision on our 2021 GRC. Consistent with D.14-12-025, SCE plans to subsequently address Step 10, which may involve the completion of the Risk Mitigation Accountability Report.

III.

RAMP

A. SCE RAMP Overview

The RAMP report marked a significant milestone in the progress of SCE's risk-informed decision making framework, consistent with the evolution of the framework that has been developing in the SMAP. SCE has taken great care to incorporate the RAMP risk assessment work into this GRC. SCE's RAMP report examined the top safety risks to our customers and the communities we are privileged to serve, to our company, and to our employees and contractors.[8] After rigorous analysis and evaluation, SCE identified these nine top safety risks that warranted inclusion in RAMP: *Building Safety; Contact With Energized Equipment; Cyber Attack; Employee, Contractor, and Public Safety; Hydro Asset Safety; Physical Security; Wildfire; Underground Equipment Failure; and Climate Change*.

Figure III-1
SCE RAMP Top 9 Safety Risks

SCE explained and assessed in detail each of these nine risks in the individual chapters of the RAMP report. We analyzed existing controls and identified new mitigations that can and will help address these risks. For each mitigation plan, we also presented two separate alternative mitigation plans

[8] Throughout the RAMP report, SCE collectively referred to our employees and contractors as "workers."

that we considered. We outlined why, out of the three potential alternatives, we ultimately chose the mitigation plan we selected.

SCE also deployed a new multi-attribute probabilistic risk evaluation model to evaluate these risks and the effectiveness of their associated controls and mitigations. The attributes examined include serious injury, fatality, reliability, and financial. In developing our report, SCE tested several new risk modeling parameters that collectively will advance and illustrate many aspects of the SMAP Settlement Agreement (Settlement).[9] This was SCE's first-generation probabilistic risk evaluation model for use in RAMP, and we expect to refine the model in future RAMP reports.

Finally, SCE candidly discussed lessons learned, and improvement opportunities for future RAMP reports. The RAMP report represented a significant step forward in how SCE thinks about, plans for, and mitigates our top safety risks.[10] It has informed the safety-related funding requests included in this GRC.

B. <u>SED and Intervening Parties' Feedback on RAMP</u>

SED proposed a number of recommended actions for SCE to undertake in its 2021 GRC and subsequent RAMP filings. SCE appreciates these recommendations and has taken each of them into consideration as SCE finalized its 2021 GRC Application. SCE will also carefully consider each recommendation when SCE develops its next RAMP report.

In this chapter, SCE responds to six risk policy-related recommendations provided in the body of SED's report. Other SED comments are addressed in individual chapters throughout SCE's GRC testimony, as applicable. For a roadmap showing the location in SCE's 2021 GRC testimony for each SED comment and corresponding SCE response, please refer to Appendix SCE-01, Volume 2, SED Recommendation Roadmap.

SCE also received comments from the Public Advocates Office (Cal Advocates) and The Utility Reform Network (TURN). Due to the short timeframe between SCE's receipt of these comments and the deadline for SCE to submit its 2021 GRC application, SCE has focused on incorporating and addressing

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[9] A.15-05-002, SCE's Safety Model Assessment Proceeding application, submitted May 2015.

[10] SED concluded that SCE had met the applicable RAMP requirements. See *A Regulatory Review of Southern California Edison's Risk Assessment Mitigation Phase Report for the Test Case 2021 General Rate Case* (SED Report), p. 60. The SED Report is dated May 15, 2019 and was placed into the record of I.18-11-006.

SED's recommendations. SCE will continue to carefully consider the Cal Advocates and TURN comments for purposes of future regulatory filings.

SED Comments & SCE Responses:

Wildfire Risk Comments:

1. **SED Comment:** For the upcoming GRC proceeding, it is recommended that SCE provide a full accounting for activities related to transmission wildfire risks in conjunction with its efforts related to its distribution assets.[11]

   SCE Response: Although the observed quantity of ignitions associated with SCE's transmission assets is substantially lower than its distribution assets, SCE agrees that transmission assets should be carefully evaluated and remediated as needed. SCE has included transmission infrastructure as part of its Enhanced Overhead Inspection (EOI) program,[12] and has performed remediations and additional inspections on these assets. Further, SCE will endeavor to include transmission assets as a component of future wildfire risk analyses. In that context, SCE has included a preliminary wildfire risk analysis regarding transmission in Section IV.F of this testimony.

2. **SED Comment**: In California's new framework, the Commission should require utility vegetation management programs that are consistent with these findings and demonstrate how they are in alignment with current fire science knowledge and best forest management practices. In SCE's GRC filing, it would be informative for the Commission if it included how such programs inform SCE's efforts in wildfire safety. (p. 43)

   SCE Response: SCE's vegetation management programs focus on managing the risk associated with vegetation contacting our overhead infrastructure. As described in Exhibit SCE-02, Volume 6 (Vegetation Management), over the last several years SCE's vegetation management programs have evolved from using regulatory compliance-based criteria to incorporating more

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[11] SED Report, p. 32. The page citations for SED comments in this section of my testimony refer to the SED Report.

[12] Please refer to Exhibit SCE-04, Vol. 05 – Wildfire Management for further discussion of SCE's Enhanced Overhead Inspection & Remediation program.

risk-informed criteria. These changes include, but are not limited to, materially expanded pruning clearances for vegetation in SCE's High Fire Risk Areas (HFRA) as well as the removal of trees that pose risk to our infrastructure through SCE's Hazard Tree Management Program (HTMP). SCE supports the implementation of best forestry management practices by the appropriate stakeholders. These stakeholders include private landowners, and public agencies such as the California Department of Forestry and Fire Protection, and the U.S. Forest Service. In Exhibit SCE-04, Volume 5 (Wildfire Management), SCE describes its efforts in utilizing Fire Sciences as well as advanced modeling to inform various wildfire mitigations across SCE's service territory.

3. **SED Comment:** It would be informative if SCE describes in its upcoming GRC filing how it intends to develop its wildfire safety program during the GRC period of 2018-2023 and beyond that reflects industry best practices and emerging standards. (p. 43)

   SCE Response: From a risk analysis perspective, SCE will incorporate additional engineering and operational subject matter expertise into its risk analysis, and data collected through inspecting equipment in HFRA, including distribution, transmission, and substation infrastructure. As noted in our Grid Safety and Resiliency Program (GSRP) and RAMP filings, SCE is also building and utilizing enhanced situational awareness capabilities to help mitigate wildfire risk.[13] It is important to note that the Commission will be actively considering additional wildfire-related risk-reduction potential "metrics" in Phase 2 of the SB 901 OIR in the months that follow the filing of this GRC.

Flooding / Mudslides:

1. **SED Comment:** Due to the magnitude of these types of events, it warrants that this risk is given prominent consideration in the upcoming GRC proceeding with SCE providing an assessment of the risk of flooding and mudslides that could impact SCE assets and a description of how SCE is addressing this risk. (p. 33)
2. **SED Comment**: With the significant impacts of flooding and mudslides on Southern California communities, SCE should submit additional information on how they are addressing this risk in

[13] Please refer to Exhibit SCE-04, Vol. 05 – Wildfire Management for further discussion of SCE's Enhanced Situational Awareness capabilities.

its 2021 GRC filing. In that filing, SCE should submit a report on the impact that flooding and mudslides have had on their infrastructure in the past five years. In addition, SCE should submit a supplemental risk assessment looking solely at the risk of flooding and mudslides in the designated landslide zones and potential impacts to SCE infrastructure. (p. 43)

SCE Response: SCE did not evaluate this risk as part of RAMP because the primary direct impacts are believed to be reliability, rather than safety. However, SCE will evaluate these risks for potential inclusion in our next RAMP report. In addition, SCE is in the process of evaluating impacts to our electric infrastructure from these risks and provides further information in this GRC in Exhibit SCE-04, Volume 1, Business Continuation (in the Climate Adaptation and Severe Weather section). Additionally, having a more defined scope and understanding of the intent of this recommendation within the RAMP context would be helpful to SCE in examining whether and to what extent the recommended analysis is pursued.

Wildfire / Contact with Energized Equipment

1. **SED Comment**: Additionally, as further discussed in Appendix C, a more refined risk analysis, circuit by circuit or line segment by line segment, would be worthwhile, especially for the Wildfire Covered Conductor Program (WCCP) where Index Scores have already been calculated by SCE. (p. 48)

   SCE Response: SCE agrees and is currently developing a fire consequence model at a circuit-segment level, which will further inform the prioritization for various mitigations based on wildfire risk exposure. This is described within SCE's Wildfire Mitigation Plan (WMP) and is addressed in more detail in Chapter 4 of my testimony.

C. RAMP Integration with GRC

Since SCE's 2018 RAMP report was a new element preceding this 2021 GRC, SCE has carefully incorporated the RAMP risk assessment work into this GRC, including respectful consideration of the Safety and Enforcement Division's (SED) recommendations in its report on SCE's RAMP report. RAMP is a pre-requisite filing of the GRC, allowing the Commission to understand how utilities identify/mitigate safety risks and ensure utilities are placing safety as a top priority.

The GRC process was modified by D.14-12-025, which established the RAMP reporting to help ensure utilities incorporate risk-based decision-making into GRCs, allow the Commission's Safety & Enforcement Division (SED) to evaluate/report on the utilities' RAMP reports, and allow for intervenor engagement and comment. Throughout the testimony supporting our funding request in this GRC, SCE will indicate if work performed within a GRC Activity relates to a control or mitigation as described in SCE's 2018 RAMP report. This content can be found throughout the GRC showing in a "RAMP Integration" section that appears in both O&M and Capital portions of testimony (as appropriate and applicable).

Within the "RAMP Integration" section, there will be a comparison and reconciliation between what SCE estimated in its 2018 RAMP Report, and what SCE now forecasts in this GRC.[14] This will be shown for each control and mitigation within each GRC Activity in the "Reconciliation Between RAMP and GRC" subsection, due to the fact that risk planning has necessarily evolved in the nine-and-a-half months since we filed our RAMP Report. Also, within the "RAMP Integration" section, SCE may, as applicable and appropriate, address feedback that SED or parties provided with regard to SCE's RAMP report.

A RAMP to GRC Roadmap maps each RAMP risk to the corresponding GRC activity and provides the location of the description /reconciliation in each GRC exhibit / volume. Most mitigation plans included in RAMP are primarily consistent in scope and forecast with our 2021 GRC request. However, SCE's accelerated wildfire mitigation plan introduced material scope and forecast changes, which in turn has resulted in re-running certain RAMP risk models. Our efforts here have resulted in revised risk analyses for the following RAMP risks; the updates to the model inputs are summarized below, and the results are discussed in our model refresh workpaper.[15]

1. **Wildfire**:
    a. Driver Frequency - added wildfire incidents to the 2015-2017 ignition dataset used in RAMP with the inclusion of the 2018 CPUC-reportable data; updated the Commission's HFRA designations.
    b. Outcome Percentages – recalculated the outcome percentages based on the 2015-2018 ignition data previously described.

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[14] Please see WP SCE-01, Vol. 02, "2018 RAMP to 2021 GRC Forecast Comparison," pp. 1-3, for a comparison of RAMP to GRC forecasts for RAMP controls and mitigations with forecast costs (2019-2021 for O&M, and 2019-2023 for Capital). For comparison purposes, the RAMP and GRC forecast dollars in the workpaper and in RAMP to GRC comparison tables in various "RAMP Integration" sections of GRC testimony are shown in nominal dollars.

[15] Please see WP SCE-01, Vol. 02, Updated RAMP Risk Analysis, pp. 4-10.

c. Consequences – updated the safety and financial consequence distributions with the inclusion of the 2018 Camp Fire.[16]

d. Mitigations

i. Included Enhanced Overhead Inspections (M10) and Targeted Undergrounding (M11) as new mitigation programs.

ii. Increased scope and cost forecasts for Covered Conductor, Fire Resistant Poles, and Vegetation Management.

2. **Underground Equipment Failure**:

a. Reduced volume of underground cable program work (distribution IR) and cost forecasts.

b. Updated driver frequency to include 2018 data.

3. **Contact with Energized Equipment**:

a. Reduced volume of overhead conductor program work (distribution IR) and cost forecasts.

b. Updated driver frequency and safety consequences to include 2018 data.

Please refer to Appendix SCE-01, Volume 2, RAMP to GRC Roadmap for the location of each RAMP control / mitigation in the corresponding GRC Exhibit / volume. Also, please refer to Appendix SCE-01, Volume 2, RAMP to GRC Comparison. In that appendix, we compare RAMP estimates to GRC forecasts for the controls and mitigations for each of the nine RAMP risks.

[16] Subsequent to the dates that SCE filed its RAMP report and its amendment to certain aspects of that report, CAL FIRE released its findings regarding the cause of the Camp Fire. https://www.fire.ca.gov/media/5038/campfire_cause.pdf

IV.

WILDFIRE RISK ANALYSIS

A. Introduction

Although wildfire risk in California is not a new phenomenon, in recent years, particularly 2017 and 2018, wildfires have increased in both frequency and devastation,[17] resulting in former Governor Brown's proclamation that we have entered a "new abnormal" of wildfire risk with a potential year-round fire season.[18] In addition, Governor Newsom's Strike Force report states that "fifteen of the 20 most destructive wildfires in the state's history have occurred since 2000; ten of the most destructive fires have occurred since 2015." That report also declares that the State and the utilities "must take action to reduce the incidence and severity of wildfires."[19]

As a result of this rapidly evolving risk, the analysis and methods that SCE has used to plan for and mitigate this risk have changed over recent years. This section explains the evolving risk management techniques employed by SCE, specific to wildfire risk assessment and mitigation deployment. SCE believes that a compliance-driven approach for wildfire risk is no longer sufficient to make sure the public is safe. Instead, SCE has deployed a risk-based approach to identify high-risk areas within SCE's service territory, and then to mitigate the risk. This approach uses risk-informed decision-making to comprehensively deploy resources and implement new programs to more effectively mitigate wildfire risk.

B. Overview of Wildfires in California

California's environment has long been conducive to wildfires. Wildfire ignition and propagation require three necessary elements: 1) a heat source that starts the ignition, 2) fuel, or dry vegetation in the case of a wildfire, and 3) oxygen. Together, these elements form the "Fire Triangle," as shown in the figure below. Each one of these elements is required for a fire, and each of these elements are affected by the California environment and continuing climate change.

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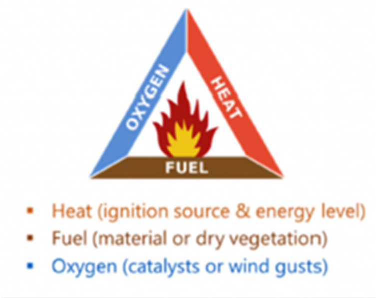
[17] Please see WP SCE-01, Vol. 02, CAL FIRE, Fact Sheet, Top 20 Most Destructive California Wildfires, pp. 11-12, https://www.fire.ca.gov/media/5511/top20_destruction.pdf (March 14, 2019).

[18] Los Angeles Times, *Gov. Brown: Mega-fires 'the new abnormal' for California* (November 11, 2018).

[19] Wildfires and Climate Change: California's Energy Future, A report from Governor Newsom's Strike Force, April 12, 2019.

Figure IV-3
Fire Triangle



Most wildfires tended to occur in the warmer, drier months. In SCE's service territory, this timeframe historically occurred between May and November. However, climate change has now expanded the risk to all months of the year. This expanded risk is driven by increasing temperatures, higher wind speeds, and reduced precipitation. This combination of factors decreases the moisture level throughout shrub-dominated terrain in California. This drier vegetation, coupled with increased tree mortality as a result of drought events and bark beetle infestation, has increased the amount of "fuel" available to start and sustain a wildfire.

While it was always understood that wildfires posed a destructive threat to California, the frequency and destruction of recent fires have begun to indicate that the threat is greater and more severe than previously thought. As stated in the Brattle Group report, "the U.S. Global Change Research Program predicts increased incidence rates and intensity of extreme temperatures, heavy precipitation events, extreme storms, heat waves, and large forest fires in the west and Alaska."[20,21] The Brattle report also notes that "both the U.S. Department of Energy and the Department of Homeland Security have

[20] The Brattle Group, "California Megafires, Approaches for Risk Compensation and Financial Resiliency Against Extreme Events, prepared for Southern California Edison," April 9, 2019.

[21] U.S. Global Change Research Program, "Climate Science Special Report: Fourth National Climate Assessment, Volume I," 2017, pp. 21–22, accessed February 2019, https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf.

acknowledged additional risks and vulnerabilities to the power sector and to the economy in general as a result of these changing trends."[22,23]

California experienced five of the most destructive fires in its history in 2017. At the time, 2017 was the deadliest and costliest year of wildfires on record. The experience of this fire season spurred Governor Brown and other officials to agree that that a "new normal" has commenced where the wildfire season is year-round.[24] CAL FIRE confirmed this view, stating that California "now often experiences a year-round fire season, with an increase in both the number and intensity of large, damaging fires over the last decade."[25]

2018 did not bring a reprieve for California from destructive wildfires. Within the past two years, eight of California's twenty most destructive fires have occurred.

C. Wildfire analysis through SMAP, GSRP, and RAMP

The Risk OIR (R.13-11-006) and the subsequent Decision D.14-12-025 established a formalized process (SMAP and RAMP) for utilities to demonstrate the processes and plans California utilities are implementing to place safety as a top priority. As discussed above, through the RAMP process SCE identified nine top safety risks for the Company. One of these risks was ignitions associated with SCE equipment that could lead to wildfires. (Please refer to SCE's 2018 RAMP report for a full explanation of how SCE selected the top safety risks.) While SCE was developing its RAMP report in 2018, SCE outlined incremental efforts to address the wildfire risk through its GSRP. Much of the analysis and planning that was conducted for wildfire risk in the GSRP influenced the analysis and planning for wildfire risk in the RAMP report.

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[22] U.S. Department of Energy, "U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather," July 2013, accessed February 2019, https://www.energy.gov/sites/prod/files/2013/07/f2/20130716-Energy%20Sector%20Vulnerabilities%20Report.pdf.

[23] U.S. Department of Homeland Security, "DHS Climate Action Plan," September 2013, accessed February 2019, https://www.dhs.gov/sites/default/files/publications/DHS%20Climate%20Action%20Plan.pdf.

[24] Ruben Vives et al., *Southern California's Fire Devastation is the 'New Normal' Gov. Brown Says*, Los Angeles Times (Dec. 10, 2017), *available at* http://www.latimes.com/local/lanow/la-me-socal-fires-20171210-story.html; *see also* CA. Exec. Order No. B-52-18 (May, 2018), *available at* https://www.gov.ca.gov/wp-content/uploads/2018/05/5.10.18-Forest-EO.pdf.

[25] News Release, CAL FIRE, Board of Forestry and Fire Protection and CAL FIRE Working to Increase Pace and Scale of Wildfire Prevention Activities (Dec. 2017), available at http://www.fire.ca.gov/communications/downloads/newsreleases/2017/2017_BOF_CALFIRE_VTPPEIR_newsrelease.pdf.

The GSRP sought to implement broader and more advanced measures to reduce wildfire risk.[26] The detailed risk mitigation analysis conducted in GSRP followed three sequential steps: fault-to-fire mapping, mitigation-to-fault mapping, and the calculation of mitigation effectiveness factors and cost-mitigation ratios. The fault-to-fire mapping was a process of mapping fire ignition data (using detailed ignition data analysis) to faults tracked in the Outage Database and Reliability Metrics System (ODRMS). This process allowed SCE to connect data regarding the frequency of faults of different types to data regarding the frequency of fires associated with those fault types.[27]

The next step involved mapping specific mitigation alternatives to the types of faults that can be avoided when the mitigation is deployed. This analysis relied on engineering subject matter expertise to identify how much of each general fault type would be mitigated by a specific mitigation measure.[28] And finally, we assessed mitigation effectiveness by combining the fault-to-fire mapping and the mitigation-to-fault mapping. This mitigation effectiveness factor is interpreted as an estimate of the percentage of fires avoided when the mitigation measure is fully deployed throughout HFRA, all else being equal.[29]

In developing our RAMP, we created a stand-alone bowtie for wildfire risk. The bowtie details how SCE broke down the risk into its different components. SCE did so to analyze, understand, and probabilistically model the risk of a wildfire on the distribution system in HFRA. Much of the data and assumptions regarding risk drivers and mitigation effectiveness that SCE developed in GSRP was also used in the RAMP report. The wildfire risk bowtie from SCE's RAMP report is shown below.

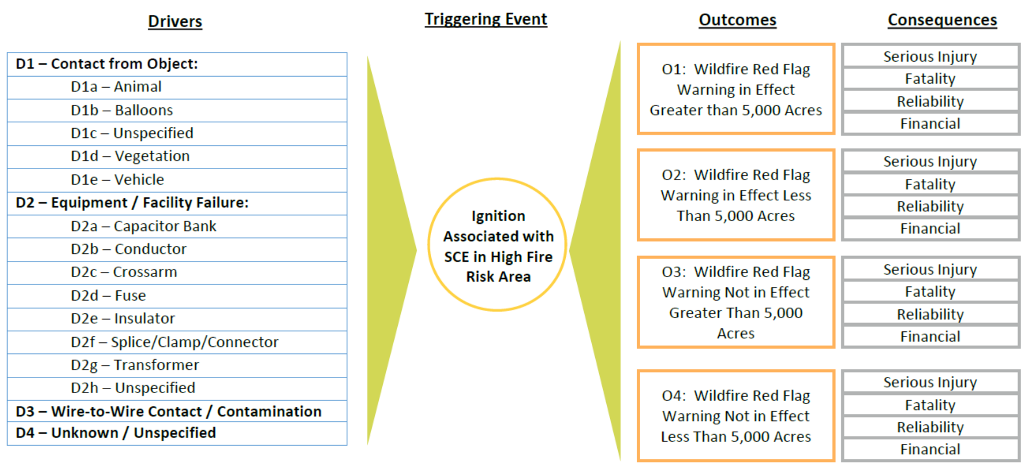
[26] 18-09-002 SCE 2018 Grid Safety and Resiliency Program Executive Summary, p. 2.

[27] SCE GSRP filing (18-09-002), September 10, 2018, p. 50.

[28] *Ibid*, p. 51.

[29] Safety Model Assessment Proceeding (SMAP), Decision 18-12-014, p. 52.

Figure IV-2
SCE's Wildfire Bowtie



From this analysis, SCE determined the four categories of risk drivers (left side of bowtie): contact from object, equipment/facility failure, wire-to-wire contact, and other. Using ignition data from 2015-2017 for ignitions on distribution voltages within the HFRA, the two main drivers were contact from object and equipment/facility failure, resulting in over 84% of events leading to an ignition. All these drivers combine to equate to an expected number of 44 wildfires ignitions per year.

On the right side of the bowtie, outcomes were broken down from the ignition data (described above) based upon the size of the fire (greater or less than 5,000 acres) and the presence of a Red Flag Warning, for a total of four outcomes. SCE used the 5,000 acre cutoff to distinguish between large fires with significant safety, financial and reliability consequences, and smaller fires with less consequences. The outcome with the greatest likelihood of occurring is "O4 – Wildfire Red Flag Warning Not in Effect, Less than 5,000 acres," with a probability of approximately 68%. The outcome with the least likelihood of happening but with the most severe consequence is "O1 – Wildfire Red Flag Warning in Effect, Greater than 5,000 acres," with a probability of approximately less than 1%.

Consequences are defined as serious injuries, fatalities, reliability, and financial. These consequences are associated with each of the four outcomes described above. Using the probabilistic model described in Chapter 2 of the RAMP report, SCE calculated expected and tail average values for each of these consequences. These values and the outputs of the wildfire risk model are discussed in detail in Chapter 10 of SCE's RAMP report.

Mitigation programs for this risk were evaluated based upon the impacts to different drivers, outcomes, and consequences. We evaluated each mitigation and portfolio of mitigation programs using MARS units and calculating RSEs to inform the effectiveness for each. The mitigation programs that we selected from the GSRP, WMP and RAMP processes are covered in more detail in Exhibit SCE-04, Volume 5 (Wildfire Management),[30] as well as SCE-02, Volume 6 (Vegetation Management).

D. <u>SCE's Current Risk-based Approach to Wildfire</u>

Wildfire risk analysis is not static and must continue to evolve. Over the past year, SCE has worked diligently to understand the risk drivers, outcomes, and consequences of wildfires through the GSRP and RAMP. This effort has led to an enhanced understanding of the wildfire risk at a system-wide or macro-level.

In the SB 901 Wildfire Mitigation Plan (WMP), SCE committed to risk-based modeling to inform decisions to improve the design, construction, maintenance, and operation of SCE's assets. SCE has now moved to a more dynamic approach to understand wildfire risk at a micro-level and design mitigation programs to target risk at a structure and circuit segment level. SCE has enhanced and will continue to refine the risk analysis and prioritization methodologies that are currently in use. This includes SCE's deployment of covered conductor. SCE considers its wildfire risk analysis to be a continuous improvement process that is informed by the best available data and analysis at the time. The analysis will also continually factor in the experience and learning that SCE obtains when implementing wildfire mitigation strategies. As we obtain better and more refined information and gather more data, we will leverage that information and data to try to find ways to get better and more efficient at mitigating wildfire risk.

In early 2019, SCE engaged Reax Engineering (Reax), an experienced fire science consultant, to develop a fire-propagation model for areas surrounding SCE's overhead facilities within the HFRA, and to identify relative consequence areas based on fire-weather climatology and Census data.[31] This in turn,

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[30] The Wildfire volume may utilize updated information compared to what SCE presented in its RAMP showing.

[31] Reax Engineering co-chaired the Peer Development Panel as part of Rulemaking (R.) 15-05-006 to develop the statewide HFTD maps.

along with the number of structures within a modeled fire perimeter, was used to predict the consequence of wildfire ignitions. The more technical details are found in our workpapers.[32]

In addition to using this fire-propagation model, SCE enhanced its prioritization methodology to target high-consequence structures and areas, together with overhead assets that were susceptible to wire-to-wire contact and equipment failure under elevated fire-weather conditions. SCE also included additional equipment types (beyond what was included in GSRP and RAMP) in its updated analyses. These additional equipment types were ones were not associated with reportable historical ignitions in SCE's HFRA, but could potentially lead to an ignition. Some examples are lightning arresters, poles, protective relays, and switches. Accordingly, certain high-risk segments of circuits[33] are now being prioritized, as opposed to entire circuits. This prioritization methodology is discussed further in SCE-04, Volume 5 – Wildfire Management.

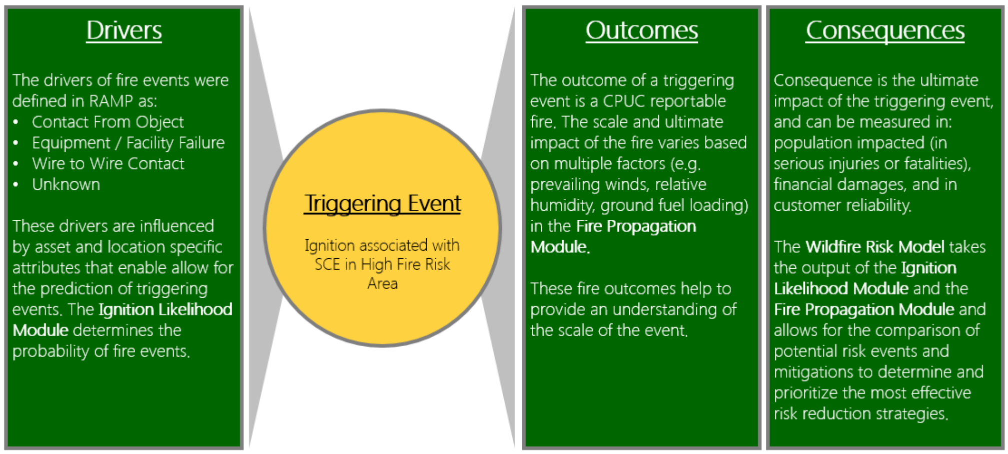
SCE leveraged the outputs of the Reax model to develop a Wildfire Risk Model. The Wildfire Risk Model builds upon the principles outlined in RAMP for the impact and consequences of wildfires. The Risk Model applies ignition probability and fire propagation to specific SCE circuits and circuit segments across the service territory. The Wildfire Risk Model once again uses the bowtie approach, but applies the approach at the circuit and segment level to localize the drivers, outcomes, and consequences for each specific circuit and segment.

The output of the Wildfire Risk Model is a risk score that identifies potential high-risk circuits and segments where additional mitigation considerations, such as covered conductor, targeted undergrounding, circuit relocation/elimination, or other strategies may be considered. The model has three components: an ignition module, a fire propagation module, and a consequence module.

[32] Please see WP SCE-01, Vol. 02, Reax Fire Risk from Overhead Electrical Facilities, June 2019, pp. 13-43.

[33] "Segment" refers to the length of conductor between two isolation points – dead ends, switches, tap lines, etc. The segment length here typically ranges between 0.5 and 1 mile long.

Figure IV-4
Wildfire Risk Model Overview Adapted to Bowtie Framework



The ignition module determines the likelihood or probability that a circuit or a segment will experience a fault that leads to an ignition. Ignition probabilities are predicted at the risk driver levels defined in GSRP and RAMP, namely Contact-from-Object, Equipment/Facility Failure, and Wire-to-Wire Contact. The model predicts the annual probability of these ignitions occurring by analyzing various independent variables at the circuit and segment levels. The ignition probabilities generate an overall ignition likelihood. That overall ignition likelihood determines the annual frequency of an ignition event for each circuit or segment.

The second module is the fire propagation module which replaces the broader "outcome" scenarios presented in GSRP and RAMP by forecasting the following specific items:

- A fire's characteristics once it starts;
- Where the fire will move;
- The intensity of the fire; and
- The potential structures impacted by the fire.

Fire simulations near each HFRA circuit and segment are currently provided by Reax using its fire modeling technology (ELMFIRE). That technology utilizes a twenty-year fire weather climatology model to recreate historical days of fire weather across SCE's service territory. High-resolution, hourly-gridded fields of relative humidity, temperature, dead fuel moisture, and wind speed/direction were extracted from this analysis. These items were then provided as inputs to a Monte Carlo[34] simulation using hundreds of thousands of ignition locations distributed randomly within an extended perimeter or "buffer" surrounding SCE's overhead facilities in the HFRA. Fire volume (*i.e.*, the spatial integral of fire area and flame length) were also tabulated and recorded.

This process was repeated across SCE's service territory for hundreds of thousands of combinations of ignition location and time of ignition. Outputs from this Monte Carlo fire-modeling analysis were used to quantify consequence as the product of Fire Volume and Impacted Structures. Impacted Structures is quantified as the number of structures within a modeled fire perimeter.

The third and final component of the model is the fire consequence module. This module enhances the Reax consequence output to consider not only the destruction of homes and structures, but also the risk to life for civilians and firefighters, and acres of property burned. In addition to these immediate consequences, there are additional impacts, such as economic and community impacts, and forced relocations. Structures are fixed locations; therefore, a higher ratio of structures can be destroyed in a fire. People can be moved or displaced, which fortunately leads to lower rates of injury and loss of life. In order to prudently estimate these impacts, SCE has updated the building structure and population data with a 2017 data set. As part of continuous improvement, SCE intends to evolve its wildfire risk analysis tools by appropriately using more advanced fire-modeling technology solutions as they become available and feasible to use.

E. <u>Risk Analysis of Near-Term Shift of Resources to Mitigate Wildfire Risk</u>

As discussed by Mr. Payne in SCE-01, SCE is vigorously working to mitigate the risk of wildfires. This involves reprioritizing resources from traditional infrastructure programs to perform work on wildfire mitigations. SCE expects this to be a near-term exercise to address this very real and emergent threat. In the course of deciding to pursue this strategy, SCE performed a risk analysis to evaluate the public safety impacts of shifting resources from traditional infrastructure replacement programs to wildfire mitigations.

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[34] Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values – a probability distribution – for any factor that has inherent uncertainty. It then calculates results over and over, each time using a different set of random values from the probability functions. By using probability distributions, variables can have different probabilities of different outcomes occurring. Probability distributions are a much more realistic way of describing uncertainty in variables of a risk analysis. It tells not only what could happen, but how likely it is to happen. Additional Monte Carlo simulation information is available at http://www.palisade.com/risk/monte_carlo_simulation.asp.

This analysis shows that the safety reduction *gained* through the enhanced portfolio of wildfire mitigations *exceeds* the safety reduction *lost* in other risk initiatives in RAMP, specifically Contact with Energized Equipment and Underground Equipment Failure. The methodology and summary of results can be found in our workpapers.[35]

F. Wildfire Risk Associated with Transmission Assets

SCE adopted the same principles developed and used in RAMP to analyze the risk of wildfire associated with Transmission assets. A similar bowtie was used with Transmission-specific drivers, maintaining the same outcomes and consequences for ignitions associated with Distribution assets. Since there is a much lower frequency of fires associated with Transmission assets,[36] SCE used the annual average CPUC-reportable ignitions over the 2015-2018 period in SCE's HFRA. However, to better sample the distribution of these ignitions, we examined all investor-owned utility CPUC-reportable ignitions associated with Transmission assets across the entire California High Fire Threat Districts (HFTD).[37] This distribution of drivers and sub-drivers was then normalized to SCE's HFRA annual Transmission ignition frequency. Please see our workpaper on Transmission Ignition Analysis for more information.[38]

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[35] Please see WP SCE-01, Vol. 02, Wildfire Tradeoff Risk Analysis, pp. 44-46.

[36] Even though such fire incidents occur less frequently compared to distribution assets, SCE undertakes a number of measures to help mitigate the risks. These efforts include performing drone inspections and making use of Light Detection and Ranging technology (LiDAR) to help identify potential safety issues regarding overhead transmission lines.

[37] As defined by the Commission.

[38] Please see WP SCE-01, Vol. 02, Transmission Ignition Risk Analysis, pp. 47-49.

V.
OTHER OPERATIONAL RISK

A. Overview

While ERM identifies and tracks *enterprise* risks for the Company, there are certain *operational* risks identified and evaluated among operational units (OUs). The senior leadership and risk management teams at the OU level develop a deep understanding of the risks that the OU faces on a day-to-day basis. The OU level is responsible for identifying operational risks, assessing these risks, developing mitigation plans and alternatives, evaluating the mitigation alternatives, and calibrating risk scores and mitigation plan efficacy within each OU.

As a result, the data and analytics that these OUs develop are primary inputs when other arms of the Company, particularly ERM, are making risk-informed decisions. Across OUs there are varying levels of risk management structure and tools, driven by the risk faced by each OU and the available data and tools. Below, we have included a few examples of these operational risk approaches for Transmission & Distribution, Generation (Hydro), and Cybersecurity below.

B. Transmission & Distribution Prioritized Risk Informed Strategic Management (PRISM)

SCE's Transmission & Distribution Organization (T&D) follows a risk assessment framework referred to as Prioritized Risk-Informed Strategic Management (PRISM). SCE began piloting the PRISM framework within T&D in 2014. PRISM primarily evaluates safety, reliability, and financial risk. Where applicable, PRISM will also evaluate environmental and compliance risks associated with the electric system.

PRISM is based on an event-based methodology that evaluates the potential negative outcomes that can result from a particular event. PRISM risk assessments rely on empirical data and are supplemented by subject-matter expertise. Risk assessments are completed across a variety of T&D activities. The results are reviewed by T&D staff before being used to influence operational and planning decisions. The process followed to complete PRISM risk assessments is consistent with the ERM framework that includes identifying risks, evaluating risks, identifying risk mitigations, evaluating risk mitigations, planning and making decisions with respect to risks, and monitoring risks and reporting on them.

In SCE's 2018 RAMP report, PRISM results were used as an input for modeling of those activities that had complete PRISM risk assessments. Asset-specific risk scores informed RAMP input assumptions regarding effectiveness of controls and mitigations. Incorporating PRISM results in RAMP modeling allowed SCE to account for the benefit of targeting the highest-risk assets first through "targeting benefits" for controls and mitigations. As T&D continues to complete risk assessments, PRISM is expected to support future RAMP and GRC efforts, which are required to adopt the principles and practices of the SMAP Settlement.

In T&D, PRISM risk assessment results have been applied to inform prioritization of work within an activity and to inform decisions on allocating funds across a subset of activities.

PRISM results are used to inform prioritization of work within an activity, such as helping to determine which specific equipment in an asset group to replace first or which project to prioritize over others. Current PRISM analysis is equipment- or project-specific and is detailed enough to be used by project scoping organizations to inform prioritization within an activity. Five Distribution Infrastructure Replacement (IR) activities and two Substation IR activities currently rely on PRISM analysis to inform detailed prioritization decisions.[39]

In addition to PRISM analysis results, a variety of other factors are considered as constraints in making a final determination with regard to equipment or project prioritization. These factors include execution constraints, work that was initiated before PRISM results were available, and field assessment input.

In addition to informing prioritization of work within an activity, PRISM results are used to inform decisions on allocating funds across activities while taking into account funding and resource constraints. T&D accounts for the inherent risk exposure and the effectiveness of mitigation activities when allocating funding and resources. PRISM risk assessment results include mitigation risk reduction and risk spend efficiency metrics comparable across activities.

Evaluating risks, identifying and prioritizing work, and allocating resources has always been part of T&D planning for SCE. SCE has developed PRISM as a framework to consistently document existing risks and risk reduction benefits for mitigations. The scope of PRISM risk assessments and methodology will continue to advance, utilize new data sources as they become available, and expand to incorporate requirements and feedback from regulatory proceedings such as SMAP.

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[39] Distribution IR activities assessed by PRISM include the Overhead Conductor Program (OCP), the cable portion of the Worst Circuit Rehabilitation (WCR) program, 4kV Cutover and Substation Elimination, Covered Pressure Relief Restraints (CPRR), and UG Switches. Please see Exhibit SCE-02, Vol. 01, Chapter 2 for details. Substation IR activities assessed by PRISM include Circuit Breakers and Transformers. Please refer to Exhibit SCE-02, Vol. 03 for details.

C. Generation (Hydro)

SCE operates a portfolio of 33 hydroelectric plants, supported by 81 dams, that provide a combined 1,153 MW of generating capacity. The dams are typically located in remote mountainous areas and designed to capture the energy from high elevation rain and snowmelt that flows downward. Most of these dams were constructed in the early 20th century, with the oldest dating to 1893 and the most recent dating to 1986. SCE performs a number of compliance tasks and controls that cost-effectively mitigate the hydroelectric plant risks. Therefore, SCE's RAMP report recommends continuing these controls and does not contain any new types of mitigation activities.[40]

SCE approached its analysis of Hydro Asset Safety by building on its existing Dam Safety Risk Assessment Program. SCE's Dam Safety Risk Assessment Program was initiated in 2008 and modeled after hydro dam risk management best practices established by the U.S. Bureau of Reclamation. The approach is based on identifying the potential ways a specific dam could fail, known as Potential Failure Modes (PFMs), and then evaluating the likelihood of occurrence and the consequence of each PFM. The risk assessment methodology is consistent with the FERC Risk Informed Decision Making Guidelines and the Federal Guidelines for Dam Safety Risk Management.

D. Cybersecurity

The energy sector is under continuous cyberattack.[41] The attack methods, strategies, and capabilities are constantly evolving as new types of attacks are discovered and carried out. Intrusion attempts against SCE continue to increase. Such attacks include computer viruses, worms, phishing, spyware, and advanced persistent threats. Any of these aggressive actions, if successful, could significantly damage SCE's information systems. A prominent security-related periodical has noted: "The modern enterprise network has become expansive, porous, and completely blurred due to the large number of Internet facing applications that have been deployed and adopted. The number of potential entry points into the enterprise network has proliferated uncontrollably."[42]

Cybersecurity's importance to utilities has expanded as systems and data have become more integral to business operations, and as the electric infrastructure has become more essential to national

[40] See SCE 2018 RAMP report, Chapter 8 – Hydro Asset Safety.

[41] Please refer to SCE's Test Year 2018 General Rate Case, A.16-09-001, Exhibit SCE-04, Vol. 02, Workpapers Book A, pp. 115-116.

[42] Refer to A.16-09-001, Exhibit SCE-04, Vol. 02, Workpapers Book A, pp. 117-120.

commerce and communications capabilities. Cyberattacks are continually growing in number and sophistication, and the availability of cyberweapons[43] is on the rise as well. Therefore, maintaining a strong defense against cyberattack requires a continually evolving set of strategies. SCE's efforts and analysis concerning cyberattacks and cybersecurity are discussed in Exhibit SCE-04, Volume 3.

SCE's bowtie structure for this cyberattack risk identified several options to mitigate the risk. In its RAMP showing, SCE presented a proposed plan that balanced risk mitigation, execution feasibility, and cost efficiency. That proposed portfolio of mitigations in RAMP leveraged the success of existing and ongoing cybersecurity programs and addressed enhanced capabilities that would help maintain SCE's defenses amidst the growing and persistent threat of cyberattack.

[43] For example, BlackEnergy malware was initially used to steal banking credentials, but later re-designed to attack the Ukraine power utilities in 2015. A summary is available at https://attack.mitre.org/wiki/Software/S0089.

2021 General Rate Case
Workpapers SCE-01, Vol. 02

DOCUMENT	PAGE(S)
WP SCE-01, Vol. 02 – 2018 RAMP to 2021 GRC Forecast Comparison	1 – 3
WP SCE-01, Vol. 02 – Updated RAMP Risk Analysis	4 – 10
WP SCE-01, Vol. 02 – Top 20 Most Destructive California Wildfires	11 – 12
WP SCE-01, Vol. 02 – Reax Fire Risk from Overhead Electrical Facilities	13 – 43
WP SCE-01, Vol. 02 – Wildfire Tradeoff Risk Analysis	44 – 46
WP SCE-01, Vol. 02 – Transmission Ignition Risk Analysis	47 - 49

Workpaper Title:

2018 RAMP to 2021 GRC Forecast Comparison
SCE-01, Vol. 2

2018 RAMP to 2021 GRC Forecast Comparison
O&M and Capital (Nominal Dollars)

2021 GRC Mapping					RAMP O&M			GRC O&M			O&M Variance			RAMP Capital					GRC Capital					Capital Variance				
Test. Exhibit	Test. Volume	BPG	BPE	GRC Activity / Sub-Activity	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
2	1. Pt. 1	Distribution Grid	Infrastructure Replacement	Overhead Conductor Program (OCP)	-	-	-	-	-	-	-	-	-	139,000,000	127,926,044	113,839,590	110,534,494	119,426,517	100,062,502	34,992,203	70,939,298	83,134,386	92,891,405	(38,937,497)	(92,933,841)	(42,900,292)	(27,400,109)	(26,535,111)
2	1. Pt. 1	Distribution Grid	Infrastructure Replacement	Worst Circuit Rehabilitation (WCR)	-	-	-	-	-	-	-	-	-	103,680,537	93,369,686	93,367,476	93,367,447	99,701,603	67,291,234	32,565,877	6,959,874	7,161,186	7,733,505	(36,389,303)	(60,803,810)	(86,407,602)	(86,206,261)	(91,968,098)
2	1. Pt. 1	Distribution Grid	Infrastructure Replacement	Cable Life Extension (CLE) Program	-	-	-	-	-	-	-	-	-	21,750,688	20,277,891	20,277,891	20,277,891	20,277,891	20,573,744	-	-	-	-	(1,176,944)	(20,277,891)	(20,277,891)	(20,277,891)	(20,277,891)
2	1. Pt. 1	Distribution Grid	Infrastructure Replacement	Cable-in-Conduit (CIC) Replacement Program	-	-	-	-	-	-	-	-	-	42,828,194	40,000,000	40,000,000	40,000,000	40,000,000	17,074,377	13,866,195	5,989,111	6,162,344	5,987,391	(25,753,817)	(26,133,805)	(34,010,889)	(33,837,656)	(34,012,609)
2	1. Pt. 1	Distribution Grid	Infrastructure Replacement	Underground Switch Replacements	-	-	-	-	-	-	-	-	-	16,689,596	17,388,066	17,789,012	22,017,150	23,091,555	3,388,941	3,520,227	2,641,612	3,284,274	3,495,247	(13,300,655)	(13,867,839)	(15,147,400)	(18,732,876)	(19,596,308)
2	1. Pt. 1	Distribution Grid	Infrastructure Replacement	Underground Structure Replacements	-	-	-	-	-	-	-	-	-	8,000,000	15,000,000	15,000,000	15,000,000	15,000,000	8,015,000	8,208,000	8,420,000	8,639,000	8,836,000	15,000	(6,792,000)	(6,580,000)	(6,361,000)	(6,164,000)
2	6	Distribution Grid	Vegetation Management	Wildfire Vegetation Management	40,768,796	80,656,831	81,771,899	15,590,482	31,564,490	42,567,512	(25,178,314)	(49,092,341)	(39,204,387)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	2	Customer Interactions	Communications, Education & Outreach	External Communications	5,450,660	5,450,660	5,450,660	6,455,209	6,455,209	6,512,146	1,004,549	1,004,549	1,061,486	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	1	Resiliency	Business Continuation	All Hazards Assessment, Mitigation & Analytics	1,031,000	1,031,000	1,031,000	831,000	1,032,000	833,000	(200,000)	1,000	(198,000)	6,608,200	5,619,000	6,500,000	6,500,000	6,500,000	9,000,000	8,000,000	8,000,000	8,000,000	8,000,000	2,391,800	2,381,000	1,500,000	1,500,000	1,500,000
4	1	Resiliency	Business Continuation	All Hazards Assessment, Mitigation & Analytics	527,000	383,000	389,000	645,566	703,090	853,957	118,566	320,090	464,957	-	-	-	-	-	-	200,000	1,360,000	2,600,000	2,600,000	-	200,000	1,360,000	2,600,000	2,600,000
4	2	Resiliency	Emergency Management	Training, Drills and Exercises	135,000	138,000	138,000	228,002	233,081	265,548	93,002	95,081	127,548	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	2	Resiliency	Emergency Management	Training, Drills and Exercises	2,110,971	2,141,071	2,169,542	2,009,306	2,038,893	2,069,368	(101,665)	(102,178)	(100,174)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	2	Resiliency	Emergency Management	Emergency Preparedness & Response	1,357,100	1,398,000	1,442,071	1,801,367	1,855,408	1,911,070	444,267	457,408	468,999	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	2	Resiliency	Emergency Management	Emergency Preparedness & Response	799,000	798,000	822,000	557,999	550,399	567,141	(241,001)	(247,601)	(254,859)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Grid Mod Cybersecurity	708,712	624,307	628,319	722,181	625,316	629,922	13,469	1,008	1,603	32,016,318	36,010,299	26,163,050	20,596,290	29,757,050	25,702,283	24,949,280	45,245,041	28,933,844	36,426,367	(6,314,035)	(11,061,019)	19,081,991	8,337,554	6,669,317
4	3	Resiliency	Cybersecurity	Cyber Delivery	2,721,204	2,990,225	4,485,658	2,804,701	3,001,423	6,230,622	83,498	11,198	1,744,964	13,099,352	13,578,739	13,577,476	13,584,693	13,587,122	16,099,352	19,602,216	37,577,476	37,414,693	35,417,122	3,000,000	6,023,477	24,000,000	23,830,000	21,830,000
4	3	Resiliency	Cybersecurity	Cyber Delivery	1,818,724	2,483,485	3,634,171	1,922,890	2,488,351	5,637,334	104,166	4,866	2,003,163	8,253,666	8,102,638	8,107,197	8,108,020	8,111,119	8,253,666	8,102,638	8,107,197	8,108,020	8,111,119	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Cyber Delivery	1,543,821	2,101,839	3,419,915	1,646,842	2,118,574	5,359,202	103,021	16,735	1,939,287	5,991,341	6,067,803	6,070,815	6,071,358	6,073,405	5,991,341	7,267,803	8,570,815	8,571,358	12,373,405	0	1,200,000	2,500,000	2,500,000	6,300,000
4	3	Resiliency	Cybersecurity	Cyber Delivery	2,393,327	2,644,606	3,833,116	2,476,328	2,690,531	5,401,761	83,001	45,925	1,568,645	2,447,921	2,549,308	2,551,498	2,551,893	2,553,382	2,447,921	2,549,308	2,551,498	2,551,893	2,553,382	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Cyber Delivery	1,619,478	3,130,541	4,474,018	1,724,053	3,007,802	6,319,304	104,575	(122,739)	1,845,286	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Cyber Software License & Maint	1,803,100	2,383,100	2,383,100	1,610,631	2,383,100	2,383,100	(192,470)	(0)	(0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Cyber Software License & Maint	1,039,635	1,039,635	1,039,635	928,660	1,039,635	1,039,635	(110,975)	(0)	(0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Cyber Software License & Maint	171,795	171,795	171,795	153,457	171,795	171,795	(18,338)	(0)	(0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Cyber Software License & Maint	132,958	132,958	132,958	118,766	132,958	132,958	(14,192)	(0)	(0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	3	Resiliency	Cybersecurity	Cyber Software License & Maint	2,005,042	2,005,042	2,005,042	1,791,016	2,005,042	2,005,042	(214,026)	(0)	(0)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	4	Resiliency	Physical Security	Work Force Protection/Insider Threat	-	-	-	-	-	-	-	-	-	-	-	-	-	6,000,000	-	-	-	-	-	-	-	-	-	(6,000,000)
4	4	Resiliency	Physical Security	Protection of Grid Infrastructure Assets	100,000	130,000	140,000	81,557	74,490	16,922	(18,443)	(55,510)	(123,078)	19,683,270	39,529,240	31,148,267	19,593,484	20,120,789	20,774,000	38,652,000	27,715,000	35,210,000	29,201,000	1,090,730	(877,240)	(3,433,267)	15,616,516	9,080,211
4	4	Resiliency	Physical Security	Protection of Generation Assets	-	100,000	160,000	-	-	40,000	-	(100,000)	(120,000)	3,335,000	3,471,000	3,523,000	3,648,371	3,780,197	2,335,260	2,471,380	3,210,808	2,648,371	2,780,197	(999,740)	(999,620)	(312,192)	(1,000,000)	(1,000,000)
4	4	Resiliency	Physical Security	Protection of Major Business Functions	-	200,000	220,000	-	97,900	97,900	-	(102,100)	(122,100)	9,672,000	9,920,000	10,104,000	10,545,000	11,006,000	9,738,302	9,988,255	13,423,528	16,968,183	16,516,534	66,302	68,255	3,319,528	6,423,183	5,510,534
4	4	Resiliency	Physical Security	Technology Solutions	42,077	83,081	51,032	45,086	91,616	212,497	3,008.28	8,534.97	161,465.07	-	1,858,900	17,437	2,017,437	7,437	5,076,000	7,198,000	-	2,000,000	-	5,076,000	5,339,100	(17,437)	(17,437)	(7,437)
4	4	Resiliency	Physical Security	Security Technology Operations and Maintenance	20,951,118	20,331,550	19,567,672	20,857,298	22,782,376	24,143,324	(93,820)	2,450,826	4,575,652	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	4	Resiliency	Physical Security	Work Force Protection/Insider Threat	139,033	139,033	139,033	139,033	139,033	139,033	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	4	Resiliency	Physical Security	Protection of Major Business Functions	-	-	57,000	-	-	-	-	-	(57,000)	1,249,000	4,351,000	3,435,000	-	-	-	-	1,249,000	4,351,000	3,435,000	(1,249,000)	(4,351,000)	(2,186,000)	4,351,000	3,435,000
4	4	Resiliency	Physical Security	Protection of Major Business Functions	-	-	-	-	-	-	-	-	-	2,125,000	850,000	1,042,000	1,042,000	1,042,000	-	-	-	-	-	(2,125,000)	(850,000)	(1,042,000)	(1,042,000)	(1,042,000)
4	5	Resiliency	Wildfire Management	Enhanced Situational Awareness	4,760,770	6,120,928	4,840,790	5,350,058	3,303,067	3,640,881	589,288	(2,817,861)	(1,199,909)	12,483,061	8,499,632	21,941	-	-	6,364,433	4,158,791	-			(6,118,628)	(4,340,841)	(21,941)	-	-
4	5	Resiliency	Wildfire Management	Infrared Inspections	465,807	474,832	481,293	406,350	411,348	416,055	(59,457)	(63,484)	(65,239)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	5	Resiliency	Wildfire Management	Wildfire Covered Conductor Program	-	-	-	51,123	-	-	51,123	-	-	42,407,432	194,586,993	236,542,605	296,118,195	359,146,902	156,336,715	533,803,106	771,099,049	906,746,092	1,107,731,703	113,929,283	339,216,113	534,556,444	610,627,897	748,584,801
4	5	Resiliency	Wildfire Management	Wildfire Covered Conductor Program	-	-	-	-	-	-	-	-	-	12,881,055	13,289,370	13,715,704	14,117,671	14,518,907	-	-	-	-	-	(12,881,055)	(13,289,370)	(13,715,704)	(14,117,671)	(14,518,907)
4	5	Resiliency	Wildfire Management	HFRA Sectionalizing Devices	284,891	-	-	1,260,367	158,251	-	975,476	158,251	-	9,089,892	19,288,367	-	-	-	6,292,248	28,452,419	5,209,104	5,359,776	-	(2,797,644)	9,164,052	5,209,104	5,359,776	-
4	5	Resiliency	Wildfire Management	Fusing Mitigation	1,735,480	21,674,976	-	53,258	8,229,742	1,213,589	(1,682,222)	(13,445,234)	1,213,589	46,490,192	9,990,425	-	-	-	50,172,864	8,742,923	-	-	-	3,682,672	(1,247,502)	-	-	-
4	5	Resiliency	Wildfire Management	Wildfire Covered Conductor Program	-	-	-	-	-	-	-	-	-	5,148,620	23,624,504	28,718,269	35,951,249	43,603,466	-	-	-	-	-	(5,148,620)	(23,624,504)	(28,718,269)	(35,951,249)	(43,603,466)
4	5	Resiliency	Wildfire Management	PSPS Execution and PSPS Customer Support	3,703,781	3,768,995	3,475,468	26,322,267	26,560,087	30,439,319	22,618,486	22,791,093	26,963,851	-	-	-	-	-	180,000	1,212,013	737,864	-	-	180,000	1,212,013	737,864	-	-
5	1	Generation	Hydro	Hydro	-	-	-	-	-	-	-	-	-	500,000	-	-	-	2,000,000	500,000	-	-	-	2,000,000	-	-	-	-	-
5	1	Generation	Hydro	Hydro	-	-	-	-	-	-	-	-	-	-	-	-	-	500,000	-	-	-	-	500,000	-	-	-	-	-
5	1	Generation	Hydro	Hydro	-	-	-	-	-	-	-	-	-	4,000,000	3,000,000	2,500,000	2,000,000	-	4,000,000	3,000,000	2,500,000	2,000,000	-	-	-	-	-	-
5	1	Generation	Hydro	Hydro	-	-	-	-	-	-	-	-	-	5,550,000	1,500,000	-	-	5,000,000	5,550,000	1,500,000	-	-	5,000,000	-	-	-	-	-
5	1	Generation	Hydro	Hydro	-	-	-	-	-	-	-	-	-	2,000,000	2,000,000	3,900,000	2,600,000	-	2,000,000	2,000,000	3,900,000	2,600,000	-	-	-	-	-	-
5	1	Generation	Hydro	Hydro	-	-	-	-	-	-	-	-	-	1,495,000	2,853,202	250,000	-	-	1,494,674	3,516,230	250,000	-	-	(326)	663,028	-	-	-
6	2	Enterprise Support	Legal	Workers' Compensation	75,000	75,000	75,000	75,000	75,000	75,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	3	Enterprise Support	Employee Benefits & Programs	Recognition	74,400	74,400	74,400	74,400	74,400	74,400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	3	Enterprise Support	Employee Support	Talent Solutions	170,000	170,000	170,000	167,574	170,000	170,000	(2,426)	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	3	Enterprise Support	Employee Training & Development	Training and Development	20,000	20,000	20,000	20,000	20,000	20,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	3	Enterprise Support	Employee Training & Development	Training and Development	182,600	192,600	202,600	182,600	192,600	202,600	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	3	Enterprise Support	Employee Training & Development	Training and Development	17,728,585	945,000	275,000	15,527,981	1,265,875	3,956,133	(2,200,604)	320,875	3,681,133	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	4	Enterprise Support	Safety Programs	Employee and Contractor Safety	2,200,000	2,200,000	2,200,000	2,200,000	2,200,000	2,200,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	4	Enterprise Support	Safety Programs	Employee and Contractor Safety	200,000	200,000	200,000	200,000	200,000	200,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	4	Enterprise Support	Safety Programs	Employee and Contractor Safety	-	-	-	-	-	-	-	-	-	5,000,000	4,000,000	4,000,000	-	-	-	-	-	-	-	(5,000,000)	(4,000,000)	(4,000,000)	-	-
6	4	Enterprise Support	Safety Programs	Employee and Contractor Safety	15,000	15,000	15,000	15,000	15,000	15,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

2018 RAMP to 2021 GRC Forecast Comparison
O&M and Capital (Nominal Dollars)

2021 GRC Mapping					RAMP O&M			GRC O&M			O&M Variance		
Test. Exhibit	Test. Volume	BPG	BPE	GRC Activity / Sub-Activity	2019	2020	2021	2019	2020	2021	2019	2020	2021
6	5	Enterprise Support	Facility & Land Operations	Facility Asset Management	$ 177,000	$ 181,000	$ 179,000	$ 5,000	$ 5,000	$ 5,000	$ (172,000)	$ (176,000)	$ (174,000)
6	5	Enterprise Support	Facility & Land Operations	CRE Project Management	$ 1,575,000	$ 1,714,000	$ 1,628,000	$ 575,000	$ 714,000	$ 628,000	$ (1,000,000)	$ (1,000,000)	$ (1,000,000)
6	5	Enterprise Support	Facility & Land Operations	CRE Project Management	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
6	5	Enterprise Support	Facility & Land Operations	Facility Asset Management	$ 500,000	$ 500,000	$ 500,000	$ 50,000	$ 50,000	$ 50,000	$ (450,000)	$ (450,000)	$ (450,000)
6	1. Pt. 2	Enterprise Support	Enteprise Technology	Technology Solutions	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
6	1. Pt. 2	Enterprise Support	Enteprise Technology	Technology Solutions	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
				Total	**$ 123,237,864**	**$ 171,014,491**	**$ 154,093,187**	**$ 117,677,407**	**$ 130,926,884**	**$ 158,846,070**	**$ (5,560,457)**	**$ (40,087,607)**	**$ 4,752,883**

2021 GRC Mapping					RAMP Capital					GRC Capital					Capital Variance				
Test. Exhibit	Test. Volume	BPG	BPE	GRC Activity / Sub-Activity	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023	2019	2020	2021	2022	2023
6	5	Enterprise Support	Facility & Land Operations	Facility Asset Management	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ -	$ -	$ -	$ -	$ -
6	5	Enterprise Support	Facility & Land Operations	CRE Project Management	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000	$ 1,000,000
6	5	Enterprise Support	Facility & Land Operations	CRE Project Management	$ 2,380,000	$ 2,405,000	$ 2,453,000	$ 2,502,000	$ 2,552,000	$ 2,380,000	$ 2,405,000	$ 2,453,000	$ 2,502,000	$ 2,552,000	$ -	$ -	$ -	$ -	$ -
6	5	Enterprise Support	Facility & Land Operations	Facility Asset Management	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
6	1. Pt. 2	Enterprise Support	Enteprise Technology	Technology Solutions	$ -	$ 3,400,000	$ 2,500,000	$ 2,500,000	$ -	$ -	$ 3,385,800	$ 2,483,800	$ 2,483,800	$ -	$ -	$ (14,200)	$ (16,200)	$ (16,200)	$ -
6	1. Pt. 2	Enterprise Support	Enteprise Technology	Technology Solutions	$ -	$ 1,000,000	$ 1,000,000	$ 500,000	$ -	$ -	$ -	$ 1,000,000	$ 1,000,000	$ 500,000	$ -	$ (1,000,000)	$ -	$ 500,000	$ 500,000
				Total	**$ 587,855,334**	**$ 737,307,106**	**$ 710,115,228**	**$ 753,744,642**	**$ 855,357,343**	**$ 560,094,856**	**$ 817,309,663**	**$ 1,044,593,075**	**$ 1,191,430,219**	**$ 1,397,641,380**	**$ (27,760,477)**	**$ 80,002,557**	**$ 334,477,847**	**$ 437,685,577**	**$ 542,284,036**

ıctor Program plus (C1a) OCP Utilizing Targeted Covered Conductor
(M2a) Situational Awareness, Monitoring & Analytics (Optimal). Capital RAMP estimates display amounts for Wildfire Mitigation (M7) - Enhanced Situational Awareness.
ctor Program (M1 - Wildfire and M5 - Contact with Energized Equipment). The estimates used in RAMP for M1 and M5 were the same amounts for 2019-2023.

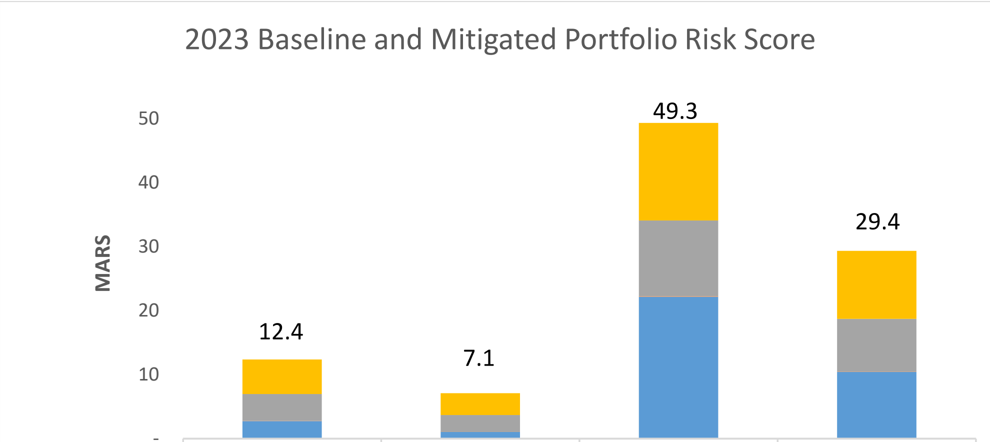
Workpaper Title:

Updated RAMP Risk Analysis
SCE-01, Vol. 2

Updated RAMP Risk Analysis

The summary charts below shows the updated Baseline and Mitigated MARS score, both the Expected Value (EV) and Tail Average[1] (TA), for the 3 updated RAMP risks discussed in Exhibit SCE-01, Volume 2. For a discussion on the methodology of how the risk score is calculated, please refer back to the RAMP report, Chapter 2.

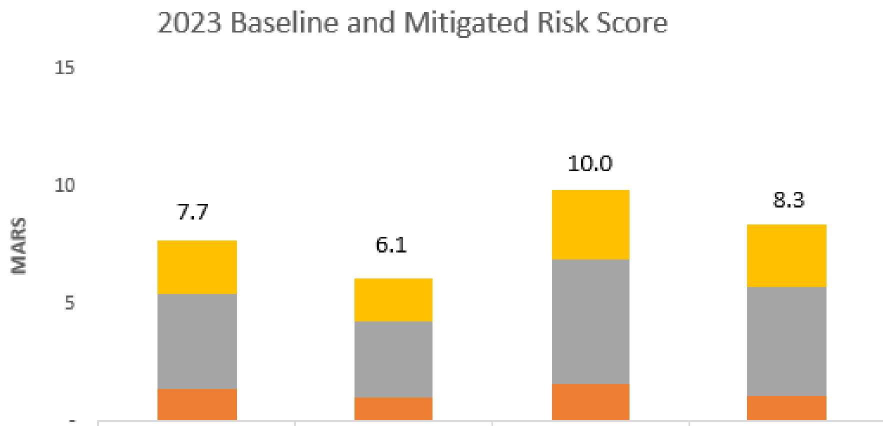
Wildfire Update [Distribution]



	Baseline [EV]	GRC Portfolio [EV]	Baseline [TA]	GRC Portfolio [TA]
Serious Injury	5.4	3.4	15.2	10.6
Fatality	4.2	2.6	11.8	8.2
Reliability	0.1	0.0	0.1	0.1
Financial	2.7	1.1	22.1	10.4

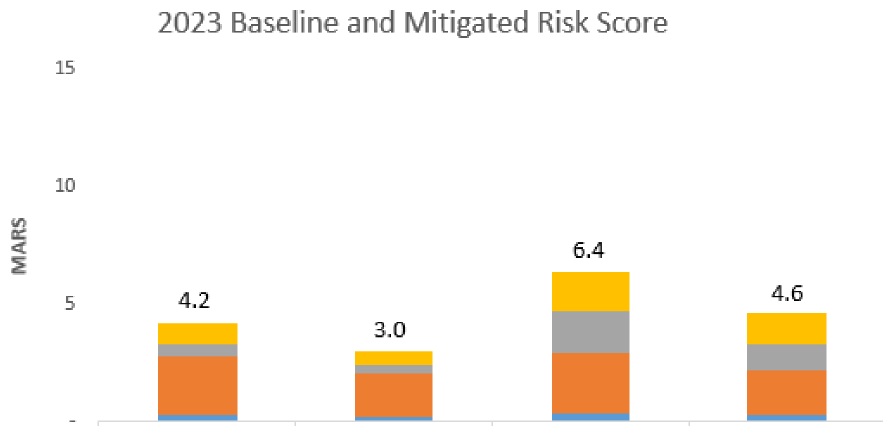
[1] Tail Average, as defined in SCE's RAMP report (Chapter 1, Appendix 1), is the average of the worst 10% of simulation results.

Contact with Energized Equipment



	Baseline [EV]	GRC Portfolio [EV]	Baseline [TA]	GRC Portfolio [TA]
Serious Injury	2.3	1.9	3.1	2.6
Fatality	4.0	3.3	5.3	4.6
Reliability	1.4	1.0	1.6	1.1
Financial	0.0	0.0	0.0	0.0

Underground Equipment Failure



	Baseline [EV]	GRC Portfolio [EV]	Baseline [TA]	GRC Portfolio [TA]
Serious Injury	0.9	0.6	1.7	1.3
Fatality	0.5	0.4	1.7	1.1
Reliability	2.5	1.8	2.6	1.9
Financial	0.3	0.2	0.4	0.3

Risk Spend Efficiency

Risk Spend Efficiency (RSE) is a measure of risk reduction per dollar ($M). Based on the updates to the three RAMP risks, SCE presents the RSE's for each of the controls and mitigations over the 2021-2023 period. SCE notes the following caveats with these RSE's:

- Each control / mitigation was calculated separately. The total risk reduction at a portfolio level is not an additive calculation of all the individual mitigations, but instead it uses the principles of compounding.[2]
  - $(RiskReduction_{MitigationA} + RiskReduction_{MitigationB}) \neq RiskReduction_{(A+B)}$
- Capital-based projects, such as Wildfire Covered Conductor Program, in general have lower RSE's than O&M based projects. The risk reduction benefit streams of these mitigation programs are not captured in the RAMP risk analysis[3] since the analysis focused on a six-year period (2018-2023). SCE did, however, pilot an illustrative example in Appendix 1, Chapter 2 of the RAMP report to show the long-term benefit streams of Covered Conductor.
- Wildfire Covered Conductor Program spans multiple RAMP risks (Wildfire and Contact with Energized Equipment). The risk reduction benefits of that mitigation are quantified only with respect to its impact on that risk's bowtie.

Wildfire

	2021 - 2023 Period	
	RSE (EV)	**RSE (TA)**
C1 - Overhead Conductor Program	0.0036	0.0101
C2 - FR3 Overhead Distribution Transformer	0.0023	0.0068
M1 - Wildfire Covered Conductor Program	0.0030	0.0099
M2 - Remote-controlled Automatic Reclosers (RARs) and Fast Curve Settings	0.1054	0.4961
M3 - Public Safety Power Shutoff(PSPS) Protocol and support functions	0.0231	0.1088
M4 - Infrared (IR) Inspection Program	0.3029	0.8366
M5 - Enhanced Vegetation Management	0.0020	0.0050

[2] See RAMP report, Chapter 2.
[3] See RAMP report, Chapter 1.

M7 - Enhanced Situational Awareness	0.0881	0.4173
M8 - Fusing Mitigation	0.0545	0.1616
M9 - Fire Resistant Poles	0.0007	0.0052
M10 - Enhanced Overhead Inspection	0.0092	0.0281
M11 - Targeted Undergrounding	0.0013	0.0033

Contact with Energized Equipment

	2021 - 2023 Period	
	RSE (EV)	**RSE (TA)**
C1 - Overhead Conductor Program	0.0058	0.0059
C2 - Public Outreach	0.0161	0.0216
C1a - Overhead Conductor Program utilizing Targeted Covered Conductor	0.0030	0.0028
M4 - Infrared Inspections	0.7310	0.7553
M5 - Wildfire Covered Conductor Program	0.0005	0.0005

Underground Equipment Failure

	RSE (EV)	**RSE (TA)**
C1 - Cable Replacement Program (WCR)	0.0026	0.0029
C2 - Cable Replacement Program (CIC)	0.0138	0.0154
C3 - UG Oil Switch Replacement Program	0.0019	0.0023
M1 - Cover Pressure Relief and Restraint (CPRR) Program	0.0191	0.0406

Changes to RAMP Models

This section will discuss changes to the baseline model inputs for each of the 3 RAMP risks described previously. SCE refers the reader to the document "RAMP to GRC Roadmap.xlsx", which describes where each mitigation is discussed as well as any scope and/or forecast spend changes from RAMP.

Wildfire

Model Input Parameter	RAMP input	Updated Input
Driver	Annual Driver Frequency (2015-2017) : 44	Annual Driver Frequency (2015-2018), including updates to HFRA: 35.75 Exhibit SCE-04, Volume 5, Table II-5 shows the drivers of ignitions associated with SCE – Distribution only for the period 2015-2018.
Outcome Percentages[4]	O1 – "Red Flag Day, >5,000 Acres": 0.8% O2 – "Red Flag Day, <5,000 Acres": 31% O3 – "Not Red Flag Day, >5,000 Acres": 0.2% O4 – "Not Red Flag Day, <5,000 Acres": 68.1%	O1 – "Red Flag Day, >5,000 Acres": 0.7% O2 – "Red Flag Day, <5,000 Acres": 27.2% O3 – "Not Red Flag Day, >5,000 Acres": 0.14% O4 – "Not Red Flag Day, <5,000 Acres": 72% Changes to the percentages driven by the driver frequency updates.
Consequences	O1 – "Red Flag Day, >5,000 acres" consequence distribution parameter: Serious Injury: 22.2 Fatality: 2.7 Financial: $530K	O1 – "Red Flag Day, >5,000 acres" consequence distribution parameter: Serious Injury: 90.5 Fatality: 10.9 Financial: $2.1B Inputs were updated based on the inclusion of the 2018 Camp Fire

Contact with Energized Equipment

Model Input Parameter	RAMP input	Updated Input
Driver	Annual Driver Frequency (2015-2017) : 1,159	Annual Driver Frequency (2015-2018): 1,125

[4] Percentages shown are rounded to the nearest tenth.

Consequences	O1 – "Energized Wire Down" consequence distribution parameter: Serious Injury: (0, 0, 0.009) Fatality: (0, 0, 0.007) O3 – "Intact Energized Wire Contact" Serious Injury: (0, 0, 1.7) Fatality: (0, 0, 1.2)	O1 – "Energized Wire Down" consequence distribution parameter: Serious Injury: (0, 0, 0.009) Fatality: (0, 0, 0.007) O3 – "Intact Energized Wire Contact" Serious Injury: (0, 0, 1.9) Fatality: (0, 0, 1.1) Inputs were updated based on the inclusion of the 2017-2018 data

Underground Equipment Failure

Model Input Parameter	RAMP input	Updated Input
Driver	Annual Driver Frequency (based on 2015-2017 data) : 2018 - 2023: 1,906 to 2,233 Assume a compound annual growth rate	Annual Driver Frequency (based 2015-2018): 2019 – 2023: 2,091 to, 2,381 Assume a compound annual growth rate

Workpaper Title:

Top 20 Most Destructive California Wildfires
SCE-01, Vol. 2

Top 20 Most Destructive California Wildfires

	FIRE NAME *(CAUSE)*	DATE	COUNTY	ACRES	*STRUCTURES*	DEATHS
1	**CAMP FIRE** *(Under Investigation)*	November 2018	Butte County	153,336	**18,804**	85
2	**TUBBS** *(Electrical)*	October 2017	Napa & Sonoma	36,807	**5,636**	22
3	**TUNNEL - Oakland Hills** *(Rekindle)*	October 1991	Alameda	1,600	**2,900**	25
4	**CEDAR** *(Human Related)*	October 2003	San Diego	273,246	**2,820**	15
5	**VALLEY** *(Electrical)*	September 2015	Lake, Napa & Sonoma	76,067	**1,955**	4
6	**WITCH** *(Powerlines)*	October 2007	San Diego	197,990	**1,650**	2
7	**WOOLSEY** (Under Investigation)	November 2018	Ventura	96,949	**1,643**	3
8	**CARR** *(Human Related)*	July 2018	Shasta County, Trinity County	229,651	**1,614**	8
9	**NUNS** *(Powerline)*	October 2017	Sonoma	54,382	**1,355**	3
10	**THOMAS** *(Powerline)*	December 2017	Ventura & Santa Barbara	281,893	**1,063**	2
11	**OLD** *(Human Related)*	October 2003	San Bernardino	91,281	**1,003**	6
12	**JONES** *(Undetermined)*	October 1999	Shasta	26,200	**954**	1
13	**BUTTE** *(Powerlines)*	September 2015	Amador & Calaveras	70,868	**921**	2
14	**ATLAS** *(Powerline)*	October 2017	Napa & Solano	51,624	**783**	6
15	**PAINT** *(Arson)*	June 1990	Santa Barbara	4,900	**641**	1
16	**FOUNTAIN** *(Arson)*	August 1992	Shasta	63,960	**636**	0
17	**SAYRE** *(Misc.)*	November 2008	Los Angeles	11,262	**604**	0
18	**CITY OF BERKELEY** *(Powerlines)*	September 1923	Alameda	130	**584**	0
19	**HARRIS** *(Undetermined)*	October 2007	San Diego	90,440	**548**	8
20	**REDWOOD VALLEY** *(Powerline)*	October 2017	Mendocino	36,523	**546**	9

**"Structures" include homes, outbuildings (barns, garages, sheds, etc) and commercial properties destroyed.
***This list does not include fire jurisdiction. These are the Top 20 regardless of whether they were state, federal, or local responsibility.

3/14/2019

Workpaper Title:

Reax Fire Risk from Overhead Electrical Facilities

SCE-01, Vol. 2

Reax Engineering Inc.
Job # 19-0622

Fire Risk from Overhead Electrical Facilities

Prepared for Southern California Edison

Revision 0
June 13, 2019

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Job #	Job Name	Client
19-0622	Fire Risk from Overhead Electrical Facilities	Southern California Edison

Revision #	Date	Description	
Rev 0	June 13, 2019	Final report.	
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		Prepared by:	**Reviewed by:**
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TABLE OF CONTENTS

1.0 OVERVIEW OF FIRE HAZARD AND RISK ... 1

1.1 WILDLAND FIRE HAZARD ... 1
1.2 WILDLAND FIRE RISK ... 1

2.0 BACKGROUND: WILDLAND FIRE HAZARD AND RISK QUANTIFICATION INCLUDING UTILITY-ASSOCIATED RISK ... 3

2.1 GENERAL OVERVIEW ... 3
2.2 AUSTRALIAN WORK TO QUANTIFY POWERLINE FIRE RISK ... 4
2.3 CPUC FIRE MAP 1 ... 5
2.4 CPUC FIRE MAP 2 ... 6

3.0 FIRE IGNITION AND SPREAD MODELING METHODOLOGY ... 8

3.1 MONTE CARLO FIRE SPREAD MODEL: ELMFIRE ... 8
3.2 FUEL AND TOPOGRAPHY INPUTS ... 10
3.3 WIND AND WEATHER INPUTS ... 10
3.4 STOCHASTIC SELECTION OF IGNITION LOCATIONS AND WIND/WEATHER CONDITIONS ... 13
3.5 QUANTIFICATION OF FIRE CONSEQUENCES ... 14

4.0 QUANTIFICATION OF UTILITY-ASSOCIATED FIRE RISK WITHIN SCE'S SERVICE TERRITORY ... 16

4.1 FIRE PROBABILITY ... 16
4.2 FIRE CONSEQUENCE ... 16
4.3 FIRE RISK ... 16

5.0 MODEL OUTPUTS AND GIS DATA ... 17

5.1 FIRE AREA, VOLUME, IMPACTED STRUCTURES, AND RISK ... 17
5.2 FIRE PERIMETER DATA ... 19

6.0 CONCLUDING REMARKS ... 22

7.0 REFERENCES ... 23

List of Figures

Figure 1. Phoenix RapidFire map of estimated home losses across Victoria for powerline fires ignited under Ash Wednesday weather conditions [13]. 5
Figure 2. Sample ELMFIRE fire spread simulation for individual fire ignition. (a) Fire type (surface fire, passive crown fire, or active crown fire). (b) Flame length. 9
Figure 3. Example showing SCE overhead facilities. 13
Figure 4. Example showing ignition locations distributed randomly within a 100 m buffer surrounding SCE overhead facilities. 14
Figure 5. Butte Fire footprint (dash line). (a) Census blocks (solid lines) on orthoimagery. (b) Housing density (structures per square mile) colored from 0 (blue) to 32 (red). 15
Figure 6. Smoothing kernel applied to data from Figure 4. 18
Figure 7. Data from Figure 4 resampled to 300 m resolution. 19

LIST OF TABLES

TABLE 1. IGNITION PROBABILITY BY WOODY EMBERS/FIREBRANDS AS TABULATED BY SCHROEDER [42]. 12

1.0 OVERVIEW OF FIRE HAZARD AND RISK

The primary goal of this work is to quantify utility-associated wildland fire hazard / risk in SCE's service territory The terms *fire hazard* and *fire risk* are often used inconsistently and the meaning of these terms in the wildland fire literature is sometimes different from their meanings in other branches of science and engineering. To avoid confusion, and to explicitly identify what this work quantifies, the meanings of *wildland fire hazard* and *wildland fire risk* within the context of this work are explained below.

1.1 Wildland fire hazard

The preferred terminology among land managers is that *fire hazard* should be used to represent the overall flammability of a fuel complex independent of weather conditions. Consistent with that meaning, Hardy [1] proposed the following definition of *fire hazard*:

> Fire hazard: A fuel complex defined by volume, type, condition, arrangement, and location that determines the degree of ease of ignition and resistance to control. Fire hazard expresses the potential fire behavior for a fuel type, regardless of the fuel-type's weather-influenced fuel moisture content.

A timber stand located in an area with weather conditions conducive to high fuel moisture contents, sheltered from the wind, and located 30 miles from the nearest structure represents less of a threat to the built environment and life safety than an identical stand of trees in the wildland urban interface that regularly experiences high winds and low fuel moisture contents. However, since the fuel complexes are identical except for weather related factors, under Hardy's nomenclature [1] they would have the same fire hazard.

Bachman and Allgöwer [2] presented definitions of *hazard* and *wildland fire hazard* that are more appropriate for wildland fire hazard assessment:

> Hazard: A process with undesirable outcomes.
>
> Wildland fire hazard: A wildland fire with undesirable outcomes.

The term *wildland fire hazard* is used here in a manner consistent with the Bachman and Allgöwer definitions [2].

1.2 Wildland fire risk

Hardy [1] also proposed the following definitions of *fire risk*, indicating there is broad agreement on this definition among US and international organizations:

> Fire risk: The chance that a fire might start, as affected by the nature and incidence of causative agents.

This definition is problematic for wildland fire risk assessment, as illustrated by the following thought experiment: Consider a plot of cured grass with fine fuel moisture content of 2%, surrounded on three sides by a fire break and on one side by a busy highway. Under Hardy's *fire risk* definition [1], the fire risk associated with this plot is very high because there is a high probability of ignition. However, the negative consequences of such a fire are minimal, as it would be contained by fire breaks with no impact to the built environment or life safety.

For consistency with the use of the term *risk* in the risk analysis literature, the following definitions of *risk* and *wildland fire risk* proposed by Bachman and Allgöwer [2] are adopted here:

> Risk: The probability of an undesired event and its outcome. An undesired event is a realization of a hazard.
>
> Wildland fire risk: The probability of a wildland fire occurring at a specified location and under specific circumstances, together with its expected outcome as defined by its impacts on the objects it affects.

These definitions are consistent with the conventional definition of *risk*, which is usually taken as the probability of an event occurring multiplied by the potential consequences of that event. Unlike Hardy's definition, a high probability of fire occurrence does not necessarily indicate a high fire risk if values of concern (structures, standing timber, *etc*.) are unaffected [3].

2.0 BACKGROUND: WILDLAND FIRE HAZARD AND RISK QUANTIFICATION INCLUDING UTILITY-ASSOCIATED RISK

With the terms *wildland fire hazard* and *wildland fire risk* now defined, this section presents a general overview of past efforts at quantifying wildland fire hazard/risk (Section 2.1) and a recent study specifically aimed at quantifying wildland fire hazard/risk from powerline fires (Section 2.2).

2.1 General overview

There is no "one size fits all" approach to quantifying wildland fire hazard or risk. Different approaches may be appropriate under different circumstances. Wildland fire hazard/risk assessment using fire behavior modeling has recently seen increased usage due in part to more powerful computational resources, improved fire models, and readily available geospatial input data. For example, ArcFuels [4-5] provides a desktop-based interface between ArcGIS and widely-used fire behavior models such as FARSITE [6] and FLAMMAP [**7**].

Keane *et al.* [8] highlighted the potential for Monte Carlo analysis to be used for wildland fire risk quantification, stating "Andrews (2007) FSPRO approach in which maps of fire intensity distributions are computed from thousands of FARSITE [6] runs is perhaps the most significant step towards fine scale risk mapping." One advantage of such approaches is that fire shadows, islands, and related effects can be captured. For example, with all other factors held constant, an area downwind from an obstacle to fire spread such as a large barren area or water body is less likely to burn than areas upwind from the obstacle to fire spread. Similarly, a patch of highly flammable fuels surrounded by less flammable fuels is less likely to burn [9]. These spatial effects cannot be captured by analyses that consider conditions only at a point, or burn every point as a head fire, but would be captured by analyses that include fire progression. For these reasons, Monte Carlo simulations wherein fire spread is modeled from tens of thousands of separate ignition locations under a range of weather conditions is one of the most promising tools for quantitative wildland fire risk/hazard assessment.

Carmel *et al*. [10] conducted Monte Carlo simulations of fire spread using hundreds of FARSITE [6] runs to assess fire risk in a 300 km^2 area near Mt. Carmel in Northwestern Israel. Weather inputs were developed from three nearby weather stations during a single year (2004). Standard fuel models were adapted for local conditions. Noting that most fires in this area are anthropogenic, 80% of ignition locations were randomly placed in a buffer zone near roads and hiking trails, with the remaining 20% of ignition locations placed randomly across the landscape. 500 FARSITE [6] simulations were conducted and used to generate a heat map that identified hot spots and cold spots corresponding to the number of times that a particular location was burned by the simulated fires, which can be thought of as being analogous to fire frequency. The Carmel *et al*. study was published in 2009 [10]; tragically, in December 2010, a 2180 hectare fire burned through the Mt. Carmel area, causing 45 deaths. This provided an unfortunate but unique opportunity for the authors to assess their pre-fire risk map [10] in a post-fire study [11]. In the later study [11], the authors concluded that most of the areas burned in the 2010 fire corresponded to high risk levels in the pre-fire risk map.

Ager, Finney, and McMahan [12] indicate that the actuarial definition of wildfire risk is "the expected net value change calculated as the product of (1) probability of a fire at a specific intensity and location, and (2) the resulting change in financial or ecological value." Based on that definition, they developed a modeling framework that can be used to calculate the net value change for fire events of various severity. Their modeling process involved three separate steps: 1) Applying the Forest Vegetation Simulator/Parallel Processing Extension to simulate the effect of various landscape fuels treatments; 2) Using FLAMMAP to calculate elliptical fire spread dimensions, and 3) Applying RANDIG to simulate propagation of randomly ignited fires. One of the emphases of this work was the effectiveness of fuels management type and area. Three different prescriptions were simulated for six different treatment areas and four hypothetical loss functions. Flame length was used as a metric so that fire occurrence was considered a net positive event for low-intensity fire, but a net negative event for high intensity fire. Fire spread duration was established using a Monte Carlo approach to investigate the differences in net value change attributed to the different loss functions, fuels treatment types, and treatment areas.

2.2 Australian work to quantify powerline fire risk

On 7 February 2009, hot dry winds led to ignition and rapid of several powerline-ignited fires in the Australian state of Victoria, ultimately resulting in over 150 fatalities and the loss of thousands of structures. Motivated by these tragic fires, the Powerline Bushfire Safety Program (part of the Victoria State Government Department of Economic Development, Jobs, Transport, and Resources) commissioned a project to identify powerline fire ignition points likely to result in high fire loss consequence with a goal of targeting investment at areas of highest bushfire risk as a priority [13].

A fire spread simulator known as PHOENIX RapidFire [14-18] was used to simulate fire spread from multiple ignition points under specific weather conditions. Key inputs and assumptions of that study are summarized below:

- 27,860 separate ignition points within 1 km of powerlines were established across Victoria on a 2 km grid
- Weather conditions were based on the 1983 Ash Wednesday fires (a similar pattern to Black Saturday as mentioned above)
- Negligible suppression response, *i.e.* fire development not affected by firefighting activities
- Grass curing and moisture was assumed to be worst-case conditions based on driest years in the past decade
- Fuel climax conditions (recently burned fuels modeled as if they had not recently burned)
- Time of ignition corresponded to the peak Forest Fire Danger Index (FFDI) of the day

In the Australian work, probability of ignition was assumed to be uniform across Victoria, meaning all areas were assumed to be equally likely to experience powerline-related ignitions. The primary output from this work was an estimate of the number of homes burned by a powerline-ignited fire starting at a particular location. Figure 1 shows the primary output of this analysis. Each of the 27,860 ignition points is colored according to the number of home losses predicted for a fire starting at that particular location. Red and purple dots correspond to locations where a fire ignition (under the specific set of modeled conditions) would result in more than 2,000 destroyed homes.

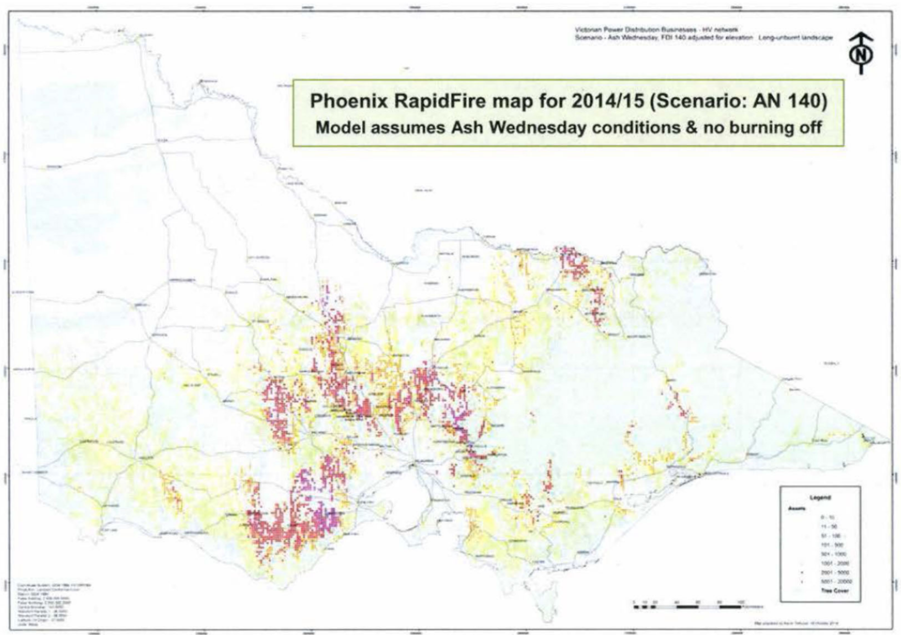


Figure 1. Phoenix RapidFire map of estimated home losses across Victoria for powerline fires ignited under Ash Wednesday weather conditions [13].

2.3 CPUC Fire Map 1

Development of CPUC fire risk maps in California proceeded in two phases. The first phase, termed “Fire Map 1,” commenced in early 2014 and concluded in early 2016. Fire Map 1 depicted the physical and environmental conditions associated with an elevated risk of power-line fires. The second phase (“Fire Map 2”) commenced in mid-2016 and concluded in early 2018. Fire Map 2 designated utility fire-hazard zones with elevated risk of power-line fires occurring and spreading rapidly so that the fire-prevention measures/regulations could be effectively deployed.

The California Public Utilities Commission directed an Independent Expert Team (IET), led by CALFIRE, to develop a statewide map that identifies “the fundamental physical and environmental features that lead to an elevated likelihood of overhead utility facilities initiating fires that are then likely to lead to large and damaging wildfires” [19]. Fire Map 1 development is described in a report issued by the IET on February 16, 2016 [19].

In Fire Map 1, a 10-year climatology was developed using the Weather Research and Forecasting (WRF) model [20-21] to provide gridded statewide hourly wind/weather fields. After filtering based on Fosberg Fire Weather Index (FFWI), these climatological inputs were distilled to a small subset that was used to drive a statewide Monte Carlo fire spread analysis involving over 100 million randomly distributed ignition points. Fire progression was simulated for a duration of one hour using GridFire [22], an open source raster-based fire spread model that is similar to HFire [23]. The Monte Carlo analysis was mirrored by Reax Engineering in its capacity as subject matter experts for several stakeholders using ELMFIRE [24-25] (Eulerian Level Set Model for Fire Spread).

The final Fire Map 1 product was termed the "Utility Threat Index" (UTI). It is a combination of an "ignition index" (which considers wind speed and fuel moisture content) and a "spread index" (which describes fire spread rate and intensity using fire "volume", *i.e.* burned area multiplied by average flame length from each ignition point). Fire Map 1 did not address assets at risk such as structure density or proximity to communities or populated places; it was only intended to quantify potential for ignition and spread of wildland fires independent of their potential impacts to communities.

2.4 CPUC Fire Map 2

CPUC Fire Map 2 was developed by a Peer Development Panel (PDP) in accordance with the workplan prescribed in CPUC Decision 17-01-009 [26] issued on January 19, 2017. Fire Map 2 is a 3-tiered map with each tier defined as follows:

1. Tier 1 is all area in the state of California that is not in Tier 2 or Tier 3.
2. Tier 2 is elevated risk (including likelihood and potential impacts of occurrence) from wildfires associated with overhead utility powerlines or overhead utility powerlines also supporting communication facilities, including impacts to people or improved property.
3. Tier 3 is extreme risk (including likelihood and potential impacts of occurrence) from wildfires associated with overhead utility powerlines or overhead utility powerlines also supporting communication facilities, including impacts to people or improved property.

In late 2016, a preliminary map known as "Shape A" was developed by the PDP co-leads (Pacific Gas & Electric, Reax Engineering, and San Diego Gas & Electric) according to a "recipe" prescribed in the Fire Map 2 work plan. Per the work plan, Shape A was a hybrid of Fire Map 1, fire history, an earlier map known as the FRAP Fire Threat Map, and designated communities at risk. Due to the coarse nature of the Shape A recipe, it encompassed essentially all areas of California capable of supporting propagating wildland fires (including nonburnable "islands" such as waterbodies, urban/developed areas, and barren landscape). Due to the "broad brush stroke" used to create Shape A, the PDP co-leads removed obviously nonburnable areas from Shape A to create and "initial Shape B" which was ultimately approved by the IRT and filed with the CPUC on March 20, 2017. The initial Shape B was considered as a starting point for the Tier 2 footprint.

After the initial Shape B / Tier 2 was created, utilities designated one or more Territory Leads (TLs) to classify areas of their service territory as either Tier 1, Tier 2, or Tier 3 upon consideration of the Tier definitions presented above and examination of a multitude of factors such as local knowledge, fire history, Fire Map 1 scores, and potential impacts to communities. TLs made recommendations to the PDP (which consisted of representatives from utilities, communication infrastructure providers, industry experts, fire officials, and interested stakeholders). The PDP then reviewed each TL proposal and subsequently made recommendations to an Independent Review

Team (IRT), led by CALFIRE, which provided PDP oversight and ultimately approved or rejected each TL/PDP proposal. The final 3-tiered CPUC fire threat map was developed through this iterative process.

Between March and November 2017, more than 1,300 changes to the Initial Shape B were proposed, analyzed, and adjudicated by TLs, the PDP, and the IRT. Three types of map changes were used:

1. Classify an area as Tier 1 that was classified as Tier 2 in the initial Shape B
2. Classify an area as Tier 2 that was classified as Tier 1 in the initial Shape B
3. Classify an area as Tier 3

As described earlier, each proposed map change was reviewed first by the PDP and then by the IRT. This was accomplished using through this process a public-facing web-portal developed specifically for this mapping project. In some cases, these proposed changes went through several iterations with IRT rejections followed by resubmissions with boundary adjustments or new supporting data. This iterative process of expert input and review further refined designated map tiers.

Since the Tier definitions included “impacts to people or improved property” but the Utility Threat Index from Fire Map 1 was agnostic as to the locations of structures and communities, during the Map 2 development process it became necessary to combine structure density with Fire Map 1 to inform classification as Tier 1, Tier 2, or Tier 3. In summer of 2017, the PDP co-leads developed “draft Tier 3 guidance” that combined the Utility Threat Index from Fire Map 1 with structure density from the US census. The Independent Review Team modified this approach slightly and developed an Integrated Utility Threat Index (iUTI) that combined Fire Map 1’s Utility Threat Index with structure density from a California-specific layer known as “WUIDEN4”.

Although the iUTI was originally developed to prioritize areas for designation as Tier 3, it eventually became apparent that the iUTI could also inform Tier 2 designations. Late in the Fire Map 2 development process, deliberations between the PDP and IRT regarding areas proposed for removal from Tier 2 were guided by iUTI scores. This suggested that the arduous process of developing Shape A, removing nonburnable areas to create an initial Shape B, and then manually proposing and reviewing over 1,300 map changes could have been automated and expedited using iUTI or similar data products.

CPUC Fire Map 2 was finalized by the PDP in November/December 2017, and ultimately approved by the CPUC in early 2018.

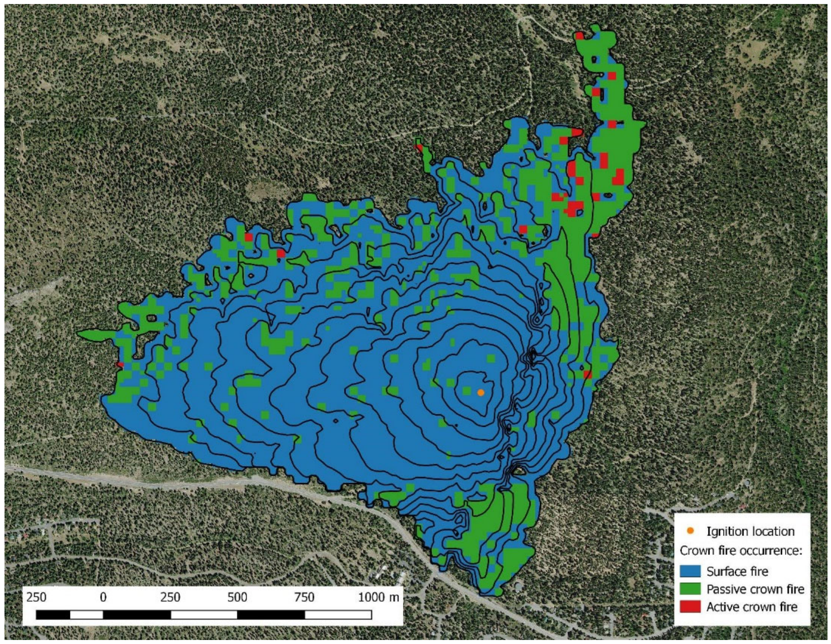
3.0 FIRE IGNITION AND SPREAD MODELING METHODOLOGY

As described in Section 2.1, Monte Carlo analysis has shown great promise for quantifying wildland fire hazard and risk. Furthermore, this same basic approach has already been successfully applied in Victoria, Australia to quantify fire risk associated with overhead electrical utility ignited fires (Section 2.2). The current section describes the Monte Carlo analysis that is used here to quantify wildland fire hazard / risk across SCE's service territory. The methodology applied here is based on that described by Lautenberger [27].

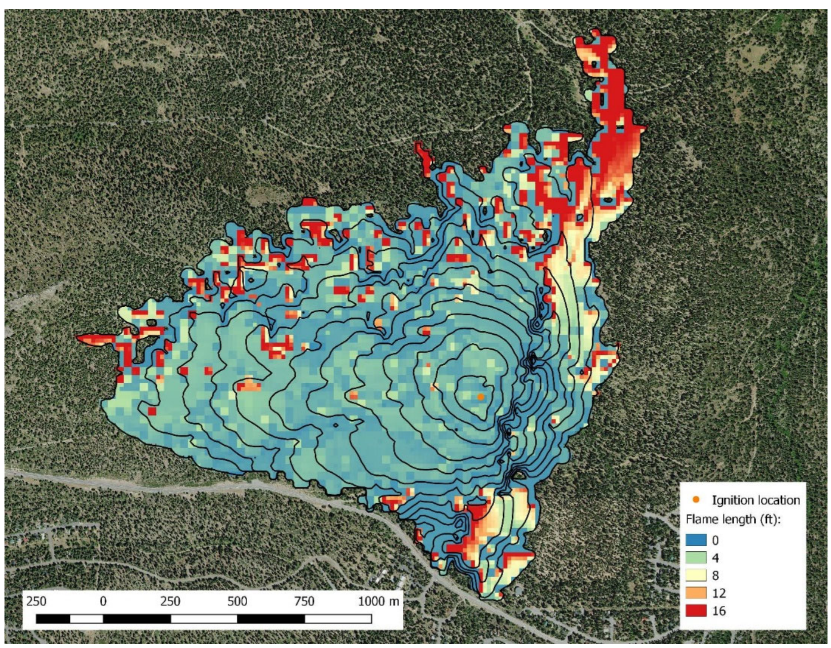
3.1 Monte Carlo fire spread model: ELMFIRE

The open source software ELMFIRE [24-25] (Eulerian Level Set Model for Fire Spread) is used here to quantify wildland fire hazard via Monte Carlo analysis. ELMFIRE's computational engine is similar to other two-dimensional fire simulators such as FARSITE [6] or PHOENIX RapidFire [14-18] in that it calculates surface fire spread rate using the Rothermel surface spread model [28, 29], assumes that each point along the fire front behaves as an independent elliptical wavelet [30] with length to breadth ratio determined semi-empirically [6, 31], and simulates transition from surface to crown fire using the Van Wagner criterion [32] (with passive/active crown fire spread rates calculated from Cruz *et al*. [33]). ELMFIRE tracks the fire front using a narrow band level set method [34], a numerical technique for tracking curved surfaces on a regular grid. Parallelization is achieved using Message Passing Interface (MPI).

To demonstrate how ELMFIRE simulates fire spread, Figure 2 shows 24-hours of fire progression from an individual ignition site. The black contour lines in Figure 2 a represent fire front position at 2-hour intervals. Figure 2 a also shows which parts of the burned area experienced surface fire (blue), passive crown fire (green), or active crown fire (red). Figure 2b similarly shows fire perimeter contours and flame length variation within the fire perimeter. Flame length is highest in areas that burn as heading fires or those that experience crown fire, and lowest in areas that burn as a flanking or backing fire or as a surface fire. In this example, fire area after 24 hours of spread is approximately 560 acres.



(b)



(a)

Figure 2. Sample ELMFIRE fire spread simulation for individual fire ignition. (a) Fire type (surface fire, passive crown fire, or active crown fire). (b) Flame length.

3.2 Fuel and topography inputs

Fuel and topography layers were obtained from the LANDFIRE 2014 (LANDFIRE 1.4.0) database [35-36] at a resolution of 30 m. Topography layers include elevation, slope, and aspect. Fuel layers include surface fuel model (in the Scott and Burgan 40 system [37]), canopy height, canopy cover, canopy base height, and canopy bulk density. The surface fuel layer was modified to correct known mapping errors in LANDFIRE using the methodology of Sapsis *et al*. [19].

3.3 Wind and weather inputs

The general approach to developing wind and weather inputs involves using the North American Regional Reanalysis (NARR) dataset [38] in conjunction with a fire weather filter to identify days of historical fire weather significance. The Weather Research and Forecasting (WRF) model is then used to generate wind and weather fields only for those days identified as being significant from a fire weather perspective.

The NARR dataset is maintained by the National Centers for Environmental Prediction, the National Weather Service, and the National Oceanic and Atmospheric Administration. It is a gridded meteorological dataset that provides a "snapshot" of the atmosphere every 3 hours at approximately 32 km resolution. Being a reanalysis, NARR is a hybrid of weather modeling and meteorological observations (surface observations of temperature, relative humidity, wind speed/direction, and precipitation, weather balloon observations of wind speed/direction and atmospheric, sea surface temperatures from buoys, satellite imagery for cloud cover and precipitable water, *etc.*). Essentially, a weather model similar to WRF assimilates/ingests several thousand weather observations over a 3 hour period and then uses that information to create a 3D representation of the atmosphere every 3 hours. This includes not only surface (meaning near ground level) quantities but also upper atmosphere quantities as well. The NARR dataset is available from 1979 (when modern satellites first became available) to current day (with a lag of a few weeks).

Although NARR's 32 km resolution is too coarse to be useful for fire spread modeling purposes, it can be used to identify historical fire weather days to be recreated at higher resolution using WRF. The basic idea is to determine dates for each 32 km by 32 km NARR pixel in SCE's service territory where the most severe fire weather conditions have occurred between 1999 and 2018. The primary advantage of identifying historical fire weather events using reanalysis data, instead of surface (weather station) observations, is that the NARR dataset is both spatially and temporally uniform whereas point observations are not.

The first step to identify historical fire weather days is selection of a single criterion that can be used to identify the most severe fire weather conditions in the NARR dataset. While there are many possibilities, a modification to the Fosberg Fire Weather Index (FFWI) [39] was selected. FFWI combines temperature, relative humidity, and wind speed into a single index ranging from 0 to 100, with 100 corresponding to a wind speed of 30 mph and fine fuel moisture content of 0%. The FFWI formula is presented as Equation 1:

$$\text{FFWI} = \eta\sqrt{\left(1+U^2\right)} \quad (1)$$

where U is the 20-ft wind speed in miles per hour and η is a function of equilibrium moisture content, M_{eq}:

$$\eta = 1 - 2\left(\frac{M_{eq}}{30}\right) + 1.5\left(\frac{M_{eq}}{30}\right)^2 - 0.5\left(\frac{M_{eq}}{30}\right)^3 \quad (2)$$

In Equation 2, M_{eq} is calculated as [40, 41]:

$$M_{eq} = \begin{cases} 0.03 + 0.28 \times \text{RH} - 0.00058 \times \text{RH} \times \text{T} & \text{for RH} < 10\% \\ 2.23 + 0.16 \times \text{RH} - 0.0148 \times \text{T} & \text{for } 10 \le \text{RH} < 50\% \\ 21.1 - 0.4944 \times \text{RH} + 0.00557 \times \text{RH}^2 - 0.00035 \times \text{RH} \times \text{T} & \text{for RH} \ge 50\% \end{cases} \quad (3)$$

where RH is relative humidity in percent and T is temperature in °F.

FFWI is very sensitive to wind speed, and less sensitive to relative humidity and temperature. For example, FFWI is 80 for a wind speed of 50 mph and an equilibrium moisture content of 10%, but only 73 for a wind speed of 25 mph and an equilibrium moisture content of 2%. Ignition and growth of a wildland fire to threatening scales may be more likely under the latter conditions, but spread rates for an *already established* wildland fire could be higher under the former conditions.

It was found during the CPUC Fire Map 1 development process that using a Fosberg Fire Weather Index (FFWI) could result in "off season" (generally, during the winter, *i.e.* after significant rains) days being falsely identified as fire weather days. To avoid these problems, a Modified Fosberg Fire Weather Index (MFFWI) is used in this work to identify wind events that occur simultaneously with low relative humidities and high temperatures. MFFWI is defined as follows:

$$\text{MFFWI} = \text{FFWI} \times \frac{P_{ign}}{100} \quad (4)$$

where P_{ign} is Schroeder's ember ignition probability [42] as given in Table 1 as a function of fuel temperature and fine fuel moisture content. The data were originally published [42] with temperatures in degrees Fahrenheit and this convention is retained here. It is seen that the ember ignition probability is strongly sensitive to moisture content, and less sensitive to temperature.

Table 1. Ignition probability by woody embers/firebrands as tabulated by Schroeder [42].

Fuel	*Fine Fuel Moisture Content (%)*														
Temp (F)	*1.5*	*2.0*	*2.5*	*3.0*	*4.0*	*5.0*	*6.0*	*7-8*	*9-10*	*11-12*	*13-16*	*17-20*	*21-25*	*26-30*	*>30*
30-39	87	80	74	69	59	51	43	34	25	17	10	4	1	0	0
40-49	89	83	77	71	61	53	45	36	26	18	11	5	1	0	0
50-59	92	85	79	73	63	54	47	37	27	20	11	5	2	0	0
60-69	94	88	81	76	65	56	49	39	29	21	12	6	2	0	0
70-79	97	90	84	78	68	59	51	41	30	22	13	6	2	0	0
80-89	100	93	87	81	70	61	53	42	31	23	14	7	2	1	0
90-99	100	96	90	84	73	63	55	44	33	24	15	7	3	1	0
100-109	100	99	93	86	75	66	57	46	35	26	16	8	3	1	0
110-119	100	100	96	89	78	68	59	48	36	27	17	9	3	1	0
120-129	100	100	99	93	81	71	62	51	38	29	18	9	4	1	0
130-139	100	100	100	96	84	74	65	53	40	30	20	10	4	1	0
140-149	100	100	100	99	87	77	67	55	42	32	21	11	5	2	0
150-159	100	100	100	100	90	80	70	58	45	34	22	12	5	2	0

First, 10 m wind components, 2 m temperature, and 2 m relative humidity are extracted from the NARR dataset and converted to GeoTiff files at 3 hour intervals from 1999 to 2018 (20 years). 10 m wind components were used to calculate 20 ft wind speed, in mph, and wind azimuth, in degrees. FFWI and MFFWI were then calculated at 3 hour intervals using the formulas presented above. Because rapidly spreading fires often cause significant damage in the first ~6 hours of a burn period, MFFWI values were averaged over a 6-hour period.

Next, the 6-hr average files were processed to determine the maximum 6-hr average MFFWI that occurred in a particular calendar day. Finally, for each 32 km by 32 km pixel in the NARR dataset, the ~7,000 (20 yr × 365 days/yr) daily maximum MFFWI values were sorted from high to low, with the date carried along and sorted analogously. These were then written to two (MFFWI and date) stacked GeoTiff rasters such that the first band in the MFFWI file contains the highest MFFWI value over 20 years, and the date file contains the date corresponding to the highest MFFWI. The second band contains the second highest MFFWI and date corresponding to that MFFWI, and so on.

With historical fire weather dates now identified, a 20-year (1999-2018) fire weather climatology was developed using the Weather Research and Forecasting (WRF) model to recreate historical days of fire weather significance across SCE's service territory. Approximately 900 days were included in this climatology, but for fire modeling purposes this data set was distilled to the most severe 40 days for a given location within SCE's service territory. High-resolution (2 km) hourly gridded fields of relative humidity, temperature, dead fuel moisture, and wind speed/direction were extracted from this analysis and provided as input to a Monte Carlo-based fire modeling analysis.

3.4 Stochastic selection of ignition locations and wind/weather conditions

SCE provided Reax was GIS data depicting the locations of overhead transmission and distribution lines. Figure 3, as an example, shows GIS data depicting the location of SCE overhead facilities. A 100 m buffer was applied to these facilities data to create an "ignition mask" where random ignitions are distributed within in areas defined by the ignition mask layer. In the Monte Carlo fire spread modeling analysis, 30% of the pixels within this buffer are ignited. As an example, Figure 4 shows ignition locations distributed randomly within a 100 m buffer surrounding SCE overhead facilities. Each 30 m pixel is colored according to risk calculated for that ignition location / time of ignition combination.

For each random ignition location, the weather stream is also selected randomly from the 40 most severe fire weather days (based on FFWI) for that ignition location. Six hours of weather data, corresponding to approximately one burn period, are extracted from the fire weather stream and provided as input to the fire spread simulation.

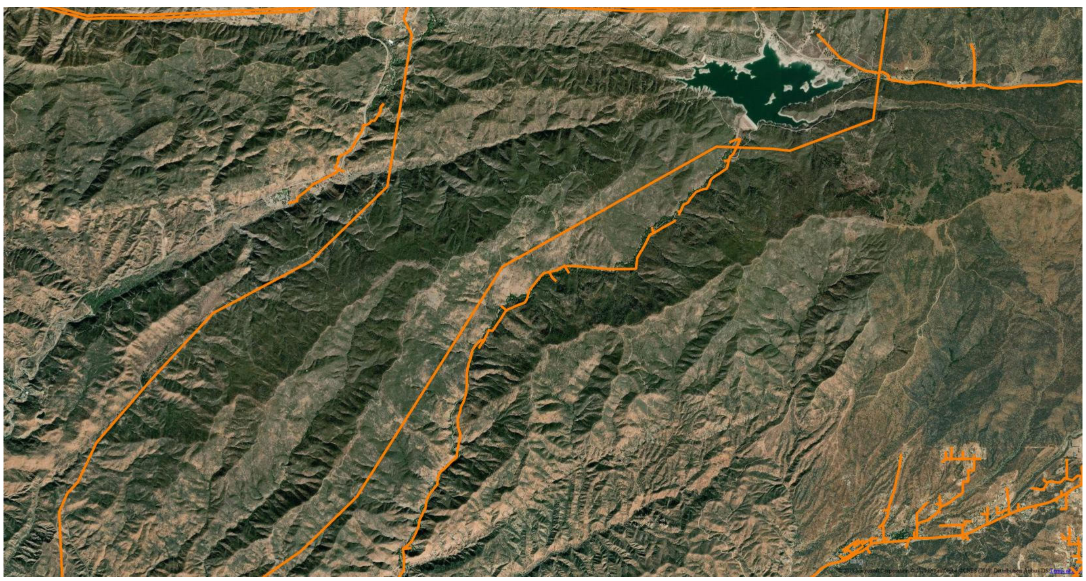


Figure 3. Example showing SCE overhead facilities.

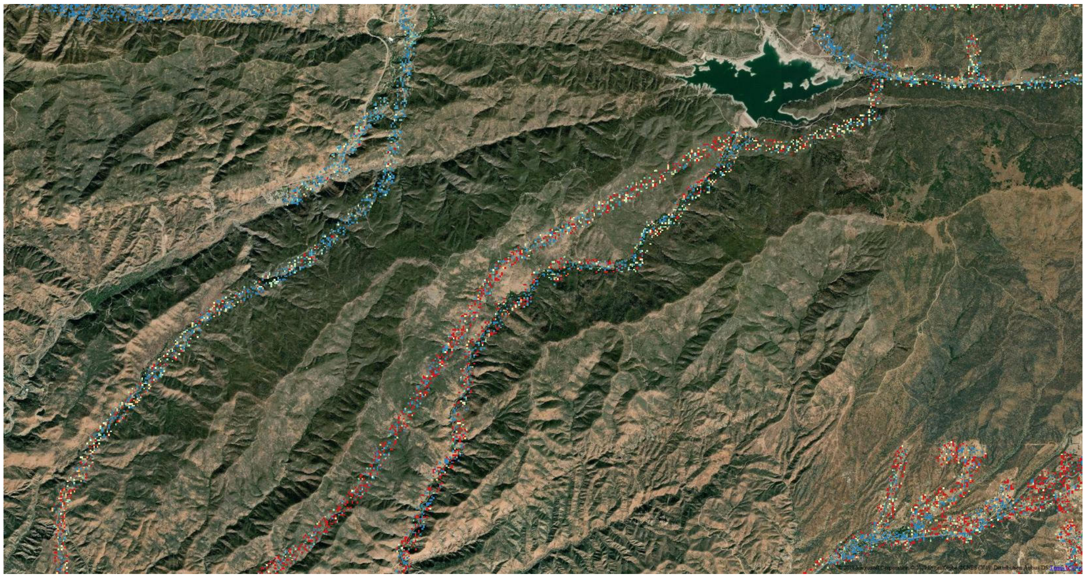


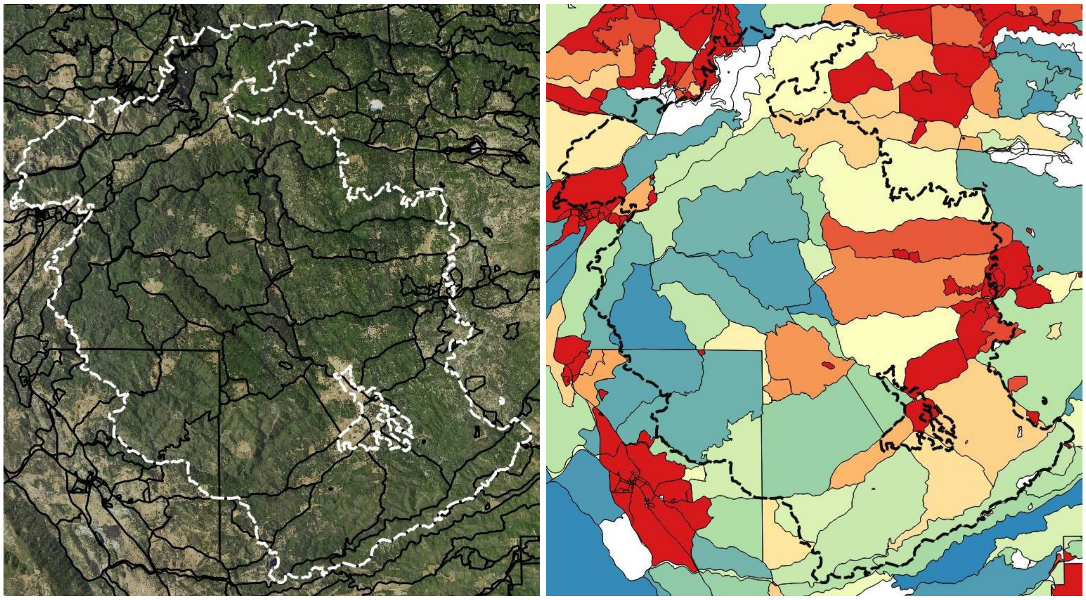
Figure 4. Example showing ignition locations distributed randomly within a 100 m buffer surrounding SCE overhead facilities.

3.5 Quantification of fire consequence

Miller and Ager [3] emphasize that within the context of wildland fire, both positive and negative outcomes can be realized from a given fire. A low-intensity fire occurring within the historic range of variability may provide a net benefit to the burned areas. While this may be true for some fires, it is usually not true for fires burning under extreme fire weather conditions (high wind, low humidity) in areas adapted to low intensity high frequency fire. It is also not likely true for fires burning through intermix or interface areas with structures. Fire consequences may include impacts to structures and people, natural resources, critical infrastructure, and other assets at risk. In this work, at the direction of SCE, only negative impacts to structures is addressed.

The first step in modeling fire impacts to structures and communities is to develop a dataset that identifies the location of structures. 2010 US Census data for California were obtained in GIS (shapefile) format [43 - 44]. Population density (people/mi^2) and housing density (structures/mi^2) were then calculated for each of the 710,145 census blocks in California by dividing the population or housing count for each census block by its area. The result was then burned to a raster having the same projection and resolution (30 m) as the underlying fuels inputs.

An example of this structure density calculation (outside of SCE's service territory) is shown graphically in Figure 5. The dashed line is the outline of the 2015 Butte Fire. In Figure 5a, census blocks (black lines) are overlaid on orthoimagery. Figure 5b shows housing density calculated for each census block. The values range from close to 0 (blue) to greater than 30 structures/mi^2 (red). White polygons in Figure 5b have zero housing density.



(a) (b)

Figure 5. Butte Fire footprint (dash line). (a) Census blocks (solid lines) on orthoimagery. (b) Housing density (structures per square mile) colored from 0 (blue) to 32 (red).

For each simulated fire, the total number of impacted structures is estimated by integrating area burned with housing density for each pixel within the fire perimeter at the end of a 6-hour simulation. While this method cannot determine whether specific structures would be impacted by a particular fire, it captures average losses at the census block level. For example, if a fire burns 1 sq mi of an area having a housing density of 20 structures per square mile, the total number of impacted structures reported by ELMFIRE would be 20. Actual impacted structures would depend on the location of those structures in the census block relative to fire location.

Affected structures (*i.e.*, those within the fire perimeter) does not necessarily correspond to damaged or destroyed structures. Post-fire inspection of neighborhoods that have experienced wildland urban interface fires often reveals that many structures within the fire perimeter survive. Structure survivability is a complex function of defensible space, construction techniques, suppression efforts, etc. While others have attempted to model structure losses based on factors such as flame length or ember density, such methods have not been validated and may introduce a false sense of precision. For this reason, no such attempts are made here.

4.0 Quantification of Utility-associated Fire Risk within SCE's Service Territory

As described in Section 1.2, wildland fire risk is "*The probability of a wildland fire occurring at a specified location and under specific circumstances, together with its expected outcome as defined by its impacts on the objects it affects*." This is closely related to the classic general definition of risk as probability times consequence. Therefore, in order to quantify fire risk within SCE's service territory, it is necessary to quantify probability (Section 4.1), consequence (Section 4.2), and their product (risk, Section 4.3).

4.1 Fire probability

In this work, ignitions are distributed randomly and uniformly within a buffer encompassing SCE's overhead electrical facilities. This inherently assumes that all electrical assets present similar ignition probabilities. However, given differences in protective measures on circuits and spatial variations in wind, fuels, canopy, etc. this may or may not be the case. Previous work that was conducted during the Fire Map 1 development process was unsuccessful at developing correlations between outages/ignitions and environmental variables.

For that reason, the probability leg of the risk equation is viewed here as the conditional probability that once a fire occurs it grows sufficiently rapidly that it escapes initial containment efforts. This is justified because most fires are controlled or extinguished while still small. It is a small percentage of fires – specifically those that escape initial attack and become extended attack or campaign fires – that are responsible for the majority of hectares burned in California. Fires are most likely to escape initial containment when fuels, weather, and topography lead to rapid fire spread, long flame lengths, and spotting that hinder control operations. Therefore, fire volume (the spatial integral of burned area and flame length) is used here as a proxy for probability of fire escaping initial containment efforts.

4.2 Fire consequence

Fire consequence is taken here as fire's impact on the objects it affects. As described earlier, the only assets at risk continued here are homes from the 2010 US Census. Impacts to homes are quantified for each modeled fire by calculating the spatial integral of fire area and structure density.

4.3 Fire risk

With probability and consequence now quantified, risk is now calculated as probability times consequence.

5.0 MODEL OUTPUTS AND GIS DATA

Geospatial outputs from this analysis have been delivered to SCE via Citrix ShareFile. An initial data delivery was made on February 22 for all areas within CPUC Tier 2 & 3 with an additional ½ mile area. After that delivery, SCE requested that "Bulletin 322" areas outside of the previous footprint also be analyzed. These were delivered on March 5th. GIS data associated with these deliveries are described in Section 5.1.

After these initial deliveries, SCE requested fire perimeter data for all modeled fires. This type of data at the scale of SCE's service territory had not been generated in earlier work. Significant development efforts were required to generate these data, which were delivered to SCE via Citrix ShareFile on May 10th and are described in Section 5.2.

5.1 Fire area, volume, impacted structures, and risk

Outputs from this Monte Carlo fire modeling analysis were post-processed to quantify risk as the product of probability and consequence. Fire volume is used here as a proxy for probability because rapidly spreading fires with are most likely to escape initial containment efforts than slowly developing fires. Consequence (or impact) is quantified as the number of structures within a modeled fire perimeter. To limit the order of magnitude of risk scores to $\sim 10^4$, risk was calculated as $0.001 \times$ fire volume $\times$ impacted structures.

The ShareFile .zip archive includes the following GeoTiff rasters:

- `fire_area.tif`: Fire area (acres) at 30 m resolution
- `fire_area_smooothed.tif`: Fire area (acres) at 30 m resolution with smoothing kernel
- `fire_area_300m.tif`: Fire area (acres) resampled to 300 m resolution
- `fire_area_1000m.tif`: Fire area (acres) resampled to 1000 m resolution

- `fire_volume.tif`: Fire volume (acre-ft) at 30 m resolution
- `fire_volume_smoothed.tif`: Fire volume (acre-ft) at 30 m resolution with smoothing kernel
- `fire_volume_300m.tif`: Fire volume (acre-ft) resampled to 300 m resolution
- `fire_volume_1000m.tif`: Fire volume (acre-ft) resampled to 1000 m resolution

- `impacted_structures.tif`: Number of impacted structures at 30 m resolution
- `impacted_structures_smoothed.tif`: Number of impacted structures at 30 m resolution with smoothing kernel
- `impacted_structures_300m.tif`: Number of impacted structures resampled to 300 m resolution
- `impacted_structures_1000m.tif`: Number of impacted structures resampled to 1000 m resolution

- `structure_risk.tif`: Product of fire volume and impacted structures at 30 m resolution
- `structure_risk_smoothed.tif`: Product of fire volume and impacted structures at 30 m resolution with smoothing kernel
- `structure_risk_300m.tif`: Product of fire volume and impacted structures resampled to 300 m resolution
- `structure_risk_1000m.tif`: Product of fire volume and impacted structures resampled to 1000 m resolution

As shown previously in Figure 4, model outputs are natively generated as raster files with a resolution of 30 m. These rasters depict fire area/volume, number of impacted structures, and risk (defined later) for each modeled fire. Before outputs from the Monte Carlo fire spread simulations can be viewed and analyzed at scales approaching size of SCE's service territory, smoothing or resampling is required. Figure 6 shows a smoothing kernel applied to data from Figure 4, and Figure 7 shows the same data from Figure 4 resampled (averaged) to 300 m grids.

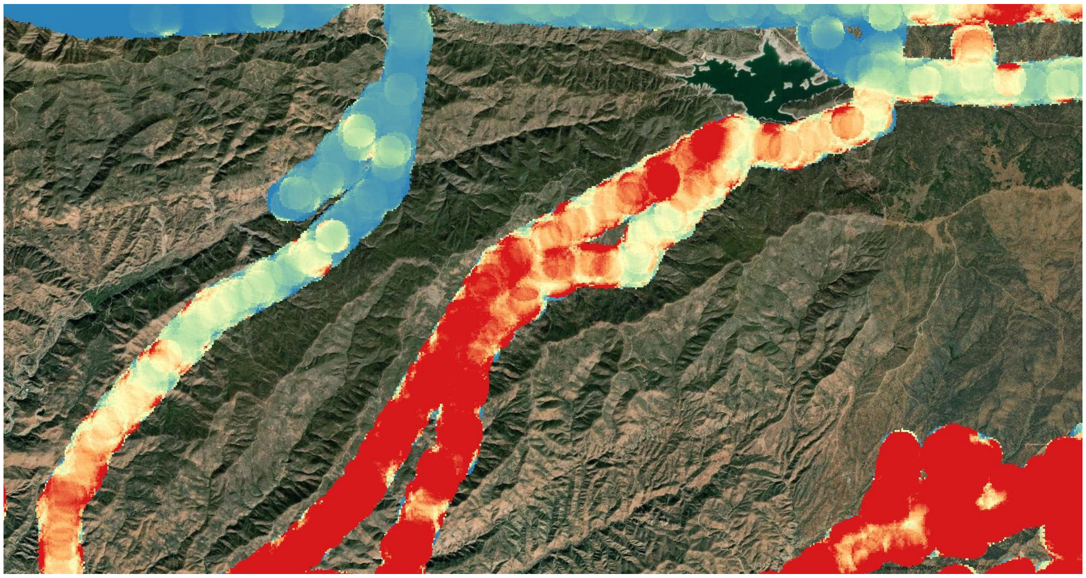


Figure 6. Smoothing kernel applied to data from Figure 4.

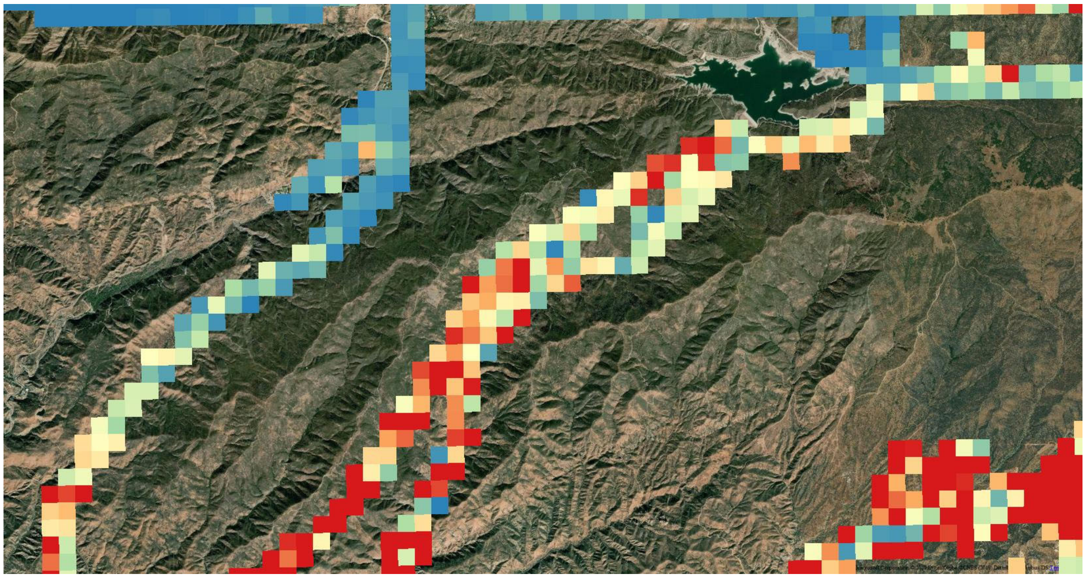


Figure 7. Data from Figure 4 resampled to 300 m resolution.

5.2 Fire perimeter data

SCE's territory was divided into 30 km by 30 km tiles. Those tiles containing overhead electrical facilities located within the high fire threat district (taken here as CPUC Tier 2 and Tier 3 with a ½ mile buffer plus SCE's Bulletin 322 areas) were identified. A map showing these tiles along with a four-digit identifier is presented in Figure 1. Analogous GIS data can be found in the ESRI shapefile tiles.shp in the root of the Sharefile .zip archive.

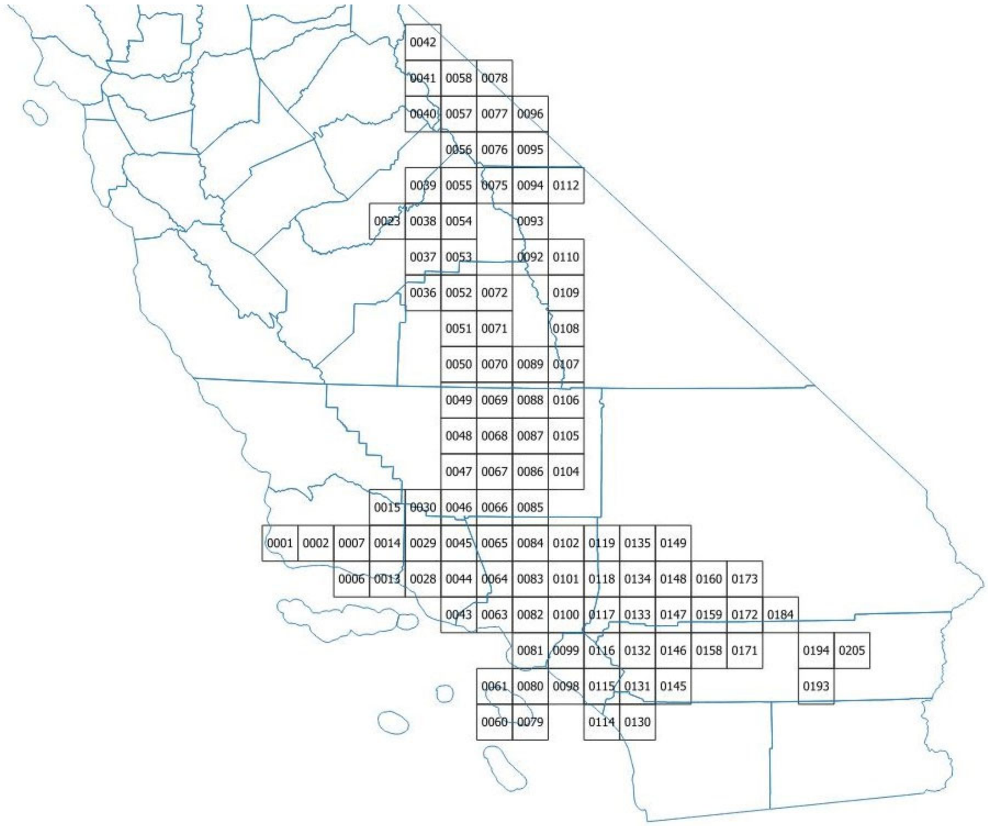


Figure 1. 30 km master tiles containing SCE facilities located within the high fire threat district.

Every 30 km master tile was broken into 10,000 sub-tiles (each subtile is 300 m by 300 m). The naming convention for subtiles within a master tile used here, and as the naming convention in GIS output files, is:

####_XXX_YYY

Here, #### is the four digit tile identifier shown in Figure 1, XXX is a three digit integer describing the subtile's *x* (East/West) offset from the lower-left corner of the master tile, and YYY is a three digit integer describing the *y* (North/South) offset from the lower left corner of the master tile. As an example, subtile 0046_030_025 is the subtile in master tile 0046 with its lower left corner offset by an x distance of $(30 - 1) \times 300$ m = 8700 m from the lower left corner of the master tile and its lower left corner offset by a y distance of $(25 - 1) \times 300$ m = 7200 m from the lower left corner of the master tile.

A Monte Carlo fire spread analysis comprising approximately 1.2 million ignitions distributed randomly and uniformly within a buffer surrounding SCE overhead electrical facilities was initiated to facilitate calculation of conditional burn probability from all ignitions occurring in each

300 m subtile. Although the underlying fire spread simulations are run on a 30 m grid, conditional burn probability is tabulated on a 300 m grid. This process generated approximately 100,000 GeoTiff rasters containing conditional burn probabilities from all ignitions within each 300 m subtile containing SCE overhead facilities.

GIS data can be found in the “tifs” directory within the .zip archive. The subfolders within the tifs directory correspond to the master tiles shown in Figure 1. Individual tif files are named using the convention described above.

6.0 CONCLUDING REMARKS

While the modeling analysis described herein is based on the best available inputs and fire modeling technology, the analysis is subject to several limitations, including:

- All fire models – including ELMFIRE – lack capabilities to model fire spread through built up or urban areas, which are typically marked as nonburnable in LANDFIRE.

- Structure density data were obtained from the 2010 census and do not reflect development that has occurred since 2010. Structure density data are at the census block level and do not reflect precise locations of individual structures.

- Structure impacts are calculated as the spatial integral of fire area and structure density at the census block scale. Factors that may affect survivability such as firewise practices or compliance with Chapter 7A of the California Building Code are not included.

- Fuels inputs were obtained from the most recent LANDFIRE product (LANDFIRE 2014 / LF 1.4.0). This data product includes disturbances, such as fires, through 2014 but does not reflect fire activity from 2015-2018. For that reason, near-term fire risk will be over-estimated in recently-burned areas and it is recommended that near-term risk in recently burned areas be analyzed on a case by case basis after considering the level of regrowth. An ESRI Shapefile with fire perimeters from 2015-2018 is included in the .zip archive (`fire_perimeters_2015-2018.shp`).

- By distributing ignitions randomly and uniformly within a buffer surrounding overhead facilities, it is inherently assumed that ignition likelihood is equal at all locations within the analyzed area. Other factors that may affect ignition likelihood such as protective devices on circuits, presence or absence of canopy, and highly localized wind patterns are not considered in this analysis.

- Fires are modeled for a duration of 6 hours; consequently, impacts beyond 6 hours of spread are not addressed.

- Suppression or firefighting activities are not modeled.

- LANDFIRE data products tend to over-estimate fire behavior in desert areas. Desert fuels typically do not burn due to lack of fuel continuity. However, in years where rainfall has been plentiful, an herbaceous surface layer capable of supporting propagating fires may be present. LANDFIRE inputs for desert areas reflect fuel conditions when an herbaceous surface layer is present.

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Workpaper Title:

Wildfire Tradeoff Risk Analysis

SCE-01, Vol. 2

Tradeoff Analysis Work Paper

Methodology

SCE intends to show through this safety risk analysis that the safety reduction gained through the portfolio of wildfire mitigations exceeds the safety benefit reduction (loss) in other RAMP-only safety risk initiatives (specifically, Contact with Energized Equipment and Underground Equipment Failure). This safety focus aligns with the discussion in Exhibit SCE-01, Volume 1, Section II, "… SCE's primary and foremost mission is the safety of the public, its customers, and its workers."

This analysis will leverage the principles of the Multi-Attribute Risk Score (MARS)[1], which allows risk consequences to be aggregated into a generic, unit-less risk score; more specifically, given the foundational mission for safety, the focus will be on the two safety consequences reviewed in RAMP, namely serious injuries and fatalities.

Step 1: Updated Baseline Assessment

In order to assess the risk reduction or new risk level, we must first determine a baseline score. The baseline, as discussed in RAMP, is the unmitigated risk score. For this analysis, we updated the risk baseline assumptions (i.e. such as Driver Frequency) for 1) Wildfire 2) Contact with Energized Equipment and 3) Underground Equipment Failure. Next, instead of adding the MARS score for the four consequences[2] in RAMP, we focus only on the safety components (serious injuries and fatalities) for the reasons discussed above, and add the safety MARS score together for those three risks to arrive at a total safety baseline MARS score.

Step 2: Risk Score using RAMP mitigation funding levels

We now need to determine the risk level of these three risks using the forecast spending costs as we submitted in the RAMP filing. This step serves as a risk reduction benchmark; we can now compare the risk reduction using a different set of forecast spend, in this case the GRC request (see Step 3). For this step, we use the Proposed Mitigation scenario for each of the three risks and run it with the revised baseline (Step 1). We again add the safety MARS score together for each of these three risks to arrive at total safety MARS score based on the RAMP mitigation funding levels.

Step 3: Risk Score using requested GRC funding levels

Step 3 is similar to Step 2, but instead of using the forecast RAMP spend, we instead use the requested GRC funding levels. The impact of the re-allocation of dollars will be further discussed in the Results Summary below. As in Step 2, we add the safety MARS score together for each of these three risks to arrive at a total safety MARS score based on GRC funding levels.

Results Summary

The figure below shows the results for each of the steps described above.

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[1] See RAMP filing, Chapter 1 (http://www3.sce.com/sscc/law/dis/dbattach5e.nsf/0/B2ADFEF6506791E9882583460074389A/$FILE/I.18-11-006%20SCE%202018%20RAMP%20Report.pdf)

[2] Serious Injury, Fatality, Reliability, and Financial.

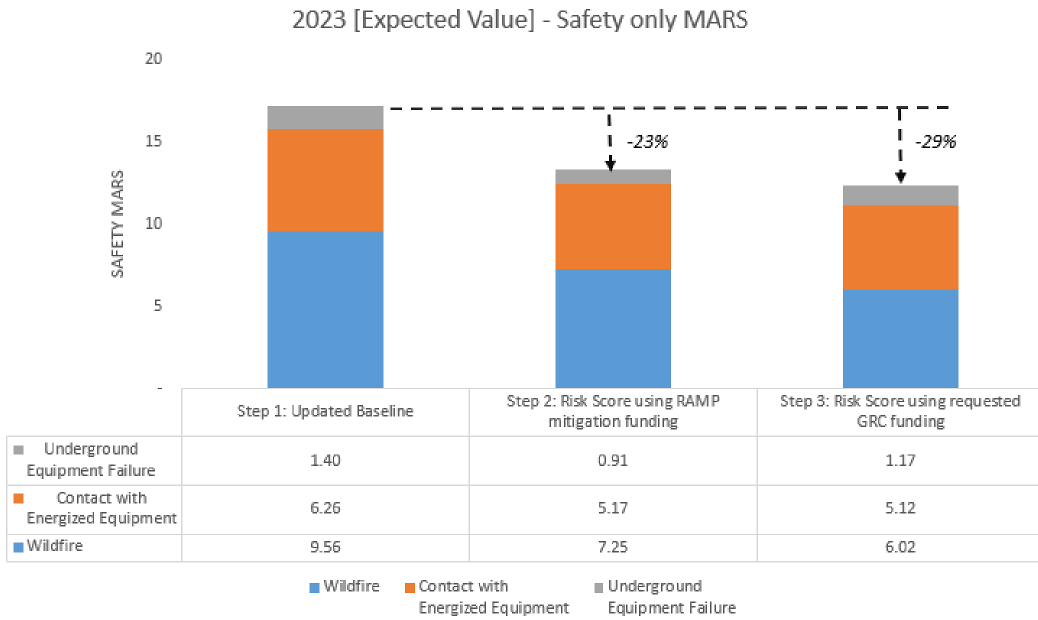


Figure 1: Safety Risk Levels

The risk analysis shows that the safety risk score based on the requested GRC funding levels provides a better safety risk reduction than the mitigation portfolio proposed in the RAMP filing. Specifically, as the mitigation dollars were reallocated from Underground Equipment Failure and Contact with Energized Equipment to Wildfire, the safety risk reduction from wildfire (Step 2 to Step 3) more than offset the slightly elevated risk levels for the other two risks.

Workpaper Title:

Transmission Ignition Risk Analysis

SCE-01, Vol. 2

Transmission Risk Analysis

Methodology

SCE used the RAMP bowtie framework to analyze the risk of wildfire associated with Transmission assets. Given the limited frequency of events, as shown below in Table I, SCE has made the following modeling assumptions:

- Maintain the same outcomes and consequences associated with the wildfire Distribution analysis.
- SCE sought an ignition driver dataset with a higher sample rate.
  - Examined the CPUC reportable ignitions associated with Transmission assets across the High Fire Threat Districts (HFTD) for all investor owned utilities (IOU) in the State.
  - Normalized the ignition frequency to that of SCE's HFRA annual Transmission ignition frequency.

Table I

Drivers of Ignitions Associated with SCE – Transmission

(Transmission Voltage Infrastructure in HFRA from 2015-2018)

Transmission

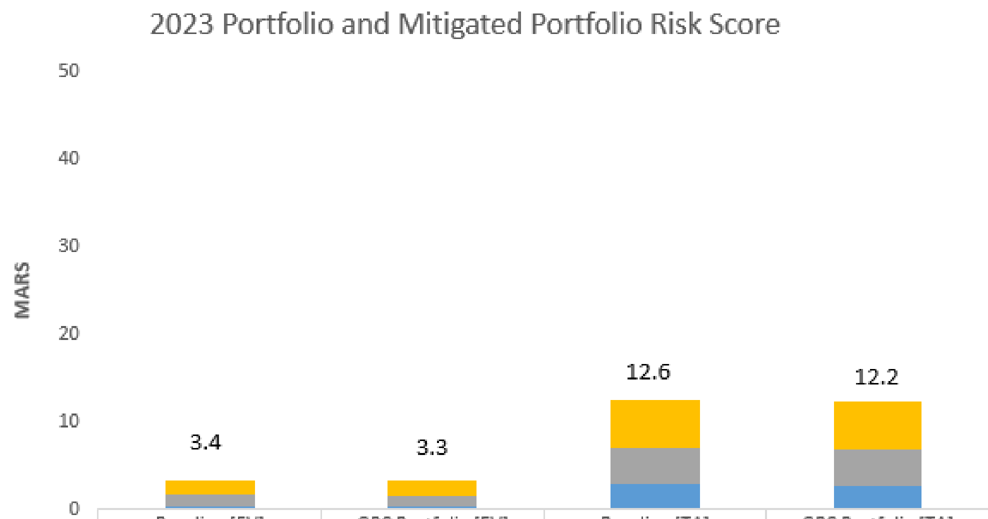
Suspected Initiating Event	**Count**	**Percentage***
Contact From Object	12	75%
Equipment/Facility Failure	1	6%
Other, Unknown, Wire-Wire Contact	3	19%
Total	16	100%

Contact From Object	**Count**	**Percentage**
Animal	5	31%
Balloons	3	19%
Other	1	6%
Vegetation	1	6%
Vehicle	2	13%
Total	12	75%

Equipment/Facility Failure	**Count**	**Percentage**
Other	1	6%
Total	1	6%

* Percentages shown are rounded to whole numbers

Results Summary



	Baseline [EV]	GRC Portfolio [EV]	Baseline [TA]	GRC Portfolio [TA]
Serious Injury	1.7	1.7	5.5	5.3
Fatality	1.3	1.3	4.2	4.1
Reliability	0.0	0.0	0.0	0.0
Financial	0.3	0.3	2.8	2.7

Financial Reliability Fatality Serious Injury

The MARS risk score reflects the lower ignition driver frequency of the wildfire transmission analysis, as compared to the results from the distribution analysis which can be seen in Workpaper "WPSCE-01V02ChIVUpdatedRAMPAnalysis."

For this first analysis effort, SCE focused only the Enhanced Overhead Inspection mitigation associated with Transmission.

The RSE is shown below:

RSE (2021-2023)	
Expected Value	**Tail Avg**
0.00237	0.00999